University of Florida
Department of Electrical and Computer Engineering
Spring Semester 2016

EEL 4665/5666: INTELLIGENT MACHINES DESIGN LABORATORY (IMDL)

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Web Site: http://www.mil.ufl.edu/5666/ **Class Email: UF.IMDL@gmail.com.**

Announcements

- Labs meet in NSC 407. See the Spring 2016 Lab Schedule in class and the class website. You **must** attend your assigned lab every week and *should* attend a minimum two lab periods weekly.
- You must create, maintain and update your own **IMDL website by 1/11/16** posting/blogging your weekly (due every Tu. by 8:30a starting on 1/12) and other progress reports as required/appropriate.
- Make sure you take note of the important dates and deadlines (on page 7). You must have your electronic board(s) ordered by the week of 1/11, and the board(s) built & tested by the week of 1/19.
- Your robot must have an ***approved*** special system/sensor {not IR, Cds cells, Sonar, force sensor or bump, i.e., no digital or simple analog sensor and no camera performing simple color/blob detection}. You will report on this system (with a parts list & completion timeline) in March.
- You **must** follow the posted guidelines in the class website for ***all*** reports and ***all*** oral presentations (PowerPoint or equivalent). Failure to make a ***meaningful*** Final Oral Presentation may result in a **ONE LETTER GRADE** final grade deduction.
- **Demo Day** and **Media Day** are required attendance/participation days. Failure to attend and/or demonstrate a robot on Demo Day and Media Day (both days) will result in an automatic failure (a letter grade of **E** assigned for the course grade). Media Day is done in two segments, one in the morning (Private Media Day) for robots that are not ready for public viewing and one in the afternoon (Public Media Day) for all projects deemed ready for public viewing. If the Media Day (either segment) robot demo is judged to be significantly weaker than the Demo Day robot demo, up to a letter grade deduction may be assessed by the faculty (to discourage slaking off between demos). Students must generate a video of their functioning robot which ***must*** be posted/linked in their website ***prior*** to the actual campus demo (Pre-Demo Day, Demo Day and Media Day).
- Your robot **must have LCD** some other ***approved*** feedback mechanism during robot development stages. Use LEDs liberally to indicate what sections of code/behavior your robot is engaged in.
- Use smart phones as cameras. Smart phones can provide the majority of sensors required for a robot.
- EEL-5666 graduate student designs are expected to be higher caliber and more sophisticated than EEL-4665 undergraduate student designs both in software, hardware and in autonomous behaviors.
- Check **your email** and the **class web site** daily!!! Much information is distributed electronically.

Recommended Textbook

Thomas Braunl, *Embedded Robotics 3rd Edition*, Springer, ISBN 978-3-540-70533-8, 2008
Pay close attention to the hardware/software discussions in Chapters 1-6 & the Mobile Robot Design section (Part II).

Optional Reading List

Fred Martin, *The 6.270 Robot Builder's Guide*, MIT, Cambridge, MA, 1992.
Pay close attention to the hardware/software hints in this optional reference. It is posted on our website.

Course Robot Design Options

1. Normal Track: design, build, and program an autonomous mobile robot using parts combined with novel circuits and mechanics of your design. You can design your own PC boards or buy a board.
2. Design Intensive Track: Build a sophisticated mechanical system emphasizing the mechanisms (hardware/platform) with less sophisticated software. This must be pre-approved by the IMDL Jury.
3. Software System/Differential Track: Build a scaled-down version (using a lot of off the shelf components) of the hardware as the normal track above but with **significant software** to implement sophisticated machine intelligence behaviors. This must be pre-approved by the IMDL Jury.

Equipment Costs

In most projects, your autonomous mobile robot will cost from $200 to $300 for parts, depending upon your own private stock and sources.

