A Robotic Forceps Based on a Fuzzy Coach-Player System Using Hierarchical Instructions

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Abstract

A fuzzy coach-player system is here improved as an instruction system with voice interface. However, this system deals with some fuzziness included in voice instructions and introduces hierarchical instructions, which is composed of two instruction levels. One is a local instruction level that uses any action commands directly. The other is a global instruction level that uses a task command. Such a fuzzy coach-player system is applied for the manipulation of a robotic forceps and the effectiveness of the present system is verified through some experiments.

1 Introduction

Recently, voice is often used as a communication interface between human and robot, because it is very natural and convenient to use it in a social robotics. We can see several situations that used the voice as a communication tool, e.g., in welfare robots, powered wheel chairs, guidance robots, pet robots [1]–[5], etc.

We have already developed a fuzzy coach-player system, where a human can be viewed as a coach in a sport, while a robot can be regarded as a player, and they communicate each other through the natural voice instructions uttered by the coach. This system has been already applied for the learning of commands for the motion of a manipulator [6],[7], the recognition of colored objects[8], the getting of complex motions of a redundant manipulator[9], etc. Note however that using only a direct voice instruction such as "move to the right" to a robot is an inconvenient instruction to a concrete task implementation, such as "travel to a target point."

In this paper, the fuzzy coach-player system is further improved as an instruction system with voice interface. However, this system deals with some fuzziness included in voice instructions and introduces hierarchical instructions, which is composed of two instruction levels. One is a local instruction level that uses any action commands directly. The other is a global instruction level that uses a task command. Such a fuzzy coach-player system is applied for the manipulation of a robotic forceps and the effectiveness of the present system is verified through some experiments.

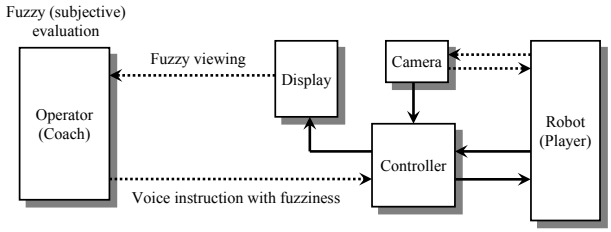

Fig. 1: A fuzzy coach-player system

2 Fuzzy Coach Player System

2.1 The Outline of Fuzzy Coach Player System

The fuzzy coach-player system regards the relationship between human and robot as a coach and a robot, where it can take account of any fuzziness included in voice instructions and can deal with a subjective evaluation due to the coach. The outline of a fuzzy coach-player system in this research is shown in **Fig. 1**.

In order to make human and robot perform a cooperative work smoothly, it needs to have the following items:

1. *Intention understanding*: The player reflects fuzzy representations, which are included in a voice instruction uttered from the coach, into his actions, according to his state conditions;
2. *Evaluation due to the coach*: The coach observes the action of the player, performs the subjective evaluation of whether the desired action has been attained, and he decides whether to issue the following instruction;
3. *Improvement by the player himself*: The player not only receives an instruction from the coach, but performs an improvement so that the former actions may be employed efficiently.

2.2 Voice Instruction by the Coach

Assume that at time k, an input sequence of fuzzy voice instruction uttered by the coach and collected from a microphone, $v(k)$, is handed over by a voice recognizer, and

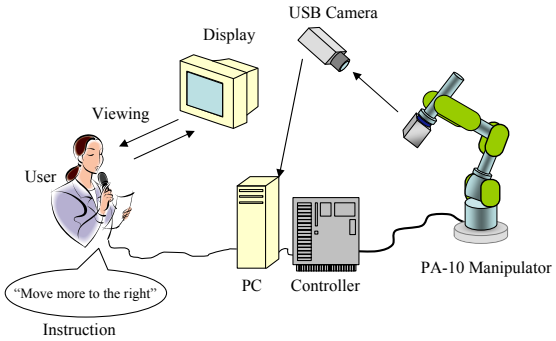

Fig. 2: System structure

Table 1: Keywords

	Keywords
v_{bt}	hold, carry, travel
v_{bd}	close, release, complete, move
v_c	yellow, black, white
v_d	right, left, forward, backward, up, down
v_e	a little, more

it can be split into an unnecessary language variable to the motion command, $v_a(k)$, a task related verb $v_{bt}(k)$, a direct action related verb $v_{bd}(k)$, an action objective noun $v_c(k)$, a direction related adverb $v_d(k)$, and a degree related adverb $v_e(k)$. Here, $v(k) \in \mathcal{V}$, $v_a(k) \in \mathcal{V}$, $v_{bt}(k) \in \mathcal{V}$, $v_{bd}(k) \in \mathcal{V}$, and $v_c(k) \in \mathcal{V}$, $v_d(k) \in \mathcal{V}$, $v_e(k) \in \mathcal{V}$, where $\mathcal{V}$ denotes a voice space that represents a time series in character level.

