# Computational Soccer Architecture

McGill Reddogs

July 21, 1999

**Abstract**

The approach of the McGill Red Dogs Sony Legged Robot system for soccer competition is described. A robotic system capable of playing soccer has many requirements that need to be met. Any soccer strategy is only as good as it can be executed on the underlying mobile platform.

Our approach uses customized ambulation and vision to achieve dynamic localization and global map maintenance. This global map will provide information to modify a behavior state-transition engine as the match evolves. Behavior modes are switched on-the-fly to best suit the conditions that are detected, and to modularize design.

## 1 Introduction

Any soccer strategy is only as good as it can be executed on the underlying mobile platform. The approach adopted was largely aimed at having a strong flexible mobile robotic core abilities for use to achieve relatively simple short term goals. A process timing kernel has been developed to allow for the parallel execution of these systems together with the behavior mechanisms in a manner that allows for custom dedication of computing resources.

Robust locomotion and vision systems run concurrently and combine to give robust estimates for higher level behavior despite noisy measurements. Locomotion is scalable and capable of stable turning over a wide range of radii. Vision is based on probabilistic scene reconstruction using various voting heuristics.

Another important aspect of our research relates to the recognition of context to drive the high-level behaviors of agents. A state-based modeling system is used to anticipate the development of the game. This includes a model of both the motion and position of other agents, as well as a simple model of their intentions. This information provides sufficient knowledge for an agent to adopt one of several alternative roles, for example offense, defense and blocking.

## 2 Infrastructure

The use of a custom designed process control kernel allows for concurrent execution of computational processes. Implementation of this system was undertaken to allow for optimal distribution of computational resources. Also the advantages provided by the ability to control execution more than justify the use of this real-time task scheduling abstraction layer in our system.

Larger processes like the state-transition engine, localization, vision and ambulation run concurrently through the control afforded by the process kernel. Moreover distribution of resources can be easily modified.

The maintenance of a global map is assisted by the lower level capabilities of the system. Fusion of sensor data from feature extracted vision and filtered odometric estimates combine to place each robot, and objects that it detects in a global map.

Reasonably precise internal robot geometry is used to provide a position estimation system for propagation from local to global map coordinates. Relative estimates from the vision system are also transformed to global coordinates for object tracking and map registration.

Localization is done in a global map according to corrected odometry and vision based methods. Known features are extracted from the vision system and merged with known estimates from the map. Partial scene reconstruction is done to register sensor detected objects with the global map. Any ambiguities in this object registration are resolved in order to maximize global map coherence.

## 3 Ambulation

Custom ambulation has been achieved for the 4 legged robot in order provide a responsive and tunable mechanism for locomotion. We used closed loop ambulation for stability that can be scaled for dynamic velocity updates. Development of the ambulation system has allowed the opportunity to provide better feedback to the odometry estimate system and to provide greater flexibility in locomotion with respect to robot speed and cornering capabilities.

## 4 Vision

We have a 3 tier custom vision system for image based feature extraction. Raw images are read from the camera and recombined for color segmentation. A Bayesian decision voting technique is used to determine connected components from the color space. A space reduction is performed using smoothing and topological information. The subsequent scene contains information on detected features, along with a confidence measure, and distance estimates for each feature based on a perspective projection, and feature attributes.

Feature detection allows for learned landmark tracking which is useful for global map registration. The system is flexible and robust enough to compensate automatically for variations in lighting conditions and environmental artifacts, such as mild specular effects. The system is capable of processing roughly 12 frames per second.

# 5 Strategy

The high level behavior of the robot is guided by decisions made from the state of the global map with the use of a finite state machine. Short term behaviors include goal attempt, attack/ball handling, ball interception and defense modes. Medium term behavior is based on a finite state transition model for choosing between appropriate behaviors based on information from the global map and the associated lower level detection functions. Long term behavior is governed by asymmetric mode switching between agents whose large scale behaviors differ. The ability to switch between modes of behavior is provided, although the transition trigger is dependent on specific configurations of a soccer game, that may not occur in every game.

Care has been taken in these behavior models to make use of implicit communication between robots to avoid destructive behavior such as agent clustering. The state based modeling system is used to anticipate configurations of the game including the behavior of other agents on the field. This includes a model of both the motion and position of other agents, as well as a simple model of their intentions.

# 6 Conclusion

We have described the aspects present in our approach to the Legged Robot category of the RoboCup Robotic Soccer Initiative. We have stressed a reliance upon the underlying hardware and the robustness of the lower level tasks. The combination of solutions to these core problems will result in a tunable behavior oriented robotic soccer system.

To combine lower level aspects of a robot, we implement a custom process synchronization kernel to allow precise control of these aspects. The lower level tasks are tasks such as ambulation, vision, path planning and mapping. This kernel allows for efficient distribution of available resources to the running system.

The combination of control over the underlying tasks and the state transition graph will result in a tunable adaptive behavior. This adaptive behavior is blended with any advantage afforded by the known constraints of the environment.

# References

[1] G. Dudek, Paul Freedman, Souad Hadjres, *Using multiple models for environmental mapping*, Journal of Robotic Systems, 13, 8, Aug 1996, pp. 539-559.

[2] R. Smith and P. Cheeseman, *On the Representation and Estimation of Spatial Uncertainty*, vol. 5 International Journal of Robotics Research, 1986.