Imitation of Human Action Intelligence for the Environment of Desktop Teleoperation

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Abstract

It is well known that humans have high-level action intelligence. If such action intelligence could be represented in certain form, it could contribute to the path-planning problem of autonomous mobile robot. Therefore we shall address to transfer human action intelligence to mobile robot by means of imitation and acquire such action intelligence. Based on the effectiveness of previously proposed imitation method in simulation environment, we need to further verify the effectiveness of proposed imitation method and achieve the imitation of action intelligence on a real mobile robot. In this paper, the imitation of human action intelligence for the environment of desktop teleoperation, including experimental platform, research methods, and experimental procedures, was discussed. Firstly, imitation problem was clarified from the viewpoint of problem solving system, which provides guidance to the construction of imitation system. As an experimental platform, a desktop teleoperation system, including mobile robot and manipulation interface, was introduced. Through the developed teleoperation system, the intention representing human action intelligence can be easily transferred into mobile robot and meanwhile the corresponding action data can also be obtained for modeling. Then, based on the teleoperation system, the imitation procedure of human action intelligence was described. Finally, the effectiveness of proposed imitation method was illuminated by experiment.

1 Introduction

It is well known that humans have high-level action intelligence. If such action intelligence could be acquired in certain form, it can be applied to various fields such as the development of autonomous mobile robot, which can freely move even under complex environment. Naturally, if desired actions were appropriately achieved by imitating human action, such imitation methods would transfer human action intelligence into practical application and facilitate the acquisition of human action intelligence. So far, many imitation approaches have been popularly developed in the field of both robotics and artificial intelligence [1-3]. For our research, we believe that human action can remain in form of direct data and human action intelligence is certainly hidden in the remaining data. Thus we address to extract action knowledge representing human action intelligence from human action data and then imitate human action by employing the extracted action knowledge. Based on the effectiveness of previously proposed imitation method in simulation environment [4], we need to further verify the effectiveness of proposed imitation method and achieve the imitation of action intelligence on a real mobile robot.

The construction of this paper is organized as follows: imitation problem is clarified from the viewpoint of problem solving system in section 2. The objective imitation system is verified to construct in term of reasoning method, knowledge acquisition and knowledge base. As an experimental platform, the teleoperation system is described in section 3. Then an imitation procedure is proposed to construct objective imitation system. Here, learning method and reasoning method emphasizing knowledge usage are considered to implement the imitation of action intelligence. To illustrate the characteristics of proposed method, the experiments are conducted in section 4. The paper finishes with a conclusion in section 5.

2 Problem solving system for imitation

As the basic definition of imitation, imitation is not to create an original act or instance, but to try to reproduce an existing one so that same or similar act or instance could happen in imitator. Consequently, it can be said that if an imitation system (virtual imitator) does same or similar act as human, such system can be thought to be as intelligent as human. According to the development of problem solving system [5], the imitation system of action intelligence can be constructed just as in figure 1 by means of acquiring action knowledge, memorizing action knowledge, and reproducing the action. Knowledge acquisition method can be adopted to acquire action knowledge; knowledge base can be constructed to memorize knowledge representing human action intelligence; based on the acquired and memorized knowledge, not only precise action, but also predictive action for environmental variation is needed to reproduce, so fuzzy reasoning method can be adopted to implement this function.

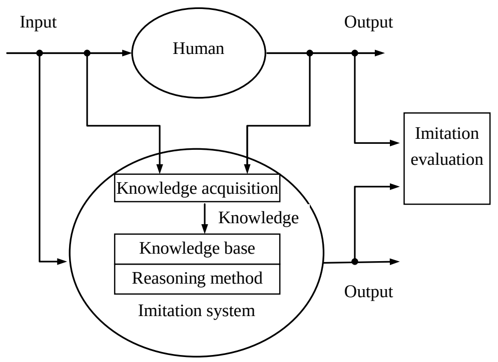


Figure 1. Construction of imitation system

3 Teleoperation system

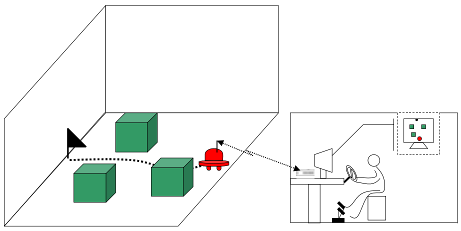


Figure 2. Teleoperation system

Just as in the figure 2, the developed teleoperation system connects the interaction between human and corresponding environmental space and provides a platform to fully employ human's obstacle avoidance ability. The platform mainly includes two parts: mobile robot equipped with digital camera and supersonic sensor, manipulation interface with the functions of both manual operation and autonomous operation.

Facing the visual environmental space of manipulation interface, an operator can control the speed and direction of a mobile robot by joystick. By judging the goal and surrounding obstacles, operator can try to avoid obstacle and arrive at the goal. As a result, operation is treated as successful operation, only if the robot controlled by operator arrives at a goal from a starting point with free collision during a specified time interval; otherwise, it is treated as failed one.

