Task-6

By Group-6

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Prepare a research report on the added FPGA features/computation in the given article (Architecture of the FPGA to Detect Moving Objects using Principal Component Analysis (PCA) algorithm)

Research Report on Intelligent Architecture for Moving Object Detection Using FPGAs

Introduction

The rapid advancements in CMOS sensor technology and the increasing demand for high-performance image processing have necessitated innovative solutions for real-time applications. This report delves into a novel intelligent architecture designed using Field Programmable Gate Arrays (FPGAs) to detect moving objects through Principal Component Analysis (PCA). This architecture aims to achieve high-speed, high-quality image processing suitable for autonomous systems.

Background

The detection of moving objects is a critical task in computer vision, involved in various applications like navigation, tracking, video compression, and image sequence reconstruction. Traditional systems often rely on sequential processing platforms, which struggle to meet the computational demands and real-time performance required by modern applications. The proposed solution leverages the parallel processing capabilities of FPGAs to enhance performance.

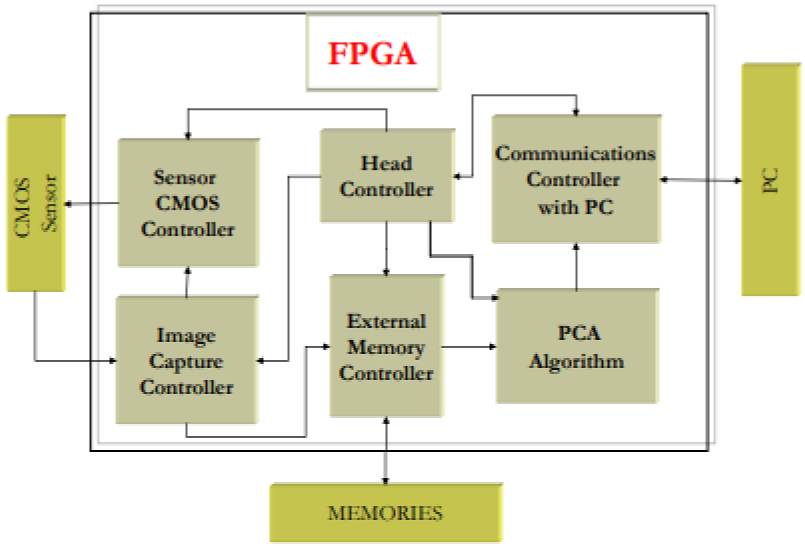

Fig 1 :Block Diagram of the internal architecture of the FPGA

Principal Component Analysis (PCA)

PCA is a statistical method used to reduce the dimensionality of large datasets while preserving most of the variance in the data. In image processing, PCA helps in reducing redundant information by focusing on the principal components, which are the most significant features of the image. This reduction is crucial for efficient object detection and background subtraction.

Steps of PCA in Image Processing:

1. Image Acquisition: Capture multiple reference images to construct a model of the scene.
2. Vector Representation: Convert each image into a vector.
3. Mean Image Calculation: Compute the mean image from the reference images.
4. Covariance Matrix Formation: Create a covariance matrix from the image vectors.
5. Eigenvalues and Eigenvectors: Calculate the eigenvalues and eigenvectors of the covariance matrix.
6. Projection Matrix: Form a projection matrix using the principal eigenvectors.
7. Image Reconstruction: Project new images onto the PCA space and reconstruct the images to detect differences.

FPGA Implementation

The FPGA-based architecture parallelizes the PCA algorithm, addressing the inefficiencies of sequential processing. Key components of the implementation include:

