Computer Engineering Lab

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Computer Engineering Laboratory

- Focuses on how to use FPGAs to solve demanding problems: novel architectures, applications and design techniques for problems combining signal processing and machine learning
- Expertise
  - Deep neural network acceleration
  - Time series prediction
  - Signal processing
  - FPGA design
- Collaborations
  - Xilinx, Intel, Exablaze
  - Defence, TASDCRC and DSTG
  - clustertech.com
- Ex-students
  - Waymo, Intel, Synopsys

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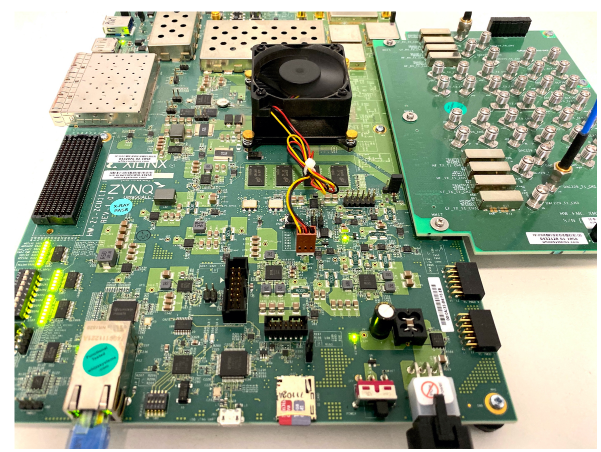
Motivation for FPGAs

› Field programmable gate arrays (FPGAs) are COTS, user-customisable integrated circuits

› They offer an opportunity to provide ML algorithms with higher throughput and lower latency through

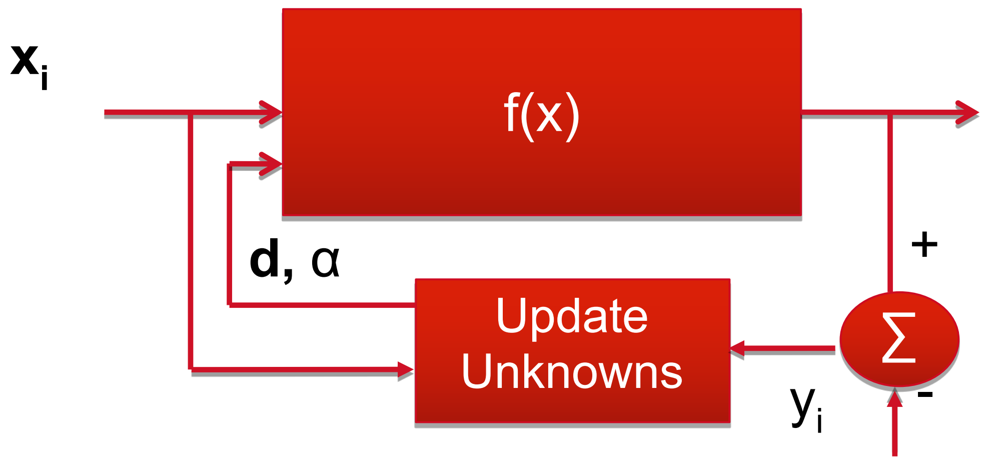
- **E**xploration– easily try different ideas to arrive at a good solution
- **P**arallelism – so we can arrive at an answer faster
- **I**ntegration – so interfaces are not a bottleneck
- **C**ustomisation – problem-specific designs to improve efficiency

› **Describe some of our work on ML hardware implementations that use these ideas**