Local Supply Stores

Lowe's, Home Depot, Radio Shack, Hobby Town USA, Hobby Lobby

Course Objectives

The *Intelligent Machines Design Laboratory (IMDL)* constitutes a type of capstone advanced undergraduate laboratory and/or a beginning graduate laboratory that provides students with a realistic engineering experience in design, simulation, fabrication, assembly, integration, testing, and operation of a relatively complex, intelligent autonomous machine. A course project, oriented about a small, microcomputer controlled, electronically sensualized, autonomous mobile robot that exhibits various tasking behaviors, requires the integration of various sub-disciplines in electrical and computer engineering: microcomputer interfacing and programming, analog and digital electronics, computer aided engineering, control, mechanical design, CAD and communications.

Pedagogical Philosophy

This course is non-competitive in nature. Your grade will be determined from how you meet the course performance objectives (as proposed by you and approved by us), not by how well you perform compared to a fellow student. If you meet your own instructor/TA approved performance objectives, you will earn an A! You are encouraged to help your classmates with ideas, concepts, and advice as well as to discuss problems encountered. Someone may have already solved a problem that is plaguing you, so speak up about your successes and difficulties. If you like someone's concept about a sensor, a behavior, an actuation mechanism, a mechanical structure, etc., and want to include the same on your robot, feel free to do so, ***but you must always give credit to the student in your document***s, i.e., you must reference the author's work. If you do not reference the original author's work and you are found in violation of the UF Honor Code, you will obtain a failing grade. This course encourages and teaches the practice of sound Engineering and UF Ethics.

How to Make an A in this Course

For a standard robot design and implementation the following requirements will merit an *A* grade in this course. Your robot must:

1. Be designed to perform a "practical" task(s). Examples include: vacuum cleaning, lawn mowing, golf ball fetching, tennis ball fetching, trash collection, game playing, predator-prey action, group behavior (flocking, formation, homing, predation, etc.), minefield sweeping, tile laying, wall building, material handling, map making and navigation, toy sorting, smart warehouse, etc.
2. Possess a minimum of 4 types of sensors: 1) proximity detectors (e.g., IR, Sonar, etc.), 2) bump sensors (e.g., mechanical sensors, bend, tilt, etc.), 3) A unique "special" sensory system of your own design, 4) anything else you want/can afford (e.g., encoders, voice, GPS, wireless camera, etc.)
3. Several integrated behaviors that use the sensors and accomplish the task or tasks established by you.

In addition you must

1. Write a pre-proposal and informal proposal and two formal written reports, which include a bill of materials and a proposed completion timeline. Use bulleted lists in all your proposals that include types and counts of sensors, actuators, special systems, behaviors and a bill of materials.
2. Post weekly formatted reports (due every Tu., starting 1/11/16) detailing your progress,
3. Give three oral reports (PowerPoint) on your robot progress (***must*** follow published guidelines),
4. Be prepared to give weekly in-lab demonstrations concerning your robot and its development.

By the end of week five, most of you will have implemented two sensory systems (e.g., proximity and bump detection) and one behavior, e.g., collision avoidance, on the robot. Now your job is to come up with two or more additional sensors, a system of your own design (a special sensor), and three or more simple behaviors. We encourage you to design your robot to perform some type of mechanical manipulation of objects. The instructor (with TAs) will negotiate with students doing their own creative designs in order to determine phase requirements and accomplishments necessary to make a grade of *A*. A special sensor can be a novel design or the use of existing sensors in a new/novel way. The special sensor/system is a negotiated agreement between the student and the instructors/TAs.

Course Structure

Three/four lecture periods per week will explore the theory of behavior-based robotics with emphasis on reaction-based machines. Midway in the semester lectures will be replaced with more laboratory time. Advanced students with the appropriate background may, if they choose, investigate topics involving short-term perceptual memory, environmental modeling, or cognition and learning. The course emphasizes hands-on experience and not theory. AI theory is covered in EEL-5840 & EEL-6841 (Machine Intelligence 1 & 2). These courses are available as complementary courses to EEL-5666 to help you investigate the science and applications of autonomous mobile robot in intelligence and learning. You can apply these AI principles to the robots you build in EEL5666. Other courses include:

