Project Proposal

Machine Learning on FPGA on a Drone

ELEC 491 Capstone Team 109
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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.

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 suitor proposing this project is not a business, the business aspects typical to real-world engineering projects should not be applicable.

The suitor of this project is a team of undergraduate students studying at University of British Columbia (UBC) under the name Skynet. The members of Skynet are all students in the Facutly of Applied Science in disciplines 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 assgined 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 autonomous airborne object tracking through integration of Machine Learning (ML) into field-programmable gate arrays (FGPAs) on a independent mobile deployment vessel, such as a drone. The ML implementation will focus on video processing for the object tracking component of this project.

The grounds of the project is to expand on the application possibilites for ML. FPGAs offer faster performance against conventional software and GPU applications, as well as lower power consumption and the capbility of reconfiguration. This makes FPGAs desirable as an option for an autonomous computing platform. Implementing an FPGA for autonomous object tracking on a drone can streamline many potential proccesses, 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 refered sometimes as *requirements*. These are a list of *yes-or-no* qualities that the student team would like to achive 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 constrainted 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 groundstation, which could be a laptop computer, or a mobile phone. The transmitted video data should have reasonabler 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 Resposibilities

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

4.4.2 Client Tasks

4.5 Schedule

4.6 Budget

The specifics of budget is not determined. But we do get $650 for the entire capstone team to start.

4.7 Quality Goals

4.8 Risk Profile

5 Approval

5.1 Acceptance Statement

5.2 Client Identification

5.3 Capstone Team Identification

References