

# **DEVELOPMENT OF A HUMANOID ROBOT FOR EDUCATION AND OUTREACH**

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## **ABSTRACT**

Robots have engendered a certain public fascination since the term was first coined by Josef Čapek in the 1920s [1]. In particular humanoid robots have the capacity to excite (and in some cases intimidate) the general public about the future developments in the field. Several researchers have harnessed this interest in outreach and education activities.

This paper presents the design of a novel modular humanoid robot for education and outreach. The robot uses a chain drive system actuated by servomotors to achieve locomotion, while the location of the centre of gravity of the robot is altered by using a sophisticated weight distribution system in the 'torso'. The robot has six active degrees of freedom in its legs and one in its torso.

A review of humanoid robots used in education and outreach is presented before an exposition of the design, realization and testing of the robot. Future publications will report on the evaluation of the effectiveness of the robot in outreach activities.

**KEYWORDS:** Humanoid, Education, Robotics

## **1. INTRODUCTION**

### **1.1 What is a Humanoid?**

The Oxford Dictionary describes the term 'humanoid' as "having an appearance or character resembling that of a human" [2]. In robotics the term 'humanoid' is a name generally given to robots that have as few as one feature that resembles that of a human (i.e. legs, hands, head).

A robot comprised of only two legs, such as the robot shown in Figure 1.1, could be called a humanoid even though it does not possess any upper limbs. Similarly NASAs Robotnaut-2 (Figure 1.2) is also in the humanoid category even though it possesses no lower body.

Therefore it can be concluded that the term humanoid describes a broad category of robots which have an appearance or character that resembles a human being.



Figure 1.1 M2 Biped Robot [3]



Figure 1.2 Robonaut-2 Humanoid [4]

## 1.2 Robotics in Education and Outreach

In the last number of years robotics is being used more extensively in education and outreach from primary school level [5] to university level [6]. There are many types of robots being used in education such as the Lego NXT which are mainly used at primary and secondary school levels to introduce children to the world of robotics by allowing them to design, build and program their own robots [7]. The focus of this paper is the use and evaluation of humanoid robots for education and outreach.

Humanoids are being used to teach many different subjects in schools from operating as instructional media in elementary language education [5], to operating as a teacher's assistant [8]. They have also been used in autism research to determine if a robot can help encourage social interaction skills and have shown positive results [9]. Kai-Yi Chin *et al.* in [8] had very positive results from the children which took part in their study of using a humanoid robot as a teaching assistant for primary education with the children agreeing that the robot helps them understand more about science and technology and hoping that the robot will return in the next class. B. Robins *et al.* discuss in [9] the positive preliminary results of using a humanoid robot to encourage social interaction skills of children with autism spectrum disorder (ASD). B. Robins *et al.* obtained positive results from their study, but due to the nature of spectrum disorders further longitudinal studies are required.

The results of these studies show a positive correlation between the use of humanoid robots in education and increased student interest in the STEM subjects. They also show positive preliminary results for increased social interaction skills of children with ASD, however more research needs to be conducted in this area.

### 1.3 Research and Design Objectives

The objectives of the work presented in this paper are to design and develop a modular, humanoid bipedal robot for education and outreach that can:

- (i) Achieve static stability under its own weight.
- (ii) Successfully complete a squatting test, which involves the robot bending down as close to the floor as possible.
- (iii) Successfully complete a walking test.
- (iv) Have modular components which are interchangeable.

## 2. DESIGN OF THE HUMANOID ROBOT

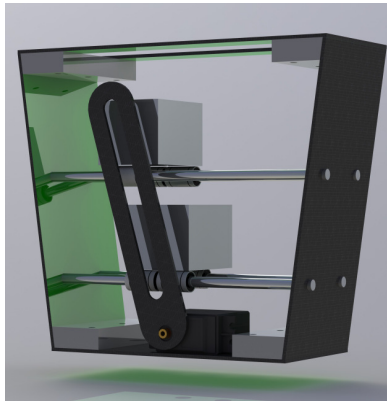
Building on the objectives presented in the previous section, the main objective of this work is to develop a modular, humanoid bipedal robot for education and outreach (Figure 2.1).