EEL 5840: Elements of Machine Intelligence	**EML 6281 Robots 1**
EEL 6841: Machine Intelligence and Synthesis	**EML 6282 Geometry of Mechanisms & Robots II**
EEL 6825: Pattern Rec. & Intelligent Systems	**CAP 4621 Artificial Intelligence and Heuristics**
EEL 6562: Image Processing & Computer Vision	**CAP 5635 Artificial Intelligence Concepts**
EEL 6814: Neural Networks for Signal Processing	**CAP 5416 Computer Vision**
EML 3806 Geometric Modeling & Robotic Manipulators	**CAP 6617 Advanced Machine Learning**

Tentatively, tutorials (as needed) will allow the student to learn proper soldering, wire-wrapping, electronic circuit prototyping procedures, electronic circuit debug and testing techniques, PC board layout, PC fabrication, PC board assembly techniques, mechanical design techniques, and Computer Aided Engineering and Design *(CAD)* capabilities on computer workstations/laptops. In addition, some of the tutorial time will be spent developing documentation, checking student progress and proffering advice. By mid-semester tutorials will fade into lectures about the behavior-based paradigm, biologically inspired robot design and fundamental issues in machine intelligence. Behavior theory will guide and assist the student in the preparation and implementation of behavior algorithms for their robots.

A minimum of two weekly, three-hour laboratories allows the student to utilize various resources under instructor/TA supervision. During scheduled laboratory times, students will work on hardware portions of their projects and demonstrate circuits or robot capabilities from time-to-time as proof-of-progress. Students may attend additional laboratory times on a space-available basis.

Students are encouraged to work individually, or in **very special cases** in teams of no more than two people with two independent autonomous mobile robot of their own design, in order to meet the course objectives. The contributions of each team member must be explicitly laid out for the instructor to review and evaluate. The instructor(s) will provide structure and guidance to assist the students with specific steps in the engineering process, from concept to design, to realization, to test, to operations. Design freedom will be factored into the project to allow the students creative expression. You will develop functional hardware and software modules during the course of the semester. Incremental development will be the key. At each stage you will have an operational robot, which increases in functionality and competence as the semester progresses. This approach avoids the *big-bang/blue-smoke phenomena* wherein students produce last minute systems that fail, to the disappointment of everyone.

At the end of the semester, each student or team will have produced a sophisticated, microcomputer controlled, autonomous mobile robot with electronic sensors—a robot that can exhibit “interesting” behavior that is a consequence of intention. The specific choice of robot design, sensor selection, machine perception algorithms, and behavior control algorithms are left up to each student based on their individual preferences and creativity.

Grading Criteria

Table 1 illustrates grade accounting. There are no exams. You will write one proposal and two reports, give three oral presentations and give several demonstrations of your hardware. You will also generate out 12 short weekly progress reports, which are graded.

Each week, starting week 1, you have In-Lab check-offs, which consists of some software/hardware in-lab demonstration specific for that week. Details on each of the semester’s In-Lab requirements are posted on the *announcements* section of the class web site. Two of these are graded at 5% each and the first four at 2.5% each. Others, though not graded per se, are required.

The informal proposal abstract due at the end of week 2 (R 1/14) consists of one to three pages, excluding figures and tables. You should draw a sketch, list a bill of materials, and detail your proposed work schedule. In addition, you should specify the purpose, function, structure & design of your robot and predict your robot’s capabilities upon completion of your project. This pre-proposal will then be submitted to the IMDL jury (the professors and TAs) and you will be notified electronically as to the suitability/unsuitability of the proposed robot. You will then generate an informal written proposal on the work by the end of the third week (R 1/21). During the fourth week you will report formally (orally, 3 minutes and in written form) on your proposed robot.

Around the middle of the semester, you will demonstrate your robot executing collision avoidance (sense/react) in the laboratory. For students taking creative, high-risk projects, or designing complicated mechanisms the expectations of this demonstration will be negotiated with the instructor/TAs.

The special system design report will present theory of operation, circuits, software and experimental data on your own “special” sensor (or whatever you have negotiated with the instructor). This document should not require more than 10 pages, excluding figures, tables, schematics, specification sheets, and appendices. You will give a 3-minute talk to the class about your design. You can extract your talk directly from your report. You will also do a hardware demonstration of your special system in lab.

