# Fuzzy Coach Player Method with Shared Environmental Data

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**Abstract**

In recent years, voice is used as an interface between human and robot or computer. An interface between human and robot, based on a fuzzy coach player method, is discussed in this paper. The concept of a coach player method comes from the training of athlete with his/her coach. In general, the coach teaches a skill for the athlete by speech with fuzziness. Therefore, authors propose a fuzzy coach player method so as to reflect a fuzzy voice command. Some simple examples are shown by experiments on a robot manipulator.

## 1 Introduction

In general, speech or voice is used as a major communication method between humans. Now, we are considering with teaching using voice for robots, because the communication by voice has several advantages. As for the advantages that one uses voice to an interface, it is easily pointed out that 1) there are few burdens to users because we need not necessarily remember the special knowledge and operations on input devices such as keyboards and mouse; 2) it is an available interface to the man who has a handicap in hand and foot, old people, and the man whose both hands are closed by some manual operation; and 3) since it is a sociable interface ordinarily utilized by human beings, we can have an attached heart to a controlled object.

From the above backgrounds, attention has gathered also in the research of a robot control by voice commands [1]~[4]. However, in the conventional research of a robot control by voice, it is difficult to apply for an actual task, because a user has to command by voice repeatedly with observing carefully the robot motion. In other words, a user provides many voice commands to the robot to perform an actual task.

In this paper, in order to achieve a cooperating between human and robot, we construct a voice interface with a fuzzy coach player method using shared environmental data. The effectiveness of the present method is illustrated through some simple experiments.

## 2 Fuzzy Coach Player Method

In order to smoothly realize a cooperative operation or work between a human and a robot, some intelligent exchanges need to be found between them. In particular, when a human issues "an operation command" through a natural spoken-language command to a robot, an ambiguous (or fuzzy) expression is always contained in the human conversation. Through the exchange of the knowledge of a human and a robot, especially through operator's voice commands and the observation of robot behaviors, a series of actions in which an operator makes a robot realize a desired behavior or motion is similar to the relation between a coach and a player who are doing the coaching of skill acquisition and performance improvement.

In this case, the following three points should be noted:

1. *Intention understanding* : A player incorporates the "command" well according to his performance state and posture, and reflects it on acquiring of skill or improving of performance, in spite of containing ambiguous expressions in an advice to the player by the coach voice.

2. *Evaluation of the player by the coach* : On the other hand, from the aspect of a coach, the coach judges subjectively whether performance, as the image which the coach has, and skill acquisition have been attained by the player, and decides whether to issue the following improvement command.

3. *Improvement of the motion skill by the player itself*: The player itself does not only blindly response to the spoken-language command from a coach; rather he usually improves his performance etc. so that the former effort (or action) result is employed more efficiently. Furthermore, he has an ability of accumulating the knowledge that can realize a more efficient performance by him, using sometimes reading of coach intent from a simple voice command.

## 2.1 Constructing a fuzzy coach player model

### 2.1.1 Interpretation of "fuzzy indication" from a coach

The voice indication of a coach is based on his experiences and consists of action (verb) plus action modification (adverb) or repetition of action.

### 2.1.2 Subjective evaluation of a coach

After giving a voice indication, a confirmation (through a direct observation or indirect observation) is performed on the motion of a player and the subjective evaluation based on the past experience of a coach is performed to the motion of the player. For example, an index of degree-of-satisfaction of the coach is introduced.

### 2.1.3 Improvement commands after evaluation

If the player motion is satisfactory based on the coach data-base, then any further improvement commands are not given to the motion. Otherwise, a further improvement command should be provided.

### 2.1.4 Introduction of a sub-coach

We consider the introduction of a virtual sub-coach who can support the role of a coach and reduce the load of the coach, by using a data-base composed of various intelligent information that could be acquired from the indirect vision through any display and camera and the voice uttered from the coach, i.e., using a set of sequential data composed of the subjective evaluation and the improvement command to the player. After the sub-coach obtains the behavior and intelligence of the coach by any way, the sub-coach (i.e., computer) and the coach (i.e., operator) control a robot in a cooperative manner.

