SRPe
Scottish Research Partnership in Engineering

Embedded Processing for Single-Photon Imaging in Autonomous Navigation

Student: Jack Iain MacLean
Institution(s): University of Edinburgh
Supervisor: Dr Istvan Gyongy
Industry Sponsor(s): ST Microelectronics

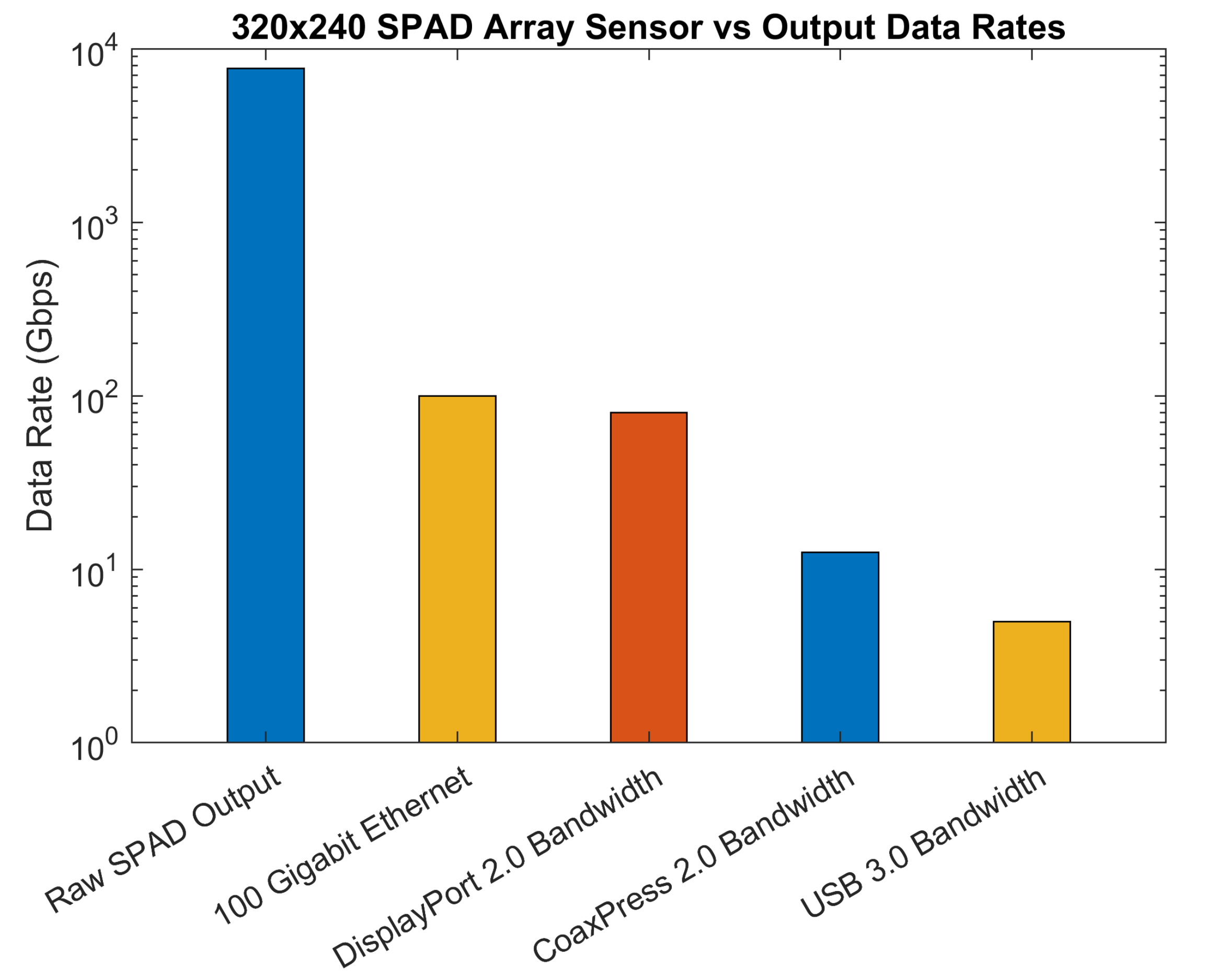

Figure 1: Maximum output data rate from a 320x240 SPAD array sensor vs contemporary data readout solutions

Autonomous systems and robotics require the rapid extraction and robust tracking of objects and features in an environment to operate safely and efficiently. Their vision systems must therefore operate at **high frame rates** and offer a sufficiently large Field of View (FoV). Recent developments in the architecture of **Time-of-Flight (ToF) sensors utilising Single Photon Avalanche Diodes (SPADs)** enables depth data to be captured at **hundreds of frames per second**. However, this high frame rate currently **cannot be fully utilised due to bottleneck issues inherent in off-chip data processing** on a CPU. SPAD based sensors also suffer high power consumption as a result of the high data output due to the 3rd (depth) dimension.

