Humanoid Robot Control System by Wireless Marionette Style

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Abstract— **When a speaker communicates a message to the listener, it can be expected to be transmitted more accurately by attaching an appropriate gesture to message. That theory is valid, whether the speaker and the listener are near or far away. However, for a speaker to deliver messages and gestures to a remote listener synchronously, it is necessary to have a real-time conversation system using video images. Therefore, in this research, we propose a mechanism for presenting gestures synchronized with gestures at low cost when sending messages to remote listeners. To realize that, we develop a method to move the robot near the speaker instead of conveying the gesture of the speaker by the video shot. In this proposed method, motion data of the hand of the speaker is acquired using a motion sensor, the data is processing, converting into information for moving the motor corresponding to the joint of the robot, and the information is transmitting to the remote robot, the robot moves with motion according to the intention of the speaker. To realize the proposed method, we prepared a mechanism to convert the hand gesture of the speaker into the motion data of the robot in real time and manipulate the robot in a remote place. In our system, we realize a function to transmit information of high urgency such as disaster information all at once to robots installed in each household. Based on these requirements, we developed a prototype of an information presentation system. By using this system, we expect the speaker's message to communicate to the multiple listeners effectively.**

Index Terms— **remote control, humanoid robot, human gesture, robot motion, telepresence**

I. Introduction

Recently, robot technology has been rapidly evolving. It is to enrich people's lives by utilizing robots for society. For example, security robots that protect public security, nursing robots for supporting care recipients. Extreme high safety is most important to put these robots into practical use in society. In addition, people need to feel an affinity with robots. Implementing the function to realize natural communication between the robot and the human being is a particularly important task.

We have acquired surrounding environmental data using various sensors, analyzed the data by computer, derived useful information, and effectively present that information to people. The purpose of these studies is that computers help people in various situations of human life. And, we aim to build a system that prevents the occurrence of obstacles and accidents by advising people on the risk factors that threaten people's save lives.

In this research project, we have developed a system that makes it easy to transmit and visualize data obtained by measuring intra-building Wi-Fi radio intensity [1]. As another research, by continuing to observe the indoor environment, we realized a system that warns by voice message when the temperature and humidity become high and the risk of heat stroke increases [2]. And, we have constructed a system aiming at sustaining concentration by working on olfaction when the driver of the car is going ahead [3]. Further, we built a system that effectively communicates information through the robot according to the driving situation of the car and the content of information transmission [4][5].

Because of those researches, when conveying a message to a person using a robot, we found that it is good to send the movement of the robot synchronously with the voice message. However, continuing to steer the remote robot at the same time as the speaker is speaking is a complicated task. For a robot to present a motion simultaneously with a word to a listener at a remote place, a mechanism is required to enable the speaker to steer the robot with a simple gesture. Also, it is necessary to have a mechanism in which a robot located in a remote place moves without delay according to the manipulation of the speaker.

In this paper, we first define a robot motion design scheme that encompasses various combinations among different sensing technologies

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and robots. Then, we elaborate an implementation method for a specific case among the combinations. With the remote message transmission method incorporating the mechanism proposed here, the speaker can transmit the message and the motion to the remote listener through the robot only with a simple operation. We expect that the acceptance level of listeners' messages will increase with the combination of remote language communication and nonverbal communication and communication robots. Our goal is to construct a robot motion design method that is independent of specific devices and technologies as much as possible.

II. Related Work

In this research, the humanoid robot expects the speaker to play a role as an interface for correctly communicating what he wishes to tell the hearer. Research that transmits information via a robot has been conducting in various ways. Matsui et al. propose that the humanoid robot has some advantage for mapping man movements to robot motions [6]. Patsadu et al. proposed a method to detect the gesture of the whole body of a person by learning the joint shape of the person photographed by the depth camera of the light coding system [7]. It is a difficult task for appropriately designing and creating motion data so that the robots behave like a human. The most promising method is to directly use human behaviors as is and map them to the series of commands for driving the robots. Jung et al. propose that not only when the robot is speaking, but also when you are not singing voice send the message appropriately by using the motion of the robot [8].

Even in past research, they used humanoid robots as interfaces for delivering messages to humans. Williams and Breazeal have developed a robot of AIDA (Affective Intelligent Driving Agent) that sends a message to encourage safe driving [9]. They installed it on the dashboard of the car and conducted experiments and proved that providing the message via the robot is effective. Zeng et al. are working on research to realize a guide dog by a robot for guiding the visually impaired and living support [10]. Liang et al. introduced a rehabilitation support robot that realizes two-way communication to restore the physical function of a stroke patient and showed that it is effective for improving the motor function of patients [11]. Miyachi et al. introduce that both the recreation for health caregivers and the health gymnastics were effective by using the humanoid robot 's speaking and action functions together at the care facility [12].

