Technology Entrepreneurship in Developing Countries: Role of Telepresence Robots in Healthcare

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Abstract—*Developing countries represent about three-quarters of the world's population and have become the main driver for the global population and economic growth. Technology entrepreneurship plays an important role in sustainable development of vulnerable social groups and element. These efforts can channel technological benefits to underdeveloped regions. We discuss technology entrepreneurship in developing countries, with a focus on mobile health (mHealth) and telepresence robots. Specifically, we discuss how mHealth can help aged and disadvantaged developing country populations cope with normal life difficulties and challenges—but also in the extreme case and threat of a pandemic. Using past practices and lessons in telepresence robots, we propose FLEXTRA, a flexible robot mechanism to support instant video calls, smart medicine dispensation, and remote control. We also illustrate the applications of FLEXTRA in healthcare, e.g., fighting against COVID-19.*

Key words: Aged care, COVID-19, developing countries, entrepreneurship, mobile health (mHealth), telepresence robots

I. Introduction

Technology entrepreneurship involves high levels of innovation and business skills. Technology entrepreneurship has the potential to address sustainable development challenges including economic prosperity, social equity, and environmental protection.

Sustainable development success depends on developing country social development given that more than three-quarters of the world's population live there and have limited access to food, education, and health care. As global population growth and economic growth rates in developing countries typically higher than those in developed countries, promising business opportunities and markets will likely emerge there.

Technology entrepreneurship plays a key role to link people with technology, thus achieving a win-win situation for investments and the public interest. Therefore, it is critical for technology entrepreneurship for sustainable development (TESD) to have a focus on addressing developing country challenges. Governments in developing countries have limited resources. Thus, it is extremely important to encourage and support TESD—an important form of social entrepreneurship.

TESD covers many sectors and include healthcare, education, aged care, childcare, disability care sector. In this article, we focus on the healthcare sector—one of the largest business sectors in the world.

Information and communication technologies (ICT) play a major role in the universal health coverage [1]. One important ICT is mobile health—*mHealth*—which is healthcare based on mobile technologies. It represents a promising solution to boost healthcare quality; globally and for developing countries. We focus our TESD on mHealth technologies.

The improvement of infrastructure in developing countries, mobile technologies—phones, drones, robots, Apps, and wearable monitoring devices—will play a key role in transforming the developing country healthcare landscape with improved access to quality healthcare in a cost-effective manner. Nevertheless, the success of mHealth in developing countries inevitably requires overcoming many challenges from technology, culture, sustainability, and management dimensions. TESD in mHealth services provides some mechanisms to overcome these challenges [2].

The COVID-19 pandemic is the most recent and current crisis that has devastated the economy and social structures, especially in developing countries. The elderly and sick are most vulnerable to COVID-19. We provide insights into one potential mHealth solutions—telepresence robots for aged care and COVID-19.

The remainder of the article begins with Section II by overviewing the background of the project in the context of TESD that emphasizes the need for technology entrepreneurship for the developing countries, especially in social sectors, such as healthcare. Section III provides a survey on the applications of telepresence robots to aid the elderly. Section IV proposes our design of FLEXTRA, a low-cost telepresence robot with the benefits of cost and extensibility, and its applications to help COVID-19 pandemic damage. The discussions in these sections also provide lessons for pandemic outbreak management. This issue is especially pertinent for elderly—people above 65 years of age–is generally the most vulnerable group during the COVID-19 pandemic. For example, more than 80% of the deaths from COVID-19 are for people 60 years and older, and those with underlying medical conditions. Finally, Section V concludes the article.

II. Background

TESD is aimed at supporting the most vulnerable populations including the poor, elderly, and disabled in developing countries. The authors of this article have been working on illustrating TESD with a multicountry and multidisciplinary initiative that involves the application of mHealth technologies—smartphones, Internet of Things, and robots—tailored for developing countries [4]. The objective of this initiative is to leverage entrepreneurship to improve healthcare system quality at reduced-cost levels, with increased general public accessibility to vulnerable populations, using mobile technologies (mHealth).

This mHealth initiative was launched in 2018 under the leadership of University of Michigan–Shanghai Jiao Tong University during the Entrepreneurship Week 2018 in Shanghai, China. The initiative involved five projects involving more than 50 researchers in 12 countries. The outcomes were published in the book [4] led by the five project leaders [6]. These are as follows.