The structure of an experimental setup in this research consists of a robot manipulator with 7-dof (called PA10, which is provided by the Mitsubishi Heavy Industries Ltd.) where a forceps is attached on the tip of the manipulator, a PC for control, a microphone for gathering voice input, and a camera for image input. The outline of the system is depicted in **Fig. 2**.

In the voice processing part, the voice input $v(k)$ coming from the microphone is processed in turn for the voice recognition, the morphological analysis, and the pattern matching in order to extract $v_{bt}(k)$, $v_{bd}(k)$, $v_c(k)$, $v_d(k)$, and $v_e(k)$. The keywords used in this research are tabulated in **Table 1**.

3 Hierarchical Voice Instruction

In a method that makes the robot travel to a desired position by repeating a direct action instruction such as "move to the right," "more right," etc., the robot is just repeating a local motion, so that it cannot recognize a task such as "travel to a target." In order to recognize a task, it needs to use a hierarchical instruction composed of a global instruction in a higher level and a local instruction in a lower level, where the robot travels deciding by him for the global instruction, whereas the coach observes and evaluates it, and consequently gives a local instruction. In other words, the player should acquire the knowledge and the decision criterion required for completing the task. Thus, a set of these exchanges are needed for the fuzzy coach-player system.

Two instruction levels are introduced into the proposed system. One is a global instruction that instructs a task, consisting of v_{bt} and v_c. The other is a local instruction that instructs a direct action, consisting of the combination of v_{bd}, v_d and v_e.

For such a proposed system, the user first makes a global instruction and then makes a local instruction, observing the actions of the player. The player makes a decision that there was a global instruction, if v_{bt} and v_c were included in the contexts of the instruction uttered by the coach. Since there is no information initially for implementing the task, however, it needs to obtain a local instruction from the user. When acting under the local instruction, the required knowledge should be memorized, according to the global instruction.

4 Actions of the Player

The player decides the next action, according to the instruction uttered by the coach. Let the variables used for deciding the action be given by

$\boldsymbol{r}(k)$: the tip coordinate vector for the manipulator
$m(k)$: the amount to move
$\boldsymbol{d}(k)$: the direction to move
$\boldsymbol{P_i}$: the coordinate of the objective i

Here, k denotes the step number of the voice instruction, where $k = 1$ for the instant when the task v_{bt} was instructed from the coach. P_i denotes the position coordinate for the task objective, where initially i is to be 0 and its position is to be unknown. Assign a number to multiple v_c's from 1 at the order instructed from the coach.

4.1 The Decision of the Movement Direction

When receiving the task v_{bt} from the coach, the player decides the movement direction $\boldsymbol{d}(k)$ based on the following procedure:

```
if( there is no directional instruction
    from the coach ){
  if( Pi is not memorized ){
    if( k = 1 ){
      case 1
    }else{
      case 2
    }
  }else{
    case 3
  }
}else{
  case 4
}
```

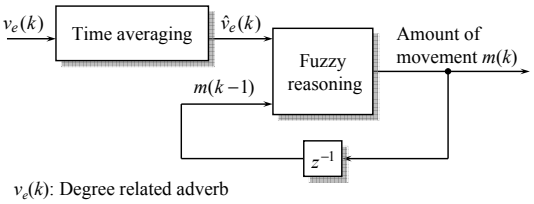

Fig. 3: The quantification of a degree related adverb

Here, each processing shown in the above procedure is as follows:

- case 1: a random direction given by

$$\boldsymbol{d}(k) = random \tag{1}$$

- case 2: a direction that a random component is added to the previous movement direction, given by

$$\boldsymbol{d}(k) = \boldsymbol{d}(k-1) + random \tag{2}$$

- case 3: a direction that is direct from the current position to the object, described by

$$\boldsymbol{d}(k) = \frac{\boldsymbol{P}_i - \boldsymbol{r}(k)}{\|\boldsymbol{P}_i - \boldsymbol{r}(k)\|} \tag{3}$$

- case 4: a direction instructed by the coach, given by

$$\boldsymbol{d}(k) = direction(v_d(k)) \tag{4}$$

4.2 Determining the Amount of Movement by Fuzzy Reasoning

The degree related adverb $v_e(k)$, which is included in the voice instruction, is quantified by using a fuzzy reasoning as shown in **Fig. 3**. The fuzzy reasoning is a simplified reasoning method, which consists of two inputs and one output, and its consequent part is composed of a constant. After expressing $v_e(k)$ numerically as shown in **Table 2**, the first input to the fuzzy reasoning, $\hat{v}_e(k)$, is a weighted time-averaging value described by

$$\hat{v}_e(k) = \frac{1}{w_1 + w_2}\{w_1 v_e(k) + w_2 v_e(k-1)\} \tag{5}$$

where $v_e(0) = 0.5$, $w_1 = 1.8$ and $w_2 = 1$. The second input to the fuzzy reasoning is the previous amount of movement, $m(k-1)$, where $m(0) = 0$.

