EEL 5666

Intelligent Machines Design Laboratory

Summer 1998

Baby Boomer

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Abstract

The goal of this project is to design and develop an autonomous robotic vehicle that would be launched in a modified high-power model rocket kit. After launching, the robot must extract itself from the launch vehicle and perform a simple sequence of movements that would simulate exploring the landing area. The vehicle incorporates a variety of sensors that assist in the performance of these operations.

Executive Summary

The desired outcome of this project is a rocket-delivered robot that, upon landing, would release itself from the rocket and perform simple terrain exploration maneuvers. The robot is an original design that incorporates a Motorola MC68HC11 microcontroller and two servos to provide control and mobility. A variety of sensor systems were proposed to be incorporated on the robot. Several of these sensor systems were completed and utilized on the final system. The sensor systems researched are an altimeter, compass, orientation sensor, and bump sensor. One facet of this project was to design and construct a container that would carry the robot aloft and then, upon landing, release the robot so that it may perform maneuvers. The launch vehicle is a modified version of a commercially available medium-scale model rocket kit. The project was only a partial success in that while the major components were designed and/or constructed successfully however several key components were not completed in the allotted time which affected the robots ability to perform all the tasks originally envisioned.

Introduction

In the spirit of the recent Mars Sojourner project, I proposed to design and develop a much simpler, although similar, system for my project in EEL5666, Intelligent Machines Design Laboratory, during Summer Term 1998. Using a modified, commercially available model rocket kit, an autonomous robotic system was constructed that can be launched and upon landing, release itself from the payload compartment and perform simple maneuvers. The project consists of three main sub-systems; the robot, the payload mechanism, and the rocket. These components are discussed in detail in the remainder of this report.

Design parameters were dictated by class requirements and, for this project, by the Federal Aviation Agency. Class requirements include:

- Construct an autonomous mobile vehicle.
- The robot must include sensors, including a unique or novel sensor function.
- The robot must exhibit several behaviors.

Federal Aviation Agency restrictions are covered by the Federal Aviation Regulations section 101 which specify:

- Maximum launch weight of 1500 g.
- Maximum propellant weight of 65 g.
- 48 to 24 hour advance notice of launch with local ATC.

Additionally, the project was impacted by the drought-caused ban on fireworks. This ban restricted my ability to perform testing on the airframe.

Integrated System

Clearly this project is a multifaceted system consisting of a hierarchy of components. All of these components are interdependent on each other in order for successful mission completion. The system is composed of three main components that are the rocket, payload carrier, and the robot. The rocket is a modified P.E.M. Patriot scale model rocket kit. The modification consists of a redesigned payload container that is both large enough to contain the robot and includes a facility that will permit the release of the robot after touch down. The payload container, which was originally envisioned to be a mechanical system that would operate as desired, was eventually designed to incorporate an explosive charge that separates the nose cone from the payload compartment thereby opening the payload container and permitting the robot to exit the payload bay. The robot is the most complex system in this project. Consisting of a completely original design, the robot incorporates a microcontroller, servos, steering assembly, drive train, and sensor package.

Mobile Platform

There are three separate components that make up the platform. These are the robot, payload compartment, and the rocket. Obviously, the robot is the most complicated of the components but the other parts were nontrivial none the less.

Robot

The robot system is of an original design that is assembled on a 3.75” x 8” x 0.125” balsa wood base. Locomotion is provided by a RC servo that has been modified to permit continuous rotation of the drive mechanism that is attached through gears to a rear axle drive system. Directional control is implemented with an unmodified RC servo and a steering mechanism removed from a RC car. The servos are controlled by an MSCC11 single-board computer incorporating a Motorola MC68HC811E9 microcontroller operating in the single chip mode. The dimensions of the robot were dictated by the size constraints imposed by the dimensions of the payload container. The overall weight limit of 1500 grams also restricted the design of the mobile platform.

There are several main components that make up the robot. These are the base, the steering assembly, the drive train, and the electronics components. Overall physical dimensions of the robot were constrained by the size of the payload compartment. The rocket kit is based on 4 " diameter paper tubing, therefore the robot had to fit within this diameter. The 4 " diameter allowed for a wide enough base to construct a robot of reasonable size, however this restricted the size of the wheels that could be used. Finding the correct size wheels proved to be a non-trivial exercise. Initial testing was performed using 2" diameter wheels that are used in model airplanes, but these would not fit into the payload compartment. Finally a set of Lego brand wheels were recommended by MIL TA's, and they proved to be of appropriate size. It turned out that the thickness of the wheels was the 'critical' dimension.

