PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Vincenzo Di Capua

XXXIV Cycle

Training and Research Activities Report – Third Year

Tutor: Prof. Pasquale Arpaia

Information

Vincenzo Di Capua, Master degree in electronic engineering–Università di Napoli Federico II

XXXIV Cycle- ITEE – Università di Napoli Federico II

Fellowship with CERN

Tutor: Prof. Paquale Arpaia

Study and Training activities

- Stephane Deghaye, “Controlling the CERN Accelerator Complex”, 29/11/2021-02/12/2021 (3 CFU) (online)
- Multiple speakers, International PhD Excellence School "Italo Gorini" 2021, 06/09/2021-10/09/2021 (2 CFU) (online)
- Multiple speakers, “BASNet: International School on Sensors for Body Area Network”, 31/06/2021-04/07/2021 (3 CFU) (online)
- Gregory Clement, “Linux kernel driver development (Bootlin)”, 28/04/2021-07/05/2021 (10 CFU) (online)
- Multiple Speakers (CERN), “Finding happiness in patent information databases”, 22/04/2021-23/04/2021 (1 CFU) (online)
- Elias Fernandez-Combarro Alvarez (CERN), “A practical introduction to quantum computing: from qubits to quantum machine learning and beyond” 06/11/2020-18/12/2020, (4CFU) (online)

	Credits year 1								Credits year 2								Credits year 3									
	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary	Total	Check
Modules	10	0	0,4	0	8,2	0	0,4	**9**	10	0	0	0	0	0	10	**10**	21	4	0	6	5	3	5	**23**	**42**	30-70
Seminars	4	0	0,5	0	0	0	1,5	**2**	10	0,5	0,5	0,5	0,5	0,5	6,5	**9**	5	0,5	0,5	0,5	2	0,5	2	**6**	**17**	10-30
Research	52	9	9	9	9	9	9	**54**	50	9	9	9	9	9	9	**54**	40	7	7	7	7	7	5	**40**	**148**	80-140
	66	9	9,9	9	17,2	9	10,9	**65**	70	9,5	9,5	9,5	9,5	9,5	25,5	**73**	66	11,5	7,5	13,5	14	10,5	12	**69**	**207**	180

Research activity

During my third year, I was involved in 5 kinds of activities.

Real-time measurement and prediction of the magnetic field in particle accelerators

The first one regards the design and implementation of a new measurement system of this kind currently being deployed throughout the European Organization for Nuclear Research (CERN) accelerator complex. I analyzed first the measurement principle, the general system architecture and the technology employed, focusing in particular on the most critical and specialized components to be developed, that is, the field marker trigger generator and the magnetic flux integrator. I was involved in the design of the system, its static and dynamic characterization and its commissioning for operations.

Drift-Free Integration in Inductive Magnetic Field Measurements Achieved by Kalman Filtering

The second one concerns the development of a method for the cancellation of the integrator drift. The method is based on a first-order linear Kalman filter combining the data from an induction coil and a second sensor. Two case studies were analyzed. In the first one, the second sensor is a Hall probe, sensing the magnetic field directly. In a second case study, the magnet's excitation current was used instead to provide a first-order approximation of the field. Experimental tests showed that both approaches can reduce the measured field drift by three orders of magnitude. The Hall probe option guarantees, in addition, one order of magnitude better absolute accuracy than by using the excitation current.

Full nutritional factor Neural network based Metabolic predictors

The third one regards the development of two innovative algorithms to predict the postprandial blood glucose concentration after the meal in T1D patients on AP systems are presented. The proposed algorithms, which cover a time span of prediction of 180 minutes, take into account not only the carbohydrates amount of in the meal but also other selected nutritional factors. More specifically, the proposed algorithms are based on feed forward multi-layer neural networks (FFNNs) and long short-term memory networks (LSTMNs) with a specific hyper-parameter configuration. The output of the proposed architectures consists of a predicted glycemic curve.

