Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2016, 3(5): 8-15

Review Article **ISSN: 2394 - 658X**

Humanoid Robots – Past, Present and the Future

Joe Denny, Mohamed Elyas, Shannon Angel D'costa and Royson Donate D'Souza

Department of Mechatronics Engineering, Manipal University, Dubai, U.A.E
joe.denny619@gmail.com

ABSTRACT

This journal presents the timeline of humanoid robots divided into 3 aspects such as its past, its present and its possible future .This paper showcases the need for the creation of the first few humanoid robots to the present ones to the ones that are yet to be created. The need for the robots to have aspects of a human is put forward in this paper along with the specific application of the robots. The journal has three parts as mentioned above. The first section consists of the present scenario about humanoid robots under this section the complexity of the motion of a human hand and the biomechanics required in duplicating the motion is showcased alongside the mimicking of human functions such as walking and swimming. The first part even comprises about the sensing method for a humanoid robot. Advancement of humanoid robots in the field of cerebral palsy and autism has also been briefed through in this journal. The second phase of the journal comprises the past life of the humanoid robots; the beginning thoughts that lead to the idea of humanoid robots to the first ever created working humanoid robots is shown in the second section along with the advancement in bipedal locomotion and in environmental perception . The third section consists of the upcoming future development in the field of humanoid robots .The difficulties in the existing means of motion of humanoid robot and the further possible future motion of humanoid robots is depicted in the third phase. Human to humanoid control is briefed in the final chapter of the journal along with other technology such as grasping force .It also shows the trend towards the research in robotics towards development of humanoid robots using cogitative system utilizing artificial intelligence .At the end of the journal the list of humanoid robot developments as to understand the depth of development in the field of humanoid robots and the importance of humanoid robots in the existing and the coming era.

Key words: Humanoid robot, history of humanoid, medical treatment using humanoid, biped locomotion, future of humanoid

---

INTRODUCTION

The ever increasing need for the technology of humanoid robot in fields is going from a battlefield to as simple as a home has caused a revolutionary increasing in the growth of the technologies of humanoid robots. A computer being among us to help us out in ways better than an expected individual can is more than enough reason for the necessity of humanoid robots. They look like us, they communicate like us, they walk like us; all of these simple actions that humans are born with are nearly perfected to be duplicated by humanoid robots. As simple as the name suggests they are derivatives if human nature. This journal goes by the notion of bringing the past of a humanoid robot and its change into the present and to the possible future of it; A 'diary' of humanoid robots. Depicting human nature from a tiny movement to a finger to looking as close to an actual human has been a huge development in the field of robotics. The growth of the development of humanoid robots has to be considered one of the best possible growths in the field of robotics. The journal is divided into 3 stages of humanoid robots as for a human. The past, where how it all started out and the growth of it from literal and fictional state to a physical state. The present; where it showcases the current life of humanoid robots and the future; where it's most likely to be.

PRESENT LIFE

Humanoid robot lifespan is ever increasing with the aging of population and declining of birth rates [1]. With the increase need for manpower which is not to be found in terms of humans itself the best possible substitute have become humanoid robots because of which the technology relating humanoid robot has increased along the present years and is estimated to improve in the forthcoming years. The attributes of a humanoid robot should have the least flaw as compared to an actual human. Following the path of a human hand is considered to be one of the vital movements of a humanoid robot. A Human hand has a degree of freedom of 22 as shown in the figure 1.making it one of the hardest human motions [2]. The Matlab model of the human hand consists of direct and inverse kinematics, trajectory generator, drawer, and dynamics block [2]. Biomechanics of the human hand tends to duplicate the motion of the human hand into a humanoid robot and its necessity is required in fields such of health services, home robots etc. [3]. Replacing prosthetics arms with robotic prosthetic arm is one of the key purposes of biomechanics. Simulations through Matlab have been used to create the motion of a human hand movement.

