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Development of a 20 Degrees of Freedom Kid Sized Humanoid Platform with Vision

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***Abstract*—A humanoid robot is a robot which has anatomy similar to the human body. They are becoming increasingly popular as research platforms, and are well suited for real world applications due to the ease with which humans perform arbitrary tasks in versatile environments. Progress of humanoid robotics is, however, inhibited due to a shortage of affordable platforms with diverse capabilities. In this work, we present a prototype of GATIK-II, a KidSize humanoid robot. This robot prototype is the second in the GATIK series of humanoid robots, and has been developed with sufficient power and capabilities so as to be employed for various applications. It has autonomous capabilities and can effectively function in a foreign environment by employing a HaViMo vision module and inertial measurement units. Alternatively, it can also be controlled in real time and via an android based mobile phone, thus exhibiting semi-autonomous mode of operation.**

***Index Terms*—kidsized humanoid, vision, havimo, biped, degree of freedom, research platform**

I. INTRODUCTION

A Humanoid Robot is a robot which has a structure similar to a human, and generally possesses two legs, two arms, a torso and a head. The development of human-like machines has its basis in ancient mythology where it combines many desirable features, including natural human-like locomotion, and natural human-friendly design and behavior [1].

The concept of an artificial companion has greatly motivated researchers for the past few decades, and a number of humanoid robots in use across the world today. The first humanoid robot was built by the late Prof. Ichiro Kato in 1973 at Waseda University, Tokyo, Japan. It was called WABOT-1, and consisted of a limb control system, a vision system and a conversation system. It was able to communicate with a person in Japanese and measure the distance and direction of objects using external receptors such as artificial ears and eyes. Hydraulically powered, it uses disproportionately large feet for stability. A shuffler more than a walker, WABOT-1 was able to walk statically [2]. In 1980, WABOT-2 was developed which was the first personal robot to be developed in the world. Unlike it predecessor WABOT-1, the robot was a specialist robot and it had the intelligence and dexterity to play the keyboard, and could accompany a person while he listened to the person singing [3].

This breakthrough in the field of humanoid robotics inspired companies and research institutes all across the globe to undertake and invest in humanoids. Honda developed a series of bipedal humanoid robots named E0-E6 during 1986 to 1993. Early models (E0-E3) focused on developing legs that could simulate the walk of a human. Successive models (E4-E6) focused on walk stabilization and stair climbing [4]. These robots were experimental in nature, and were later evolved into the Honda P series, which in turn paved the path towards the development of Honda's most advanced humanoid ASIMO. A new ASIMO was released in 2005 which could walkand run up and down the stairs [5].

Apart from full sized humanoids, small sized humanoids have also been developed. Although they are hard to be to a work for a human because of their limited size and performance, they can be appropriate research platforms for their manageability and affordability [6]. Apart from research, small sized humanoid robots possess competitive features for the entertainment sector. Small sized humanoid have also been used for the therapy of autistic children. Various studies have been done to explore this avenue, and have demonstrated the benefits of using small robots in the therapy and education of children with autism [7].

For an appropriate research platform, a humanoid robot must be constructed considering expandable, modifiable system structure, high performance, simple maintenance, familiar development environment, and affordable prices [6].

II. OVERVIEW OF MECHANICAL DESIGN

The research platform proposed in this paper is the humanoid robot GATIK-II, which is depicted in Fig. 1. It is the latest in the GATIK series of humanoid robots. It has a height of 45 cm, and a weight of approximately 2.3 kgs.

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Figure 1. GATIK-II.

A. *GATIK*-I

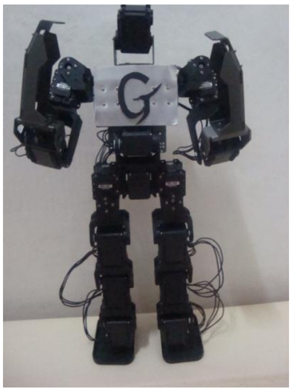


Figure 2. GATIK-I.

