PhD in Information Technology and Electrical Engineering

Università degli Studi di Napoli Federico II

PhD Student: Alessandro Tocchi

XXXIII Cycle

Training and Research Activities Report – Third Year

Tutor: Prof. Mauro D'Arco

1. Information

PhD Candidate: Alessandro Tocchi

MSc title: Master's degree in Electronic Engineering, University of Naples Federico II

Doctoral Cycle: XXXIII- ITEE-University of Naples Federico II

Tutor: Prof. Mauro D'Arco

Year: Third

I graduated in Electronic Engineering at University of Naples "Federico II". I am a PhD Student

of the XXXIII cycle of ITEE. My tutor is Prof. Mauro D'Arco.

2. Study and Training activities

a. Courses

- MSc Course, "Sensors Data Fusion and Measurement Uncertainty Management", Prof. R. Schiano Lo Moriello, January, 12 CFU.
- Ah hoc module, Design and Implementation of Augmented Reality Software Systems, Prof. Domenico Amalfitano, June 2020, 4 CFU

b. Seminars

- "How to Get Published with IEEE", IEEE Xplore Webinar, April 30th-2020,0.3 CFU
- "Large Scale Training of Deep Neural Networks" Organizer: Prof. Carlo Sansone, University of Naples Federico II, May 6th–2020, 0.5 CFU
- "Italo Gorini 2020", Doctoral School promoted by the Italian "Electrical and Electronic Measurement" (GMEE) and "Mechanical and Thermal Measurement" (GMMT) associations, University of Naples Federico II , Naples (Italy), September 4th to 9th 2020, 3 CFU.
- "How to Publish Open Access with IEEE to Increase the Exposure and Impact of your research",IEEE Xplore Webinar, September 23th-2020,0.3 CFU
- "Network Systems, Kuramoto Oscillators, and Synchronous Power Flow", Organizer Prof. Francesco Bullo, University of California ,December 3th-2020, 0.2 CFU

CS Summary

Student: Alessandro Tocchi					Tutor: Prof. Mauro D'Arco				Cycle XXXIII																											
alessandro.tocchi@unina.it					darco@unina.it																															
	Credits year 1									Credits year 2										Credits year 3																
		1	2	3	4	5	6				1	2	3	4	5	6					1	2	3	4	5	6	7	8	10						
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Check	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Check	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary	Check	Total	Check			
Modules	20	0	0	9	9	0	0	18	20-40	15			2	6			8	10-20	5	12,0		4,0							16	0-10	42	30-70			
Seminars	7	0,6	0	2	1,6	4	1,5	9,7	5-10	7	0,4	1,4	1,2	0,6	4		7,6	5-10	5		0,3	0,5		3,3	0,2				4,3	0-10	21,6	10-30			
Research	33	7	11	7,8	1	7	1	34,8	10-35	40	10	3	6	10	7	8	44	30-45	45	9,0	14,0	16,0	4,0		10,0	2,0	2,0	2,0	59	40-60	137,8	80-140			
	60	7,6	11	19	12	11	2,5	62,5	58,8	62	4,4	9,2	17	11	8	60	59,6	62	55	21	14	21	4	3,3	10	2	2	2	79,3	60	201,4	201,4			

3. Research activity

The research activities carried out during the Ph.D. have been mainly focused on the definition of innovative methods and strategies, tailored for the implementation of IoT platforms for the measurement and carrying out performance assessment on IoT communication protocol. In particular, a first research activity has deeply investigated a conceptual IoT framework that best suits the issues related to fire Propagation Map simulation and Evacuation Plan Model of animals, OPERA (OPtimal Evacuation Route for Animals), to support the activities of the Regional Veterinary referral Center for non-epidemic emergencies (CeRVEnE) in the Campania Region. The main issue but also the innovation is the integration of Distributed Sensor Network (DSN), an ad-hoc software to generate timely simulations for fire risk modeling, and a GIS (Geographic Information System) for all the activities. Guaranteeing the prevention of systematic failure in disaster risk management is the main goal of the system which use a “Foresight approach” perspective to grant it. A strong criticality is that the considered scenario, the Mount Vesuvius, hosts a unique combination of both animal and anthropic elements within a delicate natural ecosystem. IoT approaches are used with efficiency in human rescue activities, but this is not the case for animal rescue. Filling this gap by proposing one of the first attempts of IoT-enforced rescue system for companion, farm and wild animals well suits my research course.