### 2.1.5 Autonomous action modification of player

If there exist multiple commands of action modification from the coach, or repetition of the same commands, then it may be need to set a function that can suddenly increase or decrease the amount of the action modification, which is normally based on the current state of the player. Namely, by predicting the irritation of the coach, we need to make a function that can cope with a more action modification than the usual increment (or reduction) for the next step.

## 2.2 Representation of a relationship between the coach voice indication and the operation input

In the framework of a conventional robot control, it needs to control the joint position and velocity of the robot (or the end-effector position and orientation) using the joint input torques, or to control the velocity of the end-effector position and orientation using the joint input velocities.

On the contrary, in the fuzzy coach player system, it needs to find the followings: For example, the control inputs for a manipulator consist of motion indication commands that are very vague and are composed of a verb and adverb (or multiple adverbs, or adverb phrase), such as "move more quickly," "move to the right more slowly," "lower an elbow more and move," "move as it is," etc., which are different from the conventional input torques that are taken within a real-number region.

Therefore, let the input sequence of a fuzzy human voice indication from a microphone at time $k$ be $v(k) \in \mathcal{V}$, and the $v(k)$ passed through a speech recognizer is assumed to be split into the language variable $v_a(k) \in \mathcal{V}$, which is not necessary for the action indication, the verb $v_b(k) \in \mathcal{V}$, and the adverb (or adverb phrase) $v_{ab}(k) \in \mathcal{V}$,

$$v(k) = v_a(k) + v_b(k) + v_{ab}(k)$$

where $\mathcal{V}$ denotes the voice space that is a time-series of signal or character level. A fuzzy NN is used to generate a desired velocity command $\boldsymbol{u}(k) \in \Re^m$ (or torque command $\boldsymbol{\tau}(k) \in \Re^m$) to the robot, from the effective action indication language variables $v_b(k)$ and $v_{ab}(k)$.

For example, we consider the method of changing multiple action FNNs. In this method, an action $i$ is selected and switched out of $N$ action modules, according to the consistence with the current pseudo sentence such as

$$\boldsymbol{u}(k) = \sum_{i=1}^{N} \phi_i(v_b(k), v_{ab}(k)) FNN_i(s_i(k), v_{ab}(k))$$

where $FNN_i(\cdot) : \Re \times \Re \mapsto \Re^m$ and it is assumed that

$$\phi_i = \begin{cases} 1 & \text{if } \{v_b(k), v_{ab}(k)\} \text{ is consistent with } i\text{-th action} \\ 0 & \text{otherwise} \end{cases}$$

Note here that if there exists no inconsistence between the action and the action modification languages in the voice command uttered from a coach, then the above judgment of $\phi_i(k)$ can be implemented by only using the information of $v_b(k)$.

## 2.3 Observation of robot state

Considering the general dynamical model of a robot, it follows that

$$\boldsymbol{f}(\ddot{\boldsymbol{q}}(t), \boldsymbol{q}(t), \boldsymbol{q}(t)) = \boldsymbol{\tau}(t)$$

where $\boldsymbol{q}(t) \in \Re^n$ is the generalized coordinate vector and $\boldsymbol{f}(\cdot) : \Re^n \times \Re^n \times \Re^n \mapsto \Re^m$ is a vector-valued function representing the robot dynamics. Instead of measuring the joint angles and velocities as the robot states, the coach (i.e., operator) generally observes the velocity of the end-effector or the elbow that is the overall and ambiguous information for the state and orientation of the robot. Therefore, it is assumed that

$$\boldsymbol{z}_h(k) = M_d(\dot{\boldsymbol{q}}(k), \boldsymbol{q}(k))$$

for the observation of the robot state through direct human eyes and

$$\boldsymbol{z}_{id}(k) = M_{id}(\dot{\boldsymbol{q}}(k), \boldsymbol{q}(k))$$

for the displayed information of the robot, respectively, where $\boldsymbol{z}_h(k), \boldsymbol{z}_{id}(k) \in \Re^p$ and $M_d(\cdot), M_{id}(\cdot) : \Re^n \times \Re^n \mapsto \Re^p$. Moreover, the observation through human eyes for the displayed information is assumed to be

