An Interdisciplinary Approach for Problem Solving in a Robotics Application

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Abstract
The Trinity College Fire-Fighting Robot Contest was created to inspire roboticists of varying backgrounds and skill levels to identify and implement techniques for using robotics in place of humans to extinguish fires. To perform this development of robotic technology, a team of students and faculty was established at Trinity College in Hartford, CT. The interdisciplinary background of the team membership allowed the design and development process to flow in a highly productive manner. Internal dynamics of the team played an significant role in determining its efficiency. As a result, this project enabled the team members to learn about robotics through an interdisciplinary exchange of ideas while forcing them to become efficient at functioning as a diverse collective with a common set of goals.

Introduction
The use of robots in place of humans in fire-fighting can reduce the danger inherent to the job of a human fire-fighter. Unlike humans, there is no risk to life or limb associated with the use of a robot in a hazardous situation; the cost of losing a robot in a fire is purely monetary while the cost of losing a human life is immeasurable. In either residential or industrial settings, a fire-fighting robot could serve as a means of containing or extinguishing fires before a human fire-fighting team is able to respond. Robotic fire-fighters also represent a means of combating fires that present a level of danger that exceeds safety standards for human fire-fighters. These principles provide the primary motivations for the Trinity College Fire-Fighting Robot Contest.

The robot contest challenges participants to build a mobile robotic device capable of moving through a known model of a single floor house, detecting a fire (represented by a lit candle) and extinguishing it. The model house is composed of a maze of hallways and rooms that resemble an actual dwelling. Though the model house is not full scale the concept and spirit behind the task remains unchanged. Contest participants are provided with a chance to demonstrate and exchange their unique design ideas with other contestants from over 20 different states within the U.S. and foreign countries. Participating teams range from college professors and professional engineers to elementary school and college students.

The Trinity College robot team was established the Spring semester of 1995. The team at that time consisted of one professor, several junior and sophomore electrical engineering students, a sophomore mechanical engineering student and two first year students. A significant amount of progress was made that first year on the design and construction of the Trinity fire-fighting robot, Phoenix. The work done by the original team inspired other students to become involved in following years creating a team that has endured the test of time and became a source of pride for the Trinity College Engineering department.

Team Organization

The individual components and subsystems of the Phoenix robot were designed by separate groups within the Trinity team, each consisting of members sharing a common interest. The electronic systems of the robot were designed and created by various groups of electrical and computer engineers. A group composed of primarily computer engineer and computer science students was established to develop the software control algorithms to govern the robot as a whole. The design of the base of the robot was carried out by a group consisting of mechanical engineering students and a computer science student with machining experience. This group was also responsible for integrating the mechanical and electrical subsystems.

With the separation of individuals into specialized groups, the expertise and interest of each student was utilized to its fullest extent while allowing for a positive group learning environment and a healthy exchange of ideas. Team members were free to move from one group to another if their interests changed or if their expertise could be used by other groups. Students were allowed to belong to several groups, allowing them to expand their general knowledge about the robot and its systems.

Interdisciplinary Approach

The design of a single component or subsystem for the robot by an individual team member or team subgroup often demanded that they enlist aid from other members of the team. For example, while developing software for Phoenix, the software development team found it necessary to install a front proximity sensor. The software development group approached the electrical group for assistance with this problem. Both groups worked together on the design specifications of this unit resulting in a component that was ideal for not only the sensor system of the robot, but for the software developers who requested it.

The interdisciplinary approach also facilitated the development of a second Trinity robot, Ot-Bot. It was decided by the mechanical group that the use of DC servo motors was advantageous compared with the stepper motors used on the Phoenix. These motors were lighter, smaller in size, consumed less power, and contained built-in gear drives providing an ample amount of torque. The mechanical team worked together with the electrical systems group on the creation of the motor controller for this device by providing input on ideal speeds of operation and testing the prototype controller as it was developed.

While developing software for the Phoenix robot, the software development group expressed the need for a more precise flame sensor using IR. Members of this group and members of the electrical systems group designed a new sensing circuit that employed three different detectors to create a weighted average of the IR signals seen by the sensors. After the creation of the sensor's circuitry, the electrical systems group explained the design principle to the mechanical group which then created a special fixture for holding the IR detectors to provide for optimum sensitivity.

