Project Proposal

Machine Learning on FPGA on a Drone

ELEC 491 Capstone Team 109
University of British Columbia

Deutsch, Peter   He, Muchen   Hsueh, Arthur
`me@peterdeutsch.ca`   `i@muchen.ca`   `ah11962@outlook.com`
Wang, Meng   Wilson, Ardell
`wzfftxwd@gmail.com`   `ardellw96@gmail.com`

`TODO: UBC and Client branding image here`

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Revision History

Revision history written here.

Version #	Initials	Release Date	Changes Made
0.0	MH	2019-09-30	Initial skeleton of the document.
1.0	MW	2019-10-08	First draft

Contents

Terms and Abbreviations

Technical terms and abbreviations dictionary go here.

List of Figures

List of Tables

1   About This Document

Briefing for this section.

1.1   Purpose

FIXME (requires editing)

The purpose of this document is to solidify the project outline, objective and requirements. It is meant to

1.2   Intended Audience

The intended audience is the client so that the client can confirm the requirements of the project is as they expected. It is also intended for the instructors and the TAs of our capstone team, such that they may aid us accordingly.

Furthermore, the document is also intended for our own teammates as a reference throughout the duration the milestones of the project.

1.3   Reading Guide

How to read this document.

2   Background

This section outlines the context of the project. It will go over the background of the suitor, and the project the suitor is proposing.

2.1   Business Background

As the project is a proof-of-concept research project, the business aspects typical to real-world engineering projects should not be applicable.

The suitor of this project is a team of undergraduate students at the University of British Columbia (UBC). The name of the team is Skynet. The members of Skynet are all students in the Faculty of Applied Science in discipline of Electrical and Computer Engineering. The members of Skynet are all students taking the fourth year Engineering capstone course (ELEC491/CPEN491) at UBC, in which they have been assigned this engineering project. Relating to the context of the project, the members of Skynet all have experience working with FPGAs, and in RTL design.

2.2   Project Context

The proposed project is an examination of the feasibility of deploy trained machine learning model on board using field-programmable gate arrays(FPGAs) to the drone.

The ML implementation will focus on video processing for the object tracking component of this project.

The ground of the project is to expand on the application and possibilities for ML. FPGAs can have higher performance against conventional software and GPU applications. FPGAs also have lower power consumption and the capability of reconfiguration. This makes FPGAs a great option for a mobile computing platform. Implementing an FPGA for autonomous object tracking on a drone can streamline many potential processes, such as disaster response, wildlife management and demographic studies.

3 Objectives, Constraints, & Goals

This section elaborates the objectives to be pursued in the project, constraints that limit the project scope, and the goals to be achieved.

The definition that the student team will use will be as follows:

- **Objectives**: Also referred sometimes as *requirements*. These are a list of *yes-or-no* qualities that the student team would like to achieve in order to consider the project as "successful".

- **Constraints**: The constraints are limiting factors that affect the variability of our success, and to what extent our goals can be achieved.

- **Goals**: Goals are quantitative specifications that would be ideal to achieve; they are the target specification the student team is aiming for, but is not necessary for the project to be considered successful.

3.1 Objectives

The main objectives have been separated into three categories.

Machine Learning Implementation on the FPGA

- The FPGA and its connected hardware receives usable video data.

- Adequately implemented datapath and or processor to facilitate data-flow.

- Adequately implemented machine learning model such as CNN, RNN, or YOLO in hardware.

- Video can be processed in real time with help of reduced frame rates and or resolution.

Integration of Electronics with the Drone

- The total package of the electronics and hardware (that is, equipment used to gather, process, and transmit video data) is reasonably compact and deployable on a drone.

- Total power draw is reasonable.

- Total power output (heat) is reasonable.

Video Transmission to Ground Station

- Video stream is able to be received from the ground station along with processed ML data.

- Transmission in the chosen frequency bands is legal (no further actions required if 2.4GHz or 5.2GHz is used).

3.2 Constraints

In pursuit of the objectives listed above, the main constraints relating each main objective is as follows:

The most important constraints are the non-technical ones. The project described here is considered very large in scope. The limited 8-months period is extremely limiting and thus will affect design decisions. The budget is a significant constraint which will affect the components and parts the student team chooses.

The FPGA is a highly adaptive device that can deliver almost-ASIC level speed but a large number of logic elements are required to implement a large model such as a machine learning - computer vision - model. The inherit constraints with FPGA RTL designs such as timing, area, and power constraints will ultimately limit the processing throughput of the video data. Bottleneck for limiting processing resolution and frequency (frame rate).

Common machine learning models for computer vision is designed for GPU to maximize parallel computing. The FPGA cannot match GPU data throughput, thus the limited amount of logic elements would also constrain our architecture design.

