MINI URBAN CHALLENGE

Rulebook

Revision 2016 V1.0

Published September 18, 2015

Sponsored By

DOOLITTLE INSTITUTE
speed - innovation - solutions

AIR FORCE RESEARCH LABORATORY

JOHN DEERE

Table of Contents

1 General Overview

The Doolittle Institute (DI) announces the 8th Annual Mini-Urban Challenge (MUC) sponsored by DI, the Air Force Research Laboratory (AFRL), and Special Operations Command (SOCOM).

The purpose of this competition is to design and program a robotic vehicle that can autonomously navigate a mini-urban city, using a LEGO® MINDSTORMS® EV3 kit. This kit will be provided free of charge to each new team, once the team completes registration.

At both the regional and national competitions, teams will be scored in a variety of categories. Points are earned for navigating the mini-urban city, giving a technical presentation, and an engineering design notebook. The winning team will be selected based on the highest total score. The top two teams from each regional tournament will be invited to compete at the national competition. Awards will be presented in several categories.

The national competition will be held in Tampa, Florida. A stipend is provided to help cover travel and hotel for the teams invited to attend. Teams will be responsible for any expenses beyond this stipend.

1.1 General Team Rules

1. Teams must be comprised of high school students. The team may have a minimum of 3 students and a maximum of 10 students.

2. Schools may have up to two teams. Each team must have separate hardware, program code, and application forms. Teams may be supervised by the same teacher.

3. Team members must participate in the regional competition to be eligible national competition.

4. Each team must be supervised and accompanied to competitions by at least one teacher over 21 years of age. On the application, the supervising teacher will certify that all team members are high school students and will have the school principal sign the application as verification. The teacher must also include a signed waiver for himself/herself plus a waiver for each student signed by the student and the student's parent/guardian if the student is under the age of 18.

5. A pit area will be provided at the competition with power connections. Teams are responsible for bringing any equipment they will need the day of the competition.

6. We cannot guarantee Wi-Fi will be available at the competitions.

7. All teams are required to turn in the following at the registration table when they arrive:
    a. A copy of the team's code
    b. A copy of the team's PowerPoint presentation
    c. (Optional) A single page addendum to the engineering notebook

These items should be copied onto a flash drive that is clearly labelled with the team's name. The flash drive will not be returned to the team nor shared with any other teams. Failure to turn in these items will result in a scoring deduction and may result in disqualification from participating in the national competition.

8. Enlisting the help of team mentors is encouraged. Competition staff will work to pair mentors with teams. Mentors may be professionals in science, technology, engineering, or mathematics (STEM) fields working in the local area or students in STEM disciplines attending schools in the local area. Mentors are encouraged to:
   - attend practices
   - help students learn general concepts and processes
   - advise teams on their programming and on maintaining the engineering notebook
   - provide other needed support to the teacher

The teacher/mentor's role should be limited to guiding problem solving and providing concept examples. The teacher/mentor is not to build any part of the project or write any of the code used in the competition.

2 Mini-Urban Challenge

2.1 The Challenge

The mini-urban city competition will take place on two identical city mats measuring 10'x42' and comprised of 2'x2' SoftTiles. Each team will compete twice during the day of the competition, once in a morning session and once in an afternoon session.

Each team will have 30 minutes at a calibration station, followed by 30 minutes in the mini-urban city competition area. While at the calibration station, teams will be given the assigned city, home base, and 3 parking lots to visit while navigating the mini-urban city. The parking lots will be listed in random order and do not necessarily represent the optimal order of the lots. For the 2016 competition season, robot vehicles park **ONLY** in the five parking lots which are on the left side of the robot. These parking lots are 1, 3, 4, 6, and 9. (See Appendix A, Figure 1.)

After calibration, the teams move to the mini-urban city. Two teams compete simultaneously on each city mat, starting in home bases at opposite corners. During this 30-minute period, teams may have practice runs as well as judged runs. Teams are allowed to have up to three officially scored runs during this time. A team must inform the judges before beginning an official run that will be scored. At the end of the 30-minute time period, all scoring will stop.

The robot must enter the mini-urban city from the home base, travel through the city to the parking lots, park in any parking space in each assigned parking lot, and then exit the city by returning to the home base and parking in the home base. The robot should use the optimal path (shortest distance) through the mini-urban city to visit the parking lots. A penalty will be assessed if the robot does not follow the optimal path. While in the city, the robot should obey traffic rules by stopping at stop signs and following standard right-of-way rules when other vehicles are encountered.

Bonus points can be earned by a team if the robot can demonstrate the ability to dynamically re-route its path to the assigned parking lots when a roadblock is encountered at an intersection. If a team decides to attempt to earn the bonus points, they must inform the judges before an official run. After the robot begins the run, a judge will place a roadblock at an intersection on the optimal path to a parking lot. When the robot encounters the roadblock, it should calculate a new path based on an alternate route to the parking lot.

