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Research Report on FPGA-Based Intelligent Architecture for Moving Object Detection Using PCA

This report examines the research article titled "An Intelligent Architecture Based on Field Programmable Gate Arrays Designed to Detect Moving Objects by Using Principal Component Analysis" by Ignacio Bravo et al. The article, published in Sensors 2010, presents a novel architecture for real-time detection of moving objects using the Principal Component Analysis (PCA) algorithm implemented on Field Programmable Gate Arrays (FPGAs). The research, conducted by the Electronics Department at the University of Alcala, Spain, introduces a parallelized approach to the PCA algorithm, enabling high-speed image processing and reliable hardware integration with commercial CMOS sensors.

Introduction

The demand for real-time image processing in computer vision applications has surged due to the increased resolution and frame rates of CMOS sensors. Traditional sequential processing on conventional computers struggles to meet the computational demands of these applications. To address this, the authors propose a specialized hardware platform using FPGAs, which allows for efficient parallel processing and high-speed computation.

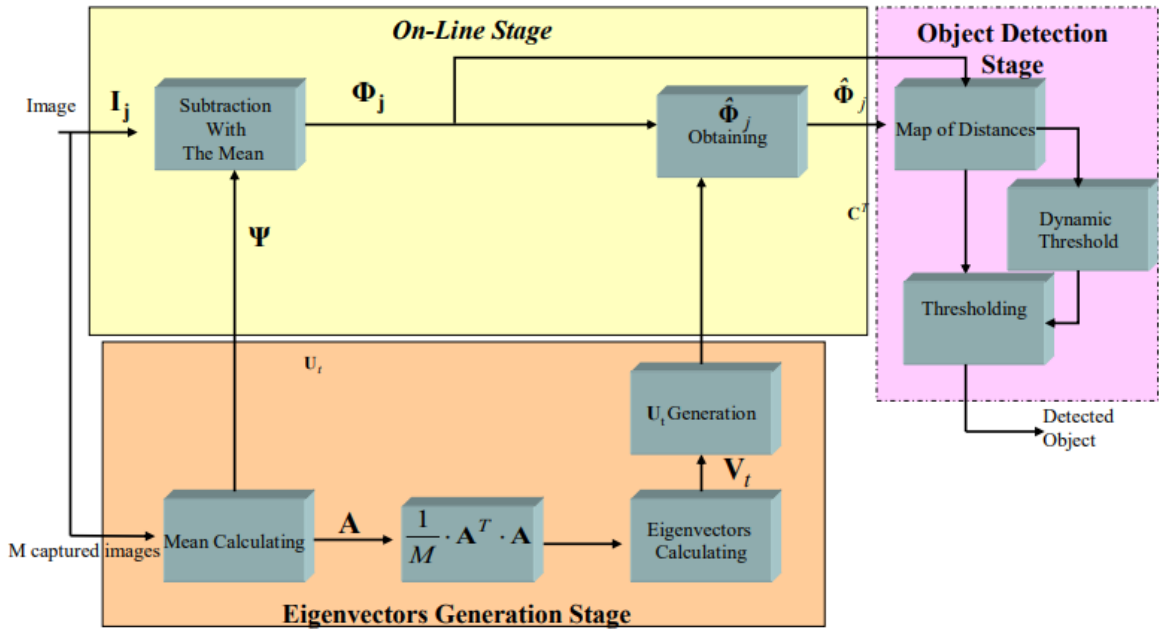

Figure. Block diagram of the PCA algorithm implemented on an FPGA.

FPGA Feature Highlights

1. Parallelization of PCA Algorithm: The classical sequential PCA algorithm has been parallelized to leverage the FPGA's parallel processing capabilities. This includes the computation of the correlation matrix, matrix diagonalization using the Jacobi method, and subspace projections of images.

2. Hardware Implementation of PCA Stages: The research involves the specific development and implementation of hardware for each stage of the PCA algorithm. This includes the calculation of eigenvalues and eigenvectors, matrix multiplication, and the dynamic thresholding for moving object detection.

3. Motion Detection Algorithm: An FPGA-based motion detection algorithm is presented, which dynamically thresholds the differences between the input image and the PCA-generated background model.

4. High Processing Speed: The proposed system achieves up to 120 frames per second, significantly enhancing the real-time processing capabilities for applications requiring immediate analysis and tracking.

5. Embedded and Reliable Architecture: The architecture is designed to be autonomous and reliable, eliminating the need for a PC in the processing loop, which is beneficial for standalone systems.

Technical Details

FPGA Device: The research utilizes a Xilinx V2P7 FPGA, which is considered medium/low-end, demonstrating the feasibility of implementing complex algorithms on cost-effective hardware.

Image Processing: The system captures images using a high-speed CMOS sensor and processes them on the FPGA, which includes the generation of eigenvectors, on-line processing, and object detection stages.

Dynamic Thresholding: A new method for dynamically calculating the threshold for object detection is proposed, which adapts to the scene's features and lighting conditions, reducing false positives.

Results and Conclusions:

The system's performance was validated with a test bank of 1,000 images, achieving a remarkable accuracy of around 97% true matches. The research concludes that the FPGA-based architecture significantly improves the efficiency and speed of PCA-based object detection, offering a robust solution for real-time computer vision applications.

Interference:

In Night, we can use the thermal cameras and we can do thermal image and video processing using the FPGA Xillinx Spartan 6. So this application we can use where we need security.