Sword Tracer: Visualization of Sword Trajectories in Fencing

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CCS CONCEPTS

• **Computer methodologies → Computer vision problems**;

KEYWORDS

Visual object tracking, machine learning, fencing

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1 INTRODUCTION

This paper describes a system for visualizing sword trajectories in fencing. Fencing swords are very thin and move so fast that it is difficult for audiences to follow their movements even in slow-motion video replays. The system thus tracks the tips of the swords in the image coordinates and visualizes their movements with computer graphics (CG). We call it "Sword Tracer."

Sword Tracer measures each sword's position in the infrared (IR) image by detecting IR light reflected from reflective tape put on the tip of the sword. Although optical motion capture systems also use IR light [Guerra-filho 2005], they require many IR cameras and numerous reflective markers to be placed on the player's bodies. In contrast, Sword Tracer uses only a single camera and a single marker at the tip of the sword. Thus, the system is compact and can be used in official fencing games.

Both fast and accurate tracking of the sword in the video sequence is required for use in a live fencing broadcast. Conventional tracking methods tend to be slow and fail to track fast-moving swords. On the other hand, Sword Tracer accurately detects the tips of the swords by using supervised machine learning and predicts its position in the next frame. The system composites the trajectory CG of the sword tips on the broadcast image in real-time.

The system was used at the All Japan Fencing Championships in December 2017 for the first time. Figure 1 shows samples of broadcast images from that event. Commentators and TV viewers approved of the new visual effects afforded by Sword Tracer because it helped them to follow the fast-moving swords.

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Figure 1: Broadcast images of sword trajectories in All Japan Fencing Championships 2017.

2 DEVELOPED SYSTEM

2.1 Overview

Figure 2 shows the process of Sword Tracer. Light reflective tape is put at the tip of each fencing sword just before a game. The system irradiates the playing field with IR light from a LED array, and the light is reflected by the tape. The RGB/IR camera captures two kinds of images, a visible color (RGB) image and IR image. The system detects and tracks the reflected light in the IR image and draws trajectory CG at the detected positions of the swords. The CG are composited with the RGB image by the keyer, and the trajectory composited image is output in real-time.

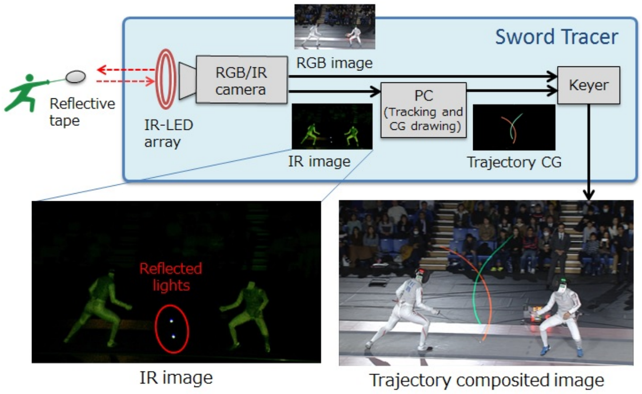

Figure 2: Processing flow of Sword Tracer.

2.2 RGB/IR camera

Figure 3 shows a photo and the architecture of the RGB/IR camera in the system. The light entering the broadcast lens is separated into visible light and infrared light through a prism spectroscope that is set in the spectroscopic adaptor. The IR and RGB light are input to the IR camera and the broadcast camera, respectively. Because of this optical architecture, the system can capture IR and RGB images with the same angle of view even when it pans, tilts, and zooms. The optical architecture of the RGB/IR camera realized single-camera operation of the system.

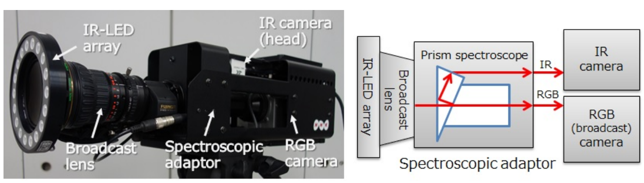

Figure 3: Photo of the RGB/IR camera and its architecture.

2.3 Sword detection and tracking

The system detects and tracks reflected light from the tips of the swords in the IR image. A supervised machine learning scheme is used to detect the sword tips and eliminate other noise objects, such as reflected light from the shafts of swords and the players' uniforms. In the learning phase, a support vector machine (SVM) classifier was trained with more than 1,000 images of swords and other images [Anusha and Jule 2014]. In the operation phase, the tip of the sword is accurately detected from candidate objects in the input image by using the classifier.

The tips of the two players' swords are tracked by predicting their positions in the next frame. A particle filter is used for the prediction [Arulampalam et al. 2002]. Each light is searched only in the search area defined with the distribution of particles. The position, size, and aspects of the search area are changed according to the distribution every frame. This limitation of the search area contributes to fast and accurate tracking of the swords.

The system can be used in live broadcasting because all procedures are performed within the frame rate of a broadcasting camera (59.94 frames/second).

2.4 Drawing trajectory CG

Bezier curves, which are colored red or green depending on the player, are drawn at the detected positions of the swords. These trajectory CG are composited with the RGB broadcast image without any coordinate transformation because the angles of view of the IR image and the RGB image are the same.

3 EXPERIMENT

We evaluated the accuracy and speed of our tracking method. The average error distance [pixel] and average processing time within a single frame [msec/frame] were calculated over ten video sequences of fencing games. Three conventional tracking methods, multiple instance learning (MIL) [Babenko and Belongie 2011], boosting [Grabner et al. 2006], and kernelized correlation filer (KCF) [Tang and Feng 2015], were compared.

The results are shown in Table 1. Our method was the most accurate and fastest of the tracking methods in this evaluation. The fencing swords moved quickly in the camera images, and the conventional tracking methods tended to lose them. In contrast, our method robustly tracked them by predicting their positions. The SVM classifier also contributed to the accurate detection of the swords.

Table 1: Results of comparison with other tracking methods.

	MIL	Boosting	KCF	Proposed
Error distance [pixel]	127.6	72.3	42.0	5.7
Processing time [msec/frame]	54.6	21.3	11.2	2.8

4 PRACTICAL USE

We used the system in the 70th All Japan Fencing Championships held in December 2017. We set the RGB/IR camera on an audience seat on the second floor, 25 meters from the playing field. The light reflected from the tips of the swords was tracked on the IR image, and the trajectory CG were drawn in real-time.

The trajectory composited images were broadcast in video replays just after the original plays, as shown in Fig. 1. It was the first time that sword trajectories were shown in official fencing games to the best of our knowledge. The commentator explained the strategy of the game on the basis of the sword trajectories, and TV viewers appreciated this new video effect because it helped them to follow the fast-moving fencing swords and better understand fencing.

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