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Bio-inspired Robotics as Assistive Technology to Aid of Differently abled and Elderly People

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***Abstract*— At present technology is evolving into many areas. The advancement of bio-inspired robotics technology can be applied and benefited in many areas. Assistive technology can dramatically benefit from bio-inspired robotics to provide aid and assistance to people with disabilities and elder people. Process of modeling biological being into machine involves highly complex methodology and applies that technology to the aid of people with special needs a huge challenge. Applications of robotics can be categorized into several aspects. Based on these aspects numerous researches and applications exist. This review paper aimed to provide a deep discussion on bio-inspired robotics as assistive technology, researches carrying on, its applications and effectivity of those applications. Furthermore, it describes the limitations and future direction of using bio-inspired robots as assistive services or products.**

***Keywords*— Assistive technology, Disabilities, Bio-inspired robotic, Prosthetic, Accessible robots**

I. INTRODUCTION

The idea of building robots which are using the features of living beings was introduced by a long time before in the time of Leonardo Da Vinci. His prototypes and drawings of a machine that fly like a robot bought the idea of "Bio-Inspired Robots". After truly successful attempts during 20th-century scientists and engineers were able to create machines which had the ability to swim, fly or walk [1]. After a large number of research works, in present there are machines that have the potential recognize facial expressions, recognize voice, and locomotion like humans [24] which are in general called as "Robots".

Robotics is growing grounded on artificial intelligence (AI) technology, with capabilities like humans in sensing, speech in natural languages, interaction, decision making, learning, and even creativity [7]. Such that, creation of biologically inspired intelligent robots specifically requires the knowledge of anatomical and biological models, as well as knowledge of robotics engineering and those robots, are including materials, sensors, structure, control, autonomy, functionality and intelligence [24]. Bio-inspired robots can be considered according to four central features:

Mobility, *Interactivity*, *Communication*, *Autonomy*

"Assistive Technology" states to robotics and practical tools that help and support for the people with disabilities and elder people [18,23]. The robots that are developed as bio-inspired robots are also a part of this assistive technology. These bio-inspired robots can help people with those different needs in five wide sub-categories, which are: motor, vision, hearing, cognitive and communication disabilities [18]. So that is present there is a trend of using bio-inspired robots as assistive technology to support people with different needs.

This research paper will be discussed broadly about the way of supplying aid for those differently abled people using bio-inspired robots. The second section of this paper has described the overview, focuses, applications, approaches and the barriers of the assistive technology. Then the next part of this is about the approaches, methodology, an overview of the robotics and bio-inspired robotics. Major researches which are conducted on robotics to use as an assistive technology for the aid of elderly people and disable people will be the next part. As the next part, it specified what are the challenges, drawbacks, and barriers to use robotics in assistive technology. Modern world application of robotics technology as assistive technology will be discussed in the next part which is followed by the discussion of this review paper and the possible future direction of robotics to use in assistive technology.

II. OVERVIEW – ASSISTIVE TECHNOLOGY

A. *Overview of Assistive technology*

Assistive technology is used as a tenure for both products and associated service area which is using assistive technology. The explanation of assistive technology is "assistive products and technology as any product, instrument, equipment or technology adapted or specially designed for improving the functioning of a person with a disability" according to international cataloging of functioning, Disability, and Health (ICF). This assistive technology may include software, hardware, equipment and instruments [10,23]. There is a massive variety of assistive technology applications are extending along with a variety from low technology such as brail language to high technology such as prosthetic arms developed using Artificial Intelligence. ISO categorizes such assistive products as follows: individual medical care

and conduct, personal mobility, an exercise in aids, communication and information, housekeeping, education, and medical process performing.

B. *Applications and focus on Assistive Technology*

Assistive technology service able to provide substantial return on the venture has been done on the technology for both the Government and user of the assistive product or technology. It helps to fulfill the gaps between society and people with special needs. WHO defined every person on the world has equal rights whether the person is disabled or aged or not. That milestone can be achieved through the use of this assistive technology. Assistive technology provides an exclusive possible to deliver on many social policies and global rules distressing the lives of people with disabilities and elderly people [18,23]. Moreover, assistive technology provides the support to elder people and people with disabilities to entree and enjoy their privileges as human beings; do the things that they value; and gaps, differences between people with and without incapacities [10].