The membership functions for $\hat{v}_e(k)$ and $m(k-1)$ are set respectively, as shown in **Fig. 4** and **Fig. 5**. The number of resultant fuzzy rules is $3\times3 = 9$ as shown in **Table 3**, where the constants of consequent parts are tabulated in **Table 4**. When defining the output of fuzzy reasoning as $m(k)$, the next tip coordinate $\boldsymbol{r}(k+1)$ is determined by

$$\boldsymbol{r}(k+1) = \boldsymbol{r}(k) + m(k) \cdot \boldsymbol{d}(k) \tag{6}$$

Table 2: Numerical values for the degree related adverbs

Word	A little	None	More
v_e	0	0.5	1

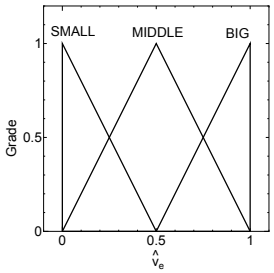

Fig. 4: Fuzzy set for $\hat{v}_e$

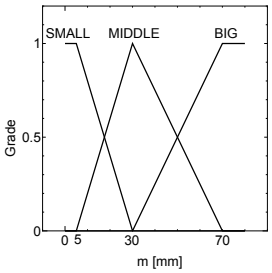

Fig. 5: Fuzzy set for $m(k-1)$

4.3 Memory of Objective Positions

When receiving two successive instructions consisting of v_{bt} = "hold" and v_{bd} = "close," v_{bt} = "carry" and v_{bd} = "release," or v_{bt} = "travel" and v_{bd} = "complete," the player memories the current tip position of the manipulator as a position coordinate P_i for the object i.

5 Experiments of Real System

As experiments for a real system, the tip position control of a robotic forceps was conducted to hold and carry some objects. The coach who is also a user first globally makes an instruction that includes a task v_{bt} and its object v_c. According to such an instruction, he observes the motion that was produced by the robot who is also a player, and locally makes an instruction that includes a directional modification v_d and a degree-related modification v_e, if necessarily. Here note that the negative x-direction means the forward direction, the negative y-direction denotes the right direction, the positive z-direction means the upward direction, and the height of the work support is assumed to be known.

As an example of the actions due to the real system, **Figs. 6**, **7** and **8** show the scenes where tasks such as "travel to white," "hold yellow," and "carry to white" are performed in order.

Since the player had no information on "white" and "yellow" for the tasks of "travel to white" and "hold yellow," the coach made the robot reach the objective points by instructing the direction and the degree, if needed. For the third "carry to white," the player was directed linearly to the object by using the information on "white" that had been already acquired by him.

Table 3: Fuzzy rules

		Previous amount of movement		
		S	M	B
Voice command	S	VS	S	M
	M	S	M	B
	B	M	B	VB

Table 4: Fuzzy set for $m(k)$

Label	VS	S	M	B	VB
Value [mm]	5	20	40	100	150

6 Conclusion

This paper has tried to realize a cooperative work between human and robot by introducing a hierarchical instruction for a fuzzy coach-player system. Combining a global instruction and a local one proved that a holding task of an object or a traveling task of the tip of a forceps was performed effectively.

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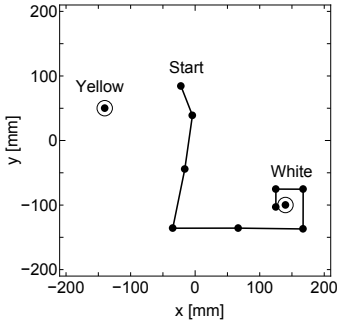

Fig. 6: Tip path with a command as "travel to white"

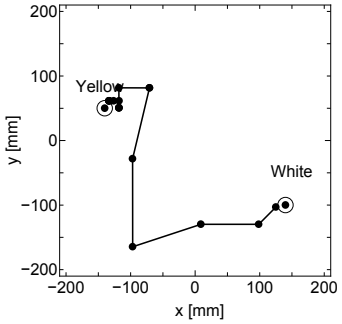

Fig. 7: Tip path with a command as "hold yellow"

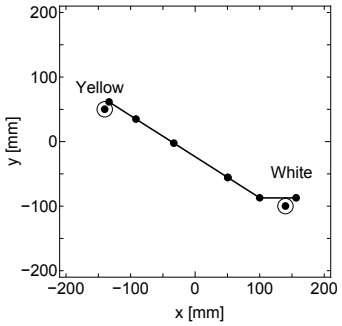

Fig. 8: Tip path with a command as "carry to white"

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