1. A global challenge focusing on different stakeholders for mHealth intervention.
2. Portable health clinics, for mHealth use as the primary healthcare in remote developing regions.
3. Sustainable and resilient mHealth services, for health services even in cases of catastrophic disasters.
4. mHealth for the elderly and their concerns, and mHealth for chronic illnesses, including managing social impacts and cost-effective solutions.

This article is based on the work being done in project#3 that aimed to develop low-cost telepresence robots for healthcare. This project aimed to make telepresence robots (for the elderly) cost-effective in developing countries. The next section discusses some of the existing telepresence robots that have been deployed for the elderly in pilot projects in developed countries, such as in Europe and USA as part of the European Union (EU) Victoryahome project [8].

This technology is discussed in the next section.

III. Existing Telepresence Robots for the Elderly

Robotic technologies used for healthcare can be divided into nine categories; companion, telepresence, manipulator service, rehabilitation, health-monitoring, reminder, domestic, entertainment, and fall detection-prevention robots. Telepresence robots allow busy people to be remotely represented by telepresence robots at meetings, consultations, etc. However, EU Victoryahome project and similar other projects have trialed the use of telepresence robots to remotely represent family members and carers at the homes of elderly living independently. That is expected to improve the emotional health of the elderly. Most telepresence robots available on the market do not focus on the elderly and there was little consideration given to the needs and expectations of older individuals in the design of such robots.

Research has demonstrated the importance of addressing human factors in designing ICT products for elderly wellbeing [7]. Giraff and Double are two examples of telepresence robots being used for aged care as briefly described below.

A. Giraff Robots The Giraff robot was originally created by Giraff Technologies AB, a small-to-medium enterprise based in Sweden, and later further developed within the scope of the EU VictoryaHome project [8]. The Giraff robot is a large machine, which includes a full-size desktop computer tower plus batteries (see Figure 1). It has the ability to raise and lower the interaction screen, change the screen angle to appear like nodding the head of the Giraff, zoom camera for a specific area, a night vision switch for dark rooms, and finely controlled speed and maneuverability of the machine.

The Giraff can be remotely activated by a secondary user such as care workers or family members who want to contact the primary user using the telepresence robot. They can request a visit to the primary user—such as the elderly individual. The primary user can see an image of the caller on the Giraff screen and can either accept or reject the incoming call. Some secondary users can also be given permission that allows them to make emergency calls. In these instances, they can activate the Giraff and start a visit without any intervention by the primary user to check on the primary user and their well-being—as may be the case with a suspected fall.

Figure 1. Giraff Robot.

Evaluations of the robots were conducted by partners in the Victoryahome project in The Netherlands, Norway, Portugal, Sweden, and Australia in the form of a controlled research trial with the results meant to inform further development of the device in order to provide a solution that would, as closely as possible fit the needs of older people living in their own homes. The trial was extensive with 20 private homes of elderly users, across Europe and two more in Australia. As the trial was designed to determine the usefulness of the Giraff robot, a series of questions were asked both from the primary user (the elderly) and the secondary users (the caregivers) perspective [8].

The Giraff robot has been evaluated in various sites in Europe (7) and at two sites in Australia. However, it is too expensive (approximately US$10 000) for home use. It also has difficulties such as firewall issues, video freezing, and driving lag. Although it can be a baseline system on which one can design and build a low-cost telepresence robot—an ultimate goal of the team.

B. Double[1] The Double robot was originally created by Double Robotics from California. Both Double and Double 2 consist of three major components: a charging dock, a self-balancing base with two wheels and motors, and an iPad serving as the brain power, the camera, and speakers. Double and Double 2 can be driven by an iPhone or iPad with its internet operating system app or by a personal computer or Macintosh computer with Google Chrome or Firefox browsers. It can be remotely controlled to park, raise, or lower is head to suit sitting and standing scenarios, and make forward, backward, left, and right moves.

[1]https://www.doublerobotics.com

Similar to the evaluations of the Giraff robot, Double 2 underwent a controlled research trial at Sunshine Coast, Australia to explore the match and gap between the existing functionality and the needs of elderly individuals living in their own homes. However, the participants were reluctant to adopt an iPad-only solution. Moreover, the reliance on the attached iPad for camera/video/audio and communication limited the capabilities of Double 2. It also suffered the problem of driving lag due to the Bluetooth-based connection between the iPad and the base. The trial suggested that the telepresence robots for the elderly and healthcare should be flexible and extensible. It costs approx. US$3500+ and there was a need to reduce the cost of such robots for use by elderly at homes.

