Rochester Institute Of Technology
Multi-Disciplinary Robotics Club
presents

AMOS III

TEAM MEMBERS AT COMPETITION

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1.0 Introduction

The Rochester Institute of Technology (RIT) Multi-Disciplinary Robotics Club (MDRC) is pleased to announce that we will be returning to the 17th annual IGVC competition for the fourth year in a row. Like last year, we will be using our AMOS III competition platform, and we have added several new hardware and software innovations, including a new vision algorithm.

2.0 Innovations

2.1 Improved Testability and Integration

After reviewing last year's progress, design decisions, and the many lessons learned from competition, MDRC decided to make testing and integration a very high priority. Each algorithm was tested before and after overall system integration. To maximize performance at the competition, a full-scale test field was created to mimic the conditions of the actual course. This also included potentially more difficult versions of the course.

2.2 Player/Stage

Our former in-house hardware abstraction layer was replaced by Player/Stage. With the burden of developing and debugging a custom software framework lifted, our software developers were able to concentrate on higher-level tasks such as algorithm design, implementation, testing, and writing hardware drivers.

2.3 AI-Based Path Recognition

In previous years, visual path recognition proved very challenging for our team. This year we have decided to rely on an academic, statistics-based AI approach whereby our vision is resilient to noise and widely varying light conditions. The most important feature of our new vision algorithm is that it allows AMOS to learn from experience.

2.4 Improved Motor Control

A more simplified motor control system has been implemented using a small, off-the-shelf, embedded platform. Simple communication protocols between this controller and the main computer allow on-the-fly reconfiguration of controller parameters.

2.5 More Elegant Obstacle Avoidance

We replaced our previous obstacle avoidance algorithm with a simpler and more elegant alternative. This algorithm, named "artificial potential field" or APF planning, allows us to combine all of our sensor data into one generalized type. Through testing we found that it performs substantially better than previous algorithms.

2.6 Hardware Flexibility

AMOS III's hardware is used by our team in several events each year, some of which require additional torque and speed from the motors. In order to fulfill these requirements, we have implemented a combination of switches and relays which allow us to provide its the motors with either 12 or 24 volt power. During the competition our robot will only use 12 volt, which will force compliance with the five mph speed limit.

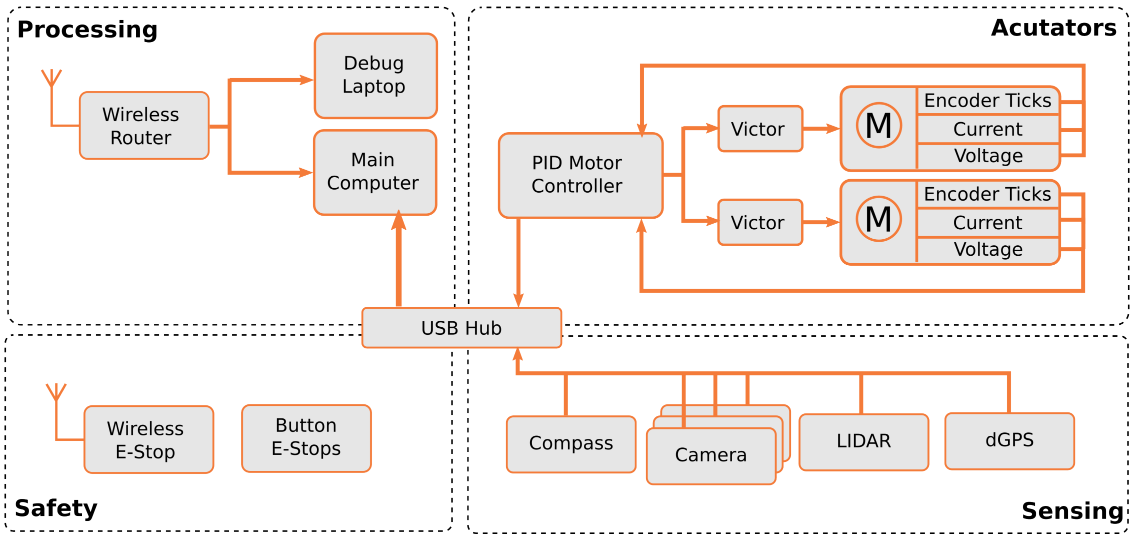
3.0 Team Structure

MDRC is a small, highly focused team of motivated students. Since our organization is multi-disciplinary, each team member brings his unique perspectives and talents. Our approach has been to distibute tasks to the team members most passionate about them. Since each member had a vested interest in the robot's success, they remained passionate and productive even through the most arduous tasks.

