International Journal of Swarm Intelligence Research
Volume 9 • Issue 1 • January-March 2018

Co-Design System for Template Matching Using Dedicated Co-Processor and Cuckoo Search

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ABSTRACT

Template matching is an important method used for object tracking, in order to find a given-pattern within a frame sequence. Pearson's Correlation Coefficient (PCC) is widely used to quantify the similarity between two images. Since this coefficient calculus is computed for each image pixel, it entails a computationally expensive process. In this article, an embedded co-design system is proposed, which implements the template matching, in order to accelerate this process. The dedicated co-processor, responsible for performing the PCC computation, is used in two configurations: serial and pipeline. Cuckoo Search (CS) is used to improve the search for the maximum correlation point of the image and the used template. The search process is implemented in software and is run by an embedded general-purpose processor. The performance results are compared to those obtained through Particle Swarm Optimization (PSO) using the same hardware approach.

KEYWORDS

Co-Design, Co-Processor, Cuckoo Search, Embedded Systems, PCC, Template Matching, Tracking

INTRODUCTION

Image analysis is an important tool for decision making. Environment observation allows to identify objects of interest. Continuous monitoring lets making strategies and deciding the moment to act. Quality of information must be enough not to induce to mistakes on scenarios evaluation or future actions. As soon as personnel collects true information, the planning can be done and goals are defined, reducing risks and exploring opportunities.

The acquisition of information, which is extracted from images and videos, became possible and led to advances on an important research area. Development and enhancement of sensors and the advent of intelligent equipment capable of capturing, storing, editing and transmitting images accelerate decision processes, enabling more robust strategies. Necessary time to obtain an information and process it is directly responsible for successful operations. Artificial intelligence tools can help finding true information quickly. Slow search process may delay decision taken until recorded data become insufficient or inefficient at that moment (Jihang et al., 2012).

DOI: 10.4018/IJSIR.2018010104

An airplane pilot observes the environment to avoid any possible collision. Similarly, a plane using an automatic guidance system uses environment information to decide path changes due to random objects in its way (Salmond, 2013). In defense and security fields of expertise, this kind of research is very relevant for target recognition and tracking using image sequences to provide solutions for the development of surveillance and monitoring systems (Narayana, 2007). It can provide in guidance (Choi et al., 2014), navigation (Forlenza et al., 2012), remote biometrics authentication (Benfold et al., 2011), fire control, control of guided weapons (Olson et al., 1999), among many other applications.

Template Matching (Mahalakshmi et al., 2012; Ahuja et al., 2013) is one of the most used techniques for finding then tracking patterns in images. It consists of finding a pre-defined small image, termed as the template, inside a larger image. An important advantage of template use is the presence of spatial and appearance information (Yilmaz et al., 2006). Among the methods used to evaluate the matching process, the normalized cross correlation is very known and widely used because of its properties of invariance to linear brightness and contrast variations (Perveen et al., 2013). Template matching is computationally very expensive, especially when using large templates with an extensive image set (Sharma et al., 2012).

This work proposes a software/hardware co-design system implementation of template matching. The software is optimized with the Cuckoo Search (CS) approach. The required computation of Pearson's Correlation Coefficient (PCC) is implemented in hardware, using a dedicated co-processor previously proposed in (Tavares, 2016). In order to evaluate the proposed design, the processing time as required by the software-only and the co-design systems are evaluated and compared. The results are compared to the Particle Swarm Optimisation (PSO) implementation achieved by (Tavares et al., 2017), which uses the same software/hardware co-design implementation.

This paper is organized into five sections. First, in Section Theoretical Background, we present the Template Matching, correlation and CS concepts as they are used in this work. Then, in Section Hardware Architecture, we describe the used hardware. In Section Proposed Implementation, we introduce the experiments to be executed. After that, in Section Results, we discuss the obtained results by the proposed system. Finally, in Section Conclusion, we conclude the work and point out some new directions for future works.

THEORETICAL BACKGROUND

Template Matching

Template matching (TM) is used in image processing to determine the degree of similarity of two images. TM also is used to compare portions of images against one another, where even a sample image may be used for recognizing purposes of similar objects (Ahuja et al., 2013).

The pattern to be recognized in an image is compared to a pre-defined template. After the similarity evaluation considering all the possible pixels, the pixel that provides the highest correlation degree is identified as the location of the pattern inside the image.

Some difficulties are present during template matching process (Yilmaz et al., 2006): loss of information; noisy images; complex object motion; nonrigid or articulated objects; partial or full object occlusions; complex object shapes; illumination changes in environment; and real-time processing requirements. Among the similarity measures for template matching, the normalized cross correlation is often used, because of its invariant results to the global brightness changes (brightening or darkening) of either image or template (Perveen et al., 2013).

The Pearson's Correlation Coefficient (PCC) is a dimensionless measure of similarity between two variables due to normalized cross-correlation process. Regarding two images P and A, the PCC can be computed as defined in Equation (1):

An Experimental Performance Comparison for Indexing Mobile Objects on the Plane

S.Sioutas, G. Papaloukopoulos, K. Tsichlasand Y. Manolopoulos (2012). *Intelligent and Knowledge-Based Computing for Business and Organizational Advancements (pp. 340-358).*

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