$$\boldsymbol{z}_{hd}(k) = M_{hd}(\dot{\boldsymbol{q}}(k), \boldsymbol{q}(k))$$

where $\boldsymbol{z}_{hd}(k) \in \Re^p$ and $M_{hd}(\cdot) : \Re^n \times \Re^n \mapsto \Re^p$.

For example, if we focus on the motions of the end-effector and the elbow for a robot manipulator with seven-degrees-of-freedom, then we can set $p = 6$ and $\boldsymbol{z}_h(t) = [\boldsymbol{z}_{htip}^T \quad \boldsymbol{z}_{helb}^T]^T$, where the first three-dimensional vector $\boldsymbol{z}_{htip} = [z_{1htip} \quad z_{2htip} \quad z_{3htip}]^T$ denotes each subjective and fuzzy (interpretation) variable for the position, velocity and orientation of the end-effector (e.g., the position is almost good; the velocity is a little late; and the orientation is generally good) and the latter three-dimensional vector $\boldsymbol{z}_{helb} = [z_{1helb} \quad z_{2helb} \quad z_{3helb}]^T$ similarly denotes the information of the elbow. In addition, observation vectors $\boldsymbol{z}_{id}(t)$ and $\boldsymbol{z}_{hd}(t)$ are defined similarly.

### 2.4 Generation of voice commands for the next step operation through a human subjective evaluation

After observing the fuzzy position, velocity and orientation of the robot end-effector and elbow through direct eyes or display, and evaluating such a motion with the subjective criterion of the coach, the voice command $v(t)$ for the next step operation is assumed to be generated by

$$v(k) = BF(\boldsymbol{z}_h(k)) \text{ or } v(k) = BF(\boldsymbol{z}_{hd}(k))$$

where $BF(\cdot) : \Re^p \mapsto \mathcal{V}$ is a criterion, for realizing a desired robot motion, in which the coach (or human) has been assumed to have it in advance.

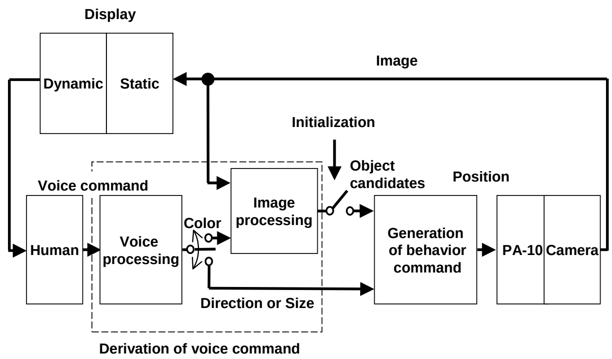


Figure 1: Example of fuzzy coach-player model with shared environmental data

## 3 Example of Fuzzy Coach Player System

The construction of proposed voice interface with vision is shown in Fig. 1. The proposed system is constructed with the derivation part of object candidates and the generation part of behavior command. At first, a user command by voice is given for object's color at first. The environmental data is initialized with each geometric center of object candidates and the commanded color. The initial object is determined as the object which has minimum distance between the initial position of manipulator's tip and the geometric center of the object. Next, if a user command is given for direction, then the derivation part of object candidates outputs the commanded direction to the generation part of behavior command. Finally, the generation part of behavior command provides the reference point of the manipulator's tip in the world coordinate depending on direction command and the environmental data.

The derivation part of object candidates is constructed with the voice processing part and the image processing part. The voice processing part is constructed with the voice recognition process, the morphology analysis and the pattern matching. The image processing creates the environmental data for the generation part of behavior command. The image process is carried out at initial stage or at changing the color of the object. The derivation part of object candidates outputs the command or the environmental data.