GATIK-I (as shown in Fig. 2) is the first robot in the GATIK series of humanoid robots. It has a height of 50cm and a weight of 1.5kgs. Its framework was realized using ABS plastic, which made the robot robust and light weight. The actuators used were Dynamixel AX-12.

Each motor weighs 53.5g, and has a running degree of 300deg. The processor board used was CM-510, whose main controller is ATMEGA® 2561. GATIK-I has a 2 5-DOF legs, which includes a 2-DOF ankle joint, 2 3-DOF arms, which include a 1-DOF elbow joint and a 2-DOF shoulder joint, a 2 DOF waist and a 1-DOF head, totalling up to 19 DOF.

GATIK-I has an Absolute Distance Measurement Sensor, and 2 DOF Gyroscope and an IR sensor to effectively interact with the environment. It does not possess a vision module, and hence is semi-autonomous i.e. it cannot make decisions on its own, and is controlled either in real time or through a remote control.

B. *Mechanics of GATIK-II*

The mechanical framework of GATIK-II (Fig. 1) has been constructed similar to the framework of the DARwIn-OP research platform, and has mainly been fabricated from Aluminium 5052 such that the platform developed would be light weight, durable and sturdy.

GATIK-II has a 2 DOF shoulder joint and a 1 DOF elbow joint, for a total of 3 DOF per arm. Each leg has a 3 DOF hip joint, a 1 DOF knee joint, a 2 DOF ankle joint, for a total of 6 DOF per leg. The last hip joint, the knee joint, and the first ankle joint are all parallel to the Z axes. The 2 DOF head enables pan and tilt for the camera via azimuth R joint and an elevation R joint [8].

The center of mass is located at the center of its pelvis, which is optimal for proper balancing and distribution of inertia during gait, especially at the extremities [6]. As opposed to its predecessor, GATIK-II has higher rigidity and is able to support heavier structures and more powerful motors due to its aluminium framework. It has been provided with a HaViMo vision module and a 6 DOF IMU, comprising of a 3 DOF accelerometer and a 3 DOF gyroscope, which gives it the ability stable locomotion, and assists with its autonomous operation, as opposed to GATIK-I which had a 2 DOF gyroscope.

The detailed specifications of the robot developed are summarized in Table I, and the kinematic model of the GATIK-II is depicted in Fig. 3.

TABLE I. SPECIFICATION OF GATIK-II

Parameters	Specifications
Height\Weight\DOF	45cm\2.3kg\20DOF
Actuators	Dynamixel MX-28 robot actuators
Sensors	6 DOF IMU, Absolute Distance Measurement Sensor, IR sensor, HaViMo 2.0 module
Processor Board	CM-700 (main controller ATMEGA-2561), CM-700 SUB Board
Operating System	Windows, Linux
Interfaces	TTL, RS485, USB
Power	11.1V Rechargeable LiPo battery 1000mA\PCM, SMPS for external power

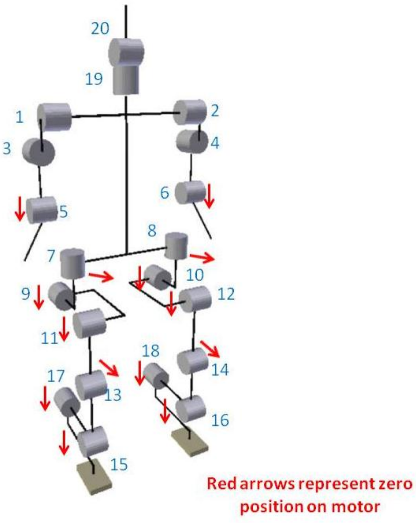


Figure 3. Kinematic model of GATIK-II.

C. *Actuators*

The actuators used for GATIK-II are Dynamixel MX-28 actuators manufactured by Robotis Co. Ltd., shown in

Fig. 4. These actuators were preferred over AX-12A (in GATIK-I) due to their higher resolution, faster communication speed, low power consumption and powerful controller.

The Dynamixel AX-12A had a range of 300deg and could also be used in free running mode. In contrast, the MX-28 implements an absolute contactless magnetic potentiometer, which effectively enables it for continuous rotation by eliminating an operation angle limit.

