Tao-Pie-Pie: Humanoid robot

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Abstract. This paper describes the design and implementation of TAO-PIE-PIE, a small humanoid robot.
The robot TAO-PIE-PIE is used as a vehicle for research into control of complex robotic systems with many degrees of freedom.
The focus of the research has so far been on the implementation of different walking gaits as well as learning of robust and versatile gait patterns.

1 Introduction

This paper describes TAO-PIE-PIE, a small humanoid robot designed by us at the University of Auckland. The mechanics of the robot were designed in conjunction with Dr. Nadir Ould Kheddal's group at Temasek Politechnic, Singapore.Fig 1 shows a frontal and side view of TAO-PIE-PIE.

TAO-PIE-PIE is the third generation of humanoid robots developed in our lab. The first two humanoid robots RX-78 and Zaku (see Fig. 2) were both based on commercially available model figures. Both model provided important stepping stones and insights into the design of a small humanoid robot.

2 Design Goals

Cost was an important design criteria in TAO-PIE-PIE's development. Previous experience has shown us that the use of commonly available cheap components does not only help to keep the cost of a project down and the Head of Department happy, but it also has lead to the development of novel, versatile, and robust approaches to problems in robotics.

For example, most teams in the small sized league use a camera mounted directly overhead. Since the viewing field is limited with a standard lens, most teams purchased wide angle lenses and expensive cameras. In contrast, our small size league team, the All-Botz , mounted the camera with a side view. This made the vision problem much harder and required the development of more complex and robust camera calibration routines. However, this effort is now paying off since the development system is flexible and robust enough to handle the newer larger playing fields introduced in 2002 as well as even larger playing fields planned for the future.

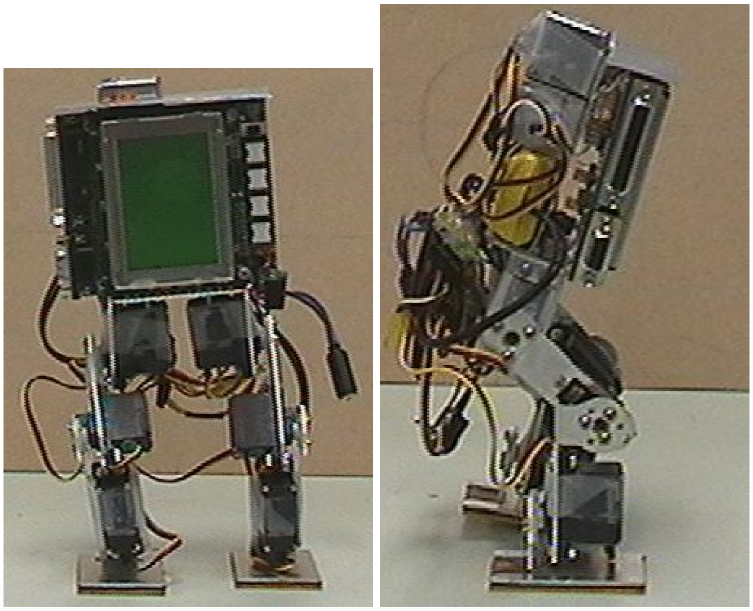

Fig. 1. Front and side view of Tao-Pie-Pie.

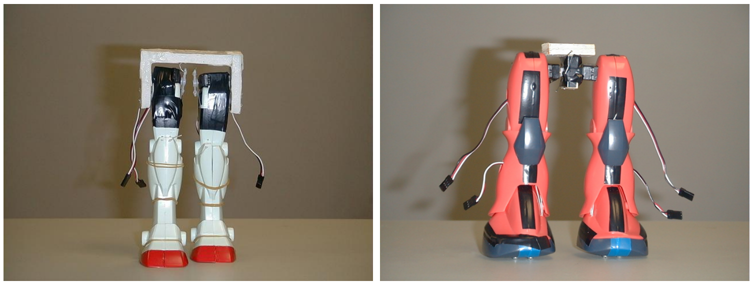

Fig. 2. Front and side view of Rx-78 and Zaku.