To ensure that each team member's work became integrated with the collective effort, work periods were organized in which team members were encouraged to coordinate individual efforts into their larger modules, discuss design decisions, to generate and receive feedback on new ideas, and to socialize.

4.0 System Overview

4.1 Hardware Systems



4.1.1 Electrical

A complete rework of the motor layer's electrical wiring was completed. Additional components in the motor layer necessitated a more structured method of wiring which is accomplished through wire harnessing and using enclosures for functional units of the circuitry.

Battery systems were completely rewired this year for better functionality and robust operation at both 12 and 24 volts. Two batteries are used for driving the motors and one large, high capacity battery is used for the top computing layers. Two relays are used to redirect battery power. The first cuts the connection to the batteries if any of the E-Stops are activated, and the second switches the two motor batteries between series and parallel connection (12 and 24 volts respectively). The flexiblity to switch between 12 and 24 volts is very helpful to make the robot a general purpose platform.

The motors, motor controller, and other control circuitry located in the lowest section of the robot is called the "motor layer." To maintain modularity, the only connections between the motor layer and the layers above is a USB cable and the E-Stop connector. Modularity between the top layers and motor layer is extremely useful during transportation and for debugging purposes; this allows us to split the robot into two halves which are seperately transportable.

Additionally, when wiring and debugging the motor layer, detaching the top layers exposes wiring for easy access.

4.1.2 Computing

The main computer is responsible for communicating with hardware and doing computations on raw data. Therefore, maximizing computing performance was a high priority this year. The table below summarizes the analysis used when buying the main computer:

Requirement	Satisfied By	Advantage	Disadvantage
High performance CPU	Intel Core 2 Quad Q8200	-Excellent performance, multiple cores. -Facilitates multi-threaded nature of Player/Stage	Comparatively high power consumption
High speed memory access	4 GB of DDR2 SDRAM (in four seperate sticks)	Fills all four motherboard RAM slots, allowing maximum simulataneous memory access	None
More than one USB bus	Motherboard with 3 USB buses	-High I/O count motherboard -Meets USB requirements -Form factor is well within shelving space	Comparatively expensive motherboard
Shock and vibration resistance	32 GB Solid state drive	-Unaffected by heavy vibration and shock -Extremely fast read and write speeds compared to conventional hard drive	Much higher cost per GB than conventional hard drives
High efficency power conversion	250W DC-to-DC convertor	- No need to convert from AC back to DC within the supply - Small	None

A laptop is connected to the top layer of the robot to act as a debug terminal and to interface with our main computer as a Player client. This laptop can be used to see data in real-time to help find and fix errors.

4.1.3 ◁Motion Control

An in-house motor controller was created to abstract the operation of the robot's movement. Closed loop motor control is accomplished using PID and optical encoders on both wheels. An RS-232 interface (connected via serial-to-USB converter) uses a simple protocol to communicate motion commands from the computer. The controller is capable of changing parameters such as the PID gains on-the-fly as well as report motor current draw and battery voltages.

The core of the controller is a robostix which is based on Atmel's ATMega128. Although the hardware is a commerically manufactured part, the robostix platform has broad open source support including the GCC toolchain. This provided an easy setup and integration process.

The low resolution optical encoders used in the PID control are simple, economical, and easy to use. Each wheel's encoder has two channels, each with a resolution of only six ticks per revolution. Despite this, the PID is still able to effectively control the motion. This reduced the overall cost and complexity of using more sophisticated sensors.