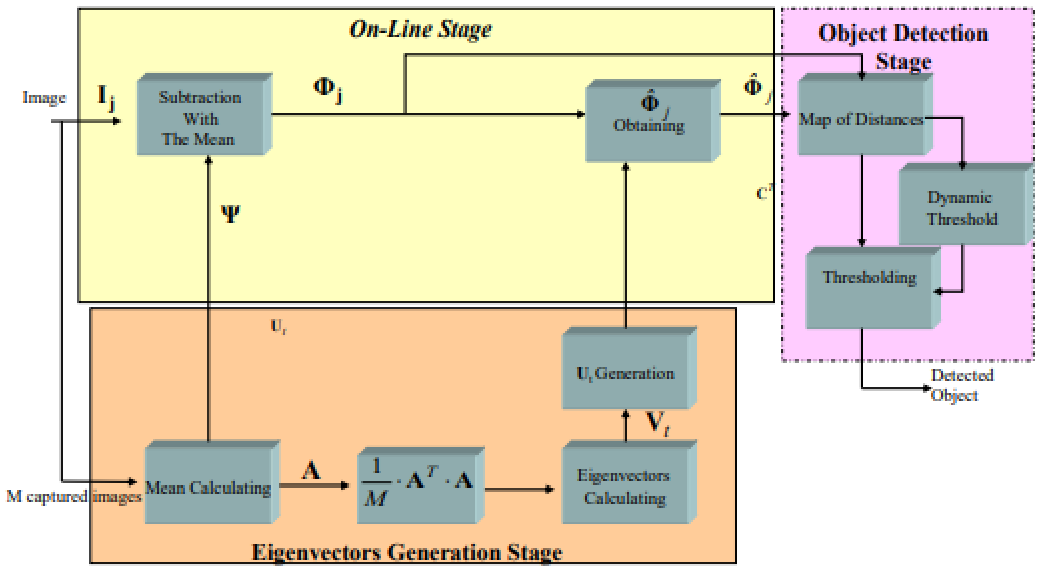

Fig 2: Block diagram of the PCA algorithm implemented on an FPGA.

1. Correlation Matrix Computation: Efficiently compute the correlation matrix in hardware.
2. Matrix Diagonalization: Implement the Jacobi method for matrix diagonalization.
3. Subspace Projections: Perform projections of images onto the PCA subspace.

The architecture integrates a CMOS sensor and FPGA to form an intelligent camera capable of real-time motion detection. This setup can process up to 120 frames per second, ensuring high-speed performance.

Motion Detection Algorithm

The motion detection algorithm operates by dynamically thresholding the differences between the input image and the PCA-based background model. The key steps are:

1. Projection: Project the new image onto the PCA space.
2. Reconstruction: Reconstruct the image from the PCA space.
3. Error Calculation: Compute the difference between the input image and the reconstructed image.

4. Thresholding: Apply a dynamic threshold to detect new objects in the scene.
5. Localization: Determine the spatial location of detected objects.

The threshold is dynamically adjusted based on the scene conditions, enhancing the robustness of the detection system.

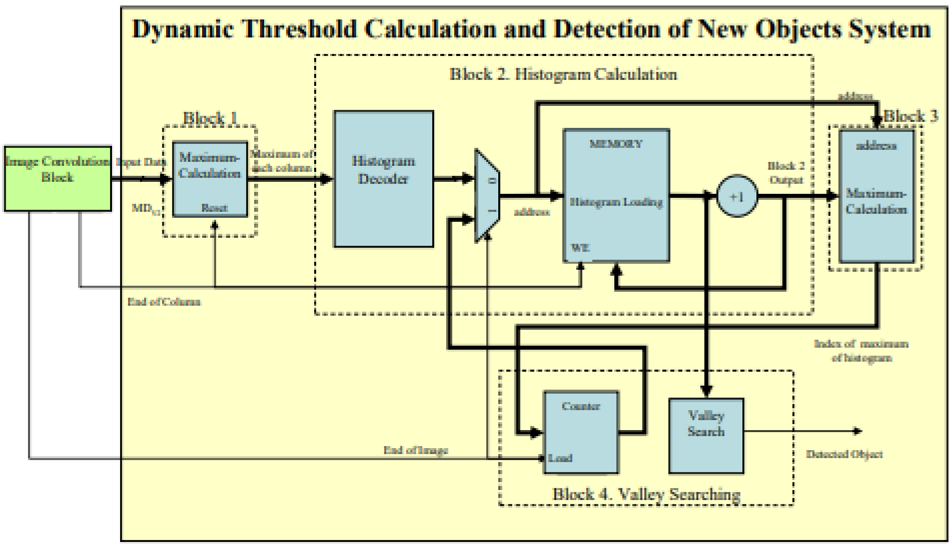

Fig 3: Block diagram on an FPGA of the dynamic threshold calculating system for detecting new objects.

Results and Conclusion

The FPGA implementation of the PCA algorithm significantly improves the processing speed and accuracy of moving object detection. The intelligent camera system demonstrates high-quality segmentation results, making it suitable for a range of real-time applications. This approach highlights the potential of combining advanced statistical methods with reconfigurable hardware to address complex image processing challenges.

The study concludes that FPGA-based architectures, with their parallel processing capabilities, offer a viable solution for real-time moving object detection, providing a balance of performance, accuracy, and cost-effectiveness.

References

Bravo, I., Mazo, M., Lázaro, J. L., Gardel, A., Jiménez, P., & Pizarro, D. (2010). An Intelligent Architecture Based on Field Programmable Gate Arrays Designed to Detect Moving Objects by Using Principal Component Analysis. Sensors, 10(10), 9232-9251. doi:10.3390/s101009232