Development of an Open Humanoid Robot Platform for Research and Autonomous Soccer Playing

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Abstract

This paper describes the development of a fully autonomous humanoid robot for locomotion research and as the first US entry in to RoboCup. DARwIn (Dynamic Anthropomorphic Robot with Intelligence) is a humanoid robot capable of bipedal walking and performing human like motions. As the years have progressed, DARwIn has evolved from a concept to a sophisticated robot platform. DARwIn 0 was a feasibility study that investigated the possibility of making a humanoid robot walk. Its successor, DARwIn I, was a design study that investigated how to create a humanoid robot with human proportions, range of motion, and kinematic structure. DARwIn IIa built on the name "humanoid" by adding autonomy. DARwIn IIb improved on its predecessor by adding more powerful actuators and modular computing components. Finally, DARwIn III is designed to take the best of all the designs and incorporate the robot's most advanced motion control yet.

Introduction

Dynamic Anthropomorphic Robot with Intelligence (DARwIn), a humanoid robot, is a sophisticated hardware platform used for studying bipedal gaits that has evolved over time. Five versions of DARwIn have been developed, each an improvement on its predecessor. The first version, DARwIn 0 (Figure 1a), was used as a design study to determine the feasibility of creating a humanoid robot abd for actuator evaluation. The second version, DARwIn I (Figure 1b), used improved gaits and software. The third version, DARwIn IIa (Figure 1c) has not only even better gaits and control software, but also has artificial intelligence. The platform is primarily used as a research tool for studying bipedal and humanoid locomotion. Additionally, DARwIn IIb (Figure 1d) has been tailored for the international autonomous robot soccer competition, RoboCup. RoboCup, aside from being a competition, is a venue for advancing research in humanoid locomotion and robot intelligence [1-2].

The initial design study on DARwIn 0 showed successful integration of software and motor control of a 21 degree of freedom (DOF) humanoid robot. DARwIn 0 could stand up and walk under the control of software created at RoMeLa. However, this initial design study did not use

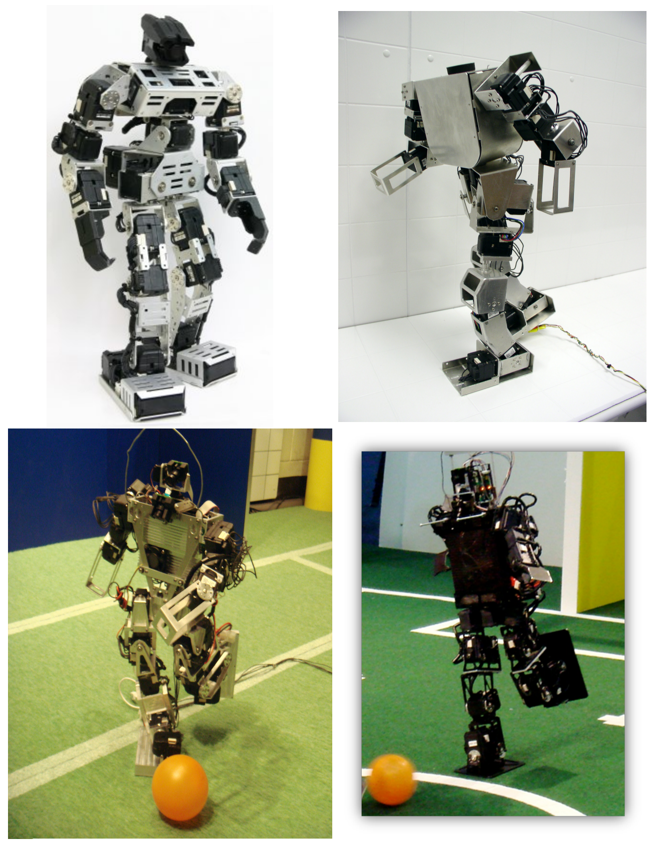

Fig. 1. Pictures of Dynamic Anthropomorphic Robot with Intelligence (Left to right, top to down): (a) DARwIn 0, (b) DARwIn I, (c) DARwIn IIa, (d) DARwIn IIb.

rate gyros or force sensors for feedback to control the motions.

DARwIn I, was a great improvement from DARwIn 0. DARwIn I was controlled by more sophisticated software and gait generation techniques from [3-4], which led to stable walking motions. DARwIn I was also designed to house an onboard computer, battery power, and a rate gyro.

