Team DARwIn-XOS

Team Description for Humanoid TeenSize League of RoboCup 2013

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Abstract: This paper details the hardware, software, and electrical design of the humanoid robot family, DARwIn (Dynamic Anthropomorphic Robot with Intelligence) – a robot family designed as a platform for researching bipedal motions. Last year was our first TeenSize competition, and, having learned much, we wish to push our technology forward for 2013.

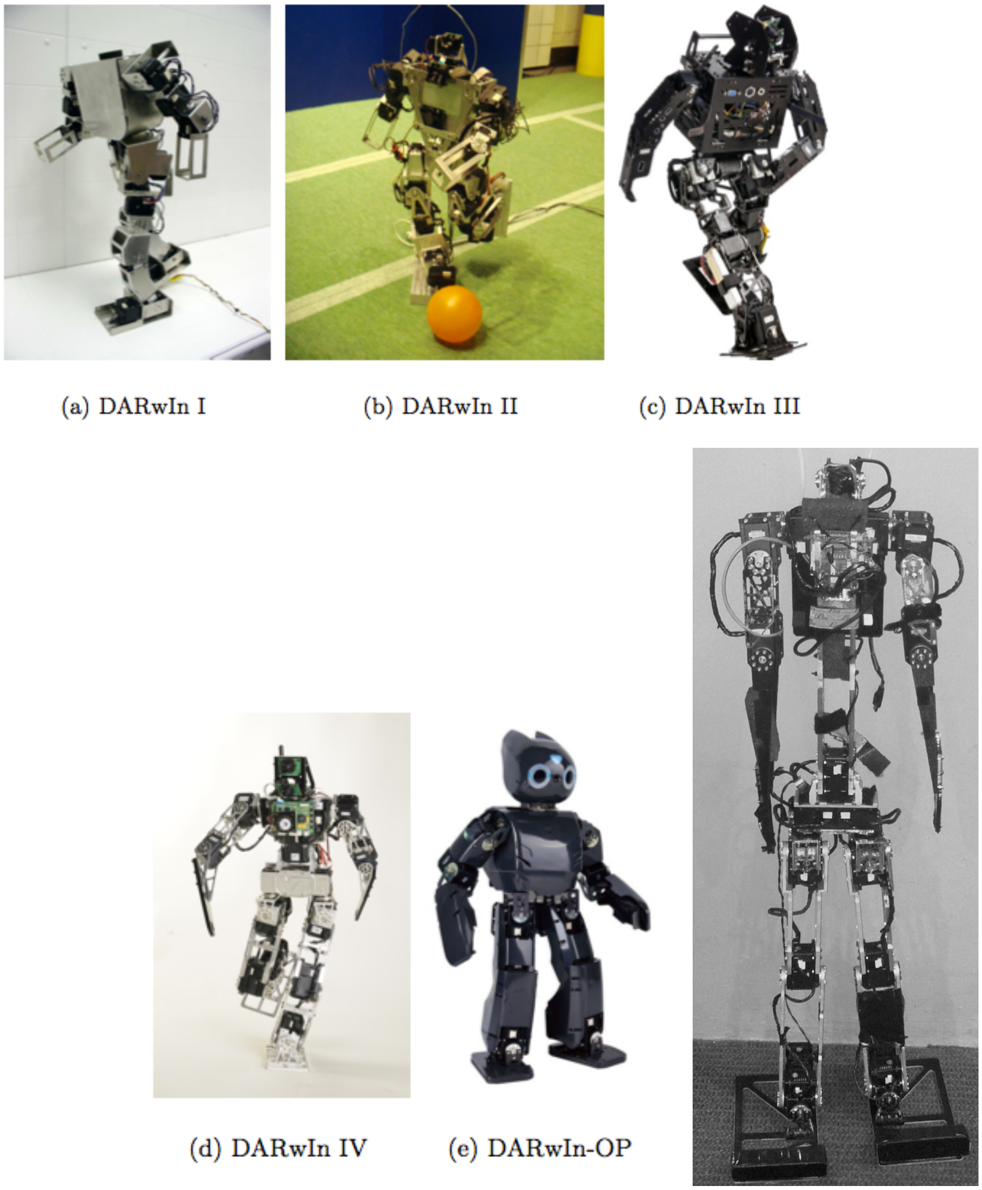
1 Introduction

The DARwIn (Dynamic Anthropomorphic Robot with Intelligence) series robot is a family of humanoid robots capable of bipedal walking and performing human-like motions (Fig. 1). DARwIn is a research platform developed at the Robotics and Mechanisms Laboratory (RoMeLa) at Virginia Tech for studying robot locomotion and sensing. It was also utilized as the base platform for Virginia Tech's first entry to the humanoid division of RoboCup 2007. [1,2].

