TeleBot: Design Concept of Telepresence Robot for Law Enforcement

*Mangai Prabakar[1)] and Jong-Hoon Kim[2)]

[1), 2)] *Discovery Lab, School of Computing and Information Sciences*
Florida International University, Miami, FL 33199, USA

ABSTRACT

There are several telepresence robots that exist as minimalist mobile structures with attached video screens. The TeleBot, created in Discovery Lab at Florida International University, was developed for disabled veterans and police officers to remotely perform patrolling and law enforcement duties. This telepresence robot takes on a humanoid form to make human interaction more comfortable and resemble a law enforcement figure. The TeleBot needs to look intimidating and authoritative enough for citizens to obey the commands, since the orders are given by an actual disabled police officer remotely controlling the robot. A helpful, friendly appearance is also necessary, however, to make the TeleBot approachable to citizens of all ages. This challenging design constraint is resolved with the TeleBot prototype. For ground motion, we use a two-wheeled structure instead of four wheels. This occupies less space and leaves a small footprint similar to a human, whereas a tall bipedal robot will take long strides. The design resembles a police officer riding a Segway, an accustomed sight for citizens. Using a two-wheel mechanism contributes to efficiency, smaller footprint size, and reduced cost.

However, certain cases of balance mechanism failure are not appropriate during human interaction. In this instance, we alter the architecture with a two-wheel to three-wheel transformation to stabilize the system. This guarantees stationary balance during human interaction in case of uneven terrain, balance mechanism malfunction, or excessive TeleBot bending and arm motions. Since the TeleBot is remotely operated, the control mechanisms and motions are simplified to make the operation easier. For increased stability of the robot, the frame is designed to position the center of mass at the bottom third of the robot with housing for battery. In addition, to reduce the weight of the TeleBot, the frame is built with lightweight metal tubes and the exterior shell is fabricated with durable, lightweight material. The three dimensional surface design of the shell takes into account both ergonomics and aerodynamics. In this paper, we present the full architecture and design of the TeleBot. The implementation of the robot prototype shows feasibility of this design.**Keywords:** TeleBot; telepresence robot; two-wheeled robot

[1)] Graduate, E-mail: mangai@cis.fiu.edu
[2)] Professor, E-mail: kimj@cis.fiu.edu

1. INTRODUCTION

Telepresence robots allow human controllers to operate in remote locations through a virtual display. Remote teleoperation of advanced robotic technologies has great potential in many areas and the applications include education, deep sea exploration (Forrest et al., 2010), dangerous military missions, hazardous environments (Parker and Draper, 1998) off-shore projects (Heyer, 2010; Mazzini et al., 2011), space exploration (Fong 2012), health care (Giullian et al., 2010; Scassellati, 2009) and telesurgery (Hannaford et al., 2013; Kong et al., 2006; Lum et al., 2009; Newman et al., 2011; Tinelli et al., 2011).

With the increasing number of U.S. troops return from the Iraq and Afghanistan War, the Veterans Administrationand Census Bureau figures show that an ever-larger number of disabled veterans will cost the nation billions for decades to come. Many of these veterans are unemployed and they are not able to reenter the workforce. In addition to military veterans, thousands of police officers are forced to retire every year because of disability. A mobile telepresence robot is one of the best solutions for them to serve in law enforcement without requiring their physical presence.

The TeleBot project was started at the Discovery Lab in Florida International University where the researchers are working to build telepresence robots that will allow disabled veterans and police officers to reconnect with the workforce and simultaneously give them the opportunity to use their skills to remotely conduct patrol duties in urban streets through the TeleBot.

2. CONCEPT DESIGN

Several iterations were done in arriving at the final design for TeleBot V1.0. For law enforcement tasks, the TeleBot requires a robust and authoritative appearance in order to get citizens to comply with the citations or obey directions given by the remote controller--disabled police officer or veteran.