There are many studies so far in the field of Telepresence, Telexistence, in a method of presenting information to a remote party. Telepresence is a term indicating a technology that provides a realistic feeling as if they are faced on site with members in remote areas. As one method of realizing telepresence, Maimone and Fuchs implemented a real-time 3D telepresence environment realized by synchronizing several inexpensive depth cameras [13]. Adalgeirsson and Breazeal developed a robot that enables a speaker to navigate a remote robot to achieve nonverbal communication, thereby proving that the impression of the listener improved [14]. Wang et al. developed a micro telepresence robot that projects itself to another space remotely, moves around, communicates via video and audio, using the smart device of the user [15]. Telexistence is a term for the technology that enables a human being to have a real-time sensation of being at a place other than where they exist and being able to interact with the remote environment [16] [17] [18].

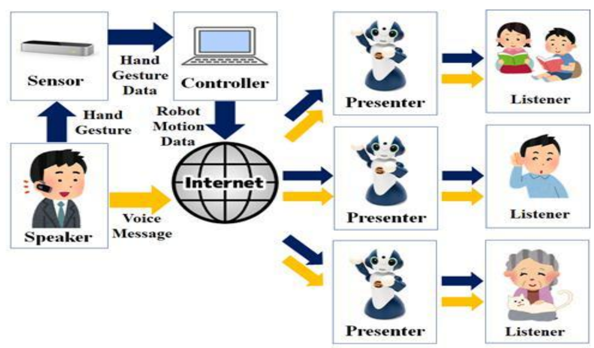

Figure 1. Dataflow of proposed robot motion broadcasting system.

III. System Organization

The proposed system measures the gesture of the speaker in real time, converts it into the motion of the robot, transmits its motion data, and drives the robot in the remote place. In the proposed system, one speaker can operate all at once on multiple robots. Fig. 1 shows the configuration.

This system has five objects Speaker, Sensor, Controller, Presenter, Listener. Speaker performs a word message and a hand gesture to operate the robot at the same time for the listener. Sensor acquires speaker’s hand gesture and converts it to data. The controller converts hand gesture data into robot motion data and transmits it via the internet. Presenter receives motion data of robot and voice message and outputs motion with the message. The listener receives information sent from the robot.

Fig. 2 shows to generate the movement of the robot from the movements of both hands of the operator. As a sensor that acquires the motion of both hands, a sensor that analyzes the movement of the operator's hand is used This sensor detects

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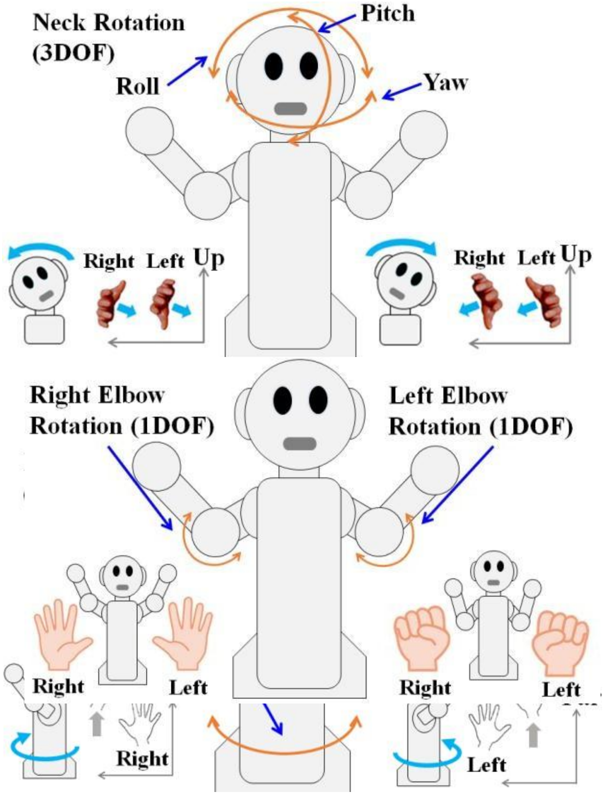
movement of the palm and fingers of the operator in real time. Based on the detection result, the



movement of the robot corresponding to the movement of the operator is generated. In general, as a method of using the gesture of the speaker for the motion of the robot, it is possible to think of a method in which the speaker moves the entire body and imitates the movement as it is on the robot.

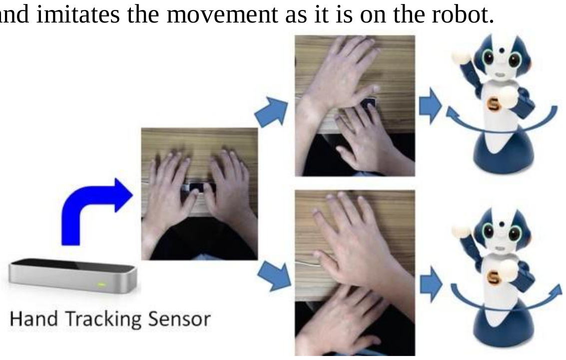


Figure 2. Move the robot with hands gesture.