The 95 cm tall, 4 kg DARwIn-XOS (a branch of the DARwIn platform) has 21 degrees-of-freedom (DOF) with each joint actuated by coreless DC motors via distributed control with controllable compliance. DARwIn-XOS was developed through collaboration between Virginia Tech and the University of Pennsylvania. Using a computer vision system and accelerometer, DARwIn-XOS can implement human-like gaits while navigating obstacles and traverse uneven terrain while implementing complex behaviors such as playing soccer. The iteration used in the 2013 competition will be a modification of the entry used in the 2012 competition.

For RoboCup 2013, we expect to fine tune the hardware platform, but the team will consist of solely the University of Pennsylvania. Additionally, we expect to incorporate even more software from the kid size Team DARwIn entrant than last year for quicker development.

Team DARwIn-XOS would like to commit to participate in the RoboCup 2013 Humanoid League competition – teen size division. Team DARwIn-XOS is able to provide students who participated in last year's competition (through the kid sized league) to serve as referees, as they have sufficient knowledge of the rules.



(a) DARwIn I (b) DARwIn II (c) DARwIn III

(d) DARwIn IV (e) DARwIn-OP

Fig. 1. Family of DARwIn Robots

2 Research

The DARwIn family serves as a research platform used for studying dynamic gaits and walking control algorithms. With few exceptions (i.e. the Honda ASIMO, the Sony QRIO, and the KAIST HUBO [3–7]), most legged robots today walk using what is called the static stability criterion. The static stability criterion is an approach to prevent the robot from falling down by keeping the center of mass of its body over the support polygon by adjusting the position of its links and pose of its body very slowly to minimize dynamic effects [5]. Thus at any given instant in the walk, the robot could "pause" and not fall over. Static stability walking is generally energy inefficient since the robot must constantly adjust its pose to keep the center of mass of the robot over its support polygon, which generally requires large torques at the joint actuators (similar to a human standing still with one foot off the ground). Humans naturally walk dynamically with the center of mass rarely inside the support polygon. Thus human walking can be considered as a cycle of continuously falling and catching its fall: a cycle of exchanging potential energy and kinetic energy of the system like the motion of an inverted pendulum. Humans fall forward and catch themselves with the swinging foot while continuously progressing forward. This falling motion al- lows the center of mass to continually move forward, minimizing the energy that would reduce the momentum. The lowered potential energy from this forward motion is then increased again by the lifting motion of the supporting leg.

One natural question that arises when examining dynamic walking is how to classify the stability of the gait. Dynamic stability is commonly measured using the Zero Moment Point (ZMP), which is defined as the point where the influence of all forces acting on the mechanism can be replaced by one single force without a moment term [8]. If this point remains in the support polygon, then the robot can have some control over the motion of itself by applying force and/or torque to the ground. Once the ZMP moves to the edge of the foot, the robot is on the verge of stability and can do nothing to recover without extending the support polygon (planting another foot or arm). Parameterized gaits can be optimized using the ZMP as a stability criterion or stable hyperbolic gaits can be generated by solving the ZMP equation for a path of the center of mass. Additionally, the ZMP can be measured directly or estimated during walking to give the robot feedback to correct and control its walking. DARwIn is developed and being used for research on such dynamic gaits and control strategies for stability [5, 9].

3 Hardware

DARwIn-XOS has 21 degrees of freedom (six in each leg, three in each arm, and two in the head, and one in the waist). The robot's links are fabricated out of aluminum. The robot uses Robotis' Dynamixel RX and EX series motors, which operate on a serial TTY network, allowing the motors to be daisy chained together. Each motor has its own built-in optical encoder and position feedback controller, creating distributed control. The computers, sensors, electronics, and computer ports are distributed about DARwIn-XOS's upper torso.

