Energy-Gathering Autonomous Mobile Robot

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Introduction.

Every year, the IEEE Region 5 branch holds a robotics competition whose main objective is to facilitate self-learning of design techniques in building autonomous robots. We sought to use our team's previous experience and acquired abilities to build a robot which was not only able to compete at the conference, but to place at it.

Method of Movement.

It was important in the design of the robot to develop a simple, yet effective drivetrain which was capable of fast, occasionally violent movements. After much deliberation, it was decided that a holonomic drivetrain was the best option. This drivetrain uses 4 omni-wheels, wheels which can power in 1 direction while providing no resistance in another, in a square pattern. By doing this, the robot was able to maintain the same orientation throughout the run. Additionally, this drivetrain allowed us to dedicate each side of the robot to a specific task, elimination the front-end clutter associated with most conventional designs.

Solar Gathering.

The solar cells on the robot were a tricky design issue. The initial solar cells, more voltage than current oriented, were unable to charge the capacitor bank fast enough. Through more research on the charging of capacitors, it was determined that solar cells should be current oriented with a maximum output voltage slightly higher than the full-charge voltage. This led us to decide on a solar bank of three 6V 150mA solar cells, which covered most of our robot.

Energy Storage.

The capacitor bank was a part which required both calculation and experimentation. To facilitate a wide range of possible capacitances, several 2.7V 1.5F capacitors were bought. It was initially thought that a bank of 5.4V max with 1.5F would be the most effective bank size. Through experimentation, however, it was discovered that a bank with 8.1V and 1F would charge much faster to a voltage range capable of turning the output flag.

Direct Connection.

In order to gather energy from the electric source, as well as discharge stored energy into the motor, we created physical contact points to directly connect our storage bank to the source or load. These Claws, as we named them, were created using cardboard as the supporting material which was flexible, durable, and cheap. Our physical contact points were fashioned by simply wrapping several strands of copper wires around the cardboard to create two bands, one positive and the other negative. This was to give the contact points some flexibility as well as to give the robot more opportunities to make a connection. These bands were connected directly in parallel to the capacitor bank and formed an open circuit when not connected to a source or load which meant minimal voltage leakage from the capacitor bank. When they touched the source or motor the circuit loop was closed and the capacitor bank was allowed to charge/discharge.

The Brain.

For controlling the robot we decided to use an Arduino microcontroller as they are known for their simplicity and price. The code was programmed in the Arduino IDE to avoid communication issues and for its C++ like language which was familiar. There were four main movement functions created that allowed the robot to move north, east, south, and west (as oriented to the playing field), and several functions used for moving along walls. These functions were written to be reusable and allow adjustable motor speeds. They were used in conjunction with code that took sensory input and decided which of the 3 sources were on and where to go next.

Sensors.

To determine if the solar source was active, two photodiodes were used from which lighting was measured. To focus these measurements into a binary decision of whether the solar was on or off a boundary voltage was manually set. Voltage monitoring, specifically rising voltage, of the energy stored in the capacitor bank was used to determine if the electric source was active. Four normally open bumper switches were used to tell the program that the robot has made contact with a wall and on what side of the robot that wall was. Using this information, along with the shape of the field, allowed the robot to know roughly where it was located on the field.

Technical Accomplishments.

We managed to complete several of our goals before the competition. Our robot was able to gain a full charge on our capacitor bank with only 45 seconds of charging on either the solar source or the electric source. In fact, we managed to pull slightly more power from the solar source with a great selection and positioning of our solar cells. A single charge is capable of raising the flag over a foot in approximately 90 seconds, start to finish. To automate the entire process the robot had to discern which source was active. We were able to initially check if solar was active with photodiodes, and if it wasn't, we checked if the electric source was active via direct connection and voltage monitoring. We ignored the wind source to cut down on design time and were able to pull more efficiency out of our solar and electric gathering. The wind source would only be active by itself for a period of a minute and we decided to use this time to travel across the field. One of our crowning achievements was the robot's total cost, which was under $500. After talking with several other teams at the competition we realized that we had one of the cheapest robots there. Finally, we were able to distinguish ourselves by having a reliable robot that was able to consistently complete multiple test runs with little variation in our results.

Knowledge Gained.

We designed our robot to be of a modular design so that we could easily make alterations when needed. There were several instances that this approach helped out tremendously such as when we added the compass component to help with steering issues. This reinforced our beneficial thoughts towards modular design. Without a modular design we would have wasted time and money trying to modify our robot to be able to handle additional issues. A major lesson we learned was how to schedule time to work on a several month long project while maintaining our academics and general living. We did this by setting milestones and planning our schedule around major events that were not related to the project such as academic tests or family events. One of the hardest lessons was that a team cannot plan for everything as we occasionally fell behind schedule due to monetary conflicts or delays in receiving parts. We did manage to finish our initial prototype with enough time for heavy testing and adjustments which led to increased efficiency, reliability, and speed. This reinforced our ideas on scheduling plenty of time for a testing/modification phase. Even though we wanted a modular robot, we designed it with our competition playing field in mind. We kept going over various design pros and cons until we came up with one that was simple, yet could traverse the playing field efficiently. This led to a minimal amount of sensors and components, which led to an overall cost reduction, and allowed for less complex programming, which reduced time spent on software.