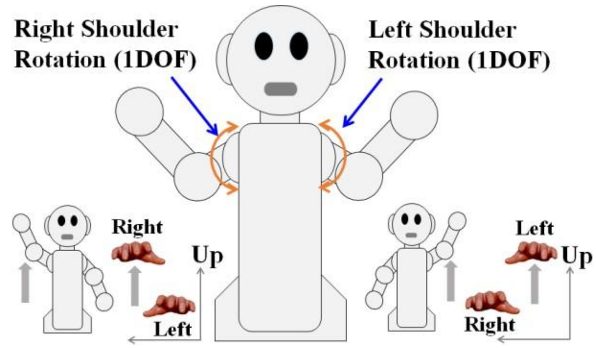


Figure 3. Mapping from human hand gesture to robot shoulder motion.

Figure 4. Mapping from human hand gesture to robot elbow motion.

Figure 5. Mapping from human hand gesture to robot body motion.

Figure 6. Mapping from human hand gesture to robot neck motion.

The reason why we did not use the method of directly using the speaker's gesture in this research is to make the robot generate motions consciously rather than moving the robot with gestures that the speaker performs unconsciously. Moreover, to recognize the gesture of the whole body, it is necessary to have a high-performance computer and photographic equipment.

In this system implementation, we decided to target only the speaker's hands and fingers as a method of recognizing the speaker's gesture. Therefore, we use Leap Motion [19] as photographic equipment to detect the movement of the hands and fingers of the speaker. Fig. 3 to 6 explain the mapping between the gesture of the speaker's hand acquired by Leap Motion and the robot movement. We use Sota [20] made by Vstone, which is used as a robot on the listener side in this research. The robot has eight servo motors in the body. These motors are one at the left shoulder, left elbow, right shoulder, right elbow, the base body and three at the neck, causing free rotation movement, respectively. By coordinating and moving these motors at the same time, we can create natural motion like human beings.

Fig. 3 shows that the operator raises and lowers the sensor's hand to move the left and right shoulder of the robot up and down. Likewise, Fig. 4 shows that the speaker is realized by opening and gripping the hand on the sensor to bend and extend the elbow on the left and right of the robot. Also, Fig. 5 shows that the speaker pulls one of the left and right hands towards you to move the body of the robot. Finally,

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Fig. 6 shows that the speaker can freely move the robot's neck by changing the orientation of the palm on the sensor. Between these gestures and the movement of the robot, there are rules and calculation formulas for conversion respectively. The system converts the information of the captured hand to the corresponding motor angle value of the robot.

In this research, to realize nonverbal communication in conformity with the message by the speaker during the conversation, we detect the movement of the hands and fingers of the speaker and generate the motion of the robot based on the result. It is necessary to perform processing to convert a human gesture into a movement of a robot. We describe the procedure for realizing the proposed system.

IV. System Configuration

Fig. 7 shows the overall configuration in the implementation of this system and the modules installed in each component. This system is divided into three components. They are “Controller”, “Broadcasting Server”, “Communication Robots”.

In this system, the controller first acquires the user's gesture data continuously using the sensor. The gesture- motion conversion module converts the received gesture data to the angle value of the motor to realize the movement of the robot. The broadcasting server continues to transmit the motor angle value to the message server all the time through the robot motion publisher module of the controller. According to the value, the communication robots continue to drive the motor using the robot motion activation module.

The data flowing between the parts is a total of eight angle values of the joints for the robot to move and a flag indicating whether the hand of the speaker is recognized. Next, we show the details of each component.

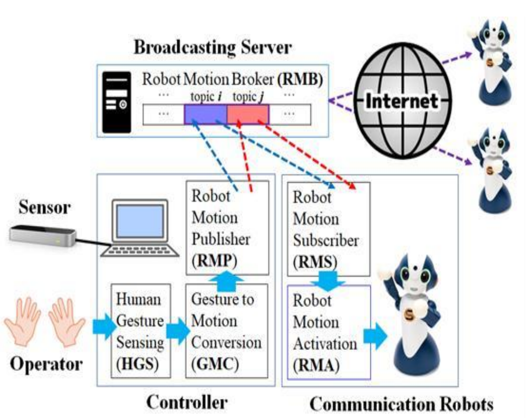

Figure 7. Dataflow of proposed robot motion broadcasting system.

A. Controller

In this system, the controller acquires the gesture of the hand of the speaker, converts the data into motion data of the robot, and is responsible for transmitting the data.