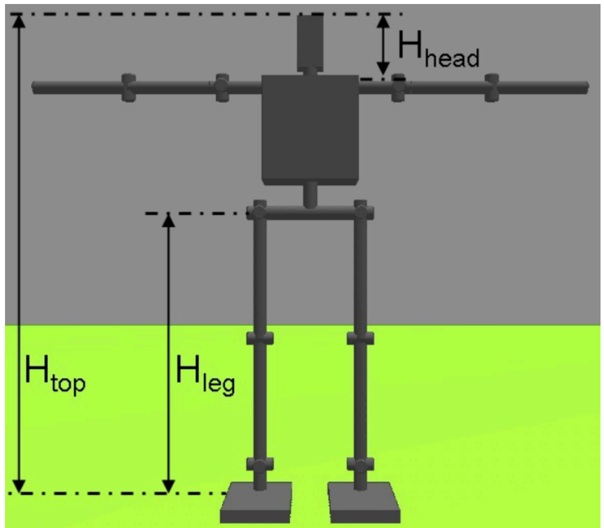


Fig. 2. Robot height dimensions

The DARwIn-XOS stands 95 cm in full height. The body consists of 50 cm legs, a 35 cm torso, and 10 cm head. The heights fulfill all of the TeenSize requirements for total height, leg length, and head size.

4 Electronics

DARwIn-XOS's electronic system provides power distribution, communication buses, computing platforms, and sensing schemes aimed at making sense of a salient environment. DARwIn's power is provided by a 14.8V battery that is connected to the joint actuators and electronics. These batteries provide DARwIn-XOS a little over 10 minutes of run time.

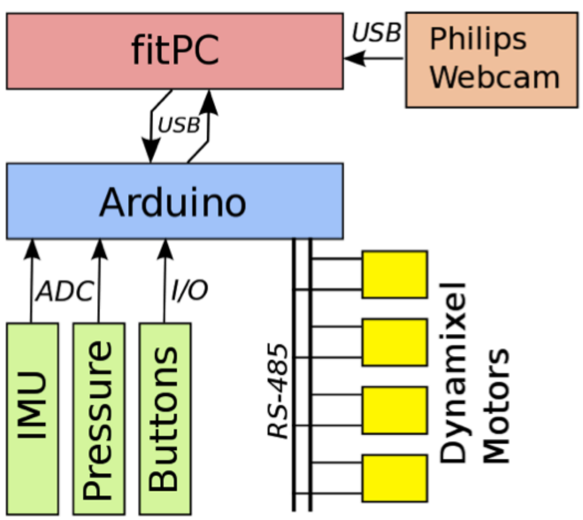


Fig. 3. Electronics architecture

Computing tasks are performed on a Compulabs Fit-PC2 computing system that runs the Intel Atom Z530 CPU with 1GB of onboard RAM and built-in WiFi. The PC runs off the main battery supply, and consumes 8W at full CPU usage. In addition, the computer connects to both a Philips SPC1300 camera and an Arduino microcontroller board.

The Arduino board, featuring the ATmega1280, acts as the communication relay between the Dynamixel motors and the fitPC. The microcontroller also provides sensor acquisition and processing. Switches, a 6 degree of freedom Inertial Measurement Unit (IMU), and foot sensors will aid in correcting gait cycles in the face of perturbations. A block diagram that outlines the computing relationship is shown in Fig. 2.

5 Software

The software architecture for the robots is shown in Fig. 3. This architecture is novel in that it uses Lua as a common development platform. Since many of the students do not have strong programming backgrounds, this development platform allows them to participate more fully on the team. Low-level interfaces to the hardware level are implemented as C routines callable from Lua. These routines provide access to the camera and other sensors such as joint encoders and the IMU, and allow the higher-level routines to modify joint angles and stiffnesses.

