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## A VIDEO FEEDBACK SYSTEM PROVIDING MOTIONS SYNCHRONIZED WITH REFERENCE EXAMPLES FOR MOTOR LEARNING

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### SUMMARY

This paper proposes a video feedback system for motor learning. The proposed system enables video feedback of a self-motion in synchronization with a reference motion soon after the trainee executes a target movement. It provides these functions without requiring trainees to wear special devices or special clothes, and works well by using one commercial camera with no calibration. The system runs a playback of the self-motion with delay of a few seconds. This enables immediate video feedback without trainees' changing their motions, which is a frequently encountered problem when trainees check their own motions in front of a mirror. The system also has a function for generating a synchronized playback of the self-motion and the reference motion. To the best of our knowledge, this is the first system that can provide video feedback of self-motions in synchronization with reference motions during training. Experiments verified that the system works well whether the self-motion and reference-motion actors are the same or not.

### INTRODUCTION

For practicing motor skills in sports, the importance of video feedback of self-movements is widely acknowledged. However, there are limited opportunities for obtaining video feedback in the practice scenes. The most popular way to get such feedback is to capture videos during practice sessions and check them afterwards. In this case, however, temporal intervals between the sessions and receiving video feedback deteriorate one's memory of the motions one made. This lessens the effect of such video feedback schemes.

The use of a mirror enables immediate video feedback. However, to obtain video feedback from a mirror, trainees need to slightly change their usual motions. To solve this problem, a commercial system "Dart Trainer Team Pro" includes a function called "Live Delay", which captures videos and runs playbacks with delay [2]. This system has enabled immediate video feedback to be provided while one's memory of motions is still clear.

However, systems of this sort only show a trainee's self-motions. Therefore, the information that can be obtained from them is limited. In sports training scenarios, an

effective way for trainees to achieve proficiency is to examine their current motions by comparing them with reference motions such as successful ones, ones captured under good conditions, and ones performed by elite athletes. One example way of making such comparisons is to generate a synchronized playback of self-motions and reference motions. This is technically feasible, but requires input from technically trained persons and a fairly substantial amount of creation time.

This paper proposes a system that provides immediate video feedback of self-motions synchronized with reference motions. It runs self-motion playbacks with delay of only a few seconds. During the delay, it automatically synchronizes self-motions and reference motions. When it detects that a motion similar to a reference motion has been made, it synchronizes the motions and runs a synchronized playback of them. The system's most important feature is that it functions on the basis of a camera input only, without requiring the wearing of special clothes or devices.

### PROPOSED SYSTEM

The system has two important functions: playing back self-motions with delay of only a few seconds and synchronizing self-motions and reference motions during the delay. Figures 1 and 2 show the system flowchart and an example setting for the system.

The method first registers the reference motion and the synchronization point in time. The motion information at the

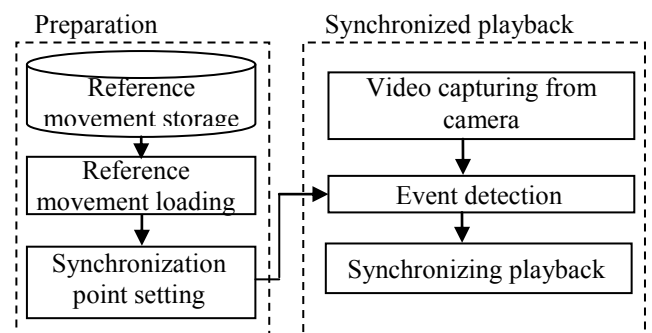
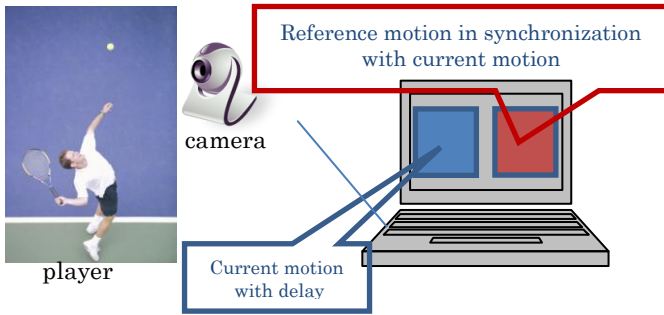


Figure 1: Flowchart of the proposed system.