The steering mechanism was the next component to be designed into the robot. I chose to use a stock steering mechanism that had been removed from a RC model car. Using this mechanism relieved me from the task of designing and constructing a steering assembly. Proper mounting of this assembly proved to be challenging and required numerous attempts in order to provide a suitable mount. Electronic control of the steering mechanism was provided by a RC servo. By sending the appropriate PWM signal to the servo, the microcontroller could control the direction that the robot traveled. Unfortunately, software development did not proceed to the point where the robot actually used the steering facilities.

The drive train was assembled around a 'hacked' servo and a 'home-brewed' rear axle. The axle, which had a gear attached, was removed from a toy car. The axle was mounted to the robot base with aluminum U channel. This channel was drilled such that ½" lengths of Teflon tubing were inserted into the channel. The Teflon was drilled to accept the drive shaft and acted as both a drive shaft mount and bearing. A gear removed from the toy car was mounted to the hacked servo that mounted to the robot so that the servo would drive the drive train.

Payload Compartment

The task of the payload compartment is twofold. First it must provide a safe container in which the robot rides during flight and, secondly, it must be able to open in some fashion such that the robot can extricate itself and begin its maneuvers. Originally I had attempted designs for a system that had mechanically controlled access doors or panels that would open to permit the robot to exit. Initial results suggested that a system such as this would require not only an exorbitant amount of effort to complete but would also weigh more than the maximum permitted weight alone. With this in mind I began to attempt to design a completely different system.

It is common practice in high power rocketry to use electronically ignited black powder charges to cause deployment of recovery parachutes. These charges develop sufficient pressures to cause separation of the rocket body, thereby releasing the parachute. I have modified this system in order to separate the nose cone of the rocket from the payload container such that the robot is then free to exit the payload bay. Since it seemed unwise to expose the robot to the extreme forces that are developed when the explosive charges are ignited, I designed a system that would protect the robot from direct exposure to the blast. This system incorporates a barrier that is inserted into the payload compartment between the robot and the separation charge. This essentially forms a second compartment in the payload section that is used to isolate the robot from the effects of the blast. The rockets' nose cone is at the other end of this 'blast chamber', but it is also attached to the blast barrier with an elastic cord. The blast barrier is not permanently attached to any part of the payload container. Therefore, when the charge is ignited, the nose cone is forced away from the payload section. Since the blast barrier is attached to the nose cone with the elastic cord, the forces that push the nose cone off the payload container also cause the blast barrier to be carried away from the payload compartment with the nose cone.

The blast charges are constructed from three components which are a ¾" length of ½" plastic tubing, an Estes ignitor, and ½ g of Pyrodex or 4f black powder. After inserting an ignitor into one end of the tubing, the tubing and ignitor are sealed at one end with candle wax. The Pyrodex is then poured into the open end of the tube, and it is finally sealed with cellophane tape. The ignitor is designed to be activated with a 6 volt signal. When activated, the ignitor wire heats up which in turn ignites a small amount of flammable material that is coated on the ignitor. This finally causes the Pyrodex to ignite thereby opening the payload compartment.

Fearing damage to the robot, all testing has been performed via a series of simulations. Initial testing used a simulated payload compartment and nose cone and the charge was ignited with standard launch controller. The next level of simulations used the 'HC11 processor in an EVBU. I wired a DIP relay and Sonalert in the prototype area of the EVBU and then wrote software that would fire the blast. Since I was not able to complete the altimeter, I have developed a simple timing algorithm that times out the anticipated flight time and then ignites the separation charge. The Sonalert is used to provide feed back as to the current state of the software. For the first 10 minutes, the software issues 3 second tones on the Sonalert. After 10 minutes have expired, the Sonalert is activated for 10 seconds. Then the relay is closed, which connects a 6-volt battery pack to the ignitor.