Fig. 1 Artist rendering of TeleBotexterior

Fig. 2 TeleBot head

The TeleBot also needs a friendly and protective appearance to make it comfortable for citizens, including children, to approach it and vice versa. A study by (DiSalvo et al., 2002) presented general proportions of humanoid heads that highlighted human features but still maintained a robot look. While a humanoid robot can make it seem more approachable, too much human resemblance may make some people wary. Therefore, anthropomorphism in the TeleBot would be attributed to a certain degree by highlighting only a few key facial features such as the eyes, jaw, and ears seen in Fig. 2. From the psychology aspect of human-robot interaction, our humanoid TeleBot with an obvious robotic appearance serves as a reminder to citizens on the street that it is still a robot being remotely controlled by a fellow human officer.The design resembles a police officer riding a Segway, a familiar sight for citizens.

3. ENGINEERING DESIGN AND MANUFACTURING

Using the artist concept as a guide, we modeled and altered the TeleBot exterior in 3D CAD engineering programs to make it viable for physical construction based on feasibility, limitations ofmanufacturing, materials, budget, and time.The skeleton of the TeleBot was engineeredby focusing on two main aspects, simplicity for remotely operated motions and weight distribution of the hardware. Similar to human anatomy, the TeleBot has a spine and rib cage to protect the internal hardware. The structure of the metal frame has a foundation of a continuous backbone (Cibert et al. 2013), which bears most of the robot’s weight. For increased stability, the center of mass is located at the bottom third of the TeleBot by placing the heavy lithium-ion rechargeable batteries in a lower compartment.

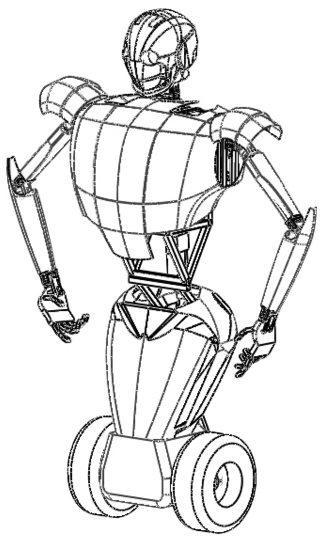

Fig. 3aModified physical TeleBot exterior with framefor the real world

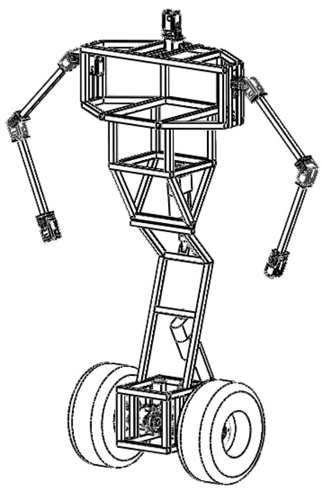

Fig. 3b TeleBot lightweight metal frame angled to maintain TeleBot shape

The TeleBot frame in Fig. 3 is comprised of lightweight metal tubes and the exterior cover is fabricated with a durable and lightweight material. The new covers were designed with maintenance and convenience factors in mind (Oh et al.,2006). Through the use of 3D printers, machining, and CNC routers, the TeleBot V1.0 prototype was manufactured at FIU Discovery Lab, showing feasibility of the design.The backbone framewas angled to match the final TeleBot exterior. Due to the chosen lightweight materials and hardware, the TeleBot structure is stable and withstands the given loads with stress analysis simulation. If the TeleBot is required to pick up heavy loads in the future, however, vertical support beams will be added to the bottom of the spine.

4. WHEEL MECHANISM

The TeleBot uses a 2-wheeled structure for ground motion instead of four wheels. While four wheels will present less balancing challenges, the TeleBot occupies less space, leaving a small footprint similar to a human. The wheeled robot also reduces the amount of computational as well as mobility power required to move the same distance as a bipedal system. With a dynamic balancing system, these wheeled robots can reach higher speeds resulting in greater momentum on the ground (Stilmanet al.,2009). Use of a two-wheel mechanism contributes to efficiencyand reduced cost.
(Wu et al.,2013) shows the progression of contact points with the human foot and flat ground during one step. Free of bipedal movement, the TeleBot's 2-wheel mechanism maintains constant contact with the level ground. When the TeleBot comes to a full stop to engage in a human interaction, it transforms its architecture from a 2-wheel to 3-wheel structure by extending a third caster wheel down with a linear actuator as seen in Fig. 4a and 4b. This guarantees stationary balance as the TeleBot will not constantly be micro-adjustingback and forth with its built-in balance mechanism. The third wheel is also a backup in case of balance mechanism failure, uneven terrain, or excessive TeleBot arm motion withforward bending at the waist. The TeleBot can bend forward at the torso with the aid of another linear actuator located within its spine.

