A Walk Support System for Two Distant Persons using Mobile Robots

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Abstract

A remote walking partner system for two distant persons is newly proposed. A pair of persons is accompanied by a mobile robot as a complement of telepresence of the each person. The robots communicate measured position of the adjacent human with each other and mimic the movement of the remote human. The concept of the system and results of a preliminary experiment are detailed in this paper.

1 Introduction

In order to communicate in real-time with another person when being at a distant place, usually one can use telephone for speech transference, text-based chat on the Internet or TV-phone for live video transmission as many others. However, by using those conventional systems, it is difficult to make people to have the sensation that they are sharing a common physical space because only information flows are transmitted. In this study, we propose a novel method for communication between two people localized distantly, which can transfer their behaviors by using mobile robots. Each person is accompanied by a mobile robot as a complement of telepresence of the other person. The robots communicate measured position of the adjacent human with each other as well as to mimic the movement of the remote human.

In recent bibliography, a robot is used for giving instructions by gesture or speech to a remote human [1], [2]. Also, a face robot has been developed for displaying realistic facial expressions [3]. While those systems aim mainly to exchange information, the objective of our system is to exchange human behavior remotely. Similarly, a 'virtual' walking system for two distant people has been proposed in [4]. Our system performs a real-time remote walking by two persons in a 'real' environment thanks to the assistance of mobile robots.

The concept of the system is being described as well as some results from preliminary experiments.

2 Concurrently walking of two distant persons

2.1 Motion communication throughout distant places

In this system, such method is performed by two mobile robots, whereby each robot stands aside of its corresponding person and mimics their motion located remotely, as shown in Fig.1. A robot located at place P moves with the progressive motion of the person located at place Q. Concurrently, the other robot located on Q, moves according to the displacement of the person on P. Likewise, the person on P walks while thinking that robot beside personifies the people on Q. The person on Q walks while experiencing the same from side robot as the person P.

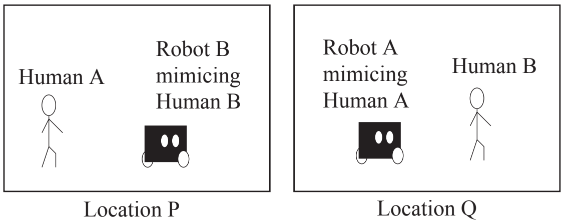

Figure 1: Motion communication between distant people by mobile robots.

2.2 The motion flow

The motion flow in the accompanying walk of two distant persons is shown in Fig.2. When the human A on the place P walks, the robot A on the place Q just behaves similarly to the human A movements. Then, the human B on the place Q walks together with the robot A. The robot B on the place P moves in the same manner as the person B. This enables the humans A and B from distant places to walk virtually together in the real world.

2.3 Exchange of localization information

To realize such a system, each robot has to be informed of the motion of the human located remotely. Therefore, each robot measures its relative position to the human on the same location, and sends it to the other robot. Each robot moves keeping a relative position respect to the aside person equal to the received relative position. As a result, the robot could mimic the motion of the remote human.

As shown in Fig.3, the robot B on the place P measures the relative position of the human A from the robot and sends it to the robot A on the place Q. The robot A measures the relative position to the human B and runs as the position becomes the same as the received position. The robot A also sends the relative position of the person B to the robot B on the place P.

2.4 Surrounded environment

In this study, we have started within a wide empty space environment where only humans and robots are considered. Because, if we take into account the existence of some other objects in the environment, it would be necessary to distinguish them from humans at this premier level. Moreover, in case of those objects be obstacles, an avoiding behavior must be considered. Therefore, the environment is simplified as a first step and the usefulness and feasibility of the proposed system are examined.

Once the first step for establishing the conditions of the environment has been defined, in the near future the following environments will be dealt with.

