Advancement of Android and Contribution of Various Countries in the Research and Development of the Humanoid Platform

Md. Akhtaruzzaman akhter900@yahoo.com
Department of Mechatronics Engineering
International Islamic University Malaysia
Kuala Lumpur, 53100, Malaysia

Amir A. Shafie aashafie@gmail.com
Department of Mechatronics Engineering
International Islamic University Malaysia
Kuala Lumpur, 53100, Malaysia

Abstract

A human like autonomous robot which is capable to adapt itself with the changing of its environment and continue to reach its goal is considered as Humanoid Robot. These characteristics differs the Android from the other kind of robots. In recent years there has been much progress in the development of Humanoid and still there are a lot of scopes in this field. A number of research groups are interested in this area and trying to design and develop a various platforms of Humanoid based on mechanical and biological concept. Many researchers focus on the designing of lower torso to make the Robot navigating as like as a normal human being do. Designing the lower torso which includes west, hip, knee, ankle and toe, is the more complex and more challenging task. Upper torso design is another complex but interesting task that includes the design of arms and neck. Analysis of walking gait, optimal control of multiple motors or other actuators, controlling the Degree of Freedom (DOF), adaptability control and intelligence are also the challenging tasks to make a Humanoid to behave like a human. Basically research on this field combines a variety of disciplines which make it more thought-provoking area in Mechatronics Engineering. In this paper a various platforms for Humanoid Robot development are identified and described based on the evolutionary research on robotics. The paper also depicts a virtual map of humanoid platform development from the ancient time to present time. It is very important and effective to analyze the development phases of androids because of its Business, Educational and Research value. Basic comparisons between the different designs of Humanoid Structures are also analyzed in this paper.

Keywords: Humanoid Robot, Android, Biped Robot, Evolution of Humanoid Robot.

1. INTRODUCTION

Nowadays robots become very powerful elements in industry because of its capability to perform many different tasks and operations precisely. Moreover it does not need the common safety and comfort like human. Besides these industrial robots, significant advances have been made in the development of biologically inspired robots or social robots. Bipedal robot especially humanoid robot is naturally enthused from the functional mobility of the human body. However, the complex nature of the skeletal structure as well as the human muscular system cannot be reproduced in this system. A bipedal robot therefore has fewer degrees of freedom (DOF) than a human body. It is very important to choose the number of DOF for each articulation where the selection approach consists of analyzing the structure of the robot from three main planes, sagittal, frontal and transversal planes.

Japanese have a predilection for humanoid robots. In 1952 a Japanese cartoonist, Osamu Tezuka created a human-like robot character, “Atom”, also known as “Astro-boy” in overseas, who became the favorite idol for Japanese children. One hundred fifty years ago Japan had a super-technology in a mechanical doll, a tea serving doll. If a tea cup was putted on a tray, the doll carried it to the guest, served the tea cup and then came back to the start position. Basically today’s humanoid robots are nothing but walking or dancing dolls and are not ready to serve our house hold works. Though humanoids are neither intelligent enough nor autonomous, they currently represented as one of the mankind’s greatest accomplishments. It is the single greatest attempt of mankind to produce an artificial, sentient being. In the recent years manufacturers are making various types and kinds of humanoid robots which are more attainable to the general public.

This paper describes the evolution of humanoid platform based on the earlier and present research work on various mechanical designs and control systems to make the humanoid more friendly and presentable to the world. Some female like androids and humanoid robot kits are also introduced in this paper that holds the values both for the economical and educational advancement.

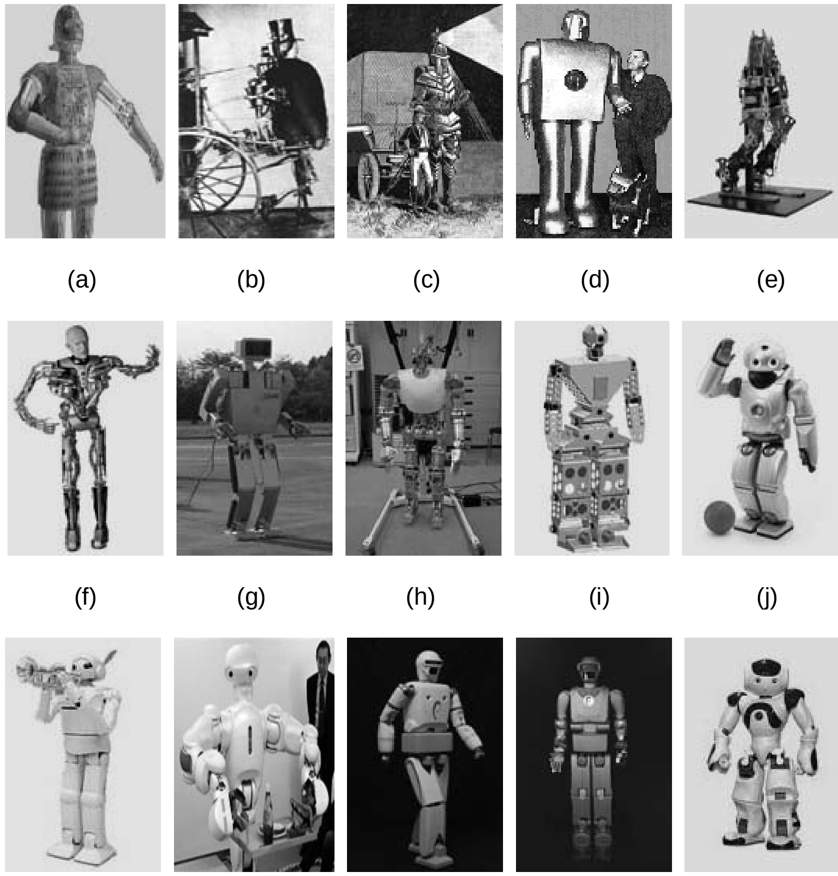
2. EVOLUTION OF HUMANOID ROBOT PLATFORM

Early research on Humanoid system

Leonardo de Vinci who is considered as the first man, have drawn a humanoid mechanism in 1495 [11]. It was designed to sit up, wave arms, move head while opening and closing its jaw. The 18th century can be considered as the fertile period in the development of many autonomous which were able to reproduce some human movements. In 1773, Pierre and Henry Louis invented the first automation which was able to write [11]. The mechanical trumpeter was created by Fridrich Kaufmann in 1810 [11]. The trumpeter contained a notched drum which was used to activate some valves that helped to pass air through twelve tongues.

Construction and development period of humanoid begins in the 19th century when John Brainerd invented the Steam Man in 1865 [10]. It was moved by steam-engine and used to pull carts. In 1885 the Electric Man was built by Frank Reade Junior which was more-or-less an electric version of the Steam Man [10]. A prototype soldier called Boilerplate was built by Dr. Achibald Campion in 1893.