The actuators and sensors consist of widely available servos and gyroscopes for remote controlled cars and helicopters. The Eyebot controller was chosen as computation platform, since it is relatively inexpensive, yet powerful enough to provide vision information.

3 Walking Pattern

Controlling the walking stability is a problem. We have to keep the COM within the supported area. By using a divide and conquer technique, we divide the walking pattern into six phases, three for each leg.

Thus, keeping the static balance at the end of each phrase become feasible and the transition between each phase are closely related (COM lies within the tract between the two phases).

By using the Gyroscopes, we can determine which axis is currently turning. This helps us determine abnormal behaviors occur during the transition between each phase.

This feedback allows us to move into a different phase if the robot fails to perform a particular phase successfully. For example, sometimes instead of moving the leg forward, the robot will fall unto the leg too early. This abnormality can be detected by the gyroscopes and Tao-Pie-Pie will terminate the current pattern early.

Furthermore, we intend to apply reinforcement learning to the walking pattern algorithm using the feedback from the gyroscopes as reinforcement signal. If a gyroscopes notices that a phase has been completed successfully, it will reward the current parameter settings, otherwise the current parameter settings will be penalized. This means that in the future, the robot is more likely to perform the successful parameter settings.

4 Inverse Kinematics

Inverse Kinematics allow us to compute the correct joint angle to position a robotic link at a target position. It is an important aspect since the most difficult problem to make the humanoid walk is stability. After working out the center of mass, we need to keep the COM within the supporting area. By controlling the joints angles, we can control the stability during the motions.

To keep the humanoid balanced, we must keep the center of mass within the supporting region during all pahses of the walking motion. We manipulate the Inverse Kinematics of the robot in order to grant a better view on how much actuators angles can be.

$$\theta_2 = \frac{\cos(x2 + y2 - L12 - L22)}{2L1L2}$$

$$\theta_1 = \frac{-(L2 \sin(2)x + (L1 + L2 \cos(2)y)}{(L2 \sin(2)y + (L1 + L2 \cos(2)x)}$$

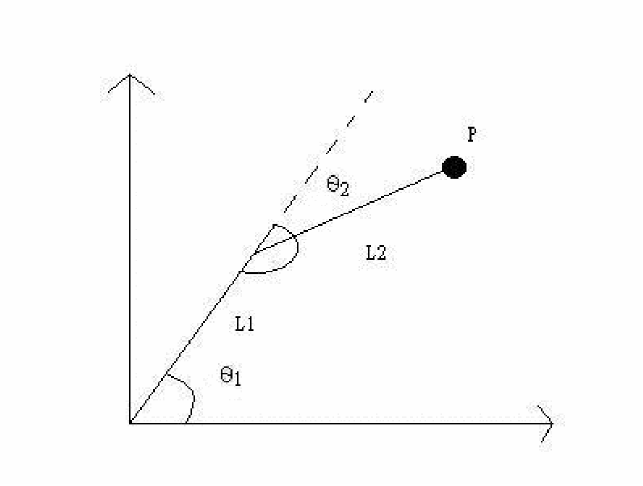

Fig. 3. Inverse Kinematics problem depicts the robot. P, represent center of mass. $L2$ - hip joint link, $L1$ - knee joint link.

5 Conclusion

When comparing our model with other teams, it is obvious that our model is much simpler and much less expensive. Tao-Pie-Pie follows the same philosophy as the All Botz (global vision F-180 league), the 4 Stooges (local vision F-180 league team) , and the Keystone Fire Brigade (Rescue league).

This year is the first year that we enter the humanoid competition. The goal for us this year is to compete Tao-Pie-Pie against other robots. Hopefully, this will allow us to find out the weakness of our approach and present us with opportunities for improving our design.