Verbale della riunione del Collegio dei docenti del Corso di dottorato di ricerca in Ingegneria dell'Informazione del 28 ottobre 2016 ore 11.00.

La riunione, convocata con posta elettronica del 20 ottobre 2016, si è tenuta nell'Aula Magna "Antonio Lepschy" DEI/A, Dipartimento di Ingegneria dell'Informazione.

La posizione dei convocati è la seguente:

Presenti:
Leonardo Badia, Matteo Bertocco, Alessandra Bertoldo, Andrea Bevilacqua, Andrea Cester, Alessandro Chiuso, Luca Corradini, Di Camillo Barbara, Emanuele Menegatti, Enrico Pagello, Luca Palmieri, Mortem Gram Pedersen, Pini Maria Silvia, Luca Schenato, Giorgio Spiazzi, Paolo Tenti, Tomasin Stefano, Zanoni Enrico.
Dottorandi: Biason Alessandro, Bof Nicoletta, Chiariotti Federico, Palombit Alessandro.

Assenti giustificati:
Avanzini Federico, Carli Ruggero, Cenedese Angelo, Ferrante Augusto, Grisan Enrico, Meneghesso Gaudenzio, Nicolosi Piergiorgio, Paccagnella Alessandro, Ruggeri Alfredo, Santagiustina Marco, Sparacino Giovanni, Valcher Mariaelena, Zampieri Sandro, Zanella Andrea, Zorzi Michele.
Dottorando: Centenaro Marco.

Assenti:
Nevio Benvenuto, Claudio Cobelli, Matteo Comin, Chiara Dalla Man, Carlo Ferrari, Matteo Fischetti, Andrea Galtarossa, Andrea Gerosa, Carmen Losasso, Andrea Neviani, Gianluigi Pillonetto, Silvano Pupolin, Michele Rossi.

Presiede la seduta il Direttore del Corso Prof. Matteo Bertocco, svolge le funzioni di segretario verbalizzante il Prof. Giorgio Spiazzi.
Il Presidente riconosce valida la seduta, la dichiara aperta per trattare, come dall'avviso di convocazione, l'ordine del giorno di seguito riportato.
Le deliberazioni prese in questa riunione vengono approvate seduta stante.

Ordine del giorno

1. Approvazione verbale seduta del 8 giugno 2016
2. Comunicazioni
3. Progettazione del corso di dottorato
4. Pratiche studenti
5. Valutazione dell'attività svolta dai dottorandi del 29^ ciclo nel triennio: ammissione alla valutazione della tesi
6. Elenco Valutatori tesi dottorandi 29^ ciclo

7. Commissioni esame finale dottorandi 29^ ciclo
8. Attività formativa e di ricerca dei dottorandi del 32^ ciclo
9. Valutazione dell'attività svolta dai dottorandi Cappelleri Vicenzo Maria, Pagnutti Giampaolo, Samory Mattia 28^ ciclo, indirizzo in Scienza e tecnologia dell'Informazione, in proroga (12 mesi): ammissione all'esame finale
10. Proposta al rettore della commissione per l'esame finale per i dottorandi Cappelleri Vicenzo Maria, Pagnutti Giampaolo, Samory Mattia 28^ ciclo, indirizzo in Scienza e tecnologia dell'Informazione, in proroga (12 mesi)

1. Approvazione verbale della seduta del 8 giugno 2016

Il Collegio approva.

2. Comunicazioni

Dati relativi al concorso di ammissione 32^ ciclo:

Domande presentate: n. 90
Dottorandi iscritti: 32

Borse di Ateneo: 13
Forse finanziate da Enti esterni e da dipartimenti: 6
Posto riservato ad un candidato di cittadinanza cinese laureato all'Università di Guangzhou: 1
Posti senza borsa: 5

Contratto di Apprendistato in Alta Formazione: 1

Pratiche studenti

Il Coordinatore ha approvato le seguenti richieste di autorizzazione:

Modifica di supervisore

Dott. Antonello Morris, curricolo Scienza e tecnologia dell'informazione 30^ ciclo, in accordo con entrambi i supervisori, il cambio dell'attuale Emanuele Menegatti con il proposto Stefano Ghidoni.

Modifica piano di studi

Dott. Biadene Davide, curricolo Scienza e tecnologia dell'informazione 30^ ciclo, eliminare il corso "Applied functional analysis" e inserire il corso "Digital processing and measurementy information".
Dott.ssa Mansutti Giulia curricolo Scienza e tecnologia dell'informazione 31^ ciclo, di modificare il piano con i seguenti corsi: "Applied functional analysis and machine learning", "Statistical

methods", "Random graphs and stochastic geometry in networks", "Information-theoretic methods in security".

Dott. Miotti Paolo, curricolo Scienza e tecnologia dell'informazione 31^ ciclo, togliere il corso "Applied linear algebra" e inserire il corso "Statistical methods".

Dott.ssa Pielli Chiara curricolo Scienza e tecnologia dell'informazione 31^ ciclo, di modificare il piano con i seguenti corsi: "Statistical methods", Real time systems", Information-theoretic methods in security", Random graphs & stochastic geometry in networks".

Dott. Rigobello Francesco curricolo Scienza e tecnologia dell'informazione 31^ ciclo, di modificare il piano con i seguenti corsi: "The FFT and its use in digital signal processing", Information theoretic methods in security", Statistical methods", Random graphs and stochastic geometry in networks".

Dott. Stanco Andrea curricolo Scienza e tecnologia dell'informazione 31^ ciclo, togliere il corso "Physics and operation of heterostructure-based electronic and optoelectronic devices" e inserire il corso "Digital processing of measurement information".

Dott.ssa Tajalli Alaleh curricolo Scienza e tecnologia dell'informazione XXXI ciclo a inserire il corso "Digital processing of measurement information".

Mobilità

Dott. Waqas Bin Abbas curricolo Scienza e tecnologia dell'informazione XXIX ciclo, a trascorrere il periodo da luglio a settembre 2016 presso National University of computer and energing sciences – ISLAMBAD per motivi di studio e ricerca su underwater acoustic sensor networks, sotto la supervisione del Dr. Affan Syed.

Dott.ssa Acciaroli Giada curricolo Bioingegneria XXXI ciclo, a trascorrere il periodo da giugno a luglio 2016 presso DEXCOM, San Diego, CA, USA, per motivi di studio e ricerca, sotto la supervisione del Prof. Apurv Kamath.

Dott. Antonello Morris curricolo Scienza e tecnologia dell'informazione XXX ciclo, a trascorrere il periodo da settembre 2016 a gennaio 2017 presso Vision & Robotics Group, Austria, per motivi di studio e rierca su Semantic mapping e Object detection, sotto la supervisione del Prof. Markus Vincze.

Dott. Chiariotti Federico curricolo Scienza e tecnologia dell'informazione XXXI ciclo, a trascorrere il periodo da agosto a settembre 2016 presso Nokia Bell Labs, Dublino, Irlanda, per motivi di studio e rierca, sotto la supervisione del Prof. Stepan Kucera.

Dott.ssa Favaretto Chiara curricolo Scienza e tecnologia dell'informazione XXX ciclo, a trascorrere il periodo da settembre a dicembre 2016 presso Università della California, Riverside, per motivi di studio e ricerca, sotto la supervisione della Prof.ssa Elisa Franco.

Dott.ssa Mazzonetto Ilaria curricolo Bioingegneria XXX ciclo, a trascorrere il periodo da ottobre a dicembre 2016 presso Faculty of Kinesiology and rehabilitation sciences, KU Leuven, Belgio, per motivi di studio e ricerca su preprocessing e source reconstruction di dati EEG, sotto la supervisione del Dott. Dante Mantini.

Dott. Miotti Paolo curricolo Scienza e tecnologia dell'informazione XXXI ciclo, a trascorrere il periodo da ottobre a dicembre 2016 presso DESY, Hamburg, Germania, per motivi di studio e rierca, sotto la supervisione del Prof. Stefan Dusterer.

Dott.ssa Pielli Chiara curricolo Scienza e tecnologia dell'informazione XXXI ciclo, a trascorrere il periodo da ottobre a dicembre 2016 presso Aalborg Universitgy, Aalborg, Danimarca, per motivi di studio e ricerca, sotto la supervisione del Prof. Petar Popovski.

Dott. Rebato Mattia curricolo Scienza e tecnologia dell'informazione XXXII ciclo, a trascorrere il periodo da ottobre a dicembre 2016 presso Aalborg University, Aalborg, Danimarca, per motivi di studio e ricerca sullo Spettro in in mmwave e reti mobili 5G, sotto la supervisione del Prof. Petar Popovski.

Dott. Rizzo Antonio curricolo Scienza e tecnologia dell'informazione XXXII ciclo, a trascorrere il periodo da settembre a dicembre 2016 presso Department of energy conversion and storage DTU, Roskilde, Danimarca, per motivi di studio e ricerca suli processi e la chimica coinvolti nella produzione di dispositivi organici (celle solari), sotto la supervisione del Prof. Suren Gevorgyan.

Dott.ssa Stival Francesca curricolo Scienza e tecnologia dell'informazione XXXI ciclo, a trascorrere il periodo da agosto a novembre 2016 presso University of Applied Sciences Western Switzerland, Sierre (HES-SO Valais), Svizzera per motivi di studio e ricerca su EMG-based robot motion, sotto la supervisione del Prof. Atzori Manfredo.

Dott. Zucchetto Daniel curricolo Scienza e tecnologia dell'informazione XXXI ciclo, a trascorrere il periodo da agosto a settembre 2016 presso TELENOR ASA, Norvegia, per motivi di studio e ricerca, sotto la supervisione del Prof. Kashif Mahmood.

Tutor junior a.a. 2016-2017

Autorizzazione concessa sotto la a condizione di NON svolgere altre attività di didattica integrativa (ex-supporto) i dottori:
Capron Giacomo, curricolo Bioingegneria, XXXII ciclo
Palombit Alessandro, curricolo Bioingegneria, XXXI ciclo

Pielli Chiara, curricolo Scienza e tecnologia dell'informazione XXXI ciclo
Scalabrin Maria, curricolo Scienza e tecnologia dell'informazione XXXI ciclo
Silvestri Erica, curricolo Bioingegneria, XXX ciclo.

Attività didattica integrativa a.a. 2016-2017 (entro il limite di 40 ore complessive)

Dott. Baggio Giacomo, curricolo Scienza e tecnologia dell'informazione XXX ciclo, n. 20 ore all'insegnamento di Stima e filtraggio, II semestre, corso di laurea magistrale in Ingegneria dell'Automazione, Titolare del corso Prof. Stefano Pinzoni.

Dott. Bez Francesco, curricolo Scienza e tecnologia dell'informazione XXXI ciclo, n. 8 ore all'insegnamento di Elettronica industriale, I semestre, corso di laurea Ingegneria Elettronica, Titolare del corso Prof. Tenti Paolo.

Dott. Biadene Davide, curricolo Scienza e tecnologia dell'informazione XXX ciclo, n. 8 ore all'insegnamento di Elettronica industriale, I semestre, corso di laurea Ingegneria Elettronica, Titolare del corso Prof. Tenti Paolo.

Dott. Carraro Marco, curricolo Scienza e tecnologia dell'informazione XXX ciclo, n. 18 ore all'insegnamento di Elaborazione di dati tridimensionali, I semestre, corso di laurea magistrale Ingegneria Informatica, Titolare del corso Prof. Emanuele Menegatti.

Dott. Celin Alberto, curricolo Scienza e tecnologia dell'informazione XXIX ciclo, n. 22 ore all'insegnamento di Circuiti integrati per l'elaborazione del segnale, I semestre, corso di laurea magistrale Ingegneria Elettronica, Titolare del corso Prof. Andrea Gerosa.

Dott. Lago Nicolò, curricolo Scienza e tecnologia dell'informazione XXX ciclo, n. 24 ore all'insegnamento di Elettronica organica e molecolare, I semestre, corso di laurea magistrale Ingegneria Elettronica, Titolare del corso Prof. Andrea Cester.

Dott. Luvisotto Michele, curricolo Scienza e tecnologia dell'informazione XXX ciclo, n. 12 ore all'insegnamento di Progettazione di sistemi di controllo, I semestre, corso di laurea magistrale in Ingegneria dell'Automazione, Titolare del corso Prof. Angelo Cenedese.

Dott.ssa Mansutti Giulia, curricolo Scienza e tecnologia dell'informazione XXXI ciclo, n. 10 ore all'insegnamento di Fibre ottiche e propagazione guidata, I semestre, corso di laurea magistrale Ingegneria delle Telecomunicazioni, titolare del corso Prof. Luca Palmieri e n. 16 ore all'insegnamento di Dispositivi a microonde, I semestre, corso di laurea magistralen Ingegneria elettronica, Titolare del corso Prof. Andrea Galtarossa.

Dott. Marcon Leonardo, curricolo Scienza e tecnologia dell'informazione XXXII ciclo, n. 10 ore all'insegnamento di Fibre ottiche e propagazione guidata, I semestre, corso di laurea magistrale

Ingegneria delle Telecomunicazioni, titolare del corso Prof. Luca Palmieri, n. 10 ore all'insegnamento di Propagazione guidata e dispositivi, II semestre, corso di laurea in Ingegneria elettronica, titolare del corso Prof. Andrea Galtarossa, n. 10 ore all'insegnamento di Sistemi in fibra ottica e laboratorio, II semestre, corso di laurea magistrale in Ingegneria delle telecomunicazioni, titolare del corso Prof. Luca Palmieri, n. 10 ore all'insegnamento Antenne e propagazione wireless, II semestre, corso di laurea magistrale in Ingegneria delle telecomunicazioni, titolare del corso Prof. Marco Santagiustina.

Dott. Palombit Alessandro, curricolo Bioingegneria XXXI ciclo, n. 14 ore all'insegnamento di Neuroengineering, I semestre, corso di laurea magistrale Bioingegneria, titolare del corso Prof.ssa Alessandra Bertoldo.

Dott. Polese Michele, curricolo Scienza e tecnologia dell'informazione XXXII ciclo, n. 40 ore all'insegnamento di Telecommunication networks / Computer networks, I semestre, corso di laurea magistrale in Ingegneria delle Telecomunicazioni, Titolare del corso Prof. Andrea Zanella.

Dott.ssa Prando Giulia, curricolo Scienza e tecnologia dell'informazione XXIX ciclo, n. 24 ore all'insegnamento di Machine learning, I semestre, corso di laurea magistrale in Ingegneria dell'Automazione, titolare del corso Prof. Alessandro Chiuso e corso di laurea magistrale in Ingegneria informatica, Titolare del corso Prof. Fabio Vandin.

Dott. Rigobello Francesco, curricolo Scienza e tecnologia dell'informazione XXXI ciclo, n. 40 ore totali per gli insegnamenti di: Dispositivi a microonde, I semestre, corso di laurea magistrale in Ingegneria Elettronica, Titolare del corso Prof. Andrea Galtarossa; Propagazione guidata e dispositivi, II semestre, corso di laurea in Ingegneria elettronica, Titolare del corso Prof. Andrea Galtarossa; Antenne e propagazione wireless, II semestre, corso di laurea magistrale in Ingegneria delle telecomunicazioni, titolare del corso Prof. Marco Santagiustina; Sistemi in fibra ottica e laboratorio, II semestre, corso di laurea magistrale in Ingegneria delle telecomunicazioni, titolare del corso Prof. Luca Palmieri.

Dott.ssa Rubega Maria, curricolo Bioingegneria XXIX ciclo, n. 16 ore all'insegnamento di Analisi di dati biologici, I semestre, corso di laurea magistrale in Bioingegneria, titolare del corso Prof. Giovanni Sparacino.

Dott.ssa Vettoretti Martina, curricolo Bioingegneria XXIX ciclo, n. 20 ore all'insegnamento di Informatica medica, I semestre, corso di laurea magistrale in Bioingegneria, titolare del corso Prof. Giovanni Sparacino.

Attività lavorativa – Sorveglianza Esami di stato

Dott. Biral Andrea, curricolo Scienza e tecnologia dell'informazione XXIX ciclo, n. 1 ora per il giorno 22/06/2016.

Dott. Celin Alberto, curricolo Scienza e tecnologia dell'informazione XXIX ciclo, n. 1 ora per il giorno 22/06/2016.
Dott. Centenaro Marco, curricolo Scienza e tecnologia dell'informazione XXX ciclo, n. 1 ora per il giorno 22/06/2016.
Dott. Chiariotti Federico, curricolo Scienza e tecnologia dell'informazione XXXI ciclo, n. 2 ore per il giorno 23/06/2016.
Dott.ssa Maistro Maria, curricolo Scienza e tecnologia dell'informazione XXX ciclo, n. 1 ora per il giorno 23/06/2016.
Dott.ssa Mazzonetto Ilaria, curricolo Bioingegneria XXX ciclo, n. 1 ora per il giorno 22/06/2016.
Dott. Palombit Alessandro, curricolo Bioingegneria XXXI ciclo, n. 1 ora per il giorno 22/06/2016.
Dott. Pretto Niccolò, curricolo Scienza e tecnologia dell'informazione XXXI ciclo, n. 1 ora per il giorno 23/06/2016.
Dott.ssa Erica Silvestri, curricolo Bioingegneria XXX ciclo, n. 1 ora per il giorno 22/06/2016
Dott. Tonietto Matteo, curricolo Bioingegneria XXIX ciclo, n. 2 ore per il giorno 23/06/2016.
Dott. Zucchetto Daniel, curricolo Scienza e tecnologia dell'informazione XXXI ciclo, n. 1 ora per il giorno 23/06/2016.

Attività lavorativa – Altro

Dott.ssa Rubega Maria, curricolo Bioingegneria, XXIX ciclo, a svolgere dal 10/09/2016 al 31/12/2016 per un impegno settimanale di n. 4 ore, presso Gate-Italy Psdova, un corso di matematica e e crittografia a bambini ad alto QI.

Dott.ssa Silvestri Erica, curricolo Bioingegneria, XXX ciclo, a svolgere dal 24 al 24 novembre 2016 per un impegno settimanale di n. 30 ore, presso Fiera di Verona, attività di orientamento scuole superiori, evento "JOB&ORIENTA".

3. Progettazione del corso di dottorato

Offerta formativa a.a. 2016-2017 – Ratifica
Il Coordinatore illustra al collegio il Catalogo dei corsi per l'a.a. 2016-2017 (si veda l'area web http://www.dei.unipd.it/node/2399) organizzato dal Prof. Alessandro Chiuso e approvato, per motivi di urgenza, dal Coordinatore stesso.
Il Catalogo è composto da 15 corsi (Allegato 3.1). Si ricorda che i dottorandi potranno inoltre scegliere corsi dal Catalogo 2016/2017 della Scuola di dottorato in Scienze Matematiche (area web http://dottorato.math.unipd.it/node/144) e precisamente: "Courses of the school', Courses of the 'Computational Mathematics' e Courses of the 'Mathematics'.

Fatte salve le istanze di revisione espresse e il mandato al Coordinatore ad applicare eventuali correzioni, il Collegio ratifica l'approvazionedella programmazione didattica 2016/2017.

4. Pratiche studenti

Apprendistato in Alta Formazione – Dottorato di Ricerca 32^ ciclo
Approvazione Progetto congiunto di Formazione e Ricerca (ratifica)

Si chiede al Collegio di ratificare l'approvazione data dal Coordinatore per motivi d'urgenza del Progetto congiunto di formazione e ricerca (di seguito i dati):

Azienda: ELECTROLUX ITALIA SpA - Pordenone

Titolo progetto: Sviluppo di sensori virtuali tramite tecniche di Apprendimento automatico per elettrodomestici Fabric Care

Tutor aziendale: Ing. Claudio Diodato
Responsabile scientifico del dottorando: Prof. Alessandro Beghi

Il Collegio ratifica.

Mobilità
Il dott. Altieri Federico, curricolo Scienza e tecnologia dell'informazione 30^ ciclo, chiede di trascorrere il periodo ottobre 2016-maggio 2017 per motivi di studio e ricerca presso University College of London, sotto la supervisione del prof. Evangelos Himonides.

Il Collegio approva.

Il dott. Centenaro Marco, curricolo Scienza e tecnologia dell'informazione 30^ ciclo, chiede di trascorrere il periodo agosto 2016-gennaio 2017 per motivi di studio e ricerca presso NOKIA BELL LABS, Stoccarda, Germania, sotto la supervisione del Prof. Stephan Saur.
Il coordinatore chiede al collegio di ratificare l'autorizzazione già data per motivi d'urgenza.

Il Collegio ratifica.

La dott.ssa Michieletto Giulia, curricolo Scienza e tecnologia dell'informazione 30^ ciclo, chiede di trascorrere il periodo settembre 2016-febbraio 2017 per motivi di studio e ricerca presso LAAS – Tolosa, Francia, sotto la supervisione del Prof. Antonio Franchi.
Il coordinatore chiede al collegio di ratificare l'autorizzazione già data per motivi d'urgenza.

Il Collegio ratifica.

La dott.ssa Zorzan Irene, curricolo Scienza e tecnologia dell'informazione 30^ ciclo, chiede di trascorrere il periodo settembre 2016-febbraio 2017 per motivi di studio e ricerca presso Lund University, Faculty of Engineering (LTH), Lund, Svezia, sotto la supervisione del Prof. Anders Rantzer
Il coordinatore chiede al collegio di ratificare l'autorizzazione già data per motivi d'urgenza.

Il Collegio ratifica.

Presentazione della tesi - Istanza di proroga di 6 mesi

La dott.ssa Antonela Comisso, indirizzo Scienza e tecnologia dell'Informazione e il dott. Andrea Nordio, indirizzo Bioingegneria, hanno presentato istanza di proroga alla presentazione della tesi di 6 mesi
Il Collegio approva la richiesta di proroga.

Ammissione al Terzo anno
Pesce Massimiliano, indirizzo Scienza e Tecnologia dell'Informazione
Supervisore Prof. Michele Zorzi

Il Coordinatore ricorda al collegio la situazione di Pesce Massimiliano il quale, alla data corrente ha frequentato con regolarità le attività del corso di dottorato; inoltre ha presentato in una commissione allargata di quattro membri l'attività svolta nel corso del periodo di dottorato.
Da comunicazioni intercorse tra il Coordinatore e il dottorando è emersa l'intenzione dello stesso a voler presentare quanto prima istanza di rinuncia al corso di dottorato.
Risulta quindi non necessario deliberare in merito al passaggio all'anno successivo.
Il Collegio prende atto.

5. Valutazione dell'attività svolta dai dottorandi del 29^ ciclo nel triennio: ammissione alla valutazione della tesi

Il Coordinatore ricorda al collegio che per l'ammissibilità dei dottorandi alla valutazione della tesi da parte dei valutatori si è adottata la procedura prevista per l'ammissibilità all'esame finale.
Illustra al Collegio il risultato della valutazione condotta dalla commissione sull'attività complessiva svolta dal dottorando alla data corrente.
Sulla base della valutazione della Commissione (All. 5.1-5.20), il Collegio propone all'unanimità l'ammissione alla valutazione della tesi da parte dei valutatori (esclusi i dottorandi Comisso Antonela e Nordio Andrea che hanno chiesto una proroga) come di seguito elencati:

Abbas Waqas Bin, Baruzzo Giacomo, Biral Andrea, Caparra Gianluca, Carson Wigdahl Jeffrey, Ceccarello Matteo, Celin Alberto, Dalcanale Stefano, De Luca Alberto, Del Testa Davide, Guimares Sa Correja Pedro, Hoosmand Mohsen, La Grassa Marco, Marin Giulio, Prando Giulia, Romeres Diego, Rubega Maria, Tomasin Marco, Tonietto Matteo, Vettoretti Martina

e ne predispone la presentazione dell'attività come di seguito riportata.

Presentazione sull'attività svolta da Abbas Waqas nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Scienza e Tecnologia dell'Informazione.

Dall'inizio del corso di dottorato ad oggi il dott. Abbas Waqas ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Scienza e Tecnologia dell'Informazione.

Il dottorando dichiara quanto segue:

FIRST PART: EDUCATION

Courses, trainings and summer school activities

- List of courses taken
    - Applied linear algebra
    - Digital processing of measurement information
    - Random graphs and stochastic geometry in networks
    - Statistical methods

- List of seminars attended

    - Cognitive testbed
    - A study on remote data retrieval strategies in underwater acoustic networks: the UFetch protocol
    - Wireless Sensor Networks: a channel access analysis
    - A Markov Analysis of SR ARQ with Variable Round Trip Time
    - An Introduction to Interference Alignment and its Practical Challenges
    - Distributed Power Loss Minimization in Residential Micro Grids: a Communications Perspective
    - Joint User Association and Resource Allocation in UE-Relay Assisted Heterogeneous Networks
    - Context-Aware Handover in HetNets
    - Optimal policies for two-user Energy Harvesting Device networks with imperfect State-of-Charge knowledge
    - System, Security, and Privacy Issue in Mobile Networking
    - Opportunistic Data Gathering and Dissemination in Urban Scenarios
    - Research challenges in Machine to Machine Communication
    - Toward Practical Distributed Compression for Spatio-Temporal WSN Signals
    - BITCOIN, an attempt at a separation of money and state
    - Shaping 5G
    - Mathematical Scientific Challenges of 5G

- Caching Strategies in Heterogeneous Networks with D2D, small BS and macro BS communications
    - Lightweight Lossy Compression of Biometric Patterns via Denoising Autoencoders
    - Abnormal EEG patterns in writer's cramp patients
    - writing a EU proposal
    - Toward Lightweight Biometric Signal Processing for Wearable Devices
    - Schedulability Analysis for Fixed Priority Real-Time Systems with Energy-Harvesting
    - Simulation of Multimodal Optical and Acoustic Communications in Underwater Networks
    - The IEEE 802.11n wireless LAN for real-time industrial communications
    - Learning with Computational Regularization
    - Covariogram-based Compressive Sensing for Environmental Wireless Sensor Networks
    - Constellation Shaping and LDPC coding in a bidirectional Full Duplex communication
    - Full Duplex Radios
    - A Stochastic Geometry Framework for Asynchronous Full-Duplex Communications
    - LTE Floating Car Data application off-loading via VANET driven clustering formation
    - A brief on recurrent neural networks
    - Pulse design optimization for ToA-based localization
    - Distortion Minimization in Multi-Sensor Estimation Using EnergyHarvesting and Energy Sharing
    - Underwater communication: current research work at SIGNET
    - Improved Active Sensing Performance in Wireless Sensor Networks via Channel State Information
    - Learning methods for long-term wireless channel prediction
    - Cross layer Sensing, Estimation & Control in Wireless Networks
    - RFID based People-Object Interaction Detection
    - Resource Sharing in 5G mmWave Cellular Networks

- National and international conferences attended
    - **European Conference on Networks and Communications, EUCNC'16, Athens, Greece**

- Other activities
    - NS3 workshop, Barcelona, Spain. May 2015

Teaching activities

- None

Mobility actions

I spent two months (i.e., July and August 2016) in NUCES, Islamabad, Pakistan, where I worked on the "variable resolution ADCs architecture" to further reduce the power consumption of a fully digital receiver architecture.

Stage

- None

SECOND PART: RESEARCH

This work investigates the energy efficiency (EE) of a multiple input multiple output (MIMO) receiver equipped with large antenna arrays. In a receiver architecture, both in new millimeter wave (mmWave) bands and in standard frequencies with massive MIMO, the use of a high resolution analog-to-digital converter (ADC) is traditionally considered as a main bottleneck in achieving an energy efficient receiver design. Moreover, the required number of ADCs in a receiver is directly related to the choice of the beamforming scheme. To address this issue, we analyzed a MIMO system with low resolution ADCs and compared the performance of analog, hybrid and digital beamforming (ABF, HBF and DBF) based receiver architectures. Results showed that DBF results in a better spectral and energy efficiency than ABF and HBF in most scenarios and for both control plane and data plane communication. Results also showed that based on ADC power consumption model there is an optimal number of ADC bits that achieves maximum EE (where we compute energy efficiency as EE=Capacity/Power Consumption).

To further reduce the power consumption of DBF, a novel variable resolution ADC architecture is proposed, which motivates the use of variable resolution ADCs instead of conventional fix resolution ADCs based receiver architectures.

To address the issue of beam search delay associated with large antenna array system, a low power phase shifters network based receiver architecture which compares and selects the best beam in analog hardware and requires only a single RF chain is proposed.

The main highlights of the works focusing on EE can be summarized as:

- Analyzed and compared the power consumption of ABF, HBF and DBF receiver architectures
- Analyzed and compared performance of a MIMO sysyem with low resolution ADCs for ABF, HBF and DBF

- Showed that DBF may result in lower EE and a better SE vs EE trade-off than other schemes in many scenarios
- Showed that there is an optimal number of ADC bits which results in maximum EE
- Proposed a variable resolution ADC based receiver design to further reduce the power consumption of DBF
- Proposed a PSN based receiver architecture to reduce the search dealy and power consumption associated with initial cell discovery

During my research, I also studied and analyzed how in a multi-hop network, a hybrid automated repeat request (HARQ) scheme based on fountain codes can reduce the probability of failure at the destination. The analysis performed for both unrestricted and restricted flooding scenarios, and results verified that above a certain minimum link failure probability restricted flooding performs similar to unrestricted flooding and therefore restricted flooding which allows fewer nodes to tranmit results in a transmission efficient communication. Moreover, we also proposed two practical restricted flooding policies, 1) Predetermined restriction, which performs similar to restricted flooding, 2) Adaptive restriction, which adapts its number of transmission according to the link failure probability and perform similar to unrestricted flooding. In addition, we studied the trade-off between average number of transmissions and the amount of redundancy required to achieve a fix probability of success at the destination. Furthermore, we also study the performance of a network in the presence of multiple helping nodes (which can decode and generate extra redundancy packets in the network). Results show that the inclusion of helping nodes can further reduce the number of transmission as compared to a case where only source is transmitting while achieving almost similar probability of success (Ps) compared to a case where only source is transmitted redundancy packets. The main outcomes of this work can be summarized as:

- Devised a probabilistic model to evaluate Ps at destination, for a fountain coded transmission
- Studied both restricted and unrestricted flooding models and evaluated the transmission vs redundancy trade-off
- Proposed two practical transmission policies for restricted flooding schemes
- Analyzed the network performance with multiple helper nodes

Definitive title of thesis : Energy Efficient Communication in Wireless Networks

Supervisor: Prof. Michele Zorzi

THIRD PART: PUBBLICATIONS

- List of publications in international journals

- W. b. Abbas, P. Casari M. Zorzi, "Controlled Flooding of Fountain Codes", submitted to IEEE Transactions on Wireless Communications.
- W. b. Abbas, F. Gomez-Cuba and M. Zorzi, "Millimeter Wave Receiver Efficiency: A Comprehensive Comparison of Beamforming Schemes with Low Resolution ADCs", submitted to IEEE Transactions on Wireless Communications.
- W. b. Abbas, N. Ahmed, C. Usama and A. Syed, "Design and evaluation of a low-cost, DIY-inspired, underwater platform to promote experimental research in UWSN", Ad Hoc Networks, 2015

- Publications list related to international conferences
  - P. Casari, W. b. Abbas and M. Zorzi, "On the number of transmissions vs. redundancy tradeoff for flooded fountain codes", in Proc. of IEEE International Workshop on Computer-Aided Modeling Analysis and Design of Communication Links and Networks (CAMAD), December 2014, Athens, Greece
  - W. b. Abbas and M. Zorzi, "Context information based initial cell search for millimeter wave 5G cellular networks", in Proc. of European Conference on Networks and Communications (EuCNC), June 2016, Athens, Greece
  - W. b. Abbas and M. Zorzi, "Towards an Appropriate Receiver Beamforming Scheme for Millimeter Wave Communication: A Power Consumption Based Comparison", in Proc. of European Wireless, May 2016, Oulu, Finland
  - W. b. Abbas, F. Gomez-Cuba and M. Zorzi, "Bit Allocation for Increased Power Efficiency in 5G Receivers with Variable-Resolution ADCs", submitted to IEEE International Conference on Communication (ICC), May 2017

Il Collegio prende atto di quanto esposto e osserva che il dott. Abbas Waqas si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Baruzzo Giacomo nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Bioingegneria.
Dall'inizio del corso di dottorato ad oggi il dott. Baruzzo Giacomo ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Bioingegneria.

Il dottorando dichiara quanto segue:

FIRST PART: EDUCATION

Courses, trainings and summer school activities

- PhD School Courses
  - Bayesian Machine Learning, Prof. G. M. Di Nunzio
  - Mathematical modeling of cell Biology, Prof. M. G. Pedersen
  - Real-Time Systems and applications, Prof. G. Manduchi
  - Statistical Methods, Prof. L. Finesso

- Seminars
  - Brain-Computer Interface and Motor Learning in Stroke Rehabilitation - Prof. Junichi Ushiba - Seminar, Department of Information Engineering, University of Padova – May 16, 2014
  - Programming Distributed Machine Learning Applications/Frameworks - Prof. Vijay Saraswat - Seminar, Department of Information Engineering , University of Padova – June 3, 2014
  - Brain-Machine-Interfaces (BMI) in Complete Paralysis, Stroke and Neuropsychiatric Disorders - Prof. Niels Birbaumer - Distinguished lecturer series DEI, University of Padova – November 5, 2014
  - Learning with Computational Regularization - Lorenzo Rosasco - Seminar, Department of Information Engineering, University of Padova – March 27, 2015
  - Deep architectures and deep learning in chemoinformatics: the prediction of properties and activities of drug-like molecules - Gianluca Pollastri, PhD - Seminar, Department of Information Engineering, University of Padova – April 29, 2015
  - Big Data Integration: from Population to Single Cells - Lana Garmire, PhD - Seminar series, Institute for Biomedical Informatics, University of Pennsylvania - July 20, 2015
  - Social Media Mining for Public Health Monitoring and Surveillance - Graciela Gonzalez - Seminar series, Institute for Biomedical Informatics, University of Pennsylvania – July 27, 2015
  - Lean Big Data Integration for Systems Pharmacology - Avi Ma'ayan, PhD - Seminar series, Smilow Center for Translational Research, University of Pennsylvania – September 14, 2015

- Kernel Machine Methods for Complex Genomic Data: Integrative Analysis and Accommodating Interactions - Michael C. Wu, PhD - Seminar series, Abramson Research Center, University of Pennsylvania – October 16, 2015
- Open Genomics with Open-Source Data Pipelines - Alexey Khrabrov - Seminar series, Institute for Biomedical Informatics, University of Pennsylvania - November 5, 2015
- Lo straordinario percorso dell'informatica - Franco P. Preparata - Seminar, Department of Information Engineering, University of Padova – May 24, 2016

- Workshop
  - RNA-Seq Full Day Hands-on Workshop for the Bioinformatician – University of Milan - June 11, 2014
  - AxA Workshop - Workshop on Advanced Algorithms on Strings – Venice – from June 21, 2016 to June 24, 2016

- National and international conferences:

  - 2015 ITMAT SYMPOSIUM "Systems Pharmacology and Translational Therapeutics" - Institute for Translational Medicine and Therapeutics, University of Pennsylvania: "Systems Pharmacology and Translational Therapeutics" from October 12, 2015 to October 13, 2015
  - NETTAB 2014 - From structural bioinformatics to integrative systems biology – Turin - from October 15, 2014 to October 17, 2014

Teaching activities

- Lab Support at "Bioingegneria per la Genomica", Prof.ssa Barbara Di Camillo, A.A. 2015/2016, University of Padova

Mobility actions

Visiting student at Institute for Translational Medicine and Therapeutics (ITMAT), University of Pennsylvania, Philadelphia, USA from June 2015 to December 2015. Bioinformatics group lead by Prof. Gregory R. Grant.

SECOND PART: RESEARCH

The main topic of my research activity was the analysis of NGS data. In particular, the focus of my work was the study and the development of methods for the analysis of RNA-seq data.