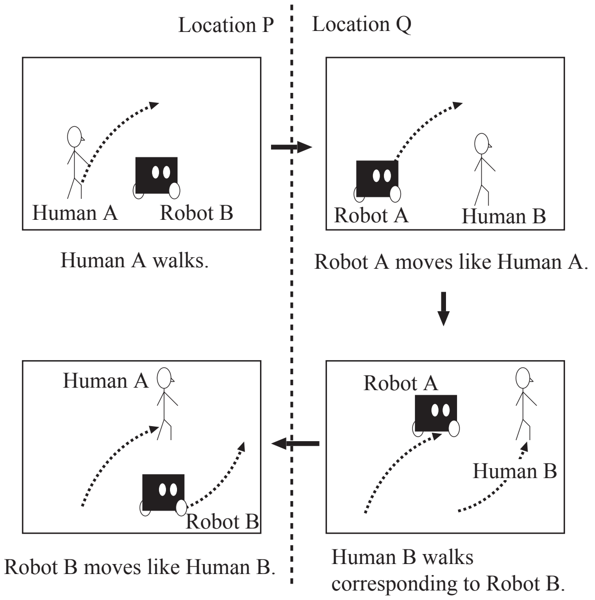

Figure 2: Motion flow in the accompanying walk of two distant persons.

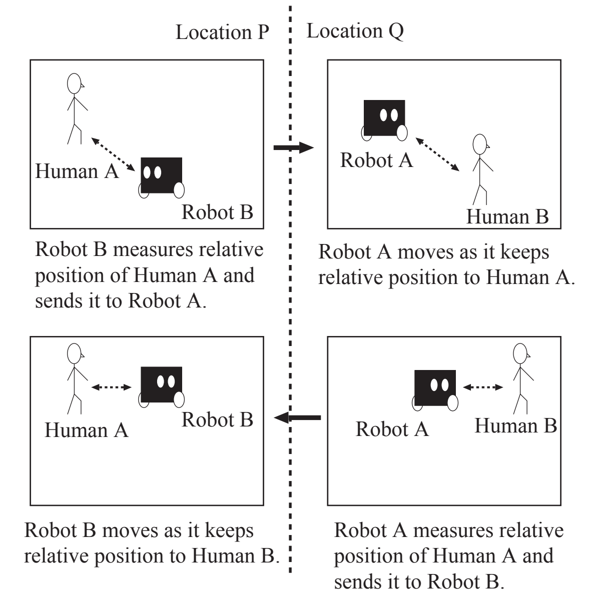

Figure 3: Communication of position information between 2 robots at distant places.

1. Simultaneously, when both humans walk by two roads, whereby trajectories (direction's angle) are different, e.g. one is a straight road while the other is a curved road. At this stage, behavior control should be done considering relative position between robot and road environment.
2. Both scenes include different obstacles.
3. The case when the road has some branches will be considered as the last environment.

3 System configuration

The configuration of the proposed system in this study is shown in Fig.4. The robot is equipped with a range sensor in order to measure the position of people. The measured sensor data is then acquired by a PC which is mounted on the robot, and such information is subsequently transmitted to another PC.

Each PC processes people positioning locally, receives position of the human from remote places, as well as position and speed of the robot. The system acts as a master controller by determining motion commands of the robot and considering the information previously obtained. Fig.5 shows the two mobile robot used in the experiments. A black box mounted on the top of the robot is the range sensor used to detect human position.

Fig.6 shows software architecture of the system. The measured data by the range sensor are sent to the local PC and subsequently processed. The calculated human position is then transmitted into the remote PC and sent to the information manager sub-system too. Both PCs are connected each other via a wireless LAN. Data transmission process is performed by a message passing transaction between both application programs (Spread Tool Kit software is being used [5]). The reference path and speed of the robot are determined from the received data and the current robot position already stored by the information manager. Thus, the corresponding motion commands are sent to the locomotion controller of the robot.

