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SMART WEARABLES: CHALLENGES AND OPPORTUNITIES

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ABSTRACT

This research outlines challenges and opportunities in the field of smart wearables which ranges from wearables for wellness and healthcare and robotics to smart materials. This field makes advances in applying wearables in pervasive and dynamic environments typical of internet of things and internet of everything. They give opportunities for creating new computational models and deploying these in edge computing, which in turn assist in creating internet of things and internet of everything. Challenges are numerous and range from problems in creating suitable materials to problems typical of modern edge computing.

INTRODUCTION

Wearables are hands-free gadgets with practical uses, powered by microprocessors and they can usually send and receive data via the Internet.

The definition of wearable technology is given in (Hayes, 2021) as a category of electronic devices that can be worn as accessories, embedded in clothing, or implanted in the user's body. They can even be tattooed on the skin (Morrow, 2019).

(StatInvestor, 2021) shows us that the number of connected wearables has more than tripled from 325 million in 2016 to 929 million in 2021, thereby placing wearable technology at the forefront of the Internet of things (IoT).

In this research we also extend the concept of wearables to wearable robotics. (Pons, 2008) gave this early understanding of the concept: Wearable robots are advanced human symbiotic robotic systems characterized by suitable shape, kinematic, and weight factors to be worn on the human body with the function of either augmenting and assisting (exoskeletons) or restoring human limb function (prosthetic robots).

This paper is organized as follows: In the next section we talk about wearables in the particular domain of wellness and healthcare, we move to wearable robotics in the section which follows, and we overview smart materials for soft wearable robotics before we look at challenges in past and present wearables. In the conclusion we debate what the future holds.

WEARABLES FOR WELLNESS AND HEALTHCARE

(Lukowicz et al., 2002) created a watch-like medical monitoring computer designed to free high-risk patients from the constraints of stationary monitoring equipment. The system combined complex medical monitoring, data analysis and communication capabilities over a wireless datalink.

(Kiryu, Moriya, & Mizuno, 2003) created a wearable unit monitoring heartrate and myoelectric signals. This was connected to a torque assisted bicycle to continually monitor and adjust the exercise level for the individual. They used cutting-edge technologies at the time, an internet-based history database and wired or unwired serial communication.

(Hiremath, Yang, & Mankodiya, 2014) conceptualized Wearable Internet of Things discussing design, function, and applications. They looked at the building blocks, such as wearable sensors, internet-connected gateways and cloud and big data solutions.

Creating a comfortable wearable device that can monitor blood pressure is a challenge since the traditional way is using an inflatable cuff. (Helén, Langelid, Solicki, & Larsen, 2019) developed a system and an algorithm for continual and non-invasive measurements of blood pressure variations using Photoplethysmography (PPG) – optical measurements.

(Bui et al., 2021) created eBP, an ear-worm device. This included a light-based inflatable pulse sensor which goes inside the ear, a digital air pump with a controller, and blood pressure estimation algorithms that eliminated the need of blocking the blood flow inside the ear.

We are seeing wearable monitoring devices for specific applications: (Heintzman, 2015) defined a digital ecosystem of data-driven tools to link patients and their care teams for precision management of diabetes using smartphone apps, and wearable devices and sensors. (Forkan & Hu, 2016) uses a FitBit and ECG sensors and a context aware model to capture cardiac patients' health data. The data is processed on a cloud platform and then sent to the patient's friends, family and doctors who are interested to know about his/her health condition.

(Cinel, Tarim, & Tekin) proposed a patient monitoring system to be used for diagnosis and monitoring of sleep apnea. This is done by tracking the respiratory rate of patients with wearable sensor technology, either an accelerometer sensor to be placed on the patients' abdomen or a temperature sensor to be placed on their noses.

WEARABLE ROBOTICS

"The six million dollar man" was an American science fiction and action tv series running 1972-78. It featured an astronaut that was rebuilt with superhuman strength, speed, and vision due to bionic implants after an accident. A decade later (Kazerooni, 1989a, 1989b) defined "Extenders" – a class of robot manipulators worn by humans to increase human mechanical strength.