RNA-Seq has revolutionized the manner in which transcriptomics analysis is performed, resulting in more than 4000 publications since the first works in 2008. Depending of the goal of the experiment, RNA-Seq data allow identifying and quantifying expressed gene/transcripts, identifying exon bounds, gene fusion, alternative splicing, single nucleotide variants, etc

Even though the just mentioned downstream analyses require different analysis pipelines, they share some preprocessing steps. Between these common steps, the most critical task is identifying which genes/transcripts are represented by the available reads. The most common approach to solve this problem is to align the reads to a reference genome. Since the accuracy and reliability of many downstream analyses heavily depends on the alignment step, part of my research activity was focused on this common part of the RNA-Seq data analysis.

Alignment is a very challenging problem due to the existence of polymorphism, sequencing error, low complexity sequence, intron sized gaps, intron signals, incomplete annotation, alternative splicing and pathological splicing events. The pivotal importance of the read alignment step and the consequent big effort of the research community result in a large number of methods with conflicting claim of superiority. In this unclear scenario, a significant part of my research activity has been focusing on the extensive benchmark analysis of many widely used alignment algorithms. The preliminary steps involved a literature search of the available methods, the definition of a set of comprehensive metrics at read, base and junction level and the creation of several test datasets representing different scenarios.

The first part of the benchmark analysis focused on a comparison of fourteen common splice-aware methods. In addition, the effects of annotation, reads preprocessing and parameter's tuning were studied. The benchmark was performed on simulated data from two genomes, *H.sapiens* (human) and *P.falciparum* (malaria). Human genome was used due to his importance, while malaria genome was chosen because it is a commonly studied organism very different from human. The benchmark analysis shows some interesting results, especially the good performances of some rarely used software and the poor correlation between the popularity of some methods and their accuracies. Moreover, the pivotal role of parameters tweaking suggests that the accuracy of many studies involving complex data could have been negatively affected by too strict default settings. Since the great majority of RNA-Seq studies employ tool's defaults and a precise parameters tweaking on real data is unfeasible, it was developed a complete set of suggestions about parameters tuning for each tested tool.

In the second part of the comparison, it was performed a benchmark analysis of four of the most popular splice-unaware alignment methods. Even though these tools are not suitable for any kind of RNA-Seq reads, splice-unware methods could be used for simple organism, where the splicing is absent of negligible. In general, splice-unaware methods are simpler than splice-aware methods, resulting in fewer mapping options and reduced computational requirements. The methods were tested on simulated libraries from *S.cerevisiae* (Yeast), due to the low number of introns in the Yeast genome. The benchmark results highlight small differences in terms of precision, while the recall has a more variable trend between metrics and tools, both at read and base level. Interestingly, the accuracy at read and base level are oppositely affected by different alignment policies (i.e. end-to-end vs local alignment).

In the last part of the comparison, performance metrics about RAM usage and execution time were collected for both splice-aware and splice-unware methods, resulting in very different computational requirements between methods.

The results of the benchmark study provided many useful information, allowing to identify the most appropriate tools for the particular downstream analysis. For example, a study involving the discovery of new exon bounds would benefit from a tool having a high junction recall, while a DE analysis would benefit from a method having a high accuracy at read level.

Indeed, the improvement of future DE analysis through the choice of the best alignment methods would be certainly one of the most important results for the research community. Among all the RNA-Seq downstream analyses, the study of differentially expressed genes is probably the most common task. This kind of study compares the gene expression levels between different groups or condition, so the first task consists in quantify the expression level of each gene. The digital measure of gene expression is called "counts" and the procedure of calculate these values is called "quantification". Unfortunately, the counts are affected by several biases and a normalization step is required before comparing the different expression levels. In order to better characterize these important procedures, the second part of my research activity was devoted to the quantification and normalization steps. In particular, my work focused on exon level quantification/normalization on simple organism, where the negligible splicing effects allow to use exon quantification as good proxy for gene expression level. The common way of compute counts (i.e. counting the reads overlapping a gene) was compared with more complex approaches that exploit the coverage information. In addition, the effect of employing different alignment strategies and the benefit of using the strand information during the count computation were tested. The results show small differences between the count methods, highlighting that at exon level the different counts strategies achieve comparable results. During this study, it was developed a patch to the popular tool BEDTOOLS which add the function to quantify paired-end strand specific data.

The useful information collected from the previous alignment and quantification/normalization analyses were finally applied in the design of a robust pipeline for a real RNA-Seq study involving Mycobacterium tuberculosis. Mycobacterium tuberculosis (MTB) is a pathogenic bacterial species and the major causative agent of tuberculosis, a common and often lethal infectious disease.

The aim of the study is the characterization of the transcriptional response of MTB in conditions of phosphate starvation, focusing on the identification of the genes regulated by *sigmaE* factor. Investigation of the genes involved in the MTB response to these stress conditions (phosphate starvation) may give new insights about tuberculosis pathogenesis and treatment. The study consisted in a 5 points time series, having 3 biological replicates at each time point for both wildtype and mutant condition (*sigE* gene deleted). In addition, ERCC spike-in were added during sample preparation. In order to design the best analysis pipeline, several workflows employing the previously studied alignment methods, alignments strategies and quantification/normalization techniques were tested. The results were assessed both using ERCC spike-in quantification and applying the same pipeline analyses on simulated data. The results allow identifying a robust analysis pipeline that could be apply on many studies involving MTB or simple organisms. From the biological point of view, the final pipeline allows identifying

a list of DE genes, many of them regulated by *sigmaE* factors, and the DE results were also mapped to a transcriptional network. From the methodological point of view, the DE analysis highlight the new challenges introduced by time series data and the need of robust methods to handle this new kind of data.

As in the MTB study, time series data have become very popular in the last years due to the decreasing in the sequencing costs. Even though many methods were developed to solve the DE problem, the great majority of these methods were not specifically designed to work on time series data. Starting from a previous methods developed by the research group, it was designed a new approach for the analysis of RNA-Seq time series data. The new methods estimate the expression level and the counts variance, using them as parameters of a Negative Binomial distribution in order to create a new dataset describing the population of not DE genes. The dataset created in the previous step is used as null hypothesis in the following DE statistics test. In addition, instead of using the single expression values, the methods used the area between the temporal expression profiles in the two conditions. The use of the area allows quantifying the entire time series using a single value and it was already demonstrated to be more robust compared to single counts values.

Title of thesis: Improving the RNA-Seq analysis pipeline: read alignment and expression level quantification

Supervisor: Barbara Di Camillo

THIRD PART: PUBBLICATIONS

- List of publications in international journals
    - G. Baruzzo, K. Hayer, E. Ji Kim, B. Di Camillo, G. Fitzgerald, G. Grant "Benchmark Analysis of RNA-Seq Aligners" Nature Methods (Current stage: Accepted in principle)

- Publications list related to international conferences
    - G. Baruzzo, F. Finotello, E. Lavezzo, A. Serafini, R. Provvedi, S. Toppo, L. Barzon, R. Manganelli and B. Di Camillo "Benchmarking RNA-seq mapping strategies for paired-end reads " at NETTAB 2014
    - G. Baruzzo, K. Hayer, E. J. Kim, B. Di Camillo, G. Grant "Benchmark Analysis of RNA-Seq Aligners" at Intelligent Systems for Molecular Biology (ISMB) 2016
    - N. Lahens, E. Ricciotti, O. Smirnova, E. Toorens, E. Ji Kim, G. Baruzzo, K. Hayer, T. Ganguly, J. Schug, G. Grant "A comparison of Illumina and Ion Torrent platforms in a

study of differential gene expression" at Intelligent Systems for Molecular Biology (ISMB) 2016

Il Collegio prende atto di quanto esposto e osserva che il dott. Baruzzo Giacomo si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Biral Andrea nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Scienza e tecnologia dell'Informazione.
Dall'inizio del corso di dottorato ad oggi il dott. Biral Andrea ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Scienza e tecnologia dell'Informazione.

Il dottorando dichiara quanto segue:

FIRST PART: EDUCATION

Courses, trainings and summer school activities

- Courses: Real Time Systems, Bayesian Machine Learning, Statistical Methods, Random Graphs and Stochastic Geometry, Applied Functional Analysis, Academic English Course for PhD Students.

- Seminars: weekly Signet group meetings (please see the following link for a list https://docs.google.com/spreadsheet/pub?key=0AvJIK59uXa3qdFIxV0Q5VnVxNkt6eTdETUtqVUxZRGc&output=html); "Biological Network Analysis," by Simona Rombo, on March 06, 2014; "Rosetta e OSIRIS: 10 anni di viaggio verso la cometa," by Giampiero Naletto, on April 07, 2014; "Rosetta rendez-vous with the 67P/Churyumov-Gerasimenko comet," by Luigi Colangeli, on November 27, 2014; "Shaping 5G," by Federico Boccardi, on March 26, 2015; "Mathematical Scientific Challenges of 5G," by Merouanne Debbah, on June 03, 2015; "How to Teach an Old Code a New Trick," by Ruediger Urbanke, at NYU Polytechnic School of Engineering, on October 08, 2015; "Tactile internet: the ultimate case of low latency, reliable communications," by Toktam Mahmoodi, on May 18, 2016; "Optical Flow Switching: A Dynamic, Fast and Agile On-demand Optical Network Architecture," by Vincent W.S. Chan, on July 15, 2016; "FOG-based radio access network (RAN) for ultra-low latency applications in 5G," by Chun-Ting Chou, on July 22, 2016; "Research on Radio Spectrum and Access Sharing at CRC NTU," by Shi-Chung Chang, on July 22, 2016; "On-going MIMO research at NSYSU," by Chih-Peng Li, on July 22, 2016.

- National and international conferences: XII Italian Networking Workshop (INW), held in Cavalese (TN), Italy, on January 14-16, 2015; IEEE Global Communications Conference (Globecom) 2015, held in San Diego (CA), USA, on December 06-10, 2015.

Teaching activities

- Other activities: Second advisor for graduating students; assistant for the projects of the course "Telecommunication networks".

Mobility actions

Five months Internship, from July 23 to December 21, 2015 at the Alcatel-Lucent Bell Labs, Murray Hill (NJ), USA, under the supervision of Howard Huang, Head of the Wireless Technologies for the Internet of Things group.

SECOND PART: RESEARCH

Description of the research during the PhD (max 2 pages) highlighting the original results achieved: The research activity developed mainly over the following topics: Microfluidic networking and Machine to Machine (M2M) Communications.

1)Microfluidic Networking: The purpose of this work was to introduce part of the concepts of information theory and telecommunications (e.g., throughput, channel capacity, and MAC protocols) into the microfluidic domain.

To this end, we performed a preliminary study of the state of the art aimed at identifying the governing rules that control the flow of fluids in droplet-based microfluidic circuits. Such principles were exploited to develop mathematical models that describe, at a high-level, droplet formation, motion, splitting, and switching.

This allowed us to implement a simulator which is able to capture the "macroscopic" dynamics of a microfluidic network and predict the path followed by the droplets in the circuits. To validate the simulator, we compared its results both with the experimental outcomes obtained after facricating and testing microfluidic devices in our laboratory and with the results obtained with OpenFOAM, which is a well-known software for the resolution of computer fluid dynamics systems. The main advantage of our simulator with respect to traditional Computer Fluid Dynamic (CFD) softwares, such as COMSOL or OpenFOAM, resided in its reduced computational complexity. Indeed, although our simulator is not able to capture fine-grain physical phenomena, it provides fast and accurate predictions of droplets routing inside microfluidic networks.

Accordingly, we used such tool to design and analyse arbitrarily complex microfluidic networks. We also started a collaboration with a research group from Austria that led to the proposal, analysis and design of a novel network architecture and MAC protocol to route droplet through multiple nodes in Networked Labs-on-a-Chip.

Finally, we presented a solution to send information in a microfluidic system based on the modulation of droplets length/interdistance.

2)Machine to Machine Communications: The work started with a survey on M2M Communications that highlighted the results obtained so far and the problems still to be addressed in this context by the scientific community. In light of this, we focused on two main issues that are expected to affect M2M Communications: contention resolution and energy-efficiency.

Concenring contention resolution, we studied the combined use of Multiple Packet Reception (MPR) and Successive Interference Cancellation (SIC) techniques in the context of M2M, where the aim is to guarantee high channel access probability to many nodes that have low transmit rates. In particular, we investigated the limiting performance of such a scenario when the population of transmitters grows, while the per-user bitrate decreases. We then find an approximate model to estimate the maximum throughput of a wireless cellular system, where the receiver is capable of performing MPR and perfect SIC.

The research activity on energy efficiency in M2M Communications is the result of the collaboration with Alcatel-Lucent Bell Labs, USA. It consisted in the study of the optimal resource allocation strategy to be used by Machine Type Devices (MTDs) with timing contraints in order to minimize the average total energy cost for packet upload. Note that, besides considering the transmit energy dissipated by the power amplifier, our energy model also accounts for the so-called circuit energy, i.e., the rate-independent energy consumption of the transceiver board, which has non-negligible impact on the typically low-bitrate MTDs communications. Such problem was solved for various scenarios that differ both for the accuracy on the available Channel State Information (CSI) and the capabilities at the receiver.

Definitive title of thesis and name of supervisor: "Novel network paradigms: microfluidic and M2M communications", supervisor: Prof. Andrea Zanella.

THIRD PART: PUBLICATIONS

- List of publications in international journals
  - A. Biral and A. Zanella, "Introducing purely hydrodynamic networking functionalities into microfluidic systems," *Nano Communication Networks*, vol.4, no.4, pp. 205–215, December 2013.
  - A. Biral, M. Centenaro, A. Zanella, L. Vangelista, and M. Zorzi, "The challenges of M2M massive access in wireless cellular networks," *Digital Communications and Networks*, vol.1, no.1, pp.1-19, February 2015.
  - A. Biral, D. Zordan, and A. Zanella, "Modeling, simulation and experimentation of droplet-based microfluidic networks," *IEEE Transactions on Molecular, Biological, and Multi-Scale Communications*, vol.1, no.2, pp. 122-134, June 2015.

- Publications list related to international conferences
  - A. Biral and A. Zanella, "Introducing purely hydrodynamic networking mechanisms in microfluidic systems," in *IEEE International Workshop on Molecular and Nanoscale Communication (IEEE MoNaCom)*, Budapest, Hungary, June 2013.
  - A. Zanella and A. Biral, "Design and Analysis of a Microfluidic Bus Network with Bypass Channels," in proceedings of *IEEE International Conference on Communications (ICC) 2014*, Sydney, Australia, June 2014.
  - A. Zanella, A. Biral, and M. Zorzi, "Asymptotic Throughput Analysis of Massive M2M Access," in *Information Theory and Applications (ITA) Workshop 2015*, La Jolla, San Diego, CA, USA, February 2015.
  - A. Biral, D. Zordan, and A. Zanella, "Transmitting information with microfluidic systems," in proceedings of *IEEE International Conference on Communications (ICC) 2015*, London, UK, June 2015.
  - A. Biral, H. Huang, A. Zanella, and M. Zorzi, "Uplink resource allocation in cellular systems: An energy-efficiency perspective," in proceedings of *IEEE Global Communications Conference (Globecom) 2015*, San Diego, CA, USA, December 2015.
  - A. Biral, D. Zordan, and A. Zanella, "Simulating macroscopic behavior of droplet-based microfluidic systems," in proceedings of *IEEE Global Communications Conference (Globecom) 2015*, San Diego, CA, USA, December 2015.

- A. Biral, H. Huang, A. Zanella, and M. Zorzi, "On the Impact of Transmitter Channel Knowledge in Energy-Efficient Machine-Type Communication," in *IEEE Globecom Workshop on Energy Efficiency in the IoT*, Washington, DC, USA, December 2016.

- Works submitted for publication in journals and conferences:
  - W. Haselmayr, A. Biral, A. Grimmer, A. Zanella, R. Wille, and A. Springer, "Addressing Multiple Nodes in Networked Labs-on-a-Chip," submitted to *IEEE International Conference on Communications (ICC) 2017*, Paris, France, May 2017.

Il Collegio prende atto di quanto esposto e osserva che il dott. Biral Andrea si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Caparra Gianluca nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Scienza e Tecnologia dell'Informazione.
Dall'inizio del corso di dottorato ad oggi il dott. Caparra Gianluca ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Scienza e tecnologia dell'Informazione.

Il dottorando dichiara quanto segue:

FIRST PART: EDUCATION

Courses, trainings and summer school activities

Courses:
- Applied Linear Algebra
- Information theoretic Methods in Security
- Statistical Methods
- The FFT and its use in digital signal processing

Summer schools:
- "ESA/JRC International Summer school on GNSS 2015", Barcelona, Spain, 31/8/2015-10/9/2015

Seminars:
- "Sistema di controllo satellitare del traffico ferroviario ERTMS/ETCS", Nicola Laurenti, Fabio Senesi, Giorgio Bonafè, 6/5/2014, at DEI
- "Future Internet Security and Privacy (challenges)", Mauro Conti, Moreno Ambrosin, 31/10/2014, at DEI
- "Applicazioni dei sistemi di radiolocalizzazione satellitare nei settori della sicurezza e della logistica", Romano Lovison, 15/4/2015, at DII
- "Digital forensic, analisi del traffico telefonico e delle immagini di videosorveglianza nella lotta ai reati in genere. Aspetti interdisciplinari a confronto", 16/4/2015, at DEI
- "Proof, Secrets, and Computation", Silvio Micali, 25/5/2015, at Bo
- "Mathematical Scientific Challenges of 5G", Mérouane Debbah, 3/6/2015, at DEI
- "Shaping 5G", Federico Boccardi, 3/6/2015, at DEI
- "Coordinated Multi-Point Schemes for Interference Management in 5G networks", Paolo Baracca, 8/6/2015, at DEI
- "GNSS Spoofing Attacks and Countermeasures", Christina Popper, 17/09/2015, at Torre Archimede
- "Bitcoin, an attempt at a separation of money and state", Pratap Pattnaik, 25/09/2015, at DEI
- "Computational Thinking, Inferential Thinking and Data Science", Michael I. Jordan, 21/6/2016, at DEI
- "Dialogue on the Quantum revolution", Seth Lloyd, 14/7/2016, at DEI

- "Networks: Brain, Health, and Society", Maurizio Corbetta, 29/9/2016, at DEI
- "A little knowledge is truly a dangerous thing", Stefano Rini, 19/7/16, at DEI
- "Galileo Satellite Navigation System: Current status and research opportunities", Oscar Pozzobon, 14/6/16, at DEI

Presentations at seminars:

- "Workshop on Spoofing and Authentication for GNSS", 13/2/2015, ESA-ESTEC, Noordwijk, The Netherlands,
- "2nd ESA Workshop on Spoofing and Authentication: Results and Optimizations", 6/7/2015, ESA-ESTEC, Noordwijk, The Netherlands
- "3rd Spoofing and Authentication Workshop: Status and coordination", 5/2/16, ESA-ESTEC, Noordwijk, The Netherlands

National and international conferences:

- ESA Workshop on Satellite Navigation Technologies and European Workshop on GNSS Signals and Signal Processing, NAVITEC 2014, ESA-ESTEC, Noordwijk, The Netherlands
- International Conference on Localization and GNSS (ICL-GNSS), Barcelona, Spain, 2016
- Institute Of Navigation GNSS+ 2016, Portland, Oregon, USA, 2016
- ESA Workshop on Satellite Navigation Technologies and European Workshop on GNSS Signals and Signal Processing, NAVITEC 2016, ESA-ESTEC, Noordwijk, The Netherlands

Other activities:

- Take part to the experiment "Applications of Optical Quantum Links to GNSS" at Thales Alenia Space Italia, Torino.

<u>Mobility actions</u>

From 20 November 2015 to 4 June 2016 ESA-ESTEC, Noordwijk, The Netherlands.

SECOND PART: RESEARCH

The research activity focused on the authentication and integrity protection of Global Navigation Satellite Systems (GNSS) Open Service signals and Internet of Things (IoT).

In the scope of the Advanced GNSS Open Service Signal Integrity Protection and Authentication at the Physical Layer (A GOSSIP, A PLAY) project, the goals of the research are: the security analysis, the simulation and the performance evaluation of current authentication techniques proposed for GNSS; and the proposal of novel techniques. Defences operating both at data and signal layer were evaluated. At data layer, I performed a security evaluation on the Navigation Message Authentication (NMA) scheme proposed by the European Commission for the Galileo E1 signal. An output of the research was that some of the proposed mechanism are vulnerable on precomputation attacks. The uni-directional broadcast link with limited bandwidth used for

data dissemination required the adaptation of standard schemes. This is the case of TESLA-based mechanism that was proposed to be used in the GNSS context. These adaptations include a truncation for reducing the bandwidth requirements. The impact of this nonstandard construction on the security of the scheme was not assessed in the literature. A probabilistic model was developed to evaluate the impact of the padding-truncation construction, showing that it is not ideal and leads to a reduction on the security level offered. This model can be used to select the system parameters in order to match the user requirements [ICL '16].

Based on the analysis on the TESLA-based NMA schemes, a novel NMA scheme, SigAm, was proposed, designed to be cryptographically secure and to achieve good performances. SigAm achieve data authentication through traditional digital signatures and exploit chained authentications for allowing fast re-authentication of previously authenticated data and to complementing signal layer mechanisms. A noteworthy difference with respect to TESLA-based NMA schemes is that does not require time synchronization of the receivers in order to be secure, and this allows the secure bootstrap of receivers even after long off-periods. [ION GNSS+ '16 (a), InsideGNSS '16]

On the topic of NMA I was involved by ESA in the review of the Galileo OS authentication.

At signal level, the first work performed targeted the Secure Code Estimation and Replay (SCER), and strategies for its detection. This techniques, rather than attacking the cryptographic mechanism implemented, simply aims at making an estimation of the signal and broadcast this estimation to the victim receiver. Instead of simply replaying the sampled signal, SCER leverage the predictable part of the GNSS signal to reduce the estimation noise and make harder for the receiver to distinguish between a noisy legitimate signal and a noisy spoofed signal due the low SNR of the received signal.

The results achieved on the topic are a generalization of the attack strategy in such a way that it can be optimized to minimize the Kullback–Leibler divergence between legitimate and spoofed signals, both in a time invariant or time-varying attack strategy. About the detection strategy, the GLRT detection strategy was introduced and the performance was evaluated for both LRT and GLRT detection [NAVITEC '14].

During the mobility period at ESA-ESTEC, the instrumentations of the navigation laboratory was used for performing experimentations with real RF signals on signal layer attacks, showing that they are easy to be implemented even with low cost devices. On the other hand, they are hard to be detected due to the rapidly changing environments on the signals that makes it difficult to discriminate between spoofing or natural effects due to multipath/shadowing. Moreover, such attacks can be detected by hypothesis testing based detection strategy only if the attackers advantage (e.g. antenna gain) respect to the victim receiver is limited.

In order to improve the resilience to spoofing, a new autonomous anti-spoofing detection based on codeless/semi-codeless tracking techniques was developed. This mechanism exploits the lower energy per chip of the military ranging signals and the fact that these secret chips are never disclosed to the users, so they cannot be used to generate spoofing signals [NAVITEC '16].

In the scope of the EGNOS Authentication Security Testbed (EAST) project, the feasibility of data layer authentication methods for Satellite-Based Augmentation Systems (SBAS) were assessed. The analysis shown that it is difficult to insert authentication on the current SBAS signal because may require a new system certification due to strict safety critical requirements and achieve

limited performances. For these reasons a more promising solution is to design a new signal component dedicated to authentication [ION GNSS+ '16 (b)].

Another research topic on which I worked is the physical layer authentication for Internet of Things (IoT). In this context the devices are usually resource constrained and battery powered, hence having an efficient authentication mechanism is crucial. Traditional data layer cryptographic authentication mechanisms are in general computational heavy and may not be well suited for this context. A possible alternative solution is physical layer authentication. In this case rather that performing a cryptographic verification on the received message, the physical layer authentication compares a previously authenticated channel estimation by some other mean, with the channel estimation of the current message and accept the message only if the difference does not exceed a threshold. In this context the research goal was to find an energy efficient node activation strategy that maximize the network lifespan while meeting the required performance in terms of probability of missed detection and false alarm [ICC '16].

I also participated in the experiment "Applications of Optical Quantum Links to GNSS" carried out at the Thales Alenia Space Italia facility in Torino. The experiment foresees the simulation of a quantum key exchange using an optical link using two telescopes. The goal of the experiment is to verify the feasibility of the coexistence of a traditional optical link and a quantum one, for an inter-satellite link applied to the GNSS constellation.

On realted topics I supervised the thesis work of Varuni Mehrotra, Silvia Sturaro and Silvia Ceccato.

The title of my thesis will be "Authentication and Integrity Protection at Data and Physical layer for Critical Infrastructures" and the supervisor is Nicola Laurenti.

THIRD PART: PUBLICATIONS

List of publications in journals/books:

- G. Caparra, C. Wullems, S. Ceccato, S. Sturaro, N. Laurenti, R. T. Ioannides, and M. Crisci, "Design Drivers for Navigation Message Authentication Schemes for GNSS Systems," InsideGNSS, vol. 11, no. 5, pp. 64–73, 2016.
- G. Caparra, M. Centenaro, N. Laurenti, S. Tomasin, and L. Vangelista, "Energy-Efficient Physical Layer Authentication in the Internet of Things," in Information Theoretic Security and Privacy of Information Systems, R. F. Schaefer, H. Boche, A. Khisti, and H. V. Poor, Eds. Cambridge University Press, in preparation, 2016.

List of publications in international conferences:

- G. Caparra, S. Sturaro, N. Laurenti, and C. Wullems, "Evaluating the security of one-way key chains in TESLA-based GNSS Navigation Message Authentication schemes," in 2016 International Conference on Localization and GNSS (ICL-GNSS), 2016, pp. 1–6.

- G. Caparra, S. Sturaro, N. Laurenti, C. Wullems, and R. T. Ioannides, "A Novel Navigation Message Authentication Scheme for GNSS Open Service," in ION GNSS+ 2016, 2016.
- Dalla Chiara, G. Da Broi, O. Pozzobon, S. Sturaro, G. Caparra, N. Laurenti, J. Fidalgo, M. Odriozola, J. Caro Ramon, I. Fernandez-hernandez, and E. Chatre, "Authentication Concepts for Satellite-Based Augmentation Systems," in ION GNSS+ 2016, 2016.
- G. Caparra, M. Centenaro, N. Laurenti, S. Tomasin, and L. Vangelista, "Energy-based anchor node selection for IoT physical layer authentication," in 2016 IEEE International Conference on Communications (ICC), 2016, pp. 1–6.
- G. Caparra, C. Wullems, N. Laurenti, and R. T. Ioannides, "An Autonomous GNSS Anti-Spoofing Technique," in NAVITEC, 2016.
- G. Caparra, N. Laurenti, R. T. Ioannides, and M. Crisci, "Improved Secure Code Estimation and Replay Attack and Detection on GNSS Signals," in ESA Workshop on Satellite Navigation Technologies and European Workshop on GNSS Signals and Signal Processing, NAVITEC, 2014.

Il Collegio prende atto di quanto esposto e osserva che il dott. Caparra Gianluca si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori**

Presentazione sull'attività svolta da Ceccarello Matteo nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Scienza e Tecnologia dell'Informazione.
Dall'inizio del corso di dottorato ad oggi il dott. Ceccarello Matteo ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Scienza e tecnologia dell'Informazione.

Il dottorando dichiara quanto segue:

Supervisor: Andrea Alberto Pietracaprina
Thesis title: "Clustering-based algorithms for big data computations"

FIRST PART: EDUCATION

Courses, trainings and summer school activities

Courses:

- Bayesian Machine Learning (Di Nunzio)
- Statistical Methods (Finesso)
- Principles of Cloud Computing (Vardanega)
- Random Graphs and Stochastic Geometry in Networks (Dey)
- Resilient, Parallel, Big Data Application Framewors in X10 (Saraswat)
- Randomized Algorithms and Probabilitistic Analysis (Upfal - Brown University)

Seminars:

- Programming Distributed Machine Learning Applications / Framework - Vijay Saraswat – 03 June 2014
- Analysis of Randomized Work Stealing with False Sharing - Vijaya Ramachandran – 20 June 2014
- Arithmetic for Rooted Trees – Fabrizio Luccio – 6 November 2015
- Fast and Simple Computation of Top-k Closeness Centralities – Pierluigi Crescenzi - 30 October 2015
- Bitcoin, an attempt at separation of money and state - Pratap Pattnaik – 25 September 2015
- Graph Summarization with Quality Guarantees - Matteo Riondato - 26 September 2016

National and international conferences

- ScalPerf'14 - Scalable Approaches to High Performance and High Productivity Computing - Bertinoro - 21/26 September 2014 – with presentation.
- SODA'15 - ACM-SIAM Symposium on Discrete Algorithms - San Diego, California, USA - 4/6 January 2015
- ALENEX'15 - Algorithm Engineering and Experiments - San Diego, California, USA - 5 January 2015 – with presentation.

Research Retreat on Graph Analytics - Bertinoro - 9/11 December 2015 – with presentation.

IPDPS'16 - 31th IEEE International Parallel and Distributed Processing Symposium- 23/27 May 2016 – with presentation

Other activities

International School on Mathematics "Guido Stampacchia": Graph Theory, Algorithms and Applications 3rd Edition - Erice - 08/09/2014 – 16/09/2014

Teaching activities

During the second semester of Academic Year 2015/2015, I worked as Professor Pietracaprina's teaching assistant for the Data Mining class. This activity, supported by the Tutor Junior project, consisted mainly in the supervision and evaluation of the final projects of the class. Furthermore, I assisted the students in the implementation of the project, and I gave a lecture about the data mining software Weka, which was used in the projects.

During the three years of my PhD course I co-advised some students, both Bachelors and Masters, who did their theses with Professors Pietracaprina and Pucci.

Mobility actions

During the third year of my PhD I spent six months at Brown University (Rhode Island, USA) as "visiting research fellow". During this period, from February to August 2016, I did my research activity in collaboration with Professor Eli Upfal's group, with whom I had already worked before my visit. Furthermore I had the occasion to take the class "Randomized Algorithms and Probabilistic Analysis" of Professor Upfal, studying techniques and topics fundamental for my research. Finally, I continued to work on the problem of clustering of uncertain graphs, which I started in Padova before leaving.

At the end of my stay at Brown, Professor Upfal stated his satisfaction for my work, and said he is looking forward to continue our collaboration in the future. I consider this experience very positive, and fundamental for my research training.

SECOND PART: RESEARCH

My research activity is focused on the development of efficient algorithms in the context of big data processing. In this setting, traditional algorithms cannot be applied since the input is much bigger than the memory available to single processors. My goal is to design and analyze algorithms for the new big data computational models. In particular, I studied three problems:

- Graph diameter approximation
- Clustering of uncertain graphs

- Diversity maximization

We developed algorithms based on the clustering to solve the aforementioned problems. In one case, uncertain graph clustering, the clustering is the goal; in the other two cases provides a useful way of building a succinct representation of the input, from which we can compute an approximate solution to the problem at hand. During my PhD course, I collaborated with Carlo Fantozzi, Andrea Pietracaprina, Geppino Pucci, Francesco Silvestri, Eli Upfal, and Fabio Vandin.

Before studying the above problems, we carried out an experimental evaluation of the MapReduce platform, a popular computational model in the big data setting. Specifically, we investigated experimentally the theoretical model introduced by Pietracaprina, Pucci, Riondato, Silvestri, Upfal in the paper "Space-round tradeoffs for MapReduce computations" [ICS'12]. As a case study, we chose matrix multiplication, because of its high computation and communication complexity. Our findings have been published in a paper [3] which appeared in the proceedings of the conference SIAM-ALENEX 2015.

1. Graph diameter approximation

The computation of a graph's diameter is a fundamental primitive of graph analytics: together with the number of nodes and edges, it is a measure of the size of the graph. The exact computation of the diameter requires solving the All Pairs Shortest Path problem, whose complexity, at least quadratic in the number of nodes, is prohibitive in the big data setting. Other approaches proposed in the literature feature either a superlinear space complexity or a linear parallel time complexity, making them unsuitable for big data computational models. We developed parallel algorithms for the approximation of the diameter, with a complexity which is sublinear in the diameter itself and which requires only linear space. Our algorithms can be applied to both unweighted and weighted graphs, and are the first ones which can efficiently approximate the diameter of large graphs. We proved that our algorithms have a polylogarithmic approximation factor. This theoretical result is supported also by an extensive experimental work, carried out with a software that I developed and optimized. Thanks to this software, the algorithm has been applied to graphs up to billions of edges, and we found that the approximation factor obtained in practice is much better than the theoretical one.

This work was published in two papers, presented at the conferences ACM-SPAA 2015 [4] and IEEE-IPDPS 2016 [5].

2. Clustering of uncertain graphs

In several contexts, the relationships between entities modeled with a graph are affected by noise. An example are Protein-Protein interaction networks, where interactions are established with noisy biological experiments. In these cases it is necessary to assign a probability to each edge of the graph, which is then called an *uncertain graph*. These types of graphs require the development of ad-hoc algorithms, since classical algorithms don not take into account the edge

probabilities. Furthermore, the exponential number of possible instantiations of an uncertain graph places this problem in the big data setting.

In this context, a fundamental primitive is to identify *k* groups of nodes such that nodes in the same group have a high connection probability. The challenge posed by this problem is twofold: the clustering problem is NP-hard, and the estimation of connection probabilities is #P-complete. We developed both a sequential and a parallel approximation algorithm for this problem. As opposed to other approaches found in the literature, our algorithms feature provable theoretical approximation guarantees. This theoretical analysis is complemented by an extensive experimental evaluation, which studies the behaviour of our algorithms with respect to their competitors. At present we are concluding the experimental analysis and the paper [7], which will be submitted to the VLDB journal.

3. Diversity maximization

The *diversity maximization* problem requires that, given a set of points in a multi-dimensional space, a subset of fixed size is found such that its diversity is maximized, for some measure of diversity given by the application. For instance, in news aggregators we want to select from the set of all articles a small subset containing news representative of different topics. This optimization problem is NP-hard, and typically the applications involve large volumes of data: we need distributed or streaming algorithms, which do not require all the data in memory.

We developed approximation algorithms based on the coreset technique. In particular, we developed a Streaming algorithm, that can be applied in the case where the input is generated in real-time, and an efficient MapReduce algorithm, which is able to process large volumes of data in parallel. Algorithms proposed in the previous literature feature constant approximation factors, which do not adapt to the computing resources available. Our algorithms, instead, leverage the *doubling dimension* of the input to obtain approximation factors depending on the available resources, and in general better than the ones found in previous literature. We also carried out an extensive experimental evaluation of the performance of our algorithms. Our implementation is able to handle billions of elements in parallel, and streams of hundreds of thousands of elements per second.

The paper describing this work has been submitted to the VLDB journal and passed the first round of reviews. A preliminary version is publicly available at arxiv.org [6].

