Gesture Recognition with an FMCW Radar*

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Abstract. This paper presents a Dynamic Hand-Gesture Recognition (HGR) demo using a millimeter-Wave 140 GHz Frequency Modulated Continuous Wave (FMCW) radar. An event-driven architecture is proposed to enable real-time inference, where we used a Convolutional Long Short-term Memory (CLSTM) model for gesture recognition.

1 Introduction

HGR is gradually being recognized as an alternative contact-less technology for Human-Computer Interfaces. It can be used in application domains such as, smart-homes, smart-factories and autonomous vehicles.

Section 2 describes the overall methodology, the radar sensor and an event-driven inference approach. System specifications are discussed in Section 3, while Section 4 concludes the work with prospective future work.

2 Radar Sensor and Deep Learning Model

In this demo we used a 140 GHz FMCW radar, developed by IMEC, which uses a frequency modulated sawtooth-waveform, with a bandwidth of 10 GHz. The main building blocks of the radar system are highly-linear Phase-Locked Loop (PLL) module and a transceiver chip with on-chip antennas.

The radar sensor illuminates the human hand in its Field-of-View and senses the returned echoes, which are demodulated, low-pass filtered and digitized for a preprocessing step (see Figure 1). After analog-to-digital conversion, the echoes are converted to a range-Doppler-Angle data-cube [1]. To achieve real-time performance and remain within the latency constraints, we first detect the presence of a hand. Once detected, a CLSTM module is triggered for feature extraction and classification.

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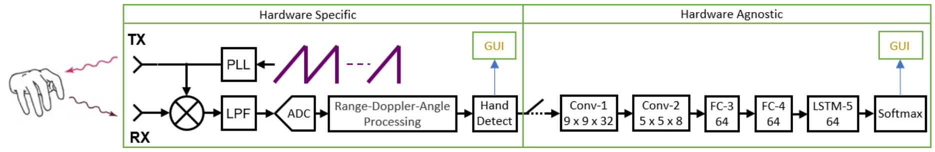

Fig. 1. High-level signal-processing and machine learning pipeline.

3 System Specification

High-bandwidth of the radar together with high-frequency carrier operation enables range and Doppler resolution of 1.5 cm and 29 mm/sec. Furthermore, the hand is illuminated with more than 100 fps(Hz), which allows us to extract high-fidelity micro-range and micro-Doppler features. The radar data-cube sequence containing a gesture is presented to the Convolutional layer, where spatio-temporal features are extracted, while an LSTM layer learns the long-term temporal dependencies [2]. Multi-class classification results are displayed on the GUI in real-time at 30 fps.

The demo contains an Analog-Front-End (AFE) module, which includes the PLL and the transceiver chip. AFE is interfaced with a data-acquisition module, which includes an ADC and an FPGA. The preprocessing step and the machine learning model are run on a GPU enabled laptop, where the former runs on the CPU. Both laptop and an FPGA are connected over an Ethernet interface. The machine learning model running on the GPU, requires computation effort of 24 GFlops/sec and 16 MBs of parameter storage. The model was trained with more than 3000 sequences and yielded more than 95% accuracy with an out-of-sample test subjects.

4 Conclusion

In this paper we presented an FMCW radar-based real-time HGR demo, with an event-driven approach to machine learning inference. As a future work, we plan to implement both hardware-specific and hardware-agnostic pipelines in an embedded accelerator.

References

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