(Maeda & Ando, 2002) gave us The Parasitic Humanoid, a wearable robot for modeling nonverbal human behavior. It did not have any connection to an external computer, and they defined a need for the robot to learn as it was used.

(Anjum & Rajput) designed two wearable gloves for patients with rheumatoid arthritis. The first glove is designed for physiotherapy and for exercise of the patient. It consists of a sponge ball, a keypad and a pressing device which is helpful for the motion of the hand. The second glove holds home automation functions and includes an Arduino mega board, voice control kit and an LCD unit. The purpose is to help in exercise and home automation functionalities using less time with low cost and without the consultation of a physiotherapist.

(Park et al., 2020) presents the performance of a robotic orthosis designed to assist the paretic hand after stroke. It is a fully user-controlled augmentation with a dual purpose: it serves as a therapeutic tool that facilitates device-mediated hand exercises to recover neuromuscular function and it is an assistive device for use in everyday activities to aid functional use of the hand.

High cost and lack of resources means that children with motor disabilities is limited to wheelchair support in poor areas of the world like Sri Lanka. (Pabasara, Fernando, Sandaruwan, Kumara, & Alahakoon) presents wearable walking robotic legs that are automated and attached to a walker that can give the children give them necessary therapy and walking experience simultaneously.

Colonization of the moon is a potential future use for soft robotics. The moon represents a hazardous environment for humans. It will be necessary to biomedical support to reduce the consequences of space conditions on the astronauts. (Ticllacuri, Lino, Diaz, & Cornejo) has presented the design of a wearable soft robotic system to stimulate, rehabilitate and reduce the harmful effects of space conditions in the muscles involved during the astronauts' gait in future lunar missions. The system is capable of exerting mechanical stimuli on the astronauts' muscles and thereby improving the blood flow in the lower limbs. This will reduce the adverse effects of long inactivity periods in hypogravity, such as muscle atrophy.

SMART MATERIALS FOR SOFT WEARABLE ROBOTICS

(Mertz, 2018) discussed soft robotics – the goal is to generate tools that conform to and interact with the human body in a much more natural and lightweight way. This research showed us prototypes, an exosuit to assist an individual's movement and a glove to help individuals who have difficulty with grasping are examples discussed.

(Guo, Xiang, Helps, Taghavi, & Rossiter, 2018) gave us a range of smart fabrics and reactive textiles for soft robotics. It showed that conductive textiles have the potential to deliver simple, comfortable, multi-function and wearable soft robotic devices and complete soft robots.

(T. E. Vo, Jhangiani, Robbins, & Elor, 2020) presented us with a simulation approach for finding optimal actuation positions towards a bio-inspired exoskeleton The actuators' position to control the suit's movement dramatically affects how much force an exoskeleton suit can exert as we work towards the goal of creating an exoskeleton suit for users that is powerful, but lightweight, portable, and accessible for different body shapes.

(Hasni & Topsakal) designed a process to create small wearable antennas via screen printing on fabric substrates to create wearable electronics where the devices are either part of or made of everyday clothing materials.

CHALLENGES PAST

In the decades since "The Six Million Dollar Man" ruled our television sets we have seen leaps in the field of wearable devices and wearable robotics which will be discussed in this section. New technologies continue to make it possible to create smaller, cheaper, and more user-friendly devices. The wearables now are patient-friendly, they are easy to put on, and easy to wear. Smaller components have also led to devices that are more power efficient and therefore requires less maintenance when it comes to charging.

After The International Symposium on Wearable Computers 2019 (Dunne, Ward, Amft, & Laerhoven, 2020) summarized the accepted submissions to show the state of the art in wearables 2019. The highlights they mentioned are:

- Body-worn devices that offer a unique platform for haptic actuation
- Wearable technology to measure or respond to social experiences
- Textile-integrated electronics
- On-body sensing and the sensor hardware that enables sensing
- Methods and applications for detecting human activities and gestures from body-worn sensor

Communication technologies and standards have improved. As demonstrated by (StatInvestor, 2021) the growth in the number of connected wearables is explosive. IoT in the 5G system will be a game changer according to (Chettri & Bera, 2020). 5G will make new wireless architectures and smart services possible. The recent cellular network LTE (4G) cannot meet the demands of multiple device connectivity and high data rate that is required, 5G gives more bandwidth, lower latency, better quality of service (QoS), and lower interference.