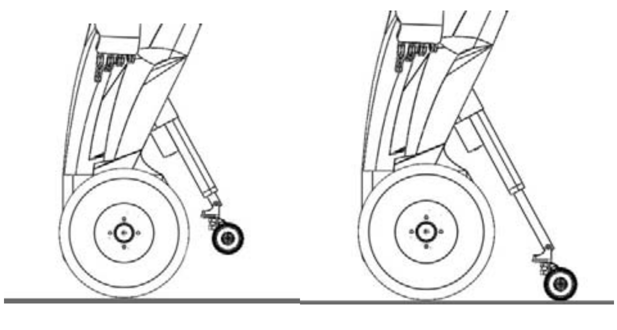

Fig. 4aRetracted linear actuator while TeleBot is in motion on flat ground

Fig.4bExtended linear actuator while TeleBot is stationaryor on uneven terrain

5. ARCHITECTURE

The TeleBot is composed of five major components: one head, one upper body, one lower body, two arms, and three wheels. The head covers the vision, audio, and speaking system. The upper body contains the main computer as well as the arm and finger control system. In addition, it encases a projector for a video streaming guide. The lower body provides a secure hold for the motor and wheels as well as the mobility system and linear actuator controllers for the third wheel and waist. The two main wheels are used for driving while the tail wheel is foldable and provides stability.

Table 1. TeleBot Dimensions

TeleBot Specifications	
Height	180 cm
Width	85 cm
Depth	55.0 cm
Total Weight	32 kg

Table 1 shows the TeleBot size is as tall as a human adultto be spottedfrom afar patrolling crowded urban streets.

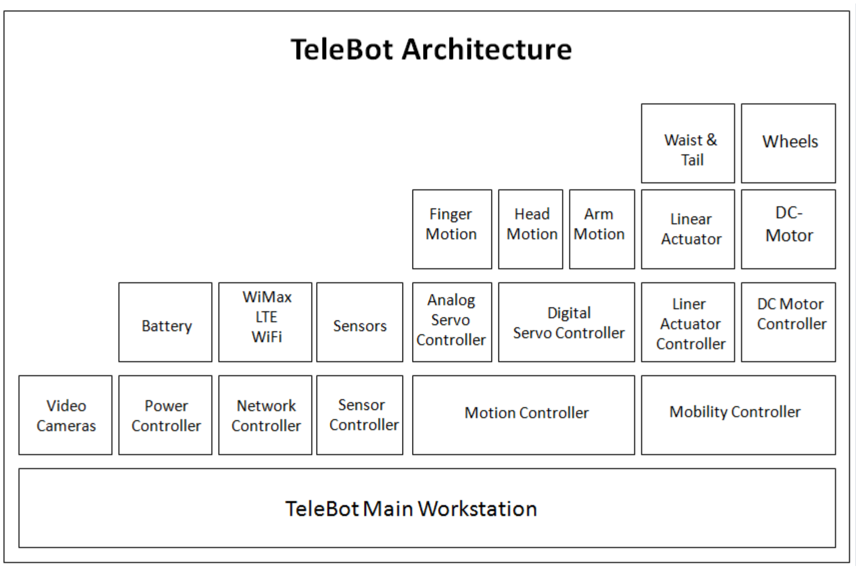

Fig. 5 TeleBot Architecture

Fig. 5 shows a breakdown of the electrical architecture of the TeleBot's main work-station setup. The eyes of the TeleBot are two cameras, which wirelessly transmit live video stream of the TeleBot's visual field to the remote operator wearing a virtual reality helmet. The head can remotely be rotated and tilted for a wider view.The limbs listed in the architecture have varying degrees of freedom listed in Table 2. These motions are possible by the power supply in Table 3. The 3D-printed TeleBot hands, with five fingers each, contain servo motors that are wirelessly controlled by an operator wearing sensory gloves created at Discovery Lab to successfully grab and pick up objects.

