VATIO UP
Team Description Paper for Humanoid KidSize League of RoboCup 2017
Nagoya, Japan

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Abstract. This document describes the own developed hardware and software of the Humanoid Robots Team VATIO-UP, which are able to play soccer autonomously with the objective to participate in the RoboCup Kid Size humanoid league. This is the sixth generation of robots developed and designed by the team VATIO-UP (previously Pioneros Mexico), being the first Mexican team playing in the humanoid league of Robocup in 2006.

1 Introduction

Robotics still represents a relatively young discipline compared to the rest of the well-known sciences; nevertheless, its strong interest as a field of study is attributed to its interdisciplinary nature, since it is a science with roots in different areas of cultural domain such as mechanics, electronics and control. The understanding of this science has driven the development of a new generation of robots, which are increasingly in contact with people and their lives, interacting, exploring and working together with humans. Nowadays, the credible fact that robots co-exist among us is the result of the scientific effort of half a century of technological advances that established robotics as a modern scientific discipline.

Humanoid robots are widely used as research tools in many scientific areas with the motivation to understand human locomotion, since the attempt to simulate the human body leads to a better understanding of it. One of these disciplines is biomechanics, which seeks to understand the motion structure and mobility of the human body for the development of new technologies such as prosthesis, orthoses and exoskeletons, looking forward to improve the quality of life and the motion performance of human beings.

With our own research Humanoid Robot platform, we attempt to develop a complex humanoid robot in order to better understand the locomotion and joints movement of the human body, looking forward to develop new technology for future robotic prostheses. Currently, our VATIO-UP Humanoid Robots are capable of bipedal walking, object tracking, getting up from fall, among many others human-like motions (Fig.1). Additionally, we have also been working along with the ROKY Team (http://www.rokirobotics.com) in the development of an exoskeleton for rehabilitation purposes; same that qualified and participated this year in the Cybathlon 2016 held in Zurich, Switzerland.

Notice of commitment: *The team VATIO UP commits to participate in RoboCup 2017 in Nagoya, Japan, providing a referee knowledgeable of the rules of the Humanoid League to serve during the competition.*