Another feature of the MX-28 is high 12-bit resolution for more precise position control all over 360 degrees without any gaps or stops. The MX-28 supports PID controller for position and speed control. The user can adjust not only position and speed profile but as well as PID gain parameter in real-time. One of the purposes of the accessibility of PID controls of the MX-28 is to minimize or control actuator harmonic resonance-related aspects.

As a result, from a holistic standpoint, PID controls provide the robot with the highest performance for a humanoid of its type [9].

Figure 4. MX-28 actuator.

D. Electronic Components and Sensors

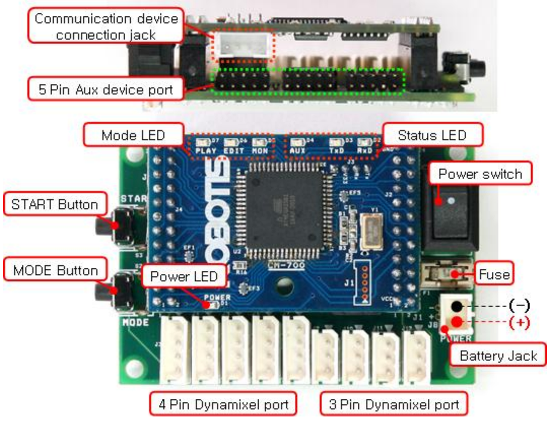


Figure 5. CM-700 main board and SUB board.

The main controller used is CM-700. It is a control module type controller with a CPU, TTL/RS485 communication circuit. Dynamixel actuators and other peripherals cannot be controlled with this board alone, and hence a CM-700 SUB board is required. A SUB Board consists of a power department, a connector department, switch and an additional circuit for 5 pin additional devices. This board features ATMEGA 2561 as its CPU, which is a high performance, low-power Atmel® AVR® 8-bit microcontroller with clock frequency 16MHz, thus providing the robot significant onboard computational power [10]. The main controller CM-700 and the SUB board are illustrated in Fig. 5.

The sensors employed in GATIK-II are:

- IR Sensor

The IR sensors assess the distance of the obstacle in front of them by producing infrared rays and calculating the amount reflected back. The sensors employed have dimensions 24x18x12mm and weighs 4g. The range of the sensors is almost 15 cm, and its accuracy, as it is effected by color and distance. It is used in GATIK-II for obstacle avoidance.

- 6 DOF Inertial Measurement Unit

The IMU is used to measure angular velocity, and to maintain the robot’s balance during movement and locomotion. The dimensions of the sensor are 23x23x10mm and its weight is 2.8g. When the angular velocity is zero i.e. when the robot is stationary, the output value of the sensor is approximately 250. When the robot turns to one axis, the maximum output of the sensor is 455 and the minimum is 45, showing a 300 degree/sec angular velocity.

- Absolute Distance measurement sensor

This sensor is used to detect obstacles with a fixed distance. This sensor weighs about 4g and has detection distance range about 10-80cm. The absolute distance measurement sensor is preferred over the IR sensor as it is not affected by color as much as the IR sensor, thus enabling more accurate measurement. It has also been employed for obstacle avoidance.

- HaViMo 2.0 Image Processing Module

HaViMo Vision Module, as shown in Fig. 6, is a tiny integrated vision module solution for low power microprocessors that gives the robot the ability to detect multiple color BLOBs and navigate in familiar environments autonomously. The integrated color CMOS camera has frame resolution 160x120 pixels with frame rate 19 Fps. HaViMoGUI is the PC-side calibration tool for the HaViMo 2.0.

Figure 6. HaViMo vision module.

III. EXPERIMENTAL SETUP

GATIK-II was programmed using C/C++ to execute numerous single and complex motions. The robot can function in three states, namely autonomous mode, wireless control through remote control, and wireless control using a mobile phone. We are considering only the following motions for the experiments: “Head-Stand”, “Sit and Stand” and “Wave”.

