Single Camera Depth Estimation in Humanoid Robots using Head Movements

The FP7-funded RoboSkin project has the goal of creating a flexible skin with tactile sensing for humanoid robots. This skin and the associated software will be designed to improve the functionality and safety of a robot operating in a busy environment and interacting with humans. Some of the functions that will be built-in to the software include tactile gesture recognition and production, and protective reflex actions. The second part of the project goal is creating generic solutions, so that hardware and software created in the course of the research will be usable across a range of humanoid robots.

Our work at the Robotic Intelligence Laboratory covers the two areas of the additional software functionality mentioned above. My PhD in particular has the goal of creating generic, protective reflexes for humanoid robots. These will prevent damage to the robot and its surrounding environment in the case of an unexpected and potentially harmful contact, and also to prevent the unexpected contact from stopping the robot completing its task.

Robotic reaching has been chosen as a good initial scenario to develop these reflexes. During the reaching task, there is the potential for the robot to encounter unexpected obstacles on its reaching trajectory. These could be objects that have not been identified with the robot's vision system, or a dynamic obstacle such as a bump or a poke from another robot or nearby human.

The initial phase of this work will involve implementing a reaching learner on our research robot. The learning mechanism currently under investigation requires the robot to learn the motor relationships between the camera and the head and arm motors. As a part of this, it is necessary for the robot to calculate the distance to an object, such as its own hand or the reaching target. As the robot used, a Nao humanoid robot from Aldebaran Robotics, only has a single video camera, this cannot be done with the usual stereoscopic techniques.

Instead, an investigation has been made into using head movements to estimate distance. Recording the position of a target object from two separate viewpoints allows the distance to the object to be calculated using parallax.

During this investigation, the accuracy and consistency of this method was tested. A distinctive marker was fitted to the robot's hand to provide a target object, and the distance to it was measured ten times using head movements with the hand held in a fixed position. During each measurement, the robot first located and identified the hand marker, and recorded the position within the camera's field of view. After turning the head to one side, the marker was again identified and the new position recorded. The distance to the marker was then calculated using an explicit formula, in terms of the offset of the camera plane from the axis of head rotation. Vision processing was provided by OpenCV libraries implemented on the robot.

To provide a more accurate reference value for the distance, a second calculation was done, using a hard-coded value of the diameter of the marker and the measured value of the diameter from the camera.

The results of this experiment showed that head movements provided a consistent measure of the distance, although they also showed a relatively constant offset from the reference measurements. This could have been caused by a number of things, including an inaccurate measurement of the distance from the camera plane to the axis of rotation.
Further work will eliminate this reliance on a robot-specific measurement and an explicit trigonometric formula. This will be done by expressing the distance to the target object only as the change in angle created by moving the head. As this angle will be proportional to the distance, and as the reaching learner works independently of any explicit knowledge of the robot's kinematics, the end result is a generic reaching algorithm for single-camera robots.

For further description of the experimental set-up and further work, including pictures and videos, please visit my webpage at: http://ril.newport.ac.uk/Palmer/index.htm