Measuring and monitoring the concentration of possible nuclear pollutants turns out to be advisable or mandatory in several environmental contexts; the fast availability of an appropriate response plan allows, in fact, the consequences of radiation to be reduced or completely removed. So, the research activities also focused on the use of Internet of Things (IoT) to realize an integrated platform based on a cost-effective wireless sensor network (WSN) for monitoring environmental radioactive pollution. This solution has fascinating features like scalability and flexibility to overcome the drawback of a classic monitoring system. Moreover, cloud data management and big data processing mechanisms, can face the relevant computational burden needed to carry out detection algorithms (as an example, those based on Bayesian methods). The monitoring platform mainly comprises sensor nodes, LoRaWAN communication modules, LoRaWAN Gateways and an Open-source IoT platform. Each sensor node consists of three modules: the radiation sensor, mandated to interact with physical quantity of interest; a suitable electronic interface, needed for analog processing the signal generated by the sensor and carrying out the required measurements; and an embedded Linux-based system, acting as node control, memory buffer and exchanging data with the communication modules. Different sensor nodes have been designed and implemented exploiting three radiation detectors. Nodes based on a Geiger sensor are exploited to measure the radiation level during the monitoring state and

if anomalous levels of radioactivity are detected, Geiger nodes activate the identification state and other two type of nodes, based on silicon and scintillation detectors, wake up to measure the energy spectrum of alpha and gamma radiation, respectively. Network sensor nodes are connected by means of LoRaWAN protocol and use the “key-value” paradigm, which grants wide area coverage with reduced power consumption, to a proper Gateway, which exchanges measurement data and node information with a suitable platform implemented with the open-source platform ThingsBoard. With specific regard to the nodes, reference radioactive source with known energy spectrum has been adopted to assess the capability of the realized conditioning section and digital processing to carry out spectrometry and transmit the results to the IoT platform for the visualization.

On the other hand, the second path of research during the Ph.D can be addressed as “measurements for IoT”. Internet of Things paradigm requires even more reliable and long-distance communication systems. In this scenario, LoRa technology, based on an efficient Chirp Spread Spectrum modulation can grant both long range distance and low energy consumption in the communication link. Also the challenge of acquiring and processing LoRa signals to extract valuable parameters like “Bandwidth and Spreading factor” has been addressed. Assessing the performance of LoRa devices is, at present, a costly task even if leader manufacturers of measurement solutions, which are also members of the LoRa Alliance, have already distributed their own proprietary hardware and software. Costs are basically related to the digitizer and its complementing acquisition memory and processor, adopted to digitize, save and process the input signal. In particular, the sampling strategy should grant a significant reduction of instrument memory requirements, which have a large impact on the hardware costs. So, an alternative approach to standard sampling paradigms, referred to as compressive sampling (CS), has been addressed. CS-based test solutions have been proposed and assessed to support classification tasks of signals exploiting common frequency modulation schemes, but LoRa relies on new challenging modulation schemes. So, during Ph.D activities a novel measurement instrument has been deeply investigated. It is based on digital signal processing strategies associated with low-cost acquisition hardware, for the reconstruction and classification of LoRa signals. The RF front-end of the instrument can be arranged using off-the-shelf modules and on CS paradigm that exploits the possibility of representing LoRa signals as locally sparse signals in terms of Discrete Cosine base functions. CS-based approach and a classification algorithm, designed to operate on the acquired signal is considered in order to highlight, throughout classification tests, the reliability at estimating the characteristic parameters of LoRa signals, bandwidth, spreading factor and symbol time of transmitted data, for given carrier frequency and sampling rate. The proposed CS approach consists in dividing the LoRa signal in short time segments, each of which characterized by signal portion exhibiting an almost stationary frequency behavior to reliably approximate the input signal by a sine wave of the same amplitude. The corresponding portions of the LoRa signal are acquired exploiting a compressive sampling approach that uses discrete cosine basis functions. The proposed approach enlists the following operating steps: Random acquisition of M samples of the LoRa signal according to a quasi-random sampling scheme; segmentation of the acquired record in different subset of Mi successive samples, related to short intervals with duration not exceeding 50 μs; computation of Ni samples by processing the Mi samples through a greedy algorithm; recovery of a long record characterized by N samples by linking the reconstructed frames.