Here are the salient points of the evaluation carried on the currently available telepresence robots for aged care [8].

- Costs: The unaffordable price of robots has become a barrier for adopting robots into a residential environment. The price for a telepresence robot operating for the elderly is generally several thousands of dollars. Financial feasibility will likely require reduction to one-tenth of the current costs.
- Functionality: A telepresence robot needs to integrate well with the home architecture such as single or double-storied buildings and have the ability to navigate furniture. In addition, it should be extensible regarding its functionality with various sensors and actuators as add-ons.
- Connectivity: Multiple telepresence robots can be connected to build a network of support so that the care assistance can be delivered continuously. This requires robots

to follow open standards and architectures so that different brands and models of robots can be linked to collaborate.
- Personal care: Privacy features, safety, and cognitive stimulation are the most desired functional robot attributes that must be provided by the robot.

This article addresses the problem of aged care in the current COVID-19 situation that necessitates remote care of elderly to prevent COVID-19 infections. Hence, we need a more flexible design of telepresence robots to address various care situations, such as medical consultations, catering, etc. The lessons learned, including the requirements of flexibility, extensibility, and economy, guide us to design FLEXTRA, a Flexible Telepresence Robot Assembly, a general-purpose robotic mechanism to help implement many telehealth solutions (discussed in the following section) urgently required during COVID-19.

IV. FLEXTRA and Its Applications Against COVID-19

Following the lessons learned, we designed and prototyped FLEXTRA to mainly achieve the benefits of cost and extensibility. It supports instant video calls, smart medicine dispensation, and remote control with the total cost of only US$500. Figure 2 illustrates its overview.

The key design principles of FLEXTRA include the following.
- Using off-the-shelf software/ hardware: FLEXTRA uses a normal Android or Windows pad as the communication terminal for end users, and users can choose any video call tool that they are familiar with, such as Skype and Zoom. FLEXTRA also uses Raspberry Pi, which is a low-cost single-board computer running Linux operation system, to implement the motor and sensor control. The use of Raspberry Pi helps to make FLEXTRA economic and easy to extend due to its active community and open-source culture.
- Using open standards: FLEXTRA applies open standards for its software implementation, including the use of Web for content displaying and SSH for secure communication.
- Using three-dimensional (3-D) printing for specific parts: The use of FLEXTRA allows in-house design and build of robots that allow a low-cost start when the demand is not high.

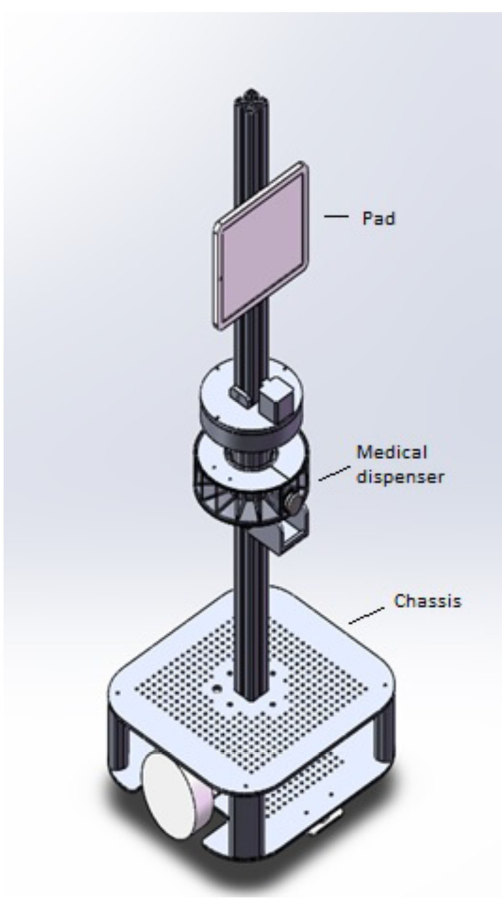

Figure 2. FLEXTRA overview.

Since COVID-19 is highly contagious, telehealth and mHealth have become very important to protect various types of service providers, particularly health professionals from infection by patients and clients who may not know that they have an infection in the view of the two-week incubation period. While hospitals are focusing on patients with confirmed coronavirus infection and its effects, the society has to deal with people who do not have confirmed coronavirus infection, but they may be suspected (e.g., people coming from a cruise).