Derivation part of behavioral command provides a reference point of the manipulator using all geometric centers of object candidates and the voice command related to the direction or size. A user observes the working environment by this image in which the left image is a movie in the current working environment and the right image is the static image when the system was started. As shown in Fig. 2, when a user commands "red", right image shows +

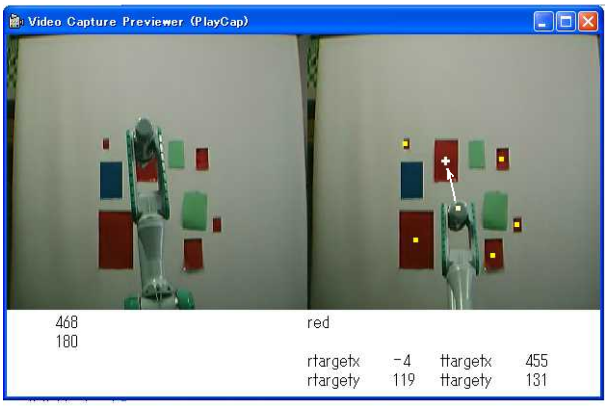


Figure 2: Initial movement with voice command "red"

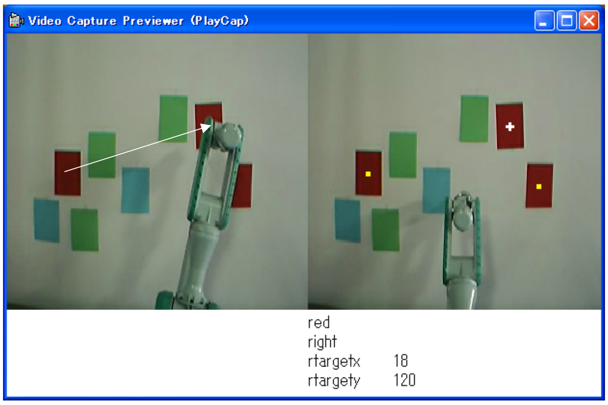


Figure 3: Result of voice command "move right"

or □ on each geometric center of red colored objects, where + means the target object, whereas □ means the red colored objects except for the target object. A user can observe the command and the position of the target object at the image coordinate through the bottom area of the image. It is found from Fig. 2 that the manipulator moves to the target object. The user confirms the desired object from + position in the right image and the displayed data at the bottom area as shown in Fig. 2. Next, when the user commands "move to left", the target object is changed, and the robot move to the left side target. When the user commands "move to up and small object", it is found from Fig. 3 that the user can perform the same fact as stated in Fig. 2. Finally, the user commands "move to smaller object" after completing the Fig. 3. The user selects a new target object on the manipulator's way to the former target object. The user can check the change of the target object in the right image and the movement of the manipulator in the left movie, as shown in Fig. 4.

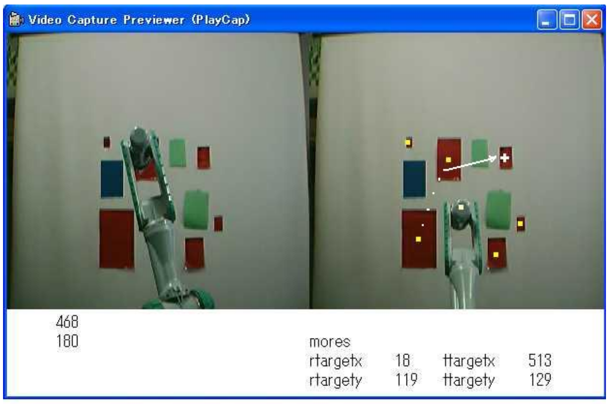


Figure 4: Result of voice command "a little small"

## 4 Conclusions

The concept of a fuzzy coach player method is discussed to smoothly realize a cooperative operation or work between a human and a robot, some intelligent exchanges need to be found between them. The environmental data is shared with image view to understand easy a robot movement. Simple experiment is carried out, so that it was easy to change the robot movement by voice command at any time.

## References

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