PhD Project Proposal

School of Electronics, Electrical Engineering and Computer Science

& ECIT Global Research Institute

Proposed Project Title: Compressive Imaging using Computational Techniques at Millimetre-wave Frequencies

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Project Description

Millimetre-waves (mmW) can penetrate through materials that are opaque at optical wavelengths, yet they are non-ionizing and thus harmless to living tissue at low power levels. Hence, mmW imaging is of considerable interest for security screening, remote sensing, biomedical imaging and many other applications. A number of microwave imaging systems have been developed and fielded, including synthetic aperture radar (SAR) and phased arrays. While these techniques have demonstrated good image fidelity, limitations remain, particularly for real-time imaging.

In the case of SAR, mechanical scanning of the scene to be imaged limits the data acquisition speed, making SAR approaches challenging to implement for real-time imaging applications. Phased arrays are optimal in terms of beamforming, but typically require large numbers of expensive components, including amplifiers and phase shifting circuits, which consume significant power, are bulky, and generally expensive.

An alternative method applicable to coherent mmW imaging is to make use of computational imaging techniques to simplify the physical architecture of the system, relying more on processing to make use of more general measurements, and to more intelligently use those measurements to estimate the scene. Computational imaging generalizes the imaging process, so that many more aperture modalities can be implemented to yield high-fidelity images. A new imaging modality that has emerged from the computational imaging framework is the frequency-diverse aperture, an aperture designed with radiating elements whose radiative properties vary rapidly as a function of the driving frequency. As a function of frequency, the frequency-diverse aperture produces a set of distinct radiation patterns that illuminate the scene. The scene can then be reconstructed from the set of measurements using computational imaging techniques. Leveraging computational imaging, there is no need for any mechanical scanning apparatus or active electronic components, leading to a simple architecture that is inexpensive and scalable to very large apertures.

This project will investigate novel computational compressive imaging techniques at millimetre-wave frequencies. The goal of this project is to develop real-time computational imaging platforms that

(a) will enable all-electronic operation while eliminating the need for phase shifting circuits,
(b) will leverage advanced processing schemes, such as principal component analysis (PCA), to achieve further compression of the measurement data,
(c) will investigate new techniques to improve the orthogonality of the measurement modes encoding the scene information,
(d) will develop parallel-processing algorithms for image reconstruction using general purpose graphics processing units (GPGPUs) and field-programmable-gate-arrays (FPGAs),
(e) will investigate the use of artificial intelligence (AI) and machine learning techniques to develop automatic threat detection (ATD) and super-resolution imaging,
(f) will investigate polarimetry to improve the information content in the reconstructed images.

The proposed project constitutes a real scientific and technological advance compared to the actual state of art in millimeter-wave imaging. The success of the project guarantees a real scientific advance for the Institute of Electronics, Communications and Information Technology, with applications ranging from security-screening to non-destructive testing and biomedical imaging.

Job Description

- High quality research and engineering design focusing on compressive sensing and computational imaging.
- Development of innovative hardware architectures and postprocessing algorithms to achieve real-time data acquisition and image reconstruction.
- Publishing and presenting results both at international conferences and in scientific journals.
- Working towards realizing a PhD in about 3 years.
- Participation in the framework of national and European academic institutions and industry.

Contact details

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