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Human Walk Pitch Extraction by Interactively Trainable Robot Vision for Human-Robot Synchronized Walking

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Abstract

This paper presents visual extraction of human walk pitch for human-robot synchronized walking. The walk pitch extraction is done by tracking human heel. The authors use their interactively trainable pattern recognition system to track the heel. This work is the first step of the authors plan to realize the synchronization. In the first step, human walk pitch is extracted visually. In the second, neural oscillator is entrained by the extracted pitch. In the third step, a walking robot is controlled by the entrained neural oscillator.

1. Introduction

In recent years, social and business demand and expectation for human collaborative, coexistent, interactive and/or co-workable robots have been remarkably increasing. Human collaborative robots, such as pet robot, service robot, entertainment robot, care robot, and so forth, are promised to expand application fields and market of robot industry in the near future.

Among various human functions, mobility is an essential one as a kind of animals. Thus mobility is also essential for such human-collaborative robot. For example, if the robot could follow us and carry our baggage, of course in our dairy life, it would be very convenient for us. And if the robot could walk or jog with us, it would contribute to our health. In such situation that the robot follows or walks with human, synchronization of walking is crucial. If walk pitches of human and robot are so different, human must feel sense of incompatibility and it may be dangerous in some case. Since the human walk pitch is not fixed, continuous adaptability of the synchronization by the robot is also crucial. If the robot adapts its walk pitch to humans discontinuously, it must cause sense of uncomfortability to the human.

As for the synchronization by the robot, Kotosaka and Kawato demonstrate one of the milestone works utilizing entrainment of neural oscillator[1]. Initially their robot beats a drum with an own pitch based on self oscillation by internal neural oscillator. When human beats another drum with different pitch, that sound, as auditory sensation, causes entrainment by the neural oscillator. Thus the robot continuously adapts its pitch of the beating to the pitch by the human. As the result, the synchronization of beating by robot and human can be realized.
As for the neural oscillator based walking robots, there have been several previous works. Typical works are Kimura[2], Tsuchiya and Tsujita [3], Takemura and Ogasawara [4], and so forth. These works demonstrate effectiveness of the neural oscillator application to the walking robot.
But their adaptation ability is limited to their environment, like rough terrain, obstacles, and gradient. It is not adaptable to human behavior, like walking.

Thus the authors start study on human-robot synchronized walking. The idea is quite simple and described as follows. Firstly human walk pitch is extracted visually. Secondly neural oscillator is entrained by the extracted pitch. Thirdly a walking robot is controlled by the entrained neural oscillator.
In this paper, we present the visual extraction of human walk pitch as the first step of the study. Fig. 1 illustrates the supposed situation. The walk pitch extraction is done by tracking human heel. We use our interactively trainable pattern recognition system [5] to track the heel.

So far the authors have proposed and developed OLDA, on-line extension of conventional linear discriminant analysis (LDA) [6]. OLDA has advantage that a new class of pattern to be identified can be easily and interactively added on-line. Using this advanced feature, the interactively trainable recognition system is implemented based upon OLDA.

In the following, overview of the vision system is described briefly. Then interactive trainability is presented. And heel tracking and walk pitch extraction are described. Experimental results are also presented.