THIRD PART: PUBBLICATIONS

- Matteo Ceccarello and Nastaran Shafiei
  Tools to Generate and Check Consistency of Model Classes for Java PathFinder
  In ACM SIGSOFT, Volume 37 Issue 6, November 2012
  (link: ACM digital library) *Articolo pubblicato prima dell'inizio della scuola di dottorato*

- Matteo Ceccarello and Oksana Tkachuck
  Automated generation of model classes for Java PathFinder
  In ACM SIGSOFT, Volume 39 Issue 1, January 2014
  (link: ACM digital library) *Articolo pubblicato prima dell'inizio della scuola di dottorato*
- Matteo Ceccarello and Francesco Silvestri
  Experimental Evaluation of Multi-Round Matrix Multiplication on MapReduce. Proc. of 17th SIAM Meeting on Algorithm Engineering & Experiments (ALENEX) 2015. (Acceptance rate 28%.) (link: ACM Digital Library)
- Matteo Ceccarello, Andrea Pietracaprina, Geppino Pucci, Eli Upfal.
  ***Space and Time Efficient Parallel Graph Decomposition, Clustering, and Diameter Approximation*. Proceedings of the 27th ACM symposium on Parallelism in Algorithms and Architectures (SPAA) 2015. (Acceptance rate 24%)**
  (link: ACM Digital Library)
- Matteo Ceccarello, Andrea Pietracaprina, Geppino Pucci, Eli Upfal.
  A Practical Parallel Algorithm for Diameter Approximation of Massive Weighted Graphs.
  Proc. of the 30th IEEE International Parallel & Distributed Processing Symposium (IPDPS) 2016. (Acceptance rate 23%)
  (link: IEEE link)
- Matteo Ceccarello, Andrea Pietracaprina, Geppino Pucci, Eli Upfal.
  MapReduce and Streaming Algorithms for Diversity Maximization in Metric Spaces of Bounded Doubling Dimension.
  (link: preprint on Arxiv)
- *Matteo Ceccarello, Carlo Fantozzi, Andrea Pietracaprina, Geppino Pucci, Fabio Vandin*
  Clustering Uncertain Graphs. *Manuscript.*

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Dall'inizio del corso di dottorato ad oggi il dott. Celin Alberto ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Scienza e tecnologia dell'Informazione.

Il candidato dichiara quanto segue:

Courses and Seminars

Courses

- Physics and operation of heterostructure-based electronic and optoelectronic devices, *Prof. G. Meneghesso* (20/01/2014 – 20/02/2014)
- Real-Time Systems and applications, *Prof. G. Manduchi* (18/02/2014 – 20/03/2014)
- Digital Processing of Measurement Information, *Prof. C. Narduzzi* (24/03/2014 – 17/04/2014)
- Statistical Methods, *Prof. L. Finesso* (16/06/2014 – 23/07/2014)
- **(Summer School of Information Engineering, Bressanone BZ, July 5-11 2015)**
- Power Electronics for automotive, *Cristian Garbossa, Infineon Technologies Italia S.r.l, Development Center Padova* (06/07/2015)
- Automotive Lighting, *Alberto Guiotto, Davide Baccarin, Automotive Lighting Italia S.p.A* (07/07/2015)
- Automotive Smart Power IC Design, *Dr. Bernhard Wicht, Robert Bosch Center for Power Electronics Integrated Circuits Reutlingen University* (08/07/2015)
- Vehicular communications, *Giovanni Pau, Laboratoire d'Informatique de Paris 6* (09/07/2015)
- Fundamentals and recent advances in vehicle platooning control, *Paolo Falcone, Chalmers* (10/07/2015)
- **(Summer School of Information Engineering, Bressanone BZ, July 3-9 2016)**
- *Security aspects and techcnologies in the IoT , **Nicola Laurenti, Lorenzo Vangelista**, Department of Information Engineering - University of Padua* (04/07/2016)
- *Large Area Electronics – Or Magical Plastic Foils, **Pawel Malinowski**, IMEC, Belgium* (05/07/2016)
- *Low power and ultra narrow band communication system (SigFox network),* **Dominique Morche,** Laboratoire d'électronique des technologies de l'information CEA LETI, France (06/07/2016)
- *Sustainable Mobile Networks: the scavenge vision, **Paolo Dini**, Centre Tecnològic de Telecomunicacions de Catalunya (CTTC), Spain* (06/07/2016)
- *Data science meets embedded systems , Stefan Dulman, Centrum Wiskunde & Informatica (CWI), Netherland* (07/07/2016)
- *Time Synchronization in Wireless Sensor Networks: Concepts and Research Trends, **Djamel Djenouri*** Centre De Recherche Sur L'information Scientifique Et Technique (CERIST), Algiers *(08/07/2016)*

- *Data mining in the IoT era: practical examples and a peek into future developments* , ***Michele Rossi***, Department of Information Engineering – University of Padua *(08/07/2016)*

Seminars

- "A Millimeter-wave CMOS Transceiver Toward more than 300Gbps"

Speaker: Kenichi Okada, *Tokyo Institute of Technology, Japan* (Sala riunioni 201 DEI-A)

- "Recent Advances in the Design of Filtering Delta-Sigma ADCs"

Speaker: Pietro Andreani, *Lund University, Sweden* (Sala riunioni 201 DEI-A)

- **"Compensation of Class A/AB Amplifiers: An Intuitive Approach"**

Speaker: Germano Nicollini, STMicroelectronics, Italy *(ESSCIRC 2014, Tutorial, Venezia)*

- **"Design of High-Precision Chopper Amplifiers"**

Speaker: Franco Maloberti, *University of Pavia, Italy* (ESSCIRC 2014, Tutorial, Venezia)

- **"Design of Class-D Amplifier for Audio Portable Solutions"**

Speaker: Angelo Nagari, *STMicroelectronics, France* (ESSCIRC 2014, Tutorial, Venezia)

- **"Phase noise, simply"**

Speaker: Donhee Ham, *Harvard* (ESSCIRC 2014, Tutorial, Venezia)

- **"Phase Noise in Harmonic Oscillators"**

Speaker: Pietro Andreani, *Lund University* (ESSCIRC 2014, Tutorial, Venezia)

- **"Fundamentals of Phase Noise and Jitter"**

Speaker: Asad Abidi, *UCLA* (ESSCIRC 2014, Tutorial, Venezia)

- **"THz-Workshop: Millimeter- and Sub-Millimeter-Wave circuit design and characterization"**

Organizer: Thomas Zimmer, *University Bordeaux, France* (ESSCIRC 2014, Workshop, Venezia)

- "Filtering A/D Converters"

Speaker: Pietro Andreani, *Lund University, Sweden* (Sala riunioni 201 DEI-A)

- "How chips helped discover the Higgs boson at CERN"

Speaker: Walter Snoeys, *PH department, CERN, Geneva, Switzerland* (Aula Magna "A. Lepschy")

- **"Networks: Brain, Health, and Society"**

Speaker: Maurizio Corbetta, Professor of Neurology, Neuroscience, Radiology, Biomedical Engineering, Washington University School of Medicine St.Louis, St.Louis (MO), USA

- **"Computational Thinking, Inferential Thinking and Data Science"**

Speaker: **Michael I. Jordan ,** Pehong Chen Distinguished Professor, University of California, Berkeley (CA), USA

Conferences and Workshops

- From 21/09/2014 to 26/09/2014 the ESSCIRC/ESSDERC 2014 conference in Venice has been attended as a member of the staff of the conference.
- From 24/05/2015 to 27/05/2015 the ISCAS 2015 conference in Lisbona has been attended and it was presented a paper with the name *"Optimal DWA Design in Scaled CMOS Technologies for Mismatch Cancellation in Multibit Sigma-Delta ADCs".*
- From 05/07/2015 to 11/07/2015 the Summer School of Information Engineering in Bressanone (BZ) about ICT for Automotive Industry has been attended.
- From 26/04/2016 to 28/04/2016 the AACD 2016 workshop in Villach (Austria) about continuous-time Sigma-Delta modulators, electronic for Automotive applications and the Power Management has been attended.
- From 22/05/2016 to 25/05/2016 the ISCAS 2016 conference in Montreal (Canada) has been attended and it was presented a paper with the name *"*A Reduced Hardware Complexity Data-Weighted Averaging Algorithm with no tonal behavior*".*
- From 03/07/2016 to 09/07/2016 the Summer School of Information Engineering in Bressanone (BZ) about **Technologies for Internet of Things has been attended.**

Teaching Activity

The tutor activity for the courses of *Circuiti Integrati per l'Elaborazione dei Segnali* and *Progettazione di Circuiti Integrati Analogici* has been followed consisting in the support for the students in the software used for the design of analog and RF circuits. This activity has been followed for all the three years of the PhD.

Scientific Activity:

Description of the Scientific Activity

Title of the Thesis: Analysis and Design of a Wide-Bandwidth Low Power Sigma-Delta ADC in CMOS Technology
Supervisor: Andrea Gerosa

The evolution of the CMOS technology brings many challenges to analog designers. The scaling-down of the transistor feature size has a big impact on analog circuit design, because it considerably degrades the performance of an analog circuit. For instance, the reduced supply voltage and the degraded device characteristics are inevitable problems for CMOS designers.
As an interface between the analog circuit and the digital circuit, the Analog-to-Digital Converter (ADC) is moving into scaled nanometer CMOS technologies due to the advantages for the digital circuit. On the other hand, the number of applications with industrial interest has also grown. In

fact, starting from the earliest in the audio band, we can find Analog-to-Digital Converters in a large variety of A/D interfaces, ranging from instrumentation to communications.

The increasing need of ADCs with wide bandwidth and large resolution, in the modern CMOS nanometric technologies, has led in the last years in a growing study in the development of ADCs. Sigma-Delta ADCs are promising candidates for the A/D conversion. The reason for that is mainly determined by the fact that, unlike the other converters that need accurate building blocks to obtain high resolution, Sigma-Delta converters show low sensitivity to the imperfections of their building blocks. This is achieved thanks to the extensive use of digital circuitry, which is preferred in CMOS technologies due to their low power and high density characteristics.

Among the possible Sigma-Delta topologies, during this PhD, the attention has been focused in particular in a topology suitable for nanometric CMOS technology. The architecture of the converter is depicted in Figure 1.

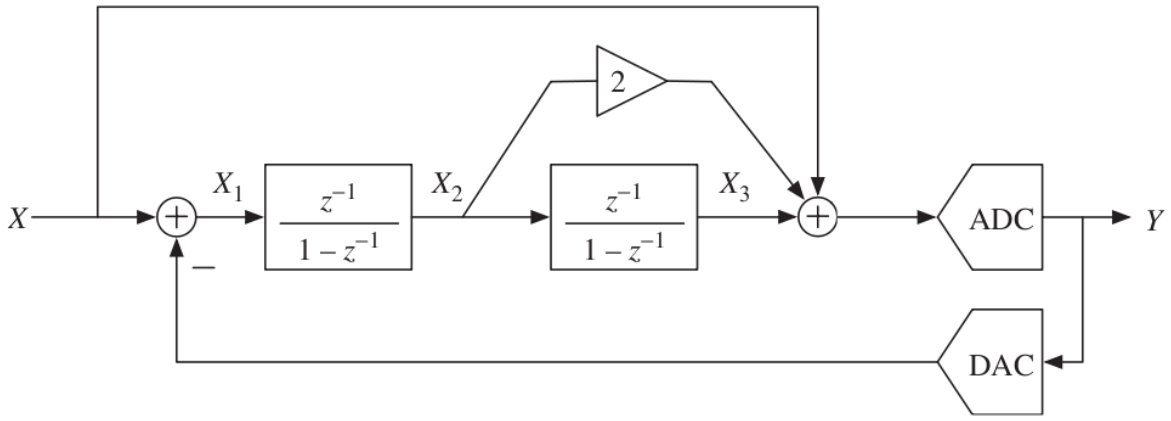

Figure 1: Architecture of the Sigma-Delta modulator.

The main characteristic of this topology is the transfer function between the input and the output which allows to reduce the linearity requirements of the modulator leading also to a reduction of the overall power consumption.

In general, in order to increase the resolution of the Sigma-Delta architecture, keeping the power consumption as low as possible, it is possible to oversample over the Nyquist frequency, reducing however the signal bandwidth of the modulator. In the context of this design, with the aim of realizing a modulator with a wide signal bandwidth, the oversampling ratio has to be chosen small, but the resolution can be increased by increasing the number of bits of the internal quantizer. However, this choice requires to use an algorithm in order to shape the distortion produced by the multi-level Digital-to-Analog Converter (DAC). These algorithms used for the mismatch cancellation are called "Dynamic Element Matching (DEM) " algorithms.

An algorithm that allows to keep a high linearity of the DAC embedded in the feedback also in presence of a multibit quantizer has been developed.

About this algorithm an innovative implementation has been proposed in order to keep a high efficiency in the shaping of the distortion produced by the DAC combined with a circuitry which minimizes the power consumption and the area.

Thanks to a collaboration with *ST Microelectronics of Lund (Sweden)* a Sigma-Delta converter has been studied and implemented, in schematic and layout level, in 65nm CMOS technology.

The dynamic of the converter is 93 dB, the signal bandwidth is 500kHz and the power consumption is 400uW. These characteristics lead to a figure of merit (FOM) of 8.7fJ per conversion. In Figure 2 the FOM is compared with the published FOM of the last years.

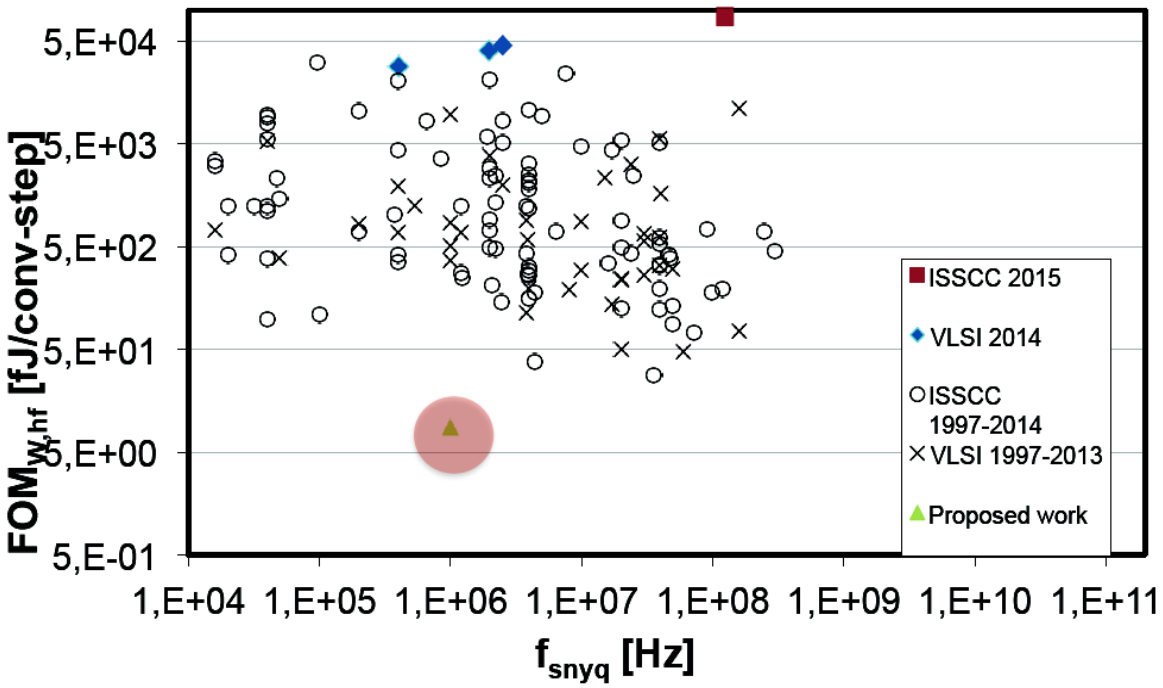

Figure 2: Comparison of the proposed work FOM with other published FOMs.

From Figure 2 it is apparent that the proposed FOM is better than the FOMs published in the last years.

The circuit is now in fabrication and it will be available for measurement in the first part of 2017.

Publications

- A. Celin and A. Gerosa "Optimal DWA Design in Scaled CMOS Technologies for Mismatch Cancellation in Multibit Sigma-Delta ADCs", *IEEE International Symposium on Circuits and Systems (ISCAS) 2015*, pp. 1454-1457.
- A. Celin and A. Gerosa "A Reduced Hardware Complexity Data-Weighted Averaging Algorithm with no tonal behavior", *IEEE International Symposium on Circuits and Systems (ISCAS) 2016*, pp. 702-705.

Il Collegio prende atto di quanto esposto e osserva che il dott. Celin Alberto si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Dalcanale Stefano nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Scienza e Tecnologia dell'Informazione.
Dall'inizio del corso di dottorato ad oggi il dott. Dalcanale Stefano ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Scienza e tecnologia dell'Informazione.

Il dottorando dichiara quanto segue:

Fist part: Education

Courses:

- Applied Linear Algebra
- Digital Processing of Measurement Information
- E. M. Waves in Anisotropic Media
- Statistical Methods

Partecipation to national PhD schools:

- July 3-9 2016: Summer School of Information Engineering - Technologies for Internet of Things

Seminars:

- February 24 2014: Daisuke Ueda. "Present and Future of GaN Power Devices".
- May 8 2014: Alberto Gurizzan. Seminario polo fotovoltaico.
- May 20 2014: Seminario pratico LabView su acquisizione dati e controllo.
- May 23 2014: Hidekazu Umeda, Tatsuo Morita. "Recent Advances of GaN Gate Injection Transistor (GIT) for high efficiency power conversion".
- May 29 2014: Tommaso Caldognetto. "Cooperative Control of Photovoltaic Inverters in Smart Microgrids".
- July 24 2014: Bastian Galler (Osram OptoSemiconductor). "Efficiency limiting mechanisms in InGaN LEDs".
- October 6 2014: Tetsu Kachi. "GaN Power Devices for Automotive Applications". Takashi Katsuno. "Degradation analysis and current collapse imaging of AlGaN/GaN HEMTs by measurement of electric field-induced optical second-harmonic generation".
- November 2014: Luca Roselli, "Green Electronics: tecnologie abilitanti per l'Internet delle cose"
- September 24 2015: Elke Meisssner, "GaN - a long way to go from crystal growth to substrates for reliable electronic devices: the effects of structural disturbances on the electrical behavior of GaN from a materials perspective"
- March 31 – April 1 2016: Gilberto Curatola. "GaN Technologies for Power Electronics"
- July 14 2016: Set Lloyd. "Dialogue on the Quantum Revolution"
- September 22 2016: Hidetoshi Ishida. "GaN-based Polarized Semiconductor Devices for Future Power Switching Systems"

- September 23 2016: Kenichiro Tanaka. "Device physics of E-mode gate-injection transistors (GIT)"
- September 23 2016: Carlo De Santi. "High-field reliability of GaN-based HEMTs"
- September 23 2016: Davide Bisi. "Threshold-voltage instabilities and breakdown mechanisms in MIS gate modules for GaN power electronics"
- September 23 2016: Isabella Rossetto. "Failure mechanisms in p-type HEMTs submitted to high gate forward bias"

Partecipation to interantional conferences:

- Conference WOCSDICE 2014 (Workshop on Compound Semiconductors Devices and Integrated Circuits) Delphi (Grecia) 16/06/2014 – 18/06/2014.
  Work presented at this onference:
  S. Dalcanale, A. Stocco, F. Rampazzo, M. Meneghini, G. Meneghesso, E. Zanoni, "Reliability improvement of AlGaN/GaN HEMTs for space applications"
- Conference ESSDERC 2014 (European Solid-State on Device Research Conference) Venezia 22/09/2014 – 26/09/2014.
- Conference "Gallium nitride Technology in Europe" Padova 27/4/2016-28/4/2016.
- Conference IWN (Interational Workshop on Nitride Semiconductors) Orlando (Florida) 2/10/2016 – 7/10/2016.

Mobilty actions:

- 02/02/2015 – 31/07/2015 mobility period by the public research center Ferdinand-Braun-Institut, Leibniz Institut für Höchstfrequenztechnik (FBH), in Berlin.

Second part: research

The research activity has been main focused on the reliability analysis of GaN HEMT transistors for power and telecommunications applications. These new generation devices could be fundamental in the future thanks to the high efficiency of converters and inverters based on this technology. It will be possible to save energy in the converters for devices like smartphones and laptop; furthermore, the inverters are fundamental for the energy conversion of renewable resource. Another field where it is possible to use this kind of transistors is the automotive, and in general al the power electronics. For the telecommunications the HEMT transistors are used in the high frequency power amplifiers. For space applications they are still used for the satellite communications and for radars. For the mobile phones the GaN-based amplifiers will pay a key role in the next 5G generation, when will be necessary to work at higher frequency limiting the power consumption.

The research activities have been carried out in collaboration with companies and international research centers, starting the first year with the European project "*Gan-based normally-off high power switching transistor for efficient power converters"* (Hiposwitch). The main research activities have been focused on the device characterization, to check how the different device solutions behave, identifying the best way to follow during the development. The device

characterization is done by means of static and dynamic measurements, current transients, leakage measurements, step stress and breakdown. Due to the application target of this transistors several test have been performed at voltage of 200 V or 600 V.

He period from 02/02/2015 to 31/07/2015 has been spent by the public research center Ferdinand-Braun-Institut, Leibniz Institut für Höchstfrequenztechnik, in Berlino. During these six months I have carried out research activities on HEMT transistors developed by the research center. This activity is a continuation of the work carried out in the European project *HIposwitch*, ended in the February 2015. In the first part they have been carried out 100h reliability tests. In the second part, this activity has been sustained by the simulator Atlas Silvaco, that was fundamental to deeply understand how the analyzed devices work. By means of two-dimensional simulations it was possible to better investigate the degradation mechanism in stress conditions.

After I come back in or department I started again a collaboration with a company in the field of power HEMT. Our role is to investigate the problems that afflict this technology, providing fundamental information for the next technological steps. In this collaboration they have been developed innovative measurements systems that allow to test in a better way the devices performances.

During the third year I have been working on RF devices, occluding a four-years project founded by the European Space Agency (ESA): "*Preliminary Validation of Space Compatible GaN Foundry processes*". In this project I completed the last reliability measurements and the final reports. These results are very important since they allow to validate the tested technology, i.e. to guarantee the reliability level required by ESA for space applications.

Definitive title of the thesis: Reliability analysis of GaN HEMT for space applications and switching converters based on advanced experimental techniques and two dimensional device simulations

Name of the supervisor: Zanoni Enrico

Third part: publications

List of publications in international journals:

- Matteo Meneghini, Piet Vanmeerbeek, Riccardo Silvestri, Stefano Dalcanale, Abhishek Banerjee, Davide Bisi, Enrico Zanoni, Gaudenzio Meneghesso, and Peter Moens "Temperature-Dependent Dynamic-Ron inGaN-based MIS-HEMTs: role of surface traps and buffer leakage" Transaction on Electron Devices vol. 62, no. 3, pp. 782–786, 2015.
- A. Stocco, S. Gerardin, D. Bisi, S. Dalcanale, F. Rampazzo, M. Meneghini, G. Meneghesso, Jan Grünenpütt, Benoit Lambert, Hervé Blanck, E. Zanoni, "Proton induced trapping effect on space compatible GaN HEMTs" Microelectronics Reliability vol. 54, pp. 2213–2216, 2014.

- A. Stocco, S. Dalcanale, F. Rampazzo, M. Meneghini, G. Meneghesso, Jan Grünenpütt, Benoit Lambert, H. Blanck, E. Zanoni, "Failure signatures on 0.25 µm GaN HEMTs for high-power RF applications" Microelectronics Reliability vol. 54, pp. 2237–2241, 2014.
- M. Meneghini, O. Hilt, C. Fleury, R. Silvestri, M. Capriotti, G. Strasser, D. Pogany, E. Bahat-Treidel, F. Brunner, A. Knauer, J.Würfl, I. Rossetto, E. Zanoni, G. Meneghesso, S. Dalcanale, "Normally-off GaN-HEMTs with p-type gate: Off-state degradation, forward gate stress and ESD failure" Microelectronics Reliability, vol. 58, pp. 177-184, 2016.
- I. Rossetto, M. Meneghini, O. Hilt, E. Bahat-Treidel C. De Santi, S. Dalcanale, J. Wuerfl, E. Zanoni, G. Meneghesso "Time-Dependent Failure of GaN-on-Si Power HEMTs With p-GaN Gate" Transaction on Electron Devices, Vol. 63, n. 6, pp. 2334-2339, 2016.

Publications list related to international conferences:

- S. Dalcanale, A. Stocco, F. Rampazzo, M. Meneghini, G. Meneghesso, E. Zanoni, "Reliability improvement of AlGaN/GaN HEMTs for space applications" in Proc. WOCSDICE, 2014, pp. 127-128
- A. Stocco, S. Dalcanale, F. Rampazzo, M. Meneghini, G. Meneghesso, J. Grünenpütt, B. Lambert, H. Blanck, E. Zanoni, "Simple technique for failure modes detection on high-performances space designed GaN HEMTs" in Proc. ESA Wide Band Gap Semiconductor & Components Workshop, 2014.
- I. Rossetto, M. Meneghini, O. Hilt, E. Bahat-Treidel, J. Würfl, R. Silvestri, S. Dalcanale, E. Zanoni, G. Meneghesso, "Experimental Demonstration of Weibull Distributed Failure in p-type GaN High Electron Mobility Transistors under high forward bias stress" Proceedings of the International Symposium on Power Semiconductor Devices and ICs 2016.
- A. Stocco, S. Dalcanale, F. Rampazzo, M. Meneghini, G. Meneghesso, J. Grünenpütt, B. Lambert, H. Blanck, E. Zanoni, "Simple technique for failure modes detection on high-performances space designed GaN HEMTs" in Proc. ESA Wide Band Gap Semiconductor & Components Workshop, 2016.

Il Collegio prende atto di quanto esposto e osserva che il dott. Dalcanale Stefano si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da De Luca Alberto nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Bioingegneria.
Dall'inizio del corso di dottorato ad oggi il dott. De Luca Alberto ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Bioingegneria.

Il candidato dichiara quanto segue:

FIRST PART: EDUCATION

Courses, trainings and summer school activities

- Courses:
  - Real Time Systems and Applications (test passed);
  - Computing Inverse Problem (test passed);
  - Bayesian Machine Learning (attended only);
  - Tissue Engineering: Principles and Applications (test passed);
  - Statistical Methods (test passed);
  - Applied Machine Learning in Biomedicine (test passed);
- National and international conferences:
  - International Society for Magnetic Resonance in Medicine (ISMRM) 22nd Annual meeting, Milan, Italy, 10-16 May 2014;
  - ISMRM 23rd Annual meeting, Toronto, Canada, 30 May – 5 June 2015;
  - ISMRM 24th Annual meeting, Singapore, 07-13 May 2016;
  - ISMRM Diffusion Workshop "Breaking the barriers of diffusion MRI", Lisbon, Portugal, 11-16 September 2016.

Mobility actions

Visiting PhD Student at the Radiology Department of University Medical Center Utrecht (The Netherlands) under the supervision of Dr. Martijn Froeling from September 2015 to February 2016.

SECOND PART: RESEARCH

My research activity over the last three years covered different Magnetic Resonance Imaging (MRI) technologies and applications. During the first year I mainly focused on structural imaging (T_1 weighted images – T_{1W}) developing a method based on fractal geometry to analyze the gray matter cortical folding in a pediatric population. The method, developed in collaboration with IRCCS E. Medea (Bosisio Parini, LC) was able to detect abnormal gyrification and cortical thickness in patients affected by "malformations of the cortical development", showing higher detection performances than existing methods. The final results of this research have been published as journal paper (De Luca et al. , Physics in Medicine and Biology, 2016), however, during different stage of its development another journal paper (Squarcina, De Luca et al., Physics in Medicine and Biology, 2015) and 2 abstracts proceedings were published. During the first year I learnt the basics of diffusion MRI (dMRI) that became my main PhD topic. In particular, during the first year I experienced the gold-standard quantification technique for dMRI data, Diffusion Tensor Imaging (DTI), and performed a clinical study on a population affected by Friedreich's Ataxia, a degenerative disease that primarily involves motor functions. I investigated the white matter (WM) comparing DTI maps computed on patients with a population of healthy controls and found alterations of the WM structure in regions compatible with the outcome, as the cortico-spinal tract and the cerebellum. These findings were presented at the "International Ataxia Research Conference", and a paper on this research is currently being prepared. During the 2nd year of PhD I mainly focused on the application and development of new dMRI techniques. In collaboration with the Verona Hospital "Borgo Trento" I performed a study of the temporal lobe in patients affected by Multiple Sclerosis (MS) with the "Neurite Orientation Dispersion and Density Imaging" (NODDI) technique, a method that supersets DTI and provides more tissue specific metrics. Results of this study have been published in a journal paper (Calabrese et al., Multiple Sclerosis Journal, 2016) and in two international conferences proceedings. Another topic I pursued during the 2nd year was the development of a novel multi-compartment model to fit dMRI data, as attempt to provide tissue specific metrics, similarly to NODDI but with fitted less parameters. This activity resulted in an abstract at an international

conference. As last project of the 2nd year, I performed a clinical study on a population affected by Williams Syndrome, which results have been presented at an international conference and are now being written in a journal paper in preparation. During the 3rd year I moved my interest toward dMRI of the skeletal muscle, where the techniques faces non trivial challenges and has been much less explored than in the brian. I visited a lab at UMC Utrecht that was already experienced on this topic, and performed a study on the effects of blood perfusion on the dMRI measures quantified either through DTI or DKI, an extension of DTI that accounts for additional effects. This research activity resulted in journal paper (De Luca et al., Magnetic Resonance in Medicine, 2016) and in three posters presented at international conferences. Actually, I am following a clinical study on a cohort of patients affected by "Limb Girdle Muscular Dystrophy", performing a comprehensive imaging study to detect alteration patterns and to extract meaningful biomarkers to provide a differential diagnosis and disease staging from a comprehensive multi-parametric acquisition protocol that includes dMRI, T_{1W} images, T_2 quantification and Dixon imaging. Preliminary results have been presented at an international and a national conference. The last project I am developing, which preliminary results have already been presented at an international conference, is a deconvolution based approach to perform non-explicit dMRI signal modeling. I applied this technique to brain data acquired with classic dMRI acquisition and a novel flow compensated sequence and quantified IVIM, free water and tissue contributions to the signal.

The title of my thesis is "**Moving beyond DTI: non-Gaussian diffusion in the brain and skeletal muscle"**, that I am writing under the supervision of Prof. Alessandra Bertoldo.

THIRD PART: PUBBLICATIONS

- List of publications in international journals:

- **A. De Luca**, A Bertoldo, M Froeling: "Effects of perfusion on DTI and DKI estimates in the skeletal muscle", Magnetic Resonance in Medicine 2016 Aug 19, PMID: 27538923 DOI:10.1002/mrm.26373.
- **A. De Luca**, F Arrigoni, R Romaniello, FM Triulzi, D Peruzzo, A Bertoldo: "Automatic localization of cerebral cortical malformations using fractal analysis". Physics in Medicine and Biology, 2016 61(16):6025-40, PMID: 27444964 DOI: 10.1088/0031-9155/61/16/6025.
- M. Calabrese, M. Castellaro, A. Bertoldo, **A. De Luca**, FB Pizzini, GK Ricciardi, M Pitteri, S Zimatore, R Magliozzi, MD Benedetti, P Manganotti, R Reynolds, A Gajofatto, S Monaco: "Epilepsy in multiple sclerosis: The role of temporal lobe damage", Multiple Sclerosis Journal, 2016 June 3, PMID:27260699 DOI: 10.1177/1352458516651502.
- L. Squarcina, **A. De Luca**, M. Bellani, P. Brambilla, FE Turkheimer, A. Bertoldo: "Fractal analysis of MRI data for the characterization of patients with schizophrenia and bipolar disorder", Physics in Medicine and Biology, 2015 60(4):1697-716. Doi: 10.1088/0031-9155/60/4/1697.

- Publications list related to international conferences:
  - **A De Luca**, A Bertoldo, M Froeling: "Effects of perfusion on DTI and DKI estimates of the skeletal muscle". ISMRM Diffusion Workshop 2016, Lisbon, Portugal, 11-16 September 2016.
  - **A De Luca**, A Bertoldo, M Froeling: "A correlation study of free diffusion and kurtosis changes in longitudinal acquisition of the skeletal muscle". ISMRM Diffusion Workshop 2016, Lisbon, Portugal, 11-16 September 2016.
  - **A De Luca**, A Bertoldo, F Arrigoni, M Froeling: "Hindered diffusion, free water and pseudo-diffusion quantification in the brain: a comparison of Stejskal-Tanner and Flow-Compensated gradients.". ISMRM Diffusion Workshop 2016, Lisbon, Portugal, 11-16 September 2016.
  - **A De Luca**, A Bertoldo, M Froeling: "Effects of perfusion on DTI and DKI estimates in the skeletal muscle". ISMRM 2016, Singapore, 07-13 May 2016

- **A De Luca**, G D'Angelo, D Peruzzo, F Triulzi, A Bertoldo, F Arrigoni: "Multi-parametric assessment of thigh muscles in patients with limb girdle muscular dystrophies (LGMD): preliminary results.", ISMRM 2016, Singapore, 07-13 May 2016.
- Arrigoni F, **De Luca A**, Peruzzo D, Romaniello R, Bertoldo A, Triulzi F: "A novel automatic method for the detection of malformations of cortical development based on fractal properties of cerebral cortex." ESNR 2015
- **A. De Luca**, M. Castellaro, S. Montemezzi, M. Calabrese, A. Bertoldo: "Tissue separation of multi-shell DW-MRI with a physiologically constrained multi compartment model and spherical deconvolution.", ISMRM 2015, Toronto, Canada, 29 May – 06 June 2015.
- **A. De Luca**, M. Castellaro, S. Montemezzi, M. Calabrese, A. Bertoldo: "Hippocampi and epilepsy in MS patients: a diffusion weighted imaging study with NODDI.", ISMRM 2015, Toronto, Canada, 29 May – 06 June 2015.
- **A. De Luca**, D. Peruzzo, F. Triulzi, F. Arrigoni, A. Bertoldo: "An automatic classificator based on local fractal features for the identification of cortical malformations", ISMRM 2015, Toronto, Canada, 29 May – 06 June 2015.
- M. Vavla, F. Arrigoni, E. Petacchi, A. Nordio, **A. De Luca**, E. Russo, S. Pizzighello, G. Paparella, E. Brighina, G. D'Angelo, E. Carraro, A. Martinuzzi: "Potential neuroimaging biomarkers validated in Friedrich's Ataxia: DTI and Functional magnetic resonance findings", IARC 2015, Berkshire, England, 25-28 March 2015.
- L. Squarcina, **A. De Luca**, M. Bellani, P. Brambilla, E. Turkheimer, A. Bertoldo: " Evaluation of gray matter complexity in psychiatric patients using fractal geometry", ISMRM 2014, Milan, Italy, 10-16 May 2014. ID Scopus: 2-s2.0-84922309065
- **A. De Luca**, L. Squarcina, M. Bellani, P.Brambilla, F. E. Turkheimer,A. Bertoldo:"Fractal dimension analysis of gray matter structure applied to schizophrenia patients",HBM 2013, Seattle, USA, 16-20 June 2013

- Publications list ralated to national conventions:

- Caratterizzazione multi parametrica del muscolo scheletrico di pazienti affetti da distrofia mediante risonanza magnetica 3T. A. De Luca, D. Peruzzo, G. D'Angelo, F. Arrigoni, A. Bertoldo. High-tech in neuroriabilitazione infantile: traguardi e sfide. 24-25 Settembre 2015, Bosisio Parini (LC).

Il Collegio prende atto di quanto esposto e osserva che il dott. De Luca Alberto si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Del Testa Davide nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Scienza e Tecnologia dell'Informazione.
Dall'inizio del corso di dottorato ad oggi il dott. Del Testa Davide ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Scienza e Tecnologia dell'Informazione.