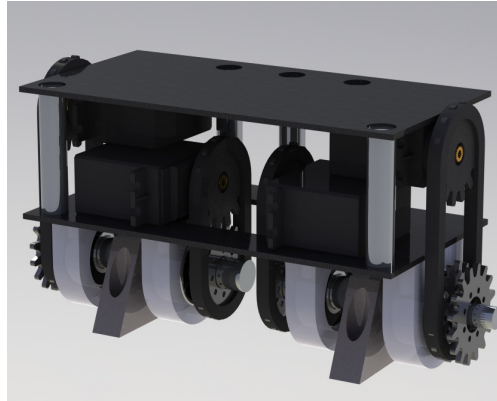
**Figure 2.1 The Final Humanoid Design**

The robot comprises of three main sections; torso, hip, and legs. The torso of the robot houses the weight distribution system and the electronics. It is made from Dibond, an aluminium composite material and uses custom made angled corner brackets to fix the structure in place. The weight distribution system (Figure 2.2) operates by sliding a mass across the robots frontal plane. This design was achieved by fixing the mass to four linear ball bearings which translate the mass across two copper rods from one side of the robot to the other. The control system of the weight distribution system is designed in such a way that the masses will always lie over the stance leg during walking i.e. when the left leg is raised and progressing through the swing phase, the masses will be over

the right leg and when the right leg is raised and in the swing phase the masses will be over the left leg. The electronics board is attached to the robots back plate. The back plate is raised slightly allowing for the wires from the motors to reach the circuit board.



**Figure 2.2 The Torso and WDS**

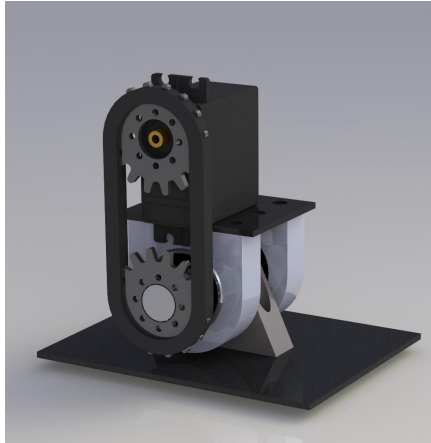


**Figure 2.3 The Hip Section**

The hip section (Figure 2.3) of the robot is responsible for the actuation of the robots hip and knee joints by means of the chain drive system. This section of the robot contains the two motors that actuate the hip joints and two motors that actuate the knee joints to achieve locomotion. These joints are actuated by using a chain drive system. The drive system that actuates the upper leg joint consists of a servo motor connected to the shaft at the joint via a chain and sprocket system. The rotational displacement of the servo at the hip is translated to a linear displacement along the chain and translated again to a rotational displacement at the shaft. Plastic sprockets are fixed to the motors and to rods in the joints. A plastic single link chain is used to connect the motors to their significant joint. To achieve actuation of the knee joint from the hip the design uses two chain systems connected in series. At the lateral side of the hips two sprockets are connected together and rotate freely about the shaft. One of these sprockets is connected to the motor while the other is connected to a fourth sprocket at the knee joint. The sprocket at the knee joint is fixed to the shaft, so that when the motor rotates, the power is transmitted through the first chain that rotates the first two sprockets that transmit the rotation to the second chain rotating the final sprocket and thus the knee joint. The horizontal orientation of the motors was chosen to reduce the overall height of the hip section by 20% and reduces the lateral dimension by ~16% allowing a similar ratio to the 50<sup>th</sup> percentile male to be achieved. It also allows the motors to be attached more rigidly to the structure by reducing the moment of inertia and bending moments acting on the motors and allows for a symmetrical arrangement of the components achieving an even distribution of mass.