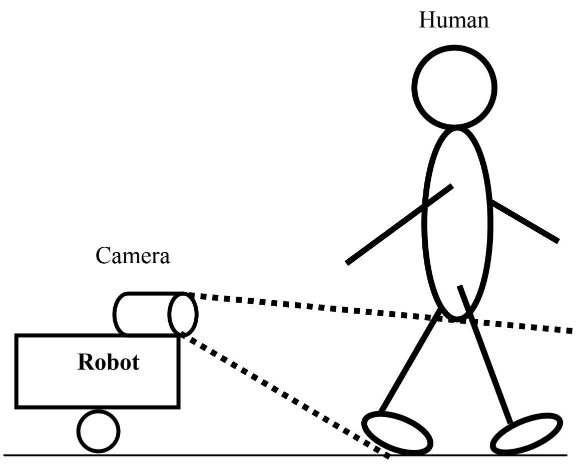


Fig 1 . Robot measures human's walking pitch

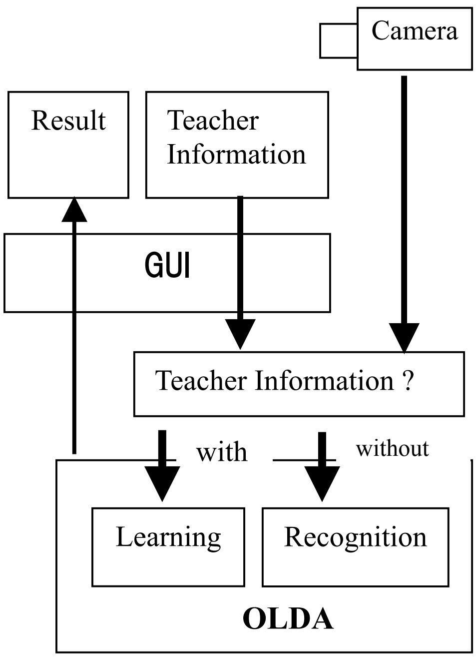


Fig. 2 Block diagram of Implemented System

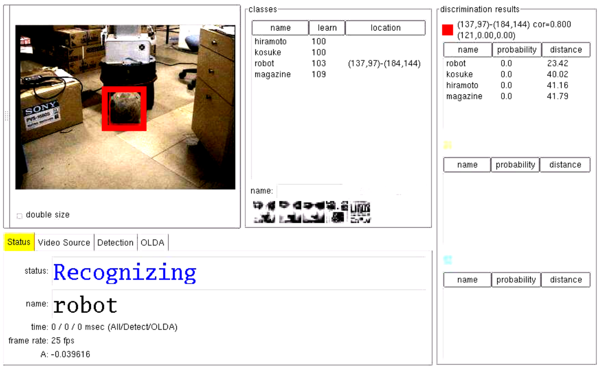
2. Implemented System

Fig.2 shows the block diagram of implemented system. The system consists of an OLDA section and a GUI section. The OLDA section has two modes of operation. They are recognition mode and learning mode. And the two modes can be dynamically changed during system operation. In the case of distinction mode, the system judges whether the image inputted from the camera corresponds to the class registered by discriminant analysis. An output is a result with probability. In the case of learning mode, teacher information (class information) and an input image are registered. This system leverages the feature of OLDA. The feature of OLDA is the ability to add dynamically the class used for discriminant analysis. The GUI section performs a mode change, the input of teacher information, and the output of a distinction result. By this GUI section, The registration and the addition of an arbitrary picture pattern in system operation can be interactively carried out.

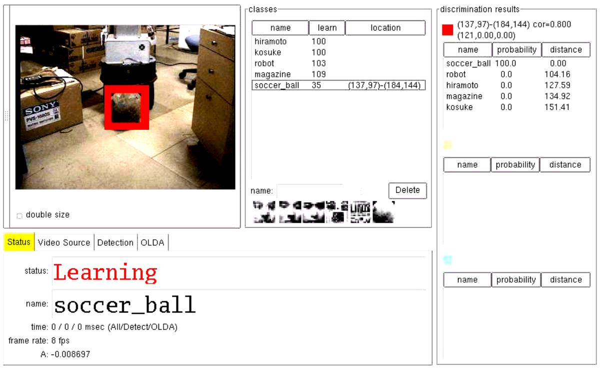
3. Experiment

3.1 Operation Experiment

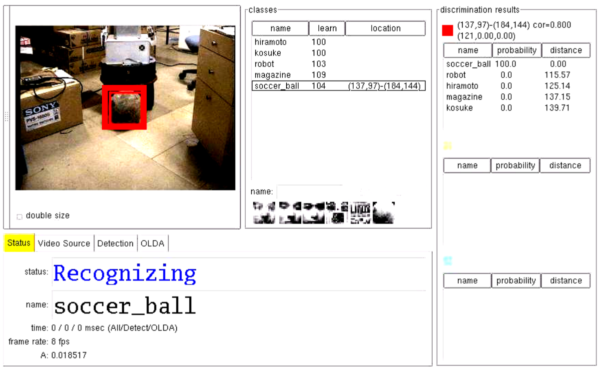
Authors experiment in order to check whether the built system can operate.
The contents of an experiment are shown below.
The class of some image patterns is registered beforehand. In this state, the pattern of a new class is registered. And it investigates whether each class can be recognized. In addition to this, It is important that this system can not only recognize a new class, but that it can recognize original classes without mixing up with new classes. Fig. 3 shows the example under system operation. Here, the size of image pattern for recognition is 10x10 pixels. This image is used for distinction analysis. Fig. 3 (a) is the scene where the non-registered ball was shown to the camera. Since the class of a ball is not registered, it is judged by other classes. Then, as shown in Fig.3 (b), registration of a new class (soccer_ball) and learning were carried out using GUI. and registration of a new pattern were carried out too. A result is shown below. As shown in Fig.3 (c), The class of soccer_ball is newly registered. As a result, soccer_ball is recognized correctly. Fig. 4 is an example of recognition in the situation that four classes are registered. It turns out that this system has recognized human's face, the magazine, and the robot correctly. Especially about human's face, two persons' face is recognized correctly.



