Design and Development of EDGAR – A Telepresence Humanoid For Robot-mediated Communication and Social Applications

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***Abstract*—EDGAR is an acronym for "Expression Display & Gesturing Avatar Robot". It is an anthropomorphic telepresence humanoid, which is designed and implemented to allow for social expression. EDGAR is a robotic avatar that was developed by Nanyang Technological University for telepresence applications. It has a total of 28 degrees of freedom and it is able to mimic the remote user's head, torso, arms as well as fingers movements. EDGAR's head is a rear-projection system such that a face texture can be displayed on EDGAR's face. The remote user can use a normal webcam for live-streaming interaction as the face image can be processed to fit the contour of the face. This means that a person's facial features and expressions can be displayed on the robot, making EDGAR suited for portraying any person. EDGAR can also serve as a social robot. A virtual character's face can also be projected on the robot so that EDGAR can be used to perform autonomous social interactions with the people around it.**

Keywords—telepresence; robot design; humanoid; robotic avatar; rear-projection head; robot-mediated communication; social HRI

I. INTRODUCTION *(HEADING 1)*

Remote communication or telecommunication has become of paramount importance in an increasingly globalizing world. A spectrum of telepresence technologies for remote communication includes phone calls, video conferencing and recently telepresence robotic avatars are being adopted by corporations to support collaboration between remote members.

Telepresence robotic avatar is an emergence of a new communication method where a mobile robot is used to augment interaction by integrating video-mediated communication tools with the robot. This method offers the means to connect to a remote location via traditional video conferencing but also has the added value of moving in that remote location via the robotic system. Such robot-mediated communication tools are commonly known as telepresence robots although some may refer to them as mobile remote presence systems [1], virtual presence systems [2], embodied social proxy [3] or robotic avatars [4]

The use of a robotic avatar as an emerging telepresence application is evidenced by the increasing amount of commercial systems available and the associated research efforts. These robots have been developed to perform in a plethora of applications such as performing medical tele-rounds in health care institutions [5] and conducting ad-hoc conversations in office environments[6].

Most of the existing telepresence robotic avatars, if not all, have a non-anthropomorphic design. The typical design of a telepresence robot includes a flat screen on a computerized movable platform - it is without arms or hands and is not human-like.

However, when people communicate face-to-face, a wide variety of sensory and motor modalities are used to regulate the conversation or complement the verbal utterances. In particular, humans use proxemics [7] (the study of spatial distance) and kinesics [8] (the study of body movement and gestures as nonverbal communication) a lot during a face-to-face interactions.

II. DEVELOPMENT OF AN ANTHROPOMORPHIC TELEPRESENCE HUMANOID

The ability to move and to express gestures are important to the coordination and performance of collaborative activities, as they serve to communicate intentions and refer to objects of common ground [9]. Although existing telepresence systems have integrated motion to video-mediated communication, only a few telepresence systems carry a laser pointer for pointing (i.e ProP [10], Qb [2] and MantaroBot [11]). The Mebot [12] and human-like Geminoid androids [13] are capable of gesticulating but are only useful for stationary ``face-to-face'' interaction.

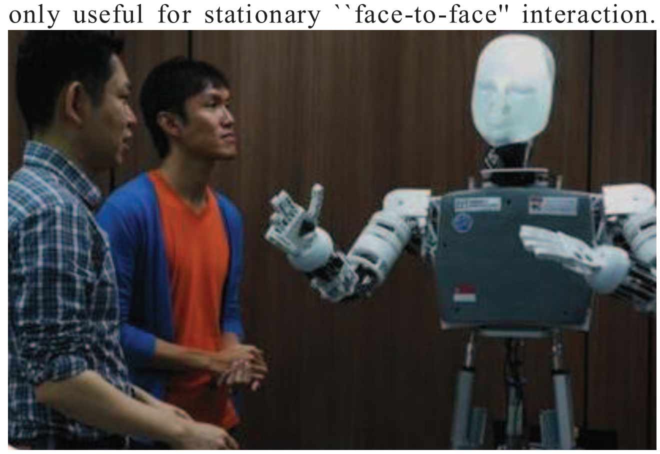

Figure 1. Social Interaction with EDGAR

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Furthermore, Geminoid telepresence android can only used to represent one user, since it has been created to resemble its user.

