Technical Paper for the International Aerial Robotics Competition

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ABSTRACT

The International Aerial Robots Competition (I.A.R.C.) is designed to challenge students and industry to work together to achieve a common goal. This goal is to survey a simulated disaster site and determine the location of survivors and potential hazards. To accomplish this, the DeVRY team has incorporated a multi-unit system that consists of both aerial and terrestrial units. By using a wireless communication system these autonomous vehicles are capable of interacting with one another to complete the required elements of the competition.

SCOPE AND SEQUENCE

This paper describes the concepts and innovations developed by Team DeVRY in preparing for the I.A.R.C. in 1999, including descriptions of system designs and safety features.

The paper is presented in the following sequence:

1.0 INTRODUCTION

- Explains the goals of the competition and the overall strategy.

2.0 COMPETITIVE STRATEGY

- Explains DeVRY Calgary's strategy of deployment in this competition.

3.0 AERIAL UNITS

- Explains the concepts incorporated in and composition of the two aerial units.

3.1 Mechanical System Design
3.1.1 Propulsion
3.2 Electronic System Design
3.2.1 Flight Navigation Scheme
3.3 Sensors
3.3.1 Threat Avoidance
3.3.2 Target Identification Techniques
3.4 Communications
3.4.1 Stability Augmentation Scheme
3.5 Visual Recognition

4.0 GROUND VEHICLES

- Explains the concepts incorporated in and composition of the two ground vehicles.

4.1 Mechanical System Design
4.1.1 Propulsion
4.1.2 Risk Reduction
4.2 Electronic System Design
4.3 Sensors
4.4 Communications
4.5 Visual Recognition

5.0 SAFETY AND RISK REDUCTION

- Explains the emergency systems developed by the team.

6.0 CONCLUSION

1.0 INTRODUCTION

A disaster scene can be an extremely dangerous and unpredictable place. Robert Michelson created the International Aerial Robots Competition to challenge students, often working in partnership with industry to come up with new and innovative ways of dealing with disaster sites while minimizing further risk to human life. He constructed a landscape that contains wreckage, fire, smoke, air and land-based shock waves, simulated survivors, and other unknown obstacles to improve future search and rescue methods. With each successive year of competition, new technical challenges are added and expectations for competing teams are expanded. As DeVRY Calgary enters their third year in this competition, Team ‘99 has incorporated previous years’ experiences with new and innovative solutions for the 1999 competition. To achieve success, Team DeVRY uses a competitive strategy, an innovative system design, hi-tech modem communications, increased safety, and modern navigation (GPS) and target identification techniques.

2.0 COMPETITIVE STRATEGY

Team DeVRY’s strategy is to use an autonomous helicopter and ground vehicle that work together to locate and map the potential dangers, to search for and rescue potential survivors, and provide an overall assessment of the disaster site without risk to human life. By using the helicopter, Team DeVRY will be able to quickly survey a large area of terrain, find survivors and send their locations to the ground units for investigation. As time is critical, the use of a second ground vehicle will increase the chance of locating survivors. Since the helicopter will not be able to get close enough to the victim, the advantage of having the ground units is that they will be able to help the victim by pinpointing the location for a human rescue team and leave a first aid kit until help arrives.

3.0 AERIAL UNITS

3.1 Mechanical System Design

The aerial units in the DeVRY entry for I.A.R.C. ‘99 consist of one X-Cell radio controlled helicopter and one computer controlled Bergen helicopter. The X-Cell 60 Class helicopter was chosen as a test bed for the electronic systems that were developed, and will be used for back up to the Bergen in the competition. The Bergen was chosen because of its durable airframe and many up-gradable components.

3.1.1 Propulsion

The airframe itself has had many modifications such as a larger engine, bigger muffler, lengthened tail boom, extended main shaft and longer blades. All these modifications were necessary to increase the maximum payload it can carry. The Bergen Twin will be the aerial unit used in the competition. It is a radio-controlled industrial helicopter weighing twelve pounds, with a gasoline-burning engine and a maximum payload of eighteen pounds excluding fuel. The Bergen is capable of flying for thirty minutes without refueling, and is highly durable and impact-resistant due to its graphite frame construction and reinforced rotor head. A modification for this year's competition is the replacement of the plastic tail assembly with anodized aluminum to solve the problems last year's team encountered with the heat.

3.2 Electronic System Design

The electronics incorporated into the helicopter include a biscuit board computer, video system and a multitude of sensors and servomotor control units.