(a) non-registered

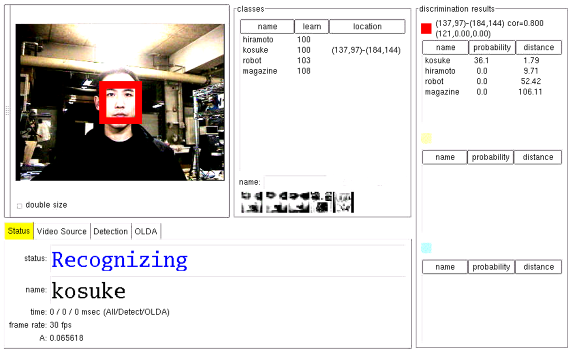


(b) Learning

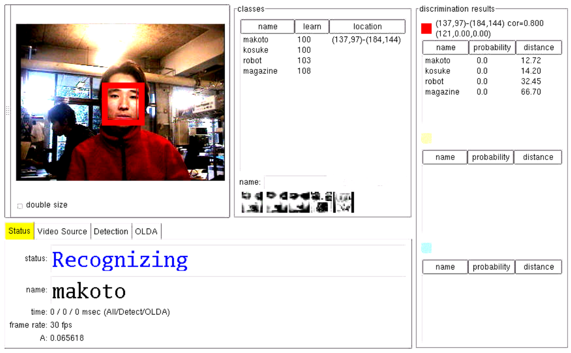


(c) Recognition

Fig.3: Flow of Pattern Registration

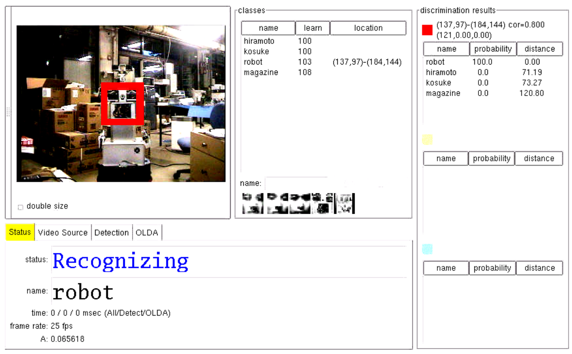


(a) Person A



(b) Person B

(c) Magazine



(d) Robot

Fig.4 : Examples of Arbitrary Patterns

3.2 Pitch Extraction Experiment

An author conducts the experiment for checking whether a robot can measure human's walk pitch. The contents of an experiment are shown below.
Fig.5 shows the situation that a robot measures human's walk pitch. There is human in front of robot.
In this situation, A robot looks at human's leg. and, a robot detects human's heel. In this case, when people come to a standstill, the position of the heel which a robot detects changes. The pitch of a walk is measured by recognizing change of the position of this heel. The conditions for execution of experiment are shown below. The size of the input image from a camera is 160x120 pixels. The size of heal template is 19x19 pixels.
Fig.6 is a figure showing a temporal response of the position of the heel of a right leg when people come to a temporary standstill in front of a camera. In Fig. 6 (a), a frame is displayed on the detected heel. In (1) to (6), When a leg is raised and the leg reaches the ground, the heel can be detected in both of situations. In Fig. 6 (b), the position where the heel was detected is expressed to graph. In this experiment, Depth and the position on either side are not measured. The value of the vertical axis is what changed the deviation from the center of a view into the angle (Fig.5). The value of horizontal axis is the number of frames. Fig. 6 (b) shows that this system can be extracting the pitch along which human's walk.

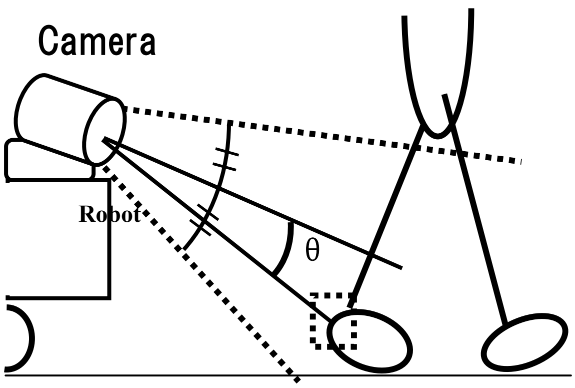


Fig. 5 Robot detected human's heel.

4. Concluding Remarks

This paper presents extraction of human walk pitch by robot vision. The work is intended to be basis for human-robot synchronized walking. The extracted pitch is to be used as visual sensation for entrainment of neural oscillator. The oscillator will generate walking pitch of a robot. To extract the walk pitch, human heel is detected and tracked visually. To track the heel, the authors use their interactively trainable pattern recognition system. Experimental result demonstrates feasibility of the idea. Experiments of the entrainment and the synchronized walk using a real robot are future works.