Authors' Backgrounds.

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Our Goal

Every year, the IEEE Region 5 branch holds a robotics competition whose main objective is to facilitate self-learning of design techniques in building autonomous robots. 2012's competition required an autonomous robot that could gather solar, wind, and electric energy and transport that energy to a motor to raise a flag.

Our objectives were:

1) Autonomous movement/gathering/depositing
2) Reliability
3) Efficiency and speed
4) Low construction cost
5) Modular for easy modifications

Claw

We created two claws, one each for gathering electrical energy and discharging, of the same design. They were connected to the capacitor bank in parallel as an open circuit. The positive and negative terminals were created with several strands of copper wire in parallel to ensure a sturdy connection. The structure was created out of cardboard for flexibility at a low cost.

Capacitor Bank

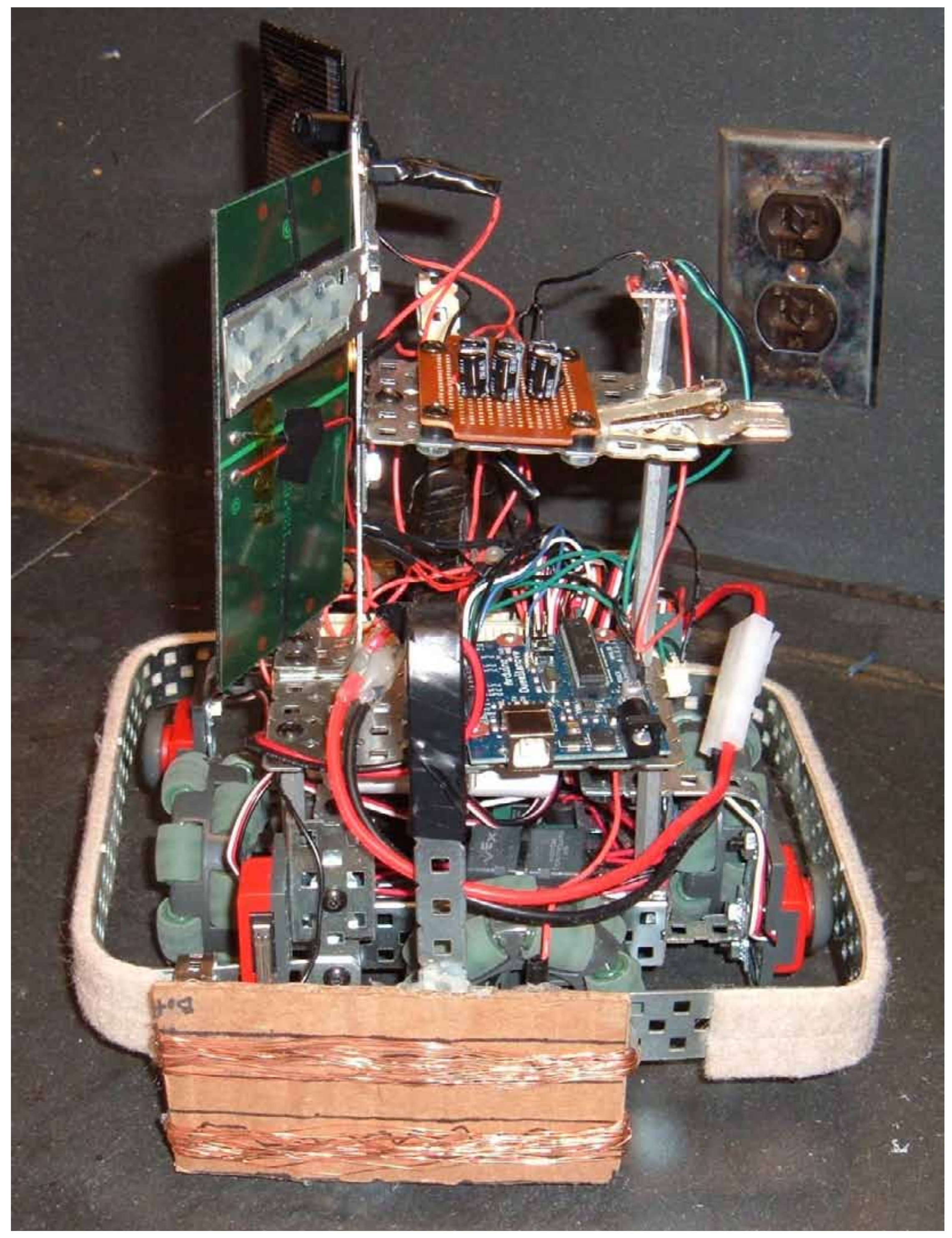
To store the energy in our robot, the only feasible method was to use supercapacitors, due to their large energy density and small form factor. In testing, it was discovered that the ideal properties were obtained with a capacitor bank capable of 8.4V and 1F.