A. Wireless Control through Remote

In this mode, a remote control RC-100A is used, which weighs 80g and has the dimensions 138x105x36mm. The remote control can communicate with the robot via IR, ZIGbee or Bluetooth. In this experiment, the communication with the robot is done with ZIGbee via IR. When a button or a combination of buttons is pressed on the RC-100A, the packet related to the pressed button(s) is transmitted to the receiving ZIGbee module which is synchronized with the transmitting IR module.

This packet is then processed, and the appropriate action executed.

B. Wireless Control through Mobile

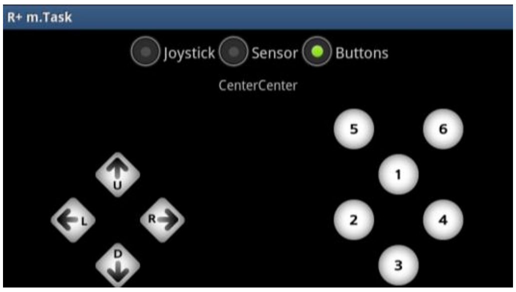


Figure 7. The buttons used to control the robot.

In this mode, the robot responds to commands as input to a mobile application on an android phone. To control the robot using a mobile, the mobile application R+m Task was used. The interface of the application is illustrated in Fig. 7.

The robot is given commands using the keyboard as shown in Fig. 8. The robot is pre-programmed to respond to certain combination of keys, such as 4+L. When the command is input to the mobile device, it communicates with the robot via the Bluetooth module on the robot, and the Bluetooth feature present in the phone.

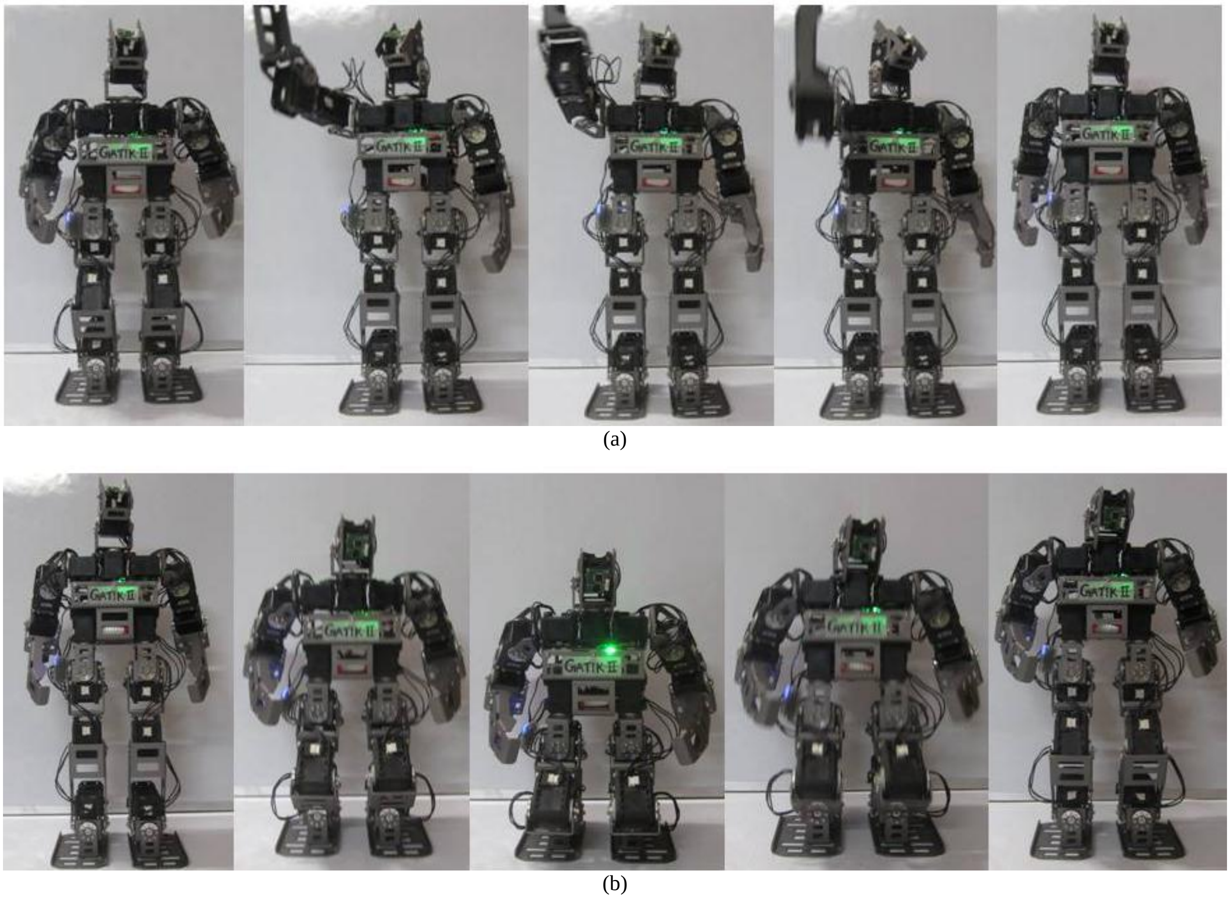
The mobile phone used in this experiment is the Samsung Galaxy SII GT-I9100.