Acknowledgement

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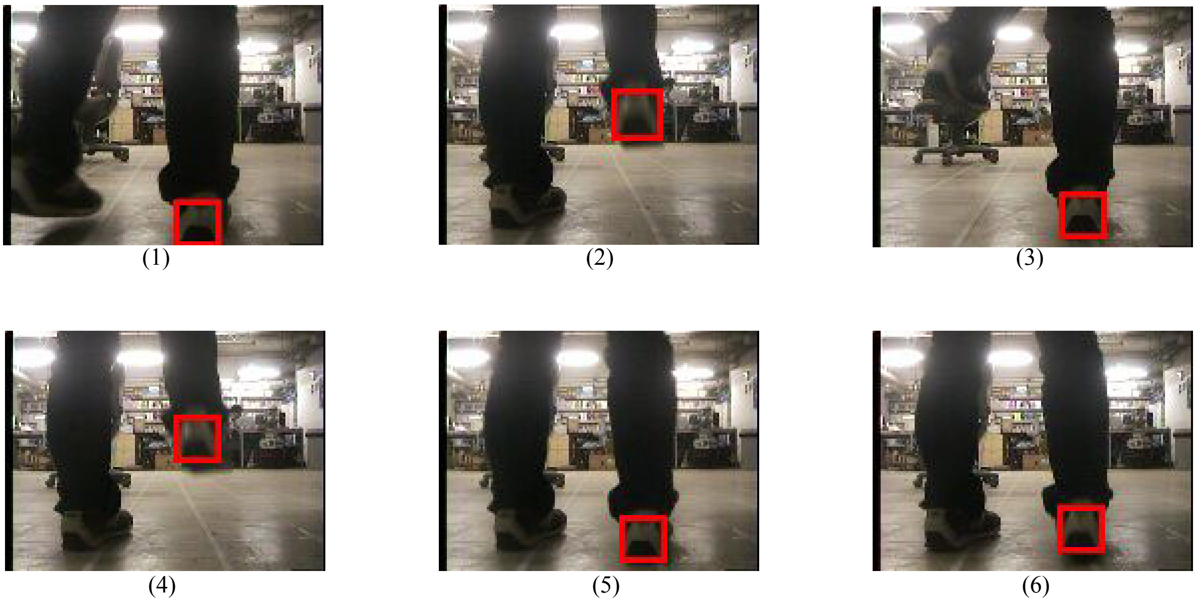
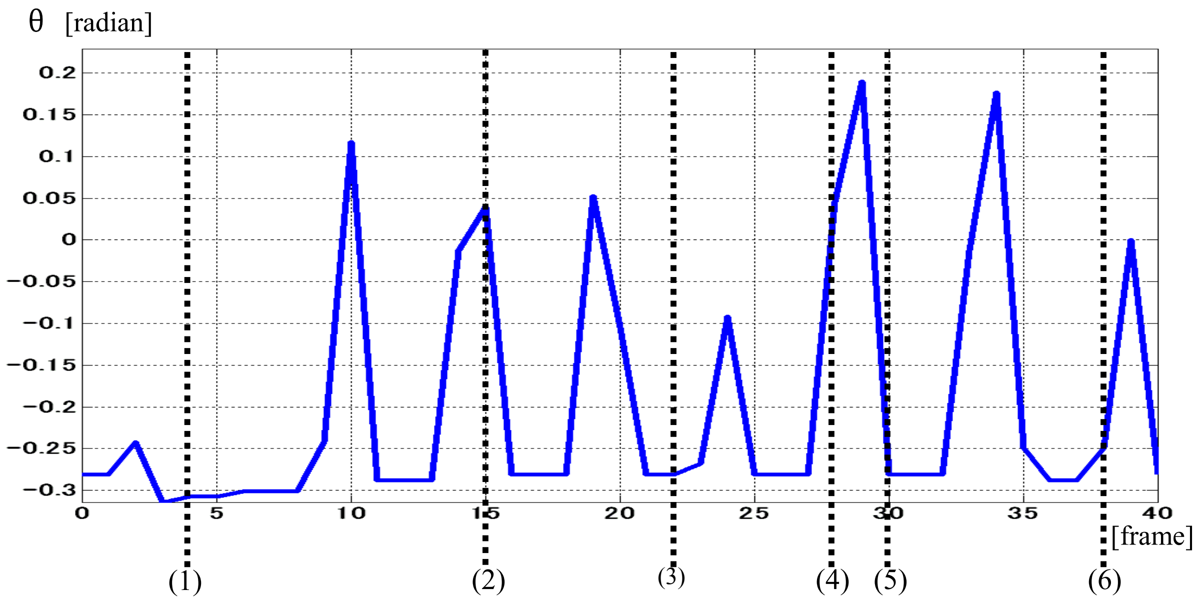


(a) Tracking right heel



(b) Time chart of right heel position

Fig 6. Experiment Result of Measuring Walking Pitch