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Research paper

FPGA-based Object Detection and Classification of an Image

Cesar A. Llorente[1]*, Elmer Jose P. Dadios[2], Jeric Adrian B. Monzon[3], Wiljay E. De Leon[4]

[1]Electronics and Communications Engineering Department, De La Salle University
**Corresponding author E-mail:cesar.llorente@dlsu.edu.ph*

Abstract

Multi-core ARM processors built-in in new FPGA (Field Programmable Gate Array) devices are becoming common-place in recent years, and are used in Embedded systems in image and video processing applications. Image detection and recognition applications such SIFT, BoF, and SVM algorithms written in python can be implemented in these devices. In this study, a standalone FPGA-based system that detects and classifies objects in an image is presented. Linux Ubuntu operating system is configured on the FPGA board where it runs the object detection and classification algorithms implemented in python. Based on the results the system is able to detect and classify three categories of objects in an image.

Keywords: *FPGA; Object Detection; Object Classification; Object Association; Zedboard.*

1. Introduction

Objects are always associated with humans whenever they travel. We can see people going to buildings and public transportation every day and security will not be able to remember everyone and their associated belongings. Security cameras are widely used for security measure but they are often just used for recordings. Common security measures today require personnel to handle the security camera and based on their observation and decision, they will check and monitor the video or images.

Advancement in technology has enabled more robust yet computationally intensive algorithms that can be realized in embedded platform with reasonable performance. This progress has made automated surveillance system popular in the research community in recent years. The advantage by automated surveillance system lies in the fact that it is a self-contained system capable of automatic information extraction and processing. Applications such as traffic control and security surveillance can take advantage of the development in FPGA-based embedded systems. One FPGA Development boards commonly used in the academic community is the Zedboard [1]. An embedded system can be synthesized using the Vivado Development Tool suite from Xilinx [2]. A Linux operating based on the Ubuntu 12.04 distribution can be installed into the system along with the OpenCV library and Python compiler [3]. The SIFT (Scale Invariant Feature Transform) [4], BoF (Bag of Features) [5], and SVM (Support Vector Machine) [6] algorithms are used in object detection and classification.

In this study, the Zedboard FPGA Development board is configured for the detection and classification of objects associated with human object in an image. With Ubuntu Linux operating system running on the Zedboard, a detection and classification application using the OpenCV library is developed. Dataset containing the images to be detected and classified will be created as the training set and test set.

2. Related Works

Object detection in images has been the focus of research in recent years. A survey on background modelling using local pattern methods in order to detect moving objects in an image is provided in [7]. Using "priori knowledge" of objects in the satellite images, [8] detects and recognised objects by creating a Bag-of-Words that describe known objects in the image. A variation of the SIFT algorithm is proposed by [9] where object detection and tracking is based on SURF (Speeded Up Robust Feature) algorithm. By combining the method with image difference method to model the background, the author claimed an improvement in terms of the speed of operation.

Implementation of different object detection algorithms in hardware in order to achieve real-time performance, have been reported in literature. The SIFT algorithm was implemented in an FPGA by [10]. Background subtraction on FPGA was reported in [11] and video segmentation in FPGA was implemented in [12]. Human object detection and moving object detection were reported by [13] and [14] respectively. The implementation of the OpenCV library for foreground and background identification was reported in [15]. This study implements the SIFT algorithm as an application running an Ubuntu Linux operating system on a Zedboard FPGA Development board.

3. Methodology

The Scale Invariant Feature Transform also known as SIFT is considered for implementation. Developing the object detection system requires two main parts: the Hardware and the Software. The hardware part is an embedded system based on the Zynq architecture built on Zedboard is shown in Figure 1.

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Fig. 1: The Zedboard FPGA Development Board.

3.1. Dataset

The dataset is composed of three categories namely, bags, books and boxes. These objects are carried by human subject. The original image will be outputted in an HDMI monitor and classification will be outputted through a serial UART port.

3.2. Test setup

Figure 2 shows the test setup composed of the Zedboard, an HDMI monitor, a keyboard and mouse. A USB hub is connected to the OTG USB port of the zedboard in order to connect the USB keyboard and mouse. The zedboard has an HDMI port that allows an HDMI monitor to be connected.



Fig. 2: Test setup

3.3. Development Flow

Developing the object detection system using an FPGA requires two main parts: the Hardware and the Software. The hardware part is the development of an embedded system and is configured using the Vivado design suite and downloaded to the FPGA. The software part include the application software that implements the SIFT algorithm. This process flow is illustrated in Figure 3.

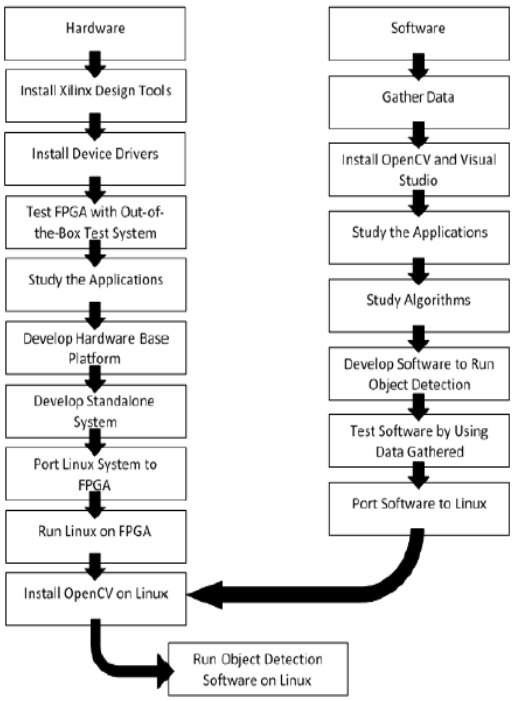


Fig. 3: Development Flow

3.4. Hardware Platform Development

A reference design was used to develop the embedded system based on the Zynq architecture for the zedboard [16]. The reference design is compiled using Vivado.