Il dottorando dichiara quanto segue:

FIRST PART: EDUCATION

Courses, trainings and summer school activities

- Courses
  - Real-time systems
  - Random graphs and stochastic geometry in networks
  - Bayesian machine learning
  - Statistical methods
- Seminars
  - DEI Distinguished lectures
  - Research group's weekly meetings
- National and international conferences
  - Med-hoc-net 2014
  - Italian networking workshop 2015
  - European wireless 2015
  - Globecom 2015
  - Gpu Technology conference 2016
- Other activities
  - Advanced topics in Machine Learning summer school, Copenhagen, 2014
  - Summer school in Information Engineering, Bressanone, 2015

Teaching activities

- Tutor junior for "Fondamenti di Informatica", BSc in Information Engineering, 2015, 2016

Mobility actions

- Deep learning research intern at Nvidia, Holmdel, NJ, USA (January – July 2016)

SECOND PART: RESEARCH

1. **Design of transmission policies for two-user Wireless Sensor Networks equipped with Energy Harvesting Devices**. In particular, I analyzed the performance degradation occurring when the central controller only has an imperfect knowledge of the State-of

Charge of the device's battery. Also, I considered the case of a correlation (spatially between the devices and temporally across time instants) in the energy arrival processes of the quanta harvested from the environment. Distinct packet arrival distributions have been considered at the two nodes, analyzing the changes in the overall performance due to those modified conditions in the scenario. The results of these research effort have been published in [J1, C1, C2, C3].

2. **Accurate prediction of network parameters in WiFi cognitive networks**. Using a WiFi ad-hoc testebed deployed in our department, I collected approximately 5400 experiments consisting of a file transmission between a Base Station (BS) and a varying number of receivers. In detail, for each experiment, I acted on network parameters including the number of simultaneously receving nodes, the WiFi transmission channel, the WiFi transmission power, the distance between the BS and the receivers, the part of the day the transmission occured. For each experiment, a 100 MB file was transmitted from the BS to the active receivers, and the Expected Time of Arrival was measured. Firstly, using the aforementioned parameters, I used a number of machine learning techniques to predict the total ETA at the beginning of each transmission, showing that this estimate was much better performing than the one alredy implemented in standard transmission algorithms like *scp*. Secondly, I designed machine learning algorithms able to detect the number of simultaneously receiving nodes in the same kind of network, using as input the total transmission time and other parameters (transmission power, distance), and showed that the F1 score related to this classification problem was approximately 10%. Finally, motivated by the latter results, I modified the previous models so as to detect the number of receivers after only the first 5% of data has been transmitted, and use this information to predict the ETA on-the-fly during each file transmission. The results for this research study have been published in [J4, C4, C5].

3. **Lossy compression of biosignals based on autoencoders**. I developed an autoencoder-based lossy compression technique for quasi-periodic biosignals, including ECG, plethismographic and respiratory signals. This tecnique achieved high compression efficiencies mantaining low reconstruction errors and moderately low transmission energy consumptions, compared to common compression techniques from the literature. The only drawback for this method is that it requires an offline training phase, which is computationally intensive but has to be performed only once. The results for this research study have been published in [J2, J3].

4. **Learning methods for long-term channel gain prediction in wireless networks**. Efficiently allocating resources and anticipating cell handovers is essential in modern wireless systems, but is only possible by means of an efficient way to gauge the future state of the network. In order to do thath, I adopted two machine learning techniques to predict the long-term channel gain in a wireless network. Previous works in the literature found efficient methods to perform this prediction with the aid of a GPS signal: however, the methods I used are able to predict the future channel gain without any geographical information, still achieving comparable results with respect to them. The results of this

study have been published in [C6].

5. **End-to-end learning for self driving cars.** During my period abroad, I helped to develop an end-to-end approach for autonomous driving cars. This approach proved to work extremely well, thus making it comparable to traditional approaches based on car/lane/pedestrian detectors. The results of this study can be found in [C7].

Title of thesis: **Stochastic optimization and Machine Learning modeling for Wireless Networking**
Name of supervisor: prof. Michele Zorzi.

THIRD PART: PUBLICATIONS

- **List of publications in international journals**

[J1] D. Del Testa, N. Michelusi and M. Zorzi, "Optimal transmission policies for two-user Energy Harvesting Device networks with limited state-of-charge knowledge," IEEE Transactions on Wireless Communications, vol. 15(2), Feb. 2016.

[J2] D. Del Testa and M. Rossi, "Lightweight Lossy Compression of Biometric Patterns via Denoising Autoencoders," IEEE Signal Processing Letters, vol. 22, Dec. 2015.

[J3] M. Hooshmand, D. Zordan, D. Del Testa, E. Grisan and M. Rossi, "Boosting the Efficiency of Wearable Devices through the Compression of Biosignals," submitted to IEEE IoT Jornal.

[J4] D. Del Testa, M. Danieletto and M. Zorzi, "A machine learning based ETA estimator for WiFi transmissions," in preparation.

- **Publications list related to international conferences**

[C1] D. Del Testa, N. Michelusi and M. Zorzi, "On Optimal Transmission Policies for Energy Harvesting Devices: the case of two users," in Proceedings of the Tenth International Symposium on Wireless Communication Systems (ISWCS 2013), August 2013, Ilmenau, Germany.

- [C2] D. Del Testa and M. Zorzi, "Optimal policies for two-user Energy Harvesting Device networks with imperfect State-of-Charge knowledge," in Information Theory and Applications Workshop (ITA), February 2014, San Diego, USA.
- [C3] A. Biason, D. Del Testa and M. Zorzi, "Low-complexity Policies for Wireless Sensor Networks with Two Energy Harvesting Devices," in 13th Annual Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net), June 2014, Piran, Slovenia.
- [C4] D. Del Testa, M. Danieletto and M. Zorzi, "Applying Machine Learning Techniques to a Real Cognitive Network: File Transfer ETAs prediction," in IEEE Global Communications Conference (Globecom), December 2015, San Diego, CA, USA.

- [C5] D. Del Testa, M. Danieletto, G. M. Di Nunzio and M. Zorzi, "Estimating the number of receiving nodes in 802.11 networks via machine learning techniques," in IEEE Global Communications Conference (Globecom), December 2016, Washington, DC, USA.
- [C6] F. Chiariotti, M. Polese, D. Del Testa, A. Zanella, G. M. Di Nunzio and M. Zorzi, "Learning methods for long-term channel gain prediction in wireless networks," in International Conference on Computing, Networking and Communications (ICNC), January 2017, accepted for publication.
- [C7] M. Bojarski, D. Del Testa, D. Dworakowski, et al., "End to End Learning for Self-Driving Cars," 2016 Neural Information and Procesing Systems (NIPS), December 2016, Barcelona, Spain.

Il Collegio prende atto di quanto esposto e osserva che il dott. Del Testa Davide si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Guimares Sa Correja Pedro nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Bioingegneria.
Dall'inizio del corso di dottorato ad oggi il dott. Guimares Sa Correja Pedro ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Bioingegneria**.**

Il dottorando dichiara quanto segue:

Il Collegio prende atto di quanto esposto e osserva che il dott. Guimares Sa Correja Pedro si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Hooshmand Mohsen nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Scienza e Tecnologia dell'Informazione.
Dall'inizio del corso di dottorato ad oggi il dott. Hooshmand Mohsen ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Scienza e Tecnologia dell'Informazione.

Il dottorando dichiara quanto segue:

FIRST PART: EDUCATION

Courses, trainings and summer school activities

- Courses
  - "Applied Linear Algebra" (Prof. Giorgio Picci)
  - "Digital Processing of Measurement Information" (Prof. Claudio Narduzzi)
  - "Random Graphs and Stochastic Geometry in Networks" (Prof. Subhrakanti Dey)
  - "Statistical Methods" (Prof. Lorenzo Finesso)

- Seminars
  - "Life after PhD," Francesco Rossetto, 30/06/2013
  - "Fundamental limits in compressive sensing of GMM sources," Francesco Renna, 9/6/2013
  - "Delay-limited source and channel coding of quasi-stationary sources over block fading channels," Roghayeh Joda, 13/09/13
  - "Dimensioning Self-sufficient Networks of Energy Harvesting Embedded Devices," Nicola Bui, Michele Rossi, 20/09/13
  - "Dynamic Compression-Transmission for Energy-Harvesting Multihop Networks with Correlated Sources," Cristiano Tapparello, 10/4/2013
  - "SECURITY ANALYSIS OF CRYPTOGRAPHIC ALGORITHMS USING COMPUTATIONAL INTELLIGENCE FOR DEVELOPMENT OF SECURED COMMUNICATION PROTOCOL IN WPAN," Vimalhandrha R., 10/10/2013
  - "Science for the cultural heritage: the role of information technology," Maurizio Seracini, 14/10/13
  - "Cognitive testbed," Matteo Danieletto, 17/10/13
  - "A study on remote data retrieval strategies in underwater acoustic networks: the UFetch protocol," Loris Brolo and Paolo Casari, 25/10/13
  - "Wireless Sensor Networks: a channel access analysis," Michele Rossi, 8/11/2013
  - "A Markov Analysis of SR ARQ with Variable Round Trip Time," Leonardo Badia, 15/11/13
  - "Where are we going", Prof. Andrew S. Tanenbaum, 20/11/13
  - "Distributed Power Loss Minimization in Residential Micro Grids: a Communications Perspective," Riccardo Bonetto, 6/12/2013
  - "Toward Implantable Ultrasonic Wireless Sensor Networks," Tommaso Melodia, 18/12/13
  - "The algorithmic power of human networks.," Lorenzo Coviello, 20/12/13

- "Joint User Association and Resource Allocation in UE-Relay Assisted Heterogeneous Networks," Marco Mezzavilla, 10/1/2014
- "So you want to present a paper…," Leonardo Badia, 25/01/14
- "Context-Aware Handover in HetNets," Francesco Guidolin, Irene Pappalardo, 31/01/14
- "On the Evaluation of the Polyanskiy-Poor-Verdù Converse Bound for Finite Blocklength Coding in AWGN," Tomaso Erseghe, 7/2/2014
- "Optimal policies for two-user Energy Harvesting Device networks with imperfect State-of-Charge knowledge," Davide Del Testa, 21/2/2014
- "System, Security, and Privacy Issue in Mobile Networking,", Prof. Alessandro Mei, 26/02/2014
- "Incentive Mechanisms based on Minority Games in Delay Tolerant Networks," Francesco De Pellegrini, 28/2/2014
- "A Low-cost and Flexible Underwater Platform to Promote Experiments in UWSN Research," Waqas Bin Abbas, 14/02/2014
- "Opportunistic Data Gathering and Dissemination in Urban Scenarios," Armir Bujari, 21/04/2014
- "Research challenges in Machine to Machine Communication," Andrea Biral, Vimalathithan Rathinasabapathy, 28/03/14
- "Energy-Efficient Transmission Policies for Delay Constrained Traffic with Limited CSI," Beatrice Tomasi, 12/9/2014
- "Microfluidics networking: from theory to practice," Andrea Biral, 26/09/2014
- "Performance assessment of an IEEE 802.11-based protocol for real-time communication in agriculture," Michele Luvisotto, 10/10/2014
- "Downlink Schedulers for LTE: Performance Analysis," Mattia Carpin, 17/10/2014
- "Design, implementation and testing of QoE-optimization mechanisms for HTTP-based video flows," Daniel Zucchetto, 24/10/2014
- Power Control in Cognitive Radio and Femtocell Networks
- Communication protocols for the Internet of Things
- Long-range, low-power communications for IoT: the LoRa technology
- On the relation between underwater acoustic and optical channels. Cruise ALOMEX'15 – Sea Trial
- Biomedical signal compression with time- and subject-adaptive dictionary for wearable devices
- Caching Strategies in Heterogeneous Networks with D2D, small BS and macro BS communications
- Lossy Compression of Biometric Patterns via Denoising AutoencodersBITCOIN, an attempt at a separation of money and state
- Shaping 5G
- Mathematical Scientific Challenges of 5G
- Caching Strategies in Heterogeneous Networks with D2D, small BS and macro BS communications
- Lightweight Lossy Compression of Biometric Patterns via Denoising Autoencoders
- Abnormal EEG patterns in writer's cramp patients
- Writing a EU proposal
- Analysis for Fixed Priority Real-Time Systems with Energy-Harvesting

- Simulation of Multimodal Optical and Acoustic Communications in Underwater Networks
- The IEEE 802.11n wireless LAN for real-time industrial communications
- Learning with Computational Regularization
- Constellation Shaping and LDPC coding in a bidirectional Full Duplex communication
- Full Duplex Radios
- "Power Control in Cognitive Radio and Femtocell Networks" 18/12/2015
- "Resource allocation in OFDMA networks with half-duplex and imperfect full-duplex users" 22/01/2016
- "On the Evaluation of LTE Random Access Channel Overload in a Smart City Scenario" 19/01/2016
- " Stochastic Geometry Framework for Asynchronous Full-Duplex Communications" 12/02/2016
- "Underwater acoustic communication" 14/03/2016
- "Boole Shannon Symposium" MIT, 18/03/2016
- "Assured High-Throughput Wireless Networking in Presence of Cross-layer Attacks" 20/03/2016
- "Multi-Carrier Ultrasonic Communications, Resource Allocation, and Medium Access for Implantable Devices" MIT, 27/03/2016
- "Enabling Motion Detection on Commodity WiFi Devices using PHY Layer Information," 28/03/2016
- "Lazy Scheduling for Freshest Data Updates and Optimal Use of
- Renewable Energy in Networks" 22/04/2016
- "Data mining in the IoT era: practical examples and a peek into future developments," 27/04/2016
- "A new method to transfer energy and data at very high efficiency in ground and water" 19/05/2016
- "New England Workshop on Software-Defined Radio", Northeatern University, 02/06/2016
- "Ultrasonic Networking Technologies for the Internet of Implantable and Wearable Things" 27/06/2016
- "MIT Institute for Data, Systems, and Society Launch Event, From Applications To Theory," 23/09/2016
- "Acoustic Energy Supplying for Intra Body Sensor Networks" 28/09/2016
- "Cross-Layer attacking, probablistic detection framework and application" 05/10/2016

- School courses
  - "Optimization models for communication network design" at Politecnico di Milano (professor Michal Pioro)

<u>Teaching activities</u>

- Advisor of master students (Correlatore)
  - Francesco Agnolazza, "Studio di algoritmi per la compressione di segnali spazio e tempo varianti in reti di sensori radio" co-supervisor, 2013-2014.
  - Emanuele mentil, "Compressione spazio-temporale in reti di sensori tramite l'utilizzo combinato della Principal Component Analysis e della stima dei covariogrammi" co-supervisor, 2013-2014.
  - Jia Qian, "Online compression of ECG signal through Gas Neural Networks," co-supervisor, 2016-2017.

Mobility actions

- Visiting Scholar, Wines Lab, Northeastern University, Boston, Ma, USA, Mar. 2016 – Sept. 2016

Stage

- "Lifetime Maximization of Visual Sensor Networks" Signet lab, University of Padova, 22/11/13
- "Toward Practical Distributed Compression for Spatio-Temporal WSN Signals," Signat lab, University of Padova, 30/05/14
- "Compression techniques for constrained sensing device", Signet lab, University of Padova,17/11/2014
- "Covariogram-based Compressive Sensing for Environmental Wireless Sensor Networks", Signet lab, University of Padova, 20/03/15
- "Toward Lightweight Biometric Signal Processing for Wearable Devices", Signet lab, University of Padova,29/05/15
- "Toward Lightweight Biometric Signal Processing for Wearable Devices", Wines Lab, ECE, Northeatern Univesrsity, 15/04/16

SECOND PART: RESEARCH

Description of the research during the PhD (max 2 pages) highlighting the original results achieved.

PhD thesis title and name of supervisor.

- **Title:** Sensing and Compression Techniques for Environmental and Human Sensing Applications
- **Supervisor:** Prof. Michele Rossi

[1] M. Hooshmand, M. Rossi, D. Zordan, M. Zorzi, "Evaluating the Gap Between Compressive Sensing and Distributed Source Coding in WSN," *IEEE International Conference on Computing, Networking and Communications (ICNC)*, February 16-19, Anaheim, California, US, 2015.

[2] M. Hooshmand, M. Rossi, D. Zordan, M. Zorzi, "Covariogram-based Compressive Sensing for Environmental Wireless Sensor Networks," IEEE Sensors Journal, Vol. 16, No. 6, pp. 1716 – 1729, 2016.

[3] Francescon, R., Hooshmand, M., Gadaleta, M., Grisan, E., Yoon, S. K., Rossi, M. "Toward Lightweight Biometric Signal Processing for Wearable Devices," IEEE Engineering in Medicine and Biology Society (EMBS), August 25-29, Milan, Italy, 2015.

[4] M. Hooshmand, D. Zordan, D. Del Testa, E. Grisan, M. Rossi, "Boosting the Battery Life of Wearables for Health Monitoring through the Compression of Biosignals," IEEE IoT Journal, Under review (second review round).

[5] "Biosignal Compression with Self Organizing Methods for Wearable Devices," in preparation.

In [1], we considered the temporal and spatial correlations of Wireless Sensor Networks (WSN) signals. WSNs are characterized by the dense deployment of sensor nodes that continuously observe some physical phenomenon. In practical scenarios, sensor observations are highly correlated in space. Furthermore, the nature of the physical phenomenon also implies some non-negligible temporal correlation. These facts, along with the collaborative nature of the WSN bring significant advantages for the development of efficient communication protocols. In this paper, several key elements are investigated to capture and exploit the spatio-temporal correlation in WSNs for the design of efficient data gathering protocols. In detail, we focus on the spatio-temporal compression of readings from the sensor nodes The objective, for each data gathering round, is to collect the WSN readings from a small percentage of nodes (*sparse sampling*), while being able to recover the entire dataset at the data collection point. To do so, the spatio-temporal features of the signals are exploited within suitable data compression tools including: Lightweight Temporal Compression (LTC), Distributed Source Coding (DSC), Discrete Fourier Transform (DCT) and Compressive Sensing (CS). The performance of these algorithms is compared for the same datasets and research directions are identified.

In [2], we have improved the CS-based compression scheme of [1]. In detail, the reconstruction step of CS-based algorithms has been improved considering the concept of *variogram* estimation and using it to refine the (estimated) covariance matrix at the data collector. As a result, the reconstruction error is substantially reduced, leading to more accurate representations of the signal. As an additional contribution, the sparse sampling strategy is improved to implement a more effective selection of the subset of nodes that are sampled at each data collection round. The impact of variogram estimation and sparse sampling is numerically assessed through a simulation tool developed in Matlab. The standard kriging reconstruction algorithm (from geo-statistics) is also considered and compared against CS-based reconstruction.

In [3], we considered temporal correlation of biosignals acquried by Wearable devices. Wearable devices are becoming a natural and economic means to gather biosignal data from end users. These type of devices owns an immense potential for applications such as continuous monitoring for personalized healthcare and use within fitness applications. Wearables are however heavily constrained in terms of amount of memory, transmission capability and energy reserve. This calls for dedicated, lightweight but still effective algorithms for data management. This paper is centered around lossy data compression techniques, whose aim is to minimize the amount of information that is to be stored on their

onboard memory and subsequently transmitted over wireless interfaces. Specifically, we analyze selected compression techniques for biometric signals, quantifying their complexity (energy consumption) and compression performance. Hence, we propose a new class of Online Dictoinary compression algorithms, designed to be energy efficient, online and amenable to any type of signal exhibiting recurrent patterns.

In [4], we extended the scheme in [3] to have a practical way of Modern wearable IoT devices enable the monitoring of vital boost the battery life of wearables and allow for fine-grained and long-term monitoring. Considering one dimensional biosignals such as ECG, RESP and PPG, which are often available from commercial wearable IoT devices, we provide a throughout review of existing biosignal compression algorithms. Besides, we present novel approaches based on online dictionaries, elucidating their operating principles and providing a quantitative assessment of compression, reconstruction and energy consumption performance of all schemes. As we quantify, the most efficient schemes allow reductions in the signal size of up to 100 times, which entail similar reductions in the energy demand, by still keeping the reconstruction error within 4% of the peak-to-peak signal amplitude. Avenues for future research are finally discussed.

In [5], we propose Neural Network-based approcahes to compress one dimensional biosignals measured from Body Sensor Networks. We used two Self Organizing mehtods, Time Adaptive Self Organizing Map (TASOM) and Growing Neural Gas (GNG) for performance improvement. TASOM has promising results, i.e., its reconstruction error with with only 9 neurons remains around 6% of the peak-to-peak signal amplitude while the signal size to be transmitted is reduced between 60 to 70 times (compression ratio). This amount of reduction can be reached with small memory requirements. However, the involved neural network has a static structure, which somehow limits its performance in terms of reconstruction fidelity for rare sequences and adaptivity. GNG retains the advantages of the TASOM-based comrpessor and moreover it has a dynamic behavior; so it can lower the reconstruction error to smaller than 6%, while retaining adaptivity and limited memory utilization.

THIRD PART: PUBBLICATIONS

- List of publications in international journals
    - Hooshmand, M., Rossi, M., Zordan, D., Zorzi, M. "Covariogram-based Compressive Sensing for Environmental Wireless Sensor Networks," IEEE Sensors Journal, Vol. 16, No. 6, pp. 1716 – 1729, 2016.
    - Hooshmand, M., Zordan, D., Del Testa, D., Grisan, E., Rossi, M. "Boosting the Battery Life of Wearables for Health Monitoring through the Compression of Biosignals," IoT Journal, under review (second review round).
- Publications list related to international conferences
    - Francescon, R., Hooshmand, M., Gadaleta, M., Grisan, E., Yoon, S. K., Rossi, M. "Toward Lightweight Biometric Signal Processing for Wearable Devices," IEEE

Engineering in Medicine and Biology Society (EMBS), August 25-29, Milan, Italy, 2015.

- Rossi, M., Hooshmand, M., Zordan, D., Zorzi, M. "Evaluating the Gap Between Compressive Sensing and Distributed Source Coding in WSN," IEEE International Conference on Computing, Networking and Communications (ICNC), February 16-19, Anaheim, California, US, 2015.

Il Collegio prende atto di quanto esposto e osserva che il dott. Hooshmand Mohsen si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da La Grassa Marco nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Scienza e Tecnologia dell'Informazione.
Dall'inizio del corso di dottorato ad oggi il dott. La Grassa Marco ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Scienza e Tecnologia dell'Informazione.

Il dottorando dichiara quanto segue:

Supervisor: Enrizo Zanoni

Part 1: Educational Activity

Attended courses (at DEI):

- E. M. Waves in Anisotropic Media (G. Someda)
- Statistical Methods (L. Finesso)
- Physics and operation of heterostructure-based electronic and optoelectronic Devices (G. Meneghesso)
- Digital Processing of Measurement Information (C. Narduzzi)

Attended courses (at IRS – Padova)
- LabView Core 1 (National Instruments)
- LabView Core 2 (National Instruments)

Seminars:

- Organic light-emitting transistors: a truly multifunctional platform with high application potential (M. Muccini)
- Modelli di trasporto quantistico nei semiconduttori (G. Verzellesi)
- Present and Future of GaN Power Devices (D. Ueda)
- Recent Advances of GaN Gate Injection Transistor (GIT) for high efficiency power conversion (H. Umeda, T. Morita)
- Efficiency limiting mechanisms in InGaN LEDs (B. Galler)
- "Light-emitting diodes and applications. The era of solid-state lighting", Dr. Matteo Meneghini, Università di Padova.
- "Multifunctional organic field-effect transistors as a technological platform for sensing and biodiagnostics ",Dr. Stefano Toffanin, ISMN-CNR, Bologna.
- GaN Marathon

Teaching activity:
Tutor Junior for the "Electronics" course in years 2015/2016 and 2016/2017.
Laboratory assistant during the course "Optoelectronic and photovoltaic devices"

Part 2: Research activity

Thesis title:

Defect-related processes and their influence on the efficiency and degradation of InGaN-based LEDs.

During these years I studied the physical mechanisms responsible for limiting the efficiency of InGaN-based light-emitting-diodes (LEDs). All our work was carried out in collaboration with OSRAM Semiconductors that provided us the samples and cooperated with us in interpreting the experimental data

The first work I carried out was a study on the relationship between the lattice defects and the Shockley-Read-Hall (SRH) coefficient, responsible for non-radiative recombination in LEDs. In fact, several defect levels are generally present within the bandgap of LEDs. The contribution of each defect to the non-radiative recombination may depend on several parameters, like their position in the bandgap, their concentration and capture cross-section. The SRH coefficient only accounts for the overall non-radiative recombination, without providing any information about the contribution of each trap. The study was carried out on a set of single-quantum-well samples realized with the same growing conditions but that, due to run-to-run and sample-to-sample variability, are characterized by a different indium content in the quantum well and by a different SRH coefficient. The analysis was performed by means of combined optical and electrical measurements, including Deep Level Transient Spectroscopy (DLTS) in order to characterize the defects in the samples, their performance at low-moderate operative current (where SRH recombination dominates) and, if any, the relation with the indium concentration. The obtained results demonstrated that in that set of samples a specific trap was mainly responsible for non-radiative recombination, since its concentration was linearly correlated with the overall SRH coefficient. The physical origin of this level was attributed to native point defects in the lattice, most likely Gallium or Nitrogen vacancies, distributed along threading dislocations. Other deep level were identified, giving minor contributions to the overall non-radiative recombination rate.

Following this study, the same set of samples underwent a dc-current and temperature stress to observe the degradation of the electrical and optical characteristics. This kind of stresses are commonly used to accelerate the aging of the devices. During the tests and at predefined time steps we monitored the performance of the devices by measuring the electroluminescence, photoluminescence, and defectiveness by DLTS. This study aimed to discriminate whether the degradation of the optical performance in the aged devices was due to a reduction in the injection efficiency of carriers into the active region of the devices or to an increased SRH recombination. The results proved that the latter was the main cause for degradation. Moreover, DLTS shown that the very same trap previously identified as the responsible for SRH recombination increased in concentration during aging, confirming its key role in determining the optical performance of these devices. At the same time, the injection efficiency was found to stay almost constant during the whole stress period.

Based on these results, on another similar set of samples we investigated what caused the increase in the concentration of the deep levels. We performed other dc-current stress tests while keeping monitored the capacitance of the devices, the optical power, the SRH coefficient and the defects concentration. The results indicated that, as expected, the emitted optical power was reduced during aging and that, correspondingly, the SRH recombination coefficient increased. However, we also found out that the increase in the non-radiative recombination rate followed a square-root dependence on time, which is an indication of the presence of a diffusion process. We therefore proposed a degradation mechanism involving the diffusion of impurities towards the active region of the devices, electro-thermally activated. Based on other reports in the literature, the

most probable diffusing impurities are magnesium, oxygen and hydrogen. The latter is the only impurity that can diffuse in the bulk crystal significantly, whilst the other two are known for diffusing through threading dislocations only due to their very low diffusion coefficient. To investigate further we performed SIMS analysis on other stressed samples, which did not detect any significant change in the Mg profile. Hydrogen seems therefore a promising candidate as main diffusing impurity, but unfortunately measuring it is not trivial and this work is still in progress in collaboration with the Physics department.

Another important aspect that we investigated was the origin of the thermal-droop in LEDs. The thermal droop is the drop of the optical power emitted by LEDs ay high. In particular, we investigated the role of defects in the thermal droop process and proposed a model which is able to accurately fit the experimental data by using values extracted from measurements and simulations and a limited set of fitting parameters.

Part 3: Publications

- "SRH non-radiative recombination in GaN-based LEDs: a study based on lifetime and DLTS measurements", M. La Grassa, M. Meneghini, S. Vaccari, B. Galler, R. Zeisel, P. Drechsel, P. Stauss, B. Hahn, G. Meneghesso, and E. Zanoni (WOCSDICE 2014).

- "Thermal droop in InGaN-based LEDs: an analysis based on temperature-dependent L-I characterization", M. La Grassa, M. Meneghini, C. De Santi, E. Zanoni (HETECH 2014).

- "Characterization of the deep levels responsible for non-radiative recombination in InGaN/GaN light-emitting diodes", M. Meneghini, M. La Grassa, S. Vaccari, B. Galler, R. Zeisel, P. Drechsel, B. Hahn, G. Meneghesso, E. Zanoni, Applied Physics Letters Volume:104 , Issue: 11, 2014.

- "Aging of InGaN-based LEDs: effects on internal quantum efficiency and role of defects", M. La Grassa, M. Meneghini, C. De Santi, M. Mandurrino, M. Goano, F. Bertazzi, R. Zeisel, B. Galler, G. Meneghesso, and E. Zanoni (ESREF 2015).

- "Degradation of InGaN-based LEDs related to charge diffusion and build-up", M. La Grassa, M. Meneghini, C. De Santi, E. Zanoni, G. Meneghesso (ESREF 2016).

- "Role of defects in the thermal droop of InGaN-based light emitting diodes", C. De Santi, M. Meneghini, M. La Grassa, B. Galler, R. Zeisel, M. Goano, S. Dominici, M. Mandurrino, F. Bertazzi, D. Robidas, G. Meneghesso, and E. Zanoni, J. Appl. Phys. 119, 094501 (2016) .

Il Collegio prende atto di quanto esposto e osserva che il dott. La Grassa Marco si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Marin Giulio nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Scienza e Tecnologia dell'Informazione.
Dall'inizio del corso di dottorato ad oggi il dott. Marin Giulio ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Scienza e Tecnologia dell'Informazione.

Il dottorando dichiara quanto segue:

Part 1 Didactic

Courses
- Applied Linear Algebra - Prof. Giorgio Picci
- Bayesian Machine Learning - Prof. Giorgio Maria Di Nunzio
- Computational Inverse Problems - Prof. Fabio Marcuzzi
- Real-Time Systems and applications - Prof. Gabriele Manduchi
- Statistical Methods - Prof. Lorenzo Finesso
- General Purpose GPU Computing - Jacopo Pantaleoni, NVIDIA Research (29-30/05/14 - Torre Archimede, Padova)

Summer schools
- International Computer Vision Summer School 2014 (13-19/07/14 – Ragusa)

Seminars
- **How to give scientific talk** – Prof. Leonardo Badia (24/01/14 - DEI)
- **Systems, Security, and Privacy Issues in Mobile Networking** – Prof. Alessandro Mei, Sapienza University (26/02/14 - Aula Magna "A. Lepschy", DEI)
- **Brain-Computer Interface and Motor Learning in Stroke Rehabilitation** - Prof. Junichi Ushiba, Keio University (16/05/14 - Aula Magna "A. Lepschy", DEI)
- **Bay Area Vision Meeting 2014** (3/10/14 – Stanford University)
- **Intel RealSense Dev Lab** (13/11/14 – San Francisco)
- **IEEE Consumer Electronics Society, "What's new in mobile"** – *Johnny Lee*, Google Project Tango lead and *Chris Pedersen*, NVIDIA Senior Product Manager for Camera Solutions (03/12/2014 – NVIDIA, Santa Clara (CA), USA)
- **The Internet of Everything: A Stanford Engineering Symposium** – *T. Lee, M. Horowitz, A. Arbabian*, Professors at Stanford University (05/12/2014 – Stanford University, Palo Alto (CA), USA)
- **Computing Conforming Triangulations for Smooth Geometries from Fixed Background Meshes** – *Hardik Kalabria*, PhD Student at Stanford University (13/03/2015 – Aquifi Inc., Palo Alto (CA), USA)
- **6th Annual HBS and Harvard Entrepreneurship Summit in Northern California** – Harvard Business School (28/04/15 – Microsoft SV Campus, Mountain View (CA), USA)
- **Dense 3D Shape in Real Time with 3D Sensors or Video Cameras** - *Prof. Carlo Tomasi* (01/06/2015, Aquifi Inc., Palo Alto (CA), USA)
- **Intel RealSense Hacker Happy Hour** - *Intel* (20/08/15 – TechShop, San Francisco (CA), USA)

- **Low Power Wide Area Networks for the IoT** – *Dr. Mark Kelly*, Intel Labs Europe (13/03/2015 – DEI)
- **Development of Wide-Angle Liquid Crystal Fovea Lens** – *Sota Shimizu*, Associate Professor, Keio University, Japan (31/03/2016 – DEI)
- **Knowledge Transfer for Scene-specific Motion Prediction** – *Lamberto Ballan*, postdoc at Stanford University (16/06/2016 – Stanford (CA), USA)

National conferences attended

- **GTTI Thematic Meeting on Multimedia Signal Processing 2014** (18-18/02/14 Forni di Sopra, Udine)
- **Smart Tools and Apps in computer Graphics (STAG) 2015** – (15-16/10/2015 – Università degli Studi di Verona (VR), Italy)

International conferences attended

- **Consumer Electronic Show (CES) 2015** – (04-07/01/2015 - Las Vegas (NV), USA)
- **Workshop on Light Field Imaging** – Stanford University (12/02/2015 – Stanford University, Palo Alto (CA), USA)
- **Conference on Computer Vision and Pattern Recognition (CVPR)** – (26/06/2016 - 01/07/2016 - Las Vegas (NV), USA)
- **European Conference on Computer Vision (ECCV)** – (11/10/2016 - 15/10/2016 – Amsterdam, Netherlands)

Teaching

- Teaching assistant for the course "Image and video processing", Laurea Magistrale in Ingegneria delle Telecomunicazioni, Dott. Pietro Zanuttigh.
- Lesson on depth cameras for the course "Computer Vision and 3D Graphics"", Laurea Magistrale in Ingegneria delle Telecomunicazioni, Dott. Simone Milani.
- Supervised students for bachelor and master degree.
- Lesson on the activity of the laboratory for students.
- Presentation of the courses in the different schools of Information Engineering at "Scegli con noi il tuo domani" (13/02/14 – Campus Agripolis of Legnaro, Padova)

Periods abroad

- October 2014 – September 2015: Aquifi Inc., Palo Alto (CA) USA
- July 2016 – September 2016: Aquifi Inc., Palo Alto (CA) USA

Internship

- October 2014 – September 2015: Aquifi Inc., Palo Alto (CA) USA

Part 2 Research

My research activity focused on the analysis of 3D data, including the acquisition and processing of data from different sensors, and some related applications.

During the first year I deepened my knowledge in the field of gesture recognition using data from depth cameras. In particular, I focused on two aspects: the first one is classification of different

parts of the hand, while the second one involves the study of depth based descriptors for the task of hand gesture classification. Some algorithms for gesture recognition rely on palm detection as the first step, and for this task we proposed a few approaches including bidimensional based methods, fitting circles and ellipses in a binary mask of the hand, and tridimensional based methods, analyzing the structure of the point cloud acquired from a depth camera. For this last approach we based our analysis on the different geometry of fingers and palm, proposing a density based clustering algorithm for the purpose of classification. This approach allowed us to correctly segment the fingers from the palm also in challenging situations including occlusions. In addition to the segmentation we also proposed a method to recognize different fingers based on linear programming.

For the task of gesture classification, we extended a method based on SVM, considering different descriptors both in the 2D and 3D domain. In particular, we developed descriptors that analyze the shape and contour of the hand.

The joint usage of data from multiple sensors has been considered in a project for gesture recognition from a depth camera and a Leap Motion, a portable device that provides the 3D position of the hand's skeleton. This topic was new in the literature, therefore we had to run many preliminary experiments to assess the quality of the data and outline advantages and disadvantages of both sensors. The goal in this project was to combine data from a depth camera and a Leap Motion to provide a more robust estimate of the gesture performed by the user. Data from Leap Motion are very precise but in some configurations, that include occlusions and particular views, the errors can be very high and there can be missing measurements. Depth sensors instead provide a higher number of 3D points but less accurate. In order to jointly use the data from the two sensors it is necessary to calibrate the two.

Since the only data provided by Leap Motion are the position of the fingertips, we developed an algorithm to extract the same information from the depth sensor. Knowing the correspondences then it's possible to estimate the rotation and translation between the two reference systems. Once calibrated we used the SVM based approach with some descriptors typical of the two systems. Experimental results show that such a system improves the performance of the two systems considered independently. For the experimental results we developed an acquisition system to collect data from those sensors simultaneously and created a dataset with multiple repetitions of gestures from different people.