The highest score out of six possible official runs for the day will constitute the score for navigation.

2.2 Navigation

While navigating the mini-urban city, the robot must obey all one-way directions, stay on the road, and maintain a safe distance from other robots. A control robot will be used to engage with the team's robot to test its ability to yield the right-of-way and avoid rear-end collisions.

2.2.1. Intersections

There are multiple intersections within the mini-urban city. The robot is required to come to a complete stop at all intersections. Intersections are marked with a red line (roughly 1.25 cm wide) running perpendicular to the road at the location of the stop sign. The red line will be located only on the sides of the intersection requiring robots to stop, based on the one-way direction of the roads. The red line does not cross into the colored lines along the edge of the road.

2.2.2 Right-of-Way

As the robot navigates the mini-urban city, conventional right-of-way rules should be followed. In a parking lot, a robot that has pulled into a parking space should yield to a robot that is passing by on the street. When a robot approaches an intersection, if another robot is already in the intersection, the robot should wait until the intersection is clear. If two robots reach the intersection at the same time, the robot on the left should yield to the robot on the right. A control robot will be placed at an intersection to test the robot's ability to yield the right-of-way. (See Appendix B for a link to a tutorial regarding the official MUC standard for right-of-way.)

2.2.3 Collision Avoidance

The robot should not come in contact with any other robot. For example, if a robot fails to slow down when approaching a robot that is travelling more slowly in front of it, and causes a rear end collision, the robot in the back will be assessed a penalty. A control robot will be placed on the mat to test each robot's ability to avoid rear-end collisions. Once the team's robot has demonstrated its ability to avoid collisions, the control robot will be removed from the mat.

2.2.4 Buildings/Parking Lots

During the challenge, the robot is required to navigate to three specified parking lots. Once the robot locates a parking lot, additional points may be earned for successfully parking in a parking space. Each parking space will be designated by a blue line on the side of the road. Parking spaces within the parking lot will be lined with white lines that are 1.25cm wide.

Each parking space is at least 20cm wide. Parking spaces are located along the edge of the road. (See Appendix A, Figure 2.)

The robot may park in **any parking space** in the designated lot. **The robot must pause for at least 3 seconds in the space to receive points.** All parts of the robot that are in contact with the floor (essentially, the tires) must be fully inside the parking space to earn full points. Robots are allowed to touch the white line, but cannot touch any surface outside of the line.

2.3 Technical Presentation

2.3.1 Oral Presentation

Each team must give a technical presentation as part of the competition. The presentations will be a total of 15 minutes: 10 minutes for the formal presentation and 5 minutes for questions from the judges. All team members are encouraged to be present during the presentation, but teams may elect to designate certain team members as their spokespeople.

Teams will be scored on the content of the presentation, as well as the overall delivery, organization and clarity. Teams are strongly encouraged to include photos, videos, and sketches or even to give a demonstration of the robot's capabilities. During the presentation, teams will be required to show their design approach and explain the method they used for path finding to navigate to the parking lots. Examples from the team's engineering notebook should be used to fully explain their ideas.

Teams should answer the following questions and add any other information thought to be important:

- Who is on the team and what did each person contribute to the competition?
- What was the team's approach to meeting the challenge provided by the Mini-Urban Challenge?
- Why was this approach unique?
- Why was this approach the best?
- Describe the process for selecting the final robot design.
- What method was used to find the optimal path for navigation?
- What challenges did the team meet along the way and how were these challenges overcome? More points will be awarded to teams who clearly explain their problem solving and engineering design techniques.
- What software programming language was used?
- What are the unique aspects of the program?

2.3.2 Engineering Design Notebook

Teams are required to turn in an engineering design notebook one week (7 days) before the competition. This will be forwarded to the judges for review. Notebooks turned in late will be accessed a late penalty. The notebooks will not be returned to the teams.

The notebook must contain an executive summary page and a picture of the team's robot. On the morning of the competition during registration, teams will be permitted to turn in a one-page addendum to their engineering notebook to explain any additional changes/progress made to their design/code during the week prior to the competition.

The engineering design notebook requirement has two purposes:

1. To provide a framework for students to learn the process of engineering design.
2. To provide a guided method to convey, in detail, the progress of their project during the time period they prepared for the tournament.

Students should use include the following the engineering design process steps:

1. Research – Discuss research strategies and findings, document sources appropriately. Research is necessary throughout the project development.
2. Problem analysis – Identify the various challenge segments, the related requirements and constraints, and how these will affect the team's ability to find the solutions.
3. Design – Prior to building or programming, discuss options for accomplishing the various challenge segments. Weigh the advantages and disadvantages of each option. Use processes such as pseudo code and/or flow charts to plan the implementation of these solutions. Veteran teams should not use the same robot from previous seasons, but should make improvements to the design each year.
4. Implementation
    a. Hardware – Explain robot function.
    b. Software – Discuss key algorithms.
5. Testing & revisions – Discuss issues with testing and document revisions.