3.5. Configuring Linux on the Zedboard

After the hardware is configured, the bootloader [17] is configured to allow the Linux operating system to boot on the zedboard. Once the bootloader is configured, an SD card is formatted to hold the boot files and the Linux operating system filesystem.

4. Results and Discussion

Test is carried out by inputting the image file to the system. The system will display the image on the monitor screen and output the test message of the classification result through the hyperterminal. 15 images were tested for each category; the accuracy can be seen in table 1.The errors appear because of the dimensions and similarities between the books and bags. When the SIFT algorithm collected their keypoint features, they appeared to be similar which is why the program thought of the books to also be a box. The simplistic design of the box appears to be a square or rectangle which is very similar to the books causes the number and feature of keypoints to be similar. This is why we get a 0% accuracy rate in the books category. It is also true to some cases that the plastic bags or paper bag is shape similar to a box and output the box category.

Table 1: Accuracy of classification

Bags	Box	Books	Human only
12 correct	13 correct	0 correct	15 correct
80%	86.7%	0%	100%

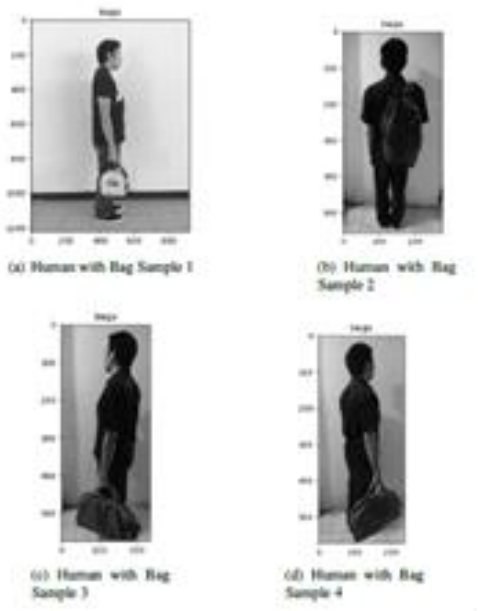
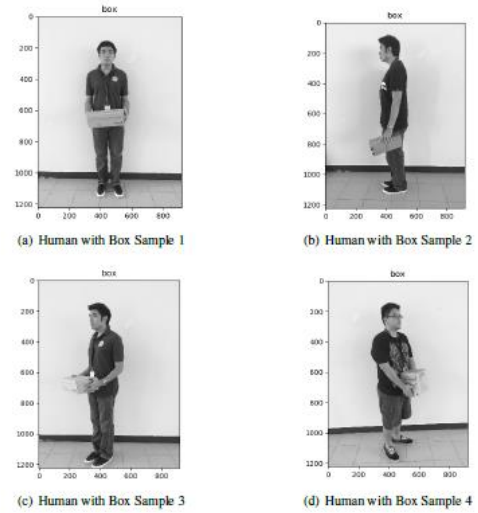


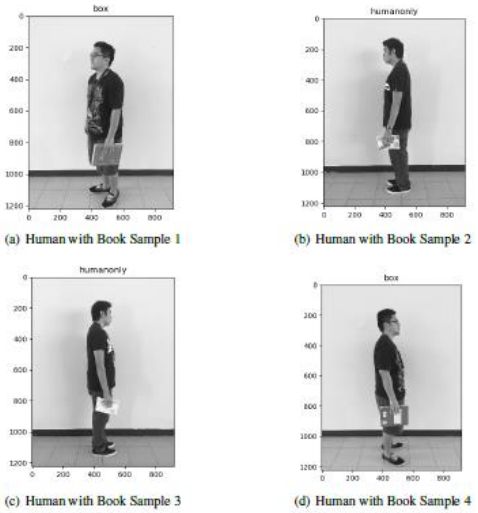
Fig. 4: Human with bag



(a) Human with Box Sample 1 (b) Human with Box Sample 2

(c) Human with Box Sample 3 (d) Human with Box Sample 4

Fig. 5: Human with box



(a) Human with Book Sample 1 (b) Human with Book Sample 2

(c) Human with Book Sample 3 (d) Human with Book Sample 4

Fig. 5: Human with book

5. Conclusion

In this work, the SIFT algorithm is implemented as a python program running on Zynq processor hosted in an FPGA platform running Ubuntu 12.04 operating system. This demonstrates that a stand-alone object detection system can be implemented on an FPGA-based embedded system. This project can find application on portable surveillance system.

There are several prospect related in this research that may be extended for further studies. So the suggested topics are listed in the following.

1. Utilize the implemented platform to develop and implement OpenCV algorithms to hardware using the Xilinx Vivado high-level synthesis tools.
2. Create device drivers and application programs for the hardware that will utilize this platform.
3. Automated Security Camera Systems via Software Programs on FPGA.
4. FPGA-Based Video-Streaming Object Detection System.
5. Porting Other Operating System in FPGA for OS Limited Applications.

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