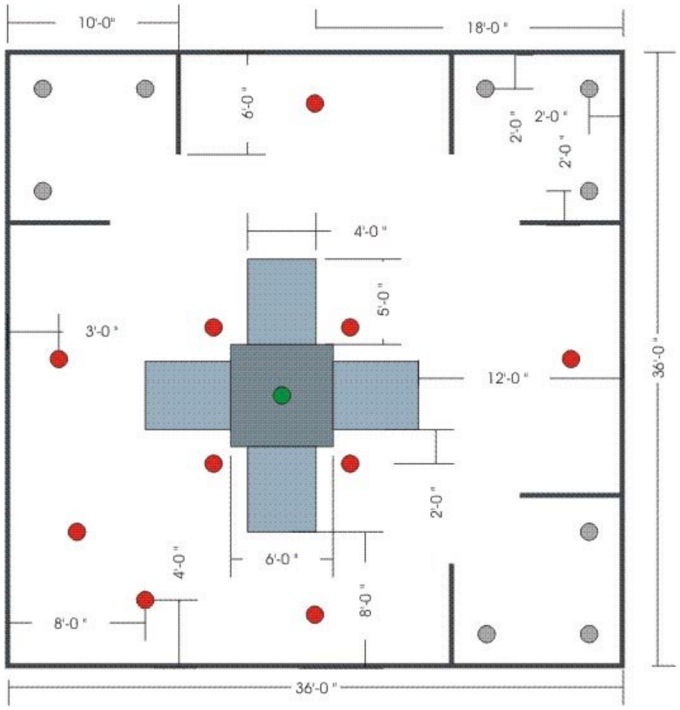
As a mechanical engineer, I participated in the robot design competition. Specifically, I worked in the Chassis group with the responsibilities to design the robot framework, item retrieval devices, and defense/offense mechanisms. Also, I acted as a liaison between the other three groups to coordinate the control and electrical specifications.

The University of Wisconsin, Madison formed an extracurricular team to participate in the annual AMD Jerry Sanders Creative Design Competition. This team was funded and supervised by the University's Electrical Engineering department as well as the Institute of Electrical and Electronics Engineers (IEEE) student chapter at UW-Madison. The goal of the robot team was to build a 1x1x1 meter robot that could achieve predefined objectives and compete against other robots for more than $5,000 in prizes

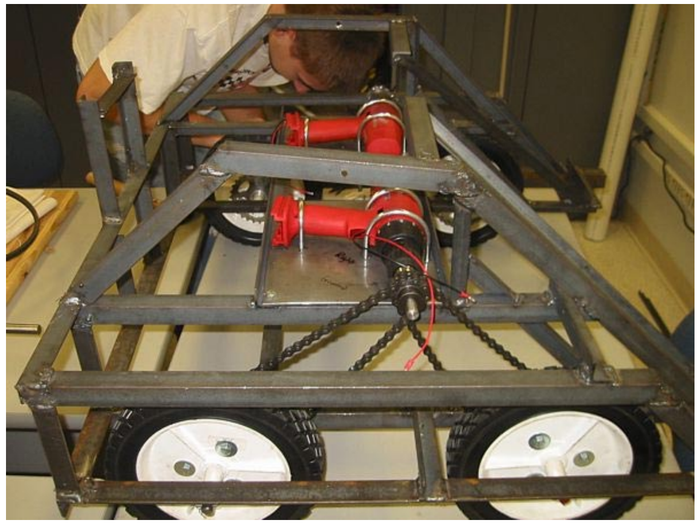


The robot's objective was to battle for possession of 10 bocce balls scattered throughout the course and a sixteen-pound bowling ball on a ramped platform located at the center of the course (shown left). The Bocce balls and bowling ball were then to be placed on pedestals within the "home" or base area. In the figure, the red circles indicate Bocce balls raised on 3-inch diameter PVC pipes 2 inches in height. Standard regulation size bocce balls were used, which are 113 mm in diameter. The gray circles represent 3-inch PVC pipe pedestals 3 inches high. The green circle represents the 16-pound bowling ball (approximately 9 inches diameter) placed on a 6 inch PVC pipe that is 2 inches high and located in the center of a raised platform. The blue rectangles represent inclines that slope to 1 foot above the rest of the course. Small strips of wood _ inch high and _ inch wide line the perimeter of the ramps and raised platform. There are 3 home areas, designated by each semi-enclosed area with 3 gray circles. The opening of each home area has a 2" high step.

During the first round, the robot began in a pre-assigned base area and attempted to collect the bocce balls and bowling ball without any other competing machines in the arena. The second and third round matched three robots of roughly the same performance. The final rounds consisted of two robots per match. Rounds involving multiple robots also involved full contact competition after a certain amount of time or movement of the bowling ball.

The goal of the team was to design an autonomous robot with a separate remote control interface in case the artificial intelligence did not succeed For efficient use of individual skills, the team was split into four collaborating groups: Chassis, Power/Electronics, Sensors, and Code. Chassis group was in charge of the physical robot, which included designing and building the frame, defensive and offensive systems and ball retrieval systems. Power/electronics group was to build any circuitry and interfaces needed to connect motors, power supplies, remote control connections and requirements, and antenna. Sensors group worked on imaging, optical and distance gauging for the Autonomous systems. The Code group wrote out the programs needed for Autonomous performance.