Machine Learning-based assessment of the vascularization quality in laparoscopic colorectal surgery

The fourth one concerns the development of an innovative algorithm based on machine learning to automatically assess the vascularization quality of the intestinal sector in laparoscopic colorectal surgery. More specifically, the algorithm exploits an image classifier system that is composed of a Feed-Forward Multi Layer Neural Network receiving as input a feature vector based on the histogram of the green band of the input image. It is used to (i) acquire information related to vascularization during laparoscopic colorectal surgery, and (ii) assist the surgeon in choosing the best strategy during the operation. Therefore, the proposed algorithm is intended to be a decision support for surgeons, providing an output related to adequate or inadequate vascularization.

Prediction of the magnetic field in magnets for particle accelerators

The fifth one regards the development of a full-fledged neural network modelling, based on a Deep

Nonlinear Autoregressive Exogenous Neural Network (NARX) architecture for quasi-static and dynamic hysteresis loops, one of the most challenging topics for computational magnetism.
This modelling approach overcomes drawbacks in attaining better than percent-level accuracy of classical and recent approaches for accelerator magnets, that combine hybridization of standard hysteretic models and neural network architectures. analyzed first of all the closed-form mathematical models studying the state of the art present in literature in this field. Since the accuracy obtained in the state of the art was not enough to satisfy the operations' requirements of particle accelerators and the computational time was not adequate to be implemented in real-time I thought to replace the mathematical model with an Artificial Neural Network (ANN), in particular, I developed a proof of concept solution based on a Deep neural network (DNN) in order to model the hysteretic response of the magnets in terms of an appropriate set of features in the input signals.

Collaborations

- European Organization for Nuclear Research (CERN)
- Azienda Ospedaliera Universitaria Federico II
- ISTC-CNR

Products

- Arpaia, P., Buzio, M., Di Capua, V., Grassini, S., Parvis, M., & Pentella, M. (2022). Drift-Free Integration in Inductive Magnetic Field Measurements Achieved by Kalman Filtering. Sensors, 22(1), 182.
- Amodeo, M., Arpaia, P., Buzio, M., Di Capua, V., & Donnarumma, F. (2021). Hysteresis Modeling in Iron-Dominated Magnets Based on a Multi-Layered NARX Neural Network Approach. International journal of neural systems, 31(09), 2150033.
- Vella Wallbank, J., Amodeo, M., Beaumont, A., Buzio, M., Di Capua, V., Grech, C., ... & Giloteaux, D. (2021). Development of a Real-Time Magnetic Field Measurement System for Synchrotron Control. Electronics, 10(17), 2140.
- Grech, Christian, et al. "Error characterization and calibration of real-time magnetic field measurement systems." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 990 (2021): 164979.
- Arpaia, P., Di Capua, V., Roda, M., & Buzio, M. (2019). Real-Time Magnetic Measurement Monitoring under cRIO-LabVIEW Based Platform (No. 1335). EasyChair.
- P.Arpaia, U.Baracale, F.Corcione, E. De Benedetto, A. Di Bernardo, V. Di Capua, R. Prevete (2021). "Machine Learning-based assessment of the vascularization quality in laparoscopic colorectal surgery", Nature scientific reports, (submitted).
- P. Arpaia, G. Annuzzi, E. De Benedetto, V.Di Capua, R. Prevete, E. Vallefuoco (2021). "Neural Network-Based Prediction and Monitoring of Blood Glucose Response to Nutritional Factors in Type-1 Diabetes", I2MTC,(submitted).
- P. Arpaia, G. Annuzzi, E. De Benedetto, V. Di Capua, R. Prevete, E. Vallefuoco (2021). "Full nutritional factor Neural network based Metabolic predictors", nature scientific reports, (ready for submission).

Conference and Seminars

- Multiple speakers, “Injectors and Experimental Facilities Workshop”, 06/12/2021-09/12/2021, (1.5 CFU) (online)
- Multiple speakers, “12th International Particle Accelerator Conference - IPAC’21”, 24/05/2021-28/05/2021 (1.5 CFU) (online)
- Multiple speakers, “Weekly Machine learning seminar”, Geneva, (cumulative 3 CFU) (online)

Activity abroad

Date	Place
From: 1/11/2020 To: 31/01/2022	Geneva, European Organization for Nuclear Research(CERN)

Tutorship

During my 3th PhD year, I spent 200 hours in tutorship activities.