Human-Robot Interaction

Wei Xuan
Department of Electrical and Computer Engineering
University of Auckland
wxua004@aucklanduni.ac.nz

ABSTRACT
Human-robot interaction is an important topic in robotics, more and more researchers paid efforts to increase knowledge for this topic. The main concerns of human-robot interaction is about communication between human and robots, level of autonomy assign to robots, how interaction between human and robots will increase the chance to complete tasks by robots and etc. In this paper, metrics of task-oriented mobile robots and a framework for future home server robots are presented. There are lots of approaches have been developed for human-robot interaction. Three approaches about this topic also illustrated. The first approach is about tracking human trajectories to choose the right style to start interaction with human. The second approach showed a possible solution to position object in 3D environment. The last approach introduced Immersive Human-Robot Interaction which is a system used to build a virtual environment to mirror robot's situation.

Author Keywords
Human-Robot Interaction (HRI), Human-Computer Interaction (HCI)

INTRODUCTION
In today's society, robots play an important role in everyone's daily life. They are used for industry, military, rescuing, housekeeping, elderly care, museum tourism and so on. One of the advantages of using robots is that they can do dangerous jobs to ensure safety of people, they are also tireless, and accuracy and quality of tasks which are done by robots is high. Along with the increase of connection between people and robots, human-robot interaction (HRI) becomes a popular research topic in recent years.

From the literal understanding, human-robot interaction is all about how people can interact with robots. However, this is a wide range topic, it includes some aspects, for example, it concerns about how people initiate an interaction with robots, how robots understand what people say, how robots remember people's face, how robots react to people's questions, what ethical problems will be raised during developing robots and vice versa. Concluding above, human-robot interaction involves topics such as robotics, artificial intelligence, social science, human-computer interaction and natural language understanding. Human-robot interaction is always restricted by the knowledge shortage of people, for example, to achieve artificial intelligence for robots, people must firstly study more about how human brain works, and also psychology needs to be well understand; for making more comfortable interaction to people, robots have to recognize more words, and need to improve image processing techniques.

Section 2 outlines problems and sub-problems of human-robot interaction. In Section 3, methodologies and findings of the topic have been addressed. Section 4 explained some approaches to human-robot interaction. Then section 5 concludes this paper. Lastly, section 6 focuses future improvement in this field.

PROBLEM

Information Exchange
The manner of information exchanging between human and robots is important to human-robot interaction. In [6], the main focus with the experiment is to resolve the robot's contextual information missing which is received by the scientists. Urban Search and Rescue (USAR) is a challenging task in today's world. If using robots to USAR, missing contextual information of robot's state and environment may refer to fail to the task. The term of information exchange can be divided into two concerns: medium of communication between robots and human, and the format of communication. The medium can be defined as visual display, gestures, natural language speech, non-speech sound and directly manipulation. The format of communication is determined by the medium of communication, for example, using natural language speech, the format will be specified to a certain language.

Autonomy
Autonomy is defined as how much freedom robot could have when completing a task. In [3], the experiment successfully presented a way that robot can automatically initiate an interaction with human naturally. In [1], AIBO dog is developed by Sony, and it is able to chase a ball like real dog. If people try to develop a robot companion, level of autonomy is most significant factor need to be concerned. The main problem of autonomy is that the lack of algorithm to achieve artificial intelligence of robots. Psychology is necessary in this field. For natural linguistic conversation to human, speech recognition and linguistics need to be studied more.

Task Completion

Robots are developed to be a substitute for human to do some dangerous tasks, or make some tasks easier to human. Whether not a robot can finish its task is what people paid the most attention to. For example, robot needs to build a map of environment for localization. However, in USAR, the environment is unstructured, this strict challenges the robot's ability of map-building, information exchange and mobility. Trust is also a concern in task completion aspect of robotics. Deborah et al. presented the importance of trust in military area in [7], they believe that *"Trust can impact the success of human-robot collaborations and may determine future robot usage"* [7]. Therefore, although continuing to develop technologies of robots is needed, it is also necessary to build trust between robots and human.

Ethical

With the rapid development of robots, robots are able to complete complicate tasks which people may not be able to do. However, increase the use of robots will permanently decrease the percentage of population in unemployment, because robots are tireless, fearless to hazards, achieving high accuracy compared to human. Moreover, more and more companies have developed robot caregivers for people. [1] argues that whether or not anthropomorphizing robot companions is an ethical issue for elderly and infants. There are quite lot robot caregivers and pets have been developed, such as Carebot, PaPeRo, AIBO dog, Pleo and etc., and they all have different functions. The authors believe that for the elderly, anthropomorphism of robots will increase their anxiety and decrease social contact, but will reduce loneliness, and may obtain a health assistant. However, to receive care from robot caregivers for children will lead to negative effects and is not good for their growth, because spending too long with robots could affect infants' linguistic, emotional and social development.