An evolutionary number of humanoid systems appear during 20th century. At the beginning of this century the Westinghouse society made a human like robot called ELEKTRO in 1938, which was capable to walk, talk and smoke [10]. During 1960s to 1990s a numerous types of legged robot platform started to appear in USA, Russia, France and especially in Japan. A great work on jumping robot was carried out at Massachusetts Institute of Technology (MIT) in 1980s [10]. The Biped Planar, Spring Flamingo, Spring Turkey, Uniroo and 3D Biped were built in MIT having remarkable performance on walking and running movements in a dynamic and stable gait. Figure 1 shows some recent and earlier development of humanoid system.



(a) (b) (c) (d) (e)

(f) (g) (h) (i) (j)

(k) (l) (m) (n) (o)

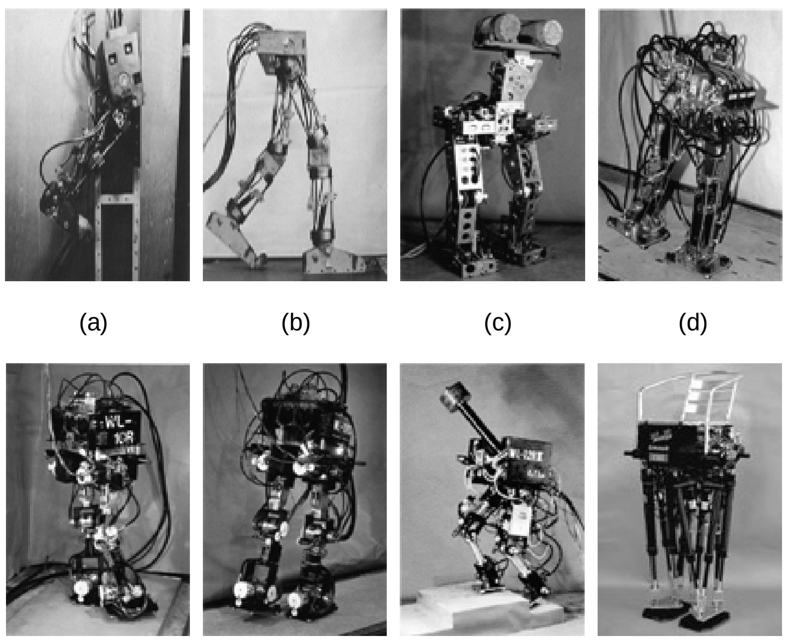
FIGURE 1: Some android platform from ancient time to present time.
(a) First humanoid by Leonardo in 1495, (b) Steam Man in 1865, (c) Electric man in 1885, (d) ELEKTRO in 1938, (e) BIPER-4 in 1984, (f) Tron-Xm developed in Australia in 1997, (g) H6 humanoid from Tokyo University in 2000, (h) Robot JACK in September 2000, (i) GuRoo in 2002, (j) QRIO from SONY on September 19, 2003, (k) Partnar Robot by Toyota Motor Company in 2004, (l) TwendyOne in November 27, 2007 from Wasida University, (m) REEM-A, chess player robot by UAE in 2007, (n) REEM-B by UAE and (o) NAO, in French 2008.

Japanese contribution in the development of humanoid system

Professor Kato's robotic team of Waseda University in Japan developed a whole family of Waseda Legged (WL) robots during 20th century. The fundamental function of bipedal locomotion was applied on the artificial lower-limb WL-1 which was constructed on 1967 [14] [16]. WL-3 was created on 1969 [14] [16] having electro hydraulic servo actuators. Master-slave method based control mechanism was constructed and it was able to manage human like movement in swing and stance phase. Automatic biped walking and the ability to change direction of walking were experimented and made possible using WL-5 in 1972 where a mini-computer was used as its main controller. WL-5 was experimented using the lower limbs of the WABOT-1 having laterally bendable body through which it could move its center of gravity on a frontal plane [14]. Instead of mini-computer, a 16-bit microcomputer was used in WL-9DR (1979 - 1980). In 1983 WL-10R was developed with one more degree of freedom at the yaw axis of the hip joint. Plane walking like walking laterally, turning, walking forward and backward were acquired in this humanoid system where rotary type servo actuator (RSA) was introduced. The latest development of these robots was WL-10RD which was developed in 1984 [10] [16]. It had 10 articulations motorized by electrical servomotors and the body parts made of plastic which were reinforced with carbon fibers. Figure 2 shows the bipedal system of WL family.

Artificial Muscle made of rubber was introduced in 1969 which was used as actuator in WAP-1. For WAP-2 the powerful pouch-type artificial muscles were used and automatic posture control was obtained by implanting pressure sensors under the soles. The three-dimensional automatic biped walking was achieved for the first time by Kato after the development of WAP-3 in 1971 [14]. It was capable to move its center of gravity on the frontal plane so that it could walk on a flat surface, descend and ascend stairs or slope and turn while walking. WL-5 was actually inspired by this mechanism. WAP bipedal robot family is shown in the figure 3.

To develop a personal robot the research on the anthropomorphic intelligent robot, WABOT (WAseda roBOT), was started in 1970s [15]. In 1973 the WABOT-1 was appear as the first fun-scale anthropomorphic robot developed in the world consisting of a limb-control system, a vision system and a conversation system. It was able to communicate with a person in Japanese and to measure distances and directions to the objects using external receptors, artificial ears and eyes, and an artificial mouth. It was able to walk with his lower limbs (WL-5 as its artificial legs) and also able to grip and transport objects with hands (WAM-4 as its artificial hands) that used tactile-sensors. It was estimated that the WABOT-1 has the mental faculty like a one and half years old child. The robot musician WABOT-2 was called as specialist robot in 1984 [15] because of its expertise to play a keyboard instrument with almost human-like intelligence and dexterity. The WABOT-2 was the first milestone in developing a personal robot that was able to converse with a person, read a normal musical score with its eye and play tunes of average difficulty on an electronic organ. It was also able of accompanying a person while listening to the person singing.



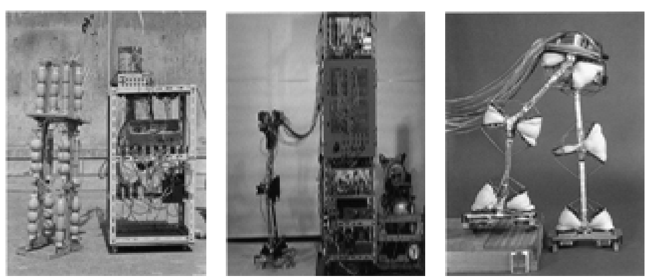
(a) (b) (c) (d)

(e) (f) (g) (h)

FIGURE 2: Evolution of Waseda Legged (WL) robot family.
(a) WL-1 in 1967, (b) WL-3 in 1969, (c) WL-5 in 1971, (d) WL-9DR in 1980, (e) WL-10R 1983, (f) WL-10RD 1984, (g) WL-12RIII in 1990 and (h) WL-16 appeared in 2004.