The electronic systems on the mobile unit are powered by two 9.6 volt 3600 mA-hour batteries, which are connected to voltage regulators to provide power to the individual on-board systems. Each battery is comprised of eight 1.2 volt nickel metal hydride cells, and weighs 424 grams. The battery life per charge cycle is conservatively estimated at 1 hour 45 minutes at a 2A load. According to manufacturer specifications, the batteries are expected to last between 300 and 1000 charge cycles. Nickel metal hydride batteries were chosen for their safety, reusability, and resistance to the "memory effect" which is a common problem with nickel cadmium batteries.

3.2.1 Flight Navigation Scheme

Five servomotors or "servos" control the five different aspects of flight: pitch, roll, throttle, collective (blade angle), and yaw. The servos operate on a 5 VDC power supply, and are controlled by means of an input pulse, which varies in duration. The longer the duration of the high pulse, the greater the servo angle. The servos are designed to receive input pulses on a 50 Hz cycle.

All navigational information is provided to the helicopters' Artificial Intelligence through the TCM2 sensor, which incorporates a tilt detector along with the directional compass for navigational control. These sub systems are all linked to the main flight control computer and work in conjunction with the Global Positioning System (GPS) to insure accurate mapping of the environment within the disaster site.

3.3 Sensors

3.3.1 Threat Avoidance

The primary sensor aboard the helicopter is the Polaroid 6500 sonar and ranging module. The basic object detection system consists of a sonar-pulse sensor system mounted on a movable base allowing it to ping a forward facing arc to detect obstacles within the flight path. A similar system is mounted on each side, so that after detection, the obstacle can be avoided until a safe distance is placed between the helicopter and the obstacle. The helicopter will have an understanding of its own flight envelope, including its' rotor size so that when plotted, the flight path allows the helicopter to avoid any potential hazards. The range of this sensor is approximately 37 feet (10 meters). To complement the sonar detection system there is an array of downward facing infrared emitters and detectors so the helicopter can take off and land with success. A thermal sensor has also been incorporated to detect heat sources, which could be dangerous to the helicopter.

3.3.2 Target Identification Techniques

The software developed for the sensors requires the system to rotate through the sensors one at a time, sending a pulse and receiving the results in step-wise fashion. The exact time the pulse takes to travel to and from the sensor in microseconds is calculated and multiplied by the speed of sound to give the distance to target (DDT). If there is no return signal within a specified time then the target is considered 'out of range'.

3.4 Communications

The Global Positioning System (GPS) used by the IARC team is provided by NovAtel of Calgary, Alberta. The electronics package is a differential GPS (DGPS) system that allows the robot to determine its absolute three-dimensional position to within 2 centimeters. The GPS antenna is also connected to the mobile unit of the robot. It provides the mobile unit with two different types of NMEA formatted messages in ASCII form. One of the mobile unit's M68HC11 microprocessors receives data from the GPS antenna in serial format. Only about one sixth of the incoming NMES codes are useful for this robots' purposes. The relevant portions of the data stream are intercepted and stored in RAM; the rest of the data is discarded.

The WI-Lan Hopper wireless modem is used as a data link to transfer commands and information between the base station and the mobile unit. The mobile unit transfers its three-dimensional positional data to the base station, along with the recorded altitude from the Earth's surface according to data from the Polaroid sensors. This data is then transmitted upon request by polling the base station.

Located within the base station, the autonomous programming is the heart of the software. The program provides the collection point for the data received from all the applications; it is then assessed and dealt with accordingly. The program takes the current position and speed from the DGPS module and uses it to calculate the desired course and course corrections. The software program also acquires object information from the image recognition system. Receiving information from the sensors and other devices, the program uses all the collected data to adjust the servomotors to make appropriate corrections to the course and target.

3.4.1 Stability Augmentation Scheme

Although the WI-Lan Hopper is extremely heavy due to its steel casing, the extra weight is being used to advantage. Since the Hopper has high durability, it will be on the bottom of the craft, and will protect the more sensitive components. It will also help to balance and stabilize the mobile unit by providing an extremely low center of gravity. Thus, the “disadvantages” of the WI-Lan Hopper (weight, bulk, and steel construction) have been turned into “advantages”.

3.5 Visual Recognition

The recognition system uses a color Charge Coupled Device (CCD) camera and wireless video transmitter with receiver to transmit video image data to the video capture card. The video capture card is a Scorpion 64 1-MB card from Tuscon Computer Corp. The image detection program will capture a Bitmap (BMP) image every 2 seconds and will convert every pixel into its corresponding character for each color. The program will then look for changes in color and compare them with the specified target color(s). It will then calculate the exact position of the object using GPS coordinates in correlation with the helicopter’s position.