III. BIO-INSPIRED ROBOTICS

A. *Overview of robotics*

Define abbreviations and acronyms the initial time they are Robotics may be the most developing trend in the modern world since robots have the ability perform intellectual tasks such as decision making, mathematics, and problem-solving as well as physical tasks. Robotics can assistance humans and they did likewise since the mid-20th century [7,9]. With developed progressive machine learning methods and technology, robots can convert to be intellectual robots, which can study and analyses from previous understanding, from human instructors or other learning programmes, and even by themselves, thereby they are theoretically developing an ability to interact with their live surrounding while taking proper behaviors according to the situations of the environment. Robotics can be used in various areas such as from do-it-yourself robots, to self-controlled drones, home-based serving robots, humanoids, manufacturing and machinery robots, assistive robots, medical and military robots [7].

B. *Introduction and Approaches for Bio-inspired Robotics*

Engineers and Scientists are reverse engineerings many of animals' performance, motions, sensors and behavioral characteristics using various types of advanced technologies. This interdisciplinary work has given rise to in huge advancement of robotics technology which creates machines that can understand speech, recognize facial expressions, and locomotion and mobility techniques in vigorous bipedal gaits, like humans. This bio-inspired robotics technology is significantly advanced from such fields as assistive technology, Integrative Biology, Functionality Elements of Bio-inspired Robots, Bio-inspired Animated Creatures, Artificial Life, Psychology of Bio-inspired Robots, and usages for Biologically Stimulated Smart humanoids. In general, with the present world's expertise and science, one can well animate the appearance and performance of any biological creature even though that creature is very complex in the build [8,10]. Building biologically inspired robots majorly require two types of understandings.

Understanding the biological models of living beings and advancements in analytical modeling -

In order to develop biologically inspired robots, first scientists and engineers must conduct a thorough and well-specified analysis and research of their biological build-up. The research must study the mechanism of the motions, energy levels, censoring, muscle memory or neural memory and the biological structure of the relevant biological and that makes this process more complex. According to engineers, this phase of analyzing phase is the most complicated one than implementations [8]. As examples, The Sprawl robots, hexapods grounded on the biomechanics of cockroaches, have been precisely premeditated to contain compliant features as their biological model (Figure 1) [1]. And prosthetic arms and other prosthetic devices are developed exactly allowing the emulating behavior and performance of real muscles of humans [4].

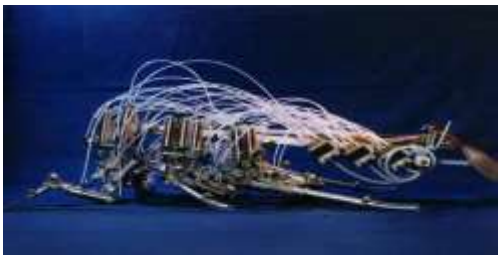

Figure 1. Robot III, hexapod modeled based on the structure and function of a cockroach.

Graphical and physical replication and the physical application of the model using the technology –

Then in the next phase of the process engineers must develop a model inspired by the bio model with the abilities of physical simulation and graphical simulation using their analysis and research. That model has specified with the special and unique features of the neural system of the bio model as well as basic functional neural communications. Based on that graphical and physical simulations engineers build the physical implementation of those models. And that process involves a highly complex process and high machinery [4]. Testing and evaluations are undertaken against the live biological model. In present engineers can

develop bio-inspired physical implementations which are perfectly similar to the actual biological models. Anatomically Correct Testbed (ACT) index finger (Figure 2), BLEEX exoskeleton and Utah Arm can be provided as examples [4,23].

Figure 2. Anatomically Correct Testbed (ACT) index finger. From Neurobionics Laboratory

IV. MAJOR RESEARCHERS IN BIO-INSPIRED ROBOTICS AS ASSISTIVE TECHNOLOGY

There is a highly increasing requirement and demand for assistive products and technologies since the world is moving forward with the technology. To develop science and technology researches must be conducted more and more. So, the field of robotics is conducting major researches on how to use bio-inspired robotics furthermore as assistive technology.

The research areas are based mainly on five different trends on how the robotics as assistive technology such as,

- Humanoids as Assistive Robots
- Prosthetic, Exoskeletons, and Rehabilitation
- Sociological Robots
- Assistive robots for blind and deaf people
- Assistive robotics for the education of disabled children

In all these areas many of the researches have been conducted and some are conducting in present also [20].

Researches for creating bio-inspired robots that have physical and intellectual abilities are a very advanced trend in robotics. And that trend is now applying as assistive robots. The famous ASIMO project is a tremendous example of that area [20,23]. And there are many kinds of research are carrying out to produce a "NANNY ROBOT".