In 1984, WHL-11 robot was also developed by Waseda and Hitachi, which walked more than 85 km at Tsukuba Science Expo 1985 [16] [17]. During 1986 and 1990, a hydraulic biped robot, WL-12 family, having a trunk and a 2 DOF waist, was constructed to establish more human like motion. A balance control algorithm was developed to improve walking stability, which compensates for moments generated by the motion of the lower limbs. Using the control method, WL-12RIII robot, shown in figure 2 (g), performed complete dynamic walking on a stair with a height of 0.1m having a step speed of 2.6s per step and a step length of 0.3m. On a trapezoid floor with a slope of 10°, it achieved complete dynamic walking with a speed of 1.6 s per step. Also, dynamic walking was realized under an unknown external force of 100 N applied to its back (Takanishi et al. 1991). WL-12RVI, developed in 1992 [16], was able to maintain stable dynamic walking on unknown paths. A walk-learning method and an optimal path generator were created for this device. In 1995, WL-RVII performed dynamic walking on Tatami, Japanese traditional mattress, with a step speed of $1.28ms^{-1}$ and a step length of 0.3m [16]. A foot mechanism using elastic pads had been proposed to absorb impact and contact forces. To improve some problems such as rigidity, power, position errors, etc. of this conventional series, biped walking robots having a parallel mechanism (WL-15 and WL-16) was developed since 2002. The robots were designed for multipurpose use such as welfare and entertainment. An aluminum chair was mounted on the pelvis of WL-16. The humanoid system performed dynamic walking for the first time in the world while carrying a human weighing up to 60kg [16].

WABIAN, an adult-size robot, was created in 1996 using electric motors and achieved the same step speed as a human. It had 35 DOF, two 3 DOF legs, two 10 DOF arms, a 2 DOF neck, two 2 DOF eyes and a torso with a 3 DOF waist. It was able to dance with a human and carry goods [16]. In 1997, WABIAN-R having 43 DOF was developed for exploring robot environment interaction. In 1999, using WABIAN-RII, having 41 motorized joints [10], the emotional motion was presented, which was expressed by the parameterization of its body motion. Human-following walking control was proposed, which has a pattern switching technique based on the action criterion of human robot physical interaction. An impedance control method for WABIAN-RIII was created in 2004 to absorb the contact forces generated between the landing foot and the ground. The control method was able to adjust impedance like the relaxed and hardened motion of muscles of a human. An online locomotion pattern generation was developed for a biped humanoid robot having a trunk, which was based on visual and auditory sensors [16].



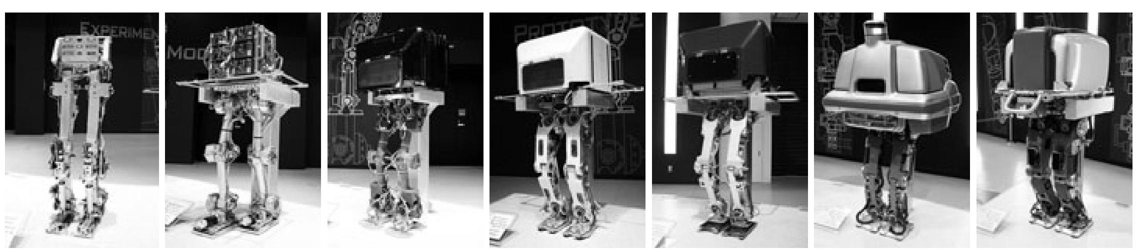
(a) (b) (c)

FIGURE 3: WAP bipedal family developed by Professor Kato's robotic team of Waseda University in Japan where artificial muscles were introduced.
WAP-1 invented in 1969, WAP-2 in 1970 and WAP-3 brought out in 1971.

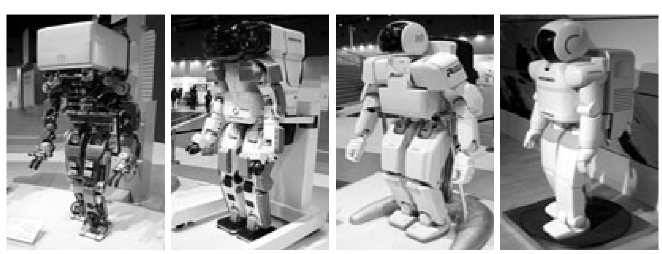
In 1980s, Miura and Shimoyama developed a bipedal robot family called BIPER which was statically unstable but dynamically stable in walking. BIPER-4 robot had non-motorized articulation at the ankles, very big feet and no articulation at the knee [10]. The analogy of an inverted pendulum's movement was used to define its gait. From 1984 to 1988, sano and Furusho's team worked on the BLR-G2 robot which had 9 DOF and was controlled by DC motors. The maximum speed of progression of the robot was $0.35ms^{-1}$. Kajita and Tani built the MELTRAN-II robot in the 1990s [10]. It had passive articulations at the ankles and one of the laws of control was a function that depended on the angle of the equivalent virtual leg. In Japan HONDA company built a whole range of bipedal robots from 1986, shown in figure 4. First there were E0 to E6, then humanoid robot called P1 to P3 and finally the most intelligent humanoid robot called ASIMO (Advanced Step in Innovative Mobility). First version of ASIMO was 1.2m high having 26 DOF and moved by electric motors. The latest version was developed in 2005 having 1.3m high and 34 DOF. Running in straight path as well as circling path was achieved in this latest humanoid robot. Basic specifications of Honda humanoid series are shown in table 1. The University of Tokyo, Japan, developed a humanoid system named SAIKO in 1997 which was low cost, light weight human size robot [3]. Another system called H6 was developed at the same university in the year 2000, as a platform for the research on perception-action integration in humanoid system [2]. Under the Ministry of Economics, Commerce and Industry, Japan, the Humanoid Robot Project (HRP) was started with the creation of a simulation platform, OpenHRP, and the creation a humanoid. The project continued for 5 years from 1998 to 2002 [1]. HRP-2 was a new humanoid robot platform, which was developed as the second version of HRP. It was 1.5m high, weighs was 58kg and had 30 DOF with the ability to move at a speed of 2.5kmh^{-1}. It had vision cameras; force and attitude sensors to control its own balance as well as making plan and control its tasks.

Series	Year	Weight (kg)	Height (cm)	DOF	Walking (Kmh^{-1})	Running (Kmh^{-1})
E0	1986	16.5	101.3	6	Very slow. 5 seconds between steps	
E1	1987	72.0	128.8	12	0.25	
E2	1989	67.7	132.0	12	1.2	
E3	1991	86.0	136.3	12	3.0	
E4	1991	150.0	159.5	12	4.7	
E5	1992	150.0	170.0	12	Slow	No
E6	1993	150.0	174.3	12	Slow	
P1	1993	175.0	191.5	30	Slow	
P2	1996	210.0	182.0	30	2.0	
P3	1997	130.0	160.0	28	2.0	
ASIMO	2000	52.0	120.0	26	1.6	
	2005	54.0	130.0	34	2.7	6.0 (straight path) 5.0 (circling path)

TABLE 1: Specification of Honda Android series.