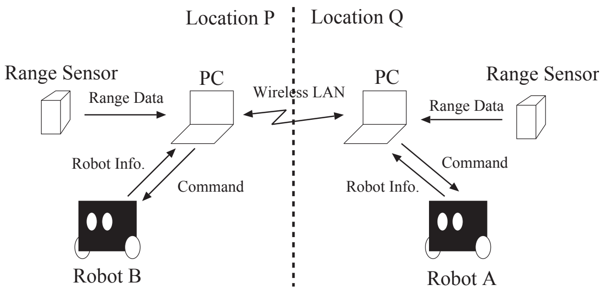

Figure 4: System configuration.

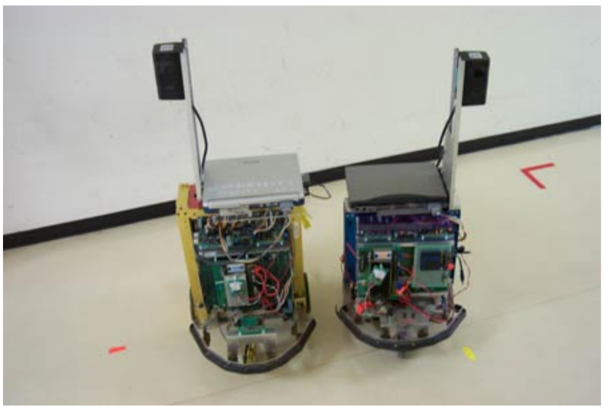

Figure 5: Mobile robot systems used for experiments.

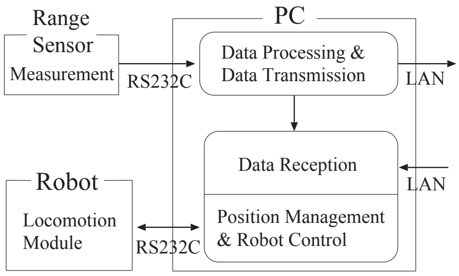

Figure 6: Software architecture of the system.

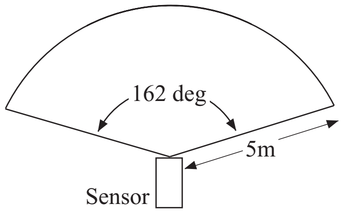

Figure 7: Measurable area of the range sensor PB9-12 used in the experiments.

4 Experiment based on the measurement of human position

PB9-12 (Hokuyo Automatic Co., Ltd.) is being used as a range sensor to measure human position. This sensor is able to measure distances from 91 directions within an area of 162 degrees by scanning an infrared light beam (Fig.7). It can detect an object up to 5m away. The sensor is connected to a PC via serial communication, the data refreshing cycle is shorter than 160ms. In short, accuracy of the sensor for human positioning measurement is examined through some experimental results.

4.1 Methods

The experiments were performed in an empty space where there was not even one object, excepting a human. The sensor was fixed on a table as shown in Fig.8. The measured data were gathered into the PC, this last placed on the same table too. The measurements were conducted according to the following two methods.

1. As shown in Fig.9, a human standing while his face angle is perpendicular to the sensor direction. Y-axis was set to the heading angle of the sensor. The position of the human was measured at five locations such as Y=100cm and X=-100, -50, 0, 50, 100cm.

2. The measurement of the human's position was done periodically by means of a determined interval time. The human just moved from the XY-coordinates at (150, 100) to (-150, 100), where the unit for the coordinates is given in cm.

4.2 Experimental results

Sensor data correction

The obtained data from PB9-12 consists of distance and angle information. During the preliminary experiments, it was found that the measured range was a little shorter than the real value. Hence, since those small differences exist, the measured range was customized by using a lookup table.