The goal of this project is to **develop signal processing techniques** which can take full advantage of the SPAD-based high-speed ToF sensors while limiting the power consumption, **targeted at robotic and autonomous navigation applications**. The first step is to develop a method of **on-chip data compression** to reduce data rates and power consumption. This will be achieved through methods such as **compressive sensing**, and **event generation** based on SPAD firings (similar to the human eye) as opposed to the conventional frame-based sensing approach. The second is to design and implement an **asynchronous spiking neural network on a Field Programmable Gate Array (FPGA)** board to interpret the scene and perform the required navigational guidance.
The system will aim to have a **total power consumption of less than one watt** and then be **implemented on a robotic vehicle/drone** to demonstrate the fast object detection/localisation which enables it to **take evasive actions with only millisecond latency**.

Asynchronous Approach

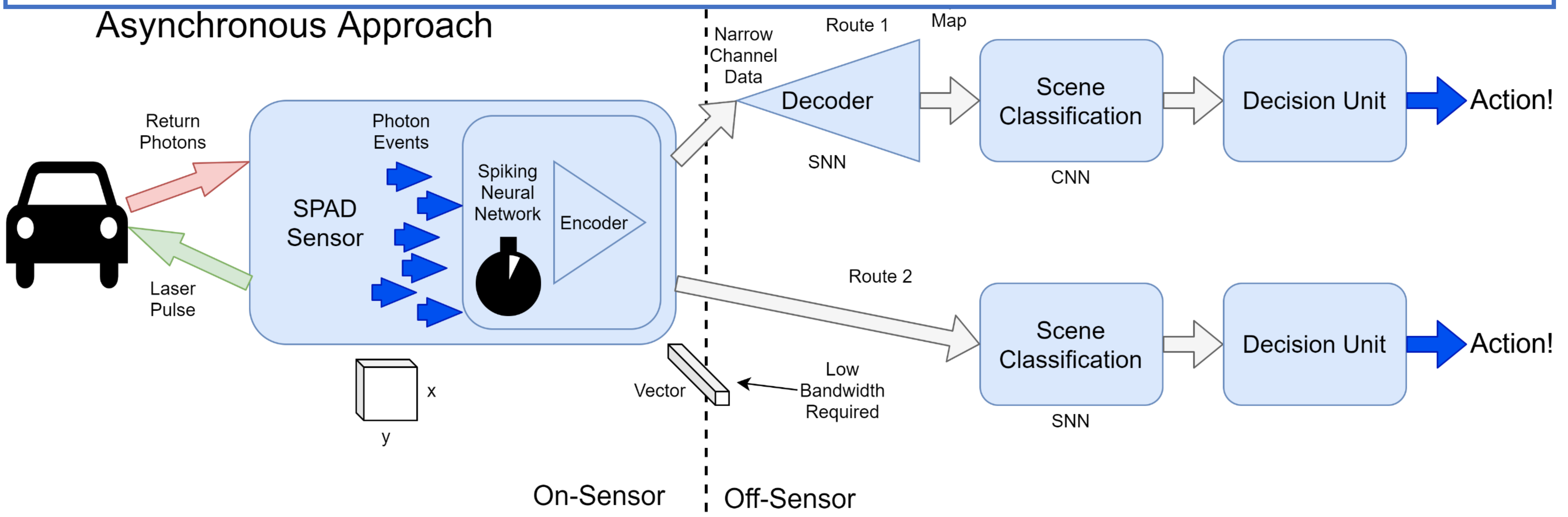

Figure 2: Illustration of the asynchronous approach to processing SPAD events in automotive LiDAR. The first step is to perform initial interpretation of the photon events using an asynchronous Spiking Neural Network (SNN), which will then compress the information for readout. This compressed form can then be processed two ways. The first is to decode the information using the SNN and then process the information using a synchronous neural network. The second is to perform all the interpretation on the compressed data while using an SNN.

The end result of this research will to have a system which is capable of asynchronous reaction to changes in a dynamic scene. This will **increase the safety for pedestrians and passengers alike** if the sensor is implemented on a self driving vehicle as it will allow faster updating of the vehicles navigation. The low power consumption make it applicable to be implemented on the smallest autonomous vehicles, allowing for more applications to benefit from faster vision.

Scottish Funding Council
Promoting further and higher education