Streaming-CNN FPGA Architecture for Communications-based Applications

Andrew Maclellan*, Louise H. Crockett, and Robert W. Stewart
Department of Electronic and Electrical Engineering, University of Strathclyde, Glasgow, Scotland
*a.maclellan@strath.ac.uk

***Abstract*—This demonstration will present a modulation classification application for wireless communications modulation schemes using convolutional neural networks (CNN) developed for the AMD-Xilinx Zynq Radio Frequency System on Chip (RFSoC) running the PYNQ software framework. The CNN was built using a streaming architecture to support wireless communication inputs, operating using fixed-point 18-bit weights, activations and inputs. The CNN weights are all stored on-chip for fast execution. The application is interacted with using PYNQ running on a Jupyter Notebook webpage where the user can select from a range of modulation schemes and visualise plots demonstrating the deployed CNN capabilities.**

***Index Terms*—RFSoC, deep learning, radio, shared spectrum**

I. Introduction

In wireless communications, the amount of available spectrum is reducing as the demand for connectivity increases. The increase of devices such as mobile phones, Internet of Things, smart vehicles, and wearable devices are making sections of the radio spectrum quite congested. Shared spectrum is an approach that aims to optimise the use of wireless communications channels to be shared among multiple users. A core aspect of shared spectrum is spectrum sensing, where a radio device detects other users within the nearby channels in order to transmit with minimal interference. Knowledge of how data has been transmitted from nearby users can assist in the transmission decisions for a radio device. In this work, we present a modulation scheme classifier Convolutional Neural Network (CNN) running on an AMD-Xilinx Zynq RFSoC 2x2 development board utilising a streaming-based architecture [5].

Our CNN is implemented entirely on the Zynq RFSoC chip including all weights and activations and uses 18-bit fixed point arithmetic. The user control and visualisation functionality is designed using the PYNQ software framework [1]. We present the demonstration on a web browser and interface with the development board using Python and interactive widgets. The project is open-source [2].

II. Streaming-CNN Modulation Classifier Demo

This demonstration will present an interactive Jupyter Notebook [3] displayed on a web browser with interactive controls to test various modulation schemes and observe waveforms, classification confidence levels, and confusion matrices captured in real-time from execution on the RFSoC device, similar to those shown in Figure 1. The demonstration supports up to 8 different modulation schemes including: 8PSK, BPSK, CPFSK, GFSK, PAM4, QAM16, QAM64, and QPSK, and allows the user to add noise to the already channel-distorted signals. The overall design of the streaming modulation classifier architecture, which is designed to accept a constant stream of inputs into the receiver, will also be described.

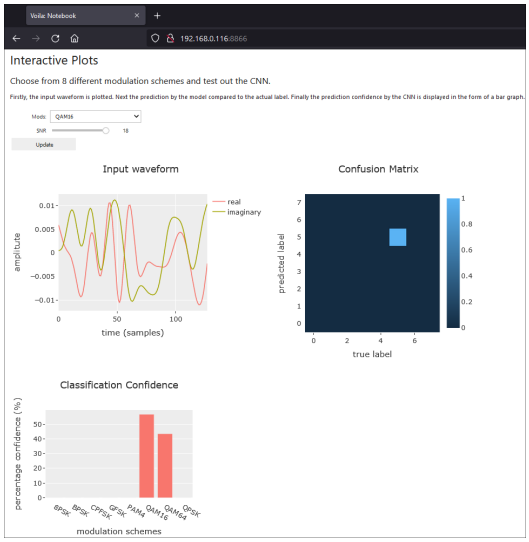

Fig. 1. Jupyter Notebook demonstration.

The testing data used in this demonstration comes from the *DeepSig.ai* RF datasets for machine learning [4]. We use this well-established dataset for direct comparison to other prior work without the need to collect or generate new datasets.

a) Equipment: This demonstration will be presented in person and will run the modulation classification and Jupyter user interface on an RFSoC 2x2 development board [5]. The demonstration does not require an internet connection to run. The demonstration requires: a monitor to show the Jupyter webpage, power outlets to power the board, laptop, and monitor, and a table to rest the items on.

References

[1] AMD. Python Productivity on Zynq, PYNQ. Accessed: March. 28, 2022. [Online]. Available: https://www.pynq.io/
[2] A.Maclellan. Streaming-CNN Modulation Classification Demonstration. [Dataset]. Available: https://doi.org/10.15129/7af1b8b1-8566-460c-86f6-ad4815c4ea53
[3] Jupyter. Project Jupyter — Home. Accessed: March. 29, 2022. [Online]. Available: https://jupyter.org/
[4] Deepsig.ai. RF Datasets For Machine Learning — DeepSig. Accessed: March. 29, 2022. [Online]. Available: https://www.deepsig.ai/datasets
[5] AMD. RFSoC 2x2 kit — RFSoC 2x2. Accessed: March. 29, 2022. [Online]. Available: https://www.rfsoc-pynq.io/