Feet play a crucial role in balance of both robots and humans. The dimensions of the foot are very important for the stability of the robot, the larger the footprint the more stable the robot inherently becomes. However very large feet can be cumbersome and cause difficulties when trying to navigate small environments. Very large feet may also cause problems for the robot when it is trying to balance on a narrow obstacle e.g. a stairs. A footprint of 80x100mm was chosen for the humanoid robot. This provides a large enough footprint for good

stability while also avoiding problems with additional weight and overlapping of the feet. The ankle joint (Figure 2.4) is actuated by a motor that is placed inside of the shank segment. This motor is connected by a single chain to a sprocket on the ankle shaft that rotates this joint and the foot. The ankle joint allows the robot to perform two events that are essential in human gait; ‘heel-off’ (when the heel leaves the ground) and ‘toe-off’ (when the toes leave the ground initiating the swing phase). These events allow humans to propel forward during gait and reduces the amount of bending at the knees and hips as the rotation about the ankle joint provides extra extension.



**Figure 2.4 Drive System of the Ankle**



**Figure 2.5 Drive System of the Knee Joint**

### **3. ELECTRONICS**

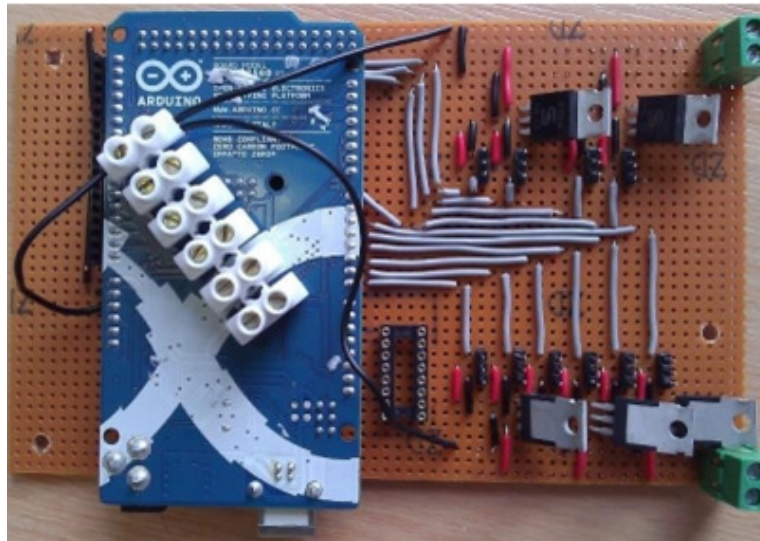
The electronics and control system of the robot consists of a number of components including an Arduino Mega, circuit board, power system, IR sensors, and servo motors. Currently the control system of the humanoid operates in the open-loop and thus does not use inertial feedback to control its motions. A closed-loop control system is under development that will utilize information received from sensors such as gyroscopes and accelerometers.

The servo motors which actuate the humanoid are controlled using the standard Arduino Servo library. Control is achieved by sending a signal to the motors which specifies individually for each motor, how many degrees to rotate.

The sensors that are used on the humanoid are Sharp IR sensors. These sensors are range finding IR sensors and are used to measure how far away objects are and avoid any possible collisions. These sensors are found on the front and back of the humanoid.

The robot is powered by two batteries; one Turnigy nano-tech 850mAh 2S 25-40C Lithium-Polymer (LiPo) battery and one Turnigy nano-tech 850mAh 3S 25-40C LiPo. It was necessary to drop the voltage of these batteries from their standard operating 7.4V to the maximum voltage of the batteries, 6V, by using voltage regulators on the circuit board. The electronics and circuit board can be seen in Figure 3.1.



