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Shooting Target Detection using Particle Filters

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1 Introduction

The problem of automatic detection of objects in images become very popular in the last two decades. Thus automation is very desirable in many different fields, including sport. During shooting competition is very complicated to obtain interim results by humans because of the safety of referees and preservation of fluency of the competition. The solution of this problem is automatic hit detection. This complex task can be divided into three subtasks: (1) shooting target detection; (2) hit detection; (3) score computation. This article is focused on the first subtask only - automatic shooting target detection, for which I decided to use particle filter algorithm.

2 Particle Filters

Particle Filters (PFs) or Sequential Monte Carlo methods (proposed by Liue et al. (1998)) are a class of genetic-type algorithm usually used to nonlinear filtering problems. PFs have three main advantages over traditional Kalman filter (see Kalman (1960)): (1) PFs do not need linearisation of the nonlinear problems; (2) PFs can approximate an arbitrary nonlinear function or transformation; (3) PFs are non-parametric methods. Moreover, PFs are easy to implement and work great for low-dimensional problems. On the other hand, PFs have also few disadvantages: (1) their behaviour is non-deterministic; (2) the one is not able to measure algorithm performance during its run; (3) PFs can be computationally very demanding.

In this task, each particle is a model of the shooting target's edges with different size (one parameter), rotation (three parameters) and position in the image (two parameters). The whole algorithm follows four steps:

1. Sampling the particles using proposal distribution - initialization of the algorithm.
2. Computing importance weights.
3. Creating a new generation of particles, resampling and adding noise.
4. Going to the step 2, if a stop condition is not satisfied.

3 Experiments and Results

The input to the algorithm is video record with the shooting target. In the first step, I converted an input RGB frame into the grayscale. Then Gaussian blur and Sobel edge detector are applied. On thus preprocessed image is applied Particle Filter algorithm. Particles initialization is based on the uniform distribution, if the input image is the first image of the video, or it is based on the results from the previous frame otherwise.

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Particle's importance weight is computed as a sum of the edges in the image, which can be found in a small neighbourhood of the edges of the particle. I tried to employ more complex weight computations, for example, I tried to take orientation of the edges into account or penalize the particles for edges inside of them. These modifications showed promising results, but at cost of computational complexity. Therefore, they were not included in the final version of the algorithm, because my goal was to develop an algorithm, which can run at speed at least 10 frames per second.

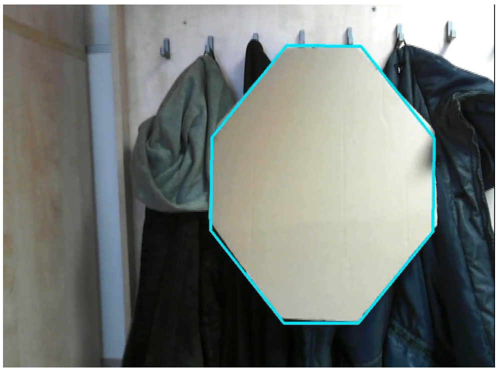

Figure 1: The result (teal colour) of the target detection using particle filter algorithm.

Creation of the new generation of particles was ensured by random selection of the particles from the previous generation, where each particle has a probability of the survival based on its weight. To enrich the new generation of particles, it was used variable Gaussian noise with mean based on the mutual position of the best particle from the previous step and the ancestor of the new one. I experimented with other options, for example, with the mean based on the particle with the best improvement over two consecutive iterations, however, the chosen variant provided best results.

As the stop condition it was chosen fixed computational time $t = 0.05s$, after which is weighted average particle declared as a solution for the given frame. The algorithm reaches very good results. Usually, it is able to robustly detect a target after first two or three frames, see Figure 1. Problematic can be objects with a very similar shape as the target, however, there is a very low probability of occurrence such situation in a real-world application.

4 Conclusion

Particle filters prove to be sufficient algorithm for the shooting target detection. In the future, I would like to speed up the algorithm by parallelization of the new particle generation.

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