Research on Key Techniques for Humanoid Robot Simulation and Physical Humanoid Robot*

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1 Research Motivation and Objectives

Our research objectives are to carry out the following researches in the frontiers of intelligent *simulation humanoid robotics and physical humanoid robotics*: perception and vision, biologically motivated computer vision, next generation evolutionary robots and their behaviors, image analysis and understanding, self-adaptive learning, and multi-robot coordination of *humanoid robotics* for RoboCup competition.

RoboCup is an international non-profit organization that promotes new technologies and advancements in robotics through an annual competition and conference. The roboCup competition is a high-technology confrontation activity which is rapidly developed in the world in recent years. It is a product uniting the sports with the high-technology. This competition involves the high-technologies of multi-disciplines, e.g. the integration of the robot, machinery and electronics techniques, the communication and the computer technology, the machine vision and the sensor fusion technology, the decision-making, and the intelligent control and so on. This reflects comprehensive strength in the information technology and the automation technology of a country. The robot soccer competition is a soccer game which is performed by a simulation robot and/or a physical robot, its rules of the game is similar to that of humanity's regular soccer game

To sum up, the roboCup competition is the frontier of the science and technology competition and the high technique resistance to take the athletics as a carrier, and an important method for training the scientists and technicians in IT fields. The roboCup competition simultaneously also is *a vivid window* to demonstrate the high technology research progresses and *a new way* to put the science and technology achievements into practice.

Humanoid robotics is a challenge project in the robot research. The problems posed by the development of humanoid robotics require a wide multidisciplinary

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approach, including philosophical, cultural and ethical considerations. The current achievements and the perspectives of *humanoid robotics research* aim at animating a cultural discussion on the philosophical and ethical issues related to the development of Humanoid Robots which can establish *a solid theoretical base* for further research.

At the RoboCup2006 in Germany, a majority of researchers would like to push the *3D simulation* towards *simulating humanoid robots*. It was considered by many as a necessary step towards the declared goal of the RoboCup initiative: to built a team of *fully autonomous humanoid robots* able to beat the *human soccer champion* by the middle of the 21st century.

2 Research Approaches

2.1 Theoretically integrative

Methodologically open, innovative, and critical. Our research approaches are not wedded to any single methodological or theoretical method. I will foster quantitative as well as qualitative studies. Our research will seek to use theoretically powerful concepts and frameworks to integrate discussion of issues and policy across all our areas of inquiry.

2.2 Technical approaches

This paper will be to extend the current 3D simulator of our university in order to simulate a humanoid robot. Furthermore, a controller for a walking motion of the simulated robot will be developed using evolutionary algorithms [3]. This will serve both as a proof-of-concept that the simulator can indeed be used for research on humanoid robots, as well as a starting point for the development of more controllers and behaviors that can be used in the actual soccer simulation. If time permits, an evaluation of the simulation accuracy could could be carried out, using the developed behavior on a real robot of the same type as the simulated one.

2.3 Developing Key Techniques to the Design of a Humanoid Robotics

- Walking controller development: implementations of biped walking behaviors including walking motions are currently mainly based on two approaches.
- Reinforcement learning, in which the system must take into account great time delays in the effects of its decisions.
- Self-equilibrium on humanoid Robot: static balance and dynamical balance.
- Tracking and recognition of the moving objects based on multi-cue stereo vision and motion vision.
- Perception: sensing, modeling of the world.
- Cognition behaviors: action selection, planning, learning.
- Multi-robot coordination: teamwork response to opponent, multi-agent learning action motion, navigation, obstacle avoidance.

3 Current Research Projects and their Description

3.1 Key techniques of autonomously computing-oriented evolutionary multi-humanoid robot behavior control based on knowledge

Autonomy oriented computation (AOC) refers to computation algorithms that employ autonomy as the core model of any complex system. They aim at modeling, explaining and predicting the behavior of such systems, which are hard to model using top-down approaches. Local interaction between the autonomous entities is the primary driving force of AOC. An abstracted version of some natural phenomenon is the starting point of AOC so that the problem at hand can be recasted. There are three different approaches of AOC and are applicable in different circumstances. We will propose some key technologies of autonomously computing-oriented evolutionary multi-robot behavior control based on knowledge [1-3]. AOC algorithms can be divided into three main approaches: a) AOC-by-fabrication–aims at replicating certain self-organized collective behavior observable in the real world. The operating mechanism is more or less known and may be simplified during the modeling process; b) AOC-by-prototyping–aims at understanding the operating mechanism underlying the system to be modeled by simulating the observed phenomenon, through modeling a society of autonomous entities; c) AOC-by-self-discovery–aims at the discovery of a solution by employing autonomy. The trial-and-error process of the AOC-by-prototyping AOC is replaced by autonomy in the system. Some evolutionary algorithms that exhibit self-adaptive capability are examples of this approach.

3.2 Coalition formation mechanism in multirobot system based on Genetic algorithm

As an important coordination and cooperation mechanism in multi-agent system, agent coalition exhibits some excellent characteristics and receives attention increasingly. An efficient algorithm is needed for this topic since the number of the possible coalitions is exponential. Genetic Algorithm (GA) has been widely reckoned as a useful tool for obtaining high quality or even optimal solutions for a broad range of combinatorial optimization problems due to its intelligent advantages of self-organization, self-adaptation and inherent parallelism [4]. This programmer proposes a GA-based algorithm with an objective to simultaneously meet the goals of high performance, scalability, and fast running time. A novel two-dimensional binary encoding approach and corresponding crossover and mutation operators are presented. Two valid parental chromosomes are certain to produce a valid offspring under the operation of the crossover operator. This improves the efficiency and shortens the running time greatly. The proposed algorithm is evaluated through a robust comparison with a heuristics. Experimental results will demonstrate that the algorithm proposed is robust, self-adaptive and very efficient.