In prosthetic, exoskeletons and rehabilitation, a number of researches are carrying out produce artificial legs, hand and muscles that have the ability to communicate with the user by using actual biological neural signals. This is going to be achieved using the advancement of machine learning and neural science technologies. "The ACT hand", "HAL", "PHANTOM" and "WAM" are some of applications and researches which are related to this area of assistive technology [4].

Sociological and robots capable of understanding human expressions and emotions are also another trend of using robotics as assistive technology. "KISMET" is the breakthrough in this area that scientists and engineers were able to achieve [8].

In general, providing assistive products to blind and deaf people is the fact that motivates bio-inspired robotics into assistive technology area. Numerous researches and innovations which are involved bio-inspired robotics are carrying out on this research area to provide better support for deaf and blind. "ROBOcart", "MELDOG", "GUIDO", "PARALOMA", and "Robotic fingerspelling hand" are the some of applications and trends on this area of research [8,17]. Education perspective of children with special needs is the most recent trend of using bio-inspired robots as assistive products to help those children and students with different impairments.

V. CURRENT ISSUES USING BIO-INSPIRED TECHNOLOGY FOR THE AID OF DIFFERENTLY ABLED AND ELDER PEOPLE

Numerous researches and innovations stated that bio-inspired robotics can be a great use of technology when manufacturing assistive products. There is a huge drawback of using assistive technologies by the people with that type of needs due to various reasons.

A. Financial issues and lack of knowledge

Then the robotics technology is having several limitations and challenges. Robotics is a very expensive technology to practice, teach and to perform experiments. The developed countries such as China, Korea, Japan, the United States, and Europe can only invest that amount of money in this area. Even though money and investments are enough robotics involves very complex mathematical and engineering that only possessed by a very tiny number of scientists and engineers [1,19]. To perform experiments on robotics it requires very advanced high machinery and exceptional environments [21].

Humanoid robotics involved a vastly high amount of expense rather than general robotics. Therefore, experiments and researches on the ways of using them as assistive technology are very limited. And it required neural mapping, neural scientific knowledge, and very fast

processors to build the prototypes and experimental level robots [11].

B. Unpredictability and Complexity

When it comes to bio-inspired robotics the basic procedure is highly unlikely to provide successful results. It involves a very complex and time-consuming process of modeling a biological model of the living being. And making those models into physical implementation needs a high amount of knowledge of neural science and that type of knowledge is very limited. That implementation process may consist of a large number of failures and high machine and material costs. That huge amount of expense on a single system is very unbearable for most of the technological and science labs around the world [8,19].

There are significant complexity and unpredictability is standing on the way of forthcoming prosthetics. The greatest serious task lies in the strategy and implantation of a regulator to allow natural locomotion of high accuracy and efficiency with minimal moral and physical assault [4]. And even though prosthetics and exoskeletons are produced for the aid of disabled and elderly people wearing them, bearing the weight of the prosthetic product or exoskeleton, and maintenance of it makes more complex and difficult to use by the user. And another limitation is lack of technology to deeper considerate of cortical control and other procedures tapping into spinal or exterior nerves, thus kickstarting the field of neuroprosthetics [4]. All the novel prosthetic hands are needed high maintenance and limited interactions with the elements that reducing the scope of movements of disabled and elder people [17].

C. Technological Issues

Prosthetic and exoskeletons in present have a very low level of neural communications which limited the real-time motions and movements and usage of them in real environments is very law. When in the highly unpredicted situations such as accidents these bio-inspired robots do not respond as effectively as a human being [8]. The robotic guidance systems for blind people is providing an only limited amount of movements and motions. Systems like MELDOG, GUIDO(PAM_AID) does not provide the ability to step up or step down. And most of the systems are slow when they are operating and that systems also need high maintenance and hugely cost in the market [15]. And assistive robots like RoboCart can only be operated in exceptional environments which makes a limitation [13,15]. The systems developed for the aid of deaf and blind people possess the limitations of the ability to recognize and reproduce a limited number of signals and letters, inability understand whole words or speech at once [24], inability to produce creativity in to interpretable medium, inability to understanding complex hand gestures and movements, system lags that not provide real-time functionality and not be accurate as much as human beings [14].

D. Social issues

Other than that half of the population of the world having a doubt on the ethical validity of constructing those types of humanoids for domestic use [9].