(a) E0 (b) E1 (c) E2 (d) E3 (e) E4 (f) E5 (g) E6



(h) P1 (i) P2 (j) P3 (k) ASIMO

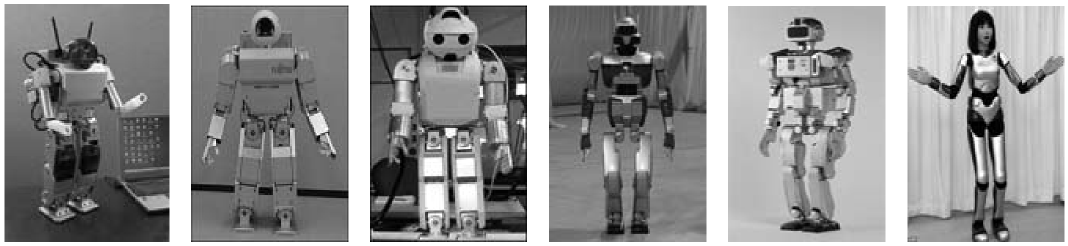
FIGURE 4: Evolution of HONDA Humanoid Robot.
E0 in 1986, E1 in 1987, E2 in 1989, E3 in 1991, E4 in 1991, E5 in 1992, E6 in 1993, P1 in 1993, P2 in 1996, P3 in 1997 and ASIMO started from 2000.

Research on humanoid system in France

The first bipedal robot having only legs and feet was studied and invented in 1993, at Strasbourg University LSIT laboratory, France [10]. 3D bipedal robot BIP2000 was designed and constructed jointly by the INRIA Rhone-Alpes and LMS Poitiers [10]. It was 1.8 meter high and weight was 105kg. Locomotive system of the robot had 12 basic mobilities which enabled it to perform walking gaits similar to that of a human. A pelvis-trunk also mounted on it having three DOF. Statically stable trajectories were obtained in this system to walk at the speed of 0.36kmh^{-1} (0.1 ms^{-s}). With the aiming to establish walking and running gait, the RABBIT project was started in 1998 with CNRS Grenoble, the Frence bipedal robot community [10]. The system had a few DOF and each of the gearboxes of the motors was capable to produce a maximum torque of 150 Nm which was necessary for running gaits. The LIRIS Laboratory at the University of Versailles made an experimental anthropomorphic biped named ROBIAN in 2004 [10]. It had a three-dimensional kinematic architecture with 16 DOF motorized freedom. The 1.30m high robot weighs was 29kg and its foot was made up of an articulated forefoot along a transversal axis moved with a compliant link. The mechanism of the trunk having three mobile mass were used to transfer weight in three dimensions.

Research on humanoid robot in Germany, Korea, Australia, Italy and other countries

Research activities in the field of human robotics are expanding rapidly. Since the advent of Honda's ASIMO and Sony's AIBO, robot fever has broken out in the general public of Japan. Serious basic research for humanoid robots is going on which may have an impact on the future of robotics. In 2002, a small but relatively fast walking autonomous humanoid robot was invented having 17 DOF at Technical University Berlin, Germany [5]. An autonomous humanoid robot was designed in University of Queensland, Australia [6]. Mechanical design of an anthropomorphic bipedal robot was carried out at the National University of Singapore in 2003. The University of Genova, Italy, designed and developed two years old child like humanoid robot called iCub in 2006 [7]. Science the year 2000, a series of KAIST Humanoid Robot (KHR) was developed in Korea. KHR-0 which was developed in 2001 had 2 legs without upper body. KHR-1 was developed on the purpose of research about biped walking which had 21 DOF with no hands and head. The objective of KHR-2, 41 DOF humanoid system, was to develop the humanoid which could walk on the living-floor with human-like appearance and movement. KHR-3 also known as HUBO shown in figure 7 (f), had more human-like features, movements and human-friendly characters. HUBO became familiar from the year 2005 [4]. The HOAP3 humanoid robot platform supplemented the one that was installed at the LAAS CNRS, Toulouse, France in June, 2006 [18]. From 28-31 March 2002 ROBODEX2002 (www.robodex.org) was held in Yokohama where a total of 28 exhibitors, including 13 companies, ten universities and three groups were showed up with a number of humanoid robots platform [19]. ASIMO (Honda), Robovie II, Robovie III (ATR), Guardrobo C3, C4 (Sogo Keibi Hosho), SDR-4X (Sony), Dream Force 01 (Takara), PINO (Tsukuda Original), QC-SR, Tmsuk04 (Tmsuk Co. Ltd), BN-7, BN-8 (Bandai), HOAP (Jujitsu Automation), Posy (SGI Japan & Flower Robotics), Morph (Japan Science and Technology Corp. Kitano Symbolic Systems Project), HRP-1S, HRP-2P (Manufacturing Science and Technology Center), The Shadow (The Shadow Robot Company, UK) were some of them. In addition, universities were showing up with their humanoid related accomplishments with YANBO III (Tokyo Institute of Technology, Hirose Laboratory), SAYA (Science University of Tokyo. Kobayashi Laboratory), KARFE (Nippon Engineering College of Engineering), Mecharobo (Nippon Bunri University, Hirakoso Laboratory), Easy Going Daddy-1 (Hosei University, Takashima Laboratory), High Bar Gymnastic Robot, Saxophone-performing Robot, MARI-1, MARI -2 (Yokohama National University, Kawamura Laboratory), WAMOEBA-2Ri, I SHA, WE-4 (Waseda University, Humanoid Laboratory) and Magdan (Kyoto University, Takahashi Laboratory).