The final document will consist of enhancing and integrating the proposal and sensor document with a complete description of the robot platform, function, circuits, behavior programs, and operation according to a specific format (see the *handouts* section of the class web site). The student will present a 10-minute final talk, and a give a 10-minute hardware demonstration covering the entire project on ***Demo/Media Day*** **(mandatory)**. These final reports, still pictures and all your videos will be placed on the IMDL web site and exposed to the Planet, so make them good!

Each week (every Tuesday starting 01/11/16) each student must post a formatted progress report stating the immediate past week's activity and accomplishments. The weekly report may typically vary from 100 to 250 words. The objective of all reports should be effective communication. Table 1 depicts final grade percentage allotted to each assignment.

Rubrics for In-Lab Demos: Obstacle Avoidance, Special Sensor, Pre-Demo

Obstacle Avoidance Rubric

- 5.0: Robot doesn't hit anything and can escape (or doesn't enter) a Braitenberg trap.
- 4.5: Doesn't hit anything but gets stuck in the trap, or, escapes the trap but hits objects (either way, the robot's obstacle avoidance is good)
- 4.0: Obstacle avoidance is decent, not great, gets stuck in the trap
- 3.5: Poor obstacle avoidance or no obstacle avoidance, is able to drive around
- 3.0: Robot is able to react with sensors and motors/servos but not able to drive around (i.e., uC, battery, motor/servo, and a pile of wires on a proto-board)
- 2.5: Robot explodes the night before, but student is able to show a video of their robot doing obstacle avoidance (must bring in robot during the In-Lab Demo even if it doesn't work!)
- 2.0-1.0: Unable to perform obstacle avoidance during the week (student cannot show a video on demo day or video does not demonstrate obstacle avoidance), demonstrates the following week
- 0.0: Student is unable to demonstrate avoidance during the demo week or the make up week.

Robots that are purposely stationary (piano playing system, beer bottle filling platform...) or is a special system (hexapod, boat, rolling robot, climbing robot...) will be graded on a case-by-case basis determined by the student and TA prior to obstacle avoidance. It is the responsibility of the student with this type of project to talk with the TA early enough to avoid last minute failures.

Special Sensor/System Rubric:

- 5.0: Special sensor is robustly demonstrated by integration with behaviors and actuators, almost ready for pre-demo day (i.e., camera tracks face/ball with pan/tilt mechanism, robot backs away/avoids object using Kinect, robot turns toward sound)
- 4.5: Special sensor is robustly demonstrated to work but has not been integrated with actuators on platform or does not affect the behavior of the robot
- 4.0: Special sensor works but not robustly (works half the time in the most ideal situations), may or may not be integrated with platform actuators/behaviors
- 3.0: Student shows that data is being received from the sensor (i.e., showing only camera feed, printing out distance data)
- 2.5: Robot explodes the night before, but student is able to show a video of the special sensor working (must bring in robot during special sensor demo day even if it doesn't work!)
- 2.0-1.0: Unable to perform special sensor demo during the week (student cannot show a video on demo day or video does not demonstrate special sensor working), demonstrates the following week.
- 0.0: Student is unable to demonstrate their special sensor during the demo week or the make up week.

Special Sensors/Systems that are not able to follow the above rubric will be handled by the TA and the student on a case-by-case basis. It is the responsibility of the student with this type of project to talk with the TA early enough to avoid last minute failures.

Pre-Demo Day Rubric:

- 5.0: Robot successfully performs its primary mission with little help, could be ready for demo day in a few hours, improvements in aesthetics fit/finish or tweaks required but overall robust system (i.e., wire management poor, operates too slowly)
- 4:5: Robot performs it primary mission successfully only under ideal situations, will be susceptible to noise/lighting/colors in NEB

- 4.0: Robot performs part of mission successfully, robot does not perform mission as stated by student's paper/presentations, missing on/off switch, no LCD screen or LED indicators (i.e., robot identifies and retrieves ball then stops)
- 3.0: The robot attempts to perform primary mission, lack of fundamental behaviors, apparent lack of effort by student (i.e., robot can see ball but does not approach or consistently runs over ball over instead of stopping and actuating grabber)
- 2.0: Robot does not work or is not functional enough to attempt the primary mission, can show a video of it performing its primary mission
- 1.0: Robot does not work and student cannot show a video of the robot performing its primary mission, simply displays a non-working robot
- 0.0: Robot is not brought to pre-demo day

Make up days for the pre-demo demonstration will be for emergencies only and on a case-by-case basis.