2.4 Design

2.4.1 Hardware

1. Robots must be autonomous and may not be remotely controlled by Bluetooth or any other control device during an official run. "Remotely controlled" includes, but is not limited to: commands to reset the robot's computer, commands to reinitialize the robot, commands to adjust the robot's route, etc.
2. Only one controller (brick) may be used per robot.
3. Robot movement must be accomplished through direct contact with the competition surface. Power may only be provided through the battery pack in the EV3 controller.
4. The robot motor may not be modified in any way.
5. The robot must be built using only LEGO® components. LEGO® parts not included in the MINDSTORMS® EV3 kit may be used. Note: for Best in Show decorations refer to Section 2.5.1.
6. The following approved sensors may be used:
    a. Color light sensor
    b. Touch sensor
    c. Ultrasonic sensor
    d. Infrared sensor

    Note: No other sensors may be used, but teams may use more than one of the approved sensors. If additional sensors are used that are not provided in the EV3 Core kit, these must be purchased by the team.

2.4.2 Software

Teams may use any programming language compatible with the EV3. If requested on the registration form, a team will be provided with either a team license for LEGO® MINDSTORMS® Education EV3 or a single-user license for RobotC. The Mini-Urban Challenge website (www.miniurbanchallenge.com) provides a list of some of the software options that are available.

2.5 Scoring

2.5.1 Navigation Scoring

The score for the navigation portion of the competition will constitute 70% of the total score.

Teams get points for navigating to each parking lot. Teams may earn additional points by parking in a parking space. Once the robot has parked in a parking space, the robot must pause for 3 seconds before exiting the parking space.

Bonus points will be awarded if a team's robot can successfully navigate around a roadblock. A team attempting to score these extra points must request to have a roadblock placed at an intersection on the mini-urban city mat. Teams must make this request prior to beginning an official run. The position of the roadblock will be unknown to the team before the robot starts it run and will be placed at an intersection by a judge after the robot has started its run.

At the completion of a run, the robot must maneuver back to its home base, park inside the block, and completely stop to obtain full points.

At any point in a scored run, a team can say "STOP" to halt the scoring. Usually this occurs just before the robot runs into a building, runs off the mat or is about to collide with another robot. All scoring stops at the point that the team says "STOP".

If a team is mid-run at the point when their allotted 30 minutes are up, the team can continue the run, but all scoring ceases and no more points are awarded after their time runs out.

2.5.2 Technical Presentation Scoring

The score for the technical presentation and the engineering notebook will constitute 30% of the total score. Teams are required to take their robot to the presentation and will have the opportunity to explain their robot design to the judges. A projector and computer with Microsoft PowerPoint 2010 will be provided.

2.5.3 Total Scoring

All rulings and scoring by the judges will be final. The final team score is the sum total of points accumulated in the navigation of the mini-urban city, the technical presentation, and the engineering design notebook. In the event of a tie, a run-off will determine the winner.

2.5.4 Run-off

At the end of the day, if two teams are tied after their composite scores have been calculated, there will be a run-off. The two teams will compete simultaneously, one team on each mat. The winner of a coin toss will choose either city 1 or city 2 and the other team will choose either home base 1 or home base 2. The teams will be given identical parking lot assignments. The teams will be allowed to have 15 minutes for calibration and five minutes for practice runs, then they both have to make one final run. Each team's run will be timed. The winner will be determined by the most points scored. If both teams are still tied, the team with the fastest run will be declared the winner.

2.6 Awards

2.6.1 Regional Competitions

The teams with the top three scores at each regional competition will be presented trophies for first, second and third place. Three additional awards will be given for:

***Best Technical Presentation**,* awarded to the team with the highest score earned for the technical presentation.

***Best in Show**,* awarded to the team that has the most aesthetically pleasing robot. The definition of “aesthetically pleasing” is subjective; therefore, teams are encouraged to personalize their robot. Teams are not required to use LEGO® components for decorating the robot, however, the robot should be fully functional with or without the decorations. No part of the decorations may shield the sensors to enhance technical capabilities. Only LEGO® parts/components may be used around the sensors.

Best Engineering Design, awarded to the team with the best use of creative design in the form and function of the robot.

All judges, including mini-urban city judges, will also have the opportunity give input to the Best in Show and Best Engineering Design awards.

2.6.2 National Competition

The top two teams from each region will be invited to compete at the national competition. A stipend will be provided to the teams to help cover travel and hotel expenses. This will be a fixed amount, based on the distance travelled. Travel stipend amounts may vary from year to year depending upon funding. Teams will be responsible for any expenses beyond this stipend.