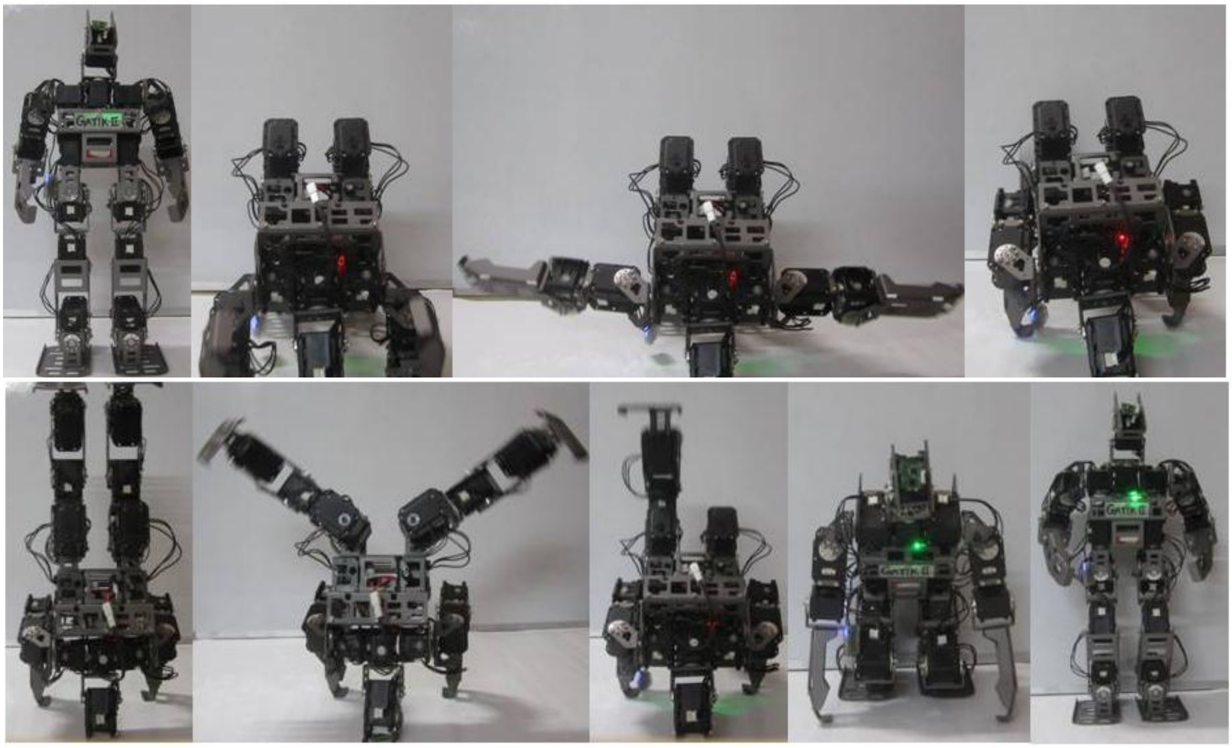
C. Autonomous Mode

In this mode, the robots vision system and the 6 DOF IMU is in function, and the robot responds to external colored stimuli. The colors are calibrated using HaViMoGUI. During this mode of operation, the robot is shown play cards, as shown in Fig. 8. The color is tracked by the HaViMo module, which estimates the color, center, amount of pixels and bounding box of the colored region. It accesses the color table through the serial bus, and executes the response to the color detected, which may be a certain movement, or a set of movements.