Another key feature that has been perfected over the years is the function of a humanoid robot to walk like a human. Throughout the years stable walking has been perfected for a humanoid robot with the concepts of zero moment point [4] and mass centre. Process of stable walking has been made easier with predictive PID controller that actually imitates the time that is calculated and in doing so it reduces the factor of complexity in the control [5]. Furthermore into humanoid robot motion would be human activities such as swimming for an example. In spite of having a really long history of competitive swimming in humans, its complete mechanics has still not been fully understood yet. Since it is an extremely complicated process in which a complex human body moves unsteadily with many degrees of freedom in the three-dimensional water flow. Robots have been made for the sole purpose of assisting humans in the process of swimming and in turn learn more about swimming through simulation. An example of it is SWUMANOID; as its name suggests is a swimming android which is used to test swimming motions. [6]

Motion like a human alone does not define a robot as ‘humanoid’, its ability to sense also comes into picture. Person detection system using vision sensors are the most economical way to incorporate a vision system. The present method is simple; it detects the person and it tracks the required person using individual camera with an incorporated image formation system [7]. Vision sensors system is the most widely used sensing system for a robot but the factors of lighting and the appearance of the object have led to cases of flaws [1]. The positioning of the object, the surrounding factors and the ability to follow a trajectory with the minimal use of energy and time should be the key features when speaking in terms of sensing. Factors such as payload limit the robot from carrying heavy sensing systems along with it [1].

Web oriented object learning and recognition is another means of learning object for humanoid robots. Cloud resources are an advantage in this case, even in the absence of internet access the robot can use the user’s camera and recognize images from them [8]. Informationally structured environment has been one way to sense the environment, an example of a structured environment is shown in the figure 2; where various data from distributed sensors are integrated to the robot system [1]. Motion detection and motion generation is one of the latest technologies used in humanoid robotics. Human motion is detected by the robot; it adapts itself to the human motion and teaches itself to follow the trajectory of the motion [9]. Repeatability is carried out by the process of training and its accuracy is determined by it. Finally it gets executed when the desired process is called for.

The need for the robot to have an appearance more like a human is essential for the Human-Robot Interaction. Studies have been carried out and a robot with ability with showcasing facial expressions and behaviour in response to its communication is much selected over others. The need for facial appearance and behaviour is an essential requirement [10].

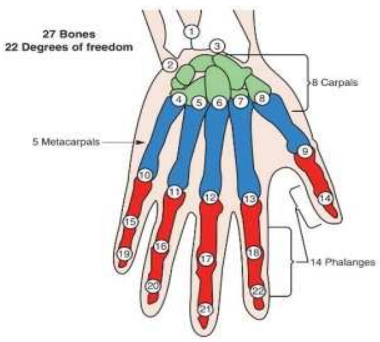

Fig.1 Human hand degree of freedom[38]

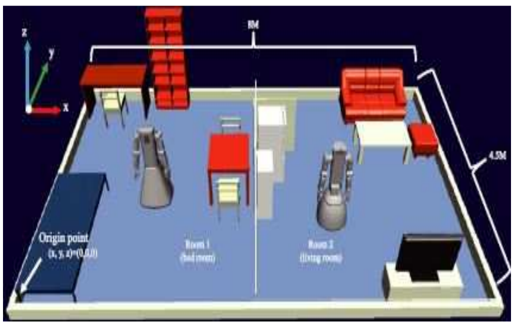

Fig. 2 Informationally structured environment[1]

The communication between the human and the robot is termed as Human-Robot interaction. Human-Robot Interactions are being carried out in various ways such as teaching method where the robot follows the gestures and motion of a human and stores the data and later on follows the trajectory when executed for that motion. Speech to text is yet another means of communication between human to robot where human gives verbal command and the data gets converted to textual data and in turn into digital signal which robots understand [11]. In the field Human-

Robot Interaction the applicability of kinematics and shape is relying on two factors. The first one is to maintain a real time communication between the robot and the human implying the use of algorithms having low cost computational time and not memory resource demanding. The second condition is more related to biological aspects. [12]