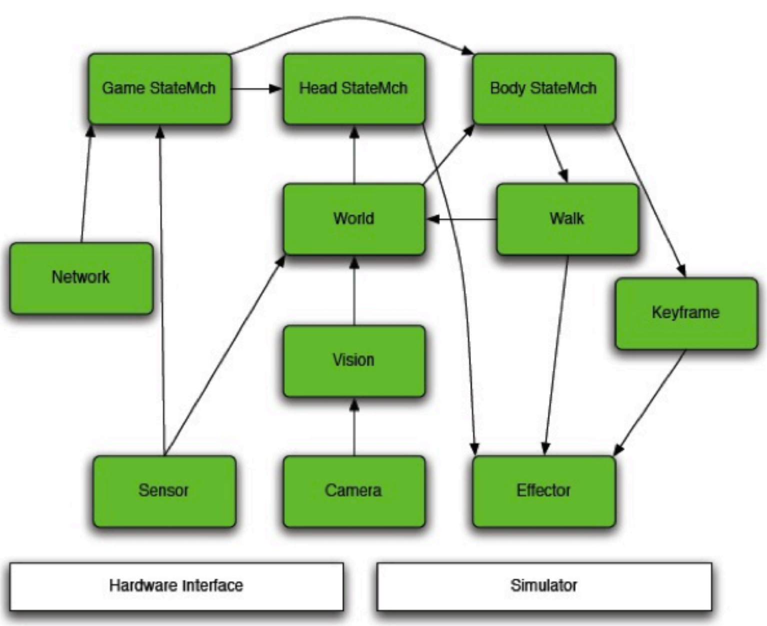


Fig. 4. Software architecture

The Lua routines consist of a variety of modules, layered hierarchically:

- **Sensor** Module that is responsible for reading joint encoders, IMU, foot sensors, battery status, and button presses on the robot.
- **Camera** Interface to the video camera system, including setting parameters, switching cameras, and reading the raw YUYV images.
- **Effector** Module to set and vary motor joints and parameters, as well as body and face LED's.
- **Vision** Uses acquired camera images to deduce presence and relative location of the ball, goals, lines, and other robots.
- **World** Models world state of the robot, including pose and altered ball location.
- **Game StateMch** Game state machine to respond to Robocup game controller and referee button pushes.
- **Head StateMch** Head state machine to implement ball tracking, searching, and lookaround behaviors.
- **Body StateMch** Body state machine to switch between chasing, ball approach, dribbling, and kicking behaviors.
- **Keyframe** Keyframe motion generator used for scripted motions such as getup and kick motions.
- **Walk** Omnidirectional locomotion module.

In order to simplify development, all interprocess communications are performed by passing data structures between the various modules, as well as between robots.

6 Vision

Fig. 5. Visualization of the color segmentation

In each new setting, we may encounter different field conditions such as a change in lighting or the actual color hue of the field objects. In order to account for this, we log a series of images that are then used to train a lookup table. A GUI tool enables us to define the YCbCr values that correspond to green, yellow, white, etc. Once these specific values are selected and defined, the distribution of the points in the color space are spread out and generalized to account for a greater variation. This is done with a Gaussian mixture model that analyzes the probability density function of each of the previously defined pixel values. The boundaries of the color classes are then expanded according to Bayes Theorem. We can then process the individual pixels of the new images by matching their YCbCr values to the broadened definition of the values in the lookup table.

After the image is segmented into its corresponding color classes using the look-up table, the segmentation is bitwise OR-ed in 4x4 blocks. The initial object hypotheses for the ball and goal posts are found by finding connected components in the smaller, bit OR-ed, image, and then using the original image we calculated the statistics of each region. Processing the bit OR-ed image first allowed us to greatly speed up the computation of the system. The bit OR-ed image also produced the set of points that are used in our line detection algorithm.

We then check the segmented components for certain attributes like size, shape, and position in order to classify objects, such as the ball and the goal posts. We also compute statistics for the position of detected objects in the world coordinate system using the inverse kinematics of the robot, the centroid, and the bounding box to further filter the object hypotheses. Using these we, are able to track the ball and identify the existence and size of goal posts and consequently localize our position on the field.

7 Prior Performance in RoboCup

Team DARwIn has been competing since RoboCup 2007 led by Virginia Tech, and in recent years has partnered with the University of Pennsylvania. RoboCup 2010 saw the team play a respectable fourth place, and drove the team to improve its hardware and software. With the introduction of the DARwIn-OP system, Team DARwIn was able to move ahead and enthusiastically took the first place trophy in the kid-size league in Istanbul 2011 and Mexico 2012.

Last year marked the first year of DARwin-XOS, in which we did not place, but learned a lot about building a new robot platform in a new league. We hope to use this experience to place highly in 2013.

This year, the team has pushed forward innovate on the hardware end of the DARwIn Open Platform; we have developed a robot to compete in the TeenSize competition. We use our own software, and provide its base at https://github.com/UPenn-RoboCup/UPennalizers for the research community.

8 Conclusion

Building on previous research and RoboCup experience, we hope to push DARwIn-XOS its highest potential. The combination of hardware, electronic, and software expertise from the University of Pennsylvania should prove to be very powerful and make Team DARwIn-XOS a formidable opponent at RoboCup, while still maintaining its primary purpose as a research platform for studying robot humanoid motions.

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