The object recognition program will also digitize the BMP image and check for changes in color(s). It will start to compare the object with objects in the computer database of digitized images. The program will then triangulate the object’s position using GPS coordinates.

4.0 GROUND VEHICLES

4.1 Mechanical System Design

The ground vehicles are incorporated to confirm the data detected by the aerial unit, navigate to the simulated survivors, and provide a map for the human rescue team to follow. By using two ground units, both a medium and a small unit, the time to find survivors will be kept to a minimum. The medium ground vehicle is designed to go over all types of terrain. Employing a six-wheel system allows it to traverse the landscape quickly and effortlessly. The small ground unit will be a scaled down version of the medium unit and acts as a scout craft.

4.1.1 Propulsion

The medium ground unit includes a steel frame and two – 3.5 hp gas engines which give the unit the power to accomplish its tasks. The small unit will be powered by electric motors instead of gas.

4.1.2 Risk Reduction

One of the predominant innovations of the medium ground unit is the incorporation of a fire control system. By using a five-gallon water container and pump, in conjunction with a thermal sensor, the unit is capable of putting out small fires. The small ground vehicle will be performing the same tasks as the medium unit except it will not include the fire extinguishing system.

4.2 Electronic System Design

The electronics on the ground vehicles will be the same as the aerial unit, refer to section 3.2. The only exception will be that the power source is a 12-volt car battery since the weight is not a factor.

4.3 Sensors

The Polaroid 6500 sensor system is also included on both ground vehicles, as per section 3.3. Thermal sensors, in addition to a navigational compass, are located on the ground vehicles. The thermal sensor is used to protect the units against fire hazards. When open flame is discovered the thermal sensor detects the heat and informs the software program of the danger to avoid. All heading information is provided to the AI through the navigational sensor.

4.4 Communications

The communications system is identical for all units. Refer to section 3.4.

4.5 Visual Recognition

The visual recognition is identical for all units. Refer to section 3.5.

5.0 SAFETY AND RISK REDUCTION

The rotary blades of the Bergen Twin helicopter are the primary propulsion system of the DeVRY aerial unit. The horizontal rotary blade is isolated by means of a crash hoop, and the tail rotor is isolated by means of an extended protective vertical barrier that extends more than three centimeters below the lowest possible arc of the tail rotor. Unless the robot crashes at an angle greater than 45 degrees to the correct side, or there is an immobile vertical object directly in the path of the tail rotor outside of the tail rotor barrier; a tail strike is not possible.

The credit for the next mechanical safety feature belongs to Larry Bergen of Bergen Machine and Tool, who designed and manufactured the Bergen Twin Industrial R/C Helicopter. One of the many innovations on all Bergen helicopters is the metal rotor head connecting the main shaft with the propeller blades. This metal rotor head contains three separate bolts to fasten the rotary head to the main shaft. Even if one bolt vibrates loose or breaks off, the rotary head of the helicopter will not disengage regardless of the speed or force at which it is rotating.

The most important safety system housed in all entries created by Team DeVRY is the Emergency Termination System. This system will be the backup control and shutdown of the air/ground-based units should a problem arise. The termination system is designed so that a range of terminations can take place. During normal operation the system will allow typical data traffic from servo to control board. When the first level of termination is activated, the system will disable the computer control system and allow manual input of commands from a typical radio control source. This way an operator can take control of the systems manually should the computer fail. The second level of termination will be a complete shutdown of the units. There will be a connection, which can be disengaged, from the termination system to the ignition coil of the aerial units' engine. In the case of the ground vehicle, this connection is to the braking system.

6.0 CONCLUSION

When an environmental disaster occurs, time is of the essence. By having an autonomous robotic response team to compliment a human intervention team, the reaction time is reduced significantly. A human rescue team has to develop a strategy before going out into a hazardous, life-threatening situation. This time used to develop strategies can be costly in these types of situations. The autonomous units can be ready to go in a rapid-response scenario. This could potentially save the lives of both the victims and rescue team members.

The many innovations added to the robots by team DeVRY include the use of safety systems like the fire extinguishing and termination systems. The use of the Wi-Lan Hopper's weight to help stabilize the aerial units adds another element of safety. The use of two ground units to speed up the assessment time of the disaster site is just another example of the achievements of Team DeVRY this year.

This year's team has developed both air and land autonomous vehicles to accomplish their mission. The rescue mission will be achieved in as little time as possible for risk assessment of the hazardous environment. The vehicles are designed to act in concert as a rapid response team while completing their tasks.