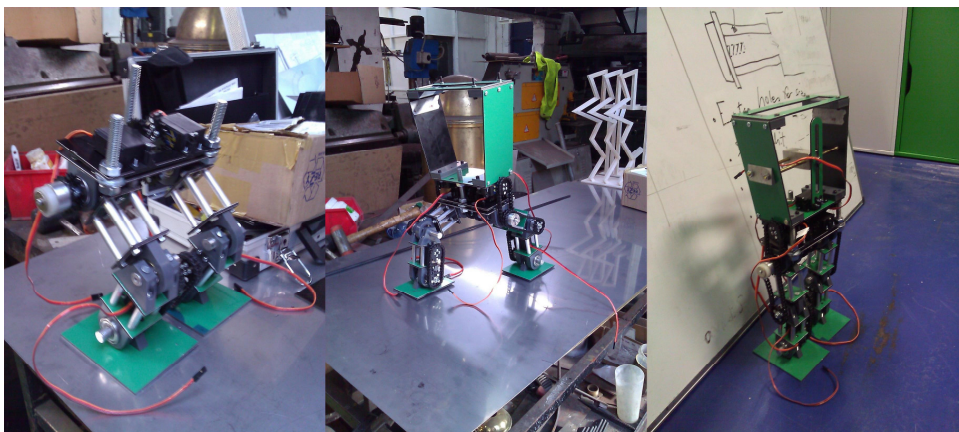


**Figure 3.1 Electronics and Control Circuit Board**

#### **4. STATIC STABILITY**

The first experiment performed to assess the stability of the proposed design took place in the very early stages of the build. This test was a static stability test. This investigation assesses the robot's ability to support itself under its own weight without any active help from the motors, in other words, when the robot was powered off. It also confirms that the motors have sufficient torque to support the robot in static conditions.

This analysis was performed throughout the assembly process to ensure that the ankles, knees and hips were capable of supporting their own weight and ultimately the overall weight of the robot. If at any point the motors were unable to support the weight of the robot, it would have been possible to adjust the design by changing materials or swapping the motors for higher torque motors. This altering of the design would have been easily achieved due to the modular design. Fortunately no adjustments were required and it can be seen from Figure 4.1 that the robot is capable of supporting its own weight and thus the design passed the static stability test.



**Figure 4.1 Static Stability Results Throughout Assembly**

## 5. DYNAMIC STABILITY

Two experiments were conducted with the humanoid to assess the performance of the robot during dynamic conditions; a squat test and a walking test. These experiments were performed to inspect the performance of the weight distribution system, chain drive system and the robots dynamic stability.

The first of these tests to be conducted was the squat test. This test required the robot to stand upright and support itself statically then begin to lower itself by bending of the knees to the lowest point, supporting itself statically again in its new position and finally arise back to its initial upright position. This was the first test conducted that fully tested the chain drive system of the robot and obtained positive results. Figure 5.1 shows the robot performing the squat test.

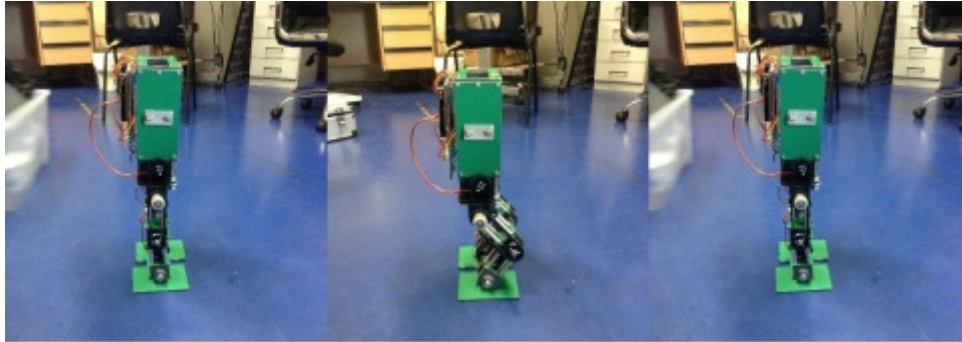


Figure 5.1 Results of Squat Test

The second test that was conducted to determine the robots performance during dynamic conditions was a walking test. This test assessed the robots ability to achieve locomotion by means of the chain drive system and weight distribution system. Figure 5.2 represents the expected results of a walking test which can be compared with Figure 5.3 which presents the experimental results from the walking test. The robot achieved two complete step cycles before falling over.