To further enhance robot-mediated communication and move it closer to face-to-face interaction at a reasonable cost, an anthropomorphic telepresence robotic system, as shown in Figure 1, can be built. This robotic telepresence system would provide mobility as well as kinesics within a robot-mediated communication by mounting an Expression Display and Gesturing Avatar Robot (EDGAR) on a remotely steerable base.

EDGAR is a robotic avatar that was developed by Nanyang Technological University for telepresence and social applications. It has a total of 28 degrees of freedom and it is able to mimic the remote user's head, torso, arms as well as fingers movements. As the robot's joints configuration is not as identical as to a real human joints configuration and that it will be mounted on a wheeled platform, it is debatable of whether it is telepresence humanoid or just an animatronic robotic avatar for telepresence. Nevertheless, it can be classified as having an anthropomorphic form and is human-like.

A. Benefits of using an anthropomorphic telepresence humanoid

If a robotic telepresence system "was perceived as being human, then effectively it should be human and not a robot" [14]. It is believed that employing anthropomorphism to a robotic system would facilitate human-robot interaction. As "humanness" is integrated in a system, from its behaviors, to domains of expertise and competence, to its social environment in addition to its form, it affects our dealings with a telepresence system, making us see it more than a machine. And this is desirable in a telepresence system because when a remote inhabitor uses the robot for communication, he would expect the local interactants to treat him as a person rather than a robot.

This has been evidenced in the study in [15] that the addition of physical proxy motion favorably influence the perceived dominance and involvement of the interaction. When the remote participant showed physically gesturing in the scenarios, he was perceived as having greater involvement and his on-site teammates were able to view him as being more equal in stature.

Furthermore, the experimental results in [16] have revealed a correlation between the amount of robot-child touch behaviors and social connectedness when a robot was brought in to interact with the children. This type of robot-child touch behaviors is similar to the peer-to-peer contacts that young children will made intentionally when they interact with each other. Fifty-three percent of this "intentional peer-to-peer contact" is directed to arms and hands.

The ability to point is also essential in human-to-human communication to disambiguate speech that is ambiguous. For instance, when a speaker says, "The toilet is on that side"; it is usually unclear to the listener where the exact location of the toilet is unless the speaker also points to a particular direction as he speaks. The findings in [17] also suggest that the pointing gestures produced by the telepresence robots can help listeners to remember more object-spatial information.

III. TECHNICAL DESCRIPTION OF EDGAR

The EDGAR robot has been designed for mimicking human movements from the waist up. EDGAR can twist, bow as well as lean to the side. Figure 2 provides a technical overview of EDGAR. He is equipped with two arms, each with 5 degrees of freedom (DOFs). Each finger on EDGAR's two hands is capable of independent movement, with the thumb having 2 DOFs. EDGAR's neck allows the head to move with 3 DOFs. All of the actuators on EDGAR are electromechanical motors running on DC power. Table 1 provides the technical specifications of EDGAR.

One unusual feature of EDGAR is that the head of EDGAR is a rear-projection system [18] such that a face texture can be displayed on EDGAR's face. The remote user can use a normal webcam for live-streaming interaction as the face image can be processed to fit the contour of the face. This means that a person's facial features and expressions can be displayed on the robot, making EDGAR suited for portraying any person.