Winners of the national competition will receive prize money as well as trophies. Prize amounts are based on the number of sponsors and will be posted on the Mini-Urban Challenge website when they are determined.

Appendix A: Mini-Urban City Mat

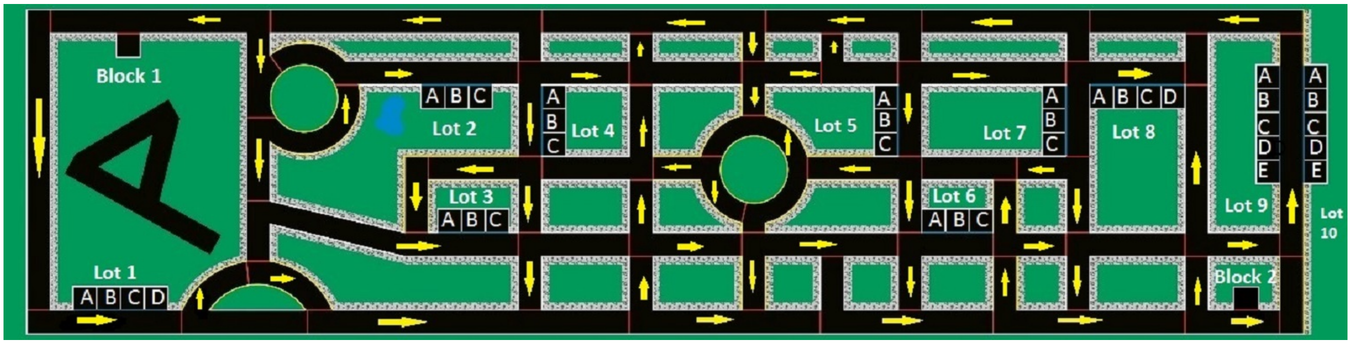

Figure 1. Course Mat Showing One-way Streets

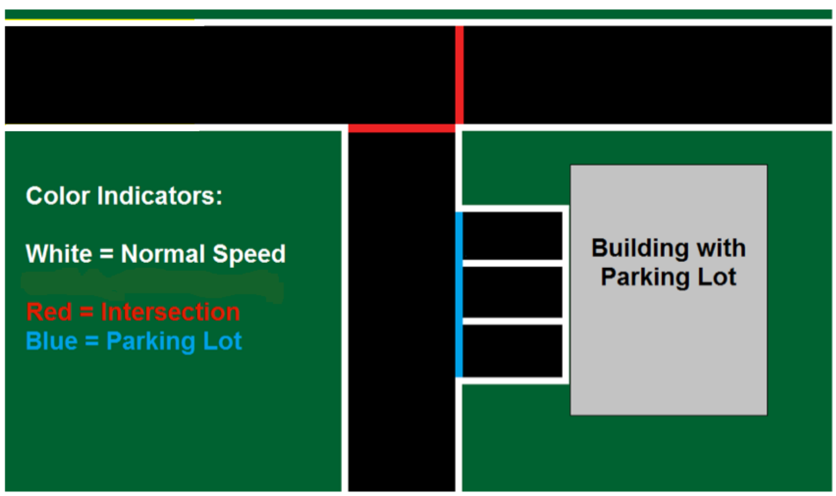

Figure 2. Mini-Urban City Mat Design Concept

The road surface will be at least 20cm wide at all times. Parking spaces measure at least 20cm x 20cm. Each road is assigned a one-way direction. The road can only be traversed in that direction. Along each edge of the road is a colored line, 1.25cm wide, giving information about the road (see Figure 2-1) The colored line will be touching the edge of the road (i.e. no black will show between the colored line and the "grass"). Between the road and the "grass" many roads have "cobblestone" sidewalks that are shades of gray. All lines will be painted using pantone colors so that teams can exactly match these colors when programming their robot:

Pantone Process Black = Road Surface
Pantone Red 032 = Stop Sign
Pantone Process Blue = Parking Lot Indicator
Pantone Green 347 = Green out of bounds

Calibration stations will be available on competition day for each team to make adjustments due to color and lighting. Calibration stations DO NOT have the "cobblestone" sidewalks. A copy of the course mat diagram can be downloaded from the MUC website.

Appendix B: Resources

1. Mini-Urban Challenge YouTube channel

   https://www.youtube.com/channel/UCSXjZYYeQWvoHfRiop7Q60g

2. Mini-Urban Challenge google groups discussion forum

   https://groups.google.com/forum/#!forum/mini-urban-challenge

3. Discussion of Shortest Path problem

   https://en.wikipedia.org/wiki/Shortest_path_problem

4. Example of Dijkstra's Algorithm for Shortest Route Problem

   http://optlab-server.sce.carleton.ca/POAnimations2007/DijkstrasAlgo.html

5. Additional resources, check the resource page at miniurbanchallenge.com