Contact-Based Gesture Recognition on an Omni-directional Mobile Robot for a Robot Companion

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I. Introduction

Human Robot Interaction (HRI) is being highlighted since the applications of robots has been extended from industry to a common human environment. The main objective of HRI is delivering an operator's intention to a robot and the state of the robot to the operator. To deliver human intention to robot, various kinds of methods can be used such as dedicated input devices, gesture, voice, and touch. Typical industrial robots have been commanded by experienced workers using dedicated input devices such as teach pendants, however, such complicated devices are not suitable for general public to control service robots, and easier methods are needed.

If a robot is used as a companion helping people achieve their daily goals rather than an object to be controlled, new HRI methods rather than complex multi-functional teach pendants are necessary because the people have to focus on their own tasks and not to be distracted by controlling robots. Therefore, the HRI should be not only intuitive and simple, but also not interfere or be interfered by operators' task.

One of the advanced intuitive methods for HRI is delivering the human intention with a body gesture. The most famous method for a gesture recognition is using a depth image made from an infrared projection such as Kinect™, and many scientists have developed precise gesture recognition techniques using it. However, the workspace is limited to an indoor environment because the infrared is vulnerable to the sunlight. The alternative to the limited infrared projection is a laser sensor. The main application of a laser sensor was measuring a distance, but it has been extended to object detection and 3D mapping. In addition, some laser sensors which are produced for 3D mapping can scan around it, so robots can recognize the gestures of all the people around it. To use a gesture recognition as a HRI for a robot companion, we need to differentiate a commanding gesture from a working motion, and it is a very difficult work in which a human behavior should be closely analyzed.

On the other hand, touching became a pervasive input method for handheld devices which have touch screen components. In the case of touch screen devices, almost all the human intentions contained in touch gestures are well-defined, but touch or contact sensing on a robot body is not investigated enough compared to touch devices. One approach to use touch gesture in HRI is utilizing tactile sensors. In this case, tactile sensors are attached to the skin of the robot, and the robot recognizes a touch by the sensor values. Another approach can be sensing a force when the touch gesture generates an interaction force to the robot [4] [5]. Usually, sensing a force has been used for guaranteeing a safe collision between a robot and human rather than HRI [1]. We have investigated external forces applied to robots from a safe perspective, not a human intention. A contact force is just one part of touch gesture, so we cannot fully estimate the gesture even though the accompanied external force is perfectly derived. For example, a pulling and a pushing can contain different intentions, but the external force itself does not have any information for differentiating them.

To satisfy the requirements for the HRI of a robot companion, we suggest a contact-based gesture recognition. A contact-based gesture allows the differentiation of a commanding gesture from a working behavior because the robot can decide that there is a commanding intention when an external force is applied to the robot. Also, compared to typical input devices, a physical interaction is much easier and simpler, so the operator will not be distracted from his or her task by the commanding. In our approach, a human behavior is estimated by a depth image generated by a rotary laser scanner on our robot, but the estimated gesture is not interpreted as a command. However, when an external force which is detected by torque sensors on its drivetrain is applied to the robot, then a contact gesture is estimated from the behavior information from the laser scanner and the size and the direction of the force, and the human intention is guessed from the contact gesture. Finally, the robot follows a predefined reaction plan which corresponding the estimated human intention.

II. Trikey, Omnidirectional Mobile Robot with 360° LIDAR and Drivetrain Torque Sensors

Trikey is a holonomic omnidirectional mobile robot which has torque sensors on its drivetrain [2], [3]. The omnidirectional movement enables Trikey to instantly react to the commanded input. Also, the omni-directional formation of the three wheels guarantees that the external force can be derived by the combination of the torques applied to the wheels.

The torque sensor located in each drivetrain senses all the torques applied to the drivetrain: both the actuator side and the load (wheel) side. So, the external force applied by an operator is detected by the torque sensors as one of the torques from the load side. From our previous work in [3], we can estimate the direction and location of the external force

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if it is a single pushing force, which is a usual unintentional collision as shown in Eq. (1).

$$\begin{bmatrix} f_x \\ f_y \\ \tau_z \end{bmatrix} = \frac{1}{r} \begin{bmatrix} 0 & -\cos(\pi/6) & \cos(\pi/6) \\ 1 & -\sin(\pi/6) & -\sin(\pi/6) \\ R & R & R \end{bmatrix} \begin{bmatrix} \tau_0 \\ \tau_1 \\ \tau_2 \end{bmatrix} \quad (1)$$

However, if the operator has an intention to manipulate the robot, then there will be many different ways to apply a force to the robot such as pushing, pulling, and pushing with two hands, and the estimated force from the torque sensors may be different from the real forces applied to the robot. From the oversimplified force estimation, the robot can hardly estimated the human intention.

