

A 3D Robot Simulation for Education

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Abstract

This paper describes the work-in-progress of creating an artificial 3D environment and robot, suitable for educational simulation. A visual 3D vehicle robot, equipped with a monocular camera navigates in a physics based 3D environment, with some artificial intelligence capabilities. Students can interact with the robot, add new objects and set the robot various tasks. This multimedia tool is designed for students with very little experience with robotics, and aims at giving students unlimited access to a relatively sophisticated robotic system, incorporating artificial intelligence, with an extremely low cost compared to using real robot systems. Our current version of the simulation software has been designed to perform three main tasks, *play soccer*, *avoid object*, and *wander*. The simulation is being designed to closely resemble its real-world counterparts, and we hope, will ultimately become a powerful research and development tool.

CR Categories: H.5.1 (Information Interfaces and Presentation): Multimedia Information Systems; I.2.9 (Artificial Intelligence): Robotics

Keywords: robot, simulation, 3D, artificial intelligence, education

1 Introduction

Robots are expensive, fragile and require careful maintenance, and working with them requires a good understanding of their many technical aspects and internal workings. This dictates that the work in this area is confined to the academic and research domains, precluding most students from having “hands-on” interaction with these systems.

We have set out to create a robotic simulation in order to introduce young students to the concepts of robotics and AI. The main development framework we have chosen for this project is *Macromedia Director Shockwave Studio*TM 8.5, which facilitates the creation of a sophisticated multimedia user interface and an accurate 3D environment. In addition, using *Director*TM simplifies the task of publishing our software on the World Wide Web.

The user interface has been designed to allow objects and robot models to be controlled in the 3D environment, and to allow students to create and manipulate their own AI, giving unlimited access to a realistic robotic simulation.

2 Background

Robots are interesting platforms to demonstrate the concept of AI to students or the wider community. There has been some work in providing educational robotics, such as in [Nou02] and [Pau02+].

However, both systems use real robots which have several disadvantages, including non-deterministic behavior (unpredictable behavior due to various software or hardware errors) and the complexity of the systems (most robots contain complex hardware and software). Some similar robot simulation projects exist (e.g. [Buchmann+]). However we have chosen to develop a system specifically to leverage our existing robotic research, helping students to understand and develop concepts that are otherwise difficult to teach.

3 Project Description

This project requires a realistic 3D simulation of a robot soccer physical environment (similar to [Kit95+]). The main development platform being used is *Macromedia Director*TM 8.5, incorporating the *Shockwave 3D*TM render engine, and the *Havok*TM real time physics module (a *Director* “Xtra”). This platform is able to operate with either *Microsoft DirectX*TM, or *OpenGL* graphics support. All 3D models were generated in *Discreet 3D Studio MAX*TM, and imported into the *Macromedia Director*TM package.

3.1 General System Design

Using the *Shockwave 3D*TM approach has many advantages for this kind of project, including the ability to generate cross-platform executables (Win32, MacOS) and the ability to utilize the *Macromedia Shockwave*TM browser plug-in to publish the application on the World Wide Web. To increase flexibility and performance we have developed a *Director*TM Xtra (C++), which externalizes most of the CPU operations.

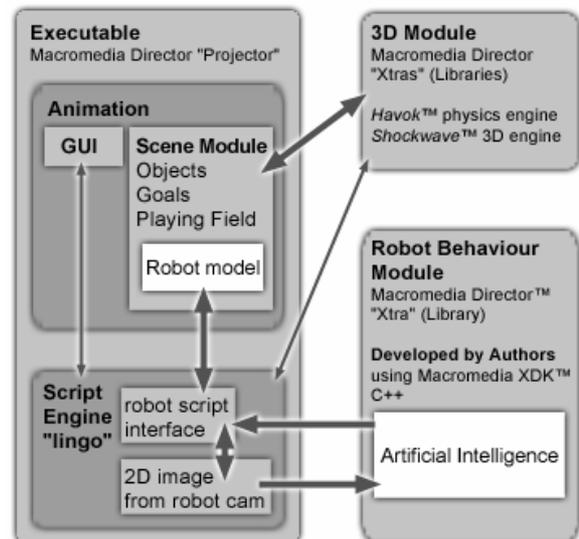


Figure 1 - Robot system design – Phase One, utilizing Macromedia Director Shockwave 3D and a Robot Behavior module

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The application utilizes the standard *Director*[®] framework to handle the GUI interactivity and animation, while our custom “Xtra” (a dynamic link library) receives 2D bitmap information from the parent *Director*[™] application, performs image analysis and AI, and returns to the Scene module an impulse value to be applied to each wheel of the 3D robot. The program has also been written to allow fine tuning of the main physics parameters including: friction, restitution (“bounce”), mass, wheel “motor power” (max impulse), color and lighting conditions

The robot identifies the ball and goal object based on their shape and color. Users can modify these parameters to optimize the ability of the robot to perform satisfactorily at these tasks. Work is currently underway to allow users to add various obstacles into the playing arena, and to add object avoidance behaviors.