The applications of humanoid robots are vast. One of the major fields where humanoid robots have brought significant help is medical .In case of Autistic Spectrum Disorders (ASD) statistics has shown an epidemic increase since 1960's. In recent years, robots have been increasingly used in autism diagnosis and treatment [13]. In its initial step they have identified the necessity needed for the robot to carry out the treatment for autism, in the second step the robots are initiated with patients with ASD and clinical intervention is carried out [13][14]. Humanoid robots have also been incorporated for the treatment for cerebral palsy (CP).CP is one of the most common motor disabilities present in children that cause impairment in movement and posture [15]. Socially Assistive Robotics (SAR) is an example of a high end technology that assists humans in rehabilitation treatment of CP and ASD. Humanoid robots allow human like gestures which leads to a dynamic interaction of humans with robots which is Human-Robot Interaction (HRI). With a human like response from humanoid robots such as ALICE and NAO as shown in figure 3 , it is possible to develop motor skills in CP patients and to Improving social and imitation skills in autistic children[13][15]. Humanoid robots are even being used in the field of orthopaedics; such surgery-assisting technology is being promoted by surgeons because it provides accurate positioning of the surgical device and can have exact predetermined exerting forces that can have high accuracy close to zero error in it and it can grant more accurate surgical treatment to patients [16]. The machine is computer guided and it does not lead to the factor of error due to human negligence.

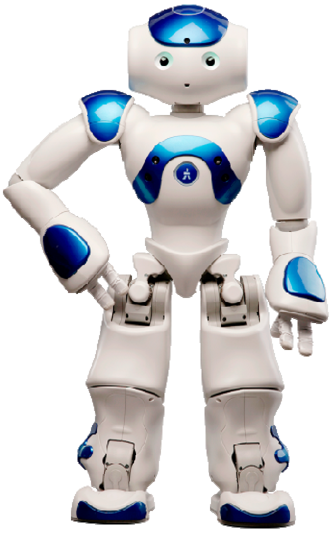

Fig. 3 NAO robot[39]

Educational is another application of a humanoid robot. An educational robot can be made to be used as a tool to make the students more motivated and interested. The NAO robot was basically created for educational purpose, for the students to interact more with it and learn more from it. NAO robots can be programmed to do tasks. It has been used as a tour guide for laboratories [17]. With every new batch of students they need to be walked through the different devices and their process. In doing so it can avoid the need for an extra operator to do the redundancy of explanation and the students get to interact with the robots. It is also being used in museums and exhibition halls as tour guides.

PAST LIFE

The term 'Robot' was coined by a play writer, Karel Capek in his play [18]. The character was a servant robot, which resembled the structure of a human being. In second century, Leonardo da Vinci created a mechanical robot knight. It consisted of a knight armor, which was fitted with gears, wheels and pulleys. It was controlled using cables and pulleys. This robotic knight could lift its visor, sit or stand and could move its head.

Then followed the era of robotics - Robots for many different purposes in industries, personal uses and so on. In 1940, the first humanoid robot named Elektro [19] was created by Westinghouse Electric Corporation. It could only move its arms and head, move around on a wheel in its base, and it could play recorded speech. It consisted of photoelectric eyes and could distinguish between red and green light. Using the sketch of the robotic knight by Leonardo da Vinci, robotist Mark Rosheim built a prototype of the same in 2002. He further modified and made it more advanced by introducing the ability to walk.

The real challenge in production of autonomous humanoid robot is not just the designing but also programming and functions. It is important to design a humanoid robot as closely as possible to the design characteristics of a human being. It should also be able to communicate easily with the others and also should be able to take decisions on its own. The design was a difficult part to execute, since the extra ordinary balancing capability of the human being was not an easy task to understand and imply on a humanoid robot. During the Tang Dynasty, a craftsman, Yang Wullian made a humanoid robot which resembled a monk. It could beg for alms with a copper cup, put it in place after collecting and even bow down to the person who gave it to the robot. All these were mechanically actuated and were either in a fixed sequence or complete manual control.

In 1973, Wabot-1[20], the first humanoid robot which could walk on two legs, communicates with human and transport objects were created by Waseda University. Although it could walk on two legs, the surface on which the robot could walk was a major challenge for the developers as it could only walk on flat floors only. This bipedal locomotion of the robot was the biggest invention but also brought more challenges into the industry – self balancing, walking on uneven surfaces, climbing and descending stairs, auto balancing after a force is applied to push the robot called as Bipedal Push Recovery. The Bipedal Push Recovery was achieved by using hydraulic actuators and was implemented on Quadruped robot called Big-Dog [21] which uses a combustion engine for power. The hydraulic system was too bulky to be able to accommodate in small indoor robots and the use of combustion engines in humanoid robots was not a good idea, hence it was not practically usable. Many researches are being done to solve this problem, and one of them is by changing the location of the leg, depending on the direction of force applied on the robot.