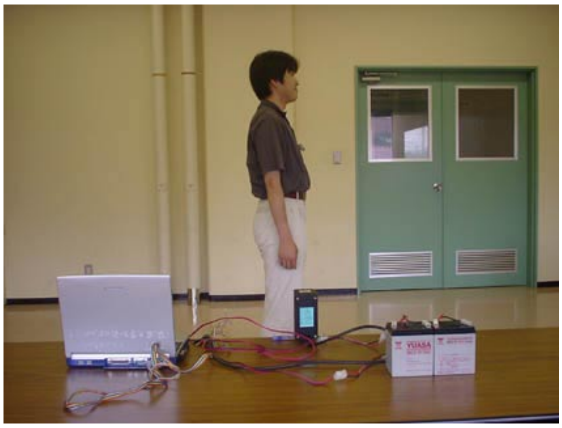

Figure 8: Scene of a preliminary experiment. A range sensor is fixed on the center of the table. The boxes on the right side of the table are batteries for the sensor.

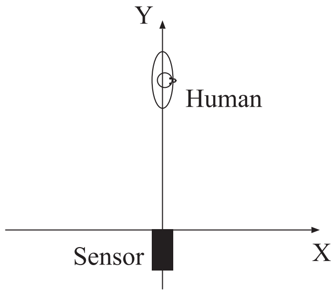

Figure 9: Arrangement of the sensor and the target human during the experiment.

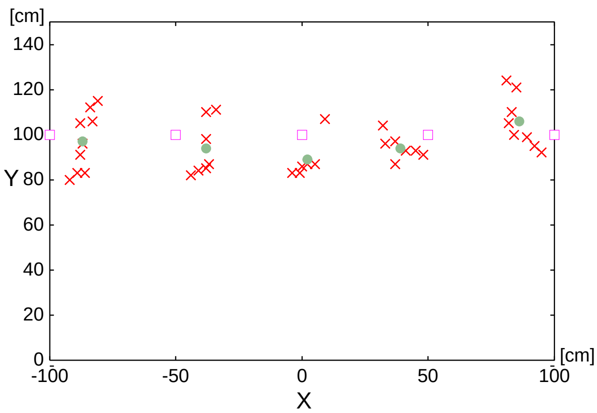

Figure 10: Experimental result of a stationary human. The position was measured at five locations of the human denoted by box marks. The raw measured data and the calculated human's position are represented by $\times$ and $\circ$, respectively.

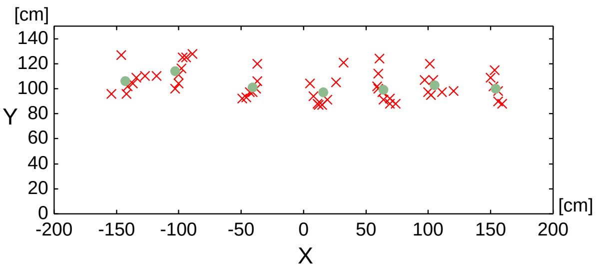

Figure 11: Experimental result of human standing measurement. The raw measured data and the calculated human's position are represented by × and ∘, respectively.

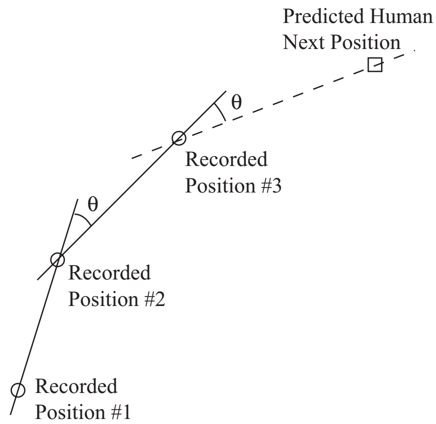

Figure 12: Prediction of a human future position, based on the history.