3.2 Scene Module

The *Scene* Module is responsible for interfacing with the GUI (buttons and feedback), the *Shockwave 3D*[™] module (3D environment), the *Havok*[™] engine (physics and collision detection) and the *Robot behavior* module (image analysis and AI).

At regular intervals (currently 5 times per second) it generates a bitmap derived from the 3D camera located on the front of the robot model, and passes (a handle to) this to the *Robot behavior* module. The *Robot behavior* module simply returns an integer impulse value for each wheel. The *Scene* Module then calculates the appropriate vector impulse to apply to each wheel using the set parameters. The *Scene* Module also handles the user events generated by the GUI, and responds accordingly.

In addition, we are currently designing and implementing a GUI to allow students to program their own robot AI behaviors. We anticipate this will use a combination of the drag and drop approach (similar in concept to *Lego MindStorms*[™]), and a text window to allow more sophisticated programming control. These behaviors will be interpreted by the *Scene* Module and run as *Director*[™] *Lingo* script.

3.3 Robot Behavior Module

The robot captures a 2D image from its environment, just as the real robot does. It then uses image analysis and AI incorporated within the *Robot behavior* module to react. Currently the robot is designed to perform three main tasks: *play soccer*, *avoid object*, *analyze object* and *wander*. When there is no task, the robot just wanders around the scene. When a ball object is created and dropped in the scene and seen by the robot, the robot will then play with it, and kick it into the goal object, when this is also created in the scene.

3.3.1. Image Analysis

The vision system uses the Region Growing [Bre99] algorithm to segment the image into constituent regions. Contiguous pixels that match to the same color range are considered to be in same region and given a unique label. These are then used to match to known objects. Instead of scanning every pixel, the program scans a fixed number of columns and rows (e.g. 2,4...) of pixels.

Color space

For simplicity, the current vision system simply uses the RGB color space to match the object by comparing the pixel with a predefined Min and Max RGB values. Lookup tables may be used to speed up the comparisons of the color matching. The environment and objects may contain texture to provide realistic visual depiction.

3.3.2. Object Detection

To detect the objects, some analysis is performed on the resultant image segmentation regions. The main object will be separated from its environment based on the color distance and shape. If the shape is a circle, the robot will identify this object as a ball. Similarly the default goal shape is identified. For other shapes, the use of a shape descriptor will be used.

3.4.3. Play soccer

In order for the robot to play soccer, apart from identifying the ball and the goal, it also needs to know the direction and path of where it should go. Since the ball is constantly moving, in order to approach the ball, the angle between robot orientation and a line from the robot to the ball must be known. Several motion patterns are implemented including move directly to the ball, turn and drive circular path to the ball.

4 Conclusions and Future Work

The current version of our 3D robot simulator includes simulation of robot soccer, which is the subject of an ongoing research program within our University. We have specifically designed this simulation application to allow us to incorporate existing AI programming developed for the “real” robot systems. Subjective evaluation of the simulation indicates we have been successful in achieving a reasonable approximation of the robot soccer environment using a real robot, and feel further manipulation of the simulation parameters (especially physics and collision detection) will bring the simulation closer to replicating the real world.

Our short term goals for this project include creating an effective set of interface tools (and supporting code) to allow students and researchers the ability to create and save their own AI modules. Planned future additions to the simulation include the “modeling” of Infra-red sensors to measure distance from robot to 3D objects and the ability to include multiple robots with the same or differing AI into the 3D environment. This will allow the demonstration of soccer games, and importantly, the ability to debug AI code before testing the program in the real robot system.

We believe this project has potential to help undergraduate students develop an understanding of the central concept of robotics and AI. With further development, we hope it will also become an indispensable research tool, allowing robot designers and programmers to make their mistakes in a virtual world.

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