The major challenges in the field of Humanoid Robotics were expressing and identification of emotions, balancing, environment perception and intelligence. Sony has developed a robot called Qrio [22], which could recognize face and facial expressions. It can also express its own emotions through speech and body language. It was a major leap in the field of Humanoid Robotics. Even though it could understand the emotions of the other human beings, it could not identify all the emotions, as the emotions in know was taught to it by graphical methods [23]. So if the emotion displayed by a human doesn't match the emotion it has recorded, the robot couldn't identify the emotion.

Bipedal Locomotion

The bipedal locomotion [24] had two main theories, which was implemented in different fields. The ZMP – Zero Moment Point [25] was the widely used theory for the bipedal locomotion of robots. This theory is defined as – at a point on ground, the sum of all the active forces equal to zero. The theory made a major advancement in the bipedal locomotion of robots. The famous Humanoid Robot, Honda ASIMO uses the ZMP theory for its walking operation. The ASIMO could run up to a speed of 6KM/h and can climb specific stairs and also walk on flat surfaces, but no theories are perfect. This theory's drawback includes the inability of the robot to walk on uneven surfaces, to climb all the stairs and the designing of the robot is done in a way that the knees of the robot are always bent, which doesn't resemble the human design in any way. This design is still used for the walking due to its ability to walk and climb and descent the stairs. Research is still going on to change the bent knee and make it more human like by adding counter weights in order to balance the forces. Figure 4 shows the biped locomotion cycle

.

In 1990, Tad McGeer proposed a new theory for the bipedal locomotion which included a simple control and energy efficient [26]. The robots using this theory for walking could go down a slope easily without any use of actuators and control, but some other problems arose when using this theory. The theory suggested round feet for the robot, due to this the robot couldn't stand still for long time and needs an external force for starting and stopping the walking action of the robot and can't even change the speed of the walking. Due to these disadvantages of the theory, it cannot be used efficiently, but the developers are trying to this theory in conjunction with the use of sensors and actuators to remove the restriction of the proposed theory.

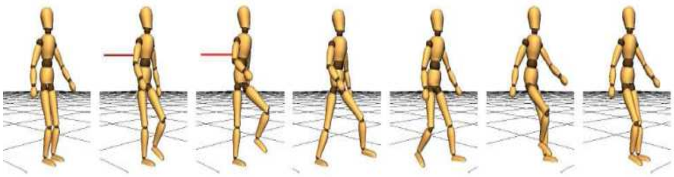

Fig. 4 Biped locomotion [40]

Environment Perception

Environment perception is an important factor for the awareness of the robot to know where it is moving, to know the surface its walking, to balance itself and so on. It is important for the robot to measure the robot attitude [27], present state of the joints and measure ground reaction forces. This was done by using potentiometers, force sensors, accelerometers and gyroscopes. The use of potentiometers for knowing the state of joint was not very efficient due to its lack of accuracy; hence the encoders were widely used for higher accuracy and ease of use.

Some robots use ultrasonic distance sensors or laser sensors for vision of the local obstacles, but it is not real time, as it takes time to transmit and receive the waves and process the information, so a new mode of vision, which uses 3D image processing [28] with the help of two cameras and speeded up robust feature – SURF [29] for real time, accurate location of obstacles. It can not only identify the obstacles, but as we use a camera, it can select its own field of view and focus on a particular object. The avoidance of the obstacles is done with fuzzy logic based avoidance motion selection [30]. Most of the humanoid robots are equipped with an on-board image interpretation system, but it cannot process all the environment accurately, hence a simple work environment is required for the robot using this technology to work efficiently.

Some humanoids are equipped with force sensors on their hand palms to and in some robots at different parts of the body of the Humanoid to sense different sensitivity of touch on or by the humanoid robot [31]. The touch sensitivity is important in humanoids; so as to know the force to be transferred into fingers can be decided, while picking up an object. The Wabot-2 [32] was such a robot created by the Waseda University on 1985. It was a robot which could play keyboard musical instruments by tapping the keys softly and the legs handling the bass drum and could also communicate with others.

The next step in humanoids was the hearing and speech capability and the ability to communicate in real time to others. The speech was not a difficult task as a wide variety of speakers are available for conveying the speech, but to know what to convey was the next challenge. The humanoid must take the input from the environment through the microphone and process the taken signal, and then it has to take a decision and convey the speech accordingly [33]. For this, the feedback during interaction is essential for the usability of the system.

