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MEASURING TRUST OF HUMAN OPERATORS IN NEW GENERATION RESCUE ROBOTS

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ABSTRACT

The utilization of mobile rescue robots in dynamic environments decreases the risk to emergency personnel in the field. Recent efforts to improve rescue robot design by using new fluid-power technology provide opportunities of studying the changes in metrics of human-robot interaction (HRI), such as trust. Trust is one of the most critical factors in urban search and rescue missions because it can impact the decisions human make in uncertain conditions. This research is to develop an instrument that can be used to measure trust in human-robotic interaction, which will allow us to collect data for building a quantitative model of trust in HRI. As the first step in this effort, a pilot study was conducted to determine the validity of an instrument to measure the appropriate dimensions of trust in this new human-robot system.

KEY WORDS
Human-Robot Interaction, Rescue Robot

INTRODUCTION

Urban search and rescue (USAR) missions are becoming more and more important in recent years, From the collapse of the World Trade Center towers to Hurricane Katrina, resuce missions are oftern done in hazardous environments. To avoid putting emergency personnel in harm's way, the use of mobile robots is a good alternative. Untethered robots are intelligent and have good maneuverability in conditions and environments that may otherwise be potentially hazardous to humans. Rescue robots are often used to gather and transmit vital information about their location and operational status to their remote operator(s). It may detect victims, check for signs of life using cameras, microphones and sensors, and even provide minor aid if possible. The cooperative relation between operator and robot enhances the coordination of search and rescue efforts and can increase the chances of lives being saved. Although there are many different types of rescue robots used in urban search and rescue, most untethered search and rescue robots are commonly powered by batteries that run out quickly and electric motors that do not provide enough force or power for rescue missions over extended periods of time [1]. Batteries and motors also create extra weight which limits the autonomy of the robot. Furthermore, human-robot interfaces (HRI) for rescue robots often tend to be hard to use, confusing, and suffer from both information overload and poor situational awareness [2]. With the development of fluid power technology, rescue robots will have a higher power density, weigh less, and will be more flexible than the electric power source robots (Binnard, 1995). For these reasons, a strong interest has recently been shown in fluid-powered rescue robots. Fluid power is the technology that deals with the generation, control, and transmission of pressurized fluids [2]. However, the use of a specific power source for robots certainly impacts the design of the robotic interface. The power source of a robot can affect the interface design of the robot, which will impact how data is relayed from the robot to the operator once it is deployed. Given these changes in design, the human-robot interaction (HRI) may be very different than in previous designs. Thus, opportunities remain for further improvement in the human-robot relationship. As part of the recent efforts in developing and utilizing new fluid power technology, a compact rescue crawler (CRC) is being utilized as an initial test bed at the Center for Compact and Efficient Fluid Power (CCEFP), a National Science Foundation (NSF) funded Engineering Research Center.

ASSESSMENT OF HRI

HRI, within urban search and rescue missions, involves complex systems in dynamic, unstable environments where human and robot must work together, as well as individually. As can be seen in Figure 1, there are various HRI metrics that are influenced by the robot, the human, and the overall human-robot system [3].
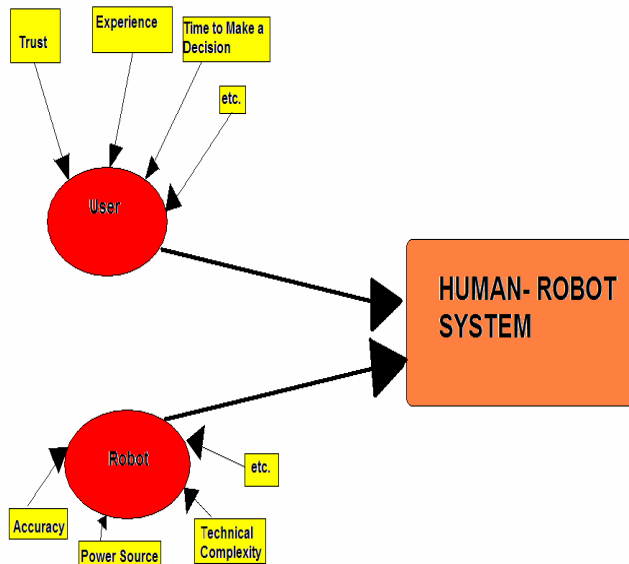

Figure 1: Representation of the Human-Robot System

Those measures include objective measurements, such as performance error of the robot, as well as subjective measurements, such as operator trust in the robot. Trust is one of the significant aspects in HRI urban search and rescue missions because it is influenced by variables within the system and has a significant effect on the output, or performance, of the overall system. The type of missions that the compact rescue crawler robot will be utilized for are characterized by a high degree of uncertainty [4]. Without operator trust in these situations, which involves teamwork between humans and robots, the team's performance can be severely impacted.