4.1.4 ◁Emergency Stop

The wireless E-Stop consists of a microcontroller and a simple 12 volt relay. This system utilizes one-way communication using an XBee wireless radio. The handheld unit broadcasts a special sequence of numbers to the robot. The microcontroller monitors the incoming transmissions to check for validity and timing. If the transmission ceases for more than 300 milliseconds, the robot's relay is deactivated which cuts power to the motor layer.

4.1.5 ◁Cameras

Three webcams are the visual sensors for the robot: one in the front and two on the sides. The two cameras on either side of the robot are pointing downwards at roughly a 60 degree angle. This enables us to see if there are any white lines immediately next to the robot. The camera in front detects obstacles and path lines.

4.2 Software Systems

4.2.1 Player/Stage

Player/Stage is a well-known and widely deployed hardware abstraction layer. We used this software's built-in drivers and our own custom drivers to communicate with hardware.

Several features built into Player/Stage have been invaluable. Specifically, its ability to record and replay data, as well as its facilities to run simulations, enriched testing and benchmarking efforts.

4.2.2 Path and Obstacle Recognition

We take an AI-based approach to the problem of image recognition. Using unsupervised learning, we apply statistical analysis to model segmentations of frames from course videos we recorded in previous years. The agent stores the statistical analysis and a human flags sections of this analysis. These flags tell the agent which types of data are interesting. Our Player client code asks the agent to prune white grassy lines from real-time video, and uses the locations of white lines as inputs to the obstacle avoidance algorithm.

For image segmentation, a custom implementation of Pedro F. Felzenszwalb's and Daniel P. Huttenlocher's 2004 publication "Efficient Graph-Based Image Segmentation" was implemented. This segmentation algorithm was chosen due its high performance and efficiency.

Data are extracted from every segmentation found and are used for identification. The features chosen to describe the regions from scenes at IGVC were average RGB color and texture (as described by color variance).

To create a model of the data, AMOS III uses Expectation Maximization (EM) to find a Gaussian mixture model. The Expectation Maximization algorithm finds the best description of data given a model - a statistical distribution which mathematically describes the expected properties of a dataset. For our mixture model, we've chosen to use multivariate (n-dimensional) Gaussian distributions.

The robot keeps a record of the mixture model it has created and uses it to identify objects in real-time video. Code for the competition uses the regions identified from the video and knowledge of camera physicality to judge the distance of objects.

4.2.3 ◁Obstacle Avoidance

We abstract knowledge of obstacle distances into force potentials. Obstacles detected closer to the robot apply greater forces pushing it away. All knowledge of the field at each moment is abstracted in this way. The robot reacts in real-time to instantaneous changes in its knowledge of the field. It is accelerated in a way determined by the magnitude and direction created by the sum of the abstract forces. The emergent behavior of this design is that it travels very closely to the path of least resistance, which is around and away from obstacles, and always in a general forward manner.

4.2.4 ◁JAUS

We use Jr. Middleware's open source implementation of JAUS SAE-AS4 standards in a custom Player driver and device proxy to realize JAUS compliance. The Player driver and device proxy break down JAUS communication into a simple API.

5.0 Bill Of Materials

Part	Manufacturer / Vendor	Part No	Qty	Unit Cost (Market)	Subtotal (Market)	Unit Cost (Actual)
Frame materials (steel channel)	Metal Supermarket	-	30. Ft	$100.	$100.	$100.
Frame materials (square aluminum extrusion)	Metal Supermarket	-	15. Ft	$75.	$75.	$75.
Misc. hardware	Various	-	-	$75.		$75.
LIDAR	SICK	LMS-291	1	$5000.	$5000.	$0.
dGPS	Trimble	AgGPS132	1	$500.	$500.	$0.
Digital Compass		CMPS03			0	
E-Stop related	Various	-	-	$80.		$80.
Motors			2	$500.	$1000.	$0.
Computer motherboard	EPIA	MII	1	$150.	$150.	$0.
Misc. connectors	Various	-	-	$40.		$40.
Solid-state storage	NewEgg.com	4GB USB Flash drive	1	$35.	$35.	$35.
Front webcam	Logitech	QuickCam Pro 9000	1	$80.	$80.	
Side webcams	Lego	Legocam	2	$30.	$60.	