The researches on the humanoid robots are still going, but still the capabilities of the humanoids are very limited compared to a normal human being. The research on this sector is purely based on the Biological model, the Human. So for developing the humanoids, research on humans are to be done thoroughly, how the joints are made, the different senses, reactions and so on. Even though many of the problems are partially or fully solved, the cost and complexity of the system is something which cannot be solved, due to the complex components. Previously, the various research tools conducted on humanoid robots have increasingly become common as they bought in.

FUTURE LIFE

New perspectives as compared to the wheeled robots; Such as, the humanoid robots are capable of manoeuvring in various terrains, in hazards environments and in climbing objects. However, there are few flaws where the humanoid robot faces, that are, they generally suffer from backlashes and frictions in joints, have walking instability and have very limited payloads during motion execution. But such motion execution usually results in terrible noises, and motion sensors may provide unreliable, unrealistic and inaccurate results. Therefore, the problem faced in humanoid robots is accurate localization.

Nowadays, various research approaches have been presented for humanoid localization; the most popular research approaches were usually carried in 2D spaces. In one such research, the 2D representation information was stored in quantized cells but they were not reliable in navigation of obstacles. So to navigate the humanoid to make its way through obstacles and to determine the heights of different objects, the 2.5D representation was utilized. However, various other approaches such as 3D representation is used for arbitrary environments having several levels , a 6D representation is used for multi-levelled and non-planar movements. In contrast to all the approaches, research has been made for determining the 6D poses of humanoid robots by using a 3D representation integrating only on-board sensors [34].

Human-to-Humanoid motion control is another research for addressing the performance of joint limits and self-collisions. By capturing numerous makers in the Cartesian space, we can define the motions in humanoid robots for determining its desired motion for retargeting. These positions of makers, which are served as natural targets for controlling the humanoid, results in task-space control. During motion retargeting task, there exhibits redundancy of motion but it often goes unnoticed. In humanoid robots, the critical satisfaction of constrained has been given the highest priority during executions. These critical constrained can be overcome by producing the constrained as the highest priority and carrying out the operational task in constrained null space. However, this approach handles limited joint movements and collisions, resulting in non-linear transition of execution of motions in a much undefined pathways. On the contrary, a well determined mechanism is needed for safely disengaging the constrained from its highest priority. Furthermore, the motion control task present in legged humanoid robot makes use of foot contact constraints. Each foot orientation of the humanoid robot is viewed and controlled as a task variable and is prioritized in resolution redundancy scheme respectively. This approach is only suitable for execution of operational tasks without exhibiting redundancy to complete the necessary motion control tasks [35].

Another latest research carried out on humanoid robots is the means analyzing the human grasping behaviour and utilize this principle on robots hand. The humanoid robot is designed and developed to interact with the real-time world. The increase degree of freedom of the robot's hand in addition to flexibility results in complexity in control. To receive response of humanoid hand control to perform various manipulative tasks and complex grasping intentions has become very cumbersome. Reason being, humans have biologically muscular system of hand to arm to wrist configuration for controlling high degree of freedom. Choices regarding parts of the hand have already been made just before acquiring a grasp, so as to allow the human hand to engage in certain tasks such as turning a knob or dial, opening and closing a lid, etc. stable grasps are determined with the guidelines of grasp intentions and they also determine the grasp functions, postures, motions, forces and torques when handling an object. Such principles of grasp intentions are applied to humanoid hand under considerations, by quantifying the material of grasp configurations to pair-wise interaction within the basic grasping surfaces of the hand. Therefore, the analysis of human hand grasping configurations is implemented by using grasping patches. Wherein, each patch visualized a single grasping force [36].