Traditionally, trust in human-machine or human-computer interactions is defined as a composite of several dimensions or components. For instance, Muir described trust in automation as "a composite expectation of the persistence of the natural and moral social orders, technical competent performance, and of fiduciary responsibility [5]" in 1994. A decade later, Lee and See, defined trust as "the attitude that an agent will help achieve an individual's goals in a situation characterized by uncertainty and vulnerability [6]." Although there has been research on trust in different human-machine systems since the 1980s, spanning

human-automation relationships and human-computer relationships, little research has been done dealing specifically with human-robot relationships. HRI in urban search and rescue is different from other human-machine systems in that the environments are characterized by a high degree of uncertainty, risk, and the human user is both supervisor and teammate with an artificial intelligence. Therefore, trust in HRI needs to be studied independently. Over the years, researchers have proposed that various dimensions of trust have characterized those dimensions differently. In 1985, Rempel et al. described trust as having three time dependent dimensions of predictability, dependability, and faith [7]. Later in 1992, Lee and Moray identified three dimensions of trust to be performance, process, and purpose [8]. In 2004, Uggirala identified several dimensions of trust to be competence, predictability, reliability, persistence, and overall trust in a system [9]. Some of the dimensions complement each other, are orthogonal to one another, or duplicate other studies; however, those previously mentioned apply to human-human, human-machine, and human-computer interactions. There has been little research on dimensions of trust that apply to human-robot interaction.

The objective of this research is to develop a tool that can effectively be used to measure trust in HRI for the new generation, fluid- powered rescue robot.

METHODOLOGY

Defining Trust Components

The first step in developing a tool to measure trust in human robotic interaction is to identify twelve (12) appropriate trust dimensions which are predictability, dependability, accuracy, helpfulness, power, adaptability, understandability, deceptive, fiduciary responsibility, experience, solidarity, and performance. Definitions of these 12 dimensions are listed in Table 1. Then, a three step procedure will be used to select and define each dimension as it applies to HRI. Subject matter experts will be consulted in this process.

Step 1: Ask each subject matter expert to define each dimension by generating a list of questions that can describe it.

Step 2: Ask each subject matter expert to rank the dimensions along with its questions based on its importance in measuring trust in HRI.

Stewp 3: Select the top eight (8) dimensions as well as the questions for each dimension that is identified and ask the subject matter experts to match the dimension with its defintion (questions). The resulting list will be the dimensions considered most applicable to HRI. A trust measurement instrument will be developed based on this list.

Table 1:   List of Proposed Trust Dimensions

Dimensions	Definitions
Predictability	the degree of consistency and desirability of past behavior in a system that enable the user to develop a mental model of future system states [7]
Dependability	the degree of understanding the stable dispositions that guide the system's behavior [7]
Accuracy	the extent to which the system is free of error [9]
Helpfulness	the extent to which the system provides alternative solutions [11]
Power	the extent to which the user is able to control the behavior of the system [4]
Adaptability	the degree to which the system can change according to a situation [10]
Understandability	representing how well the operator perceives what the computer is doing [10]
Deceptive	the extent to which the system explicitly displays or says that it will act in a particular way, but doesn't in future states
Fiduciary responsibility	the degree to which the operator expects that the system will meet its design-based criteria [12]
Experience	based on the specific user's past encounters with the system [13]
Solidarity	the degree to which the user perceives the system shares a similar purpose to himself [4]
Performance	in regards to the overall human-machine system performance [8]

Trust Measurement Instrument Development
Using the list of trust dimensions, a trust measurement instrument will be developed. This instrument will be in a form of questionnaires. Each trust dimension has questions detailing what the dimension means. A Likert scale of 1-5 will be used for each dimension with 1 being strongly disagree and 5 being strongly agree.

Proposed Experiment
To assess the validity of the instrument, an experiment will be conducted as follows:

Subjects: Twenty field experts who have experience operating rescue robot in urban search and rescue (USAR) missions will be recruited to participate in the survey. Demographic information of the subjects as well as their experience and backgrounds will be collected.
Test Materials: A scripted USAR scenario will be given to each subject. They will be asked to complete a questionnaire containing the trust measurement instrument based on the scenario.
Test Procedure: Through email, each subject will be briefed with the purpose of the experiment followed by an informed consent form. Upon agreeing to participate, each subject will be given a USAR scenario and asked to fill out a questionnaire containing the trust measurement instrument. Clarification will be provided whenever necessary. Each subject will spend about half an hour to complete the experiemnt.
Data Collection: Upon collection of the questionnaires, a score of 1-5 will be assigned to each trust dimension from each subject.
Statistical Analysis: Both descriptive statistics such as mean and standard deviation as well as inferential statistics such as correlation analysis will be used. A stepwise regression model will then be used to develop a trust model that can be used to measure operator trust in HRI. Results from this analysis will also reveal the important dimensions of HRI.

DISCUSSION AND CONCLUSION
Possible future research work lies in validating the list of the dimensions, examining any underlying constructs of the dimensions, and determining the relationships between the dimensions themselves and overall trust in the human-robot system.

The purpose of this research is to develop an instrument that can be used to measure trust in human-robotic interaction. A literature review of trust in human-automation and human-computer systems was conducted to build a solid foundation in developing a list of the dimensions of trust most appropriate for HRI in USAR environments.   An experiment is proposed to assess the validity of the tool for measuring trust in human-robot interaction for urban search and rescue missions utilizing compact crawler, fluid-powered rescue robots.   It is expected that this instrument will contribute to measuring trust in human-robot interaction.

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