Vincenzo Di Capua

Tutor: Pasquale Arpaia

XXXIV Cycle - I year presentation

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

Content

- My Background
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Background

Graduation:

- B.Sc. degree cum laude in Electronic Engineering from the University of Naples “Federico II” on October 5, 2016.
  Thesis: "Triaxial acceleration measurement with ARM STM32 microcontroller and MEMS INMO LSM6DS0 sensor on bus I2C”.

- M.Sc. degree cum laude in Electronic Engineering from the University of Naples “Federico II” on September 27, 2018.
  Thesis: "Development and Implementation of a Real-Time Magnetic Measurement Monitoring System for CERN B-Train”.

Fellowship:

- PhD Student of XXXIV cycle in Information Technology and Electrical Engineering (ITEE).
  Theme: “Real-time measurement and prediction of the magnetic field in particle accelerators”
- Doctoral student at the European Organization for Nuclear Research (CERN)

Problem

- In the LHC injectors the current-to-field characteristic of the magnets is dominated by the iron core, which gives rise to non-linear effects such as eddy currents, saturation and hysteresis.
- **Three different ways to obtain the field:**
  - Real-time magnetic measurements ("BTrain" systems);
  - Using a table of vectors containing the nominal field, fixed a certain cycle the magnetic filed in the magnets assume always the same values;
  - Prediction of the magnetic field values knowing only the current in input to the magnets (and its previous values).

Problem

- We want to estimate the Magnetic field values within a typical tolerance of 0.01% at any given time during a magnetic cycle. This in order to provide Real-time values that takes into account even non linear effects even if for any reasons it is not possible to have the Real-time magnetic measurements.

- We tested four different approaches in order to find the simplest one that fits our requirements:
  - Flexible (easy to pass from one kind magnet to one other);
  - RMSE less or equal to 0.01%;
  - Simple enough to be implemented in Real-time.

Research activity

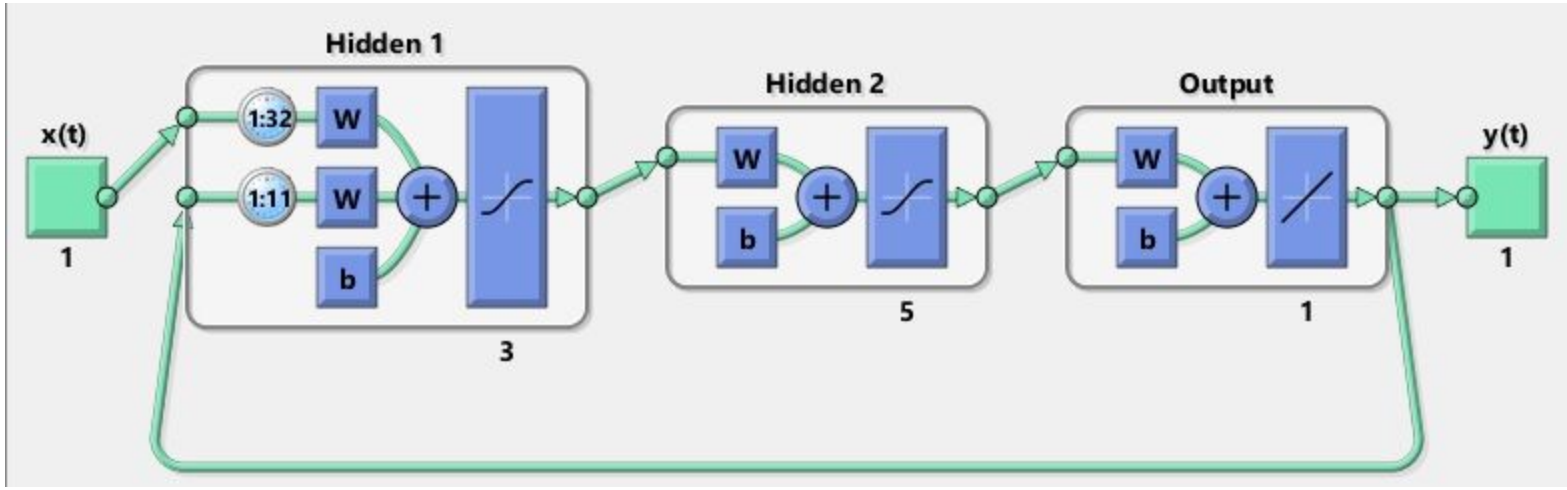
- The prediction of the magnetic field could be achieved using classical models such as:
  - Preisach model and its variants;
  - Jiles Atherton model;
  - Wlodarski model.

- Limitations
  - We could not obtain better than percent-level accuracy, which is inadequate for our purposes;
  - Difficulties in handling minor hysteresis loop;
  - Hard to be implemented in Real-time.