First, the Human Gesture Sensing (HGS) module converts the gesture into data. This work is realized by using the Leap Motion SDK used as a sensor this time. Next, using gesture to motion conversion (GMC) module, convert gesture data to motion data of the robot. To convert it, it is necessary to prepare calculation formulas after investigating the obtainable range of the gesture data and the operable angle of each joint of the robot in advance. Finally, the Robot Motion Publisher (RMP) module puts the motion data of the robot in a transmittable state. In this system, the MQTT [21] protocol is used for data transmission. By using this protocol, lightweight data transmission and reception by the Pub-Sub method can be realized.

B. Broadcasting Server

In this system, the server functions as a data broker for transmitting and receiving data between the controller and the robot. In the broker, each data is stored separately for each topic, and the data sent by specifying it as the latest topic from Publisher is rewritten. The subscriber gets the latest data for the specified topic. This data transmission/reception method has an advantage that there is no need to establish synchronization between the transmission side and the reception side. By dividing the topic into a plurality of topics, it is also possible to send motion simultaneously to robots of different shapes.

C. Communication Robots

In this system, the communication robot uses the Robot Motion Subscriber (RMS) module to acquire robot motion data from Server. The acquired data is set as the angle value of each motor by the Robot Motion Activation (RMA) module. By doing it, the robot moves as intended by the speaker. The robot used this time has a built-in controller with Linux OS. The RMS module that receives robot motion data and the RMA module that activates robot motion is created in the development environment such as Eclipse and transferred to the built- in controller. Functions such as the acquisition of a boss message and utterance are to be used already.

V. Preliminary Experiments

We constructed a prototype system based on the design detailed in the previous section and carried out the preliminary experiment. Fig. 7 shows the

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image of the installed system. The OS of the control PC is Linux (Ubuntu). All modules are running on the environment and are implemented using the Python language. Leap Motion connect to the controller PC. The PC converts the gesture of the hand obtained by the sensor into the angle value of the eight motors of the robot. To broadcast these values to multiple robots, we implemented a function using a free MQTT broker Mosquitto [22]. In the robot, all modules implemented in Java language. We used the Eclipse Paho library [23] to read robot angle values from the Broker.

Because of the operation experiment of this prototype system, when the controller and the robot are connecting to the same network, the time taken for the robot to move after recognizing the hand of the speaker is less than 0.1 seconds confirmed. Also, the speed of transmitting robot motion from the controller to the robot was over 20 times per second. Moreover, even if the controller and the robot communicate via the 4G mobile phone communication network, we confirmed that the robot moves in real time according to the movement of the hand of the speaker. In this system, even if the motion data passes through the mobile phone line, the time to reflect the gesture of the speaker's hand on the motion of the robot is very short.

Because of implementing the system and verifying the operation many times, we got some knowledge different from what was supposed. First, to operate the robot accurately at a remote position using this system, it is necessary to become familiar with the gesture operation defined in this system to some extent. Furthermore, the actions performed by the remote robot do not necessarily match the motions generated by the speaker. As one of them, the range of motion of each part such as the arm and neck of the robot conflicts. Since the robot only moves servo motors corresponding to each joint with specified values, it is necessary to prepare control values that prevent the robot side from interfering with the system side.

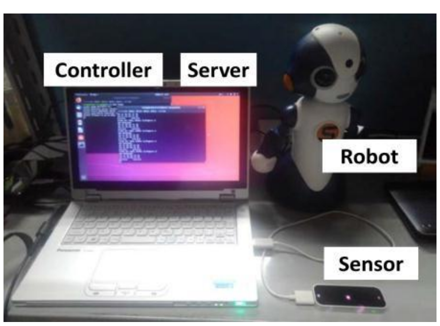

Figure 8. Prototype system implemented for preliminary evaluation.

VI. CONCLUTIONS

In this study, we developed an information presentation system using a robot that presents gestures by the operation of the speaker simultaneously with the speaker's message. We conducted an experiment using the system and confirmed that the robot at the remote location could be operated freely by the gesture of the speaker. In the future, we can expect to create even smoother and natural robot motions if we use a faster control PC and a robot with an improved built-in controller in the future. We also got some lessons from the experiments. One of them is that when linking the motion of human hand and the motion of the robot, it is necessary to accurately grasp the motion of the human and the motion of the robot and the motion range of both, and to define the correspondence.

In this paper, it was recognized by preliminary experiments that it is necessary to familiarize the gesture to some extent with generating the motion in real time with the speaker's hand gesture. In our previous study [5], the movement of the robot used with the message took the way of converting the gesture of the human hand into motion, editing the motion data, and calling it. As one of the methods to solve the problem, I would like to study the way the speaker calls the motion pattern of the robot which I made in advance by using the gesture.

In this experiment, because we could not prepare the device, we experimented with only one robot. By conducting experiments using two or more robots in the future, we would like to confirm that multiple robots perform the same movement at the same time according to the operator's operation.

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