Zigorat 2007 Development Team Description

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Abstract. This paper describes the main contributions of the Zigorat Soccer 3D development team that is going to take part in RoboCup competitions this year. *SBCE SmartSpheres 2006* was the result of our first year of developing RoboCup 3D Soccer Simulator. The RoboCup 3D Soccer Simulator is now going to take a big step towards a more realistic humanoid model. The new legged sphere model brings the competitions to a whole new level. Generating a walking pattern is the first step for developing an agent with the newly introduced model. This paper describes our studies about achieving a stable walking pattern for legged-sphere agents as well as our works with new simulators like Webots.

Key words: RoboCup, Soccer Simulation, Development, Biped

1 Introduction

In the past 10 years, not only the teams, but also the simulation servers have undergone many changes and improvements. These changes are usually caused by two different reasons; one is better knowledge of the environment that is gradually acquired. The second and more important reason is that many of the simple assumptions that were first considered for making the environment more convenient are no longer needed due to improvements of methods and technology, so they can be eliminated to make the simulation environment resemble a real environment more closely. The RoboCup 3D Development Competition is an attempt to speed up the development of the current simulation environment by encouraging members of the community to present implementations of improvements, and add missing functionality to it.

Last year the soccer simulation competitions, took another step towards a more realistic platform for modeling soccer playing robots. After many discussions within the community, it is now generally accepted that the soccer simulator must evolve directly towards a humanoid robot model (instead of adopting other intermediated robot model such as the middle-size leagues robots)[1]. But the roadmap towards such a realistic humanoid soccer simulator is still a subject of considerable debate. This year, we divided our efforts between working on legged-sphere agents and trying to do some simulations using better tools like Webots [2].

The work on legged agents consists of implementing a controller for walking, kicking, jumping, turning, standing up, and doing some studies about stable walking patterns of biped and quadruped robots. Trying to avoid reinventing the wheel, we imported many ideas from SBCe Smart Spheres 2006 soccer simulation team [3] that won the second place in 3D Developments competitions in RoboCup 2006.

2 Background

Humanoid robots are anthropomorphic robotic systems which try to imitate human capabilities, in order to achieve tasks. It is expected that in the future humanoids will have the ability to adapt to human environments (e.g. offices, homes, and hospitals) and become, along with other various mechanical and automated equipments, adequate and helpful assistants to humans. Many researchers have paid great attention on the potential of humanoid robots. This is, in part, due to their anthropoid shapes which are suitable for human-supporting actions such as: carrying building materials and tools in construction sites; atomic power plant inspection; domestic household tasks etc.[4].

In order to succeed in such real world environments, humanoid robots need to possess stable dynamic biped locomotion. However, the humanoid robots of today still do not satisfy the aforementioned demands and their level of dynamically stable mobility is insufficient in the context of the real and uncertain environment. Hence humanoids cannot cope with unexpected external forces or sudden contacts with the environment. This is partially attributable to the fact that development and implementation of responsive control algorithms has been, so far, scarce [5]. Hereby, locomotion control of humanoids research has still a long way to go. Humanoids are extremely complex and non-linear dynamical systems, suggesting that there is no closed-form solution for controlling them. This is ascribed to the following problems:

1. The inertia frame lacks fixed points, thus causing the humanoids to be *underactuated* systems. Inherently, at each contact point, a conversion from internal joint forces to external reaction forces is needed by the humanoids interaction with its environment[6].

2. Moreover, humanoids are multi-body systems with numerous “degrees of freedom” (DOFs) (usually over 20 joints). As such, they have frenzied dynamics, thereby requiring a complicated coordinate frame handling [6].

3. Humanoids are *structure-varying* systems, i.e. the link connectivity of the system changes with contact state throughout the interaction of the humanoid with its environment. Indeed, humanoid bipedal locomotion contains three various kinematic chains. Dealing with such situations in a conventional way requires the robot to plan all potential link structures beforehand and shift between them while executing [7].

Furthermore, achieving high-level behaviors and low-level dynamic stability simultaneously increases the mentioned complexity.

3 Biped Walking Patterns

Trajectory planning is perhaps the single most important aspect of stable motion of biped robots. First, some basic constraints must be satisfied throughout the entire gait cycle: existence of the solution for inverse kinematics of the legs, limitations of joint angle ranges, limitation of joint angle velocities, etc. A tool has been developed to validate different planned motions of agents, against the agent model. This tool was very helpful for experimenting with the new legged spheres.

Second, some criteria must be followed in order to ensure a stable gait generation. In case of a static walking pattern, the center of gravity (COG) must be maintained inside of the support area. Static walking is easy to implement but usually unacceptably slow [8]. It seems that the agent is unable to use static walking with its current body structure; only 3 degrees-of-freedom in each leg and no means to produce torque in the upper part of the body has made the agent somehow inflexible.