Demo/Media Day Grading

Wednesday 04/20 is the IMDL Media Day Demo which is divided into two separate events: Private Media Day in NSC-407 from 8:30a-11:00a and Public Media Day from 2:30p-4:30p typically held at the NEB Rotunda. This is your last chance to improve your IMDL Robot Demo grade. In general only those robots that were operational at a higher than 80% level on Demo Day are asked to present at the Public Media Day event (see the below performance gauge). We do this in order to avoid the embarrassment of someone being forced to demo a non-functional robot in front of a crowd. Your class robot demo grade (70% of the course grade) will be the higher grade between Demo Day & Private Media Day. The TA will be in the lab by 8:00a so you can come early and set up. If your robot in Private Media Day performs well, you *MAY* be asked to re-demo at Public Media Day later that same day (which implies that your robot is functioning at over an 80% level. In that case your robot Media Day grade will be the highest grade obtained in Private and Public Media Day).

Robot Performance Gauge for Demo day (actual grades will be assigned by the professor and faculty members/TAs attending the event):

- Successfully performs its primary mission robustly and unassisted, ready for media day today, may need a few tweaks or minor aesthetic adjustments (acceptable for media day)
- Successfully performs its primary mission with little help, could be ready for media day in a few hours, improvements in aesthetics fit/finish or tweaks required but overall robust system (i.e., wire management poor, operates too slowly) (acceptable for media day)
- Robot performs it primary mission successfully only under ideal situations, will be susceptible to noise/lighting/colors in NEB (acceptable for media day)
- Robot performs part of mission successfully, robot does not perform mission as stated by student's paper/presentations, still using proto-boards for wiring, missing on/off switch, no LCD screen or LED indicators (i.e., robot identifies and retrieves ball then stops) (may be acceptable for media day)
- The robot unsuccessfully attempts to perform primary mission, lack of fundamental behaviors, apparent lack of effort by student (i.e., robot can see ball but does not approach or consistently runs over ball over instead of stopping and actuating grabber) (not acceptable for media day)
- Robot does not work or is not functional enough to attempt the primary mission, can show a video of it performing its primary mission (not acceptable for media day)
- Robot does not work and student cannot show a video of the robot performing its primary mission, simply displays a non-working robot (not acceptable for media day)
- Robot is not brought to Demo day (not acceptable for media day)

Table 1 Grade Accounting

Written and Oral Assignments – 15%	Breakdown
Written and Oral Reports# (1 letter grade deduction for missing the Final Oral Report 4/12)	7.5%
Weekly Progress Reports & Web Site	7.5%
Demonstrations in Lab – 15%	
Weekly lab demos for weeks 2-4; Special Sensor Demo (3/10)	5%
Demo Collision Avoidance {Sense/React} (week of 2/22)	5%
Pre-Demo Day Demonstration & video (4/7)	5%
DEMO/MEDIA DAY & Video {4/14; 4/20} – 70% (An E grade assigned for missing Demo and/or Media Day. Maximum 1 letter grade penalty for a poor Media Day demo)	70%
TOTAL	**100%**