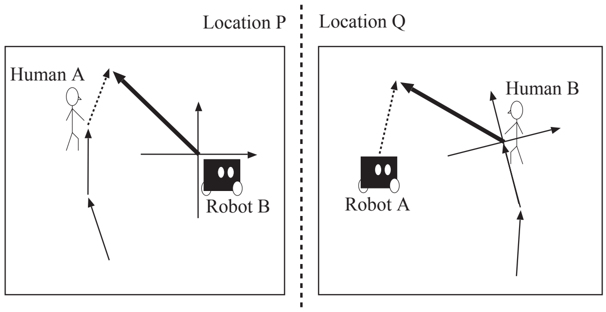

Figure 13: Calculation of reference positioning based upon remote relative position.

Measurement results of stationary people

Fig.10 shows a 2-dimensional plot of the measured data corrected by the method mentioned above. The origin of the graph corresponds to the sensor position and its vertical axis is set to the heading direction of the sensor.

Particularly, when a ranged object corresponds to a human, multiple sensed points are usually provided at one measurement. The position of the human could be represented by the center of gravity of the measured points. In case of some data points were appearing far away from the center of gravity, those data would be ignored because they fall into uncertainty considerations which produce inaccurate results. Then, the center of gravity was calculated once more for the remaining data.

In Fig.10, symbol × denotes the sensed data points and symbol ∘ represents the center of gravity of the data points obtained by a single scan. The box marks show the actual human standing locations. To be exact, the left leg of the person was placed on the box positions. Hence, it can be seen in this figure that the position of the human could be calculated with error of less than 10cm in X- and Y-direction.

Measurement results from human displacement

Fig.11 shows the plot of measured positions of a walking human from the experiment #2. The measured data of the sensor was corrected, and position of human was calculated similarly from experiment #1. In this figure, symbol × denotes measured sensor data and symbol ∘ denotes calculated center of gravity. It was found that the position of the walking human could be measured with good accuracy.

As a result of these experiments, we could conclude that the path of the robot can be determined by the data derived from PB9-12.

5 Robots motion planning

Any of both robots (e.g. robot B) receives the relative position data between a human (human B) and the remote robot (robot A), hence robot B determines its path by comparing the data with the relative position of the human aside (human A). However, it takes a moment to issue the current behavior command toward the locomotion controller, because of time computation of sensor data processing and transmission delaying of the wireless LAN communication. Therefore, a time lag will arise when the robot performs the same motion-behavior as the remote human. In order to overcome this problem, the robot has to predict the human's future position before sending it to the remote robot. The manner to predict the human future position has been already proposed in previous research, where the robot is able to move along with human [6].

The robot is able to predict the next position and speed of the human, based on the history of his position by means of time records of each periodic distance interval. The robot calculates the distance between actual and previous recorded human's positions. If the human moved along a determined distance, which is greater than a value already decided in advance, then the position of the human is registered in a list. Assuming that the human will move with the same acceleration and the same angular velocity, the next human position can be estimated by a linear approximation (see Fig.12).

After predicting the next human position, both robots exchange information with each other, such as the relative position of the human, which in the next time-position is sent by the robot. Basically, the robot calculates its next target position based on the current human position and his heading angle as well as considering the remote relative position but into their local space (see Fig.13). The path and speed of the robot should be determined according to this location. The path should be considered on a line from the current robot position to the reference position. Therefore, the speed of the robot should be set in such a way that the robot can reach the reference position for the next moment. Then, by means of this process, robot is enabled to mimic the remote human's behavior as an iterative modality.

6 Summary

In this paper, a remote walking support system for two distant people was proposed as a method for realizing communication of behaviors. The performance of the range sensor utilized on the experiments was evaluated for the usage of human position detection. The criteria to be considered for motion planning of the robot was examined.

As a future work, several considerations are being taken into account: (1) information will be communicated between two PC, via wireless LAN and a robot will displace according to the received position of the remote human. (2) In addition, the influence of data transmission delay will be analyzed in deeply. (3) A more complicated environment will be established after realizing a remote walking of two distant persons from the simplest environment. (4) Moreover, persons will be able to talk each other by adding a TV-phone to the system. We hope the system will provide a closer feeling of presence between two people.

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