As the demand for advanced features such as gesture control and high speed (5G) wireless IoT device interface increases, multiple wearable sensors/devices are needed. This directly impacts everyday practicality as at any given moment a only finite number of devices can be worn by an individual. (Hasni & Topsakal) showed how it is possible to create small wearable antennas that can be incorporated directly into the fabric of the clothes.

Interoperability gave challenges that were early defined. Data standards needed to be developed so that it is possible to combine data from several sources to give a more accurate and useful user experience. (Warren, Jianchu, Schmitz, & Lebak) presented as early as 2004 a paper that showed that interoperability standards properly applied to medical system design, could have the potential to decrease the cost of point-of-care monitoring systems while better matching systems to patient needs.

More recent work on interoperability includes wearables consisting of a sensor, a communication adapter, and a power module presented by (Pathak, Mukherjee, & Misra). They include low power adapters with each sensor that enabled linkups and on-demand network parameter reconfigurations. This support the interoperability of heterogeneous sensors by eradicating the need for sensor-specific modules through over the air based reconfiguration that allows for new sensors to connect to an existing adapter, without changing the hardware units or any external interface.

CHALLENGES PRESENT

Present challenges come in several categories. The evolving technical advances will continually give us more devices. This will be important when it comes to robotics to enhance or rehabilitate human functionality. Wearable robots will provide a unique opportunity for exosuits that can stimulate enhanced stability and strength. Creating an exoskeleton suit for users that is powerful, but lightweight, portable, and accessible for different body shapes is a challenge that must be overcome. Positioning the actuators that control the suit's movement will dramatically affect how much force the suit can exert. (T.-E. Vo, Jhangiani, Robbins, & Elor) presents a simulation approach for finding optimal actuation positions towards a bio-inspired exoskeleton that leads towards custom design of actuator positioning based on body measurements.

IoT makes it possible to store enormous amounts of data. Machine learning and artificial intelligence have made it possible to process the large amounts of data. However, IoT and machine learning have many uncertainties and grey areas when it comes to handle personal medical data gathered by wearables. (Ahamed & Farid) discusses how these data in nature are very sensitive, and there can be different types of biases involved in the process of data collection and interpretation. They show that the training data model could have an outdated version of the dataset used. This can lead to an incorrect decision from the system without the user's knowledge. They identify reliability issues and propose improvements to overcome these challenges.

The most important challenge today lies in the information stored in the cloud. As shown in (StatInvestor, 2021) the adoption of wearable devices devices is growing exponentially. This results in generation of a substantial amount of data for processing and analyzing. Besides bringing ease to the human lives, these devices are susceptible to different threats and security challenges. This should worry the users adopting it in sensitive environments, like e-health and smart homes. (Iqbal, Abbas, Daneshmand, Rauf, & Bangash, 2020) reviews the threats, security requirements, challenges, and the attack vectors pertinent to IoT networks and propose a network-based deployment of IoT architecture through software-defined networking.

Another aspect that must be solved for wearables to achieve their maximum potential is that since the computation and analysis happen to the data after it has been uploaded to the cloud, the user and the device will see delays on the reactions. (McClenaghan & Moholth, 2019a, 2019b) proposes software architectures that can compute on the edge and can combine data from several wearables.

CONCLUSIONS

Traditional wearables still have communication challenges and security issues, but they provide us with a cheap and easy way of collecting health information and for diagnosis purposes.

Edge computing is necessary to get useful and instant computing on wearables. IoT and the cloud will cause delays to be so slow that any vital warnings will be too late. The apps available at the time of writing are not able to connect commercial wearables to specialized medical wearables and more work needs to be done to make the interoperability better.

Soft robotics and smart materials can and will give wearables that help increase mobility and train or increase strength. Future will add uses when it comes to space travel and colonization. At the moment the development of smart materials and communication technology is the bottleneck, but as demonstrated in this paper there is an large variety of research and development being conducted in this area.

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