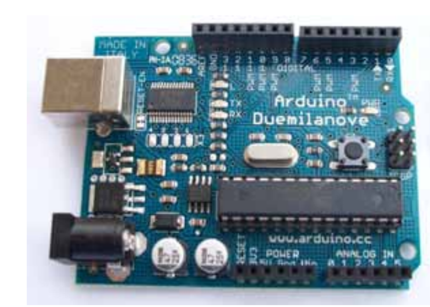
Solar

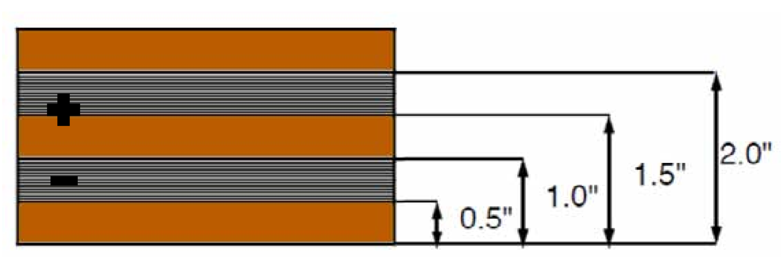
In order to place in competition, at least 2 sources needed to be gathered from. Solar was an easy choice, as solar panels come in various types, allowing us to obtain correct parameters.

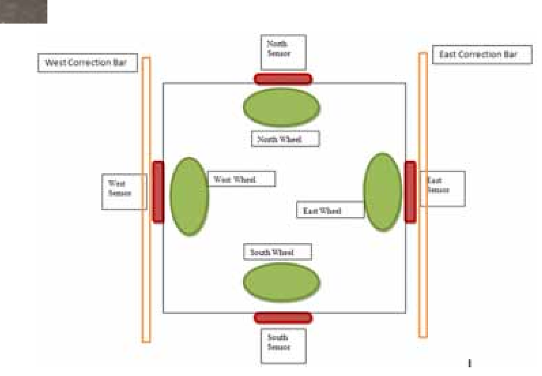
It was found that the fastest charge rate could be obtained from three 6V 150mA panels. Using these panels, the capacitors were charged at a fairly rapid rate, comparable to the direct-connect electric source.