(a) HOAP 1 (b) HOAP 2 (c) HOAP 3 (d) HRP 2P (e) HRP 3P (f) HRP 4C

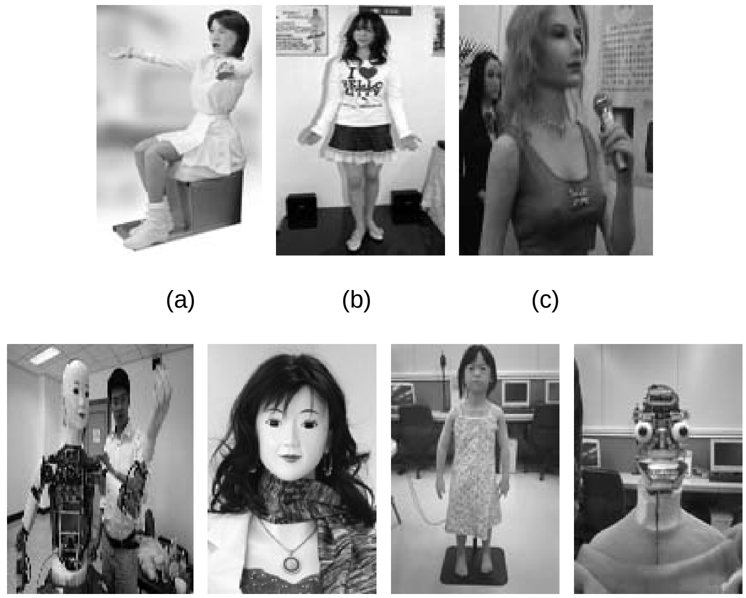
FIGURE 5: HOAP (Jujitsu Automation, Japan) and HRP (Manufacturing Science and Technology Center) family of humanoid robot platform.
HOAP 1, 2 and 3 are introduced in 2001, 2004 and 2006 respectively. HRP-2P is brought out in 2002, HRP-3P in 2005 and HRP-4C in 16 March, 2009.

Project Romeo is an ambitious to develop a functional prototype of a humanoid robot by the end of 2011. The project is undertaking by a coalition of companies and national labs in France with the aim to develop a humanoid system that will be able to assist the elderly and visually-challenged people at home. The robot will be 1.2 to 1.5 meter high bipedal intelligent machine that humans could communicate with voice and gesture. The system also could help a person to get up in case of a fall. The idea of the Project was enlightened in March 2008 and started in January 2009 [12]. The organizing company in this project is Aldebaran Robotics, which develops and sells the smaller and intelligent humanoid robot NAO, shown in figure 1 (o).

In Malaysia a small size humanoid, Malaysia Boleh, was developed with the collaboration between Universiti Teknologi Malaysia (UTM) and Cytron Technologies Sdn. Bhd. [22]. It was able to balance itself while walking and standing on inclined floor. Turning, dancing, push up was achieved in this robot. IRobo was a human like robot developed in International Islamic University Chittagong (IIUC), Bangladesh, which was capable to pick up objects, mopping floors and perform other simple tasks. Siddiky's IRobo, developed in 2007, had some special intelligence to respond some voice commands [23] [24].

Female androids and other recent humanoid projects

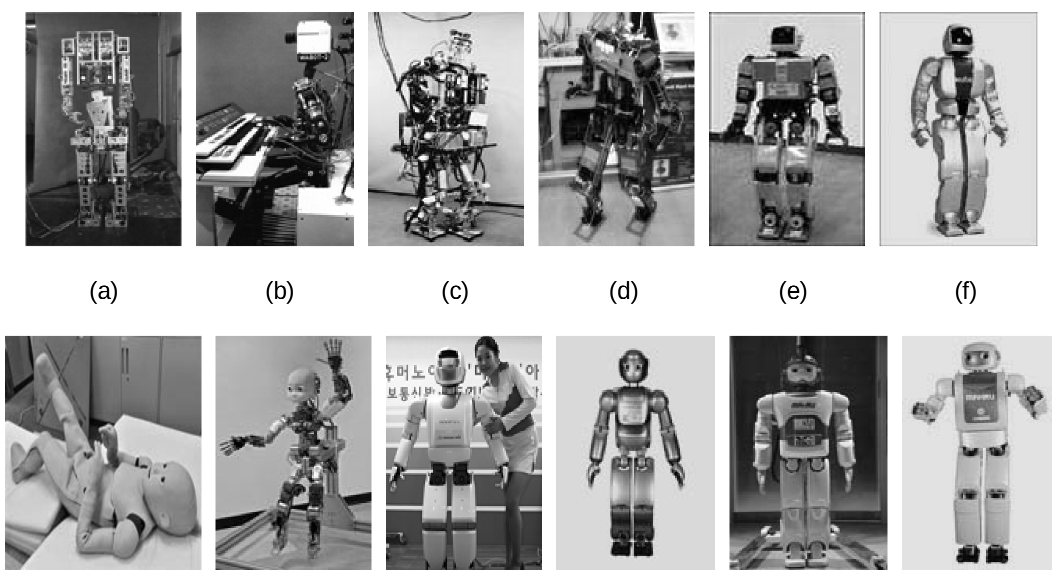
There are also many other greatest android projects both in male and female like structure. The National Institute of Advanced Industrial Science and Technology (AIST) of Japan in conjunction with Kawada Industries has released the HRP-4C humanoid, looks like a young lady with 30 DOF, stands 1.58 meters tall and weighs 43kg (95 pounds). Fashion model cat walk is achieved in this female model like robot and can walk slowly. The price of this robot is about 20 million Yen or USD 200,000. HRP-4C is shown in the figure 5 (f). Kokoro and Osaka University have developed a new life-like android called Actroid DER2 [13]. This android also looks like human lady that can talk and move its head, arms, hands, and body. This android is available for rental at the rate of USD 3,500 for 5 days. China has introduced a singing android called DION. It is a life-sized standing android with a very womanly shape but not so advanced. Another Korean group at KITECH had produced an android called EveR-1 in 2006, which was very much like Repliee-Q1, by Osaka University & Kokoro Inc. Japan. It was about 1.6m tall and weighs about 50kg. Other female androids are AIKO, a very anthropomorphic humanoid built by Le Trung (Brampton, Canada), ACTROID, a VERY realistic and sitting female android announced by Kokoro Dreams and Osaka University in 2003, small size (1 meter) android, Repliee-R1, with 9 DOF by Osaka University and RONG CHENG was introduced by the Institute of Automation of the Chinese Academy of Science in Beijing on August 7, 2006 [20]. Figure 6 shows some of the female like robotic platform.



(a) (b) (c)

(d) (e) (f) (g)

FIGURE 6: Human lady like robotic platform.
(a) and (b) DER-2 project in Kokoro and Osaka University, (c) DION, a singing android from china, (d) and (e) RONG CHENG from Institute of Automation, China, (f) and (g) Repliee-R1, small size android from Osaka University.