Even though FLEXTRA is a low-cost telepresence robot, it can be widely deployed to aid in various scenarios. This section explains some common scenarios that FLEXTRA can help to fight against COVID-19.
- *Remote Temperature Monitoring*: Temperature measurement is now a basic and fast screening method (though not complete) for COVID-19 detection deployed at

entry points of various public places, such as airports, rail stations, and office buildings. However, it exposes the person measuring temperature to possible coronavirus infection and hence FLEXTRA can help perform the task remotely. Besides, FLEXTRA can guide people remotely using the tablet on the robots. They can also open or close the entrance through motors so that only people with normal temperatures can pass. Figure 3 illustrates the workflow of applying FLEXTRA in remote temperature measuring.

- *Remote Health Consultation*: FLEXTRA can effectively manage pandemic by reducing contact between doctors and people who come to the hospital since they are potential virus carriers. Usually, doctors will update their schedule on the robot, so that patients can make reservations easily. FLEXTRA can also give basic treatments after making simple tests for patients, like measuring the temperature. If the doctor is available, he or she can communicate with patients through video calls and make a remote diagnosis.
- *Contactless Delivery of Food and Medicines*: FLEXTRA can provide contactless delivery of food or medicine in wards, which are full of virus carriers. They can save many medical resources since they do not need protection measures taken by human doctors and nurses. The video call and remote-control system can improve the user experience of the delivery process. FLEXTRA can also measure targets' temperature quickly when delivering food or medicine, using various sensors (e.g., cameras) and actuators (e.g., catering trolleys) driven by FLEXTRA.
- *Remote Room Disinfection*: FLEXTRA can help to disinfect rooms and remove germs through the spray and ultraviolet light. Users can stay outside and monitor the progress through the remote-control system. This would also require special sensors and actuators driven by FLEXTRA.

One can visualize the architecture of the above scenarios based on the illustration provided in Figure 3.

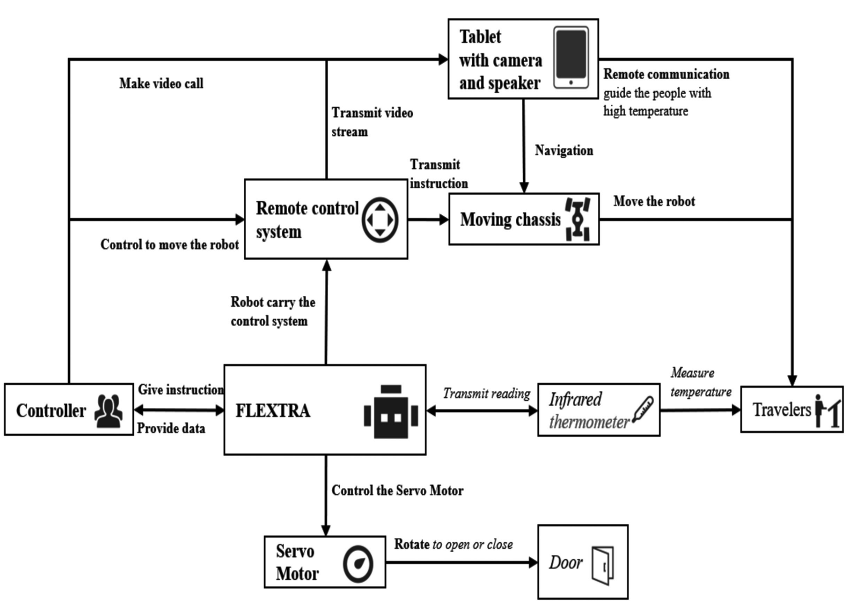

Figure 3. Remote temperature measuring with FLEXTRA.

V. Conclusion

Technology entrepreneurship has important roles to support the sustainable development of weaker sections of the society by channeling the benefits of technology to the currently under-developed regions. In this article, we discussed the technology entrepreneurship in developing countries, with the focus on applying an mHealth technology (telepresence robots) for the elderly. Specifically, we discussed how mHealth can help the aged and disadvantaged population in developing countries to cope with the difficulties and challenges in life and in the extreme case and threat of a pandemic.

Addressing the lessons learned from the past practices in telepresence robots, we proposed FLEXTRA, a flexible robot assembly mechanism to help with COVID-19 applications, such as to support instant video calls, smart medicine dispensation, and remote control with the total cost of only US$500. The key design principles of FLEXTRA include using off-the-shelf software/hardware, using open standards, and using 3-D printing for specific parts. Therefore, a person with average technical skills can reproduce FLEXTRA in-house and test its applications. This will enable the public participation and boost the iterations of development.