In order to study the working principles of depth cameras I did an internship at Aquifi Inc, a startup located in Palo Alto (CA), USA. During my period there I participated to the design and development of a structured light camera. After a deep analysis on the available technologies, I contributed to the design and optimization of the IR pattern used in the projector of the structured light camera. I also developed a system to simulate the acquisition of the pattern from a stereo camera, according to the projection laws of the diffractive optical element (DOE) used in the projector, and the standard pinhole model for cameras. Then, I contributed to the development of the pipeline to generate 3D data in real time (60 fps) from a couple of calibrated images. I also developed algorithms of image processing to be used both as pre-processing and post-processing of the depth map. The algorithms also try to reduce the artifacts caused by the coherent light of the laser used in the projector.

Another topic that interested me involves the fusion of depth data acquired from multiple sensors. In this case the goal was to improve the quality of the depth map acquired from different systems. The approach that we developed uses the depth maps from a stereo system and a Time-of-Flight (ToF) camera for which the calibration is known, and a set of confidence measures that we estimate from the acquired data. The proposed approach extends a framework for cost aggregation called Local Consistency, originally proposed for stereo systems, to use the depth maps and confidence maps estimated. For the ToF sensor we developed a confidence measure that models the received signal and the geometry of the scene. Another contribution is the introduction of a new confidence metric for the stereo data. Typical confidence measures already available in the literature do not consider the effects of the global optimization performed by most of the best performing stereo algorithms. First we analyzed the properties of the cost functions of the correspondence problem before and after the optimization. After having characterized the behavior of such functions in different conditions we proposed different models that combine information of both the functions. One model in particular has been used for the fusion of data with Local Consistency, with results that outperform the state of the art if compared with traditional confidence measures.

For the problem of data fusion we also started a project that involves the study of machine learning techniques, in particular Convolutional Neural Networks (CNN), to learn the optimal way to combine the input depth maps. A CNN requires a high amount of data to train the network, and for this task we developed a simulator of ToF and stereo systems that allows one to generate synthetic views of a given 3D model as if they were acquired from real cameras. Such a simulator also includes realistic models of the devices, allowing one to generate a big amount of data that are very realistic.

Another problem for the data fusion project is the lack of a dataset in the literature that includes calibrated images of different sensors with the related ground truth map. For this purpose we developed a system for the simultaneous acquisition of data from different sensors, including stereo, ToF and structured light. For the acquisition of the ground truth we developed a system based on line laser that allows one to obtain a detailed depth map of the scene.

The main topics faced during my research activity have been collected in a book published from Springer, in collaboration with other students and professors, on the technologies and working principles of depth sensors like ToF and structured light. It also includes applications of depth cameras like gesture recognition, segmentation, 3D reconstruction and pose estimation. During the writing of the book I deepened my knowledge especially in the working principles of depth cameras and the calibration of multiple devices. For ToF cameras in particular we derived a mathematical model of transmitter and receiver for the square wave modulation. Such a model was not available in the literature, since ToF technology is almost always protected by intellectual property by the producers of the sensors. For what concern the calibration we presented the techniques used in practice to estimate the intrinsic and extrinsic parameters of standard cameras, ToF cameras, structured light cameras and eventually the joint calibration of multiple sensors.

Title of the thesis: "3D data fusion from multiple sensors and its applications"

Name of supervisor: Pietro Zanuttigh, Ph.D.

Part 3 Publications

Books

- P. Zanuttigh, G. Marin, C. Dal Mutto, F. Dominio, L. Minto, G. M. Cortelazzo, "Time-of-Flight and Structured Light Depth Cameras: Technology and Applications", 1st ed., Springer, 2016.

Book chapters

- F. Dominio, G. Marin, M. Piazza, P. Zanuttigh, *"Features descriptors for depth-based hand gesture recognition"*, Computer Vision and Machine Learning with RGB-D Sensors, Springer, 2014

Journals

- G. Marin, F. Dominio, P. Zanuttigh, "*Hand gesture recognition with jointly calibrated Leap Motion and Depth Sensor*", Multimedia Tools and Applications, Springer, 2015.

Il Collegio prende atto di quanto esposto e osserva che il dott. Marin Giulio si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Prando Giulia nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Scienza e Tecnologia dell'Informazione.
Dall'inizio del corso di dottorato ad oggi il dott. Prando Giulia ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Scienza e Tecnologia dell'Informazione.

Il dottorando dichiara quanto segue:

Supervisor Prof. Alessandro Chiuso
Co-Supervisor Prof. Gianluigi Pillonetto

FIRST PART: EDUCATION

Courses, trainings and summer school activities

Courses

Among the courses offered in the catalogue of the PhD School in Information Engineering of the University of Padova, I attended the following courses: (taking the final examination):

- Applied Linear Algebra - Prof. G.Picci
- Random Graphs and Stochastic Geometry in Networks - Prof. S.Dey
- Statistical Methods - Prof. L.Finesso
- Applied Functional Analysis - Prof. G.Pillonetto

Among the courses offered in the catalogue of the PhD School in Information Engineering of the University of Padova, I attended the following courses: (without taking the final examination):

- Bayesian Machine Learning - Prof. G.M.Di Nunzio
- Computational Inverse Problems - Prof. F.Marcuzzi

During my period abroad at UC Berkeley, I attended the following courses (without taking the final examination):

- Convex Optimization - Prof. L. El Ghaoui
- Theoretical Statistics (Part A) - Prof. M. I. Jordan
- Theoretical Statistics (Part B) - Prof. M. Wainwright
- Topics in Deep Learning - Prof. J. Bruna
- Statistical Learning Theory - Prof. P. Bartlett

I attended the following PhD schools:

- Randomized algorithms for systems, control and networks (Gif Sur Ivette, February 3-7, 2014)
- Introduction to the analysis and control of non-linear systems (Bertinoro, July 7-9, 2014)
- Unmanned Aerial Vehicles (Bertinoro, July 10-12, 2014)
- The Gaussian Process Winter School (Genova, January 19-22, 2015)

Seminars

- 26/02/14: Alessandro Mei (Sapienza University), "System, Security, and Privacy Issue in Mobile Networking", DEI Seminars
- 11/03/14: Simona Rombo (University of Palermo), "Biological Network Analysis", DEI Seminars
- 07/04/14: Giampiero Naletto (University of Padova), "Rosetta e OSIRIS: 10 anni di viaggio verso la cometa", DEI Seminars
- 13/05/14: Massimo Fornasier (TUM Munchen), "From Mantegna's frescoes to variational methods for the inpainting of images", Colloquia Patavina
- 16/05/14: Junichi Ushiba (Keio University), "Brain-Computer Interface and Motor Learning in Stroke Rehabilitation", DEI Seminars
- 13/11/14: Florian Dorfler (ETH Zurich), "Plug and Play Operation of Microgrids", Automatica Group Seminars
- 14/11/14: Jose A. Cobos (Technical Univ. Madrid), "Power Supply Systems for Energy Efficiency", DEI Distinguished Lecture
- 13/03/15: Michele Pavon (Univ. Padova), "On the geometry of maximum entropy problems", Automatica Group Seminars
- 23/03/15: Walter Snoeys (PH department, CERN), "How chips helped discover the Higgs boson at CERN", DEI Distinguished Lecture
- 26/03/15: Federico Boccardi (OFCOM), "Shaping 5G", DEI Seminars
- 27/03/15: Lorenzo Rosasco (Universita di Genova, MIT), "Learning with Computational Regularization", DEI Seminars
- 01/04/15: "Computational Modeling in Cognitive Neuroscience: from Neurons to Robots", Cognitive Neuroscience Center Workshop
- 24/04/15: Luigi Palopoli (Univ. Trento), "When multimedia meets control: use of soft real-time techniques for control design", Automatica Group Seminars
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- 25/05/15: Silvio Micali (MIT), "Proofs, Secrets and Computation", Colloquia Patavina
- 03/06/15: Merouane Debbah (Huawei France R&D Center), "Mathematical Scientific Challenges of 5G", DEI Distinguished Lecture
- 08/06/15: Paolo Baracca (Alcatel-Lucent), "Coordinated Multi-Point Schemes for Interference Management in 5G networks", DEI Seminars
- 09/06/15: Ivar Ekeland (Univ. Paris Dauphine), "Are people rational?", Colloquia Patavina
- 17/06/15: Michel Verhaegen (Univ. Delft), "Nuclear Norm identification for lumped and distributed systems", Automatica Group Seminars
- 18/06/15: Rodolphe Sepulchre (Univ. Cambridge), "Do brains compute?", DEI Distinguished Lecture
- 07/07/15: Davide Piovesan (Univ. Gannon), "Human Arm Mechanics: from system identification to neural control", DEI Colloquia
- 09/07/15: Luca Scardovi (Univ. Toronto), "From Synchronization Analysis to Synchronization Control of Cellular Networks", Automatica Group Seminars

- 01/09/15: Kimon Fountoulakis (UC Berkeley), "Flexible Block Coordinate Descent", AMP Seminars, UC Berkeley
- 11/09/15: Benjamin Recht (UC Berkeley), "Train faster, generalize better: Stability of stochastic gradient descent", AMP Seminars, UC Berkeley
- 30/09/15: Michael Mahoney (UC Berkeley), "Combining randomized linear algebra and stochastic gradient descent", Scientific Computing and Matrix Computations Seminar, UC Berkeley
- 04/11/15: Mert Pilanci (UC Berkeley), "Fast Randomized Algorithms for Convex Optimization", Scientific Computing and Matrix Computations Seminar, UC Berkeley
- 25/01/16: Peter Stone (UT Austin), "Practical RL: Representation, Interaction, Synthesis, and Mortality (PRISM)", CS Seminar, UC Berkeley
- 22/02/16: Satinder Singh (UMichigan), "Reinforcement Learning: From Vision to Action and Back", CS Seminar, UC Berkeley
- 22/02/16: Aaditya Ramdas (UC Berkeley), "The p-filter: multi-layer FDR control for grouped hypotheses ", Practice Talk, UC Berkeley
- 29/02/16: Anirudha Majumdar (Massachusetts Institute of Technology, Cambridge, USA), "Control of agile robots in complex environments with formal safety guarantees ", CS Seminar, UC Berkeley
- 29/04/16: Various speakers , "Bay Area Optimization Meeting", Simons Institute Meetings
- 14/06/16: Oscar Pozzobon (Qascom S.r.l., Italy), "Galileo Satellite Navigation System: Current status and research opportunities", DEI Seminars
- 21/06/16: Michael Jordan (UC Berkeley), "Computational Thinking, Inferential Thinking and Data Science", DEI Distinguished Lecture
- 04/07/16: Marcello Pelillo (Universita' Ca' Foscari, Venezia), "Grouping Games: Finding Clusters in Graphs, Digraphs and Hypergraphs", DEI Colloquia
- 14/07/16: Seth Lloyd (Massachusetts Institute of Technology, Cambridge, USA), "Dialogue on the Quantum Revolution", DEI Distinguished Lecture
- 20/07/16: Subhrakanti Dey (Uppsala University, Sweden), "Sensor Scheduling in Variance Based Event Triggered Estimation with Packet Drops", Automatic Group Seminars
- 21/07/16: Enrico Lovisari (Volvo Cars, Goteborg, Sweden), "Traffic networks: modelling and control", Automatic Group Seminars
- 19/09/16: Dante Mantini (KU Leuven), "Detecting large-scale brain networks using high-density EEG", DEI Seminars
- 29/09/16: Maurizio Corbetta (Washington University School of Medicine St.Louis, Universita' di Padova), "Networks: Brain, Health, and Society", DEI Distinguished Lectures

National and international conferences

- Workshop of the European Research Network in System Identification (ERNSI 2014), September 21-24, 2014, Ostend
- 53rd IEEE Conference on Decision and Control (CDC 2014), December 15-17, 2014, Los Angeles
- Workshop on High-Dimensional Time Series in Macroeconomics and Finance, May 21-22, 2015, Wien

- 17th IFAC Symposium on System Identification (SYSID 2015), October, 19-21, 2015, Beijing
- 54th IEEE Conference on Decision and Control (CDC 2015), December 15-18, 2015, Osaka
- AMPLab Winter Retreat 2016, January 13-15, 2016, Lake Tahoe
- 15th European Control Conference (ECC 2016), June 29 - July 1, 2016, AAlborg
- Workshop of the European Research Network in System Identification (ERNSI 2016), September 25-28, 2016, Castelbrando (Cison di Valmarino)

Other activities

- During my period at UC Berkeley I attended a weekly reading group for seven months. Covered topics: bootstrap, parallel and distributed optimization, variational inference, causal inference.
- During my period at UC Berkeley I attended a weekly reading group on Deep Learning for two months.

Teaching activities

I was teaching assistant for the following courses:

- Systems and Models (Bachelor degree in Information Engineering, Fall 2014) - Prof. Mauro Bisiacco, Prof. Gianluigi Pillonetto. Work Load: 13 hours.
- Identification of Dynamical Systems (Master of Science in Control Systems Engineering, Fall 2014) - Prof. Mattia Zorzi. Work Load: 14 hours.
- Machine Learning (Master of Science in Control Systems Engineering and Computer Science Engineering, Fall 2016) - Prof. Alessandro Chiuso, Prof. Fabio Vandin. Work Load: 24 hours.

Mobility actions

From September 1, 2015 until June 2, 2016 I was a visiting student at UC Berkeley, under the supervision of Prof. Michael I. Jordan.

SECOND PART: RESEARCH

My research activity was mainly concerned the recently proposed non-parametric Bayesian approach to system identification.

According to the Bayesian paradigm, this procedure treats the impulse response of the system to be estimated as the realization of a Gaussian process; this amounts to postulate a Gaussian prior for the impulse response, as a function of some parameters (call hyper-parameters in the Bayesian framework).

The inference step is then performed by somehow approximating the posterior distribution arising once the observed data have been taken into account. A commonly adopted approximation

assumes that the posterior of the hyper-parameters is a delta-function, thus estimating them by computing the mode of their posterior. In practice, this amounts to maximize the so-called marginal likelihood, i.e. the likelihood after the impulse response has been marginalized out. With the hyper-parameters fixed at their mode, the final estimator is computed as the conditional expected value of the impulse response w.r.t the posterior distribution, which coincides with the minimum variance estimator. Assuming that the identification data are corrupted by Gaussian noise, the above-mentioned estimator coincides with the solution of a regularized estimation problem, in which the regularization term is the 2 norm of the impulse response, weighted by the inverse of the prior covariance function (a.k.a. kernel in the machine learning literature).

My research activity was focused on extending and analyzing some aspects of the above-mentioned procedure. The results achieved by the proposed extensions were always compared also with those obtained through classical system identification methods (e.g. Prediction Error Methods (PEM) and subspace algorithms).

The topics touched by my research activity are outlined in the following.

Prior design

The original formulation of the non-parametric Bayesian identification approach postulates a Gaussian prior accounting for the stability and smoothness of the impulse response to be estimated. Adopting Maximum Entropy arguments, a new type of 2 -regularization was derived, resulting in a vector-valued kernel; the aim was to introduce regularization on the block Hankel matrix built with Markov coefficients, thus controlling the complexity of the identified model, measured by its McMillan degree. Combining this Hankel-based regularization with the standard l2-type regularization adopted in previous literature, the newly designed kernel encodes, at the same time, stability, smoothness and low McMillan degree.

From the computational point of view, the most demanding step in the proposed procedure is the marginal likelihood maximization which is required to estimate the hyper-parameters defining the above-mentioned kernel. To speed up the computational requirements of the estimation algorithm, a tailored version of the Scaled Gradient Projection (SGP) algorithm was designed.

The performed experiments have proven the effectiveness of the proposed method; in particular, when applied for the estimation of MIMO systems, the proposed method significantly outperforms the original non-parametric Bayesian routine: indeed, the newly designed kernel allows to account for the coupling between the different input-output channels.

Posterior Inference

Two possible ways of approximating the posterior distribution were compared. The first one is the one based on marginal likelihood maximization (as discussed above), while the second one exploits a Markov Chain Monte Carlo (MCMC) algorithm to compute a Monte-Carlo approximation of the posterior distribution. The numerical experiments do not highlight a significant difference between the performance achieved by the two approaches.

Characterization of uncertainty

The confidence sets returned by the non-parametric Bayesian identification algorithm were analyzed and compared with the ones returned by classical parametric Prediction Error Methods (PEM). The comparison was carried out in the impulse response space: specifically, "particle" versions (i.e. Monte-Carlo approximations) of the standard confidence sets were computed in order to perform a fair comparison between the different methods.

The results show that non-parametric Bayesian methods are preferable to the classical parametric ones not only in terms of the adherence between the true system and the point estimator these methods return, but also in terms of the quality of the confidence sets they build (measured in terms of size and coverage).

Online estimation

The application of the non-parametric Bayesian system identification techniques was extended to an on-line setting, in which new data become available as time goes. In order to meet real-time estimation requirements, the computational and the memory storage requirements of the identification method have to be kept as low as possible. To this purpose, a tailored Bayesian procedure was developed by means of two key modifications of the standard "batch" procedure: (1) the quantities required for the computation of the impulse response estimate are incrementally updated and (2) the hyper-parameters are still updated through marginal likelihood maximization, but only one iteration of an iterative optimization algorithm is performed. In particular, the EM algorithm and some gradient methods were adopted at this stage and a comparison of their performances has been provided.

The proposed framework was also extended to the identification of time-varying systems, which requires to somehow discard old data. To this aim, three different approaches were compared: in the first one a sliding window is used, while the other two approaches adopt a forgetting factor in the estimation criterion, which gives more weight to "recent" data than to old ones. The Bayesian framework was also exploited to continuously update the value of the forgetting factor, by treating it as a hyper-parameter.

The experiments show that the estimation performance achieved by this online procedure are comparable to the ones returned by the standard "batch" procedure, in which the iterative algorithms adopted for marginal likelihood maximization are run until convergence. However, the computational burden is significantly reduced by means of the two proposed modifications. Moreover, when dealing with time-varying systems, the possibility of continuously updating the forgetting factor allows the identification routine to rapidly track abrupt changes of the unknown systems poles.

Post-processing: model reduction

Non-parametric Bayesian identification procedures estimate the unknown system in terms of its impulse response coefficients, thus returning a model with high (possibly infinite) McMillan degree. However, if the intended use of the estimated system involves control applications, it would be desirable to deal with a low complexity model. To overcome this issue, a completely automatic model reduction procedure was proposed: once applied on the estimate returned by a Bayesian identification method it returns a low McMillan degree model as the final estimate. Different criteria for the selection of the order of the reduced model were also compared.

Besides being more suitable for filtering and control applications, low-order models seem also to better capture the dynamics of the systems to be identified, as observed in the several Monte Carlo experiments which were performed. Furthermore, the performance achieved (in terms of adherence to the true system) by the reduced order models returned by the developed routine are comparable with those obtained by equipping classical Prediction Error Methods (PEM) with an oracle which unrealistically knows the true system to be estimated.

During my period at UC Berkeley I worked on a deep learning application under the supervision of Prof. Michael I. Jordan and in collaboration with Philipp Moritz (a PhD student supervised by Prof. Jordan).

We have investigated the use of ladder networks in a supervised learning task, specifically in the context of frame prediction. The so-called "ladder network" has been recently introduced in the deep learning community as a tool for unsupervised and semi-supervised learning. A ladder network is an autoencoder equipped with connections between the decoder and the encoder at chosen layers of the network hierarchy.

Applications of our work include video prediction and model-based reinforcement learning. Indeed, by introducing a dynamic model between the encoder and the decoder paths, the ladder network can model the transition map of a Markov Decision Process (MDP) with high-dimensional state space.

Experiments on future frame prediction of Atari games and of videos in Sports1m dataset confirm the effectiveness of the approach.

Definitive title of the thesis:

Non-Parametric Bayesian Methods for Linear System Identification

THIRD PART: PUBLICATIONS

Publications in International Journals

Maximum-Entropy Vector Kernels for MIMO system identification, G. Prando, G. Pillonetto, A. Chiuso. Provisionally Accepted as a Regular Paper for Automatica.

Publications in International Conferences

- *Bayesian and regularization approaches to multivariable linear system identification: the role of rank penalties,* G. Prando, A. Chiuso, G. Pillonetto. In Proc. of the 53rd IEEE Conference on Decision and Control (CDC 2014).
- *The Role of Rank Penalties in Linear System Identification,* G. Prando, G. Pillonetto, A. Chiuso. In Proc. of the 17th IFAC Symposium on System Identification (SYSID 2015).
- Model reduction for linear Bayesian system identification, G. Prando, A. Chiuso. In Proc. of the 54th IEEE Conference on Decision and Control (CDC 2015).
- *On-line Bayesian System Identification,* D. Romeres, G. Prando, G. Pillonetto, A. Chiuso. In Proc. of the 15th European Control Conference (ECC 2016).
- *Classical vs Bayesian methods for linear system identification: point estimators and confidence sets,* G. Prando, D. Romeres, G. Pillonetto, A. Chiuso. In Proc. of the 15th European Control Conference (ECC 2016).
- *Online identification of time-varying systems: a Bayesian approach,* G. Prando, D. Romeres, A. Chiuso. In Proc. of the 55th IEEE Conference on Decision and Control (CDC 2016).

Il Collegio prende atto di quanto esposto e osserva che il dott. Prando Giulia si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Romeres Diego nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Scienza e Tecnologia dell'Informazione.
Dall'inizio del corso di dottorato ad oggi il dott. Romeres Diego ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Scienza e Tecnologia dell'Informazione.

Il dottorando dichiara quanto segue:

Supervisor: Prof. Alessandro Chiuso
Co-Supervisor: Prof. Gianluigi Pillonetto

First Part: Education

Courses, Training and Summer School Activities

Courses

List of exams taken in the catalogue of the PhD School in Information Engineering of the University of Padova:
• Applied Linear Algebra - Prof. G.Picci
• Random Graphs and Stochastic Geometry in Networks - Prof. S.Dey
• Statistical Methods - Prof. L.Finesso
• Applied Functional Analysis - Prof. G.Pillonetto.

List of exams attended in the catalogue of the PhD School in Information Engineering of the University of Padova, without taking the final exam:
• Bayesian Machine Learning - Prof. G.M.Di Nunzio
• Computational Inverse Problems - Prof. F.Marcuzzi

List of courses attended at PhD schools:
• Randomized algorithms for systems, control and networks (Gif Sur Ivette, February 3-7, 2014)
• Introduction to the analysis and control of non-linear systems (Bertinoro, July 7-9, 2014)
• Unmanned Aerial Vehicles (Bertinoro, July 10-12, 2014)
• The Gaussian Process Winter School (Genova, January 19-22, 2015)

Seminars

• 26/02/14: Alessandro Mei (Sapienza University), "System, Security, and Privacy Issue in Mobile Networking", DEI seminars
• 11/03/14: Simona Rombo (Univ. Palermo), "Biological Network Analysis", DEI seminars
• 07/04/14: Giampiero Naletto (Univ. Padova), "Rosetta e OSIRIS: 10 anni di viaggio verso la cometa", DEI seminars
• 13/05/14: Massimo Fornasier (TUM Munchen), "From Mantegna's frescoes to variational methods for the inpainting of images", Colloquia Patavina
• 16/05/14: Junichi Ushiba (Keio University), "Brain-Computer Interface and Motor Learning in Stroke Rehabilitation", DEI seminars
• 13/03/15: Michele Pavon (Univ. Padova), "On the geometry of maximum entropy problems", Automatica Group Seminars
• 23/03/15: Walter Snoeys (PH department, CERN), "How chips helped discover the Higgs boson at CERN", DEI Distinguished Lecture
• 27/03/15: Lorenzo Rosasco (MIT-IIT), "Learning with computational regularization", DEI Seminars
• 01/04/15: "Computational Modelling in Cognitive Neuroscience: from Neurons to Robots", Cognitive

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• 24/04/15: Luigi Palopoli (Univ. Trento), "When multimedia meets control: use of soft real-time techniques for control design", Automatica Group Seminars
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• 09/06/15: Ivar Ekeland (Univ. Paris Dauphine), "Are people rational?", Colloquia Patavina
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• 09/07/15: Luca Scardovi (Univ. Toronto), "From Synchronization Analysis to Synchronization Control of Cellular Networks", Automatica Group Seminars
• 25/09/15: Pratap Pattnaik (IBM), "Bitcoin, an attempt at a separation of money and state", Distinguished Lecture DEI
• 28/09/15: Blaz Zupan (Univ. Lubiana), "Large-scale data fusion", DEI Seminars
• 05/10/15: Jun Miura (Department of Computer Science and Engineering, Toyohashi University of Technology), "Autonomous Mobile Robot Research at Active Intelligent Systems Laboratory, TUT.", DEI Seminars
• 30/10/15: Giulio Caravagna (University of Edinburgh), "Algorithmic Methods to Infer the Evolutionary Trajectories in Cancer Progression", DEI Seminars
• 21/01/16: Guilherme Maeda (TU Darmstadt), "Learning Primitives from Human Observation - Applications to Comfortable Interaction", Ober Seminar
• 21/01/16: Igor Achieser (TU Darmstadt), "Potential evaluation of eye- and headtracking data as a robust and real-time capable predictor for driver intention detection and integration into an algorithm for maneuver prediction", Ober Seminar
• 21/01/16: Dieter Buechler (MPI), "A Lightweight Robotic Arm with Pneumatic Muscles for Robot Learnng ", Ober Seminar
• 28/01/16: Danko Nikolic (MPI for Brain Research & FIAS), "Strong-AI through AI-Kindergarten ", Ober Seminar
• 28/01/16: Dorothea Koert (TU Darmstadt), "Towards Natural Human Demonstration in Imitation Learning ", Ober Seminar
• 28/01/16: Joni Pajarinen (TU Darmstadt), "Planning Under Uncertainty: POMDPs, Decentralized POMDPs, Multi-Object Manipulation ", Ober Seminar
• 28/01/16: Vittorio Lippi (Uniklinik Freiburg), "Neurorobotics and humanoids ", Ober Seminar
• 11/02/16: Svenja Stark (TU Darmstadt), "Learning Probabilistic Feedforward and Feedback Policies for Stable Walking", Ober Seminar
• 11/02/16: Takayuki Osa (TU Darmstadt), "Learning Mutiple Grasp Types by Hierarchical Policy Search", Ober Seminar
• 18/02/16: Frank Hutter (Uni Freiburg), "Advances in hyperparameter optimization of (deep) machine learning pipelines", Ober Seminar
• 11/02/16: Jannick Abbenseth (TU Darmstadt), "Cooperative Path-Planning for Service Robots", Ober Seminar
• 03/03/16: Voot Tangkaratt (Tokyo University), "Sufficient Dimension Reduction for Transition Model Estimation", Ober Seminar
• 10/03/16: Riad Akrour (TU Darmstadt), "Model-free Trajectory Optimization", Ober Seminar
• 10/03/16: Hany Abdulsamad (TU Darmstadt), "Stochastic Optimal Control with Linearized Dynamics", Ober Seminar
• 24/03/16: Daniel Wilbers (TU Darmstadt), "Context-driven Movement Primitive Adaptation", Ober Seminar
• 30/03/16: Alberto Romay (SIM), "An Object Template Approach to Manipulation for Semi-Autonomous Avatar Robots", PhD Thesis defense
• 07/04/16: Moritz Nakatenus (TU Darmstadt), "Multi-Agent Reinforcement Learning Algorithms", Ober Seminar

• 13-14/04/16: Professorship selection (Organized by TU Darmstadt), " Cognitive Science Workshop", 2 Days Workshop
• 22/04/16: Chris Watkins (TU Darmstadt), "Probability models of evolution ", Ober Seminar
• 22/04/16: Chris Daniel (TU Darmstadt), "Learning Hierarchical Policies from Human Ratings", PhD Thesis defense
• 25/04/16: Quan Zhou (TU Darmstadt), "Small robotic systems and microassembly", Ober Seminar
• 19/05/16: Guilherme Maeda (TU Darmstadt), "Programming Robots using Human Observations", Ober Seminar
• 19/05/16: Diego Romeres (University of Padova), "Analysis of Bayesian System Identification", Ober Seminar
• 24/05/16: Jerry Lin (Taiwan Tech), "Programming Robots using Human Observations", Ober Seminar
• 25/05/16: Viktor Pfanschilling (TU Darmstadt), "Genetic Programming with Haskell", Ober Seminar
• 25/05/16: Maurizio Filippone (Eurecom), "Unbiased computations for tractable and scalable learning of Gaussian processes", Ober Seminar
• 02/06/16: Viktor Pfanschilling (TU Darmstadt), "Genetic Programming with Haskell", Ober Seminar
• 15/06/16: Peter Englert (U Stuttgart), "Combined Optimization and Reinforcement Learning for Manip-ulations Skills ", Ober Seminar
• 24/06/16: Kevin Luck (AAlto University), "Multi-Group Factor Extension of the GrouPS algorithm and Real-World Robot Learning", Ober Seminar
• 27/07/16: Alexander Sproewitz (MPI-IS), "Agile and Robust Legged Robot Locomotion using Bioinspired Design and Control Primitives", Ober Seminar
• 03/08/16: Roberto Calandra (TU Darmstadt), "Bayesian modeling for optimization and control in robotics", PhD Thesis defense
• 04/08/16: Michael A Osborne (Oxford), "Probabilistic numerics: treating numerical computation as learning, or; it's Bayes all the way down", PhD Thesis defense
• 29/08/16: Maximilian Huettenrauch (TU Darmstadt), "Guided Deep Reinforcement Learning for Robot Swarms", Ober Seminar
• 29/08/16: Michael Lutter (Technische Universitaet Muenchen), "Distance measures for view-invariant dynamic texture recognition", Ober Seminar
• 29/09/16: Maurizio Corbetta (Washington University School of Medicine St.Louis, Univ. Padova), "Networks: Brain, Health, and Society", DEI Distinguished Lectures

National and International Conferences

• Workshop of the European Research Network in System Identification (ERNSI 2014), September 21-24,2014, Ostend
• 14th European Control Conference (ECC 2015), July 15 - 17, 2015, Linz
• Workshop of the European Research Network in System Identification (ERNSI 2015), September 20-23, 2015, Varberg
• 13th European Control Conference (ECC 2016), June 29 - July 1, 2016, AAlborg
• Workshop of the European Research Network in System Identification (ERNSI 2016), September 25-28, 2016, Castelbrando (Cison di Valmarino)
• 54th IEEE Conference on Decision and Control (CDC 2016), December 12-14, 2016, Las Vegas (to be attended in the end of the year)

Teaching Activities

Course Segnali e Sistemi (Bachelor degree in Mechatronic Engineering, Fall 2014) - Prof. Alessandro Chiuso, from March to June 2015. My activity consisted in an introduction to the software Matlab, support during the lab sessions and grading of final lab reports.

Mobility Actions

ETH with Prof. F. Doerfler, 5 th October - 30 th November 2014.

This project is about model reduction in power networks revisiting the classic slow coherency and area aggregation approach and it is the proceeding of my master thesis. The slow coherency approach is based on identifying sparsely and densely connected areas of a network, within which all generators swing coherently. A time-scale separation and

singular perturbation analysis then results in a reduced low order system, where coherent areas are collapsed into aggregate variables.

In this research we study the application of slow coherency and area aggregation to first-order consensus systems and second-order power system swing dynamics. In particular: we provide a complete analysis of the second-order swing dynamics – without restrictive assumptions on the system damping, we identify the reduced aggregate models as generalized first or second-order Laplacian flows with multiple time constants, aggregate damping and inertia matrices.

We are currently trying to extends this redaction model theory to structure preserving models, considering input in the system and deriving results for specific kind of network of particular interest in the literature.

TU Darmstadt with Prof. J. R. Peters, 15-th January - 16-th September 2016.

The research activity which has been carried out is described in the 'Research' section. During this period abroad I attended a weekly seminar called 'Ober Seminar' and I learnt how to use to a robotic simulator called 'SL'.

Second Part: Research

System identification, the art of estimating dynamical systems from data, has been the core of my research in the three years of PhD. The focus has been twofold: analysis and extension of linear Gaussian regression models and the estimation of the inverse dynamics of robotic platforms.

When Gaussian processes are applied to linear systems identification, according to the Bayesian paradigm, the impulse response is modeled a priori with a Gaussian distribution encoding the desired structural properties of the dynamical system (e.g. smoothness, BIBO stability, sparsity, etc.). The inference on the impulse response estimate is obtained by combining the information of the a priori distribution together with the information given by the data. Different approximations of the posterior distribution conditional on the data yield different impulse response estimates such as the Empirical and the Full Bayes estimate. The contributions achieved by my research in this field are outlined in 'Gaussian Regression Advances in System Identification'.

System identification plays also a fundamental role in robotic applications where accurate models are needed for high performance control design. Indeed, estimation of the inverse dynamics is a challenging problem that finds a direct application in robotic control, in fact it can be used as a feed forward term in classical closed loop control schemes improving the performances in tracking desired trajectories and reducing the gain of the controller. Some analysis of existing solutions as well as new methodologies proposed are outlined in 'Robotics Inverse Dynamics Estimation'.

Gaussian Regression Advances in System Identification. Nonparametric Gaussian regression models are powerful tools for supervised learning problems. Recently they have been introduced in the field of system identification as an alternative to classical parametric models used in prediction error methods. In nonparametric methods model classes are described in a flexible manner by a small number of hyperparameters. The Bayesian framework naturally suggests data driven procedures for tuning these hyperparameters, allowing to adapt the model class and its complexity while also accounting for uncertainty and noise, thus providing a robust mean to trade bias versus variance. On the other hand, one disadvantage of these nonparametric methods, is that their aim to identify directly the impulse response of the predictor model does not guarantee the stability of the simulation (or forward) model.

These advantages and disadvantages inspired my research that aim to validate and enrich the properties of the Gaussian regression models. In particular, my research focused in three main topics detailed below.

<u>Point estimators and confidence sets.</u> The performance of nonparametric Bayesian estimators in terms of error in fitting the impulse response are often superior to classical parametric methods. This was verified also in our experiments. In addition, we were interested in comparing the nonparametric and parametric approaches in terms of confidence intervals. The proposed comparison is in the impulse response space, defining sampling approximation of regions around the point estimators called 'Particle' confidence sets. The Bayesian estimates result to be preferable also in this test. Among of them, recall that the Empirical Bayes is an approximation of the more computationally demanding Full Bayes approach. Yet, no significant improvements of the latter w.r.t. the former are obtained both in terms of impulse response fitting and confidence sets.

<u>Online system identification setting.</u> In an on-line system identification setting, new data become available

As time goes and real-time estimation requirements have to be satisfied. The goal is to compute the hyperparameters and the model with a fixed computational complexity and storage of memory.

We developed a tailored Bayesian procedure which differ from a standard "batch" procedure for these main reasons: the quantities to compute the marginal likelihood and the impulse response estimate are updated iteratively, the estimation of the hyper-parameters, is approximated by computing only one iteration of a suitable optimization algorithm to maximize the marginal likelihood, and the model estimate is obtained by exploiting the same quantities used in the computation of the marginal likelihood in order to minimize the computational complexity. Both quasi-Newton methods and EM algorithm were adopted as optimization algorithm.

When time-varying systems are considered, the property of 'forgetting the past data' is required. Accordingly we have proposed two schemes: the first which uses a temporal window which slides over the data and the second which introduces a forgetting factor allowing to exponentially decrease the weight of old data. In particular, we proposed to consider the forgetting factor both as a fixed constant or as variable to be estimated.

The performance obtained by the nonparametric methods obtained are satisfactory compared to the "batch" procedure and outperform the classical parametric approaches, both in terms of computational time and impulse response fit.

Enforcing system stability in nonparametric prediction error methods. One of the main idea of Bayesian paradigm is to frame linear system identification as predictor estimation in an infinite dimensional space, with the aid of regularization/Bayesian techniques. This approach can guarantee the identification of stable predictors based on the prediction error minimization. Unluckily, the stability of the predictors does not guarantee the stability of the impulse response of the simulation model (except in the specific case when the impulse response of the two models coincides, i.e. output-error models). Three techniques are proposed to guarantee the stability property.