METHODOLOGY AND FINDING

Metrics

Metrics are existed in different areas, such as Mathematics, Software, Router and vice versa. To have metrics for human-robot interaction will help facilitating research solutions and evaluating the ranking of tasks and systems for robotics. In [4], Steinfeld et al. have developed a set of common metrics for task-oriented mobile robots. The task metrics is split into five categories: navigation, perception, management, manipulation, and social. These metrics can be biased by the delay of transmission of information between human and robot, bandwidth of communication channel, data lost during communication, robot response time such as system lag and update rate, and the capacity of the user. The term user was explained by Scholtz in [5], which includes supervisor, operator, mechanic, peer and bystander. Navigation is defined as robots move from one point to another point. Navigation is divided into two main sections: global navigation and local navigation. The major factor of navigation is obstacle avoidance. Dealing with the metrics of navigation, how well the tasks are completed by robot, time measurement, obstacles handling are comprised. Perception depends on processing sensor data which is collected by robot about environment and its own status. There are two kinds of perception, passive and active. Passive perception focuses on judgments of attributes of environment, detection and recognition circumstances, velocity and etc. Active perception mainly measures accuracy, efficiency, effort of detection and searching. The purpose of management metrics is to concern about the management of activities of a team of robots. "Fan out" is one of the management metrics which is defined as the measure of capability of number of robots which human can effectively control at one time. Intervention response time is also involved as a part of the metrics *"which can be measured either from when the operator first recognizes the problem or when the robot first requests assistance"* [4]. The last item in management metrics is the level of autonomy discrepancies. Manipulation measures the capabilities of unpredictable event handling of robots, such as arm grasping, pushing. There are lots of robots developed for health assistant purposes, therefore social metrics are important to people's lives. Five items are included in social metrics to evaluate the effectiveness of robots, which are interaction characteristics, persuasiveness, trust, engagement and compliance. Rather than task metrics, the authors also represented three common metrics, system performance dealt with how well human can interact to robots, operator performance related to the term human, and robot performance measures robots' self-awareness, human awareness and their level of autonomy.

Framework for Home Service Robot

KangWoo Lee et al. designed a framework [2] for the future home service robots. The framework is divided into three interaction modules. Figure 1 shows the overall framework. Each module is separated by the thin dashed boxes. Multi-modal Interaction Module is responsible to interact to world, in other words, this module mainly focuses on getting inputs from sensors or human, and sending outputs back to human. In addition, methods used to integrate inputs and outputs are also included in the module, such as voice recognition, face recognition and etc. Different kinds of input methods can be used on the robot through microphone, touchscreen and camera, such as facial expression, hand gestures, linguistic speeches. After robot processes of input and executes the actions, output can be made, and passed back to multimodal interaction module. The main issue for achieving good interaction between human and robot in this module is the lack of technologies of input recognition. The Cognitive Module is used to manage multi-level dialogue between people and robots. The module contains three sub-modules: Task model, Interaction model and Truth Maintenance System. Once interpreted instructions from dialogue from Multimodal Interaction Module, task model generates action lists according to the instructions, then the action

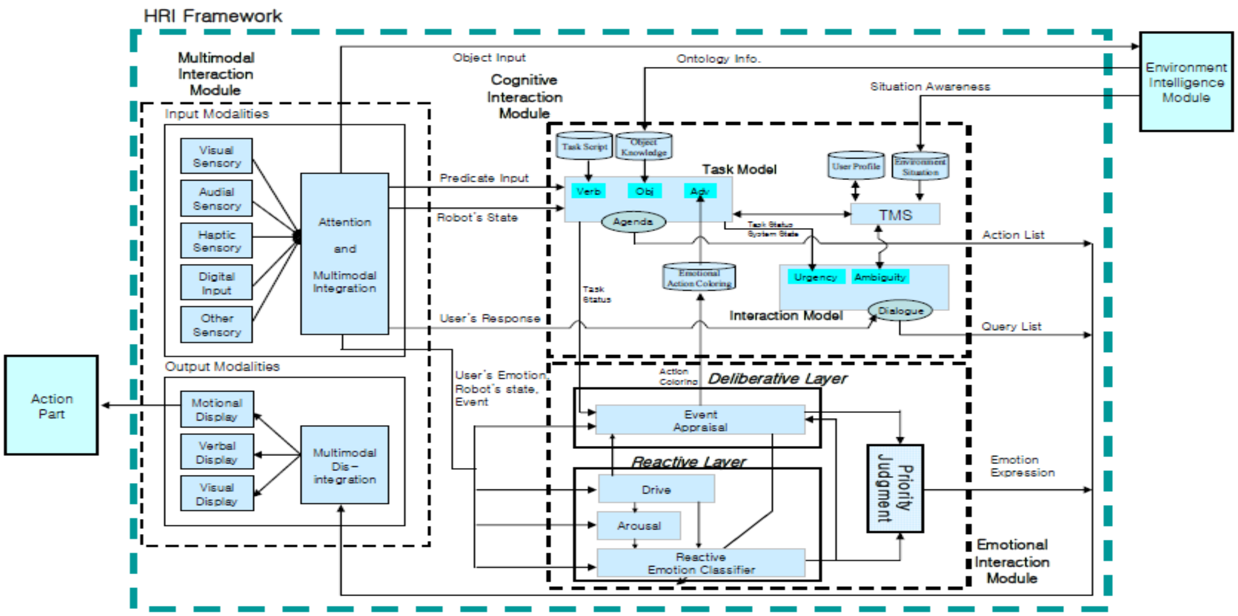

Figure 1 Overview of HRI Framework in the Robot [2]