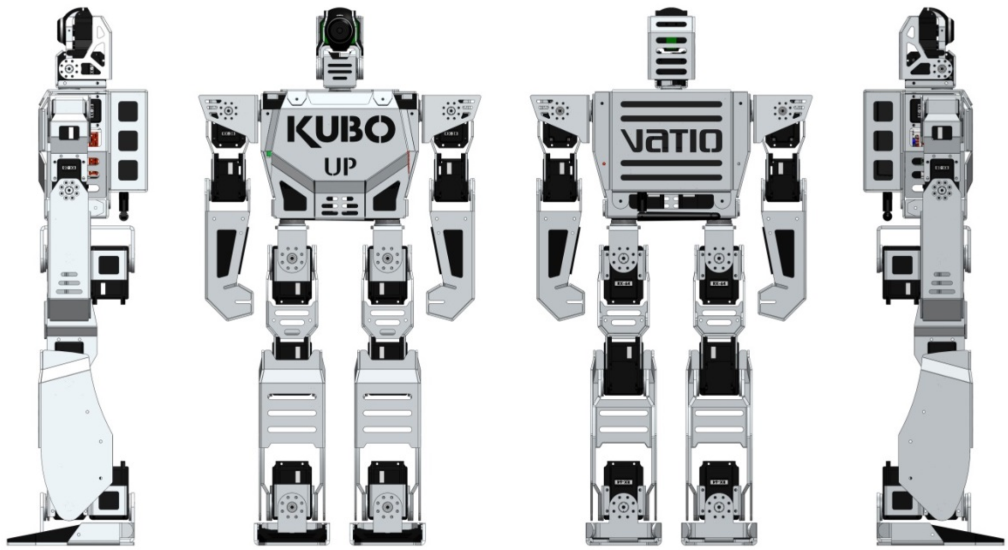


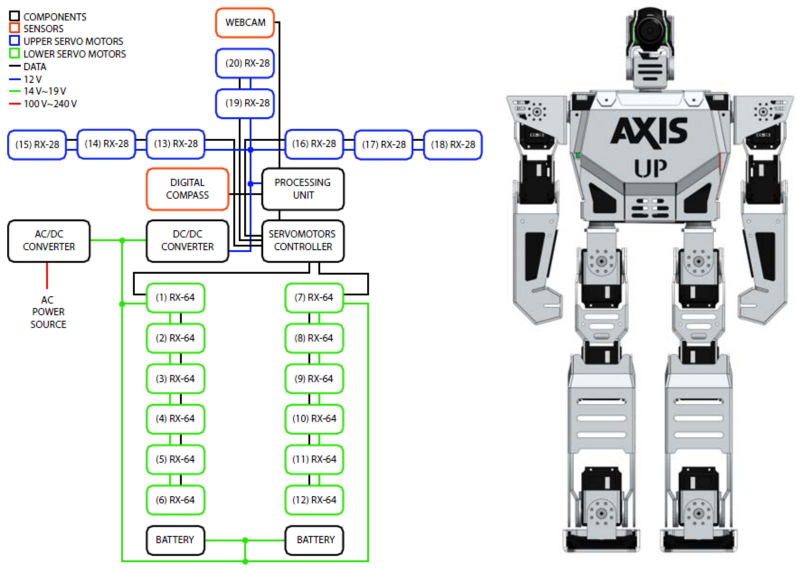
Fig. 1. VATIO-UP Humanoid Robot

2 General Architecture

VATIO-UP Humanoid Robots are a self-contained prototype with a head, a torso, two arms, and two legs. It exhibits 20 DOF powered by a total of 20 actuators. The head consists of a pan-and-tilt structure (2 DOF). Arms add 6 DOF, 3 DOF each: shoulder, arm, and elbow. Head and arms are mounted on a torso. Finally, the legs add 12 DOF, 6 DOF each: one at waist level that allows rotation of the entire leg, two at the upper part, one at the knee, and two at the foot. An open source embedded color video camera is mounted on the head's pan-and-tilt structure.

Both batteries and processing unit are to be on-board the structure. Fig. 2(a) shows VATIO-UP Humanoid Robots connection block diagram, while its physical structural design is shown in Fig. 2(b). The main structure involves four types of blocks connected each other by electrical and data lines. These blocks represent components, sensors, and the upper and lower servomotors, which form together the mechanical structure of the robot. On the upper side, there are eight servomotors RX-28 (blue), three for each arm (3 DOF) and two for the head (2 DOF), while in the lower side there are 12 servo motors RX-64 (green): six for each leg (6 DOF). Since the servomotors on the lower side require a higher torque (because of the weight they have to move), a higher voltage needs to be supplied (green line), while on the upperside, the torque is minimum and a lower voltage (blue line) can be supplied.

Two types of sensors (orange) are used to have feedback from the outer world: a camera placed on the head and a digital compass located inside the chest. This last one includes magnetic sensors and accelerometers that send information to the processing unit to keep the robot's balance and let him know if it is lied down either up face or down face.



(a) Connection block diagram (b) Structural design

Fig. 2. General architecture of VATIO-UP Humanoid Robots

Likewise, instructions for the servomotors are sent through the servomotor controller by the processing unit. Data are sent by serial connection (black line) through five data lines (one for each limb and head), even if some at the middle of the chain are not required to move. The main power source of the robot is taken either from the batteries or by plugging it directly to the AC power source (red line).

3 Hardware

The Structural design is own development of the team VATIO-UP, and is entirely made from two types of aluminum alloys: 3105-H22 and 3003-H23. The first one is malleable and is used for the most complex links containing folds. The second one is rigid and is used for the simpler links. H22 aluminum links were laser cut with a ±2 micron precision, folded with hydraulic press, and welded using gas tungsten arc welding. H23 aluminum links were manufactured with a three-axis CNC machine. Actuators powering the robot's joints are servomotors of type RX-28 and RX-64 from Dynamixel [1]. All three provide a step precision of 0.29± while torque is 28 and 64 kgf-cm respectively. RX-28 servomotors are used for the head and for the upper limbs, and RX-64 for the waist and lower limbs. The processing unit running Linux Debian 7.4, and algorithms in C++, is used for the intelligence and motion decisions, and to communicate to the servomotors controller to send the instructions for each servomotor. This unit module is located inside the robot's torso. A set of batteries are located at the arms. Robot's main physical specifications are listed in Table1 and shown in Fig.3.