VI. APPLICATIONS OF BIO-INSPIRED ROBOTICS AS ASSISTIVE TECHNOLOGY

A. Humanoids as Assistive Robots

Humanoids are machines that have the form, physical attributes, intellectual abilities or function of humans [9,12]. It is based on the graphical and physical simulations of the most complex biological model in the world which is a human model. Major researches based in developing humanoids are practiced and innovated in Japan, Korea, the United States and Europe [20]. Robots have the capability to aid elder people with day to day events that can convert more difficult with age of the robot which makes them more reliable [12].

Most famous research on that field is the ASIMO project conducted by Honda company and Osaka University [20]. These robots have many abilities such as locomotion, speech recognition, image recognition, obstacle avoidance ability and decision making as a child in age 12 (Figure 4). With these abilities, scientists are trying to make that humanoid more useful by making that a fully functional "NANNY ROBOT" for disabled people [20]. All the above researches in humanoids to achieve the final goal to supplement humanoid intelligent automatons into the human living atmosphere, to assist the old and the incapacitated people, to amuse children, to support children and to interconnect in a natural language [20]. Those researches are mainly conducted on the following topics [10].

1) Sociable human-robot borders that convert it easier for amateur operators to work with a bio-inspired robot. As examples, Speech recognition systems, electromyogram, and electrooculogram signal clarification can be considered [10].

2) Harmless human-robot collaboration. The issue must be eliminated by seeing both harmless actuation and regulate designs that decrease the influence loads connected to unrestrained gesture and safe robot-movements and functional scheduling.

3) Emotion expression and perception. This purpose is about to produce robots that understand human expressions and emotions and respond according to them [10].

4) Social education. New knowledge tactics are being engaged in robots in a human-like method to make more natural human interaction [10].

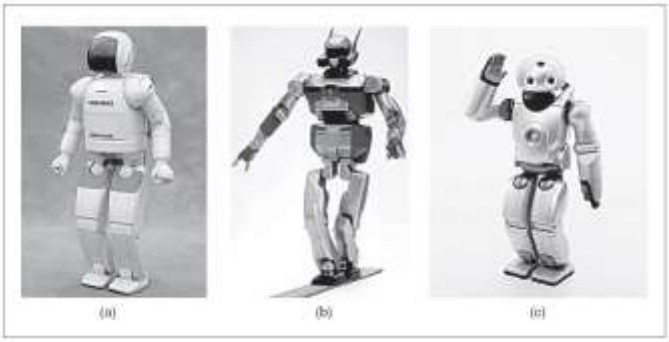

Figure 4 Latest Humanoids. Photograph of ASIMO courtesy of American Honda Motor Co. Photograph of HRP-2 courtesy of Kawada Industries, Inc. Photograph of QRIO courtesy of Sony Entertainment Robot Europe

B. *New trends of Prosthetics, Exoskeletons, and Rehabilitation*

Prosthetic-

The evidence of prosthetic usage for people with special needs drives back as clearly as ancient Egypt. A scientist was able to a fount that a mummy with a large toe had been separated in its lifetime and replaced by a cautiously manufactured timber toe, that attached by leather strings and sequence of timber plates [4]. Prosthetic involving making artificial hands and legs is now accommodated with robotics to create smart prosthetic hands and legs with highly advanced locomotion, mobility, and more energetic to make more assistive support for people with disabilities such as soldiers and wounded people faced for surgeries. For the last decade of time, the researches on robotics for prosthetic attention in upper-limb prosthetics has been in the anthropomorphic arm and hands associated with the neural interface for more smart locomotion. As new trending researches: the "Cyberhand with a single degree of freedom per finger", which intentions to interface neural locomotion and returning accurate feedback to handler [17]. The "ACT hand" is premeditated around the central tenant which is structurally perfect hand can be functioned through the exact identical neural signals used to function the physiques in the real hand of a human [4,13].

Exoskeletons-

Exoskeletons were introduced to carry weights more than 75lbs at 3 mi/h, for people which increases the productivity of human force. But now in present, these systems are providing more power to soldiers, firefighters, and industrial workers. Then with the association of robotics and neural science, these systems can be used to extending the physical abilities of humans in a more high and reliable level [4]. That leads to more researches on using robotically developed exoskeletons as assistive products [26]. Most recent research in this particular area is the "The Hybrid Assistive Limb (HAL)". It is an exoskeleton planned to assistance and to support the aged and persons with disabilities by consuming their myoelectric signals to handle motions of the exoskeleton. Though, it can also hold the user's power up to 40 kg [4,26].