lists will be inserted into agenda and pass to system state. Interaction model manages the issues of ambiguous items in the action lists and how emergent the ambiguities need to be resolved. Truth Maintenance System is used to update the resolved ambiguities to Task model and reassign the new ambiguities to Interaction model. Emphasising emotions is an important aspect in social interaction, the emotional interaction module is proposed to express emotions for robots. Two layers are involved in the module: reactive and deliberative layers. The deliberative layer concerns about the emotions with the task model, and reactive layer expresses emotions of robots directly to the user.

APPROACH

Human Trajectory Analysis and Classification

The focus of [3] is to implement a system to track people's trajectories, then determine a reasonable style to initiate interaction with human. Rivera-Bautista et al. classified people's behavior into three groups: confidence, curiosity and nervousness. If people feel curios or nervous, the robot will move to the people and start the conversation; in term of definition of confidence by the authors, people is confidence if he/she goes straight to the robot, then the robot will wait for the people to start the interaction, because he/she may not move to the robot. This system is divided into six modules. After capturing a people by using Visual Human Detection and Tracking module, the Fuzzy Pan/Tile/Zoom Camera Control module will start and track that people. Discrete Curve Evolution (DCE) module and Particle Filter Localization (PFL) module run permanently in parallel, DCE module collects data by using laser range finder and PFL module interprets those data to work out a solution of localization of that people. These data is also used by Legs Tracking module and classify people's behavior by Trajectory Classification module at last, then execute the interaction by using the right style. Their experiment has examined the success of the system.

3D Spatial Modeling

[8] proposed to create a 3D spatial model to allow robots understand the spatial relationship between objects. In previous work, 2D spatial representation worked well for robots, and they can understand the locations in a 2D map. However, the methods working in 2D situation but may not work in 3D environment. Blisard et al. extended Lowe's SIFT algorithm in [10] to create 3D SIFT points which will be used to describe the position of objects in the space. In the experiment [8], two cameras are used for collection data which are for finding out the matched points in 3D environment. After the 3D matched points are drawn in a diagram, cluster the points, and pick up the projection points to another 2D plane. The convex shapes of points are able to represent the location of each objects in the word, hence it is possible to linguistically describe the spatial relations between objects.

Immersive Human-Robot Interaction (IHRI)

The traditional way to track mobile robot remotely is either giving robot high level of autonomy and simulating robot's current state onto desktop computers, or using GUI to issue orders to the robot. IHRI [9] presented a new approach which enables natural interaction such as gesture and dialogue between human and robots. The idea of IHRI is to build a virtual environment in workspace. The environment will be synchronized to mirror the robot's sight, and the images will be displayed all around the user in the workspace. The user is able to issue orders to robot by using gesture, dialogue. The advantage of this approach is that what users see from the remote robot is not restricted by the small image on the 2D desktop monitor, and also interacting with remote robots will be easier compared to screen-based methods. This approach is useful to USAR and surveillance.

SUMMARY

In this paper, some methodologies and approaches of human-robot interaction have been discussed. Great efforts have been made to this topic, for example, metrics have been developed to help rating research solutions and provide possible measurements for future projects, KangWoo Lee et al. designed a framework with three interaction modules for home service robots. The approach designed by Rivera-Bautista et al. [3] proposed to identify human walking gestures and then decide a suitable way to initiate an interaction with human. The second was developed by Blisard et al. The goal of the approach [8] is to extend the 2D object spatial relation recognition algorithm to suit 3D environment. The last approach [9] is about to mirror robot's dynamic views to a virtual environment in workspace, and user in the workspace is able to interact to robot by using gestures and dialogue. Although many approaches have been developed, the problems of human-robot interaction still exist. For example, localization of robot is needed to build map of the environment, in some cases such as USAR, environment is unstructured and it is hard to say that is possible to build map for robots.

FUTURE WORK

Sensors of robots have potential for developing to achieve more complex goals. For example, to have a touch sensor which can easily distinguish the different behavior of touching, such as pushing, tapping, stroking and etc. More affords can be made to psychology and some related area to implement artificial intelligence to robots. The current technologies such as face, speech, gesture recognition can be improved to increase efficiency and make robots learn faster.

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