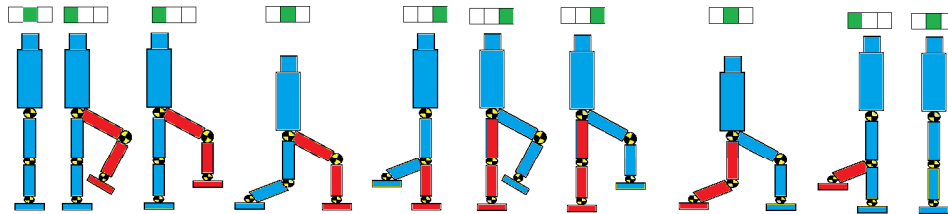


Figure 5.2 Expected Results of Walking Test

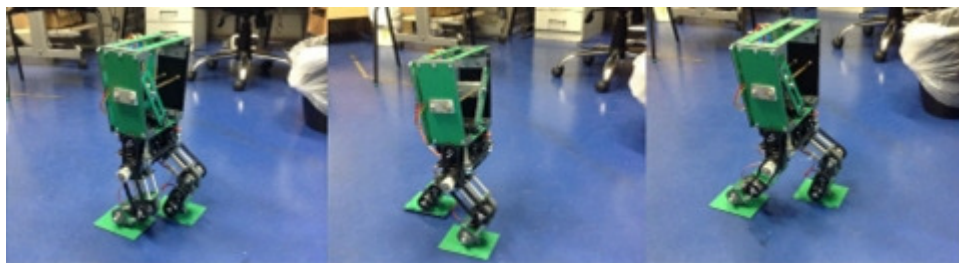


Figure 3 Experimental Results of Walking Test

## 6. CONCLUSION

The result of this work is a novel, modular, autonomous robot capable of achieving both static and dynamic stability. The robot is comprised of modular components that can be easily replaced with different components to change the overall height and weight of the robot as well as allowing easy replacement of faulty parts.

It was shown that the proposed design was capable of achieving static stability without providing power to the servos. Static stability is a fundamental characteristic of walking, due to the robots capability of static stability it demonstrates a significant improvement over earlier designs proposals.

This research has shown that it is possible to create a planar motion humanoid which does not incorporate the hips in moving the centre of gravity of the robot. This was overcome by implementing a weight distribution system in the torso section of the robot. It showed that by using a significant mass in the weight distribution system, the centre of gravity could be shifted from one position of stability to another throughout the gait cycle of the robot.

## 7. REFERENCES

- [1] Thomas R. Kurfess, Robotics and Automation Handbook, Chapter 1.1.4, 2005.
- [2] Oxford Dictionaries [Online]. Available: <http://oxforddictionaries.com/definition/english/humanoid> [Accessed 11/03/13].
- [3] M2 Humanoid Robot [Online]. Available: [http://xstar.ihmc.us/research/projects/HumanoidRobots/images/M2V2\\_hires.jpg](http://xstar.ihmc.us/research/projects/HumanoidRobots/images/M2V2_hires.jpg) [Accessed 23/06/13].
- [4] NASAs Robonaut 2 [Online]. Available: [http://www.nasa.gov/images/content/471173main\\_jsc2010e110183\\_hi.jpg](http://www.nasa.gov/images/content/471173main_jsc2010e110183_hi.jpg) [Accessed 23/06/13].
- [5] Gwo-Dong Chen, Chih-Wei Chang, Using humanoid robots as instructional media in elementary language education, *Second IEEE Int. Conference on Digital Game and Intelligent Toy Enhanced Learning*, 2008, 201-202.
- [6] Yoshihiko Takahashi, Takashi Suzuki *et al.*, Simple Humanoid Robot for University Education, *The 30<sup>th</sup> Annual Conference of the IEEE Industrial Electronics Society*, 2004, 146-151.
- [7] Damian Kee, Effective education with limited programming knowledge, *Robotics in Education eJournal*, Vol. 3, 15-19.
- [8] Kai-Yi Chin, Chin-Hsien Wu *et al.*, A Humanoid Robot as a Teaching assistant for primary education, *Fifth International Conference on Genetic and Evolutionary Computing*, 2011, 21-24.
- [9] B. Robins, K. Dautenhahn *et al.*, Robotic assistants in therapy and education of children with autism: can a small humanoid robot help encourage social interaction skills?, *Univ Access Inf Soc*, 2005, Vol. 4, 105-120.