3.3 Adaptive and robust techniques of a humanoid robotics for understanding environment by self-learning

Being able to understand the environment (usually time-varying and unknown a priori) is an essential prerequisite for intelligent/autonomous systems such as intelligent mobile robots. The environmental information can be acquired through various sensors, but the raw information from sensors are often noisy, imprecise, incomplete, and even superficial. To obtain from raw sensor data an accurate internal representation of the environment, or a digital map with accurate positions, headings, identities of the objects in the environment, is very critical but very difficult in the development of autonomous vehicles. The major challenge is from the uncertainty of the environment and the insufficiency of sensors. Basically there are two categories of techniques for handling uncertainties: adaptive and robust. Adaptive techniques exploit a posteriori uncertainty information that is learnt on-line, whilst robust techniques take advantage of a priori knowledge about the environment and sensors. We are mainly interested in model-based approaches. We are investigating techniques for automatic error detection and error-driven model adaptation or parameter adjustment. We are also developing multiple model approaches, including complex task decomposition, individual model design, and intelligent model switching or fusion.

3.4 Research on self-equilibrium on humanoid Robot

The robot self-equilibrium study research robot self- equilibrium study research roughly, the robot balance with double feet may be divided into following two kinds:

- Static balance: Refers is the quality center in the machine number of people projection area, like tumbler posture.
- Dynamical equilibrium: mainly divides into "static walks" and "dynamical walks" two kinds.

Static walking: The bodily center of gravity frequently puts in the foot heart scope walks the way.
Dynamical walking: When walks, the center of gravity can frequently surpass the foot heart the scope, by now had to borrow the bodily posture by smooth walking.
According to the human self-equilibrium operation pattern, we design a equilibrium system for a self-learning of a humanoid robot with biped walking, and enable the robot to maintain a static balance, also can maintain the dynamical equilibrium, moreover after a humanoid robot falls down to the ground, it also can automatically study how to crawl and stand, and do an injury to some part in robot body, also can study how to maintain the dynamical balanced function, and memory this stable mechanism. In other words, namely, a humanoid robot in any expected or unexpected situation, it all can restore the state of equilibrium immediately when a humanoid loses its balance. Besides the self-stable

design of the hardware, we will also establish a host control system like cerebellum function for detecting the current posture of the robot whenever necessary, and control the balance of a humanoid using software with the aid of to fuzzy control, machine learning and neural network methods or order it to make the correlation response movement.
This research focusses our attention on the human equilibrium ability. Much previous research on the robots was carried out in the unknown structured environments, so the researchers usually must have had a priori knowledge about the robot and its environment. These traditional methods for designing a robot have three serious problems. (1) The designers must have a priori knowledge of the robot and its working conditions and environment, i.e. must first establish some mathematical models of the robot and its working conditions. (2) This knowledge of the robot and its working conditions and environment must be constantly perfected, and therefore their hardware and software designs must also be constantly improved. These will greatly increase the engineering workload and the computing complexity. (3) The designers must carry out precise motion planning for the robot according to the robot's data and its internal environmental model, and so its self-adaptive ability to learn would get worse, and most does not have the self-learning function [5].
This research lays emphasis on self-learning function establishment of a humanoid also because of many freedoms of a humanoid robot, the movement complex, the dynamic equation not easy to be establish, therefore we use fuzzy control and fuzzy learning in view of an unknown environments of the controlled body pattern. Because biped walking is to study the humanity walk, naturally how to walk is inspired from the humanity, and further enable the robot to walk stably and in balance.

4 Expected Research Achievements

- Using online learning to analyze the opponents behavior;
- Walking controller development: implementations of biped walking behaviors including walking motions are currently mainly based on two approaches.
- Generating walking behaviours in the legged robots and a precise dynamics model of both the environment and the robot are needed to generate a stable walking behavior with self-adaptive learning function based on neural network, evolutionary computation and genetic algorithm;
- Our research will investigate how mechanism design and auction-based techniques can be used for decentralised control applications in general and data fusion and multiagent systems and in particular vision science, 3D computer vision, the cognitive neuroscience of visual shape recognition, next generation evolutionary robots and their behaviors, automated learning and knowledge discovery, image understanding, and intelligent and fuzzy control;
- Our work will be published in international journals of high quality. I will attend important conferences, give some seminars, deliver some lectures, and help students improve their doctoral dissertations.

5 Conclusion

- For the robot model to be simulated, a robot could, for instance, be designed and modeled *from scratch*. This would have the advantage of having full control over the design process and the resulting properties of the robot. However, designing a humanoid robot that can actually perform dynamically stable walking is a very difficult and time consuming task of its own.
- As the evaluations of the individuals in the genetic algorithm have to be evaluated in a computationally expensive simulation, it seems to be reasonable to make use of informed operators. These operators are biased towards the more favorable solutions in the search space and can lead to desirable solutions much faster than simple uniform crossover and mutation operators, especially if only a small number of generations can be evaluated (as in this case). Therefore the parameters of the GA (like mutation rate, crossover rate, selection scheme, replacement policy, and the fitness function) have to be chosen carefully [1]. Active diversity monitoring and management might be necessary.

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