We illustrated the applications of FLEXTRA in fighting against COVID-19 in four major scenarios, including remote temperature monitoring, remote health consultation, contactless delivery of food and medicines, and remote room disinfection. It demonstrated that even though FLEXTRA is a low-cost robot mechanism, it can be widely deployed to aid in various scenarios and applications, using a variety of sensors and actuators.

REFERENCES

[1] T. A. Ghebreyesus, "All roads lead to universal health coverage," *Lancet Global Health*, vol. 5, no. 9, pp. e839–e840, 2017. Accessed: Aug. 2020. [Online]. Available: https://doi.org/10.1016/S2214-109X(17)30295-4

[2] P. K. Ray and C. Zhang, "Role of entrepreneurship in universal health coverage (UHC) using mHealth," in *Proc. IEEE Technol. Eng. Manage. Conf.*, 2017, pp. 125–130.

[3] M. Yunus, *Building Social Business: The New Kind of Capitalism That Serves Humanity's Most Pressing Needs*. New York, NY, USA: Perseus Books Group, 2010.

[4] S. C. Ro, W. J. Huang, and P. Ray, "Advancing the role of entrepreneurship in the healthcare industry in developing countries," *Asian Hospital Healthcare Manage.*, no. 44, 2019.

[5] S. Ro *et al.*, Entrepreneurship Week 2018, IEEE LEADER, Nov. 2018. Accessed: Jun. 12, 2020. [Online]. Available: http://www.ieeetems.org/2018/11/25/entrepreneurshipweek-2018/

[6] P. K. Ray, N. Nakashima, A. Ahmed, S.-C. Ro, and Y. Soshino (Eds.), *Mobile Technologies for Delivering Healthcare in Remote, Rural or Developing Regions* (IET Book Series on Health Technologies). London, U.K.: IET Press, 2020. Accessed: Oct. 2020. [Online]. Available: https://shop.theiet.org/mobile-technologies-for-delivering-healthcare-in-remote-rural-or-developing-regions

[7] Y.-H. Wu, C. Fassert, and A.-S. Rigaud, "Designing robots for the elderly: Appearance issue and beyond," *Arch. Gerontol. Geriatrics*, vol. 54, no. 1, pp. 121–126, Jan. 2012. Accessed : Aug. 2020. [Online]. Available: https://www.sciencedirect.com/science/article/abs/pii/S0167494311000288

[8] D. Kerr, J. Serrano, and P. Ray, "The role of a disruptive digital technology for home-based healthcare of the elderly: Telepresence robot," *Digit. Med.*, vol. 4, no. 4, pp. 173–173, Oct. 2018.

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Chongdan Pan received a degree in electrical and computer engineering with a minor in entrepreneurship from Shanghai Jiao Tong University, Shanghai, China, in 2020. He successfully led to completion in 2019 the student groups in the University of Michigan–Shanghai Jiao Tong University (UM-SJTU) Joint Institute capstone project "Telepresence Robot for the Elderly" that formed the basis of this article. The project won the champion of COVID-19 Challenge held by UM-SJTU in May 2020 as well. He also organized and led the SJTU VEXU Robotic team to Design Division Champion, as well as Robot Skills Challenge World Champion in the World Championship held in Louisville, KY, USA, in April 2019. A total of 1600 teams from more than 40 countries attended the event including 77 university teams from renowned universities. Later, he was nominated for student of the year of SJTU, in December 2019.

Pradeep Kumar Ray (Senior Member, IEEE) has been the Founding Director of the Centre for Entrepreneurship at the University of Michigan–Shanghai Jiao Tong University Joint Institute, Shanghai, China, since 2016. He is also an Honorary Professor with the School of Population Health, University of New South Wales, Sydney, NSW, Australia, where he founded the WHO Collaborating Centre on eHealth (2013) that led several mHealth projects involving Australia, Bangladesh, China, India, Indonesia, Japan, and PNG. Recently, he led to completion a multicountry, multidisciplinary project mHealth for Belt and Road region from 2018 to 2020. This project involved more than 25 investigators from more than 12 countries into various aspects of mHealth, such as smartphone-based applications, drones, robots, blockchains, and entrepreneurship in developing countries. The project led to a book *Mobile Technologies for Delivering Healthcare in Remote, Rural or Developing Regions* (London, U.K.: IET Press, 2020). He has more than 250 international publications with an h-index of 37.