Exploration: Kernel Methods

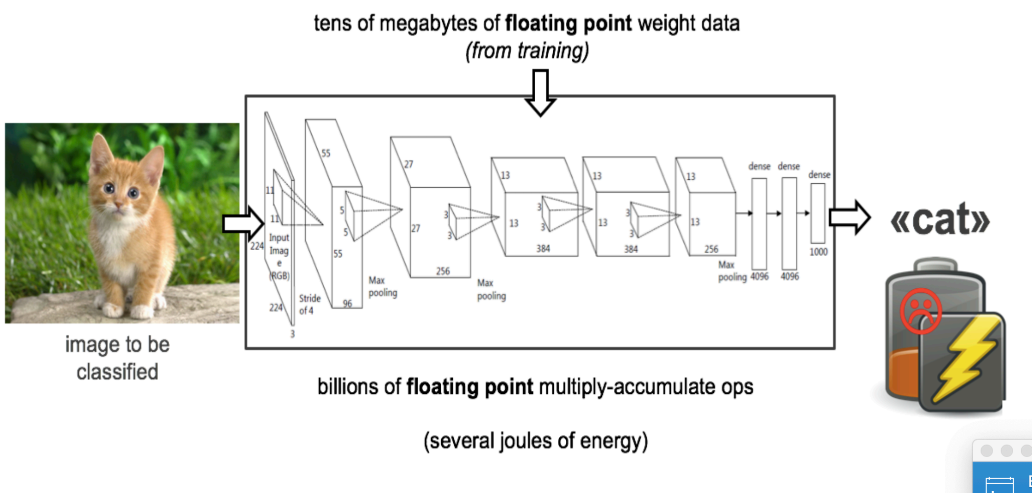
ARC Linkage with Exablaze



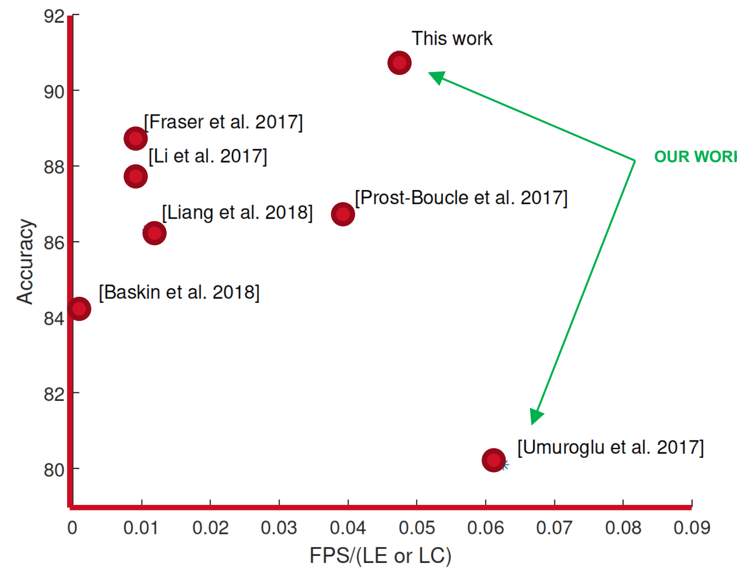
- A family of kernel methods that can do simultaneous learning and inference
  - Highest reported throughput 80 Gbps (TRETS'17)
  - Lowest reported latency 80 ns (FPT'15)
  - Higest capacity (FPGA'18)

Parallelism: Binarized Neural Networks

Collaboration with Xilinx



$$\underbrace{\begin{bmatrix} -0.4 & -0.4 & 0.9 \\ 0.9 & 0.4 & 0.8 \\ 0.4 & -0.4 & -0.4 \end{bmatrix}}_{W} \approx 0.2 \underbrace{\begin{bmatrix} -1 & -1 & 1 \\ 1 & 1 & 1 \\ 1 & -1 & -1 \end{bmatrix}}_{\alpha W^B}$$

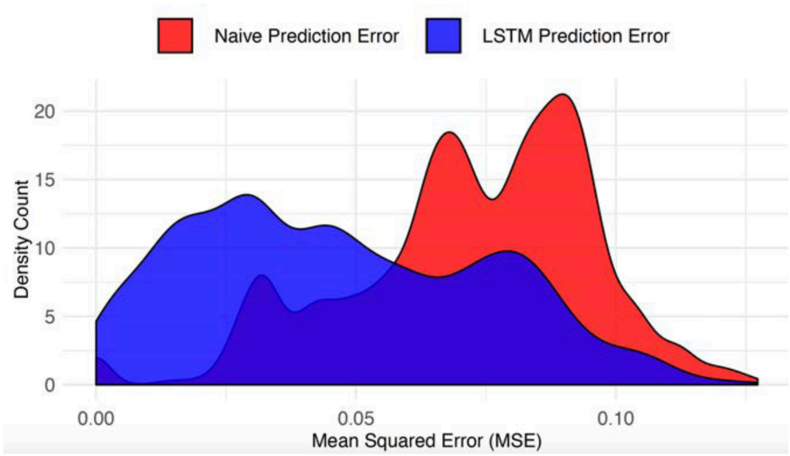


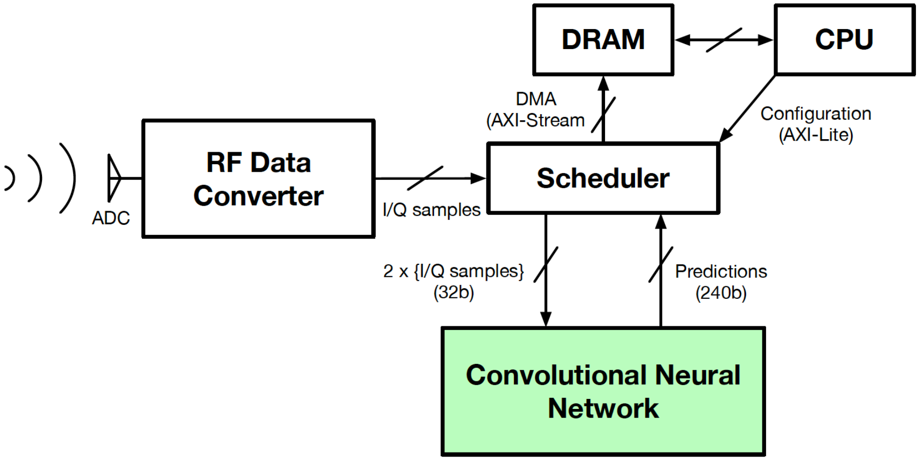
Ours is the most accurate and fastest reported FPGA-based CNN inference implementation CIFAR10: 90.9% acc, 122K fps (TRETS'19)

Integration: Radio Frequency Signals

Next Generation Technology Fund

- Processing RF signals remains a challenge
  - FPGAs allow integration of radio, machine learning and signal processing





LSTM Spectral prediction: 4.3 μs latency on Ettus X310 XC7K410T (MILCOM'18)

Ternary Modulation classifier: 488K class/s, 8us latency, Xilinx ZCU111 RFSoC (FPT'19)

Customisation: High Dynamic Range Signals

Defence Innovation Hub

- Implementation of a neuromorphic high dynamic range camera-based object detector on FPGAs
- Significantly improved accuracy in high contrast situations

Summary

- Machine learning will enable intelligent sensors and control system crucial to trusted autonomous systems
  - Combine conventional sensors, e.g. radar, lidar, video, radio with powerful object recognition and scene interpretation ability i.e. ML at the edge
- FPGAs offer EPIC (exploration, parallelism, integration, customization) advantages for miniaturization, reduced energy, and improved performance in such applications

Slides & papers: http://phwl.org/research

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