To improve the gesture estimation performance, the robot observes a human behavior with a rotary laser scanner. Hokuyo UTM-30LX is a laser scanner scans a single 270° horizontal layer continuously. Thus, the scanner is attached to the DC motor powered rotary mount vertically, then the mount rotates to scan the whole environment around the robot. Fig. 1 shows how the scanner rotates and scans the environment. The scanner scans a single layer every 40ms and the rotary mount rotates with around 600RPM speed. The motor for the rotary mount is not a precise motor, however, we attach a precise encoder which has a resolution of $6.28 \times 10^{-4}\,\mathrm{rad}$. The electrical system of the robot is depicted in Fig. 2. As a result, the rotary mount does not rotate precisely, but we know the exact orientation where the laser scanner scans. Finally, the rotating laser scanner can generate a point cloud covers its environment.

From the point cloud data, we can derive a human posture and keep track of the posture. If there is an external force and it exceeds a predefined threshold, then, the system figures out the contact gesture. We utilize the touch dictionary defined in [6], and decide the touch gesture category from the estimated posture and the external force.

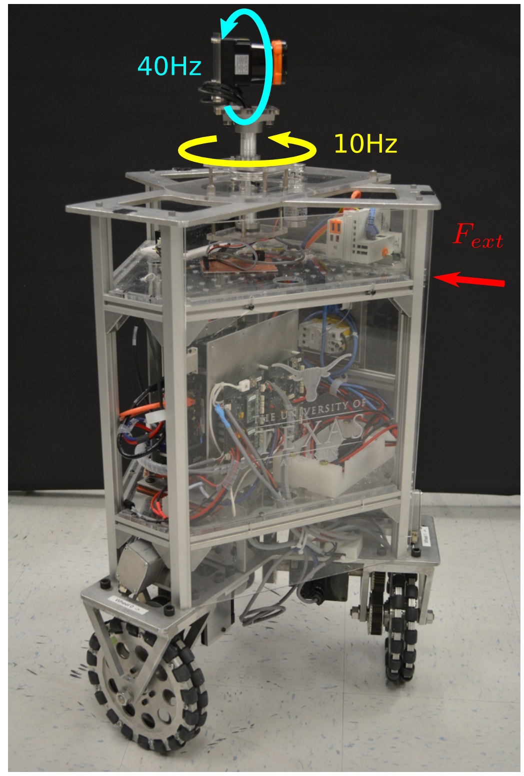

Fig. 1. **Trikey** with 360° LIDAR and torque sensors on its drivetrain. The laser ray from the LIDAR rotates with 10Hz horizontally, 40Hz vertically. Also, external forces applied to the system are detected the torque sensors in its drivetrain.

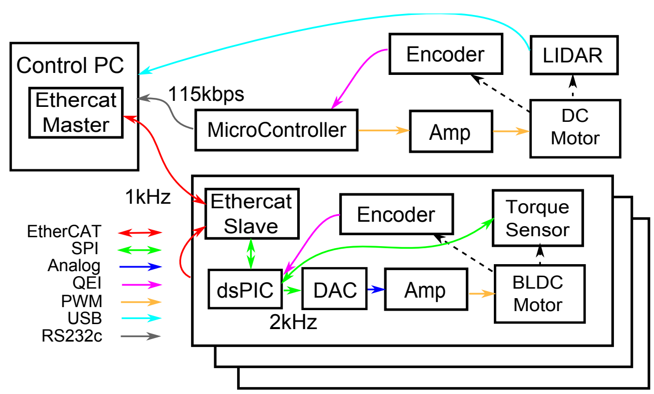

Fig. 2. **Electrical system on Trikey** controls the three motors and the rotary mount of the laser scanner. The control PC sends a command to each motor through EtherCAT communication channel. The range data from the laser scanner is directly fed to the control PC through USB connection. The orientation of the range data is derived by the synchronizing signal from the scanner and the encoder data. The microcontroller, Raspberry Pi 2, receives all the signal and generates the orientation, then deliver it to the control PC via RS232c channel with 115200bps baudrate.

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