Robotic Rehabilitation-

Since the robotic devices use this technology no need to be worn by the user which makes the interaction and usability are easier for the people with special needs the area of robotic rehabilitation is advancing from prosthetics and exoskeletons [5,13]. A diversity of haptic devices for upper limbs [PHANTOM, WAM, MIT-MANUS, PUMA (MIME,] and lower limbs (Lokomat) are used in recent major researches to show the medical efficiency in corporal treatment for the people who suffers from a stroke and other neurological sicknesses with motion incapacity [5,13].

C. *Sociable Robots to support Differently Abled and Elderly People*

In every research conducted to make robotics innovations to be assistive products, the indirect impact is that robots are making their mode into human surroundings. This process makes a new model of interaction between robots and human beings which is making robots as a friendly partner rather than a machine or an implement. This motivates the researches on robotics to make robots that act as a friend in need for the people with needs. In other words, those assistive robots provide the support and compliance that cannot be achieved by people with special needs as general human beings too with others and with society through these robots.

This drift is reinforced by plentiful experiments and researches in the area of human-computer interaction (HCI) and human-robot interaction (HRI) [8]. These educations have revealed that people carry to bear a series of community guidelines and educated manners that direct their exchanges with, and arrogance in the direction of, collaborating technologies [8].

MIT conducted research on this area to build an anthophorid called "Kismet", a bio-inspired robot that can participate with people in expressive, sensitive and complex social interaction. Kismet is Encouraged by basic social development, thinking and evolutionary standpoints, to allow to enter into ordinary and instinctive social collaboration with an individual (Figure 5). And further researches are being conducted to develop this Kismet as a socially interactive robot known as "Leonard" to provide the service of social interaction indirectly to the people

such as blind, deaf or other impairments [8]. And other than these systems there are many other sociable elderly care robots such as,

• ***Aibo*** -Aibo is researched and manufactured by SONY company [24]. Aibo is built with programmable behavior, a hard-plastic casing and different types of sensors and actuators. Aibo is mobile and autonomous [24].

• ***Paro*** -Paro is developed as a soft seal robot developed by the Intelligent Systems Research Institute (ISRI).

It contains programmable behavior and collection of sensors [11]. Paro is not mobile [11,24].

• ***Pearl*** -Pearl is aimed most severely on purposeful assistance which is one of the four most-cited and studied robots, Pearl is the one of the second group of nursing bots advanced by Carnegie Mellon University [24].

Figure 5 To the left is Kismet. To the right is Leonardo, the successor of Kismet by MIT

D. *Assistive Robotics for Blind, Deaf, and People with Other Impairments*

There are a large number of individuals in the world who are unable to hear and unable to see like normal people because of various reasons [19,24]. It is very challenging for them to communicate with others. The idea of the usage of robotic guide for their aid was single of the latent resolutions that occurred from research conducted recently by Dr. Marion A. Hersh [15].

Most machinelike guides for unsighted person research on the technique that the robot varies route when that senses a difficulty in the path of moving and transfers this alteration of direction to the user to feel the movement hepatically over the handle [15,19]. But in present researchers are trying to develop these systems in a way that it can directly communicate with the user using neural science. And most of these systems use wheels as their motion method. But researches are being undertaken to make those movements through robot legs that provide the ability to climb up and climb down from any place or staircase. Namely, some of those systems are MELDOG, GUIDO(PAM_AID), HARANOBU series and GuideCane (Figure 7). And another major research is "ROBOCART" [6]. The overall strategy of RoboCart is grounded on the ideologies of ergonomics of human and replicates the dual interface functionality over dual components which inspired by biological models and those are locomotion and haptic [6]. This robot is intentioned to provide human interaction and support for blind people to do their shopping in public supermarkets [6]. Another system consists of a standard off-the-shelf walker, retrofitted with sensors and data-processing capabilities [2]. The system additionally includes a vibration belt comprising five vibrating motors, which provide haptic feedback to the user [2,6].

Another major research is carrying out for the people with mobility impairments because of neural failures in the upper body, and for blind people which named as "Voice-Controlled Artificial Hand speak System" [12]. The first prototype of this bio-inspired robot contains a robotic arm planned through OpenSCAD and created using a low-cost 3D printer that replicates the writing system and characters of the sign language and operated via vocals only [12].
There is another research for this field to make an augmented service dog for disabled people using augmented reality applications and data communication applications [25]. The operational method consists of taking usage of the versatile aids of the dog and consuming the android to precise the essential volatility of the behavior [25].