The physical form factor of the payload (FPGA, electronics, camera, and transmitter) is an important constraint. Since the purpose of the project is to validate the viability, the payload should be light and compact such that it can be carried on a drone for a reasonable flight time to carry out applications.

The bandwidth of video transmission is also limited by transmission frequency. The range of transmission is constrained by transmission power which is limited by power draw and heat.

3.3   Goals

The main goal is by the end of the project, have a working implementation of a ML computer vision model, capable of object detection and spacial object tracking implemented on a commercial FPGA. The number of logic elements required to implement video processing, video transmission, and other data tasks are within the hardware limit allowed by the budget. The implementation is capable of being mounted on a drone and perform ML tasks continuously and autonomously. Both the unprocessed (raw) and processed data are to be transmitted wirelessly using 2.4GHz WiFi to a ground station, which could be a laptop computer, or a mobile phone. The transmitted video data should have reasonable quality of at least 640x480 resolution and at a reasonable frame rate – at least 10 fps. The total take-off weight of the drone along with the processing hardware should not exceed 25 kilograms (as specified by Transport Canada, a pilot with *Basic Operations* certificate or *Advanced Operations* certificate cannot operate a drone heavier than 25kg). Lastly, the flight time of the drone is at least 1 minute and can fly to an altitude of at least +10m to prove the viability of the concept explored in this project.

4   Project Plan

4.1   Final Milestone & Ultimate Deliverables

The project will conclude on **April 3rd, 2020**, at which point the following project deliverables will be provided to the project stakeholders (the Client and Instructors):

1. The drone prototype, a (unified) device which:

    (a) Captures video using an on-board camera,

    (b) utilizes FPGA-based neural network accelerators to processes the captured video using an FPGA (optionally with an embedded hard-processor) - computing the position of one or more (human) pedestrians in the captured video,

    (c) transmits the captured video and the associated pedestrian-location metadata to an external base-station,

    (d) and is mounted to a drone which is controlled remotely by a human and is capable of flying at least 5 minutes.

2. The base-station prototype, a device which:

    (a) Receives the wirelessly transmitted video and the associated pedestrian-location metadata,

    (b) displays the video on a screen, overlaying the pedestrian metadata in the form of *bounding boxes*,

    (c) and stores the video for further research/analysis

3. A technical dossier comprising of the following documents:

    (a) *Requirements Specification* - Outlining the functional/non-functional requirements of the product

    (b) *Design Specification* - Describing the high-level architecture and designs for technical subsystems

    (c) *Validation Specification and Results* - Describing system test architectures and results

    (d) *Operations, Maintenance, and Upgrades Specification* - Outlining FAQs, installation instructions, recommended maintenance, and troubleshooting steps

    (e) *List of Deliverables*

4. A video describing and demonstrating the product

5. A presentation and accompanying poster outlining the project

6. All source code and generated netlists

4.2 Intermediate Milestones

In order to mediate and review the project's progress as it progresses, three intermediate project milestones have been defined. In addition to the additional deliverables described below, all milestones necessitate the delivery of in-progress key documents (Requirements, Design, Validation, Operations, and List of Deliverables) in addition to an oral presentation summarizing progress to date.

4.2.1 Milestone I

Milestone I (**October 15th, 2019**) requires the production of a Project Proposal (*this document*), which outlines the baseline agreement among all stakeholders with regards to what is to be accomplished.

4.2.2 Milestone II

Milestone II (**November 25th, 2019**), the first prototype review, will outline our initial progress in implementing both video capture and neural accelerator circuitry on our selected FPGA platform. Depending on our progress, we will either demonstrate each of these components separately (i.e. displaying captured video on a screen while processing an unrelated ML task) or, preferably, demonstrate these components in a unified fashion (i.e. display captured video and process it to some extent using our ML infrastructure).

4.2.3 Milestone III

Milestone III (**February 10th, 2020**), the second prototype review, will demonstrate our continued progress in improving our video capture/neural accelerator, in addition to presenting our initial platform-mobility implementations: especially focusing on our video transmission and power-supply circuitry (including battery packs).

4.3 Major Responsibilities

4.3.1 Team Responsibilities

The student team is responsible for both day-to-day and overarching operations of the project, including (but not limited to):

- Ultimate construction of the prototype(s)

- Researching related and pre-existing solutions

- Financial management, including purchasing all required materials and devices

- Creation and maintenance of requisite deliverable documentation

- Documentation and coordination of group and client meetings

4.3.2 Client Responsibilities

The client is expected to:

- Be available to meet in-person or online given reasonable notice (72 hours)

- Provide additional education/training on machine learning and neural networks, if required

- Provide additional financial support, if required (see budget section)

4.4 High-Level Tasks

4.4.1 Team Tasks

- Gather the footage form the camera to the FPGA.

- Train the machine learning model of object detection.

- Deploy the trained model on board using FPGA.

- Send the result back to the ground station.

- Verify the result.