Table -1 Life of Humanoid Robots

S No	Humanoid robot development	Year	Reference
1	Hero of Alexandria described a machine to automatically pour wine for party guests	AD 50	Hero of Alexandria; Bennet Woodcroft (trans.) (1851). Temple Doors opened by Fire on an Altar. Pneumatics of Hero of Alexandria. London: Taylor Walton and Maberly (online edition from University of Rochester, Rochester, NY). Retrieved on 2008-04-23.
2	Leonardo da Vinci designs a humanoid automaton, known as Leonardo's robot.	1495	'MegaGiant Robotics'. megagiant.com.
3	Pierre Jacquet-Droz and his son Henri-Louis created the Draughtsman, the Musicienne and the Writer, a figure of a boy that could write messages up to 40 characters long	1774	'Best robot 2009'. www.gadgetrivia.com.
4	Elektro is the robot built by the Westinghouse Electric Corporation in its Mansfield, Ohio	1937	The Return of Electro, Jack Weeks, New Scientis
5	Wabot-1. It was able to walk, to communicate with a person and to measure distances and directions to the objects using external receptors, artificial ears and eyes, and an artificial mouth	1973	'Historical Android Projects'. androidworld.com.
6	WHL-11 is a biped robot capable of static walking.	1985	'Historical Android Projects'. androidworld.com.
7	Saika, a light-weight, human-size and low-cost humanoid robot, was developed at Tokyo University	1996	'Historical Android Projects'. androidworld.com.
8	Sony unveils small humanoid entertainment robots, dubbed Sony Dream Robot	2001	'Sony Global - Product & Technology Milestones-Robot'. sony.net.
9	Actroid, a robot with realistic silicone 'skin' developed by Osaka University in conjunction with Kokoro Company Ltd	2003	kokoro-dreams.co.jp
10	Nao is a small open source programmable humanoid robot developed by Aldebaran Robotics, in France	2006	Aldebaran Robotics
11	Justin, a humanoid robot developed by the German Aerospace Center	2008	'DLR Portal - Der Mensch im Mittelpunkt - DLR präsentiert auf der AUTOMATICA ein neues Chirurgie-System'
12	NASA and General Motors revealed Robonaut 2, a very advanced humanoid robot.	2010	'Say Hello to Robonaut2, NASA's Android Space Explorer of the Future'. Popular Science.
13	second generation Honda Asimo Robot	2011	'Latest Version of ASIMO Makes North American Debut in New York'. Honda. 17 April 2014.
14	Manav – humanoid robot developed in the laboratory of A-SET Training and Research Institutes	2014	Menezes, Bery 'Meet Manav, India's first 3D-printed humanoid robot'. www.livemint.com
15	New version of Atlas ,it is a bipedal humanoid robot developed by the American robotics company Boston Dynamics, with funding and oversight from the U.S DARPA	2016	'Modest Debut of Atlas May Foreshadow Age of 'Robo Sapiens''. New York Times.

Nowadays, the trend towards the research in robotics is more or less oriented towards development of humanoid robots using cogitative system utilizing artificial intelligence and motor capabilities. The race towards humanoid robots was dated back to BioWalker that gave inputs on cost and versatility of already existing works. The research for energy-efficient actuation systems is currently in development stages, whereby, looking into novel ideas in complex multi-sensors fusion with algorithms and processes. Embedding standard and complex components and software, we can execute and apply the research activity in neurobiological inspiration into humanoid robots. Following guidelines have been made to put forth these ideas and were classified as hybrid actuation, multiple sensors and distributed architecture control.

Humanoid robot research is mainly focused towards making it more human like principle rather than human like outer design; so as to react with the changing environment in a much feasible way. There has been heavy emphasis on controlling the centre pressure using vestibular signals. The humanoid robot differs from human mainly due to balanced body. For example, the legs of a humanoid can be articulated with dual foot planter surface, this is because it tries to mimic the biological foot movement. The following approaches can be done with the overall body of the humanoid. Consequently, all the mentioned approaches are still in their development stages and have yet to become finalized.