But in dynamic walking, we take into account dynamic effects of the robot; thus the COG may lie outside of the support region during a gait cycle, without the agent losing its balance. A popular concept called Zero Moment Point has been used for a criterion of walking stability [9][10]. The ZMP is defined as the point with respect to which dynamic reaction force at the contact of the foot with the ground does not produce any moment. Currently all the calculations are done offline; and the agent needs the set of completely specified joint trajectories at runtime. But dealing with many difficulties (especially ball handling problems) needs real-time walking pattern generations. There have been many studies about real-time walking pattern generations [11][12][13][14]. We have plans to implement the Enhanced Inverted Pendulum Model [14]. But as mentioned above, implementing it with the current agent model, seems to be quite a challenging task.

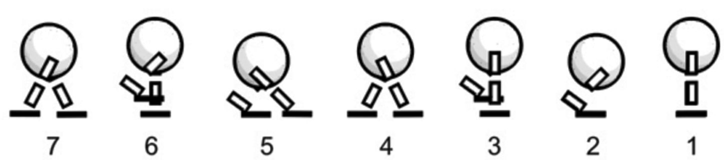

Fig. 1. The legged-sphere agent's complete gait cycle

4 Real vs. Simulated Robots

Developing autonomous robots is highly complicated and expensive, due to the following reasons. Firstly, this task requires a very calculated and thoughtful design; the developer has to decide on the type (biped, quadruped etc.), size, shape, weight, motor types, sensors and many more. Secondly, the components needed to build such robots are usually expensive due to their lightweight and hi-tech features, compactness, and materials. Thirdly, the building of such robots involves a vast interdisciplinary work in order to combine the numerous components of the robot. Usually, such work is a combination of many engineering fields: software, hardware, mechanical and bio-mechanics. Therefore, the development of such robots is still governed by full-grown research companies and a small number of universities world-wide. Besides the cost aspects compared to research on real robots, simulated robots have additional advantages which inherently derive from flexible nature of simulation. Primarily, simulation gives a complete and flexible control over the robot's model. In other words, the robots shape, weight, sensors, motors, and even appearance are modified straightforwardly to meet the researchers requirements, in contrast to physical robots adaptations which are very problematic. Moreover, the simulations flexibility is also expressed in the control over the robots virtual environment (Sometimes referred to as world). In most simulation software, it is feasible to adjust parameters such as gravity, friction, and mass of objects, or to add external effects such as wind, water, and forces. These capabilities are hardly possible in real life experiments, and if they are, it demands a great deal of effort and resources. Finally, a very important benefit entailed by simulation is to release the researcher from any mechanical or electrical (i.e. hardware) restrictions imposed by physical robots. This means that the researcher can test computation expensive algorithms which would require a lengthily run-time on a real robots microcontrollers (e.g. GAs). We plan to use *Webots* as a simulator for biped modeling. The mobile robotics simulation software named Webots enables convenient and rapid modeling, programming and simulating various types of mobile robots[2]. In the same paper, the author (and proprietor of Webots) summarizes the capabilities of Webots as follows which is also well-depicted in Figure 2:

Webots lets you define and modify a complete mobile robotics setup, even several different robots sharing the same environment. For each object, you can define a number of properties, such as shape, color, texture, mass, friction, etc. You can equip each robot with a large number of available sensors and actuators. You can program these robots using your favorite development environment, simulate them and optionally transfer the resulting programs onto your real robots.

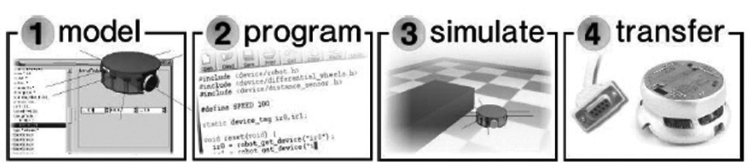

Fig. 2. Webots development cycle of robot simulation.

As the first milestone, we wrote a basic controller for QRIO robot model in Webots simulator using ZMP method for walking and also we have implemented a robot model for HOAP2.

5 Conclusion and Future Works

Defining control parameters (and setting intuitive values for some) for our current algorithms of generating walking patterns, becomes tedious and time consuming, and may not result in an optimum trajectory planning, especially when different gait speeds or highly accurate manipulation of legs are needed (e.g. driving legs for kicking the ball in any desired angle with any desired power). One possible solution is to obtain the optimal design through parameter search. It is possible to formulate the design of the biped controller and gait as a parameter search algorithm.

Another problem is the instability caused by the violent transitions between the different dynamic walking phases. There are many algorithms and designs [15][16] that can be applied to ensure a smooth transition between subsequent phases. Roadmap of RoboCup Soccer Simulation shows that next generation of soccer server is going to simulate humanoid robots. For realization of this aim, Zigorat team planned to work on biped locomotion in Webots simulator, and finally port it to Spark simulator.

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