"Samus" Our Autonomous Robot





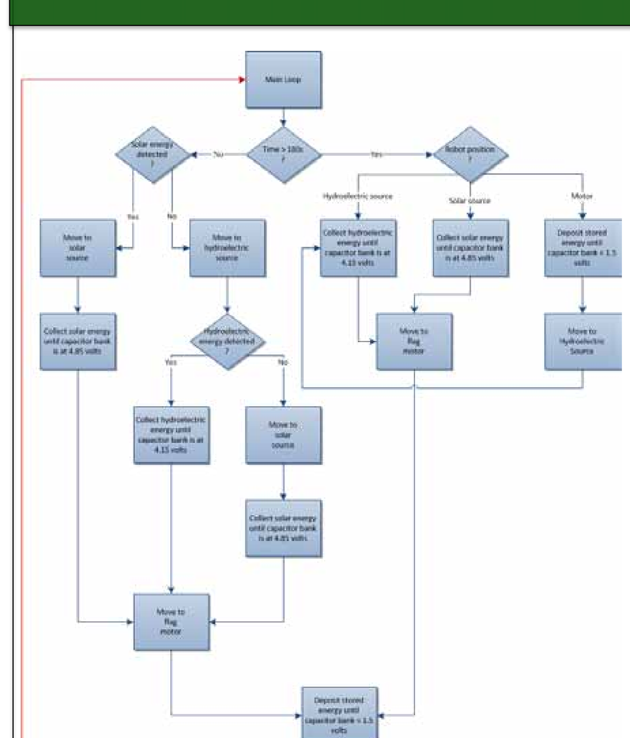




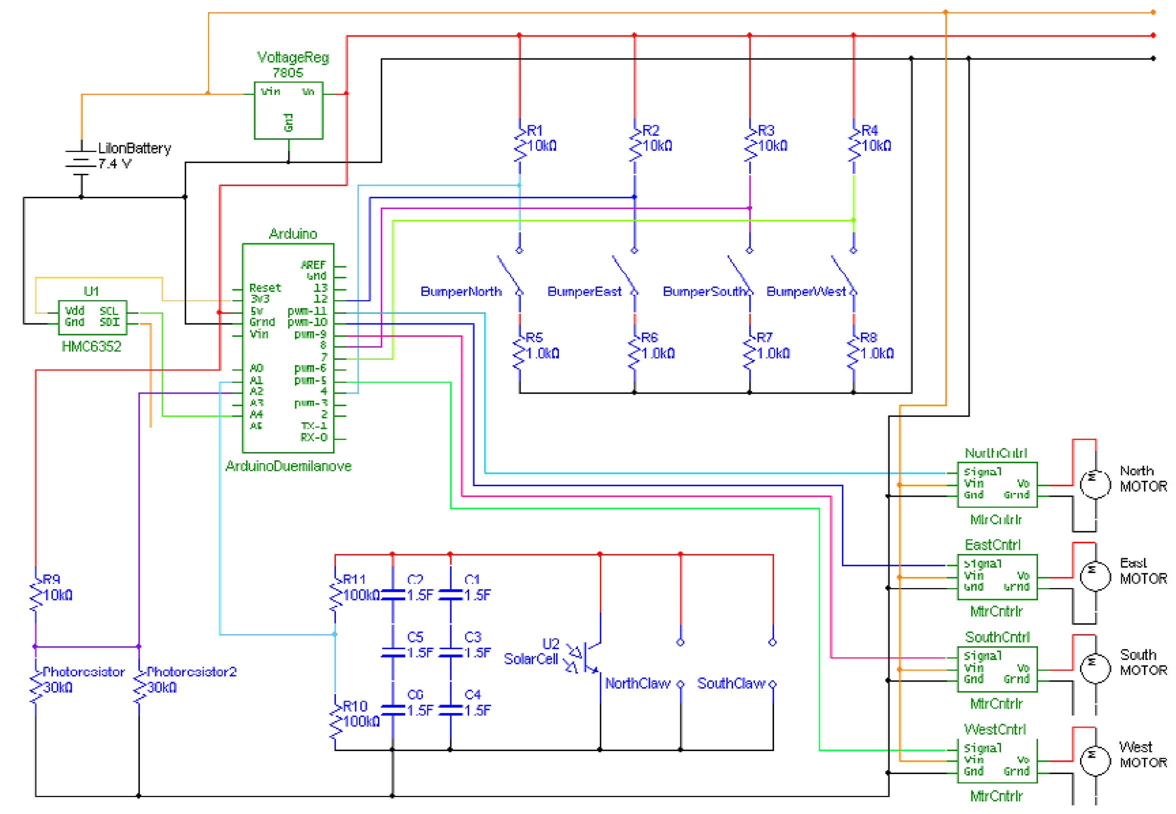
The Legs

Perhaps the most important design consideration of our robot was its method of movement. After much deliberation, it was decided to use a holonomic drivetrain. A holonomic drivetrain is characterized by its use of four "omni-wheels". These special wheels are capable of providing power in one direction while spinning freely in a perpendicular direction. Taking advantage of the layout of the field by using a square robot, we were able to devote one side of the robot to each objective, eliminating timely, imprecise turning of the robot and greatly reducing the clutter associated with putting all the gathering equipment on one side. This was a major factor of our modular design.

The Brain



The brain of the robot is an Arduino Deumilanove and the code was written with the Arduino software. The code was structured to be modular and based on functions so that the program could be easily adaptable. This proved to be advantageous as there were over a dozen changes within the last 10 hours leading up to the competition. A modular structure also allowed errors to be isolated and quickly fixed. We had decided on our holonomic drive, and not physically turning, to eliminate accumulating direction errors and this required 4 movement functions, what we declared as north, south, west, and east.



Schematic

Accomplishments

We managed to complete several of our goals before the competition. Our robot was able to gain a full capacitor bank charge with 45 seconds of charging at the solar or electric sources. This charge was capable of raising the flag over a foot and took approximately 90 seconds to complete. Our robot consistently completed these tasks with high reliability. The robot was able to determine which source was active via sensors. We ignored the wind source to cut down on design time and used the wind's active period to transition across the field. Lastly our robot was cost effective at under $500.

Harder, Better, Faster, Stronger

We learned that building the robot with room for later improvements saved us time and reduced costs. Our modular approach allowed us to adapt to environmental changes easier. There were several months from the start to deadline which gave us experience on scheduling time to aggressively work on our project without ignoring academic studies or missing our project deadline.

We would like to thank our third team member Timothy Johnson, who handle circuitry and had several creative solutions to various issues. We would also like to thank Dr. Kelvin Erickson for financial support and Dr. Maciej Zawodniok for being our advisor on the project.