CONCLUSION

The 3 aspects of time are shown in this journal. The creation of the idea of humanoid robot from the past to its present state to its future is being understood and showcased in this journal. The different aspects of humanoid robots and its application and its future possibilities are shown in this journal. The journal starts with the current status of the idea of humanoid robots. The existing technological developments in the field are shown. One of the key motions to be mastered in humanoid robots is the duplication of the motion of a human hand; the degree of freedom for a human hand is 27 making it one of the hardest to be mimicked to perfection. Humanoid robots are called as such because of its similarities to that of a human being and the technological advancements being carried out so as to attain the perfection as the name suggests is vast. A minor motion from rolling of an eye to that of taking a swim is a possibility in the existing development. The path that the field of humanoid robots has come gets dated back up to 50 AD where the ideas where fictional and dreams that were yet to be fulfilled. The development in science that led to the breakthrough of human mimicking and incorporating them into robots have been one of the major advancement in this field. Human body works in manners that are yet to be discovered, the versatility of the human body to move the way it does and to perform the way is beyond technological capabilities for the existing ones, with the development of artificial intelligence which is one of the major field for humanoid robot in the existing years and the coming years; it is believed to overcome hurdles that are yet to overcome. From a meagre dream about robots to a robot that is possible of its own dreams has been the expected life of a robot. Development in the field of A.I as put forward by the film industry show cases it as one that cannot be controlled by human nature; as robots were once a dream so have A.I come out in the form of dreams and pictorial representation. The coming years are the years of development of A.I and as we go along we are getting closer to it. Artificial intelligence is the next stepping stone for the humanoid robots and it will be achieved.

REFERENCES

[1] Y Pyo, K Nakashima, S Kuwahata, R Kurazume, T Tsuji, K Morooka and Tsutomu Hasegawa, Service Robot System with an Informationally Structured Environment, *Robotics and Autonomous Systems,* **2015,** 74, (Part A), 148–165.

[2] G ElKoura and K Singh, *Handrix: Animating the Human Hand*, Eurographics/Siggraph Symposium on Computer Animation, **2003.**

[3] I Virgala, M Kelemen, M Varga and P Kurylo, Analysing, Modelling and Simulation of Humanoid Robot Hand Motion, *Procedia Engineering,* **2014,** 96, 489–499.

[4] M Vukobratovi´C, *Zero-Moment Point — Thirty Five Years of Its Life, Int J Human Robot*, **2014, 01**, 157.

[5] S Bouhajar, E Maherzi, N Khraief, M Besbes and S Belghith, Trajectory Generation using Predictive PID Control for Stable Walking Humanoid Robot, *Procedia Computer Science***, 2015,** 73, 86–93.

[6] M Nakashima and Y Tsunoda, Improvement of Crawl Stroke for the Swimming Humanoid Robot to Establish an Experimental Platform for Swimming Research, *Procedia Engineering***, 2015,** 112, 517–521

[7] MNA Bakar and ARM Saad, A Monocular Vision-based Specific Person Detection System for Mobile Robot Applications, *Procedia Engineering***, 2012,** 41, 22–31.

[8] E Hidalgo-Pe˜na, LF Marin-Urias, FM Gonzalez, Antonio M Hernandez and HR Figueroa, Web-based and Interactive Learning - Recognition Method for a Humanoid Robot, *Procedia Technology***, 2013,** 7, 370–376.

[9] W Takano and Y Nakamura, Real-time Unsupervised Segmentation of Human Whole-Body Motion and its Application to Humanoid Robot Acquisition of Motion Symbols, *Robotics and Autonomous Systems***, 2016,** 75 (Part B), 260–272.

[10] T Minato, M Shimada, H Ishiguro and S Itakura, Development of an Android Robot for Studying Human-Robot Interaction, *Lecture Notes in Computer Science*, **2004,** 3029, 424-434.

[11] AR Wagoner, ET Matson, A Robust Human-Robot Communication System Using Natural Language for HARMS, *Procedia Computer Science***, 2015**, 56, 119–126.

[12] C Grand, G Mostafaoui, SK Hasnain and P Gaussier, Synchrony Detection as a Reinforcement Signal for Learning: Application to Human Robot Interaction, *Procedia - Social and Behavioral Sciences*, ***2014***, 126, 82–91.

[13] AR Taheri, M Alemi, A Meghdari, HR Pour Etemad and SL Holderrea, Clinical Application of Humanoid Robots in Playing Imitation Games for Autistic Children in Iran, *Procedia - Social and Behavioral Sciences,**2015**,* 176, 898–906.