DARwIn IIa was an evolutionary step from its predecessors. DARwIn IIa used gaits generated in Mathematica and simulated as an OpenGL model to walk quickly and efficiently [5]. Additionally, DARwIn IIa has a brain, which is comprised of a PC104+ computer, two IEEE 1394 cameras, a rate gyro, and 802.11 wireless network communications. Intelligent software used on DARwIn identifies and locates objects [6], and allows DARwIn to perform high level tasks, like playing soccer.

DARwIn IIb incorporates everything mentioned before, but is designed in such a way that every component is modular, which creates a flexible research platform that is capable of running almost any operating system, computing platform, or sensor. DARwIn III expands on the idea of having a flexible platform by its simple design. Though an extremely sophisticated research platform, DARwIn III can be fabricated relatively inexpensively and easily without using expensive machining tools.

Sensor and Hardware Description

The robots' motors are controlled over a serial RS-485 network and have built-in potentiometers, which give feedback joint positions [7]. While the robot is walking or moving, a rate gyro with acceleration and orientation information communicates over an RS-232 serial connection so the robot can modify its gait and balance in real-time.

Initially the only sensors needed for the robotic research platform were the servo motors' potentiometers and the rate gyro. However, taking part in the July 2007 RoboCup competition required more sophisticated hardware and sensors. Cameras (eyes), a PC104+ computer (AI, brain), and an 802.11 port (communication) were added on to the existing stable walking robot in order to make DARwIn a competitive soccer player. The 802.11 wireless networking port allows for the robot to be completely autonomous and untethered during operation. The robot is instead controlled via a web host, which gives information including stop and start signals.

Software Description

Since DARwIn is primarily a research platform for studying gaits and locomotion, it is important to have software that makes it easy to deploy and test gaits. One challenge when generating mathematical formulations of the robot's locomotion is visualizing the results. Using gaits generated in Mathematica, the motions were simulated in an OpenGL environment to visualize the robot's gait (2). This allowed for quick visual verification of generated walking gaits.

When ready to test gaits on the physical hardware, the robot's artificial intelligence, which will be explained later, can be bypassed and emulated by a user controlled joystick. The user acts as the robot's eyes and brain, while the joystick acts as an interface to control the robots motion by sending commands like: walk, kick, dive, etc. This simplifies debugging of gaits and motion generation without simultaneously debugging the robot's behavior.

Figure 3 shows how the reactive behavior based artificial intelligence interfaces with the rest of the robotic system. The artificial intelligence runs on the PC104+ board and uses sensory data like the cameras to determine the robot's action, which is sent to the gait generator. The gait generator uses feedback from the rate gyro to create a modified stable gait to send to the servo motors of the robot. The 802.11 Wi-fi port allows the robot to communicate with a web host, which allows the public to see chosen information on the web, and allows for an operational control unit (OCU) to take over control of the robot's actions.

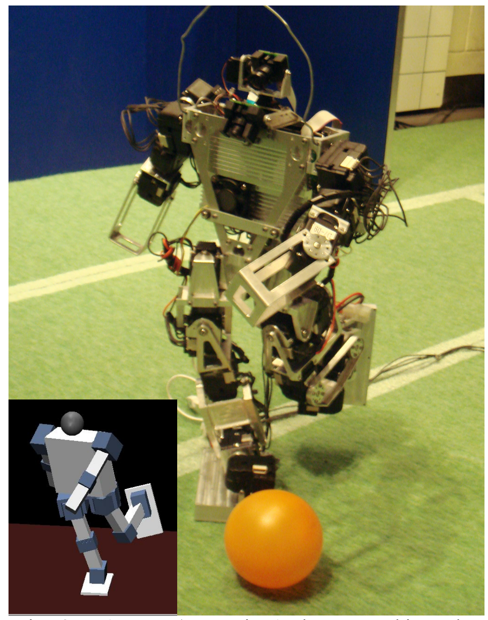

Fig. 2. DARwIn (Dynamic Anthropomorphic Robot with Intelligence) kicking a Robocup soccer ball (top). Simulation using openGL (bottom left).

Conclusion

DARwIn is a sophisticated robot that has evolved through five generations thus far. The result is an autonomous bipedal humanoid robot, that walks dynamically and has intelligence that allows it to perform higher level tasks, like playing soccer. DARwIn III will be used as a research platform for studying the differences between gaits generated using the ZMP trajectory with gaits of humans. Different types of control algorithms including posture control, landing force control, and ZMP control will also be tested on DARwIn III. Other areas of research will extend into sensors and artificial intelligence, which researchers around the world will be able to investigate since DARwIn II is such an open platform allowing for different kinds of instrumentation, electronics, computing platforms, and software platforms.

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