VRIJE UNIVERSITEIT BRUSSEL

The faculty of Engineering of the Vrije Universiteit Brussel invites you to attend the public defense leading to the degree of

DOCTOR OF ENGINEERING SCIENCES

of **Habib-Ur-Rehman Khalid**

The public defense will take place on **Monday 9th December 2024 at 4pm** in the **Green Room** (U-Residence, VUB Main Campus)

To join the digital defense, please click here

GENERALIZABLE DEEP LEARNING FOR A FREQUENCY MODULATED CONTINUOUS WAVE RADAR BASED HUMAN ACTIVITY RECOGNITION

BOARD OF EXAMINERS

Prof. dr. ir. Abdellah Touhafi

Prof. dr. ir. Wendy Meulebroeck

Prof. dr. ir. Bruno Tiago da Silva Gomes

Prof. dr. ir. Sofie Pollin

Prof. dr. François Horlin

Ir. Andre Bourdoux

PROMOTORS

Prof. dr. ir. Johan Stiens

Prof. dr. Hichem Sahli

VRIJE UNIVERSITEIT BRUSSEL

Abstract of the PhD research

Human Activity Recognition (HAR) is vital for understanding human behavior and improving people's lives. Significant advancements in the technology, the availability of cheap hardware and an increased data storage capacity has led to the vast amounts of data being generated. The overall goal of a reliable HAR system is to automatically analyze and comprehend human actions based on the data collected from various sensors and sources and from different environments. In this research, we utilize a Frequency Modulated Continuous Wave radar sensor. Radar-based HAR has several advantages over camera-based HAR. It is less affected by external environmental factors, such as the lighting conditions, smoke or dust, making it easily deployable and cost-effective. Furthermore, compared to the camera-based HAR, which may raise privacy concerns, radar-HAR is less invasive as it does not capture visual details of the participants.

In recent years, machine learning algorithms have made significant progress in analyzing big data, and HAR is one of the key areas where machine learning algorithms have been applied successfully. Much of this success is due to supervised learning, which relies heavily on the availability of large labelled datasets. However, creating labelled datasets is a time-consuming process requiring significant human effort and domain expertise. As a result, supervised learning is infeasible for unique or niche domains with limited data availability, such as radar-HAR. Additionally, supervised learning algorithms may not perform well on unseen data if there is a significant difference between the training and testing datasets, known as the “domain-shift” or “dataset bias” problem.

In this thesis, our primary goal is to focus on the generalizability aspect of the deep learning-based models in the presence of domain-shift for an indoor radar-HAR application. In this context, radar tar-get tracking-based auxiliary features and the preprocessing steps in the radar data cube are proposed. The tracking-based features provide the dynamic context of the participants in an indoor environment, while the proposed preprocessing steps in the radar data cube are driven by the Doppler and range energy dispersion-based profiles of the participant's micro-motion. A novel Multi-View CNN-LSTM-based multi-model approach is proposed, which efficiently combines the complementary, holistic view of the participants, given the dynamic auxiliary contextual features, with the energy dispersion-based spatiotemporal features from the preprocessed radar data cubes. Moreover, to facilitate robust and classagnostic feature extraction, an unsupervised Convolutional Auto-Encoder based training and model initialization step is proposed, which is followed by the supervised training and fine-tuning steps. Lastly, to address the domain-shift problem, the proposed robust model training methodology is extended with the CORrelation ALignment (CORAL) based Multi-View Unsupervised Domain Adaptation based model adaptation step.