[14] S Shamsuddin, H Yussof, S Mohamed, FA Hanapiah and HA Ainudin, Telerehabilitation Service with a Robot for Autism Intervention, *IEEE International Symposium on Robotics and Intelligent Sensors*, Langkawi, Malaysia, **2015,** Pages 349–354

[15] RAA Rahman, FAHanapiah, HH Basri, NA Malik and H Yussof, Use of Robot in Children with Cerebral Palsy : Ups and downs in Clinical Experience, *Procedia Computer Science,* **2015,** 76, 394–399.
[16] LY Qin, JZ Wen, CS Chui and KS Leung, Housing Design and Testing of a Surgical Robot Developed for Orthopaedic Surgery, *Journal of Orthopaedic Translation*, **2016,** 5, 72–80.
[17] RG Boboc, M Horațiu and D Talabă, An Educational Humanoid Laboratory Tour Guide Robot, *Procedia - Social and Behavioral Sciences,* **2014,** 141, 424–430.
[18] S Behnke, Humanoid Robot, Humanoid *Robot – From Fiction to Reality*, **2008,** 4(8), 5.
[19] H Televox, The Robots of Westinghouse, *History of Computers*, Web http://history-computer.com/Dreamers/Elektro.html
[20] A Takanishi, Humanoid Robotics Research and Its Applications, Hadaly-2 and WABIAN, *Humanoid Robots in Waseda University*, **2002**, 12(1), 25-38.
[21] C Run Bin, *Inverse Kinematics of a New Quadruped Robot Control Method*, International Journal of Advanced Robotic Systems, **2013**, 10(1), 2-5.
[22] JR Movellan, Intelligent Robotics and Communications, Origins, Principles, and First Steps, *The RUBI/QRIO Project*, **2005**, 223-228.
[23] HS Ahn and JY Choi, *Can We Teach What Emotion a Robot Should Express?*, **2012,** 1407-1412.
[24] J Pratt, Virtual Model Control, *An Intuitive Approach for Bipedal Locomotion*, **2001**, 20(2), 129-130.
[25] M Vukobratovic and B Borovac, Humanoid Robotics, *Biological Principles of Control Selection for a Humanoid Robot's Dynamic Balance Preservation*, **2008**, 5(4), 642-646.
[26] T Mcgeer, *Dynamics and Control of Bipedal Locomotion*, **1992**, 290-295.
[27] J Vaganay, Mobile Robot Attitude Estimation, *Mobile Robot Attitude Estimation by Fusion of Inertial Data,* **1993**, 1(2), 277-282.
[28] DY Lee, *3D Vision Based Obstacle Avoidance Method*, **2012**, 473-475.
[29] H Bay, Speeded up Robust Feature (SURF), *Computer Vision and Image Understanding*, **2008**, 110(3), 346-359.
[30] U Farooq, Fuzzy Logic and Obstacle Avoidance, *Fuzzy Logic Based Real Time Obstacle Avoidance Controller for a Simplified Model of Hexapod Walking Robot*, **2014**, 6(2), 127-130.
[31] K Ichiro, *The Robot Musician*, Robotics, **1987**, 3(2), 143-155.
[32] F Ferland, *Natural Interaction Design of a Humanoid Robot*, Journal of Human-Robot Interaction, **2012**, 1(2), 119-130.
[33] A Green , *Designing and Evaluating Human-Robot Communication: Informing Design through Analysis of User Interaction*, KTH Royal Institute of Technology, Sweden, **2009**.
[34] A Hornung, KM Wurm, M Bennewitz, Humanoid Robot Localization in Complex Indoor Environments, *Proc IEEE/RSJ Int Conf Intell Robots Syst [Taipei]*, **2010**, 1690-1695.
[35] GB Hammam, PM Wensing, B Dariush, DE Orin Kino, Dynamically Consistent Motion Retargeting for Humanoids, *International Journal of Humanoid Robotics*, **2015**, 12(2), 1-27.
[36] RL De Souza, S El-Khoury, J Santos-Victor and A Billard, Recognizing the Grasp Intention from Human Demonstration, *Robotics and Autonomous Systems*, **2015**, 74(PA), 108-121.
[37] V Santos, R Moreira and F Silva, Mechatronic Design of a New Humanoid Robot with Hybrid Parallel Actuation *International Journal of Advanced Robotic Systems*, **2012**, 9 (1), 115-134.
[38] *https://alessandrafusco.wordpress.com/2013/10/31/human-and-robotic-hands/*
[39] *http://thetyee.ca/News/2014/06/14/Robo-Ethics-Not-Science-Fiction/*
[40] *http://www.cs.ubc.ca/~van/papers/Simbicon.htm*