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Template Matching in Digital Images with Swarm Intelligence

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INTRODUCTION

Computer vision is a research area with many open problems. One of them is the pattern detection in digital images, where a specific pattern is intended to be located somewhere in a given image. Such pattern can be, for instance, an object, a face or people. There are several applications in which pattern detection is a fundamental step, such as person recognition, video surveillance, scene description, autonomous localization and navigation. In its essence, all these applications are kind of pattern recognition problems, demanding efficient ways to locate and extract patterns from input images/videos. Many methods were proposed in the literature for this problem, and, in this article, it is addressed by a template matching technique. Template matching consists in, given a desired image pattern, find its planar location inside an landscape image.

In a simple view, the pattern detection in digital images problem is solved by a search process, where the search space is an image. The simplest way to do the search is by analyzing the entire image, looking for the desired pattern, commonly called Full Search (FS) (Ouyang et.al., 2012). This method is computationally intensive and demands a powerful execution environment to be efficient.

In this article we present a heuristic search strategy to circumvent this issue. The pattern detection problem is modeled as an optimization problem, allowing the use of different optimization algorithms. A powerful category to solve optimization problem is the swarm intelligence methods. This kind of method is classified as a heuristic, in the sense that there are no guarantees that the optimal solution can be found. Therefore, a tradeoff between accuracy, precision and speed should be considered when employing this kind of method.

BACKGROUND

Template Matching

Given a $I_1 \times I_2$ image, called landscape, and a $P_1 \times P_2$ image patch, called pattern, the template matching consists in finding the precise location (x,y) of the pattern inside the landscape image. Here, it is assumed that the pattern size is smaller than the landscape image.

A simple approach to do this is using a sliding window along the landscape image. The process basically consists in sliding a window, of the same size of the example pattern, over every pixel of the landscape image, and extracting a patch. This patch is then compared with the example pattern using a similarity measure. Figure 1 shows an example of this process. The window with the highest similarity value is said the matching point. Several similarity measures can be used, and the common choices are the sum of the absolute differences and the sum of the squared differences.

Most common template matching approaches restrict the search in a 2D plane, in this case translation in x and y axis. This restriction occurs mainly to reduce the computational effort demanded to solve the problem.

Besides the translations of the pattern in the 2D plane, other image transformations could occur, such as scale (translation in the z axis) and rotation. Consequently, the template matching problem can be more

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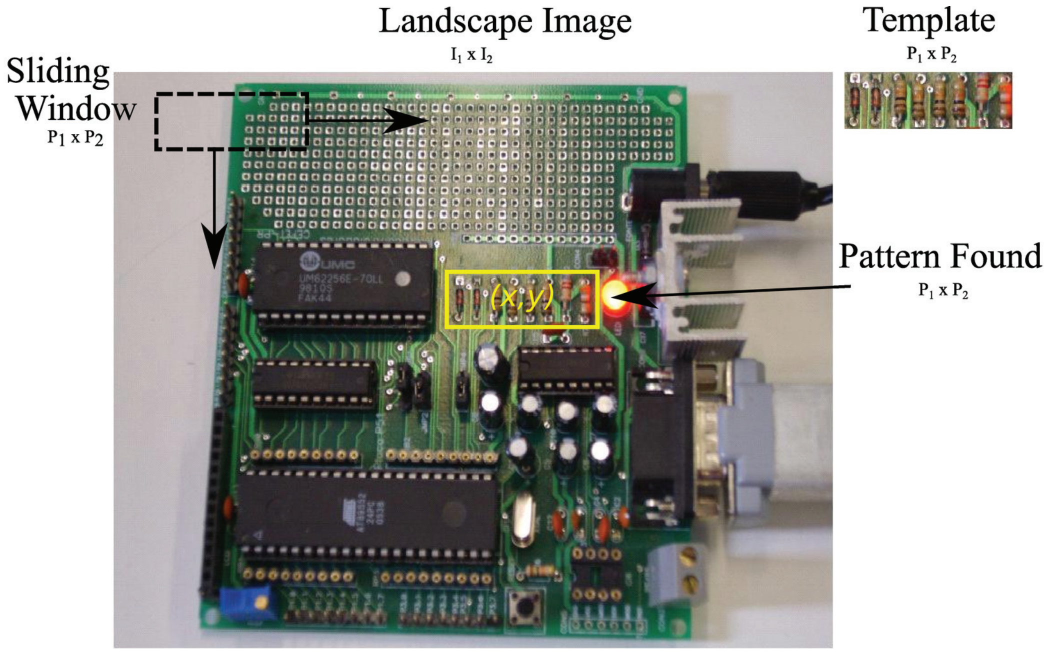
Figure 1. Example of the sliding window approach for the pattern detection problem using template matching



properly defined as finding a 4-tuple (*x, y, s, Θ*), where *x* and y are the center coordinates of the pattern, *s,* is the scale factor, and *Θ,* the rotation angle (Gonzales, 2009).

Swarm Intelligence

In recent decades, many biologically-inspired algorithms based on specific intelligent behaviors of swarms have been proposed. They have been applied to several real-world problems, mainly to solve numerical and combinatorial optimization problems (Parpinelli & Lopes, 2011). The dynamics involved in animal communities has been used as an inspiration for the development of computational models. In spite of the limited cognitive ability and simple behavior of swarms, several successful optimization algorithms have been proposed. Out of many others, here we present two them: Particle Swarm Optimization (PSO) and Artificial Bee Colony (ABC), which are discussed in the following sections. These algorithms are based on a population of cooperative agents that exchange information each other in the search for a solution to an optimization problem. Each agent is very simple and has limited capabilities, but as they act in group, a social behavior emerges, enabling the group to find out an near-optimal solution.

Particle Swarm Optimization

The PSO is a heuristic optimization algorithm, proposed by Eberhart and Kennedy (1995), and is inspired by the behavior of school of fishes and bird flocks. In both cases, each animal moves trying to keep a constant distance between the other elements of the group.

In this approach a set of agents, called particles, exchange information seeking to find the best solution to a problem inside a search space. Each particle represents a possible solution to the problem, which is generally encoded as a *n*-dimensional vector. The optimization process requires the determination of a quality measure for each possible solution, known as the fitness function.

The main idea of PSO is to keep a population of particles that “flies” over the search space with variable velocity. In some spots, the particles evaluate their position in the search space, using the fitness function. Basically a particle keeps the information of its current position and speed, and also its best position it has ever been before. The overall best position is found among all the particles and is shared by the whole population.

By means of an interactive process, each particle is evaluated and updated with respect to the quality of its solution, and the best solution found by the entire

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