EEL 5666 Reading, Report and Demo Schedule

WEEK #/DATE	PROJECT PHASE	WEEKLY PROJECT GOALS	READING 6.270 NOTES	READING BRAUNL
1. 1/5	1.1	**This week: boards considered; lab, electrical, mechanical tools overview; lab safety.**	Chap. 1,4	Chap. 1
2. 1/11	1.2	**This week: Boards & Sensors Ordered; Blink LEDs example and SolidWorks design w/ T-Tech Demo. Pre-proposal Abstract in class (1/14).**	Chap. 2,3; Sec B2	Chap. 2
3. MLK 1/18 T 1/19	1.3	**This week: Boards Functional; software to control LEDs using Cds cells and the UART. Informal Written Proposal by (1/21).**	Chap. 6; Sec B3	Chap. 3
4. 1/25	1.4	**This week: Boards functioning w/ sensor and/or actuator under software control; software using PWM and actuators. Oral Report 1 R(1/28) and Written Report 1 due R(1/28).**	Chap. 7	Chap. 5
5. 2/1	2.1	**This week: Platform Component Cutout 1**	Chap. 5	Chap. 4, 6
6. 2/8	2.2	**This week: Platform Component Cutout 2**		Chap. 7-10
7. 2/15	2.3	**This week: Platform Fully Assembled with Electronics functioning & mounted in the platform & all Sensors in hand**		Chap. 14, 15
8. 2/22	2.4	**This week: Graded Demo Collision Avoidance (Sense/React) on the completed platform.**		Chap. 16, 17
2/27 – 3/6		**Spring Break Week**		
9. 3/7	3.1	**This week: Preliminary Special Sensor / System working under software control, Special System Demo in Lab Thu. (3/10)**		Chap. 22
10. 3/14	3.2	**Special System oral/written reports (3/17)**		
11. 3/21	3.4	**This week: Tweak & Finalize Design**		
12. 3/28	4.1, 4.2	**This week: Completed Software Demo**		
13. 4/4	**Pre-Demo**	**Pre-Demo Day Thu. {4/7}**		
14. 4/11	***DEMO DAY***	**Final Presentations T{4/12}, Demo Day R{4/14}**		
15. 4/18	***Media Day***	**Final Written Reports T{4/19}; Media Day W{4/20}**		

All dates are preliminary at best

Sample Individual Robot Applications

1. Vacuum Cleaner Robot
   Picks up dust bunnies, navigates a room, avoids objects, recharges itself.
2. Lawn Mower Robot
   Detects grass, cuts grass, navigates the lawn, avoids objects, recharges itself.
3. Game Playing Robot
   Plays an action game with its Master or other robots! For example: A Laser Tag Robot
4. Detect and Collect Items
   Paper collector, construction site cleanup (pickup nails, metal scraps, soda cans),
   Golf ball fetch, tennis ball fetch.
5. Acrobat Robot
   Flips and jumps and….
6. Predator Prey Robots – Synthetic Ecosystem
   Predator detects, pursues, and captures prey. Prey avoids predator. Both ought to recharge periodically.
7. Walking Robots: six-legged insects, four-legged herbivores, or two-legged rascals.
8. Mapping and Navigation Robots
   Robot identifies approximate location and size of objects within a room.
9. Flying robots: Blimps, balloons, quad-copters, helicopters, winged vehicles, rockets
10. Water robots: Surface, submerged.
11. Hovercraft Land-Sea Robot
12. Racing vehicles
13. Construction vehicles
    Build beanbag dikes to stem the flow of water, construct drywall for house interiors, layout tile floors.
14. Military vehicles
    Tanks, scouts, minefield sweep, search.
15. Lumber Jack Robot
    Climbs trees, trims limbs, tops trees, plants trees.
16. Valet/Waiter Robot
    Serves refreshments on commands, select music and load CD, etc.
17. Manipulating Robot
    Has a mechanical arm and gripper to provide more general object handling capabilities.
18. Gladiator Robots
19. Swarm Robots
    Collective behavior of "large" numbers of simple robots providing emergent behaviors.
20. Mule Robot
    Follows you around on campus carrying your books and supplies. Take it camping to serve as a pack animal.

Previous IMDL student projects (1995 – 2015) are posted on the class website and current students are encouraged to review/peruse them for ideas and inspiration at http://mil.ufl.edu/5666/papers.htm

Example Robot Actuation

#	Motion Producer	Application
1	Gearhead DC motors	Hands, arms, legs, heads, wheels.
2	Servo mechanisms	Precise motion control over a limited range of angles.
3	Speaker coils	Speech, sound, precise limited motion.
4	Solenoids	Striking, linear motion.
5	Stepper motors	Hands, arms, legs, heads, wheels.
6	Piezoelectric motors	Small motion.
7	Artificial muscle	Hands, arms, legs.

