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DREAMTEAM 99: Team Description Paper

ISI-DreamTeam99

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1 Philosophy and Goals

Our primary goal in the Robocup project is to build autonomous physical robots that can function robustly in a challenging environment. Obviously, this implies two things about our robots:

Requirement 1: They must be autonomous. Requirement 2: They must be robust.

These requirements have significant implications on the methodology we use to build and program our robots. In particular, Requirement 1 implies that processing must be distributed and on-board. No remote computing or centralized control is allowed. Requirement 2 implies that algorithms and hardware must be simple enough to guarantee reliability. Indeed, a guiding philosophy in building these robots is to favor robustness over sophistication. Adhering to the requirements outlined above, our efforts can be decomposed into three specific specialties; hardware, vision and learning. Section 2 below describes the hardware of our physical robots, section 3 describes our vision system and section 4 describes learning. Section 5 has a brief description of our soccer playing algorithm.

2 Hardware

Our robots are constructed from scratch and by our team. The flexibility to modify our custom-built robots gives us an added dimension for experimentation. As we learn more about what capabilities are needed by an autonomous physical agent interacting with its environment, we are able to easily adapt and extend our custom-built robots. For example, in the past two years, we have been able to add dual cameras, replace motors, and redesign the base. The next section describes the hardware of our robots in detail. The base of each robot is a modified 4-wheel, 2x4 drive DC model car. Specifically, we have lowered and widened the base for added stability. The wheels are independently controlled, allowing in-place turning and easy maneuverability. We have replaced the stock motors with stronger, heavy-duty motors to support the increased weight of the car. Mounted above the base is an on-board computer. It is an all-in-one 133MHz 586 CPU board extensible to connect various I/O devices. Attached to the top of the body are twin commercial digital color QuickCam cameras made by Connectix Corp. One faces forward, the other backward. Also, we have affixed fish-eye lenses to each camera to provide a wide-angle view of the environment. The two drive motors are independently controlled by the on-board computer through two serial ports. The hardware interface between the serial ports and the motor control circuits are custom built by our team. The images from the cameras are sent into the computer through a parallel port. On board are three batteries, one for each of the two motors and one for the CPU and cameras. This year, we plan to incorporate additional hardware. In particular, we are going to extend the sensory capabilities of the robot by adding touch sensors to the body. This will allow the robot to avoid obstacles more effectively. Also, we are going to add shaft encoders. These devices allow the robot to measure the actual revolution of the wheels. We hope this will allow the robot to move about more accurately.

3 Vision

We view color-based vision as one of salient challenges in the Robocup initiative and one of the scientific issues on which we intend to focus. Building an accurate, reliable vision system that can work under a variety of conditions is one of our team's primary goals. We are continually improving this component of our robots. The following describes our current vision system. Our vision system is a custom-built, specialized software component developed specifically for detecting balls, goals and other robots. Visual information is extracted from an image of 658x496 RGB pixels, received from the on-board camera via a set of basic routines from a free package called CQCAM, provided by Patrick Reynolds from the University of Virginia. Since the on-board computing resources for an integrated robot are very limited, it is a challenge to design and implement a vision system that is fast and reliable. In order to make the recognition procedure fast, we have developed a sample-based method that can quickly focus attention on certain objects. Depending on the object that needs to be identified, this method will automatically select certain number of rows or columns in an area of the frame where the object is most likely to be located. For example, to search for a ball in a frame, this method will selectively search only a few horizontal rows in the lower part of the frame. If some of these rows contain segments that are red, then the program will report the existence of the ball. Using this method, the speed to reliably detect and identify objects, including take the pictures, is greatly improved; we have reached frame rates of up to 6 images per second. To increase the reliability of object recognition, the above method is combined with two additional processes. One is the conversion of RGB to HSV, and the other is "neighborhood checking" to determine the color of pixels. The reason we convert RGB to HSV is that HSV is much more stable than RGB when light conditions are slightly changed. Neighborhood checking is an effective way to deal with noisy pixels when determining colors. The basic idea is that pixels are not examined individually for their colors, but rather grouped together into segment windows and using a majority-vote scheme to determine the color of a window.

For example, if the window size for red is 5 and the voting threshold is 3/5, then a line segment of "rrgrr" (where r is red and g is not red) will still be judged as red. Object's direction and distance are calculated based on their relative position and size in the image. This is possible because the size of ball, goal, wall, and others are known to the robot at the outset. For example, if one image contains a blue rectangle of size 40x10 pixels (for width and height) centered at x=100 and y=90 in the image, then we can conclude that the blue goal is currently at 10 degree left and 70 inches away. A significant drawback of our current vision system is its sensitivity to lighting conditions. Its parameters must be hand-tuned to a specific environment and this is a time consuming task. We are currently exploring more automated approaches that will reduce this burdensome task.

4 Learning

Any robot situated in a dynamic environment must be able to discover new things at run-time. We view autonomous learning as our holy grail and the dream that we are striving for. We also consider it the most difficult scientific issue. There are many well-known learning algorithms that work well in simulations or on a desktop, but what happens when you attempt to run these algorithms on a physical, situated robot? In our Robocup project, we have found that there is a large gap. In particular, we found that our efforts in learning have been limited by the previous two areas, hardware and vision. But we feel that we are finally beginning to achieve a critical mass in those areas to allow implementation of on-board learning algorithms. Some of our team members are actively involved in research in the field of multiagent learning and our team has significant expertise in the area of agent learning. We are trying to apply this work to our physical robots as a validation of the research.

5 Programming Approach

Our robotic soccer team consists of four identical robots. They all share the same basic hardware, but they differ in their behavior programming. We have developed three specialized roles; the forward role, the defender role and the goalie role. Each role consists of a set of behaviors organized as a state machine. For example, the forward role contains a shoot_ball behavior, dribble_ball behavior, a search_for_ball behavior, etc. The state transitions occur in response to percepts from the environment. For example, the forward will transition from the search_for_ball behavior to the shoot_ball behavior if it detects the ball and the goal from its sensory input. At game time, each robot is loaded with the program for the role it has been assigned. Note that each robot has the integrated physical abilities to play any role (i.e. detect_ball, move_forward, turn, etc...). We feel this is a natural, flexible, efficient approach to programming the robots to play soccer.

6 Conclusion

In summary, we have stated that our primary goal is to build autonomous, robust physical robots. We aim to accomplish this goal by focusing on three important areas; physical hardware, robot vision and agent learning. We view Robocup as an exciting, strenuous testbed for our project and hope to prove the viability of our ideas and approaches in the soccer tournaments.