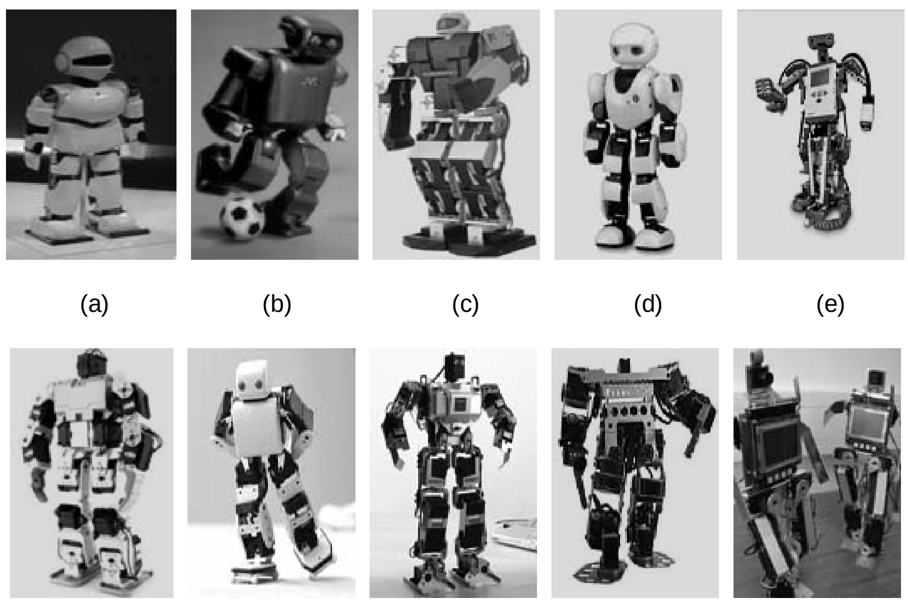


(a) (b) (c) (d) (e) (f)

(g) (h) (i) (j) (k) (l)

FIGURE 7: Some bipedal robot family from different institutes.
(a) WABOT-1 in 1973, (b) WABOT-2 in 1984, (c) WABIAN-R IV in 2000, (d) KHR-1 from Korea in 2002, (e) KHR-2 in 2003, (f) KHR-3 also known as HUBO, introduced in 2005 (g) Japanese Child Robot with Biomatric Body or CB2 in 2007, (h) iCub in 2007, (i) MAHRU-II from KIST in 2006, (j) MAHRU-III in 2007, (k) MAHRU-R in 2008, and (l) MAHRU-Z in 2010.

The JST ERATO Asada project and Osaka University have built a child-sized android called CB2 (Child robot with biometric body) shown in figure 7 (g). It is 130cm tall, weighs 33kg, and has 56 DOF. It has cameras for eyes and microphones for ears. It also has 197 tactile sensors embedded in the silicone skin. KAIST has introduced Mahru-M in 2008, Mahru-R in 2009 and Mahru-Z in 2010. E-nuvo is a 1.26m tall humanoid built by Nippon Institute of Technology [20]. Its weigh 15kg., and has a total of 21 DOF. ATOM-7xp is a new humanoid appeared in January 2010 and developed by Dan Mathias at FutureBots over the last 8 years. It is 1.58m tall, weighs 73kg, and has 49 DOF. Pal Technology of the UAE (United Arab Emirates) has announced a very sophisticated new humanoid called REEM-A. It stands 1.45m tall, weighs 41kg. and has 30 DOF [20]. Kawada has released the HRP-3P humanoid. This robot stands 1.60m tall and weighs 65kg. It has a total of 36 degrees of freedom. Tmsuk of Japan has produced a new Samurai warrior robot called KIYOMORI.



(a) (b) (c) (d) (e)

(f) (g) (h) (i) (j)

FIGURE 8: Some biped robot kits in humanoid form.
(a) ZMP INC. released PINO humanoid in 2001, (b) Japan Victor (JVC) released J4 robot in 2004, (c) Hitec-Robonova 1 released in 2005, (d) Kyosho-Manoi AT01 in 2006, (e) LEGO MINDSTORMS NXT is a robotics toolset released in 2006, (f) BIOLOID kit released from Robotics in 2006, (g) AkaZawa Plen in March, 2006, (h) KHR-2, bipedal humanoid robot kit in 2006, (i) Robovie-M version 3 released also in 2006 and (j) Flip and Flop robot kit developed in Imperial college London.

Fesco, the pneumatics experts in Australia, had built a huge android called TRON X in 1997 which was about 2.8m tall and weighs about 300kg. It was operated by over 200 pneumatic cylinders of all different sizes [20]. September 10, 2001 Fujitsu Laboratories Inc announced their toy android called HOAP-1, a 0.4572m (18 inch) tall and 5.91kg (13 pound) android with 20 degrees of freedom. The cost was USD 41,000 or 4.8 million Yen [20]. On September 19, 2003 Sony introduced a small size humanoid called QRIO. It was quite similar to the SDR-4X which could walk better and also could recover from a falls [20]. Two new humanoids called ARNE and ARNEA were announced in August 5, 2003 in Russia. These robots were built by St. Petersburg Company called New Era. These humanoids stand 1.23m tall and weigh 61kg having 28 DOF. Beijing Institute of Technology had a big humanoid project called BHR-1 on 2002. This android was 1.58m tall and weighs 76Kg having 32 DOF. It could walk with 33cm steps at a speed of $1 kmh^{-1}$. Hiroaki Kitano of Kitano Symbiotic Systems (Tokyo, Japan) which was a subsidiary of Japan Science and Technology Corp, succeeded to build an android baby called PINO on April

18, 2002 [20]. The PINO had 29 motors and stands about 75cm tall and weighs 8kg. This android was one of the most popular open source platforms to develop humanoid robot. Another project called TWENDYONE from the Sugano Lab at Waseda University in Tokyo was appeared in 2007 [20]. The big advance in this humanoid was its very sophisticated hands with fingers which had tactile sensors. The humanoid had 47 DOF and stands 1.47m tall and weighs 111kg. Imperial College London had two humanoid projects which had an upper half of a humanoid similar to COG - called LUDWIG. They also had other two small humanoids called FLIP and FLOP which stand about 0.3556m (14 inch) tall [20]. MITs M2 leg project, Fukuda Lab at Nagoya University project called the Biological Inspired Robot System (BIRS), Iranian android called FIRATELLOID (First Iranian Intelligent Humanoid) are some of the recent projects in the field of humanoid robot research. Figure 8 shows some biped robot kit in humanoid form.

Android	**Year**	**Weight (kg)**	**Height (cm)**	**DOF**	**Power Source**	**Continuous operating time**	**Motor type**	**Main controller**
H6 [2]	2000	51.0	136.1	33	Lead-acid battery (12V 5.0Ah)	10 to 15 min.	DC	Dual PentiumIII-750 MHz (100 MHzFSB) with 256MB SDRAM and 6.4GB 2.5 inch IDE HDD
HRP-2 [1]	2002	54.1	154.96	30	NiMH battery (48.0V 18Ah)	60 min.	DC	Real time controller, Pentium III, 933 MHz. with ART-Linux operating system.
QRIO [20]	2003	6.5	58.0	28	Sony's proprietary lithium ion battery	60 min.	DC	Two 64 bit RISC processor, two 64MB DRAM, Sony's original real time OS (Aperios) with Open-R control architecture.
KHR-3 (HUBO) [4]	2005	55	125.0	41	24V 20Ah Lithium polymer	120 min. with movement	DC motor with harmonic drive reduction gear mechanis m	Pentium III 933 MHz embedded PC with Windows XP and RTX.
MAHRU-III [20]	2007	62	150.0	32	Lithium polymer battery, 48V 20A	30 min.	DC	Duel CPU boards structure with RT-Linux as real time OS.