4.4.2 Client Tasks

- Provide technical suggestions.

4.5 Schedule

4.5.1 Major Schedule

Milestone I - 1 week

Milestone II - 6 weeks

Milestone III - 12 weeks

4.5.2 Weekly Schedule

Weekly team meeting on Tuesday at 3:30PM.

Weekly meeting with instructor on Thursday at 4:30PM.

Client meeting: by appointment.

4.6 Budget

The department provides a budget of $650.

The following table lists the items required for this project.

Table 1: Required items

Item	Estimated Price	Remark
Camera	$30	Camera Module
Transceiver	$10	2.4G Transceiver

Continued on next page

Table 1 – *Continued from previous page*

Item	Estimated Price	Remark
Drone	$150	JJRC H68 Drone
FPGA	$300	Price estimated based on the price of the DE1 board

4.7 Quality Goals

4.7.1 Durability

The mean time between failures of the product is more than 500 hours.

4.7.2 Efficiency

The power of the whole platform is reasonable to ensure at least 10 minus of flight time.

4.7.3 Performance

The throughput of the video processing unit is more than 30 frames per second.

4.7.4 Accuracy

The result from the machine learning model has an accuracy above 95%.

4.7.5 Availability

The product can work up to 10 meters altitude under sunny, cloudy, and windy conditions.

4.7.6 Completeness

The final product is excepted to be able to perform the object detection on board. It should provide clear evidence on the feasibility of the concept of deploy the machine learning model on board using FPGA.

4.8 Risk Profile

Table 2: Risk profile

Risk description	Likelihood	Impact	Risk
Muchen become hostile	1	1	1
FPGA logic capacity is not enough to implement our solution.	0.5	0.5	0.5
Electronics and battery are too heavy for the drone to take off.	0.5	0.5	0.5
Drone cannot take off at all due to drone hardware failure.	0.5	0.5	0.5
Accidents that damage to drone and FPGA that leads to extra budget that we may not have.	0.7	0.7	0.7
Forced to buy cheaper components which leads to lower performance.	0.8	0.8	0.8
Deliveries is not meeting client's expectations	0.2	0.2	0.2

Table 2 – *Continued from previous page*

Risk description	Likelihood	Impact	Risk
Knowledge and skill (Machine Learning and Computer vision) required for project is not sufficient.	0.5	0.5	0.5
Our scrum method is not efficient	0.5	0.5	0.5
Scope of the project is underestimated which leads to burn outs	0.5	0.5	0.5
Not have enough money.	0.5	0.5	0.5
Not enough time commitment from team member due to other courses.	0.5	0.5	0.5
Team is indecisive which leads to delay - management is not good enough to make a timely decision.	0.4	0.4	0.4
Team has lack of communication and make assumptions which leads to incompatibility	0.4	0.4	0.4
Documentation is not specific / complete.	0.7	0.7	0.7
Not enough time to work on documentation.	0.7	0.7	0.7
Peter become hostile	0.5	0.5	0.5
Scope of the project is overestimated which leads to diversification of vision of the project.	0.5	0.5	0.5
Not enough machine learning training data.	0.5	0.5	0.5
Arthur becomes hostile	0.5	0.5	0.5
Wilson becomes hostile	0.5	0.5	0.5
Illegal to fly drone.	0.3	0.3	0.3
New technology or research that changes the scope significantly	0.3	0.3	0.3
Technical debt paydown impact project timeline.	0.4	0.4	0.4
Software license does not allow our application to be delivered.	0.3	0.3	0.3
Key hardware components not available	0.2	0.2	0.2
Machine learning resources lack documentation	0.3	0.3	0.3
Camera lack documentation	0.3	0.3	0.3
FPGA lack documentation	0.3	0.3	0.3
Delivered documentation not adequate for usage and upgrade.	0.5	0.5	0.5
Selected software methodology creates issues with team member that decreases productivity	0.2	0.2	0.2
Legal changes significantly affect project - drones in particular	0.2	0.2	0.2
The final product cannot be maintained or extended.	0.7	0.7	0.7
Client becoming hostile	0.2	0.2	0.2
Client wants to modify scope and requirements that leads to delays or cut features.	0.2	0.2	0.2
Development environment is inadequate.	0.2	0.2	0.2
Sabotage	0.1	0.1	0.1
Loss of client	0.1	0.1	0.1
Loss of team member	0.1	0.1	0.1
Equipment shipment is delayed or lost.	0.1	0.1	0.1
Client is not available enough to provide significant help.	0.1	0.1	0.1
Competitive offerings affect project requirement	0.1	0.1	0.1
Camera doesn't work with FPGA	0.1	0.1	0.1
FPGA doesn't work with transmission systems	0.1	0.1	0.1
Ardell becomes hostile	0	0	0

5　Approval

5.1　Acceptance Statement

5.2　Client Identification

5.3　Capstone Team Identification

References