Assessment

Each team member possessed a unique set of skills at different levels of advancement. The teamwork fostered within the group provided a way to increase personal ability through an exchange of ideas and design skills. This transfer of knowledge through cooperation was a great benefit to active team members. For instance, a sophomore computer engineering major was paired with a senior electrical engineering major on the design and implementation of a DC servo motor controller. As a result, this component was completed swiftly by sharing the work between two students while the senior student simultaneously taught the sophomore student about more advanced design principles than he had previously encountered.

The dynamics of the team played a vital role in the realization of the two Trinity robots. The communication skills developed as a result of the interactions of members of the Trinity team with others internal and/or external to the team itself was invaluable. It quickly became evident that if team members did not express themselves in concise and explicit terms, problems would not be solved. For example, the software development group left a note for the electrical systems team that the side proximity sensors were not calibrated correctly. The message was misinterpreted in a manner that became rather counterproductive. The member of the electrical systems team that received the note thought that the problem existed with all of the side sensors and proceeded to calibrate all four sensors. In actuality, only one of the four sensor units was producing bad data. The unnecessary calibration of all of the sensors affected the parameters used in the motion control code. This resulted in a setback that cost the team a week's worth of time.

There were also communication problems within each subgroup. The software development group quickly learned that without proper communication the status of a piece of software is very unclear. Problems arose when members of the software development team began working on the same piece of code without the knowledge of others in the group. As the code was written proper comments were not kept furthering the confusion. Group members became upset when the code they had been working on had modified without their knowledge. Senior team members intervened before the lack of communication led to hostilities between members on the software development team.

It was also discovered that conflicts involving two different components being designed by two different subgroups were solved most efficiently through meetings of both groups involved. These group meetings helped the team to create an optimal design and insure that all components would function correctly as a whole. Students used weekly team meetings discuss new design ideas or problems associated with the implementation of current designs. The weekly team meetings also served to promote a general understanding of the workings of the entire robot throughout the members of team.

The cooperative design strategies developed between subgroups of the Trinity team became the strongest piece of the team's foundation. This was exemplified by the cooperation between the electrical systems group and the software development group. While developing the motion control code for the Phoenix robot, it was often the case that new movement functions would not work as expected. Often the cause of these incorrect behaviors would remain unseen for days. While the software development group scrutinized the control code for the robot's main CPU, the electrical systems group would examine Phoenix to determine if the problem was related to hardware. While they did not always uncover problems that pertained to the situation at hand, this approach allowed the electrical systems team opportunities to identify potential hardware problems. The cooperation between the software development group and the electrical systems group always led to effective and expedient solutions to the problem at hand.

From the time of the team's inception, the dynamics of the team improved as its size grew larger. One change that took place as the team grew was the development of a hierarchy within the individual subgroups. Each group was guided by a group leader who was in charge of coordinating tasks and delegating responsibility within each specialized group. Since each group was responsible for the completion of many projects of varying size, the group leader played an integral role in making sure that tasks were completed correctly and in a timely manner. The group leaders often became the most knowledgeable and skilled individuals in their respective subgroups. This enabled them to help others in the group to complete projects or understand concepts behind the design work they were engaged in.

Conclusion

The experience of working on a project of this magnitude provided for the reinforcement of concepts taught in engineering and science courses of various disciplines. Team members often felt that material presented in these courses was either clarified or reinforced by their involvement with the Trinity robot team. This project also allowed students the opportunity to apply skills that were developed in lecture classes and expand on techniques covered in laboratory assignments in concrete applications. Frequently this experience lead students to be drawn into new areas of study relating to their respective interests.

The robot team proved to be an invaluable learning experience. It not only provided students with an outlet to apply concepts learned in the classroom but it also served as an practical method for teaching about teamwork and team management skills. Each member of the team learned that individual effort was essential to the success of the project as a whole. The combination of individual effort with the directed and focused group mentality provided students with an excellent vehicle for reaching their goals.

The team was comprised of members from a variety of different disciplines. This fact led to creation of the subgroup structure within the team. The cooperative design work and communications between these subgroups was paramount to the completion of the robots built by the team. The interdisciplinary exchange of ideas and abilities inherent to the structure of the Team resulted in the design and implementation of two fire-fighting robots for which each and every team member is proud.

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