First, the so called 'LMI - constraint' approach is considered and adapted to constrain the eigenvalues of the identified simulation model within the unit circle.

Second, in addition to the 'classic' Stable-Spline algorithm a penalty function is considered in the optimization procedure. This penalty function smoothly impose the stability constrained to the maximum absolute value of the eigenvalue of the simulation model. This technique has the advantage of being integrated directly inside the pre-existing optimization problem and do not a post-processing procedure.

Third, the 'stable posterior' which is a distribution over the impulse responses that exclude all the unstable model is considered. This distribution, that cannot be computed in closed form, is obtained in sampling form through a Markov Chain Monte Carlo approach (MCMC).

All the techniques ultimately produce stable simulation models which perform comparably in terms of prediction error. However, only the model estimated with an MCMC technique perform satisfactorily in terms of impulse response fit.

Robotics Inverse Dynamics Estimation. Two different approaches are proposed to estimate the inverse dynamics models. A prediction model approach, which aims to predict the output joint torques the more accurately possible and a structural model, which aims to identify precise and physically meaningful inverse dynamics parameters, the so called 'inertia parameters'.

A prediction model: online semiparametric learning for inverse dynamics modeling. Humanoid robots are a sophisticated platforms controlled by a mathematical model to relate the actuator inputs to the interactions with the external world read by sensor feedbacks. This model is called the dynamic model of the robot. Dynamic models can be obtained from first principles in mechanics, using the techniques of rigid body dynamics (RBD): this approach results in a parametric model in which the values of physically meaningful parameters must be provided in order to complete the fixed structure of the model. Alternatively, the dynamical model can be obtained from experimental data using Machine Learning (ML) techniques, resulting in a non-parametric model. With respect to the parametric approach, the nonparametric Gaussian regression modelling has the advantage that it does not require any unrealistic assumption on the real system, such as rigidity of the links or a simplistic modelling of the friction; indeed, it can model the dynamics by extrapolating the input-output relationship directly from the available data. On the other hand, non-parametric models are unable to generalize properly in parts of the input space that are not included in the training set. In order to exploit the advantages of both these techniques, semiparametric models have been recently introduced as a combination of RBD and nonparametric models.

The main contributions of this research are the following. First, various semiparametric learning techniques proposed in the literature are framed under a unique general model, and an online algorithm is provided for this general model. Second, the online algorithm is used to compare the various modeling approaches (parametric, non-parametric, semi-parametric) for estimating the inverse dynamics of right arm of the iCub humanoid robot, using real data. In doing so, we also compare two different approaches for estimating the hyperparameters (the parameters in the nonparametric approach), namely marginal likelihood maximization and cross validation. Third, joints positions velocities and the accelerations are the interesting quantities suggested by the physics in order describe the inverse dynamics model. However, joints velocities and accelerations in the majority of the experiments cannot be measured and are approximated by numerical differentiation of the joints positions, this procedure brings significant errors into the model. We propose to replace joint velocities and accelerations by linear combination of the previous temporal lags of the joint positions, learning the weight of the linear combination directly from data.

A structural model: bringing causality into inverse dynamics estimation. Forward and inverse dynamics are the two possible models to describe the relationship between the applied joint actuator torques/forces and the joint accelerations in a robotic platform. The inverse dynamics model is more suitable for identification purposes due to its linear dependency on the parameters. However, modelling the dynamics of the robot using the inverse model violates the causality properties own of any physical system. This leads to a wrong error model which is considered as an additive noise in the torques and instead it should affects the joint accelerations.

The main contribution of this work is that the estimation of the inertial parameters is obtained by considering the causally correct forward model, which implies taking in consideration the propagation of the error according to the dynamical behaviour of the system, as well as properly handling uncertainty and noises.

The preliminary results on simulation data are satisfactory, the method proposed outperforms existing state of the art techniques. Currently, we are running experiments on a real robotic arm platform, trying to validate the identified inverse dynamics model in control applications.

Thesis Title

Advances in System Identification: Gaussian Regression and Robot Inverse Dynamics Learning

Third Part: Publications

Publications in International Conferences

- *Online semi-parametric learning for inverse dynamics modeling*, D. Romeres, M. Zorzi, R. Camoriano and A. Chiuso. In Proc. of the 55th IEEE Conference on Decision and Control (CDC 2016).

- *Online identification of time-varying systems: a Bayesian approach*, G. Prando, D. Romeres, A. Chiuso. In Proc. of the 55th IEEE Conference on Decision and Control (CDC 2016).

- *On-line Bayesian System Identification*, D. Romeres, G. Prando, G. Pillonetto, A. Chiuso. In Proc. of the 15th European Control Conference (ECC 2016).

- *Classical vs Bayesian methods for linear system identification: point estimators and confidence sets*, G. Prando, D. Romeres, G. Pillonetto, A. Chiuso. In Proc. of the 15th European Control Conference (ECC 2016).

- *Identification of stable models via nonparametric prediction error methods,* D. Romeres, G. Pillonetto and A. Chiuso. In Proc. of the 14th European Control Conference (ECC 2015).

- *Novel Results on Slow Coherency in Power Networks,* D. Romeres, F. Doerfler and F. Bullo. In Proc. of the 12th European Control Conference (ECC 2013). Finalist Best Student Paper Award.

- *Region of Attraction of Power Systems,* Ulrich Muenz, Diego Romeres. In Proc. of NecSys 2013.

• *Distributed multi-hop reactive power compensation in smart micro-grids subject to saturation constraints*, S. Bolognani, A. Carron, A. Di Vittorio, D. Romeres, and L. Schenato. In Proc. of the 51th IEEE Conference on Decision and Control (CDC 2012).

Poster Presentations

• *Online semi-parametric learning for inverse dynamics modeling*, D. Romeres, M. Zorzi, A. Chiuso. Poster at the Workshop of European Research Network in System Identification (ERNSI 2016).

• *On-line Bayesian System Identification*, D. Romeres, G. Prando, G. Pillonetto and A. Chiuso. Poster at the Workshop of European Research Network in System Identification (ERNSI 2015).

• *Classical vs. Bayesian methods for linear system identification: point estimators and confidence sets*, D. Romeres, G. Prando, G. Pillonetto and A. Chiuso. Poster at the Workshop of European Research Network in System Identification (ERNSI 2015).

• *Stabilization Techniques for Bayesian System Identification*, D. Romeres, G. Pillonetto and A. Chiuso. Poster at the Workshop of European Research Network in System Identification (ERNSI 2015).

Patents

Method and Apparatus for a Load Step Robust Unit Commitment of Power Generation Units in a Power Supply System, U. Muenz, D. Romeres. Pending Patent, https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2014154305

Il Collegio prende atto di quanto esposto e osserva che il dott. Romeres Diego si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Rubega Maria nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Bioingegneria.
Dall'inizio del corso di dottorato ad oggi il dott. Rubega Maria ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Bioingegneria**.**

Il dottorando dichiara quanto segue:

1. Education

1.1 Courses organized within the department for PhD students:

- Tissue Engineering: Principles and Applications
- Computational Inverse Problems
- Digital Processing of Measurement Information
- Statistical Methods
- Mathematical Modeling of Cell Biology

1.2 Schools:

- Attendee of the School on Neurotechniques (CSNII) "The Convergent Science Network for Biomimetics and Neurotechnology" (University of Padova, NeuroChip Laboratory, March 10-15, 2014)
- Attendee of the XXXIII Annual School of Bioengineering "La Bioingegneria: dal recupero funzionale all'organo artificiale" (Bressanone, Italy, September 22-25, 2014)
- Attendee of the School on Neurotechniques (CSNII) "The toolbox for investigating the function of neural circuits" (University of Padova, NeuroChip Laboratory, March 23-27, 2015)
- Attendee of IEEE-EMBS 9th International Summer School "Enabling technologies for rehabilitation" (Pavia, Collegio Borromeo, Italy, August 30 – September 6, 2015)

1.3 Workshops:

- "La Spettroscopia nel Vicino Infrarosso (NIRS) dai fondamenti alle applicazioni cliniche" (University of Padova, Policlinico Universitario, October 29, 2014)
- "Brain-Machine Interface" (Padova, Centro Congressi, July 15, 2014)

1.4 Seminars:

- "Biological Network Analysis" (University of Padova, Department of Information Engineering (DEI), March 11, 2014)
- "The mysteries of Quantum Physics and their applications" (Padova, Collegio Morgagni, March 13, 2014)
- "Brain-Computer Interface and Motor Learning in Stroke Rehabilitation" (University of Padova, DEI, May 16, 2014)

- "Impiego della Taylor-Fourier Transform per la rimozione di artefatti in segnali EEG" (University of Padova, DEI, June 4, 2014)
- "Quantitative Magnetic Resonance Imaging of the Spinal Cord: basic concepts and applications" (University of Padova, DEI, September 16, 2014)
- "L'ingegneria del corpo: Conferenza sul Pancreas Artificiale" (University of Padova, Palazzo del Bo', October 20, 2014)
- "Rosetta rendez-vous with the 67P/Churyumov-Gerasimenko comet" - Luigi Colangeli (University of Padova, DEI, November 27, 2014)
- "Learning with Computational Regularization" - Prof. Lorenzo Rosasco (University of Padova, DEI, March 27, 2015)
- "Making better drugs"- Phillip Frost (University of Padova, Palazzo del Bo', May 13, 2015)
- "Do brains compute?" - Rodolphe Sepulchre (University of Padova, DEI, June 18, 2015)
- "Adult neurogenesis in the olfactory system: from synapse to behaviour" - Dr. Gabriel Lepousez (Padova, Venetian Institute of Molecular Medicine (VIMM), June 25, 2015)
- "Recent Advances in ERP Estimation and Classification" - Dr. Marco Congedo (University of Padova, Department of Pshycology, July 3, 2015)
- "Encoding speech through cortical oscillations" - Dr. Lorenzo Fontolan (University of Padova, Department of Biomedical Sciences, September 9, 2015)
- "Algorithmic Methods to Infer the Evolutionary Trajectories in Cancer Progression" – Dr. Giulio Caravagna (University of Padova, DEI, October 30, 2015)
- "Neuroscience Day @ DEI" – Marco Zorzi, Giovanni Sparacino, Luca Tonin, Giulia Cisotto, Federico Avanzini, Maurizio Corbetta, Alessandra Bertoldo, Mattia Zorzi, Andrea Gerosa, Gianfranco Bilardi (University of Padova, DEI, February 2, 2016)
- "Exploring the visual processing of illusory contours in 22q11.2DS using high density EEG" - Marjan Biria (Genève, Campus Biotech, March 10, 2016)
- "Preliminary results on DBS in the mouse model with focal epilepsy" - Laurent Sheybani (Genève, Campus Biotech, April 21, 2016)
- "Anatomy of the Supratemporal Areas in Humans and Baboons, and Hemispheric Specialization for Language using MRI" - Damien Marie (Genève, Campus Biotech, April 28, 2016)
- "Source space micro-states analysis" – Denis Brunet (Genève, Campus Biotech, May 12, 2016)
- "Boosting the phonemic rhythms in auditory cortex with transcranial alternating current stimulation" - Cécile Pacoret (Genève, Campus Biotech, May 19, 2016)
- "Localization of the epileptogenic zone using EEG source imaging and directed functional connectivity" – Pieter Van Mierlo (Genève, Campus Biotech, June 2, 2016)
- "Directed functional connectivity in patients with focal epilepsy using high-density scalp EEG" – Ana Coito (Genève, Campus Biotech, June 16, 2016)

1.5 International conferences:

- 8th International Conference on Advanced Technologies Treatments for Diabetes (ATTD), February 18-21, 2015, Paris, France (oral presentation of [C6])
- 37th Annual International Conference of the IEEE Engineering Medicine and Biology Society (EMBC), August 25-29, 2015, Milano, Italy (oral presentations of [C1] [C2])
- 3rd International Conference: The Brain Forum 2016, 26-27 maggio 2016, Lausanne, Switzerland

1.6 National conferences:

- IV National Congress of Bioengineering (GNB), Pavia, June 25-27, 2014 (poster of [C7])
- 9e Journée de la recherche clinique, May 13, 2016, Genève, Switzerland (poster of [C8])
- V National Congress of Bioengineering (GNB), June 20-22, 2016, Napoli, Italy (oral presentation of [C8])
- 3rd Swiss Federation of Clinical Neuro-Societies, September 28-30, 2016, Basel, Switzerland (poster of [C8])

1.7 Teaching activities (as Tutor Junior)

Providing support and one-to-one assistance in MATLAB laboratories for the classes of:

- Medical Informatics, Padova, DEI, October 2014 – January 2015 (20 hours), October 2015 – January 2016 (30 hours);
- Analysis of biological data, Padova, DEI, October 2014 – January 2015, October 2015 – January 2016 (10 hours);
- Modeling and Control of Biological Systems, Padova, DEI, March 2015 – June 2015 (30 hours);

Frontal lectures on MATLAB algorithms for Medical Informatics, Padova, DEI, October 2014 – January 2015 (4 hours), October 2015 – January 2016 (4 hours).

1.8 Mobility action

Visiting PhD student in the Functional Brain Mapping Laboratory of Prof. Christoph Michel (Department of Neuroscience, Université de Genève, Genève, Switzerland), under the supervision of Dr Markus Gschwind.

2. Research

2.1 Description of the research during the PhD:

The three-year research focused on two main topics:

a. *Analysis of the EEG signals in hypoglycemia in patients affected by type 1 diabetes (T1D).*

Hypoglycemic events (blood glucose concentration (BG) <70 mg/dl) are potentially life threatening in patients with T1D. EEG indicators in time and frequency domains on a single channel level during insulin-induced hypoglycemia have suggested a possible role of EEG as a noninvasive biosensor to detect hypoglycemia.

Firstly, we assessed the ability of a number of classical indicators to capture EEG changes in 19 T1D subjects who underwent a hyperinsulinemic-hypoglycemic clamp while continuous EEG was recorded (data were provided by Hyposafe A/S, Lyngby, Denmark). In particular, EEG segments observed in euglycemia (Eu) and hypoglycemia (Hypo) were assessed in the frequency and time-frequency domains, respectively by linear spectral analysis and power modulation calculation. Results showed that, in all the considered domains, EEG indicators significantly change when passing from Eu to Hypo and suggested their possible use in portable device prototypes presently under research with the aim of detecting hypo-events in real-time from EEG signals measured by subcutaneous electrodes.

The above approaches, as several works in the literature, have evaluated the changes induced by Hypo by considering approaches at the single EEG channel level, but multivariate analyses have been scarcely investigated in T1D subjects. Thus, secondly, we assessed if and how Hypo affects EEG coherence in a subset of EEG channels acquired in the hospital setting. In particular, EEG multichannel data, acquired in the same 19 T1D hospitalized subjects were considered. Computation of Partial Directed Coherence (PDC) through multivariate autoregressive models of P3-A1A2, P4-A1A2, C3-A1A2 and C4-A1A2 EEG channels showed that a decrease in the value of coherence, most likely related to the progressive loss of cognitive function and altered cerebral activity, occurs when passing from Eu to Hypo, in both theta ([4, 8] Hz) and alpha ([8, 13] Hz) bands. [J1] [C2] [C6]

The cited methods of EEG analysis are mainly linear measures, the only nonlinear measure investigated so far was sample entropy (SampEn), which was shown to be sensitive to Hypo, but is computationally demanding. So, thirdly, we investigated if changes in the complexity of the EEG signal induced by Hypo can be revealed by algorithms based on Higuchi's fractal dimension, computationally faster than SampEn. Data were obtained from the same 19 T1D patients. Fractal dimension features, describing both amplitude and frequency properties, were computed from P3-C3 EEG derivation data. Results evidenced statistically significant differences in 1-h intervals corresponding to Eu and Hypo. This result was in line with that obtainable by the SampEn indicator previously used in the literature, but the computational cost was lower ($\approx O(N)$ versus $\approx O(N^2)$) and more suited for possible frequent evaluation of EEG complexity in real-time applications. [J3]

Eventually – in collaboration with the Functional Brain Mapping Laboratory of Prof. CM Michel- because of topographical EEG changes of Hypo, which would indicate changes of brain network dynamics, have never been investigated, we tried to capture topographical potential field changes (EEG microstates) during the same insulin-induced hypoglycemia experiment, but in 29 patients with type 1 diabetes. Significant differences were found in the temporal dynamics of one microstate class (class D) in the delta, theta, alpha and beta bands between Eu and Hypo, suggesting further quantitative investigation of brain network changes. [C8] [MS3]

Moreover, in the same dataset, we investigated the influence of hypoglycemia on the results of cognitive tests, and the relationship between the drop in the tests performance and the above EEG quantitative measures, finding a correlation between the performance in the Trail Making Test B and the change in the power of theta, alpha and beta bands. [MS3]

To sum up, results of EEG methods applied both at the single EEG channel level and at multivariate level significantly change in passing from Eu to Hypo, proven that the well-known low-frequency power increase is most likely specific to a unique large-scale brain network. With regard to the possibility to exploit the EEG signal in the detection of Hypo, the accuracy achieved may seem far from ideal, but a further investigation of the potential usefulness of EEG in detecting hypoglycemia is still warranted. The benefit of EEG as a biomarker is that the hypoglycemia associated EEG changes are not blunted during hypoglycemia in patients with hypoglycemia unawareness, in contrast to the the counterregulatory hormonal response, and skin temperature changes. An EEG-based hypoglycemia detection device, however, still needs to be tested in a clinical setting.

The PhD thesis is based and focused on the above reported studies and is titled: *Quantitative analysis of hypoglycemia-induced EEG alterations in type 1 diabetes*

b. Analysis of the Local Field Potentials (LFPs) in the animal model for the study of memory formation, the somatosensory system, and the olfactory system.

The quantitative study of cross-frequency coupling (CFC) is a relevant issue in neuroscience. In local field potentials (LFPs), measured either in the cortex or in the hippocampus, how γ-oscillation amplitude is modulated by changes in θ-rhythms phase is thought to be important in memory formation. Several methods were proposed to quantify CFC, but reported evidence suggests that experimental parameters affect the results. Therefore, a simulation tool to support the determination of minimal requirements for CFC estimation in order to obtain reliable results is particularly useful. An approach to generate computer-simulated signals having CFC intensity, sweep duration, signal-to-noise ratio (SNR), and multiphasic coupling tunable by the user was developed in collaboration with the Neurochip Laboratory of Prof. Vassanelli. Its utility was proved by a study evaluating minimal sweep duration and SNR required for reliable θ–γ CFC estimation from signals simulating LFP measured in the mouse hippocampus. A MATLAB® software was made available to facilitate methodology reproducibility. The analysis of the synthetic LFPs created by the simulator showed how the minimal sweep duration for achieving accurate θ–γ CFC estimates increases as SNR decreases and the number of CFC levels to discriminate increases. [C5] [MS2]

LFPs also evoked by sensory stimulation are particularly useful in electrophysiological research. For instance, spike timing and current transmembrane current flow estimated from LFPs recorded in the barrel cortex in rats and mice are exploited to investigate how the brain represents sensory stimuli. Recent improvements in microelectrodes technology enable neuroscientists to acquire a great amount of LFPs during the same experimental session, calling for algorithms for their quantitative

automatic analysis. Several computer tools were proposed for LFP analysis, but many of them incorporate algorithms that are not open to inspection or modification/personalization. We presented a software which can be used to automatically detect some important LFP features (latency, amplitude, time-derivative value in the inflection-point) for a quantitative analysis - in collaboration with the Neurochip Laboratory. The software was developed in MATLAB and many features can be customized by the user according to his/her personal research needs. The incorporated algorithm was based on Phillips-Tikhonov regularization to deal with noise amplification due to ill-conditioning. In particular, its accuracy in the estimation of the features of interest was assessed in a Monte Carlo simulation mimicking the acquisition of LFPs in different SNR conditions. Then, the algorithm was tested by analyzing a real set of 2500 LFPs recorded in rat, after whisker stimulation, at different depths in the primary somatosensory (S1) cortex, i.e., the region involved in the cortical representation of touch in mammals. [C1] [MS1]

Eventually - in collaboration with the laboratory of Dr. Claudia Lodovichi (VIMM) - we analyzed the electrophysiological recordings from the mouse olfactory bulb. The olfactory system is an extremely sophisticated system able to recognize and discriminate thousands of different odors and in most animals, the olfactory system is critical to accomplish vital functions such as finding food, detecting predators and locating mates. But the olfactory system is an attractive model for the study of neuronal wiring and information processing not only in physiological but also in pathological conditions. The olfactory system is affected in several neurodegenerative and psychiatric disorders. In our preliminary results to understand the pathogenesis of these disorders, we found differences in the power spectra between controls and mouse models of diseases.

2.2 Seminars as invited speaker:

- "A biosensor to detect hypoglycemia? Hypoglycemia neurocognitive effects. Quantitative analysis of EEG signals in diabetes" – CIRMANMEC Seminars on scientific investigation 2016 – Alberto Maran, Maria Rubega (University of Padova, DEI, February 25, 2016)
- "Detecting hypoglycemia by using the brain as biosensor. Quantitative EEG analysis in type 1 diabetes" – Maria Rubega (Genève, Campus Biotech, June 9, 2016)

2.3 Awards

"Premio Giovani Ricercatori" (Young Researchers Price)
In the 5th National Congress of Bioengineering, June 20-22, 2016, Napoli, Italy

3. Publications

3.1 List of publications in international journals

[J1] Rubega M. Sparacino G. Sejling AS. Juhl CB. Cobelli C.
"Hypoglycemia-induced decrease of EEG coherence in Type 1 diabetic subjects"
In Diabetes Technology & Therapeutics 18 (3), 178-184, 2016. doi:10.1089/dia.2015.0347.

[J2] Rubega M. Fontana R. Vassanelli S. Sparacino G.
"A tunable local field potentials computer simulator to assess minimal requirements for phase-amplitude cross-frequency-coupling estimation"
In Network: Computation in Neural Systems, 1-21, 2016. doi: 10.1080/0954898X.2016.1213440.

3.2 List of publications accepted in international journals

[J3] Scarpa F. Rubega M. Zanon M. Finotello F. Sejling AS. Sparacino G.
"Hypoglycemia-induced EEG complexity changes in Type 1 Diabetes assessed by fractal analysis algorithm"
In Biomedical Signal Processing and Control

3.3 List of publications submitted to international journals

[MS1] Rubega M. Cecchetto C. Vassanelli S. and Sparacino G.
"Algorithm and software to automatically identify latency and amplitude features of local field potentials recorded in electrophysiological investigation"
Under review in Source Code for Biology and Medicine

[MS2] Fontana R. Agostini M. Murana E. Mahmud M. Scremin E. Rubega M. Sparacino G. Vassanelli S. and Fasolato C.
"Early hippocampal hyper-excitability in PS2APP mice: role ofmutant PS2 and APP"
Under review in Neurobiology of Aging

3.4 Lists of manuscripts in preparation

[MS3] Rubega M. Sparacino G. Sejling AS. Michel CM. Gschwind M.
"High degree of brain dysfunction during hypoglycemia in T1D patients assessed by topographical EEG"

3.5 List of publications related to international conferences

3.5.1 Conference papers

[C1] Rubega M. Cecchetto C. Vassanelli S. Sparacino G.

"Automated analysis of local field potentials evoked by mechanical whisker stimulation in rat barrel cortex"
In the proceedings of the 37th Annual International Conference of the IEEE Engineering Medicine and Biology Society (EMBC)", August 25-29, 2015, Milano, Italy, IEEE, 1520-1523, 2015

[C2] Rubega M. Sparacino G. Sejling AS. Juhl C.B. Cobelli C.
"Decrease of EEG Coherence during Hypoglycemia in Type 1 Diabetic Subjects"
In the proceedings of the 37th Annual International Conference of the IEEE Engineering Medicine and Biology Society (EMBC), August 25-29, 2015, Milano, Italia, IEEE, 2375-2378,2015

[C3] Frigo G. Rubega M. Lezziero G. Fontana R. Cecchetto C. Vassanelli S. Sparacino G. Bertocco M. "A software-based platform for multichannel electrophysiological data acquisition"
In the proceedings of the 2015 IEEE International Symposium on Medical Measurements and Applications (MeMeA), May 7-9, 2015, Torino, Italy, IEEE, 353-358, 2015

3.5.2 Abstracts

[C4] C. Fabris, M. Rubega, A.S. Sejling, J. Duun-Henriksen, L.S. Remvig, C.B. Juhl, G. Sparacino and C. Cobelli "Hypoglycemia-induced EEG changes in type 1 diabetic subjects"
In the proceedings of the 7th Advanced Technologies & Treatments for Diabetes (ATTD) Conference 2014, February 18-21, 2014, Wien, Austria, Diabetes Technology & Therapeutics 16, A66-A66, 2014

[C5] Fontana R. Rubega M. Sparacino G. Fasolato C. Vassanelli S.
"In vivo characterization of hippocampal theta and gamma spontaneous oscillations in familial Alzheimer's disease mouse models based on mutant presenilin-2"
In the proceedings of Neuroscience 2015, October 17-21, 2015, Chicago, USA

[C6] Rubega M. Sejling AS. Juhl CB. Sparacino G. Cobelli C.
"Hypoglycemia induced brain connectivity changes in type 1 diabetes assessed by Partial Directed Coherence analysis in EEG recordings"
In the proceedings of the 8th Advanced Technologies & Treatments for Diabetes (ATTD) Conference 2015, February 18-21, 2015, Paris, France, Diabetes Technology & Therapeutics 17, A29-A29, 2015

3.6 List of publications related to national conferences

3.6.1 Conference papers

[C7] M. Rubega, C. Fabris, A.S. Sejling, J. Duun-Henriksen, L.S. Remvig, C.B. Juhl, A. Goljahani, G. Sparacino and C. Cobelli "Assessment of EEG changes during hypoglycemia in type 1 diabetic subjects"

In the proceedings of the IV National Congress of Bioengineering, June 25-27, 2014 Pavia, Italy, (M-21)

[C8] Rubega M. Sparacino G. Sejling AS. Michel CM. Gschwind M.
"Altered EEG states during induced hypoglycemia in type 1 diabetes"
In the proceedings of the 5th National Congress of Bioengineering, June 20-22, 2016, Napoli, Italy, (ID-25)

Il Collegio prende atto di quanto esposto e osserva che il dott. Rubega Maria si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Tomasin Marco nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Scienza e Tecnologia dell'Informazione.
Dall'inizio del corso di dottorato ad oggi il dott. Tomasin Marco ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Scienza e Tecnologia dell'Informazione.

Il dottorando dichiara quanto segue:

Supervisore: Ch.mo Professor Paolo Villoresi

Education

Courses:

• " Physics and operation of heterostructure-based electronic and optoelectronic devices", Prof. G. Meneghesso
• "Digital Processing of Measurement Information", Prof. C. Narduzzi
• "Applied Linear Algebra", Prof. G. Picci
• " Statistical Methods", Prof. L. Finesso
• "Step 2015-2016 Seminars Towards Enterprise for Ph.D Students"

Didactics:

• "Tutor junor", Analisi matematica 1
• "Tutor junor", Fondamenti di informatica 1

Conferences:

• QCrypt 2014: 4th international conference on quantum cryptography. September 1-5, 2014 in Paris - Presentazione Poster
• AOIM: X Internation Workshop on Adaptive Optics for Industry and Medicine, 15 - 19 Giugno 2015, Padova
• Qcrypt 2016, 12 - 16 September 2016, Washington
• Iqis 2016, 19 - 23 September 2016, Roma, Poster

School:

• "Scientific School in integrated quantum photonics applications: from simulation to sensing, 4-6 July 2015, Roma, Poster

Seminars:

• "Do brain compute?", Rodolphe Sepulchre, 18 June 2015, DEI
• "Etica per una repubblica", Umberto Vincenti, 8 January 2015, DEI
• "Galileo Festival", 5-7 May 2016 Padova

Events:

• Veneto Night: La notte europea dei ricercatori, 26 September 2014, Palazzo del Bo', Padova - Presentazione delle attività del gruppo di comunicazioni quantistiche

Mobility:

• MLRO, Matera, Satellite QKD experiments, 27 April - 7 May 2015
• MLRO, Matera, Satellite QKD experiments, 24 September - 2 October 2015

Research activity

The principal topic of my PhD research has been the study of polarization and temporal degrees of freedom of the photon as a resources for quantum communications.

During the three years, the research has been focused on the construction of several experimental setups for the study of polarization and time-bin encoded photons.

During the first year, I developed an experimental setup for sharing a synchronization signal for the detection of hyper-entangled states in free space between two spatially separated users, and I have applied methods for the reconstruction of the density matrix of the state through the technique of compressed sensing.

In this setup, a pair of entangled photons is created using two degrees of freedom (DOFs), the polarization and time-bin DOFs. The first is obtained by exploiting a non-linear optical process called SPDC, while the second through a series of delays introduced by interferometers placed in the path of the photons.

To obtain a synchronization between the two stations, I have used a trigger to decimated the pulse of the laser source. To share this signal, a pulsed laser sent synchronization pulses at the remote side, while for the local part, it has been used the output of the decimator.

This method has proved to be very effective, allowing a very precise clocks synchronization. Then, I have reconstructed the state of hyper-entangled photons. Since the hyper-entangled state generated is represented by a density matrix of 256 elements, the normal tomography methods require at least 256 measurements for the reconstruction.

A more efficient method for the reconstruction of the density matrix, was designed and implemented using compressed sensing quantum tomography. The density matrix is in fact a sparse matrix, and it was possible to apply the compressed sensing technique in order to obtain a reconstruction of the matrix using a lower number of measurements.

In addition, the source of polarization entangled photons has been used to test and demonstrate an efficient method to extract true randomness from a quantum random number generator. By repeating a measurement on a quantum system and by swapping between two mutually unbiased bases, a lower bound of the achievable true randomness can be evaluated.

The second year research activity was about the study and development of a source of photons encoded in the time domain (time-bin) for the distribution of quantum bit in free space. The technique used to encode a photon in the time domain, consists of send the photon through an unbalanced Michelson interferometer. The output is a superposition of two temporal modes, one for the short path, and the second for the long path. This type of coding has been used in two different experiments, introduced below.

The first, has been conducted at the Luxor laboratories in Padua, and the goal of the experiment was to show that it is possible to violate local realism with a source of time-bin entangled photons. With this kind of source, obtain a violation of local realism, it is very difficult due to a loophole inherent the source.

To overcome this problem, one must have a very high ability to distinguish two opposite states, namely visibility. With our work, it has been possible to show that, by a good design of interferometers and measuring apparatus, it is possible to obtain a high visibility, sufficient to allow the violation of local realism.

The second experiment was conducted at the laser ranging station in Matera. The purpose of the experiment was to demonstrate that the temporal encoding is maintained in the transmission from the MEO satellite to the ground station. In this way it is shown the possibility of using temporally encoded qubits for future satellite quantum communications.

The scientific activity of the third year concerns the development of a source of photons encoded in the time domain (time-bin) for the violation of Bell's inequality, without the postselection loop-hole, improving the setup developed in the second year. In fact, in the last system the pulses entering the interferometer measurement could randomly choose their path.

At the output, the arrival times distribution does not allow to violate Bell. In fact, in order to violate the inequality it is necessary to make a postselection on data, removing those events relating to the "wrong path". The new measurement system allows to overcome this problem, however, the experimental implementation become more complicated. At the moment, the optical setup has been completed, and the work is focused on the stabilization algorithm for the interferometers.

Furthermore, an algorithm has been developed, based on the technique of compressive sensing (CS) for the reconstruction of the density matrix of a quantum state. This algorithm, when additional information are available, allows a good estimate of the density matrix with few measurements than standard CS methods. The purpose of this algorithm is to facilitate the measurement of the density matrix of quantum states of great size.

This algorithm allows a further improvement in the number of measurements required for convergence. It is based on a priori knowledge of the state that one wants to generate. This assumption may seem very strong, but when one works in a lab, he knows the experimental implementation, and then he can guess the generated state.

Thanks to this information, it is possible to derive a sequence of measurements that allows the reconstruction of a state with a very fast convergence. The simulation results show that with only 12 of 256 measures it is possible to have an estimate of the state with a fidelity equal to F = 94% on a noisy state. Experimental results show a good overlap with the simulated data.

Results and perspectives

The results obtained in these experiments are very useful in the field of quantum communications. We have shown that the polarization and temporal degrees of freedom can be used to obtain quantum states of larger dimensions, or that it is possible to violate Bell's inequality by adopting specific technique in the realization of the experimental setup. The results obtained in experiments conducted in Matera, open the way to new scenario for quantum communications.

In fact, for the first time it was observed interference of a single photon from a moving object in free-space. The experimental activity in Matera will continue exploring the single-photon

communication of satellites to higher orbits. Thanks to instrumental upgrade, it will be possible to reach greater distances with greater accuracy in data collection.

Proceedings:

• A. Dall'Arche, D. Bacco, D. Marangon, M. Tomasin, F. Gerlin, M. Canale, N. Laurenti, G. Vallone e P. Villoresi
Satellite Quantum Communications, Quantum Communications Networks – QCN 2014, 01/2014 Leeds

• G. Vallone, A. Dall'Arche, D. Bacco, D. Marangon, M. Tomasin, F. Gerlin, M. Canale, N. Laurenti e P. Villoresi
Turbulence as a resource in Quantum Communications, International Conference "Laser Optics", 07/2014 St. Petersburg

• A. Dall'Arche, D. Bacco, D. Marangon, M. Tomasin, F. Gerlin, M. Canale, N. Laurenti, G. Vallone e P. Villoresi
Quantum and Classical Resources for Free-space Quantum Communications, Advances in Foundations of Quantum Mechanics and Quantum Information with atoms and photons – Quantum 2014, 05/2014 Torino

• G. Vallone, D. Dequal, M. Tomasin, M. Schiavon, F. Vedovato, D. Bacco, S. Gaiarin, G. Bianco, V. Luceri, P. Villoresi
Satellite quantum communication towards GEO distances, Proc. SPIE 9900, Quantum Optics 99000J - 4/2016 Brussels

• *G.* Vallone, D. Dequal, M. Tomasin, M. Schiavon, F. Vedovato, V. Luceri, G. Bianco, P. Villoresi
Experimental Quantum Communications in Space exploiting temporal and polarization degrees of freedom, QCMC 2016 7/2016 Singapore

• G. Vallone, D. Dequal, M. Tomasin, M. Schiavon, F. Vedovato, V. Luceri, G. Bianco, P. Villoresi
Interference for Quantum Time-Bin States in Satellite Channels, Frontier in Optics 2016
10/2016, Rochester, New York, United States

Pubblications:

• G. Vallone, D. G. Marangon, M. Tomasin, P. Villoresi:
Quantum randomness certified by the uncertainty principle, Phys. Rev. A 90, 052327

• G. Vallone, A. Dall'Arche, M. Tomasin, P. Villoresi:

Loss tolerant device-independent quantum key distribution: a proof of principle, New Journal of Physics 16 063064

• G. Vallone, D. Dequal, M. Tomasin, F. Vedovato, M. Schiavon, V. Luceri, G. Bianco, *P. Villoresi: Interference at the Single Photon Level Along Satellite-Ground Channels,* PRL 116, 253601

In preparation:

• *Efficient compressive sensing for quantum tomography with priori information*
• *High visibility time-bin entanglement for Chained Bell inequality*

Thesis title:

• "*Quantum information with polarization and temporal degrees of freedom*", Supervisor: Paolo Villoresi

Il Collegio prende atto di quanto esposto e osserva che il dott. Tomasin Marco si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Tonietto Matteo nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Scienza e Tecnologia dell'Informazione.
Dall'inizio del corso di dottorato ad oggi il dott. Tonietto Matteo ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Scienza e Tecnologia dell'Informazione.