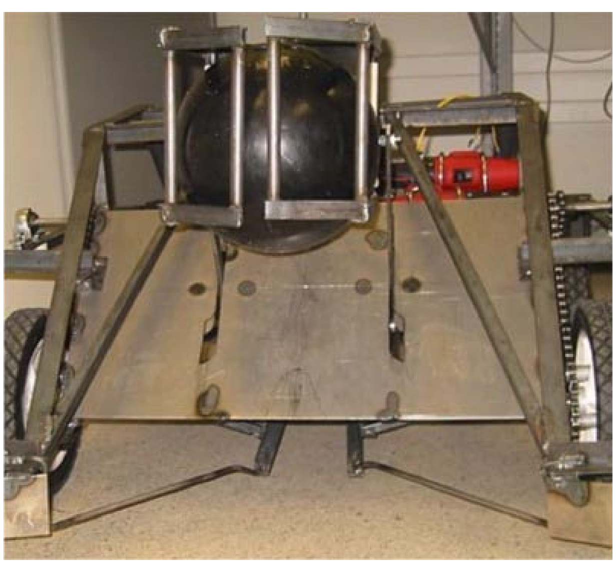
The team planned on running both autonomous and RC, therefore we designed a defensive rather than



offensive robot making is possible to hold all the points (every object) in the entire course securely within our robot while still taking abuse from contact with other robots. This meant that the robot could pick up all the bocce balls *and* the bowling ball using two independent mechanisms without returning to the home area. This robot was the only one at the competition that could perform this task. The designs were made as uncomplicated as possible so reliability would not be an issue and construction would be relatively easy.

For durability, cost, and ease of use, the robot was built out of steel angle stock. The overall frame is a square base 34"x34", just two inches under the limit. For simplicity, tank style skid-steering with a motor to drive each set of wheels was used. With this system, it is still possible to operate even if one of the drive trains fails. Individual bicycle chains connect the driver, with sprockets bolted (with spacer) to the inside of the wheels. The drivers for the wheels (and bocce ball conveyor) were standard 12-volt hand drill with rechargeable battery packs. A picture of the unfinished frame can be seen above, right. The wheels were solid plastic rims with a solid rubber tread rather than air-filled, which are vulnerable to piercing attacks.

Bocce balls were collect by a ramp and top mounted conveyor system connected to the undercarriage of the frame. The balls were channeled toward the middle of the robot by a rail on each side of the front end of the robot. Then a rubber conveyor belt rolled them up two more rails into a holding pen in the back of the robot. The lower roller of the conveyor was placed so that it would be low enough to pass the balls up the inner rails, providing enough contact to roll them all the way up the ramp, yet high enough not to impede balls from entering the ramp. However, the inner rails had to be as low as possible so bocce balls would easily roll up, yet high and wide enough to clear the PVC pedestals. The rails were finally mounted an inch off the ground, but far enough apart that a pedestal could pass between then. A solenoid controlled door connected to the very back of the robot retracted to allow the balls to roll out of the pen either for placement on the PVC pedestals or storage within the home area.



The mechanism for picking up the bowling ball had to lift the bowling ball up five inches so the bocce balls could still reach the conveyor. It also had to have a very good grip on the ball so it would not roll off if another robot hit our robot. The ball gripper was a two-fingered gripper that rotated down through an arc as it opened. A small, beveled, bi-directional motor spun a gear that was threaded onto a threaded rod at one and connected to grabber at the other end. As the motor turned clockwise, the threaded rod moved to extend the mechanism, opening the gripper, which was attached to guide bars. The guide bars slid in slots cut into a guide plate. The slots widened at the bottom of the travel path so that when the bars reached the end of the slot they would spread, opening the gripper. As the motor turned the opposite direction, the guide bars were pulled closer together, pinching the gripper shut around to bowling ball and bringing it to rest on the frame, as shown to the left and below.

The final chassis product was a protective armor covering of 1/16 inch aluminum plating. More pictures (and video) of the construction of and finished robot can be seen at: http://www.cae.wisc.edu/~ieeerobo

Consumer grade high current reversible speed controllers powered the wheels.

To drive the bowling ball snatcher, bocce ball conveyor, and to release the solenoid, the team captain interfaced the drills to our RC receiver by developing a circuit that amplified the pulse width modulated signal from the RC receiver and converted that to a simple on/off signal which could be used to turn on power transistors and each of the motors. All of the electronics were fitted to a single sheet of aluminum that could be easily unbolted from the frame for troubleshooting and switching between RC and AI control. Also, all of the connections from this board ran into a terminal strip so it could be completely removed from the chassis without disturbing connections on the board itself. The four rechargeable batteries were also connected to the circuit board and mounted in such a way to make them easily replaceable.

Given the overall complexity of the course, the most effective technique was video navigation. The competition allowed us to use a fixed video camera overhead and off-robot computing. The basic idea was to grab a frame from the camera, locate all the important objects in the picture, run that through an AI algorithm, and transmit a movement command, via RF link, to the robot. The output of the AI program was a formatted packet of 3 bytes, indicating motor speeds, directions, and several other status bits. The packet was output to a serial port on the PC that was hooked up to a RF transmitter. A matched receiver on the robot received the packet and a micro controller translated it into pulse width modulated signals for the drive motors and on/off signals for the other motors. The micro controller also had inputs from the gripper and bocce ball conveyor, indicating whether or not each had a ball. The entire AI design encompassed everything a human operator would look at and could control.

At competition day the RC version of the robot ran very well, but the AI version was almost useless. The ceiling was not high enough for our camera to be mounted directly over the course. Only a very small portion of it could be seen with a fixed camera without a wide-angle lens. There was no choice but to mount the camera high up along a wall and get a downward angle shot. This neither accurate nor efficient because obstacles obscured some of the balls and the top of the robot could not be seen very well, which was needed for calculating the direction of travel. Also, the RF link produced and extremely noisy channel and was replaced by a serial cable tether to relay commands to the robot. The command link now worked but the vision code could not find the robot. It would find the brightly colored bocce balls without a problem but the robot could not figure out where it was in relation to itself. Assuming it was on track, it slammed straight into a wall every time. The autonomous control needed modification.