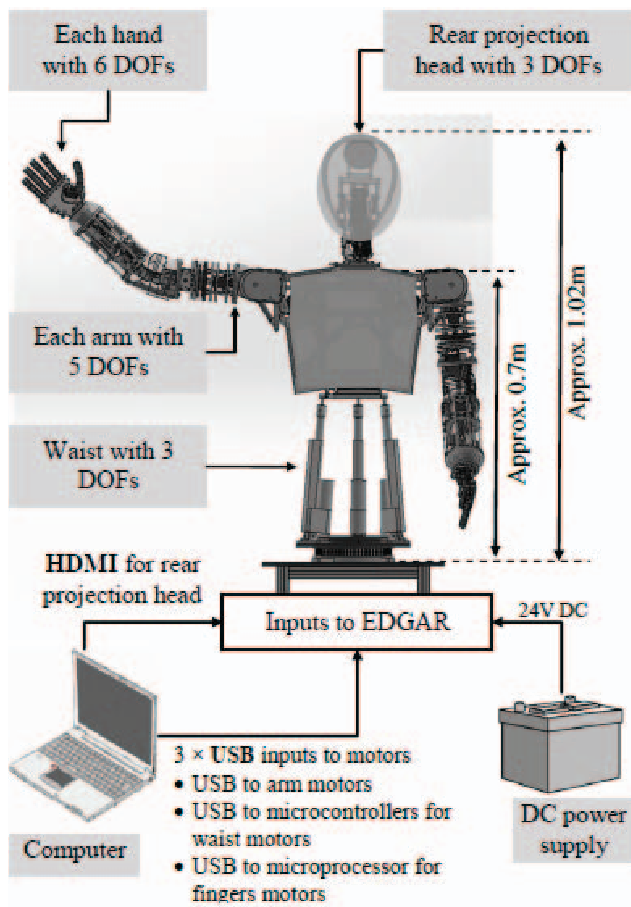

Figure 2. Overview of EDGAR

With these capabilities EDGAR is able to perform gestures with its waist and torso, its head, as well as with its arms and fingers. For example, EDGAR can turn to face some selected direction and lean forward to engage a child who is shorter in stature. EDGAR can also point and wave, make hand signs and nod its head. Additionally, EDGAR can perform scripted speeches and gestures.

The EDGAR robots use only electric motors for actuation and so unlike some other life-sized humanoid robots that utilize pneumatic actuators, EDGAR does not require an air compressor to power its movements. This makes EDGAR more easily transported and deployed.

TABLE I. TECHNICAL SPECIICATIONS

EDGAR General Features	
Height	Approximately 1m from base to top of head
Weight	Approximately 20kg inclusive of base
Sensors	Motor encoders
Actuators	High performance networked motors and DC servo motors
Power	24V DC input at maximum of 20A (with rear projection head)
Computing	User-provided computer running Windows 7 or 8
Software	Open-source demo code for local control of actuators
DOFs	28 (with rear projection head option)

IV. CAPABILITIIES OF EDGAR

At this time, there are two functioning modes of the EDGAR robot: a) a Robotic Avatar Telepresence Mode and b) an Autonomous Human-Robot Interaction Mode.

A. *Robotic Avatar Telepresence Mode*

EDGAR is primarily a telepresence robot. He helps a user to convey the user's physical presence over a distance. This is an improvement on current telecommunications methods that have been capable of relaying speech and video imagery.

A computer with an attached Kinect sensor acquires information about the user's physical pose and facial features.

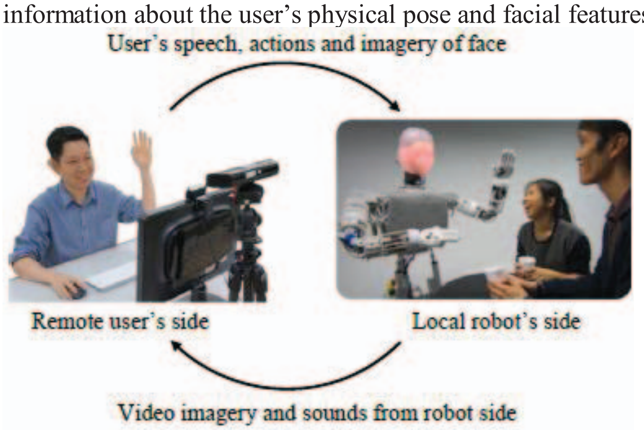

Figure 3. Using EDGAR as a telepresence robotic avatar

This information is encoded and relayed over the Internet and received by EDGAR. The robot then decodes the information to mimic the user's movements. EDGAR's rear projection head will also display the user's head based on the received information, as shown in Figure 3. Lastly, the user may wear a data glove if he or she would like to manipulate the fingers on the robotic avatar.

On the robot side, video imagery and sounds are acquired by a camera attached on EDGAR. The data are then relayed back to the user, to facilitate communication and interaction with the interactants.

B. *Autonomous Social Interaction Mode*

EDGAR can also serve as a social robot, as illustrated in Figure 1. It can act out scripted speeches and gestures and is thus highly suited to present information autonomously at public spaces. Rather than being teleoperated, EDGAR automatically engages the people whom it meets to provide information to them. It can visually observe people as well as hear and analyze what people say. EDGAR draws on its database to provide appropriate responses to the speech that it hears. If it is unable to find a suitable reply from within its database, EDGAR searches the internet for information.