It also would be useful a methodology for maintenance and troubleshooting of LoRa networks sharing the same operating frequency interval. This context requires the estimation of instantaneous frequency (IF) of signals characterized by interfering IF trajectories. Two digital signal processing methods have been adopted, the first one based on chirplet transform that addresses IF trajectories whose evolution versus time can roughly be modelled by polynomial law. The second one exploiting the warblet transform (WT), addresses signals with IF trajectories, which exhibit a certain periodicity in the time domain. They decompose the signal under analysis into a set of oscillating, time-limited functions, all obtained by modifying an original window function, respectively called mother chirplet or warblet. They overcome some limits affecting traditional solutions, such as low time-frequency resolution or appearance of IF artifacts, while showing good accuracy (within 1%) along

with remarkable resolving capability. Optimized versions also grant promising results where two or more IF trajectories interference with one another.

4. Products

a. Publications

- **Publication**

i. Tamburis O, Giannino F, D'Arco M, **PhD Student Alessandro Tocchi**, Esposito C, Di Fiore G, Piscopo N, Esposito L. “A Night at the OPERA: A Conceptual Framework for an Integrated Distributed Sensor Network-Based System to Figure out Safety Protocols for Animals under Risk of Fire”. Sensors (Basel). 2020 Apr 29;20(9):2538. doi: 10.3390/s20092538. PMID: 32365698; PMCID: PMC7249212

ii. L. Angrisani, **PhD Student Alessandro Tocchi**, D. Ruggiero, R. S. Lo Moriello, G. de Alteriis and F. Capasso, "Estimation of Instantaneous Frequency in the Presence of Interfering Trajectories,", 2020 IEEE International Instrumentation and Measurement Technology Conference (I2MTC), 2020, pp. 1-6, doi: 10.1109/I2MTC43012.2020.9128597, (25-28 May 2020)

iii. Angrisani, L., Bonavolontà, F., Dassi, C., Liccardo, A., Moriello, R.S.L., **PhD Student Alessandro Tocchi,** 7006649427;55825402400;57205436107;14631935200; 57212675767;5701488740;”On the suitability of compressive sampling for lora signals classification”(2020) International Review of Electrical Engineering, 15 (3), pp. 187-198.

iv. R. S. Lo Moriello, **PhD Student Alessandro Tocchi**, A. Liccardo, F. Bonavolontà and G. de Alteriis, "Exploiting IoT-Oriented Technologies for Measurement Networks of Environmental Radiation," in IEEE Instrumentation & Measurement Magazine, vol. 23, no. 9, pp. 36-42, December 2020, doi: 10.1109/MIM.2020.9289067.

5. Conferences and Seminars

I have not participated to conferences or seminars.

6. Activity abroad

I have spent no time abroad during the second year PhD course.

7. Tutorship

Subsidiary and / or supplementary didactic assistant for the B. S. course “Misure per l'automazione e la produzione industriale”, and the module “Ulteriori conoscenze” taught by Prof. Angrisani Leopoldo, 40 hours.