- We turn our attention to the possibilities offered by Artificial Neural Networks (ANN), which are today being used with spectacular success in variety of domains, but are still relatively unexplored in magnetics.

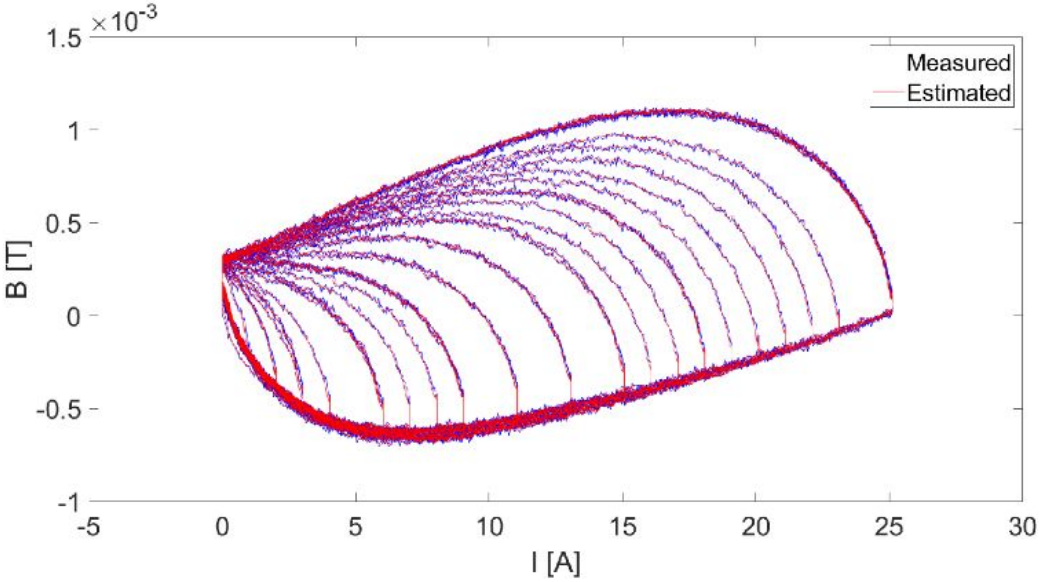
Research activity

- Non linear Autoregressive Exogenous Neural Network (NARX)



Research activity

Neural Network Architecture	Field RMSE Mean [T]	Field RMSE Variance [T^2]
MultiLayer Perceptron	$1.33 \cdot 10^{-4}$	$2.7 \cdot 10^{-9}$
Recurrent Neural Network	$2.71 \cdot 10^{-4}$	$7.78 \cdot 10^{-8}$
Time Delay Neural Network	$4.16 \cdot 10^{-5}$	$3.66 \cdot 10^{-10}$
NARX	$1.48 \cdot 10^{-5}$	$3.64 \cdot 10^{-13}$



1st year production

- F. M. Velotti, H. Bartosik, M. Buzio, K. Cornelis, V. Di Capua, M. A. Fraser,B. Goddard, V. Kain, “CHARACTERISATION OF SPS SLOW EXTRACTION SPILL QUALITY DEGRADATION” 10th Int. Particle Accelerator Conf. IPAC2019, Melbourne, Australia. (complete)

- Pasquale Arpaia, Vincenzo Di Capua, Marco Roda and Marco Buzio, “Real-Time Magnetic Measurement Monitoring under cRIO-LabVIEW Based Platform” (submitted)

- Vincenzo Di Capua, “Hysteresis modeling in iron-dominated magnets based on a Deep Neural Network approach”, 4 Oct 2019 (presentation)

- Pasquale Arpaia, Vincenzo Di Capua, Maria Amodeo, Francesco Donnarumma and Marco Buzio , “Hysteresis mo deling in iron-dominated magnets based on a Deep Neural Network approach” International Journal of Neural Systems (IJNS) (internal revision)

Next year

Research activity:

- Performance improvement of the deep neural network developed during the first year
- First hardware implementation of the designed neural network

Conferences and PhD Schools:

- Italo Gorini PhD School, Reggia Calabria, Italy, September 2020
- 2020 IEEE International Workshop on Metrology for Industry 4.0 & IoT, Roma, Italy, 3-5 june 2020

	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	15							0	15							0	9	30-70
Seminars	4	0	0.5	0	0	0	1.5	2	5							0	5							0	2	10-30
Research	52	9	9	9	9	9	9	54	50							0	40							0	54	80-140
	66	9	9.9	9	17.2	9	10.9	65	70	0	0	0	0	0	0	0	60	0	0	0	0	0	0	0	65	180

Thank you for your attention