3.1 Mobile robot

The mobile robot is equipped with ball actuator so as to be able to move on any direction of 0~360 degree. Figure 3 is the appearance of the mobile robot, and table 1 shows the specification of the mobile robot. Figure 4 shows the Hardware construction of the mobile robot. DC motor and omni-wheels are evenly arranged every 90 degrees on the lower part of robot. The regular output of DC motor is 90W and its regular torque is 45kg.cm. Five supersonic sensors are evenly equipped on the upper part of robot to measure the distance between robot and surrounding object. Its maximum measure distance is 3000mm.

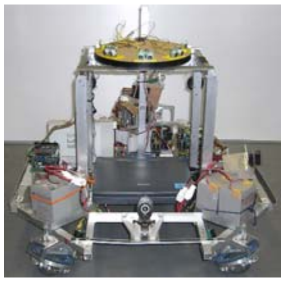


Figure 3. Photo of the mobile robot

Table 1 Specification of the mobile robot

Item	Detail
Height	600mm
Length/Width	800mm/800mm
Weight	about 50kg
Moving velocity	about 0.3m/sec

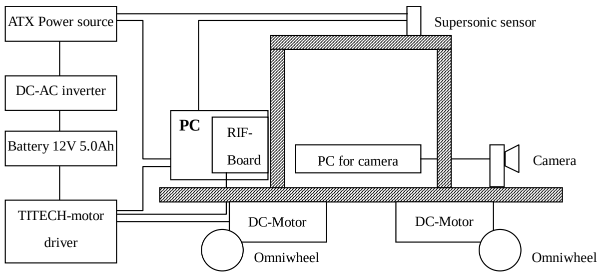


Figure 4. Hardware of the mobile robot

3.2 Manipulation interface

Manipulation interface was developed by means of Visual C++ 6.0 under the environment of windows XP. Figure 5 shows the software of manipulation interface. The left part of Figure 5 is the visual surrounding environment of mobile robot from camera (Creative technology Corp., WEBCAM NX Pro), while the right part of figure 5 are the experimental module such as teleoperation, learning and reasoning for imitation.

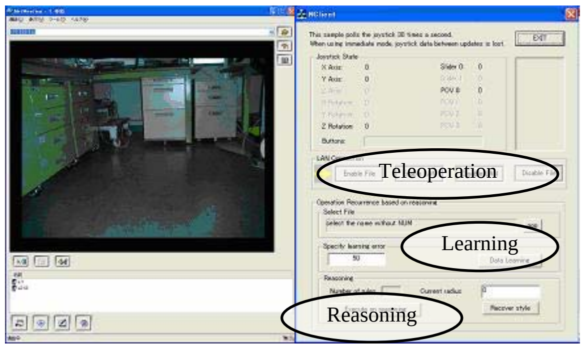


Figure 5. Manipulation interface

According to the structure of imitation system in section 2, these modules are necessary components for implementing imitation. Teleoperation module is used for manual operation of mobile robot to obtain the action data of operators. Both learning module and reasoning module are for autonomous operation of mobile robot. Learning module is used to acquire action knowledge from data, while reasoning module is used to reproduce the action of human.

Concrete learning and reasoning algorithms have been described in the literature [4]. Based on the effectiveness of previously proposed imitation method in simulation environment, we need to further verify the effectiveness of proposed imitation method and achieve the imitation of action intelligence on a real mobile robot. Compared with most of methods focusing on how to acquire knowledge better such as the acquirement and adjustment of fuzzy rules and membership function [6-8], alternatively, we are taking it into account that it will be more meaningful to pay attention to the importance of knowledge usage for imitation performance, according to the theorem that the SAM (Standard Additive Model) architecture allows independent rules to function cooperatively and the credibility of knowledge source is equivalent [9]. Also, considering the fact that human selectively employ knowledge for reasoning, i.e., not all knowledge in one's brain is used for reasoning. Considering the quantifiable characteristics of the relationship between the fact and rule, we shall adopt the distance between fuzzy set as the criterion of knowledge selection to strengthen knowledge usage during reasoning process. Concretely, the concept of knowledge radius[11] is introduced for knowledge selection. Knowledge radius q is the number of rules with the nearest distance between fact and antecedent of a rule. Where, q is an integer, $[2,\cdots,n]$, n is the number of rules.

The Distance-Type Fuzzy Reasoning method with knowledge radius is adopted to develop manipulation interface of teleoperation system. The fuzzy reasoning method is developed on the Distance-Type Fuzzy Reasoning (DTFR) method, which is a kind of fuzzy reasoning method considering the distance between fuzzy sets [10]. It features two main characteristics: asymptotic and decomposition characteristics (Modus Ponens is strictly satisfied). Thus the physical meaning of rules for reasoning is clear and reasoning tendency can be predicted appropriately.

Also, an improved learning algorithm for Distance-Type Fuzzy Reasoning is adopted for knowledge acquisition [4], because it is strongly related to the above reasoning method. Compared with conventional data learning methods for the generation of fuzzy rule such as GA or NN, this algorithm is very fast and simple with an arbitrarily specified error for learning, especially, it is suited for common numerical data learning. Meanwhile it also considers the statistical characteristics of teacher data to improve the selection of consequent for contradictive rule.