Il dottorando dichiara quanto segue:

FIRST PART: EDUCATION

Courses, trainings and summer school activities

- Courses – DEI
  - Applied Linear Algebra
  - Computational Inverse Problems
  - Statistical Methods
  - Bayesian Machine Learning
  - Mathematical Modeling of Cell Biology
  - Applied Machine Learning in Biomedicine

- Courses – Others
  - SPM Course - Translational Neuromodeling Unit, Institute for Biomedical Engineering, University of Zurich and ETH Zurich (Feb 2014)
  - First international training school on PET/MR engineering, COST action TD1007, Department of Biomedical engineering, TEI of Athens (May 2014)
  - Free Energy Workshop, Wellcome Trust Centre for Neuroimaging, London (Mar 2015)
  - Magnetic resonance techniques in Multiple Sclerosis – Eighteenth Advanced Course, Neuroimaging Research Unit, San Raffaele Scientific Institute and Vita - Salute San Raffaele University, Milan (Mar 2015)
  - Images of the Mind: new frontiers in brain imaging - Advanced (f)MRI statistical methods and their applications, University of Milano-Bicocca, Milan (Apr 2015)
  - Corso SPSS, Cognitive Neuroscience Center, Padova (May 2015)
  - Bayesian Statistics, School of statistics, University of Padova, Padova (Apr 2016)
  - PET Pharmacokinetics Course, Yale University, New Haven (Jul 2016)
  - Myelin regeneration and neuroprotection, ECTRIMS, London (Sep 2016)

- Seminars
  - Brain-Machine-Interfaces (BMI) in Complete Paralysis, Stroke and Neuropsychiatric Disorders, DEI, Padova (Nov 2014)
  - Conference on Statistics in Neuroimaging, Cognitive Neuroscience Center, Padova (Jan 2015)

- Computational Modeling in Cognitive Neuroscience: from Neurons to Robots, Cognitive Neuroscience Center, Padova (Apr 2015)
- La risonanza magnetica 3 tesla nell'epilessia farmacoresistente del lobo temporale, Pavia (Dec 2015)
- Neuroscience Day @ DEI, Padova (Feb 2016)
- Imaging the Normal and the Aging Brain, Museo di Storia della Medicina, Padova (Mar 2016)
- Long-range functional interactions in the resting human brain, Department of Psychology, Padova (Jun 2016)
- Computational Thinking, Inferential Thinking and Data Science, DEI, Padova (Jun 2016)
- Detecting large-scale brain networks using high-density EEG, DEI, Padova (Sept 2016)

- National and international conferences
  - Society of Nuclear Medicine and Molecular Imaging Annual Meeting, Vancouver, (Jun 2013)
  - The 10th International Symposium on Functional NeuroReceptor Mapping of the Living Brain, Amsterdam (May 2014)
  - Organization of Human Brain Mapping Annual Meeting, Hamburg (Jun 2014)
  - 2014 Joint ACTRIMS-ECTRIMS Meeting, Boston (Sept 2014)
  - International Society for Magnetic Resonance in Medicine - Italian Chapter, Verona (Apr 2015)
  - Organization of Human Brain Mapping Annual Meeting, Honolulu (Jun 2015)
  - 37th annual international conference of the IEEE Engineering in Medicine and Biology Society, Milan (Aug 2015)
  - 31st congress of the European committee for treatment and research in Multiple Sclerosis, Barcelona (Oct 2015)
  - International Society for Magnetic Resonance in Medicine - Italian Chapter, Bologna (Feb 2015)
  - The 11th International Symposium on Functional NeuroReceptor Mapping of the Living Brain, Boston (Jul 2016)
  - 32st congress of the European committee for treatment and research in Multiple Sclerosis, London (Sep 2016)

<u>Teaching activities</u>

- Tutor Junior
  - Neuroengineering, course held by Prof. Alessandra Bertoldo for the Master of Science in Bioengineering (2015)
  - Biological signal processing, course held by Prof. Gianna Maria Toffolo for the Master of Science in Bioengineering (2016)

- Other activities
    - Two lectures on brain connectivity and dynamic causal models during the Neuroengineering course held by Prof. Alessandra Bertoldo, for the Master of Science in Bioengineering (for both the 2014/2015 and 2015/2016 academic years)

SECOND PART: RESEARCH

- Description of the research during the PhD (max 2 pages) highlighting the original results achieved.

    - **Main research which will be part of the final thesis:**

    Kinetic analysis of dynamic Positron Emission Tomography (PET) images is based on a model of the tissue under analysis. The inversion of the model, and thus the estimation of physiologically meaningful parameters, requires two elements: the output of the model (i.e. the radioligand concentration in the tissue) and its input (i.e. the radioligand concentration in plasma). The first is obtained from the PET scanner, while the second is measured from blood samples taken from the subject radial artery. The main research activity consists in developing advanced models of the radioligand kinetic in plasma with the goal of deriving a continuous noise-free arterial input function. The first result was to improve the model used for radiometabolite correction by incorporating the knowledge of the injection duration in the models currently used in the literature. This was validated on three datasets made available from the National Institute of Mental Health. Then, starting from physiological assumptions, a model of the input function was developed and showed to outperform standard models for eight different radioligands coming from four different PET centers. Now the two models, one for the radiometabolite correction and one for the input function, are combined and estimated simultaneously in a unified framework which proved to be general (no tracer dependent), robust (no sensitive to initial parameters) and adaptive to the data (manual or automatic sampling).

    - **Side project 1:**

    Kinetic analysis at the voxel/pixel level of both dynamic PET and Contrast-enhanced ultrasound (CEUS) images based on non-linear models is a challenging task due to the low signal-to-noise ratio. Bayesian approaches, which incorporate prior information on the tissue kinetic, can be applied to provide robust estimates also at the voxel/pixel level. However, these methods are usually based on Monte Carlo sampling which is computationally expensive and thus inappropriate for large number of voxels/pixels. In this work an approximate Bayesian estimator, namely the Variational Bayes, was implemented and applied to both PET and CEUS kinetic analysis, resulting in precise and accurate estimation of kinetic parameters at a fraction of the time required by sampling methods.

- **Side project 2:**

  Multiple Sclerosis is primarily an inflammatory disorder of the brain in which focal lymphocytic infiltration leads to damage of myelin and axons. MRI derived measurements are vastly employed for the diagnosis and monitoring of the disease. However, conventional MRI is capable of tracking the disease progression only in part. The focus of this research project is to identify MRI biomarkers which reflect the current clinical status of the patient in order to track and possibly predict the evolution of the disease. Techniques employed span from atrophy measurements (e.g. cortical thickness), microstructure assessment (e.g. NODDI) to functional analysis (e.g. effective/dynamic connectivity).

- Definitive title of thesis
  - A unified framework for blood data modelling in dynamic Positron Emission Tomography studies

- Name of supervisor
  - Professor Alessandra Bertoldo

THIRD PART: PUBBLICATIONS

- List of publications in international journals
  - Tonietto M, Rizzo G, Veronese M, Fujita M, Zoghbi S, Zanotti-Fregonara P, and Bertoldo A. Plasma radiometabolite correction in dynamic PET studies: Insights on the available modeling approaches. J Cereb Blood Flow Metab, 36(2):326–39, feb 2016.
  - Tonietto M, Veronese M, Rizzo G, Zanotti-Fregonara P, Lohith T, Fujita M, Zoghbi S, and Bertoldo Improved models for plasma radiometabolite correction and their impact on kinetic quantification in pet studies. J Cereb Blood Flow Metab, 35:1462–1469, 2015.
  - Rizzo G, Veronese M, Tonietto M, Zanotti-Fregonara P, Turkheimer F, and Bertoldo A. Kinetic modeling without accounting for the vascular component impairs the quantification of [11C]PBR28 brain pet data. J Cereb Blood Flow Metab, 34(6):1060–1069, 2014.

- Publications list related to international conferences
  - Silvestri E, Tonietto M, Castellaro M, Calabrese M, and Bertoldo A. Head motion during resting state fmri acquisition significantly alter functional connectivity and it depends on patient disability. London, UK, 2016. 32nd congress of the European committee for treatment and research in Multiple Sclerosis - ECTRIMS 2016.
  - Tonietto M, Rizzo G, Veronese M, and Bertoldo A. A unified framework for the automatic blood data modelling in dynamic pet studies. Boston, MA, USA, 2016.

Eleventh International Symposium on Functional Neuroreceptor Mapping of the Living Brain - NRM 2016.

- Hellyer P, Barry E, Pellizzon A, Veronese M, Rizzo G, Tonietto M, Bertoldo A, and Turkheimer F. Exploring multi-scale brain functional dynamics and cerebral protein synthesis measured with L-[1-11C]leucine pet. Boston, MA, USA, 2016. Eleventh International Symposium on Functional Neuroreceptor Mapping of the Living Brain - NRM 2016.
- Rizzo G, Castellaro M, Tonietto M, Veronese M, Turkheimer F, Chappell M, and Bertoldo A. Parametric imaging of brain pet data using a variational bayesian inference approach. Boston, MA, USA, 2016. Eleventh International Symposium on Functional Neuroreceptor Mapping of the Living Brain - NRM 2016.
- Hellyer P, Barry E, Pellizzon A, Veronese M, Rizzo G, Bertoldo A, Tonietto M, and Turkheimer F. Exploring the relationship between structure, multi-scale functional dynamics and objective measurements of neural plasticity. Geneva, Switzerland, 2016. 22nd annual meeting of Organization for Human Brain Mapping - HBM 2016.
- Tonietto M, Rizzo G, Veronese M, and Bertoldo A. Modelling arterial input functions in positron emission tomography dynamic studies. Milan, Italy, 2015. 37th annual international conference of the IEEE Engineering in Medicine and Biology Society - EMBC 2015.
- Palombit A, Castellaro M, Tonietto M, Silvestri E, Calabrese M, and Bertoldo A. Comparative assessment of methods for quantitative susceptibility mapping on a clinical magnetic resonance data set. Milan, Italy, 2015. 37th annual international conference of the IEEE Engineering in Medicine and Biology Society - EMBC 2015.
- Rizzo G, Tonietto M, Zanoni S, Chappell M, Castellaro M, and Bertoldo A. Use of a Variational bayesian inference approach for the quantification of brain pet data at the voxel level. Honolulu, HI, USA, 2015. World Molecular Imaging Congress - WMIC 2015.
- Tonietto M, Mazzonetto I, Monaco S, Calabrese M, Castellaro M, and Bertoldo A. Effective and functional connectivity in the motor cortex are sensitive to disability in MS. Honolulu, HI, USA, 2015. 21st annual meeting of Organization For Human Brain Mapping - HBM 2015.
- Tonietto M, Calabrese M, Silvestri E, Morra A, Castellaro M, Monaco S, and Bertoldo A. Use of cortical thickness to detect localized damage in the somatomotor cortex in MS: relation with clinical disability. Barcellona, Spain, 2015. 31st congress of the European committee for treatment and research in Multiple Sclerosis - ECTRIMS 2015.
- Castellaro M, Palombit A, Silvestri E, Tonietto M, Gajofatto A, Montemezzi S, Magliozzi R, Howell O, Reynolds R, Monaco S, Bertoldo A, and Calabrese M. Heterogeneity of susceptibility mapping of cortical lesions in MS. Barcellona, Spain, 2015. 31st congress of the European committee for treatment and research in Multiple Sclerosis - ECTRIMS 2015.
- Rizzo G, Veronese M, Tonietto M, Zanotti-Fregonara P, Turkheimer F, and Bertoldo A. Kinetic modeling using a two-tissue compartment model and an additional

irreversible vascular component improves the quantification of [11C]PBR28 brain pet data. St. Louis, MO, USA, 2014. Annual meeting of the Society of Nuclear Medicine and Molecular Imaging - SNMMI 2014.

- Tonietto M, Rizzo G, Veronese M, Zanotti-Fregonara P, Fujita M, and Bertoldo A. Optimal metabolite curve fitting for [11C]PBR28. Amsterdam, Netherlands, 2014. Tenth International Symposium on Functional Neuroreceptor Mapping of the Living Brain - NRM 2014.
- Rizzo G, Veronese M, Tonietto M, Zanotti-Fregonara P, Turkheimer F, and Bertoldo A. A new modelling approach for quantification of [11C]PBR28 brain pet data including a vascular component. Amsterdam, Netherlands, 2014. Tenth International Symposium on Functional Neuroreceptor Mapping of the Living Brain - NRM 2014.
- Tonietto M, Calabrese M, Mazzonetto I, Castellaro M, Monaco S, and Bertoldo A. Effective connectivity of the default mode network in ms patients: increased self-inhibition of the posterior cingulate cortex. Boston, MA, USA, 2014. Joint congress of the Americas and European Committee for Treatment and Research in Multiple Sclerosis - ACTRIMS-ECTRIMS 2014.
- Tonietto M, Rizzo G, Veronese M, Zanotti-Fregonara P, Lohith T, Fujita M, Zoghbi S, Innis R, and Bertoldo A. Plasma metabolite correction: Improvements of current parent plasma models. Vancouver, Canada, 2013. Annual meeting of the Society of Nuclear Medicine and Molecular Imaging - SNMMI 2013.
- Tonietto M, Veronese M, Rizzo G, Zanotti-Fregonara P, Lohith T, Fujita M, Zoghbi S, Innis R, and Bertoldo A. Effect of input function modeling on kinetic quantification. Vancouver, Canada, 2013. Annual meeting of the Society of Nuclear Medicine and Molecular Imaging - SNMMI 2013.

Il Collegio prende atto di quanto esposto e osserva che il dott. Tonietto Matteo si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Vettoretti Martina nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Bioingegneria.
Dall'inizio del corso di dottorato ad oggi il dott. Vettoretti Martina ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Bioingegneria**.**

Il dottorando dichiara quanto segue:

1. Education

1.1 Courses organized within the department for PhD students

- Tissue Engineering: Principles and Applications
- Computational Inverse Problems
- Digital Processing of Measurement Information
- Statistical Methods
- Mathematical Modeling of Cell Biology
- Bayesian Machine Learning

1.2 Schools

- 33rd Annual Summer School of the Italian National Bioengineering Group, "La Bioingegneria: dal recupero funzionale all'organo artificiale", Bressanone, September 22-25, 2014
- 9th IEEE-EMBS International Summer School, "Signal Processing and Modelling in Neuroengineering: Enabling Technologies for Rehabilitation", Pavia, August 30 - September 6, 2015

1.3 Workshops

- "Brain-Machine Interface", Padova, Centro Congressi, July 15, 2014.
- "Regulatory Science Considerations for Software Used in Diabetes Management", FDA White Oak Campus**,** Silver Spring (MD), November 13, 2014 (via webcast)
- "Neuroscience Day @DEI", Padova, DEI, February 2, 2016
- "Food and Drug Administration Clinical Chemistry and Clinical Toxicology Devices Advisory Panel meeting on the Dexcom G5 Mobile Continuous Glucose Monitoring System", Gaithersburg (MD), June 21, 2016

1.4 Seminars

- Simona Rombo, "Biological Network Analysis", Padova, DEI, March 11, 2014
- Junichi Ushiba, "Brain-Computer Interface and Motor Learning in Stroke Rehabilitation", Padova, DEI, May 16, 2014
- Marco Battiston, "Quantitative Magnetic Resonance Imaging of the Spinal Cord: basic concepts and applications", Padova, DEI, September 16, 2014Del Testa

- Angelo Avogaro, Daniela Bruttomesso, Chiara Dalla Man, Giovanni Sparacino, and Riccardo Pietrabissa, "L'Ingegneria del corpo", Padova, DEI, October 20, 2014
- Luigi Colangeli, "Rosetta rendez-vous with the 67P/Churyumov-Gerasimenko comet", Padova, DEI, November 27, 2014
- Lorenzo Rosasco, "Learning with Computational Regularization", Padova, DEI, March 27, 2015
- Rodolphe Sepulchre, "Do brains compute?", Padova, DEI, June 18, 2015.
- Alberto Maran and Maria Rubega, "Correlati neuro cognitivi dell'ipoglicemia. Analisi quantitativa real-time del tracciato EEG nel diabetico: un sensore per l'ipoglicemia?", Padova, DEI, February 25, 2016

1.5 International conferences

- 8th International Conference on Advanced Technologies & Treatments for Diabetes (ATTD), Paris, February 18-21, 2015 (poster of [C3][C4])
- 37th Annual International Conference of the IEEE Engineering Medicine and Biology Society (EMBC), Milan, August 25-29, 2015 (oral presentation of [C1][C2])
- 15th Annual Diabetes Technology Meeting (DTM), October 22-24, 2015 (poster of [C6][C7])
- 9th International Conference on Advanced Technologies & Treatments for Diabetes (ATTD), Milan, February 3-6, 2016 (poster of [C8])

1.6 National conferences

- 4th Congress of the Italian National Bioengineering Group, Pavia, June 25-27, 2014 (poster of [NC1])
- 5th Congress of the Italian National Bioengineering Group, Napoli, June 20-22, 2016 (poster of [NC2])

1.7 Teaching activities (as Tutor Junior)

- Providing support and one-to-one assistance in MATLAB laboratories for the classes of:
  - Medical Informatics 14/15, Padova, DEI (20 hours, October 2014 – January 2015)
  - Analysis of Biological Data 14/15, Padova, DEI (10 hours, October 2014 – January 2015)
  - Biological Signal Processing 14/15, Padova, DEI (30 hours, March 2015 – June 2016)
  - Analysis of Biological Data 15/16, Padova, DEI (16 hours, October 2015 – January 2016)
- Frontal lectures on MATLAB algorithms for Medical Informatics 14/15, Padova, DEI (4 hours, October 2014 – January 2015) and Medical Informatics 15/16, Padova, DEI (4 hours, October 2015 – January 2016).
- Correlator activity for the master thesis:
  - "Smart calibration of continuous glucose monitoring sensors for diabetes management: Bayesian approach and validation" by Giada Acciaroli
  - "Continuous glucose monitoring based algorithms for basal insulin modulation in type 1 diabetes" by Lorenzo Meneghetti

– "Insulin bolus parameters optimization in type 1 diabetes using continuous glucose monitoring: An in silico framework" by Giacomo Cappon

1.8 Mobility actions

- July 6-13, 2014: Visit to Dexcom, Inc. (San Diego, CA) to work on signal processing algorithms within a collaboration project with University of Padova
- April 20 - May 12, 2016: Visit to Dexcom, Inc. (San Diego, CA) to work on decision-making simulation techniques within a collaboration project with University of Padova

2. Research

The research activities carried out in this three-year PhD programme are related to two major research projects. The first concerns the development of algorithms for the online calibration of continuous glucose monitoring (CGM) sensors, i.e. the process by which the current signal measured by CGM sensors in the subcutis is transformed to a glucose concentration signal. In this PhD programme, a new calibration method was developed that fits CGM current signal against the BG references collected twice a day for calibration purposes, by a time-varying calibration function, whose parameters are identified in a Bayesian framework using a priori 2nd order statistical knowledge [J1][C3][NC1]. Before parameter identification, the method compensates the distortion introduced by plasma-interstitium kinetics via non-parametric deconvolution.

This Bayesian calibration method was tested in a database of 108 CGM signals collected by the Dexcom G4 Platinum. Results show that, compared to the manufacturer calibration, the new method drives to a statistically significant accuracy improvement as measured by three commonly used metrics: mean absolute relative difference (MARD) reduced from 12.73% to 11.47%; percentage of accurate glucose estimates increased from 82.00% to 89.19%; percentage of values falling in the "A" zone of the Clark Error Grid increased from 82.22% to 88.86% [J1]. In a database of 57 CGM signals collected by the Dexcom G4 Platinum sensor, the Bayesian calibration algorithm was tested with only one calibration per day [J2][C9]. Results show that the one-per-day Bayesian calibration drives to accuracy performance similar to the two-per-day Bayesian calibration (11.8% vs 11.7% MARD, respectively) and statistically significantly better of the manufacturer calibration (13.1% MARD) [J2]. The proposed Bayesian calibration algorithms is thus effective in improving the accuracy of CGM sensors and importantly allow to halve the number of BG references required for calibration per day without deteriorating sensor performance.

The second research project concerns the development of a simulation approach suitable for the design in silico clinical trials (ISCT) assessing the safety and effectiveness of type 1 diabetes (T1D) insulin treatment scenarios. The method recently proposed by Patek et al. to "replay" in silico real-life treatment scenarios was investigated. The method of Patek et al., despite some promising ideas, presents several critical aspects that make unclear its domain of validity. The method was thus tested, by using the UVA/Padova T1D simulator, on real-life therapy scenarios like adjustment of basal insulin and insulin boluses and addition of new insulin boluses and hypotreatments [J3]. Results showed that this method well predicts the effect of small basal insulin adjustments but significantly over/underestimates glycemic outcomes in the other scenarios. This suggests that the domain of validity of the method by Patek et al. is limited to small adjustments of basal insulin, while more sophisticated techniques need to be developed to assess other treatment scenarios.

An alternate approach has been proposed in this PhD programme, based on the development of the T1D decision-making (T1D-DM) model, i.e. a mathematical model of T1D patients making treatment decisions based on measurements collected by glucose monitoring devices [MS2][C2][C6][P1]. Such a model can be used to design and test T1D insulin treatment scenarios in ISCTs. The model is constructed by connecting in a feedback scheme four components: A) the UVA/Padova T1D simulator, B) a model of glucose monitoring devices, C) a model of patient's behavior and treatment decisions and C) a model of the insulin pump. While A) and D) were previously designed by the bioengineering research group of University of Padova in collaboration with University of Virginia, B) and D) were developed in this PhD programme.

The glucose monitoring device model simulates measurements collected by both traditional self-monitoring of blood glucose (SMBG) and CGM sensor by using measurement error models. The model of SMBG measurement error was derived by a new method designed in this PhD programme [MS1][C4][C1]. The method consists in first dividing the glucose range into zones where either absolute or relative error presents a constant standard deviation, and then fitting in each zone a probability density function model to error data by maximum-likelihood. This method was tested on two data sets collected by the One Touch Ultra 2 and the Bayer Contour Next USB devices. The resulting models were validated by goodness-of-fit tests and showed better performance than simpler models previously used in the literature. The model of CGM measurement error was derived from data collected by the Dexcom G5 Mobile system, by applying a methodology recently published by Facchinetti et al., which takes into account three components of the sensor error: the distortion introduced by plasma-interstitium kinetics, the calibration error and the sensor noise.

The patient's behavior and treatment decision model simulates the patient's behavior in making therapeutic decisions, such as administration of insulin boluses and hypotreatments, based on either SMBG measurements, CGM measurements (CGM nonadjunctive use) or a combination of SMBG and CGM in which CGM information is used to trigger SMBG measurements which are finally used to make the treatment decisions (CGM adjunctive use). In order to reproduce a real-life scenario, components describing the mistakes real subjects commonly make, such as miscalculation of meal CHO content and early/delayed insulin administrations, were included in the model. The parameters characterizing the patient's behavior and treatment decision model were derived from literature studies.

The T1D-DM model can be used for several experiments. In this PhD programme the model was applied to assess safety and effectiveness of CGM nonadjunctive use [MS2][C2][C7][C8][NC2] i.e. the use of CGM measurements to make treatment decisions without requiring confirmatory SMBG measurements. This topic is currently of great interest for the diabetes research community because US regulatory agencies, like the Food and Drug Administration, are requiring clinical evidence of CGM nonadjunctive use in order to determine if CGM sensors can be approved for nonadjunctive use. In particular, two main ISCTs based on the T1D-DM model were designed in this PhD programme to assess safety and effectiveness of CGM nonadjunctive use.

In the first trial, nonadjunctive CGM was compared to SMBG and adjunctive CGM over a two-week period in a population of 100 adult virtual subjects reflecting the characteristics of a general population of T1D subjects [MS2]. Glycemic outcomes like time in hypo/hyperglycemia were evaluated for the three treatments. Results showed that the use of CGM (both adjunctive and nonadjunctive) significantly improves glycemic outcomes compared to SMBG. No significant change in the outcomes was observed between adjunctive and nonadjunctive CGM. This suggests that nonadjunctive CGM is as safe as adjunctive CGM, and thus CGM is ready to substitute SMBG for T1D treatment. Results of this first trial were presented at the Food and Drug Administration Clinical Chemistry and Clinical Toxicology Devices

Advisory Panel meeting of June 21st, 2016 to support the regulatory approval of the Dexcom G5 Mobile CGM system for nonadjunctive use. A positive feedback came from the panel that voted 8/10 in favor of the approval of Dexcom G5 Mobile for nonadjunctive use.

In the second trial the impact of CGM alerts on the performance of nonadjunctive CGM was assessed. In particular, 100 virtual subjects were assigned to 21 representative combinations of CGM high and low alert thresholds. For each alert setting, the glycemic outcomes of nonadjunctive CGM were compared to those of SMBG, to understand for which alert settings nonadjunctive CGM introduces additional risks of hypo/hyperglycemia compared to SMBG. Results demonstrated that while time in hypoglycemia is reduced by CGM nonadjunctive use with any alert setting, time in hyperglycemia is significantly worsen by CGM nonadjunctive use, compared to SMBG, when the high alert threshold is set to 350 mg/dl or higher, regardless of the low alert threshold.

The research activity of this PhD programme was carried out under the supervision of Prof. Giovanni Sparacino. At closure of the PhD programme, a PhD thesis on the development of the T1D-DM model and its applications was composed with title: "Type 1 diabetes patient decision-making modeling for the in silico assessment of insulin treatment scenarios".

3. Publications

3.1 Publications in international journals

[J1] Vettoretti M., Facchinetti A., Del Favero S., Sparacino G. and Cobelli C., "On-line Calibration of Glucose Sensors from the Measured Current by a Time-Varying Calibration Function and Bayesian Priors", IEEE Transactions on Biomedical Engineering, vol. 63, no. 8, pp. 1631-1641, Aug 2016

[J2] Acciaroli G., Vettoretti M., Facchinetti A., Sparacino G. and Cobelli C., "From Two to One per Day Calibration of Dexcom G4 Platinum by a Time-Varying Day-Specific Bayesian Prior", Diabetes Technology & Therapeutics, vol. 18, no. 8, pp. 472-479, Aug 2016

[J3] Vettoretti M., Facchinetti A., Sparacino G., Cobelli C., "Predicting Insulin Treatment Scenarios with the Net Effect Method: Domain of Validity", accepted for publication in Diabetes Technology & Therapeutics, 2016

3.2 Manuscripts submitted to international journals

[MS1] Vettoretti M., Facchinetti A., Sparacino G., Cobelli C., "A Model of the Self-Monitoring of Blood Glucose Measurement Error", submitted to Journal of Diabetes Science and Technology

3.3 Manuscripts in preparation

[MS2] Vettoretti M., Facchinetti A., Sparacino G., Cobelli C., "Model of Type 1 Diabetic Patient Decision-Making for In Silico Assessment of Insulin Treatment Scenarios", to submit to IEEE Transactions on Biomedical Engineering

3.4 Publications in international conferences

3.4.1 Conference papers

[C1] Vettoretti M., Facchinetti A., Sparacino G., Cobelli C., "Accuracy of Devices for Self-Monitoring of Blood Glucose: A Stochastic Error Model", Conference Proceedings

of the 37th Annual International Conference of IEEE Engineering Medicine and Biology Society (EMBS), Milano, August 25-29, 2015, pp. 2359-2362

[C2] Vettoretti M., Facchinetti A., Sparacino G., Cobelli C., "Patient Decision-Making of CGM Sensor Driven Insulin Therapies in Type 1 Diabetes: In Silico Assessment", Conference Proceedings of the 37th Annual International Conference of IEEE Engineering Medicine and Biology Society (EMBS), Milano, August 25-29, 2015, pp. 2363-2366

3.4.2 Abstract

[C3] Vettoretti M., Facchinetti A., Del Favero S., Sparacino G., Cobelli C., "Calibration of Glucose Sensors: Use of a Time-Varying Calibration Function and Bayesian Priors", 8th International Conference on Advanced Technologies & Treatments for Diabetes (ATTD), Paris, February 18-21, 2015

[C4] Vettoretti M., Facchinetti A., Sparacino G., Cobelli C., "A Stochastic Model of Self-Monitoring of Blood Glucose Measurement Error: Toward a Simulator of Diabetic Patient Therapeutic Decisions", 8th International Conference on Advanced Technologies & Treatments for Diabetes (ATTD), Paris, February 18-21, 2015

[C5] Acciarioli G., Vettoretti M., Facchinetti A., Sparacino G., Cobelli C., "Glucose Sensors for Diabetes Management: No Need of 24h Warm-Up Time by Use of Bayes Estimation", 37th Annual International Conference of the IEEE Engineering Medicine and Biology Society (EMBC), Milano, August 25-29, 2015

[C6] Vettoretti M., Facchinetti A., Sparacino G., Cobelli C., "Simulation of Patient Decision-Making to Test Safety and Effectiveness of CGM Sensor for Non-Adjunctive Use in Type 1 Diabetes. I. A Patient Modular System Model", 15th Annual Diabetes Technology Meeting (DTM), Bethesda (MD), October 22-24, 2015

[C7] Vettoretti M., Facchinetti A., Sparacino G., Cobelli C., "Simulation of Patient Decision-Making to Test Safety and Effectiveness of CGM Sensor for Non-Adjunctive Use in Type 1 Diabetes. II. SMBG- vs CGM-Based Therapies", 15th Annual Diabetes Technology Meeting (DTM), Bethesda (MD), October 22-24, 2015

[C8] Vettoretti M., Facchinetti A., Sparacino G., Cobelli C., "Non-Adjunctive Use of CGM in T1D Therapy: In Silico Assessment of Using Glucose Trend Information for Insulin Dosing", 9th International Conference on Advanced Technologies & Treatments for Diabetes (ATTD), Milano, February 3-6, 2016

[C9] Acciarioli G., Vettoretti M., Facchinetti A., Sparacino G., Cobelli C., "Calibrations of Dexcom G4 Platinum Reduced to One per Day by a Time-Varying Day-Specific Bayesian Prior", 9th International Conference on Advanced Technologies & Treatments for Diabetes (ATTD), Milano, February 3-6, 2016

[C10] Visentin R., Vettoretti M., Facchinetti A., Dalla Man C., Sparacino G., Cobelli C., "Incorporation of the Sensor-Augmented Insulin-Pump Therapy into the UVA/Padova Type 1 Diabetes Simulator", 9th International Conference on Advanced Technologies & Treatments for Diabetes (ATTD), Milano, February 3-6, 2016

[C11] Leal Y., Gonzalez-Abril L., Visentin R., Del Favero S., Vettoretti M., Facchinetti A., Sparacino G., Cobelli C., "Support Vector Regression for Mid-Term Nocturnal Glucose Prediction from Continuous Glucose Monitoring and Insulin Delivery Information", 9th International Conference on Advanced Technologies & Treatments for Diabetes (ATTD), Milano, February 3-6, 2016

[C12] Acciaroli G., Vettoretti M., Facchinetti A., Sparacino G. and Cobelli C., "Reduced Calibrations and Maintained Accuracy on Next Generation CGM Compared to Dexcom G5: A Bayesian Approach", accepted for publication at the 16th Annual Diabetes Technology Meeting (DTM), Bethesda (MD), November 10-12, 2016

3.5 Publications related to national conferences

3.5.1 Conference papers

[NC1] Vettoretti M., Facchinetti A., Del Favero S., Sparacino G., and Cobelli C., "An on-line calibration method to improve accuracy of subcutaneous continuous glucose monitoring sensors", Conference Proceedings of the 4th Congress of the Italian National Bioengineering Group, Pavia, June 25-27, 2014

[NC2] Vettoretti M., Facchinetti A., Del Favero S., Sparacino G., and Cobelli C., "Assessing minimum continuous glucose monitoring sensor accuracy needed for non-adjunctive use", Conference Proceedings of the 5th Congress of the Italian National Bioengineering Group, Napoli, June 20-22, 2016

[NC3] Acciaroli G., Vettoretti M., Facchinetti A., Del Favero S., Sparacino G., and Cobelli C., "Smart calibration of Continuous Glucose Monitoring sensors: utility of Bayes estimation", Conference Proceedings of the 5th Congress of the Italian National Bioengineering Group, Napoli, June 20-22, 2016

[NC4] Cappon G., Vettoretti M., Facchinetti A., Del Favero S., Sparacino G., and Cobelli C., "Simulation Framework to Optimize Parameters of Open-Loop Insulin Therapy in Type 1 Diabetes Patients", Conference Proceedings of the 5th Congress of the Italian National Bioengineering Group, Napoli, June 20-22, 2016

3.6 Patents

[P1] Vettoretti M., Facchinetti A., Sparacino G., Cobelli C., "Individualized Multiple-Day Simulation Model of Type 1 Diabetic Patient Decision-Making for Developing, Testing and Optimizing Insulin Therapies Driven by Glucose Sensors", US Provisional Patent Application with serial number 62/163,091 (intellectual property transferred to Dexcom Inc.).

Il Collegio prende atto di quanto esposto e osserva che il dott. Vettoretti Martina si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

Presentazione sull'attività svolta da Carson Wigdahl Jeffrey nell'ambito del XXIX ciclo, Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, Indirizzo Bioingegneria.
Dall'inizio del corso di dottorato ad oggi il dott. Carson Wigdahl Jeffrey ha frequentato presso il Dipartimento di Ingegneria dell'Informazione dell'Università di Padova il Corso di Dottorato di Ricerca in Ingegneria dell'Informazione, XXIX ciclo, Indirizzo Bioingegneria**.**

Il dottorando dichiara quanto segue:

FIRST PART: EDUCATION

Courses, trainings and summer school activities

- Applied Linear Algebra
- Statistical Methods
- MISS 2014 (Medical Imaging Summer School)
- REVAMMAD Marie Curie ITN Research Training Program

Teaching activities

- Taught an image processing class in 2014, 2015 focused on retinal image analysis, within the "Bioimages" course held by Prof. Maria Pia Saccomani .
- Gave a talk on detecting new vessels on the optic disc as a seminar for the Marie Curie Training network.

Conferences

- *IEEE International Conference on Engineering in Medicine and Biology (EMBC)*. Aug. 26-30th 2014, Chicago, Illinois, USA; Aug. 25-29th 2015, Milan, Italy; Aug. 16-20th 2016, Orlando, Florida USA.
- *International Conference for the Association for Research in Vision and Ophthalmology (ARVO).* May 4-8th 2014, Orlando, Florida, USA; May 3-7th 2015, Denver, Colorado, USA; May 1-5th 2016, Seattle, Washington, USA.

Mobility actions

- Spent 3 months (April 2015 – June 2015) at University of Dundee under the supervision of Prof. Emanuele Trucco.