There is another research on providing "Robotic fingerspelling hand" for the aid of the blind and deaf people. And several methods were used such as "ManneQuinPro human modeling system" to approximate the size of a human hand, golden ration to approximate the size of bones in the human hand and neural net to understand the neural network of human hand [25]. It was able to develop design the physical testing models of the fingers of the hand except for the thumb. And continuous experiments are carried out to make a perfectly functional intelligent arm that can be used by deaf and blind people [25].

"PARLOMA" is another novel human-robot interaction system for the communication of deaf and blind people. This system can work as a telephone for deaf and blind people which has the features of understanding and recognizing patterns of hand gestures and hand shapes [16]. It has the abilities of hand tracking, Gesture recognition, and Anthropomorphic Haptic Interfaces.

E. *Assistive Intelligent Robots for the Aid of Education of Children With Special Needs*

Regrettably, for children with incapacities, there are still insufficient openings for schooling basic science and engineering concepts. Because lack of communication skills and low concentration from the educational system makes that harder for the students with special needs [3]. Robots can be a great aid to the education of specifically mathematical concepts and physics [18]. Assistive robots can be used for students with incapacities in two key customs.

• *The machines and robots can be aiding in themselves*
• *Available interfaces to instructive robots can help children with disabilities taking equal involvement with robot-based learning actions.*

A fully united, robot-assisted, science tutoring programme for children with incapacities was industrialized by Howell in 1994 [3]. But bio-inspired robotics were used in applications for the aid of students with disabilities in recent past [16]. From the Department of Cybernetics at the University of Reading, UK, a set of small bio-inspired robots known as the "seven dwarves" has been developed precisely for instructive use of the students. That research continues to evolve those small robots to the aid of children with special needs [16].

VII. CONCLUSION

The purpose of this study is to identify possible ongoing researches and possible future developments of bio-inspired robotics as assistive technology to aid the disabled and older people. Those applications are chiefly conferred in this paper and this paper also focused on the boundaries of existing robotic assistive systems. This study reveals that bio-inspired robotics was massively impacted to the field of assistive technology. Concepts of biological models help to implement the intelligence features of the assistive robots. Some of the researches regarding the uses of assistive robots are describing the constraints and future developments regarding autonomous bio-inspired robots

VIII. FUTURE DIRECTIONS OF AUTONOMOUS MILITARY ROBOTS

Throughout this study, this paper was able to identify some future directions of using robotics as assistive technology in favor of providing assistive support for disabled and elder people in all five trends of this research area. For the support of any field that robotics can be useful, governments and authorities must consider the effect that can be achieved using new advanced technologies of robotics.

A. *Bio-inspired robotics as assistive technology for disabled people*

Humanoids can be developed and advanced in a way that that they are capable of full cognitive capabilities, effective locomotion as fast as humans and with perfectly designed neural network systems. And the area of prosthetic, exoskeletons and rehabilitation can be advanced in a way that those systems support much alive as biological human legs or hands or even better. This area can be upgraded by implementing complex and advanced neural network systems which actually work as a human neural system. And some researches such as "PAROMA", "Voice controlled Artificial hand system" can be improved and implemented after overcoming the issues and parts that to be modeled are created. This way, in near future people with mobility difficulties, will have their actual legs or hands for the second time of their lives [13,21]. Robotic rehabilitation will provide many services in fast healing, fast adaptation, and even life in water in the future. The systems used by people who are blind, deaf or with other impairments will be developed to provide more live communications than present systems as. Those systems can be developed to read and understand sign language even with the complex hand gestures also and speech recognition and vocals will be implemented to provide more interaction.

B. *Bio-inspired robotics as assistive technology for elder people*

The trend of innovating robots that can understand the human emotions and human expressing will be advanced for recognizing more complex expressions and emotional states of human and they will become companions for people when they need. Future development of neural science and machine learning will basically decide future trends of these companion robots for elder people and other people with special needs.

C. *Bio-inspired robotics as assistive technology for the medical field*

Medical and health care field is concerned about using these bio-inspired robotic systems as assistive technology for their field yet to be developed. Medical and healthcare bio-inspired robotics can have huge social and psychological effects, and apprehensions in the medical and healthcare field [23,22]. In near future researches and experiments for cost-effective design, cost-effective execution, appropriate task classification, a growing consciousness of on-going medical requirements, and suitable human-robot interaction will take place in a large scale in this bio-inspired robotics field [13]. And in the near future, the most complex and most crucial surgeries and tests will be executed by the humanoid nurses and surgeons if these researches and experiments are carried on towards successes [13,22].

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