**Figure 2:** Example setting of the proposed system.



**Figure 3:** MHI (left) and the snapshots of the corresponding image sequence (right). The motion is raising the left leg.

registered synchronization point is used to detect a similar motion. Then, the system runs a playback of the current self-motion in synchronization with the reference motion. We used the motion history image (MHI) method as the motion representation method.

**MHI:** The MHI method, a motion representation method proposed by Bobick et al. [3], has been widely used because of its ease of implementation. Figure 3 shows an MHI and snapshots of the corresponding image sequence, where the snapshots are shown from left to right in time order. In the MHI, the value of each pixel shows how recently a motion was detected on the pixel. Bright (white) pixels denote pixels at which motions are detected. As the time proceeds from the most recent motion, the pixels turn dark. The pixel value of an MHI at position and time can be obtained by

$$H(x, y, t) = \begin{cases} 255 & D(x, y, t) = 1 \\ H(x, y, t - 1) - g & \text{otherwise,} \end{cases} \quad (1)$$

where 255 (i.e., white) is a pixel value for pixels on which a motion is detected, and  $D$  denotes a motion detection function. Inter-frame difference is commonly used as the motion detection function. In addition,  $g$  denotes a decay parameter; if small  $g$  is used, the resulting MHI is affected by motions of long past.

## METHOD

We used two types of motions: pitching a baseball and swinging a golf club. Two usage scenarios for each motion were examined:

**CASE 1** The reference-motion and current-motion actors are the same, and

**CASE 2** The reference-motion and current-motion actors are different.

For each case, subjects (i.e., trainees) carried out the movement of pitching a baseball or swinging a golf club. We examined how precisely the reference movements and detected movements were synchronized. The experimental settings were that video was captured at 30 fps and a lap-top PC (Intel core i7 CPU) was used for computation.

## RESULTS AND DISCUSSION

Table 1 shows the system accuracy results we obtained. It shows the absolute temporal displacement of the synchronization in frame, i.e. 1/30 [sec.]. These are the average values of ten correctly synchronized movements. Figure 4 shows example snapshots of synchronized playbacks. Figure 4(a) shows snapshots of a pitching motion from CASE 1. It is clear that the motions are well synchronized despite the change in illumination condition between the snapshots. Figure 4(b) shows snapshots of a golf swing from CASE 2. In this case, there are differences between the reference and current motions in terms of both the actor's physical attributes and clothing.

The evaluation demonstrated that our proposed system works well under uncontrolled settings, i.e., uncalibrated camera, unspecified clothes, etc. However, the most important aspect needing to be evaluated is the system's effectiveness for motion training purposes and this has not yet been evaluated.

## CONCLUSION

We have developed and here propose a novel system for motion training. It provides video feedback of self-motions in synchronization with reference motions. Since it works on a lap-top computer and does not require users to wear any special devices or clothing, it can be used at training sites while the users' memory of motions they made is still vivid. Future work will include evaluating the system's effectiveness for motor learning purposes.

## REFERENCES

1. Guadagnoli M, et al, The efficacy of video feedback for learning the golf swing, *Journal of Sports Sciences*, Vol. 20, 8, 2002.
2. Dart Trainer Team Pro, DARTFISH
3. Bobick A, et al., The Representation and Recognition of Action Using Temporal Templates, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, pp.257-267, Vol. 23, 3, 2001.

**Table 1:** System accuracy [frame = 1/30 sec.]

Motion	Case 1	Case 2
Pitching	1.7	0.7
Golf swing	0.1	0.4



(a) CASE 1: pitching motion



(b) CASE 2: golf swing

**Figure 4:** Snapshots of proposed system in action.