Hardware Implementation of a Background Modelling Algorithm

Author: Alvin Yeap (3098701)
Supervisor: A/Prof David Taubman

What is Foreground-Background Segmentation?
This is the process of distinguishing and highlighting foreground objects from the background scene in a video sequence.

What is a Background Modelling?
The most effective method of performing Fg-Bg Segmentation is to understand and model the background in some way. More specifically, the background scene is represented by one or more parameters that defines its characteristics. The parameterization of the background is called Background Modelling.

Motivation
Video surveillance has become commonplace in modern society and has been shown to dramatically reduce crime in populated areas.

However, traditional analog video surveillance systems rely heavily on the attentiveness of their human operators and are costly to operate. As computational power escalates and the cost of hardware decreases, providing ‘intelligence’ to cameras by means of algorithmic detection becomes increasingly viable.

Foreground-background segmentation alone is useful for highlighting activities in the scene, and therefore permits significant reductions in storage needs. Furthermore, it serves as a fundamental component in many higher-level processes such as object tracking and facial recognition.

The Two Weights Algorithm
The Two Weights Algorithm uses intensity information to form a background model. The background model is constantly evolving and adapts at different rates according to segmentation results of previous frames.

The Two Weights Algorithm is characterized by the following equations:

\[ d(n+1) = i(n) - b \cdot i(n) \]

\[ m(n) = \begin{cases} 1 & \text{if } d(n) > \text{Threshold} \\ 0 & \text{otherwise} \end{cases} \]

\[ b(n+1) = a \cdot b(n) + (1 - a) \cdot i(n) \text{if } m(n) = 0 \]

\[ b(n+1) = a \cdot b(n) + (1 - a) \cdot i(n) \text{if } m(n) = 1 \]

Hardware Implementation
A Terasic DE2 Board was used to realize a hardware design of the Two Weights Algorithm. A Nios II Soft Processor was synthesized onto a Cyclone II FPGA.

Several custom modules were required to perform the functions of the Two Weights Algorithm. Design focused on minimizing memory usage and increasing throughput.

Several Nios peripherals were designed to achieve these goals, thereby minimizing load on the processor.

A Better Background Model
The intensity image used in the Two Weights Algorithm does not capture sufficient information to deal with a complex or ambiguous circumstances such as moving objects in the background, or homogenously-bright foreground objects.

An investigation was undertaken to find a more effective background model utilizing a classification system developed early in the project.

Four information ‘bases’ in the video sequence were tested for efficacy:
- Intensity
- Colour
- Intensity & Spatial Regions
- Intensity, Colour & Spatial Regions

Gaussian distributions were used to model dependence between parameters.

RGB Colour information was found to give the best error performance.

Outcomes
- A compact and memory efficient implementation of a background modelling algorithm – the Two Weights Algorithm.
- A classification system for existing background modelling algorithms based upon the information exploited to segment images.
- An investigation to find a more effective background model. A colour-based Gaussian model was found to have the best performance. Hardware considerations were explained.