For example, when the play card with the color green is placed in front of the robot's field of vision, it executes the head stand move. All the executed poses are shown in Fig. 9.

Figure 8. Play cards used.





(c)

Figure 9. (a) Wave pose, executed when play card 1 with color purple is shown to the robot, (b) Sit-Stand pose, executed when play card 2 with color orange is shown to the robot, (c) Head-Stand pose, executed when play card 3 with color green is shown to the robot.

IV. CONCLUSION

In this paper, a new humanoid prototype called GATIK-II has been proposed. The specifications of the robot developed are as follows:

A 20 DOF autonomous humanoid has been developed, which is 45 cm high and weighs 2.3 kgs. It was built using Dynamixel MX-28 robot actuators. The brackets are made using a 1.5mm thick Aluminium 5052 sheet, and required folding process to be built. Its body has a HaViMo vision module, IR sensors, an Absolute distance measurement sensor, a Zigbee to Serial module and a 6 DOF IMU to effectively interact with the conditions around it.

The main controller used on his body is CM-700. Interfaces include RS485, TTL and USB. It can also be programmed using multiple programming languages to do various moves.

Features in the robot developed are:

- Wireless operation using remote control zigbee module
- Wireless operation using mobile phone using Bluetooth Module
- Real time operation using zigbee to serial module
- Vision – can execute moves based on coloured stimuli within field and range of vision using HaViMo vision module by executing color tracking and image processing.

V. FUTURE APPLICATIONS AND DEVELOPMENT

This initiative has tremendous potential as it can be used as a research platform, apart from real world applications. Research in humanoids robotics has very far reaching consequences, as humanoids can be employed in practically every aspect of human life. Such a robot can be used to interact with children, particularly those suffering from Autism. Children diagnosed with autistic spectrum disorders find it difficult to communicate effectively. But due to the predictability and reduced external stimulus of technology, it attracts children with autism. Studies have shown that there is a 30% increase in social interaction and verbal communication in autistic children when a robot is in the same room [7]. They find robots and other technological devices comforting, motivating and engaging when it comes to areas like social interaction and communication. Hence, this robot can be effectively employed to interact with autistic children because while a therapist may get tired and not be consistent, the robot will never get tired and will always be consistent, so the child can learn to rely on it.

With a robot, the channels used to communicate can be regulated, such as speech, face, hand gestures etc., so as to not overpower the child, something that cannot be done with a therapist.

Even with children who are not suffering with autism, an interactive robot which can move and behave “naturally” i.e. more like a human garners a tremendous response, and hence, employment of robots in schools carries great potential.

The design of an improved robot, GATIK-III, is shown in Fig. 10.

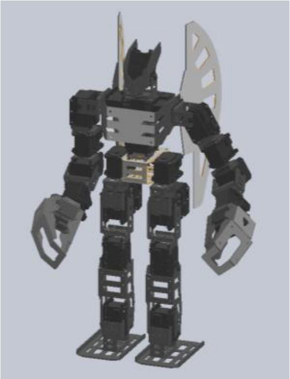


Figure 10. SolidWorks design of GATIK-III.

The present design can be improved by providing a gripper to the robot, and by using motors of higher torque, which would give the robot the ability to pick up certain relatively heavy objects. With the inclusion of a gripper in the robot, its interaction with humans would be more natural, and thus more effective in therapy of autistic children. The appearance of the robot needs to be made more friendly (more like a human) before it can be applied to any kind of therapy or educational purposes.

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