This mode enables EDGAR to address manpower requirements in the service industry by serving as a social robot for autonomous interaction. It engages people at public spaces to promote products, to give directions, to describe a museum artifact or perhaps simply to greet. EDGAR may also be used in medicine for the therapy of autistic patients.

V. ACADEMIC HIGHLIGHTS

When in telepresence mode, EDGAR mimics the movements and gestures of its remotely-situated user. It also displays the user's facial features and expressions on its head, further enhancing its capability as a robotic avatar. To control the robot, the user is not required to wear any control device but would only have to stand in front of a computer that is equipped with a Kinect sensor.

This makes the user experience a simple and comfortable affair. If necessary, the user can select pre-determined speeches or gestures on the user interface so that EDGAR can continue to represent the user for short durations of user-absence. The technology that has been developed in this system represents an improved type of telecommunication over traditional methods because it now enables the telecommunication of a user's physical presence.

When EDGAR is in the autonomous social interaction mode, it can help to reduce the manpower requirements in the service industry. To facilitate autonomous interaction, a Kinect sensor can be aesthetically integrated with the body of EDGAR. Human tracking [19] and sound localization algorithms have been implemented to allow the robot to listen to, visually observe and even analyze the people standing in front. Data gathered about the people whom EDGAR II interacts with, can be used later for demographic analysis so that retailers for instance, can improve their understanding of shopper needs. Development of EDGAR can leverage off the open-source capabilities of the highly popular Kinect sensor.

Lastly, The EDGAR robot can be applied as research platforms for the study of human-robot interaction, such that acceptability towards various physical robot forms and new autonomous behaviors can be evaluated. As they can be regarded as intelligent display devices, software applications for EDGAR can be developed in order to generate a multitude of capabilities for users of various age groups and cultural backgrounds.

VI. Result and Discussion

An anthropomorphic humanoid, EDGAR, has been constructed for the purpose of telepresence communication and social interaction. EDGAR can be used to represent any male human user during a telepresence communication mode. The main strengths of this telepresence humanoid are its cost of manufacture as well as its flexibility. The cost of designing and building the rear-projection face unit as well as the humanoid upper body system is considerably low, due to rapid prototyping and vacuum forming production techniques used. Figure 4 illustrates the comparison of the implemented EDGAR with other telepresence robot.

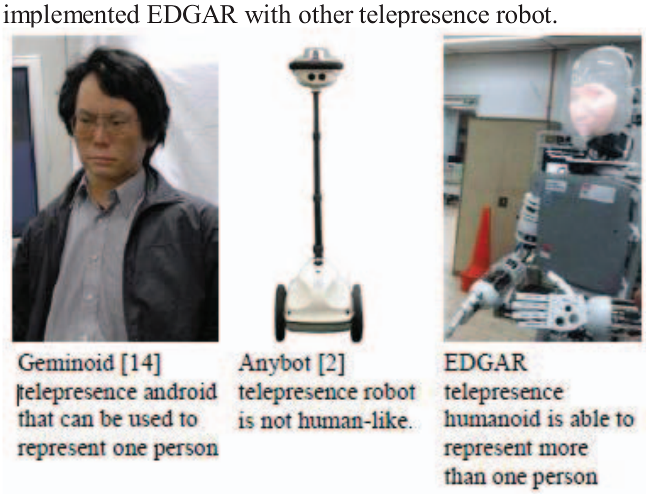

Figure 4. EDGAR in comparison to the other telepresence robots

VII. Conclusion

In this paper, the design and development of an anthropomorphic humanoid, EDGAR, for the purpose of telepresence and social interaction has been presented. The feature of this implementation which is considered to be novel is the usage of projective technology coupled with 28 DOFs of head and arms humanoid system, to bring the presence of any person or character to life, in full 3D human form. At this time, EDGAR robot can function either as a robotic avatar for telepresence or as a social robot for autonomous HRI.

Later phases of this project include the development of reliable mobility for EDGAR, enhancing its artificial intelligence, as well as increasing its robustness and reliability..

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