TABLE 2: Specification of some world greatest Androids in early 21st century.

Android	Year	Weight (kg)	Height (cm)	DOF	Power Source	Continuous operating time	Motor type	Main controller
iCub [7][20]	2007	23	90.0	53	Two power supplies from Xantrex (XFR-1.2Kw-35V-35A and XFR-2.8Kw-60V-46A)	No battery, connected with power supplies.	DC and Servo (for eyelids)	On board PC 104 hub computer connected with an off-board computer system through Gbit Ethernet cable.
REEM-A [20]	2007	40	140.0	30	Lithium-ion	90 min.	DC	Intel Pentium M (1.6 GHz)
REEM-B [20]	2008	60	147.0	51	Lithium-ion, specially designed for REEM-B	120 min.	DC	Intel Core Duo (1.66 GHz) Geode(500 MHz)
NAO [8]	2008	4.5	57.0	25	Lithium-ion 55 Wh	90 min.	Brush DC motors	CPU is an AMD Geode, running at 500 MHz accompanied by 256MB of RAM
MAHRU-R [20]	2008	67	145.0	35	--	--	DC servo motor with belt-pulley and harmonic drive gear	micro-ATX CPU board with Linux Fedora Core 5 (RTAI/Xenomai)
HRP-4C [9]	2009	43	158.0	42	NiMH DC 48V	20 min.	DC motor with harmonic drive gear	Pentium M 1.6 GHz (PCI-104 SBC) for motion control and VIA C7 1.0 GHz (Pico-ITX motherboard) for speech recognition
MAHRU-Z [20]	2010	55	130.0	35	--	--	--	--

TABLE 3: Specification of some greatest Androids from 2007 to 2010.

Table 2 and table 3 show the basic specifications of some world class humanoid robot platform appeared in the early 21st century. These androids from different institutes and companies of various countries show the greatest accomplishment of human in the field of humanoid robot research and development.

3. FUTURE OF ANDROIDS

In the next two decades robots will be used as the replacement of humans in most the manufacturing and service jobs. Economic development will be primarily determined by the advancement of robotics. Japan's current strength in this field says that they may become the economic leader in the near future. Microsoft is currently working to stabilize the fragmented robotics market with its new software, Microsoft Robotics Studio. Walking smoothly is not easy for a robot, especially when the ground is bumpy. Researchers at Japan's Waseda University have developed a pair of four foottall robotic legs that can move efficiently across uneven terrain. The Biped Walking Robot uses foot like sensors to measure the forces between its base and the floor, maintaining on-the-fly balance based on the weight of its load. In near future humanoids will exhibit emotion, forge relationships, make decisions, and develop as they learn through interaction with the environment. Robots that can incrementally acquire new knowledge from autonomous interactions with the environment are the main target to accomplish. Humanoid Robotics also offers a unique research tool for understanding the human brain and body. Humanoids have provided revolutionary new ways for studying cognitive science. According to an article in www.korea.net, in 2007 the global market for robots grew by 18.9 percent to an estimated USD 8.12 billion. The markets of manufacturing and service robots registering growth are at USD 5.89 billion and USD 2.23 billion, respectively. The industry for service robots, including humanoid robots, is hard to estimate because of its early stages of development, but it is forecasted that the market will be worth between USD 17 billion and USD 50 billion by 2012. The largest concentrations of activity are presently in Japan and Korea, two of the major leaders in the production of service robots. It is predicted that by the near future the Intelligent Service Robot industry will grow to the same size as the IT industry in 2005. Japan's Mitsubishi Research Institute predicts that each household would own at least one robot by 2020.

4. CONSLUSION

According to the famous Japanese mechanical animation designer Mr. Yutaka IZUBUCHI, the ratio of each body-parts of a humanoid system is very important for personification and friendliness. So, humanoid robot sizing is a very significant factor where Golden Ration based analysis and design can be considered. Cooling system for the actuators, especially for the leg, can be employed like the humanoid system HRP-2, Japan. Because of the continuous work, the raising of the temperature inside the actuators can be controlled by adding the cooling system that will help the robot to work for longer time. Damping mechanism is also another important factor that can be considered for the humanoid structure, particularly in designing the lower torso. The damping mechanism will help the humanoid to absorb the opposite force of the ground in landing its foot while walking, running or jumping. This damping technique may improve the control system to make the humanoid more stable and smooth in navigation. Human articulation has damping mechanism that is controlled by the muscle strength. This mechanism also can be achieved by using special actuators in the joints of the humanoid system, where a huge amount of researches are needed to accomplish this technique. To communicate with the environment, large number of appropriate sensors should be applied on the robotic platform where visual systems are very important and vital to understand the outer world. Distributed power supply unit will make the humanoid system more efficient by balancing the weight of the body parts. Moreover a good controller with appropriate, suitable and efficient control algorithm should be developed and applied to the humanoid to make an intelligent and reliable humanoid robot. The field of humanoid robotics is extensively and unavoidably multidisciplinary and has interrelations to a host of new horizon technologies, such as, Mechatronics Engineering, Neurobio Engineering, Neuromorphic Engineering, Nanoelectromechanical systems and so on. The robotics industry is experiencing exponential growth worldwide and stands poised to become one of the most exciting and expansive markets for technology in the twenty-first century. Robots will soon be everywhere, in our home and at work. They will change the way we live. This will raise many philosophical, social, and political questions that will have to be thought and answered. In science fiction, robots become so intelligent that they decide to take over the world because humans are deemed inferior. In real life, however, they might not choose to do that. Robots might follow some particular rules such as Asimov's Three Laws of Robotics, which will prevent them from creating danger for mankind.

5. ACKNOWLEDGEMENT

The authors will like to express their appreciation to Ministry of Higher Education Malaysia (MOHE Malaysia), in funding the project through Fundamental Research Grant Scheme (FRGS).