Table 2. Degrees of Freedom for TeleBot

Degrees of Freedom (DOF)	
Head	2DOF
Shoulder	3 DOF X 2
Elbow	1 DOF x 2
Wrist	2 DOF X 2
Fingers	3 DOF x 10
Main Wheels	2 DOF x 2
Body Balance	1 DOF
Third Wheel	2 DOF
Waist	1 DOF
Total	52 DOF

Table 3. TeleBot Power

Power Supply	
Wheels	2 x LiFePO4 rechargeable battery 12.8V 10A
Servo Motors	1 x LiFePO4 rechargeable battery 12.8V 10A
Workstation	1 x LiFePO4 rechargeable battery 12.8V 10A

6. STRESS ANALYSIS SIMULATION

Finite Element Analysis (FEA) of the TeleBot frame V1.0 was conducted to validate its structural integrity. The computer program used to perform the analysis was SolidWorks Simulation.The frame was designed to meet all physical requirements and the aesthetic design concept. The actual weight of the full TeleBot is 32kg where the beams are made of lightweight metal. For analysis, the weight of the entire TeleBot V1.0 is set to 60kg. This is 28kg heavier than the predicted TeleBot weight, thus providing a better factor of safety.The vertical waist beamfrom analysis is replaced by a powerful linear actuator that is welded to the frame for added structural support and functionality.

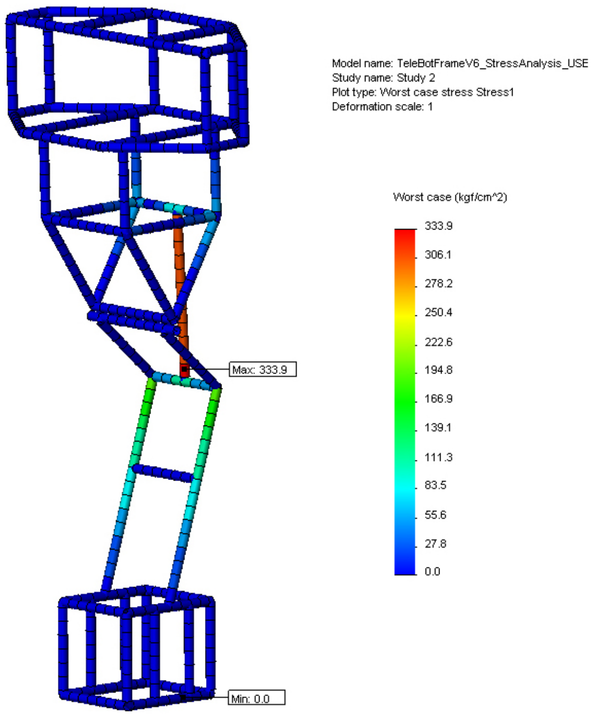

Fig. 6 Weight on upper TeleBot frame – stress analysis of worst case scenario

7. CONCLUSION AND FUTURE WORK

In this paper, we discussed the design and architecture of the TeleBot V1.0. The humanoid design was planned with regards to a citizen's view of the characteristics of an actual human patrol officer in charge of law enforcement.For the next version of the TeleBot, the manufacturing process will be streamlined with new materials and the design will be modified with the consideration of any programming constraints and challenges encountered with the TeleBot prototype V1.0. The next step would be to splash proof and dust proof the design as it will mainly be interacting outdoors (Kaneko et al.,2008).

TheTeleBot project will make a largeimpact on the lives of disabled police officers and veterans who are capable of carrying out law enforcement tasks and bettering the community with their skills, while helping to improve their social interactions at the same time.

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