3.3 Imitation procedure

Based on the reasoning engine of the Distance-Type Fuzzy Reasoning method with knowledge radius, and the acquired knowledge by the learning algorithm for Distance-Type Fuzzy Reasoning, optimum knowledge radius is verified to implement the imitation of action intelligence. The imitation procedure consists of the following four steps:

Step1: Acquire the action data of human by means of teleoperation module of manipulation interface;

Step2: Acquire knowledge from the remaining action data by means of learning module of manipulation interface;

Step3: Calculate the evaluation value of knowledge radius and set the optimum value of knowledge radius;

Step4: Treat the reasoning performance of manipulation interface based on optimum knowledge radius as the imitation performance.

4 Experiments

4.1 Learning procedure

In order to describe variable environment for knowledge acquisition, the physical units between robot and objects, including goal and obstacle, are given by (1).

$$if\ S1\ \ S2\ \ S3\ \ S4\ \ S5 \qquad then\ \ X\ \ Y\ \ Z \tag{1}$$

Where

$S1\ S2\ S3\ S4\ S5$: respectively denotes the distance between robot and the nearest point of an obstacle/goal, its value varies in;

$X\ Y\ Z$: denotes the control behavior in form of joystick's position, $X \in [-790,627]$ $Y \in [-930,215]$ $Z \in [-961,96]$.

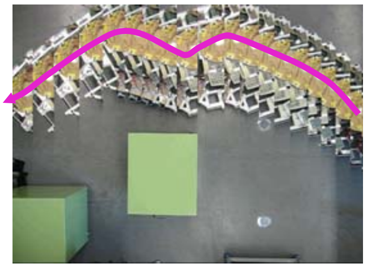


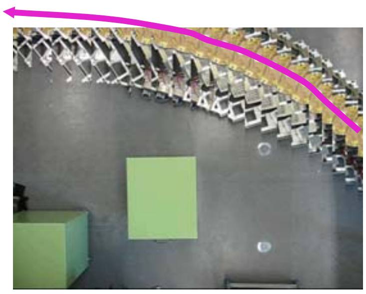
Figure 6. Operation path

As can be observed in figure 6, an operator conducted obstacle avoidance and successfully arrived at the goal point. Then by using the learning module of manipulation interface, action rules were generated. Concretely, table 2 lists the parameters for learning procedure.

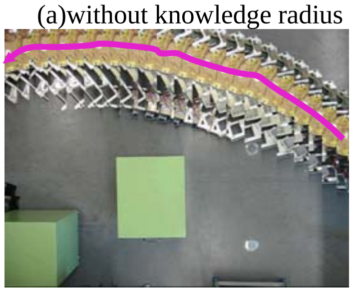
Table 2. Learning parameters

Environment	Two Static obstacles o1(250,100) o2(20,90)
Number of data	435
Learning error	50
Learning time	1.8 Second
Number of rules	96

4.2 Search of effective knowledge radius



(a)without knowledge radius



(b) with knowledge radius(q = 20)

Figure 8. Reasoning results

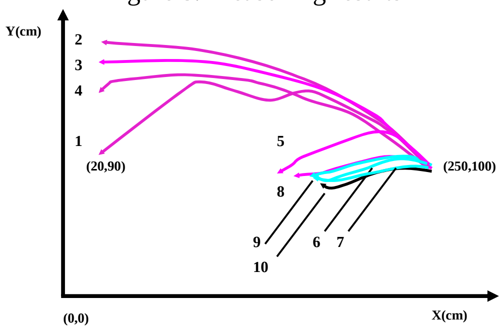


Figure 8. Control path and reasoning path

(1:control path 2: without knowledge radius 3: q = 30 4: q =20 5: q =16 6: q =15 7: q =14 8: q =12 9: q =10 10: q = 5)

For convenient analysis of imitation performance, path area error S between human's control path and reasoning path is calculated as criterion. Considering the practical problem of robot, the search scope of q is limited in [5, 10, 12, 14, 15, 16, 20, 30]. Figure 7 and 8 show the imitation performance corresponding to different knowledge radiuses. We can verify that the only optimum knowledge radius q is 20 with the minimal path area error.

4.3 Validation

The above experiment demonstrated the good performance based on the acquired rules with optimal knowledge radius 20, which does not mean the only rules within knowledge radius are useful, but all the more illuminate the effectiveness of both knowledge radius and current rules. We can draw the same conclusion as simulation that all of rules are useful, and good performance can be achieved by focusing on local knowledge, i.e., the control path can be effectively imitated by emphasizing knowledge selection.

5 Conclusion

In this paper, we discussed the imitation performance of proposed imitation method based on a developed teleoperation system and proposed corresponding imitation procedure. Through this teleoperation system, the data representing human action intelligence can be acquired and further be used for imitation. The effectiveness of imitation can be verified by experiment. Furthermore, the identification of knowledge radius is still needed to discuss for the guideline to specific problem.

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