Table 1. Physical specifications of VATIO-UP Humanoid Robots

Height	56 cm
Width (arms closed)	33 cm
Width (arms opened)	72 cm
Depth	16 cm
Arms' length	24 cm
Legs' length	32 cm
Total mass	5 kg

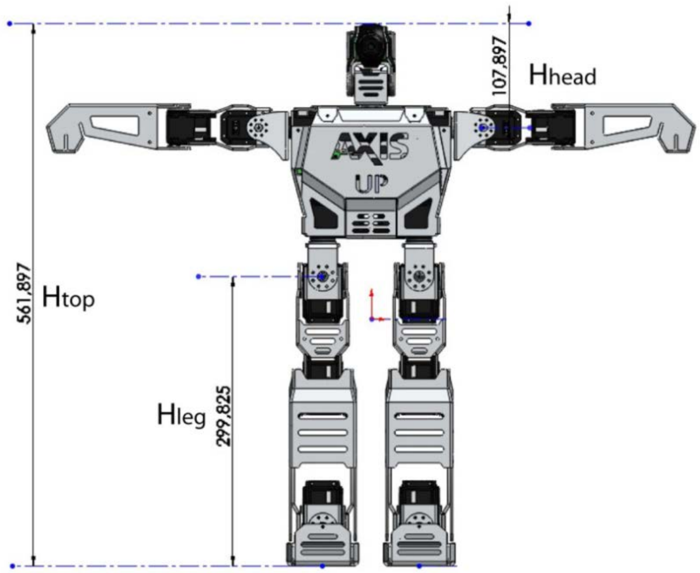


Fig. 3. Physical dimensions of VATIO-UP Humanoid Robots

4 Software

The Software algorithms of the Robots are completely implemented in C++, being also own development codes from team VATIO-UP, using event handler and multi-threading tools, that helps because it has several systems running simultaneously, and each one have different importance level and hardware requirements; in addition, depending of the situation only some systems are need to be activated, e.g. during a game it needs different systems that during motion modeling, demonstration or calibration.

The robots have separated functions in several systems: locomotion, video processing, reading sensors, controlling actuators, wireless communication, kinematic modeling, graphical interface and behavior control. In addition, each system has mechanisms to identify errors in themselves, for example, identify if a sensor or actuator is not working properly, generate alerts, and try to solve the problem.

5 Electronics

Each robot is now equipped with one Orange Pi Plus2 board [2] as the processing unit, that has is a full featured PC single board computer, tiny and power saving. This CPU has Quad-core Cortex-A7, Mali400MP2 GPU @600MHz SDRAM 2GB DDR3 (shared with GPU), 16GB EMMC Flash on-board flash storage, and using Linux Debian 7.4 as OS. That board has several interesting features which make it ideal as a brain for humanoid robots. These include low weight and power consumption, direct connection by 2x 46 pin headers for GPIO's ports for all de sensors, camera and controllers. The board also has two USB 2.0 port connected to a USB host for Wi-Fi adapter and other devices.

The UM6 Ultra-Miniature Orientation Sensor [3] combines sensor measurements from rate gyros, accelerometers, and magnetic sensors to measure orientation at 1000 Hz. Angle estimates are available as Euler Angle or Quaternion outputs, and it has direct connection to the processing unit (Orange Pi Plus2) by I2C in a GPIO. The orientation sensor is very useful to determinate the position of the robots inside the field but is used in parallel with the vision system to have redundant information.

The Dynamixel servomotors controller is a custom made embedded system with a microcontroller ATXMEGA128 [4] and other components for communication with sensors and the processing unit. This controller is directly connected to the 2x 46 pin headers for GPIO's ports in the Orange Pi Plus2 board and additionally manages regulated power to all different robot's systems.

A CMUcam5 [5] is mounted in the head with a pan-and-tilt structure to acquire image data from the outer world. Each robot has a package of batteries that provide power to have 20 minutes of autonomy at full charge. The robot has two packages of rechargeable LiPo batteries [6] of 18.5 volts at 25C 750mAh, one in each arm.

6 Robot Behavior Control

The behavior control is based on the concept of Finite State Machine, and implemented in C++, where has been used several state unknowns. Basically there are three layers: Operation Mode, Define Target and Individual System Control, but each layer may have sublayers like a hierarchy tree; for example, at layer Individual System Control there is the Locomotion sublayer, at layer Locomotion there is the Walk Forward sublayer, and at layer Walk Forward we have the DS-ZMP state (Double Support - Zero Moment Point). This kind of implementation makes very easy to add, remove or even improve states at any level of the hierarchy tree.