Example Robot Sensors and Associated Behaviors

#	Phenomena	Sensor	Example Behavior
1	Proximity	IR proximity, Sonar, vision	Collision avoidance
2	Contact	Bumper, whiskers, accelerometer, mercury switches, micro-switches, switches, relays	Object detection, sensor calibration
3	Light	Cadmium Sulfide cells, photodiodes, phototransistors, CCD cells, cameras	Phototropism, vision, color detection
4	Sound	Microphones, piezoelectric reeds	Audio tropism, hearing
5	Heat	Pyro-sensor, thermal conductivity circuit	Pyrotropism
6	Smell	Smoke detectors, hydrogen and other gas detectors, pheromones	Attractant, repellant, chemical mark detection
7	Magnetic	Coils, Hall-effect sensors, compass	Metal detection
8	Nuclear radiation	Geiger counter	Locate source of radiation
9	Pressure	Silicon pressure transducer	Pressure tropism
10	Position, Velocity, Acceleration	Wheel encoders, accelerometers, gyroscopic compasses, GPS	Motion control
11	Ranging	IR, Sonar	Object detection, recognition
12	Video, Cameras	IP Cameras, Cell Phone Cameras, Webcams	Object detection, recognition

Laboratory Times (Location NSC407) in Time

	Mon	Tues	Wed	Thu	Fri
Andy (x3)		Per. 4-6	Per. 3-5	Per. 4-6	Per. 4-6
Jake (x1)					
Ralph (x1)	Per. 4-6				

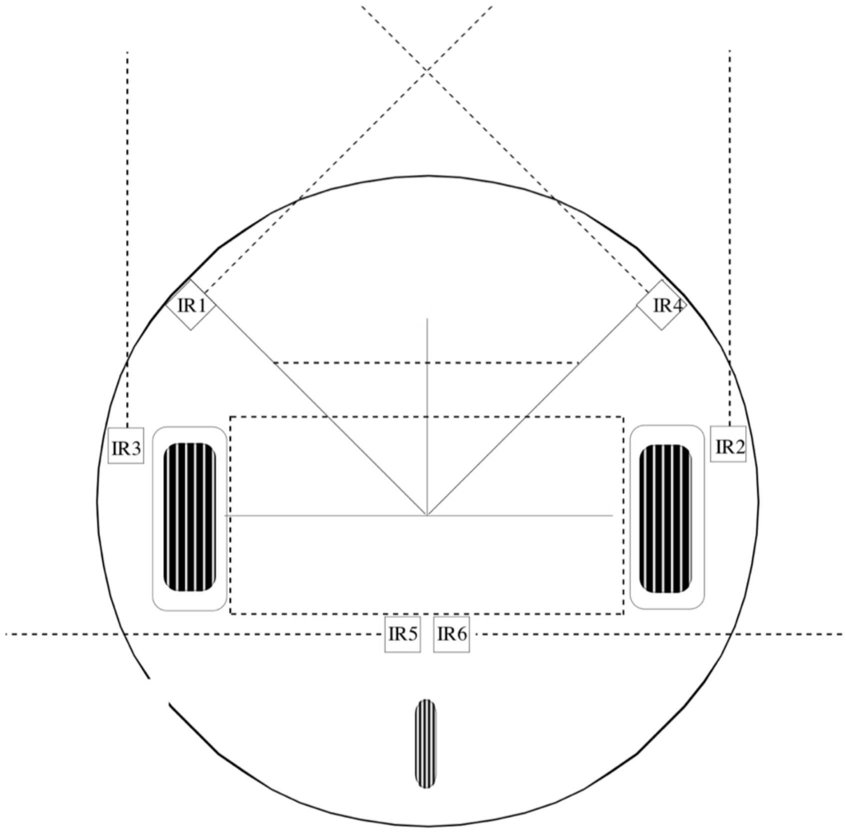

Figure 1. Example mobile robot platform.