Stage

SECOND PART: RESEARCH

1. **Retinal vessel tortuosity**. It can be an early indicator in diseases such as diabetes and hypertension as well as an important feature for determining the presence of plus disease in retinopathy of prematurity. We propose a new method for enhancing curvature as a feature for calculating tortuosity, based on a difference of Gabor filters, which can be used in a retinal image, segmented vessel, or vessel skeleton. The difference in Gabor filters comes from the aspect ratio used in the Gaussian envelope: elongated envelopes will have different responses at curvature points along the vessel compared to rounder envelopes, when other factors are normalized. The difference between the two responses on a vessel give higher responses at regions of curvature. This allows for the tuning of these filters to detect the wavelength of curves, thought to be important to a clinician making a tortuosity assessment. The curvature-enhanced image can be combined with the typical mathematical calculations for tortuosity, to provide a tortuosity score that can be optimized based on the grader. The proposed method was tested on the RET-TORT database using several methods to calculate tortuosity, and had a Pearson's correlation coefficient of .91 for arteries and .82 for veins. However, since we allow for the customization of the filter banks, using different parameters for arteries and for veins yielded the best results of .94 and .88 correlation coefficients respectively, outperforming the best rigid methods for tortuosity estimation.
2. **Retinal vessel tortuosity**. Tortuosity in retinal images can be used as a biomarker in the detection of several systemic diseases, including diabetes and hypertension. Many algorithms have been proposed to mathematically describe these curves and correlate the values back to the human grader perception of tortuosity. This perception represents a sliding scale that can effect algorithmic performance when introduced with a new dataset and/or graders. This work presents the comparison of popular automatic methods for calculating tortuosity and a new combination method on a new set of 50 vessels, graded on a scale of 0-2 by two independent graders. This data is part of a larger dataset that includes multiple graded vessels and image level tortuosity grading in a set of 74 images. Results show that several methods have good Co-hen's kappa agreement with both graders, while the tortuosity density metric has the highest single metric average agreement across vessel type and grader. Results broadly confirm those of a previous studies obtained under ideal sampling conditions on the core set of algorithms.
3. **Detection of Gunn's and Salus's sign in retinal images.** Prolonged hypertension can lead to abnormal changes in the retinal vasculature, including sclerosis and thickening of the arteriole walls. These changes can cause compression (Gunn's sign) and deflection (Salus's sign) of the veins at arteriovenous crossings. In retinal images, Gunn's sign appears as a tapering of the vein at a crossing point, while Salus's sign presents as an S-shaped curving. I developed a method for the automatic quantification of these two signs once a crossover has been detected; combining segmentation, artery vein classification, and morphological feature extraction techniques to calculate vein widths and angles entering and exiting the crossover. The method was tested on a small set of crossings, graded by a set of 3 doctors who were in agreement as having or not having Gunn/Salus sign. Results show separation

between the two classes and that we can reliably detect and quantify these sign under the right conditions.

4. **Detection of optic disc in retinal images**. The purpose of this research is to develop and evaluate a new algorithm to detect the optic disc in retinal fundus images. Optic disc detection is an important first step in many automated algorithms, either for the disc to be masked out of future processing or for the use in optic disc related disease, such as glaucoma and papilledema. I propose a new method for optic disc detection that converts the retinal image into a graph and exploits vessel enhancement methods to calculate edge weights in finding the shortest path between pairs of points on the periphery of the image. The line segment with the maximum number of shortest paths is considered the optic disc location, with refinement from a combination template matching approach in the found region. The method was tested on three publicly available datasets: DRIVE, DIARETDB1, and Messidor consisting of 40, 89, and 1200 images respectively. All images were acquired at a 45°-50° field of view. The method achieves an accuracy of 100, 98.88, and 99.42% on the DRIVE, DIARETDB1, and Messidor databases respectively. The method on these datasets performs as well as or better than state-of-the-art methods. Processing takes an average of 32 seconds (+-1.2) to detect the optic disc, with 26 of those seconds used for the vessel enhancement process. The accuracy over a wide variety of images shows that the method is robust and would be optimal for retinal analysis systems that perform vessel enhancement as part of their processing.
5. **Microdot detection in corneal images**. Microdots are bright, 1-2µm long features of the cornea. It has not been proven what these dots represent, but they are thought to be remnants of apoptotic cell death, such as lipofuscin granules. Their presence has been shown to correlate with corneal aging and extended contact use, both of which are linked to oxygen deprivation in the cornea. Confocal images of the stroma show these microdots mixed with larger keratocyte cells. This paper presents a method for detecting microdots using a two-step filtering scheme that separates the keratocyte cells and the microdots. The first filter treats the microdots as noise, and uses a median filter to remove the points, leaving just the larger cells. A LoG filter is then used to enhance the smaller circular microdots. Keratocyte cell locations are then used to eliminate falsely detected microdots. Results are compared to ground truth based on a grading scale from 0-5. Two graders were given a set of 50 images to grade using a GUI that included sample images for each of the six grades. The two graders had a correlation coefficient of .88 with each other. The algorithm had a correlation coefficient of .88 with the average of graders and .85 with each of the graders individually.
6. **Semi-automatic tool for the complete analysis of the retinal vasculature**. This tool will allow clinicians and researchers to obtain a quantitative assessment of clinical vessel parameters, provide a framework to test new automatic algorithms, and have the ability to edit results at several steps in process. The application combines automatic algorithms for vessel segmentation, optic disc detection, and Artery/Vein classification, with the ability to edit vessel segments, for the calculation of common clinical vessel parameters (tortuosity, artery/vein ratio (AVR), fractal dimension, AV nicking). After vessel segmentation, the user can edit vessel segments (add new, remove, combine, split). Vessel widths, tortuosity

metrics, and fractal dimension are calculated. Optic disc center and radius are found and can be manually adjusted. Artery/Vein classification is performed in an area between 1 and 2 disc diameters from the optic disc. The user has the ability to edit, add/remove vessels, and change vessel widths before automatic AV classification. The user can edit results again before AV ratio, central retinal vein equivalent, and central retinal artery equivalent calculation. Finally, vessel crossover points are analyzed to detect narrowing and angle in/out. Vessel widths can be edited prior to calculation. All clinical parameters are computed using our previously developed methods. Tortuosity is measured per segment and combined to give a whole image tortuosity. The set of 45 images used to test the system are from the High Resolution Fundus (HRF) image database provided by Friedrich-Alexander University Erlangen-Nuremberg. Images are 2336x3504 pixels covering a 50 degree field of view. This system provides a framework for the quantitative analysis of the retinal vasculature with the intention of making the automatic portions interchangeable, for the testing of new algorithms, while maintaining editing functions, to ensure the highest quality results. Speed, ease of use, and clinical effectiveness were the main criteria in system development.

Thesis: Retinal Vascular Measurement Framework for Diagnostic Feature Extraction
Supervisor: Alfredo Ruggeri

THIRD PART: PUBLICATIONS

Journal Papers (Published / Submitted)

1. **Wigdahl**, J., Guimaraes, P., Ruggeri, A., A Shortest Path Approach to Optic Disc Detection in Retinal Fundus Images, Journal of Modelling in Ophthalmology, Vol. 2 2016 (Pending)
2. Guimaraes P, **Wigdahl J**, Ruggeri A. A Fast and Efficient Technique for the Automatic Tracing of Corneal Nerves in Confocal Microscopy. Trans Vis Sci Tech. 2015; 5(5):7, http://tvstjournal.org/doi/full/ 10.1167/tvst.5.5.7, doi:10.1167/tvst. 5.5.7

Conference Papers (Published / Accepted)

1. **Wigdahl, J**., Guimarães, P., Poletti, E., Ruggeri, A., CANE (CORNEAL NERVE EDITOR): A User-Friendly Unified Computerized System for Recognizing, Editing and Analyzing Corneal Sub-Basal Nerves Images, ARVO 2014 (Poster)
2. Guimarães, P. **Wigdahl, J**., Poletti, E., Ruggeri, A., A fully-automatic fast technique to trace sub-basal layer nerves in corneal images, ARVO 2014 (Poster)
3. **Wigdahl**, J., Guimaraes, P., Poletti, E., Ruggeri, A., Automatic detection of microdots in the stromal layer of corneal images, Proc. 36th Annual International Conference of IEEE-EMBS, pp. 210-3, IEEE, Chicago, 2014
4. Guimarães, P. **Wigdahl, J**., Poletti, E., Ruggeri, A., A fully-automatic fast segmentation of the sub-basal layer nerves in corneal images, Proc. 36th Annual International Conference of IEEE-EMBS, pp. 5422-5, IEEE, Chicago, 2014.

5. Poletti, E., **Wigdahl**, J., Guimaraes, P., Ruggeri, A., Automatic Montaging of Corneal Sub-Basal Nerve Images for the Composition of a Wide-Range Mosaic, Proc. 36th Annual International Conference of IEEE-EMBS, pp. 5426-9, IEEE, Chicago, 2014.
6. **Wigdahl**, J., Guimaraes, P., Poletti, E., Ruggeri, A., ReVMS (Retinal Vessel Measurement System), ARVO 2015 (Poster)
7. Guimaraes P, Frizziero, L., **Wigdahl J**, Midena, E., Ruggeri A., Fully-automatic Segmentation of Conjunctival Blood Vessels, ARVO 2015 (Poster)
8. Leontidis, G., Al-Diri, B., **Wigdahl,** J., Hunter, A., Evaluation of geometric features as biomarkers of diabetic retinopathy for characterizing the retinal vascular changes during the progression of diabetes, Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS, 2015.
9. **Wigdahl, J**., Guimaraes, P., Leontidis, G., Triantafyllou, A., Ruggeri, A., Automatic Gunn and Salus sign quantification in retinal images, Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS, 2015.
10. Guimarães, P., Xiang, W., **Wigdahl**, J., Reglin, B., Pries, A., Ruggeri, A., Measuring blood flow velocity from intravital video recordings, Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS, 2015.
11. Leontidis, G., **Wigdahl, J.,** Al-Diri, B., Ruggeri, A., Hunter, A., Evaluating Tortuosity in Retinal Fundus Images of Diabetic Patients Who Progressed to Diabetic Retinopathy, Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS, 2015.
12. **Wigdahl, J**., Annunziata, R., Hughes, L., Borooah, S., Trucco, E., Ruggeri, A., Retinal Image Database for Tortuosity Estimation, ARVO 2016 (Poster)
13. **Wigdahl**, J., Guimaraes, P., Ruggeri, A., Difference of Gabor Filters as a Curvature Feature in Tortuosity Estimation, Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS, 2016.
14. Guimaraes P, **Wigdahl J**, Ruggeri A., Automatic Estimation of Corneal Nerves Focused Tortuosities, Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS, 2016.
15. Crespo-Garcia, S., Kociak, N., Skosyrski, S., **Wigdahl, J**., Reichart, C., Roubelx, C., Brunken, W.J., Koch, M., Strauss, O., Joussen, A.M., Angiogenic Role of Netrin-4 in the Retina, International Society for Eye Research, Tokyo, Japan 2016 (Poster)

Il Collegio prende atto di quanto esposto e osserva che il dott. Carson Wigdahl Jeffrey si è impegnato con dedizione e profitto nella sua attività di ricerca e di studio, evidenziando un'ottima capacità di lavorare sia in maniera autonoma che all'interno di un gruppo di ricerca. Il Collegio unanime riconosce la notevole assiduità del candidato, le sue ottime capacità nella ricerca e gli originali risultati conseguiti. **Pertanto il collegio lo ammette alla valutazione della tesi da parte dei valutatori.**

6. Elenco valutatori tesi dottorandi 29^ ciclo

Abbas Waqas Bin
1) Paolo Casari, IMDEA, Spagna
2) Sundeep Rangan, NYU Wireless, USA
S) Roberto Verdone, Università di Bologna

Baruzzo Giacomo
1) Marco Chierici, Fondazione Bruno Kessler, Trento, Italia
2) Elisabetta Manduchi, University of Pennsylvania, Philadelphia, USA
S) Hubert Hackl, Biocenter Innsbruck Medical University, Austria

Biral Andrea
1) Simon Pietro Romano, Università di Napoli
2) Ilenia Tinnirello, Università di Palermo
S) Francesco Gringoli, Università di Brescia

Caparra Gianluca
1) Christina Poepper New York University Abu Dhabi
2) James T. Curran European Space Agency
S) Daniele Borio European Commission

Carson Wigdahl Jeffrey
1) Xenophon Zabulis, Institute of Computer Science, Heraklion, Crete, Greece
2) Alauddin Bhuiyan, NYU School of Medicine, New York University, USA
S) Emanuele Trucco, University of Dundee, Scotland, UK

Ceccarello Matteo
1) Tiziana Calamoneri, Università di Roma "La Sapienza"
2) Mauro Sozio, INFRES, France
S) Roberto Grossi, Università di Pisa

Celin Alberto
1) Pietro Andreani, Dep. of electrical and information technology, Univ. Lund,
2) Paolo Bruschi, Università di Pisa
S) Matteo Bassi, Università di Pavia

Dalcanale Stefano
1) Joachim Wuerfl, FBH Berlin
2) Alessandro Chini, Università di Modena e Reggio Emilia
S) Oliver Hilt, FBH Berlin

De Luca Alberto

1) Alexander Leemans, University Medical Center Utrecht, The Nertherlands
2) Gustav J. Strijkers, University of Amsterdam, The Netherlands
S) Andrea Righini, Department of Radiology and neuroradiology, Milano

Del Testa Davide
1) Nicolò Michelusi, Purdue University, USA
2) Marco levorato, UC Irvine, USA
S) Roberto Verdone, Università di Bologna

Guimares Sa Correja Pedro
1) Emanuele Trucco, University of Dundee, Scotland, UK
2) Neil Lagali, Department of Clinical and Experimental Medicine Ophthalmology, Sweden
S) Xenophn Zabulis, Institute of Computer Science, Heraklion, Crete, Greece

Hooshmand Mohsen
1) Simon Pietro Romano, Università di Napoli
2) Ilenia Tinnirello, Università di Palermo
S) Francesco Gringoli, Università di Brescia

La Grassa Marco
1) Bastian Galler, OSRAM - Opto Semiconductors
2) Michele Goano, Politecnico di Torino
S) Roland Zeisel, OSRAM - Opto Semiconductors

Marin Giulio
1) Mattoccia Stefano, Università di Bologna
2) Miles Hansard, Queen Mary University, London, UK
S) Andrea Fusiello, Università di Udine

Prando Giulia
1) Lennart Ljung, Linkoping University
2) Simone Formentin, Politecnico di Milano
S) Romand Toth, Technical University Eindhoiven

Romeres Diego
1) Roland Toth, Technical University Eindhoiven
2) Tianshi Chen, The Chinese University of Hong Kong & Linkoping University
S) Simone Formentin, Politecnico di Milano

Rubega Maria
1) Markus Gschwind, Hopitaux Universitaires de Geneve
2) Laura Astolfi, Università La Sapienza di Roma
S) Febo Cincotti, Università La Sapienza di Roma

Tomasin Marco
1) Marco Belini, Istituto Nazionale di Ottica (INO-CNR), Sesto Fiorentino
2) Giovanni Di Giuseppe, Università di Camerino
S) Marco Barbieri, Università Roma 3

Tonietto Matteo
1) Robert T Ogden, Columbia University, NY USA
2) Paolo Zanotti Fregonara, Research Institute Houston Methodist, Houston, USA
S) Federico Turkheimer, King's College London

Vettoretti Martina
1) Hamad Haidar, McGill University, Montreal Canada
2) Andrea Caumo, Politecnico di Milano
S) Lalo Magni, Università di Pavia

7. Commissione esame finale dottorandi 29^ ciclo

Come indicato nel regolamento di Ateneo, la commissione sarà composta da un minimo di tre a un massimo di cinque membri effettivi e altrettanti supplenti, scelti tra professori, ricercatori universitari o esperti nelle discipline afferenti alle aree scientifiche cui si riferisce il Corso e appartenenti a Strutture di ricerca pubbliche e private, esclusi i supervisori dei dottoranti e i due valutatori della tesi nonché il referente membro del collegio, nel caso in cui il Supervisore sia esterno. La commissione non può essere costituita soltanto da componenti del Collegio.

Il Collegio dei docenti, ove ne ravvisi la necessità, potrà segnalare più Commissioni in considerazione dei diversi percorsi formativi e di ricerca dei candidati. Le Commissioni di norma non potranno comunque essere più di una per curriculum attivato per il ciclo che si conclude:

Per facilità si indicano di seguito i supervisori dei dottorandi del 29^ ciclo presenti nel Collegio docenti:

Indirizzo Bioingegneria
1. Bertoldo Alessandra: De Luca Davide, Tonietto Matteo
2. Di Camillo Barbara: Baruzzo Giacomo
3. Ruggeri Alfredo: Guimares sa Correia Pedro, Wigdhal Carson Jeffrey
4. Sparacino Giovanni: Rubega Maria, Vettoretti Martina

Indirizzo Scienza e Tecnologia dell'Informazione
5. Chiuso Alessandro: Prando Giulia, Romeres Diego
6. Gerosa Andrea: Celin Alberto
7. Rossi Michele: Hooshmand Mohsen

8. Villoresi Paolo: Tomasin Marco
9. Zanoni Enrico: Dalcanale Stefano, La Grassa Marco
10. Zanella Andrea: Biral Andrea
11. Zorzi Michele: Abbas Waqas Bin, Del Testa Davide
12. Bertocco Matteo, referente per i dottorandi con Supervisori esterni al collegio

Supervisori esterni
Laurenti Nicola: Caparra Gianluca
Pietracaprina Andrea: Ceccarello Matteo
Zanuttigh Pietro: Marin Giulio

Componenti del Collegio **non supervisori** di dottorandi del 29^ ciclo

Indirizzo Bioingegneria

1. Cobelli Claudio
2. Dalla Man Chiara
3. Grisan Enrico
4. Losasso Carmen
5. Pedersen Morten Gram
6. Toffolo Gianna Maria
7. Vassanelli Stefano

Indirizzo Scienza e Tecnologia dell'Informazione

8. Avanzini Federico
9. Badia Leonardo
10. Benvenuto Nevio
11. Bevilacqua Andrea
12. Carli Ruggero
13. Cenedese Angelo
14. Cester Andrea
15 Comin Matteo
16 Corradini Luca
17 Ferrante Augusto
18 Ferrari Carlo
19 Fischetti Matteo
20 Galtarossa Andrea
21 Menegatti Emanuele
22 Meneghesso Gaudenzio
23 Neviani Andrea
24 Nicolosi Piergiorgio
25 Paccagnella Alessandro
26 Pagello Enrico
27 Palmieri Luca

28 Pillonetto Gianluigi
29 Pini Maria Silvia
30 Pupolin Silvano
31 Santagiustina Marco
32 Schenato Luca
33 Spiazzi Giorgio
34 Tenti Paolo
35 Tomasin Stefano
36 Valcher Maria Elena
37 Zampieri Sandro

Dopo ampia discussione considerati i seguenti aspetti:

- il numero dei dottorandi che in prospettiva parteciperanno all'esame finale per il conseguimento del titolo
- la coerenza dei temi specifici oggetto dell'attività di ricerca triennale
- i due indirizzi del corso di dottorato

il Collegio propone unanime siano istituite due commissioni di esame una per ciascun indirizzo del corso. Inoltre determina per ciascuna commissione una composizione operativa fissata in tre membri (tre effettivi + tre supplenti).
Il Coordinatore invita ciascun settore scientifico disciplinare ad identificare possibili candidati a ricoprire il ruolo di commissario ricordando che le commissioni stesse dovranno essere definite entro i primi giorni di dicembre p.v.
Il Coordinatore ricorda inoltre al Collegio il fatto che almeno un membro di ogni commissione non sia anche componente del collegio ed inoltre i nominativi dei colleghi che non possono far parte di tali commissioni incluso il Coordinatore stesso in quanto referente dei dottorandi con supervisori "esterni al Collegio":

Indirizzo Bioingegneria
13. Bertoldo Alessandra: De Luca Davide, Tonietto Matteo
14. Di Camillo Barbara: Baruzzo Giacomo
15. Ruggeri Alfredo: Guimares sa Correia Pedro, Wigdhal Carson Jeffrey
16. Sparacino Giovanni: Rubega Maria, Vettoretti Martina

Indirizzo Scienza e Tecnologia dell'Informazione
17. Chiuso Alessandro: Prando Giulia, Romeres Diego
18. Gerosa Andrea: Celin Alberto
19. Rossi Michele: Hooshmand Mohsen
20. Villoresi Paolo: Tomasin Marco
21. Zanoni Enrico: Dalcanale Stefano, La Grassa Marco
22. Zanella Andrea: Biral Andrea
23. Zorzi Michele: Abbas Waqas Bin, Del Testa Davide

24. Bertocco Matteo, referente per i dottorandi con Supervisori esterni al collegio

Supervisori esterni
Laurenti Nicola: Caparra Gianluca
Pietracaprina Andrea: Ceccarello Matteo
Zanuttigh Pietro: Marin Giulio

Il Collegio approva.

8. Attività formativa e di ricerca dei dottorandi del 32^ ciclo

Dottorando**: AGNESI Costantino**
Curricolo: Scienza e tecnologia dell'informazione
Information-theoretic methods in security, 5 CFU
Applied functional analysis and machine learning, 7 CFU
Bayesian machine learning, 5 CFU
Technology entrepreneurship and lean start up, 5 CFU
Argomento di ricerca: Comunicazione quantistica
Supervisore proposto: Prof**. Paolo Villoresi**

Dottorando**: AGRESTI Gianluca**
Curricolo: Scienza e tecnologia dell'informazione
Bayesian machine learning, 5 CFU
Real-Time systems and applications 5 CFU
Statistical methods, 6 CFU
Technology entrepreneurship and lean start up, 5 CFU
Argomento della ricerca: Studio di nuove evoluzioni delle camere Time-of-Flight con l'uso combinato di tecniche a luca strutturata.
Supervisore proposto: Prof**. Pietro Zanuttigh**

Dottorando: **AVESANI Marco**
Curricolo: Scienza e tecnologia dell'informazione
Information-Theoretica methods in security, 5 CFU
Bayesian machine learning, 5 CFU
Real-Time systems and applications 5 CFU
Statistical methods, 6 CFU
Argomento della ricerca: Comunicazioni quantistiche
Supervisore proposto: **Paolo Villoresi / Giuseppe Vallone**

Dottorando: **BONALDO Stefano**
Curricolo: Scienza e tecnologia dell'informazione

Statistical methods, 6 CFU
Physics and operation of heterostructure-based electronic and optoelectronic devices, 5 CFU
Computational inverse problems, 5 CFU
Technology entrepreneurship and lean start up, 5 CFU

Argomento della ricerca: Sinergie tra i fenomeni di invecchiamento e di radiazione in dispositivi CMOS avanzati

Supervisore proposto: **Prof. Alessandro Paccagnella**

Dottorando: **BORGA Matteo**

Curricolo: Scienza e tecnologia dell'informazione
Statistical methods, 6 CFU
Physics and operation of heterostructure-based electronic and optoelectronic devices, 5 CFU
Diagnostics of electron devices, 4 CFU
Technology entrepreneurship and lean start up, 5 CFU

Argomento della ricerca: AlGaN/GaN HEMT con p-GaN gate: studio di dispositivi normally-off innovativi per la conversione dell'energia

Supervisore proposto: **Prof. Enrico Zanoni**

Dottorando: **BUONOMO Marco**

Curricolo: Scienza e tecnologia dell'informazione
Bayesian machine learning, 5 CFU
Technology entrepreneurship and lean start up, 5 CFU
Physics and operation of heterostructure-based electronic and optoelectronic devices, 5 CFU
Statistical methods, 6 CFU

Argomento della ricerca: Transistor e Biosensori Organici

Supervisore proposto: **Prof. Andrea Cester**

Dottorando: **CAMPAGNARO Filippo**

Curricolo: Scienza e tecnologia dell'informazione
Statistical methods, 6 CFU
Information-theoretic methods in security, 5 CFU
Real-time systems and applications, 5 CFU
Technology entrepreneurship and lean start up, 5 CFU

Argomento della ricerca: Reti sottomarine multimodali

Supervisore proposto: **Prof. Michele Zorzi**

Dottorando: **CAO Haitao** (Guanzhong University)

Curricolo: Scienza e tecnologia dell'informazione
The FFT and its use in digital signal processing, 5 CFU
Real-time systems and applications, 5 CFU
Applied linear algebra, 4 CFU
Statistical methods, 6 CFU

Argomento della ricerca: Comparing the performance of different algorithms on different architectures

Supervisore proposto: **Prof. Alessandro Paccagnella**

Dottorando: **CAPPON Giacomo**

Curricolo: Bioingegneria

Statistical methods, 6 CFU

Bayesian machine learning, 5 CFU

Computational inverse problems, 5 CFU

Technology entrepreneurship and lean start up, 5 CFU

Argomento della ricerca: Metodologie per il dosaggio di insulina in pazienti diabetici di tipo 1.

Supervisore proposto: **Prof. Giovanni Sparacino**

Dottorando: **CECCATO Silvia**

Curricolo: Scienza e tecnologia dell'informazione

Information-theoretic methods in security, 5 CFU

Statistical methods, 6 CFU

Real-time systems and applications, 5 CFU

Bayesian machine learning, 5 CFU

Argomento della ricerca: Key management schemes for GNSS services

Supervisore proposto: **Prof. Nicola LAURENTI**

Dottorando: **CICCONE Valentina**

Curricolo: Scienza e tecnologia dell'informazione

Applied functional analysis and machine learning, 7 CFU

Bayesian machine learning, 5 CFU

Statistical methods, 6 CFU

Applied linear algebra, 4 CFU

Argomento della ricerca

Supervisore proposto: **Prof. Augusto Ferrante**

Dottorando: **DALLA LIBERA Alberto**

Curricolo: Scienza e tecnologia dell'informazione

Applied functional analysis and machine learning, 7 CFU

Statistical methods, 6 CFU

Applied linear algebra, 4 CFU

Bayesian machine learning, 5 CFU

Argomento della ricerca: Machine learning e bracci robotici

Supervisore proposto: **Prof. Ruggero Carli**

Dottorando: **Thembelihle Lihle DLAMINI** (Marie Curie)
Curricolo: Scienza e tecnologia dell'informazione
Applied linear algebra, 4 CFU
Statistical methods, 6 CFU
Optimization and optimal control, 5 CFU
Technology entrepreneurship and lean start up, 5 CFU
Argomento della ricerca: Core network management procedures for self-organized and sustainable 5G cellular networks
Supervisore proposto: **Prof. Michele Rossi**

Dottorando: **FABRIS Marco**
Curricolo: Scienza e tecnologia dell'informazione
Applied functional analysis and machine learning, 7 CFU
Applied linear algebra, 4 CFU
Optimization and optimal control, 5 CFU
Statistical methods, 6 CFU
Topics in spectral theory for network analysis, 3 CFU (Matematica)
Argomento della ricerca: 3D coverage and formation control for heterogeneous robotic swarms
Supervisore proposto: **Prof. Angelo Cenedese**

Dottorando: **FABRIS Nicola**
Curricolo: Scienza e tecnologia dell'informazione
The FFT and its use in digital signal processing, 5 CFU
Applied functional analysis and machine learning, 7 CFU
Tissue engineering: principles and applications, 4 CFU
Physics and operation of heterostructure-based electronic and optoelectronic devices, 5 CFU
Argomento della ricerca: Sviluppo di strumentazione per la rivelazione fotonica di impulsi laser ultrabrevi nella regione spettrale dei raggi X soffici
Supervisore proposto: **Prof. Luca Poletto**

Dottorando: **FERNANDEZ Angel Gambin** (Marie Curie)
Curricolo: Scienza e tecnologia dell'informazione
Bayesian machine learning, 5 CFU
Low power wide area networks, 4 CFU
Optimization and optimal control, 5 CFU
Statistical methods, 6 CFU
Argomento della ricerca: Energy efficiency in 5G cellular networks within European SCAVENGE project
Supervisore proposto: Prof. **Michele Rossi**

Dottorando: **FRANCESCHIN Alessandro**

Curricolo: Scienza e tecnologia dell'informazione
Applied functional analysis and machine learning, 7 CFU
Applied linear algebra, 4 CFU
Physics and operation of heterostructure-based electronic and optoelectronic devices, 5 CFU
Statistical methods, 6 CFU
Argomento della ricerca: Progetto di circuiti CMOS per la sintesi di frequenza alle onde millimetriche a bassissimo rumore di fase
Supervisore proposto: **Prof. Andrea Bevilacqua**

Dottorando: **GINDULLINA Elvina**
Curricolo: Scienza e tecnologia dell'informazione
Bayesian machine learning, 5 CFU
Low power wide area networks, 4 CFU
Optimization and optimal control, 5 CFU
Statistical methods, 6 CFU
Applied functional analysis and machine learning, 7 CFU
Real-time systems and applications, 5 CFU
Argomento della ricerca: Distributed sensing from energy harvesting mobile devices networks within European SCAVENGE project
Supervisore proposto: **Prof. Leonardo Badia**

Dottorando: **GIORDANI Marco**
Curricolo: Scienza e tecnologia dell'informazione
Information-theoretic methods in security, 5 CFU
Technology entrepreneurship and lean start up, 5 CFU
Low power wide area networks, 4 CFU
Statistical methods, 6 CFU
Argomento della ricerca: Theoretical study and analysis of techniques for the control plane of 5G millimeter wave cellular networks
Supervisore proposto: **Prof. Michele Zorzi**

Dottorando: **LIONELLO Michele**
Curricolo: Scienza e tecnologia dell'informazione
Applied functional analysis and machine learning, 7 CFU
Bayesian machine learning, 5 CFU
Optimization and optimal control, 5 CFU
Statistical methods, 6 CFU
Argomento della ricerca: Tecniche di controllo predittive per sistemi di condizionamento complessi
Supervisore proposto: **Alessandro Beghi**

Dottorando: **LIU QING**
Curricolo: Scienza e tecnologia dell'informazione
Technology entrepreneurship and lean start up, 5 CFU
Computational inverse problems, 5 CFU

Physics and operation of heterostructure-based electronic and optoelectronic devices, 5 CFU
Statistical methods, 6 CFU

Argomento della ricerca: Nano grids for electrically autonomous buildings

Supervisore proposto: **Simone Buso**

Dottorando **MARCON Leonardo**

Curricolo: Scienza e tecnologia dell'informazione

Information-theoretic methods in security, 5 CFU
Technology entrepreneurship and lean start up, 5 CFU
Low power wide area networks, 4 CFU
Statistical methods, 6 CFU

Argomento della ricerca: Development of innovative distributed optical fiber sensors for detection of vibrations

Supervisore proposto: **Prof. Andrea Galtarossa**

Dottorando: **MICHELONI Edoardo**

Curricolo: Scienza e tecnologia dell'informazione

The FFT and its use in digital signal processing, 5 CFU
Statistical methods, 6 CFU
Real-time systems and applications, 5 CFU
Bayesian machine learning, 5 CFU

Argomento della ricerca: Definizione di un modello per l'accesso a strumenti musicali per mezzo di installazioni museali interattive, applicazioni WEB e tecnologie mobile

Supervisore proposto: **Prof. Sergio Canazza**

Dottorando: **NADEEM Ahmed Malik (EXTATIC)**

Curricolo: Scienza e tecnologia dell'informazione

Statistical methods, 6 CFU
Physics and operation of heterostructure-based electronic and optoelectronic devices, 5 CFU
Foundation module, 5 CFU (EXTATIC)
Optical systems, 5 CFU (EXTATIC)
Metrology, 5 CFU (EXTATIC)
Plus Language Modules (EXTATIC)

Argomento della ricerca: Optical and structural properties measurements of materially(s)/compounds in Extreme Ultraviolet Spectral Range

Supervisore proposto: **Dott. Paola Zuppella** (LUXOR IFN Padova), **referente: Prof. Piergiorgio Nicolosi**

Dottorando: **POLESE Michele**

Curricolo: Scienza e tecnologia dell'informazione

Information-theoretic methods in security, 5 CFU
Bayesian machine learning, 5 CFU
Statistical methods, 6 CFU
Technology entrepreneurship and lean start up, 5 CFU

Argomento della ricerca: Protocols and architectures for a consistent end-to-end user experience in mmWave 5G networks

Supervisore proposto: Prof. **Michele Zorzi**

Dottorando: **REBATO Mattia**

Curricolo: Scienza e tecnologia dell'informazione

Technology entrepreneurship and lean start up, 5 CFU

Real time system and application, 5 CFU

Low power wide area, 4 CFU

Statistical methods, 6 CFU

Argomento della ricerca: Studio e analisi di tecniche per la condivisione dello spettro su reti mobili 5G che usano onde millimetriche

Supervisore proposto: **Prof. Michele Zorzi**

Dottorando: **REGGIANI Francesco**

Curricolo: Bioingegneria

Bayesian machine learning, 5 CFU

Tissue engineering: principles and applications, 4 CFU

Computational inverse problems, 5 CFU

Statistical methods, 6 CFU

Argomento della ricerca: Bioinformatics methods and tools for personalized medicine

Supervisore proposto: **Prof. Carlo ferrari**

Dottorando: **RENSO Nicola**

Curricolo: Scienza e tecnologia dell'informazione

Statistical methods, 6 CFU

Physics and operation of heterostructure-based electronic and optoelectronic devices, 5 CFU

Diagnostics of electron devices, 4 CFU

Technology entrepreneurship and lean start up, 5 CFU

Argomento della ricerca: Analisi dei meccanismi di degrado indotti da over-stress elettrico su LED ad alta efficienza basati su nitruro di gallio

Supervisore proposto: **Prof. Matteo Meneghini**

Dottorando: **SCARAMUZZA Paolo**

Curricolo: Scienza e tecnologia dell'informazione

Statistical methods, 6 CFU

Bayesian machine learning, 5 CFU

Technology entrepreneurship and lean start up, 5 CFU

Physics and operation of heterostructure-based electronic and optoelectronic devices, 5 CFU

Argomento della ricerca: Amplificatori integrati per il 5G

Supervisore proposto: **Prof. Andrea Neviani**

Dottorando: **TORTO Lorenzo**

Curricolo: Scienza e tecnologia dell'informazione

Statistical methods, 6 CFU

Physics and operation of heterostructure-based electronic and optoelectronic devices, 5 CFU

Technology entrepreneurship and lean start up, 5 CFU

Applied linear algebra, 4 CFU

Argomento della ricerca: Analisi dell'affidabilità e modellazione di celle e moduli di celle solari a semiconduttore organico

Supervisore proposto: **Prof. Andrea Cester**

Dottorando: **YONGHENG Zhao**

Curricolo: Scienza e tecnologia dell'informazione

Bayesian machine learning, 5 CFU

Real time system and application, 5 CFU

Technology entrepreneurship and lean start up, 5 CFU

Statistical methods, 6 CFU

Argomento della ricerca: Skeleton based people detecting and pose recognition with multiple RGB-D cameras

Supervisore proposto: **Prof. Emanuele Menegatti**

Dottorando: **ZAMBONIN Giuliano**

Curricolo: Scienza e tecnologia dell'informazione

Applied functional analysis and machine learning, 7 CFU

Bayesian machine learning, 5 CFU

Statistical methods, 6 CFU

Technology entrepreneurship and lean start up, 5 CFU

Argomento della ricerca: Studio di metodi di apprendimento automatico e implementazioni su elettromestici (settore fabric care)

Supervisore proposto: **Prof. Alessandro Beghi**

Il Coordinatore pone in approvazione le proposte dei piani di studio e degli argomenti di ricerca.

Il Collegio approva.

Tenendo conto delle proposte di attività scientifiche approvate e dei vincoli imposti dal Regolamento del Corso di dottorato riportati all'Art. 13 comma 2.a): *(….per specifiche esigenze di formazione e ricerca il Collegio docenti può individuare un supervisore esterno al Collegio e in tal caso affiancargli un referente membro del Collegio*), si pone in approvazione anche la proposta di supervisore presentata da ogni dottorando e la disponibilità del Coordinatore anche per il XXXII ciclo, ad assumere per tutti il ruolo di referente ad esclusione di **NADEEM Ahmed Malik.**

Il Collegio approva.

9. Valutazione dell'attività svolta dai dottorandi Cappelleri Vincenzo Maria, Pagnutti Giampaolo, Samory Mattia, 28^ ciclo, indirizzo in Scienza e Tecnologia dell'Informazione, in proroga (12 mesi): ammissione all'esame finale.

   Nulla da deliberare.

10. Proposta al rettore della commissione per l'esame finale per i dottorandi Cappelleri Vicenzo Maria, Pagnutti Giampaolo, Samory Mattia 28^ ciclo, indirizzo in Scienza e tecnologia dell'Informazione, in proroga (12 mesi).

    Nulla da deliberare.

La riunione termina alle ore 13.00.

Il Segretario Il Coordinatore