For a good performance in the game a good Behavior Control but also a great Locomotion System are needed; to achieve this the simplified differential equations system was solved analytically (assuming constant inertial tensors) obtained from the 3D dynamic free diagram body of the humanoid, that generate a very good approximation to the ideal trajectory of the COM (Center of Mass). After that, inverse kinematics was apply to find joint angles for the legs but it changes the COM in the model, so the gradient descent algorithm was used to approach again to the ideal trajectory. Finally, the robot uses the arms to reduce to the minimal the moment generated by the variability of the inertial tensors.

In addition, the analytically solution was solved to use easily the whole algorithm, that means, it only pass some tangible parameters of the motion desired to design and it is done. Those parameters are for example the length of the step, initial altitude of the COM, distance and angle between feet, inclination angle of the back, desired velocity, step frequency, among others. The first limitation of this method is that the complete system needs an excellent dynamic model of the robot, but KUBO, AXIS and ROOT have it because each element of the robots was modeled in a CAD software.

7 Vision

The Vision System is implemented using basic open source algorithms from CMUcam5 and adapted to work in synchrony with our own intelligence and control algorithms. Goalkeeper and other player have different algorithms because their main role play; for example, If the robot is playing as a goalkeeper, the vision system needs to process almost all the time only the ball algorithm to achieve the best performance possible. Vision performance had been optimized for different identification algorithm using different techniques; for example, to identify the orange ball it only use color identification, but to identify a pole it uses morphological identification and color identification (to know which pole it is).

8 Prior Performances in RoboCup Competitions

Our team was born like “Pioneros Mexico” ten years ago, having the opportunity to participate by the first time in RoboCup Human League in Bremen 2006. Subsequently, we were actively participating in the following international RoboCup editions like Atlanta 2007, Graz 2009 Graz, Singapore 2010, Istanbul 2011, Mexico City 2012 and Eindhoven 2013. During this period, our team name changed to “Mexatronics UP” and finally to “VATIO-UP”, which is our current team name. Additionally, we also have had the opportunity to participate in local editions as RoboCup Mexican Open 2008, 2009, 2011 and 2012, and RoboCup Iran Open 2012 and 2013.

For RoboCup 2014 and 2015 team VATIO-UP was qualified to participate in the Humanoid Kid size, but due to lack of budget, was impossible for us to reach enough funds for travel expenses and decided to withdraw our participation from those RoboCup editions.

9 Conclusion

Our Humanoids Robots KUBO and AXIS, are the sixth generation of robots designed and developed originally by the team Pioneros Mexico, now called VATIO-UP. This work was inspired in amazing robots developed by other countries and our intention is to reach that level applying this knowledge, attempting to provide a competitive humanoid robot platform for the upcoming RoboCup 2017 in Nagoya, Japan.

10 Publications

– Hernández (E.) and Velázquez (R.), Diseño Mecánico y Análisis Cinemático del Robot Humanoide AXIS, Pistas Educativas, No. 108, Guanajuato, Mexico, 2014.

– Hernández (E.) and Velázquez (R.), Design and Development of Humanoid Robot ZERO, 9th IEEE Latin-American Robotics Symposium, Bogota, Colombia, 2011.

– Hernández (E.) y Velázquez (R.), Robot Humanoide ZERO: Diseño, Análisis y Prototipo, SENIE 2011 (Semana Nacional de Ingeniería Electrónica), Tapachula, Chiapas, México, 2011.

– Hernández (E.) y Velázquez (R.), Un Algoritmo de Visión Identificador de Pelotas para Cualquier Tipo de Iluminación Exterior: Aplicación en la RoboCup, 2 Encuentro de Telecomunicaciones y Análisis de Señales, San Luis Potosí, SLP, México, 2010.

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2. Orange Pi Plus2, Updated information available at: http://www.orangepi.org/orangepiplus2/
3. UM6 Orientation Sensor. Updated information available at: http://www.pololu.com/catalog/product/1255
4. Servomotors embedded controller http://www.atmel.com/devices/ATXMEGA128A1U.aspx
5. CMUcam5. Updated information available at: http://www.cmucam.org/projects/cmucam5/wiki
6. Thunder Power ProLite LiPo Batteries. Updated information available at: http://www.rcplanet.com