DIPARTIMENTO DI INGEGNERIA
CORSO DI DOTTORATO IN INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE -
PHD COURSE IN INDUSTRIAL AND INFORMATION ENGINEERING - 36TH CYCLE

Title of the research activity: Smart sensing for the IoT	
State of the Art: The development of hardware and software technologies to improve the human-computer interaction (HCI) has produced a new generation of highly sophisticated sensors that open up novel application domains. This is case for instance of 24 GHz and 76 GHz radar sensors [1] that offer at very reasonable costs processing platforms to detect falls of elderly people, to count people in a room, to track the movement of people and objects. As another example consider Time-to-digital measurement-based devices that, at unprecedented low costs, offer the possibility to measure very accurately the position of small objects at close distance [2] to allow gesture recognition and improve HCI. As a third example consider magnetic technologies applied to short-range movement tracking [3-5], developed in the lab of the research proponent, that enables applications in the healthcare (e.g. monitoring of Parkinsons's disease) or telecontrol. All these technologies share a common denominator: the possibility to better interact with the reality can be empowered by a clever application of dedicated numerical processing procedures aimed at feature extraction and precise measurements. The research lab has extensive experience in the development of technologies for the interaction of a user within his environment, through the development of applications based on ultrasound, ultrawideband-width and magnetic physical principles. The lab has also several years of experience in the design and tuning of algorithms and estimators aimed at easing the measurement of complex quantities: these techniques range from the design of very simple testing signals having specific spectral properties, to the development of a 1-bit spectral analyzer, using a 1-bit DAC and 1-bit ADC for the online identification of linear and nonlinear systems [6].	
Short description and objectives of the research activity: The proposed research activity aims at exploring the many possibilities offered by the development of dedicated data processing algorithms and estimators for maximal exploitation of	

available sensors and HCI technologies. The PhD candidate will work both on the development of new simple hardware to better interact with available hardware technologies and on the development of new estimators to realize low-cost, low-energy and low-complexity measurement systems specifically for the IoT application domain. This will include the development of a framework for very low-complexity 1-bit data acquisition system for easing data transfer and processing in huge multichannel, massive multiple-output multiple-input systems. It will also include the design and implementation of clever algorithms for the invention of low-resolution testing signals to shorten the measurement time of otherwise lengthy measurement procedures, such as in the case of Electroimpedance spectroscopy applied to battery state-of-health monitoring and sensing for cultural heritage or for healthcare. The overall subject of *frugal* measurements will be explored: finding simple-to-realize measurement architectures that enable the user to easily interact with reality and to capture the needed information.	
Bibliography: [1] https://www.ti.com/product/AWR1642 [online] [2] https://www.st.com/en/imaging-and-photonics-solutions/proximity-sensors.html [online] [3] P. Bellitti *et al*., "A Wearable and Wirelessly Powered System for Multiple Finger Tracking," in *IEEE Transactions on Instrumentation and Measurement,* 2020 – doi: 10.1109/TIM.2020.2969089. Preprint [4] F. Santoni, A. De Angelis, I. Skog, A. Moschitta and P. Carbone, "Calibration and Characterization of a Magnetic Positioning System Using a Robotic Arm," in *IEEE Transactions on Instrumentation and Measurement*, vol. 68, no. 5, pp. 1494-1502, May 2019 – doi: 10.1109/TIM.2018.2885590. Preprint [5] De Angelis, G.; De Angelis, A.; Moschitta, A.; Carbone, P. "Comparison of Measurement Models for 3D Magnetic Localization and Tracking," *Sensors* 2017, *17*, 2527 – doi: 10.3390/s17112527. Preprint [6] P. Carbone, J. Schoukens, A. De Angleis, A. Moschitta, "A 1.5 DFT Analyzer", *IEEE Transactions on Instrumentation and Measurement*, Preprint	
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