6. REFERENCES

1. Kenji Kaneko, Fumio Kanehiro, Shuuji Kajita, Kazuhiko Yokoyama, Kazuhiko Akachi, Toshikazu Kawasaki, Shigehiko OTA and Takakatsu Isozumi. "*Design of Prototype Humanoid Robotics Platform for HRP*", Proceedings of the 2002 IEEE/RSJ Intl. Conference on Intelligent Robots and Systems EPFL, Lausanne, Switzerland. October 2002. Page: 2431-2436.
2. K. Nishiwaki, T. Sugihara, S. Kagami, F. Kanehiro, M. Inaba and H. Inoue. "*Design and Development of Research Platform for Perception-Action Integration in humanoid Robot: H6*", Proceedings of the 2002 IEEE/RSJ, International Conference on Intelligent Robots and Systems. Page: 1559-1564.
3. Atsushi Konno, Koichi Nagashima, Ryo Furukawa, Koichi Nishiwaki, Takuro Noda, Masayuki Inaba and Hirochika Inoue. "*Development of a Humanoid Robot Saiku*", Proceedings of IROS 97 0-7803-4119-8/97/$10 1997 IEEE. Page: 805-810.
4. Ill-Woo Park, Jung-Yup Kim, Jungho Lee and Jun-Ho Oh. "*Mechanical Design of Humanoid Robot Platform KHR-3(KAIST Humanoid Robot - 3: HUBO)*". Proceedings of 2005 5th IEEE/RAS International Conference on Humanoid Robots. Page: 321-326.
5. Dirk Wollherr Michael Hardt Martin Buss Oskar von Stryk. "*Actuator Selection and Hardware Realizationof a Small and Fast-Moving, Autonomous Humanoid Robot*". Proceedings of the 2002 IEEE/RSJ International Conference on Intelligent Robots and Systems, Lausanne, Switzerland, September 30 - October 4, 2002. Page: 2491-2496.
6. Eddie Choong, Chee-Meng Chew, Aun-Neow Poo and Geok-Soon Hong "*Mechanical Design Of An Anthropomorphic Bipedal Robot*". First Humanoid, Nanotechnology, Information Technology, Communication and Control Environment and Management (HNICEM) International Conference, March 27-30, 2003, Manila, Philippines.
7. Ricardo Beira, Manuel Lopes, Miguel Prac¸a, Jos´e Santos-Victor, Alexandre Bernardino, Giorgio Mettay, Francesco Becchiz and Roque Saltar´en. "*Design of the Robot-Cub (iCub) Head*". Proceedings of IEEE International Conference on Robotics and Automation, Orlando, May 2006.
8. David Gouaillier, Vincent Hugel, Pierre Blazevic. "*Mechatronic design of NAO humanoid*". Proceedings of 2009 IEEE International Conference on Robotics and Automation Kobe International Conference Center Kobe, Japan, May 12-17, 2009. Page: 769-774.
9. Kenji KANEKO, Kanako MIURA, Fumio KANEHIRO, Mitsuharu MORISAWA, Shin'ichiro NAKAOKA, and Shuuji KAJITA. "*Cybernetic Human HRP-4C*". Proceedings of 9th IEEE-RAS International Conference on Humanoid Robots, December 7-10, 2009 Paris, France. Page: 7-14.
10. Christine Chevallereau, Guy Bessonnet, Gabriel Adda and Yannick Aoustin. "*Bipedal Robots Modeling, Design and walking Synthesis*". ISTE Ltd, 2009. 27-37 St George's Road. London SW19 4EU, UK. ISBN: 978-1-84821-076-9.
11. "*History of Robotics*", http://pages.cpsc.ucalgary.ca/~jaeger/visualMedia/robotHistory.html (April 8, 2010, 8:34PM).
12. "*France's humanoid robot Romeo – Big but not dangerous*". Getrobo.com, Robots that make my life (and possibly yours) rock. http://www.getrobo.com/getrobo/2009/09/frances-humanoid-robot-romeo-big-but-not-dangerous.html

13. "*Actroid DER2 fembot loves Hello Kitty*". http://pinktentacle.com/2006/10/actroid-der2-fembot-loves-hello-kitty/ (April 13, 2010, 10:00 AM).
14. "*Biped Walking Robot*". http://www.humanoid.waseda.ac.jp/booklet/kato_4.html (April 8, 2010, 10:00PM).
15. "*WABOT – WAseda roBOT*". http://www.humanoid.waseda.ac.jp/booklet/kato_2.html (April 10, 2010, 12:52AM).
16. Hun-Ok Lim and Atsuo Takanishi. "*Biped walking robots created at Waseda University: WL and WABIAN family*", Phil. Trans. R. Soc. A (2007) 365, 49–64. doi: 10.1098/rsta.2006.1920, Published online on 17th November 2006, (http://rsta.royalsocietypublishing.org/content/365/1850/49.full).
17. "*Buzzle.com Intelligent life on the web*". http://www.buzzle.com/articles/history-of-robots.html (April 10, 2010, 12:30AM).
18. "*Second Humanoid Robot In France Welcomed*". Science News, Science Daily (February 28, 2007). http://www.sciencedaily.com/releases/2007/02/070213142711.htm
19. Yoshihiro Kusuda, Japanese Associate Editor for Industrial Robot. "*The humanoid robot scene in Japan*". http://www.emeraldinsight.com/Insight/ViewContentServlet?Filename=Published/EmeraldFullTextArticle/Articles/0490290506.html (April 12, 2010, 02:32 AM).
20. "*World's greatest android projects*". http://www.androidworld.com/prod01.htm (April 12, 2010, 02:32 AM).
21. "*iCub.org*" http://www.icub.org/ (April 26, 2010, 11:12PM).
22. Malaysian robotics magazine, "*Robot Head to Toe*". Publisher: Cytron Technologies Sdn. Bhd. http://www.robothead2toe.com.my. September 2009, Volume 2, Page: 9 – 11.
23. Feroz Ahmed Siddiky, Mohammed Shamsul Alam and Tanveer Ahsan. "*High Performance Reliable Obstacle Detection and Height Measurement by Stereo Camera for Intelligent Home Service Robot*". Proceedings of International Conference on Computer and Information Technology 2007, (ICCIT 2007). UIU Dhaka, Bangladesh. 27-29 Dec. 2007. Page: 93 – 98.
24. "Bangladeshi develops humanoid robot from scrap". Azad Mojumder, DHAKA, Mon. Oct. 8, 2007, 11:11am EDT. http://www.reuters.com/article /idUSB68079720071008.
25. Toru Takenaka. "*The control system for the Honda Humanoid Robot*". Published by Oxford University Press on behalf of the British Geriatrics Society. Age and Ageing 2006, 35-S2: ii24 – ii26.
26. Malachy Eaton, "*Further Explorations in Evolutionary Humanoid Robotics*". Proceedings of 12th International Symposium on Artificial Life and Robotics (ISAROB), Oita, Japan, January 25 – 27, 2007. Page: 133 – 137.
27. Md. Akhtaruzzaman, SK. Khirul Hasan, Dr. Amir A. Shafie, "*Design and Development of an Intelligent Autonomous Mobile Robot For a Soccer Game Competition*". Proceedings of the 2009 International Conference on Mechanical and Electronics Engineering (ICMEE 2009), Chennai, India, June 27 – 29, 2009. Page: 167 – 171.
28. FA Siddiky, NH Siddique, MO Tokhi, "A New Approach to Design and Control of Biped Robot with Minimal Number of Actuators". Proceedings of International Conference on Climbing and Walking Robots and Support Technologies for Mobile Machines 2009, 09th September 2009. Page: 115 – 122.