Rocket

Even though the rocket is assembled from a commercially available kit, it demanded a considerable amount of time during the course of the project. Additionally, the size of the rocket dictates the maximum physical size of the robot system. The first problem was just finding a kit that would meet the project restrictions. Since there is a 1500 g weight restriction, I decided that allocating 750 g to the rocket and motor would be realistic. After an exhaustive search of manufacturers catalogs and web sites, I decided on the P.E.M. Patriot kit as the most logical choice for the rocket system. This is a rocket that is 4" in diameter, ~52" long, has an 8" payload compartment, weighs 1.2 lb., and will operate with unregulated motors. Since this rocket has 4" diameter body tubing, the size of the payload compartment placed serious physical constraints on the robot.

Sensors

During the course of this project, a variety of sensor systems were investigated. There is a bump sensor to detect objects that are in the path of the robot. Four mercury switches are used to provide orientation sense. A commercially available electronic compass is used to provide an indication of the direction of travel. Finally, an altimeter was to be designed and constructed in order to provide altitude sensing. Unfortunately, the altimeter prototyping efforts did not yield a functioning sensor.

Bump Sensor

The bump sensor is constructed from a micro-switch attached to a spring loaded 'bump plate' that is mounted on the front of the robot platform. The switch is connected to an input port on the 'HC11. By polling this port, the microcontroller can determine if there is an obstruction in the path of the robot.

Orientation Sensor

As there is no control over the position that the payload compartment will be in when the system lands, it is necessary for the robot to be aware of its orientation. Roll and pitch indications are implemented through the use of mercury switches mounted on the body of the robot. The mercury switches provide a binary indication of the orientation of the robot. The outputs of the mercury switches are connected to input ports on the 'HC11 which can be polled by the microcontroller in order to determine the orientation of the robot.

Electronic Compass

A commercially available electronic compass was used in order to provide directional or yaw information. This compass has an industry standard SPI output. The serial data stream contains information that indicates the direction the compass is pointing. The compass is connected to the SPI port on the 'HC11 allowing the robot to ascertain the direction that it is traveling.

Altimeter

The altimeter sensor fulfills the 'unique sensor' requirement of the course. Designed with a MEMS pressure sensor, altitude can then be determined by measuring the ambient pressure. The pressure sensor used is a PX-71 from Omega Industries that operates on the piezo-resistive principle. In this manner, pressure changes cause a resistance change in the sensor. This particular sensor can measure pressure ranges from 0 to 2 atmospheres or 0 to 28 p.s.i. When driven by a constant current source, the voltage dropped across the pressure sensor is proportional to the measured pressure. This voltage is then read by an analog input port on the 'HC11 providing an indication of the altitude. This portion of the sensor package was never successfully completed. The challenging part of the altimeter development was the design of an adequate constant-current source. While several sources were prototyped, I was never able to obtain any indication of proper operation. I assume that I damaged the sensor during the development of the circuitry.

Behaviors

Due to the complexity of the project that I proposed, the system developed only has a few behaviors. In essence, the robot needed to survive the flight and upon touchdown, release itself from the payload compartment. Once free of the payload, the robot was to use the sensor package in order to perform an exploration of the area surrounding the landing zone. Due to difficulties interfacing the electronic compass to the MSCC11, I was unable to develop software that perform the exploration of the landing area. However, the robot was able to extract itself from the payload compartment on several occasions.

Conclusions

This course proved to be extremely challenging. Not only was the original proposal overly optimistic as to what could be designed and constructed in the shortened period of a summer semester, but the ban on model rocket launches also limited the amount of testing that could be performed on the airframe. Many portions of the project were successfully completed but a substantial number of proposed items either were not completed or were not able to be integrated into the project in time. The items completed include:

- Mobile Platform
- Rocket Airframe
- Payload Compartment
- Bump and Orientation Sensors
- Basic Robot Behavior

The items that were either not completed or not incorporated into the final project:

- Altitude Sensor
- Compass
- Useful Robot Behavior

There is ample room for additional work to be performed on this project that I fully expect to complete in the near future. In particular, the altimeter will be completed and used on future flights of my rockets. In fact, if I can develop a reasonably accurate and robust design, I may use this research as the basis for a commercial product.

It is difficult to discuss project criteria that I would change if I were to start the project over again because only the minimum required systems were specified. In my case having the additional four weeks available during a Fall or Spring term may have made complete success possible.

Appendix

Items included in the appendix are:

1. Main Robot software.

2. Payload separation testing code.

3. Compass interface test code.