University of Florida
Department of Electrical and Computer Engineering
Spring Semester 2012
Revision 5 {Change in Demo Day Date}

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

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Web Site: http://www.mil.ufl.edu/imdl/

Mailing List: eel5666@mil.ufl.edu. *You must turn in your e-mail address on the 1st class day!*

Announcements

- Labs meet in NSC 407 See the Spring 2012 Lab Schedule in class and the Web. You must attend a minimum of 1 lab per week and should attend a minimum two lab periods weekly.
- Make sure you take note of the important dates and deadlines (see page 5). For example, you must have your electronic board(s) ordered by the week of 1/16/12, and the board(s) built & tested by the week of 1/23/10. Weekly reports are due every Tuesday via e-mail, starting 1/17/12.
- Your robot must have a special system/sensor {not IR, CdS cells, Sonar, force sensor or bump, i.e., no digital or simple analog sensor}. It must be approved. You will report on this system in October.
- You must use computer-driven presentations (PowerPoint or equivalent).
- Your weekly design reviews will be in class probably on Tuesdays starting after Spring Break.
- Check **your email** and the **web site** daily!!! Much information is distributed electronically.
- Your robot must have LCD feedback during robot development or approval of some other feedback.
- You must create, maintain and update your own IMDL website posting your weekly and progress reports as appropriate. Lab notebooks will be checked every week in lab.

Recommended Textbook

You may want to pay close attention to the hardware and software discussions in Chapters 1-6, and the Mobile Robot Design Section (Part II).

[1] Thomas Braunl, *Embedded Robotics 2nd Edition*, Springer, ISBN 3-540-34318-0, 2006

Optional Reading List

You may want to pay close attention to the hardware and software hints in optional reference [1] which is available on-line in our website.

[1] Fred Martin, *The 6.270 Robot Builder's Guide*, MIT, Cambridge, MA, 1992.

Course Options

1. 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 pre-built board.
2. Build a scaled-down version (using a lot of off the shelf components) of the hardware as (1) above but with additional software to implement sophisticated machine intelligence behaviors.

3. Build a very sophisticated mechanical system emphasizing the hardware / platform / mechanisms with less sophisticated software.

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

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., 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 or tasks. For example, vacuum cleaning, lawn mowing, golf ball fetching, tennis ball fetching, trash collection, game playing, predator-prey action, group behavior (flocking, formation, homing, predation, etc.). Also a minefield sweeper, tile laying, wall building, construction site materials handling, map making and navigation, 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" sensor of your own design, 4) anything else you want, or can afford (e.g., wheel encoders, voice chip, GPS, wireless, camera, etc.). For example, a classmate may have designed a cool sensor you would like to use. Go ahead and ask the classmate's permission and then give verbal and written credit to the classmate for that sensor!
3. Several integrated behaviors that use the sensors and accomplish the task or tasks established by you.

In addition you must

1. Write a one page proposal and two formal written reports,
2. E-Mail weekly (due every Tuesday, starting 1/17/12) reports detailing your progress,

3. Present three talks,
4. Give weekly in-lab demonstrations concerning your robot and its development. Engineering notebooks will be examined and verified and signed by the TA in the laboratory weekly.

At the end of week four, 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. For example, you may want to purchase a robot kit and add a mechanical forklift, gripper or arm to it. 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 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. Later in the semester the 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
- EEL 6841: Machine Intelligence and Synthesis
- EEL 6825: Pattern Rec. & Intelligent Systems
- EEL 6562: Image Processing & Computer Vision
- EEL 6814: Neural Networks for Signal Processing
- EML 3806 Geometric Modeling of Robotic Manipulators
- EML 6281 Robots 1
- EML 6282 Geometry of Mechanisms & Robots II
- CAP 4621 Artificial Intelligence and Heuristics
- CAP 5635 Artificial Intelligence Concepts
- CIS 6930 Math for Intelligent Systems
- CAP 5416 Computer Vision
- CAP 6617 Advanced Machine Learning

Tentatively, weekly 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 *(CAE, CAD)* capabilities on computer workstations/laptops. In addition, some of the tutorial time will be spent developing documentation, checking student progress and proffering advice. As the semester progresses, 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.

Two weekly, three-hour laboratories allow 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 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 realizations that typically fail, to the disappointment of everyone.

At the end of the semester, each student or team will have produced a simple, microcomputer controlled, autonomous 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 present several demonstrations of your hardware. You will also write out 12 short weekly progress reports, which are graded.

Each week, starting week 2, you have an In-Lab check off (12 total) which consists of (1) having your TA check off and sign your lab notebook and (2) some other hardware in-lab demonstration specific for that week. Details on each of the semester’s In-Lab requirements are posted at: http://www.mil.ufl.edu/5666/announce.htm. Two of these are graded at 5% each. The other ten, though not graded per se, are required. Failure to meet a particular In-Lab requirement for any week will result in a 2% deduction of your final grade (if you fail to attend the 10 non-graded In-Lab sessions you will experience a 10 x 2% deduction in your final grade, that is 20% or 2 Full Letter Grades). You will also keep a course laboratory (engineering) notebook which is checked off weekly in lab.

The informal proposal due at the end of week 3 should not be more than one to two typewritten pages, excluding figures and tables. This proposal should specify the purpose, function, structure & design of your robot and predict your robot’s capabilities upon completion of your project. You will give a 3-minute talk on your proposal during the fourth week of the course.

Around the middle of the semester, you will demonstrate your robot executing collision avoidance 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 sensor 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 be more than 10 pages, excluding figures, tables, schematics, specification sheets, and appendices. You will present 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 sensor 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 http://www.mil.ufl.edu/5666/handouts.htm). The student will present a 10-minute final talk, and a 10-minute hardware demonstration covering the entire project on ***Demo Day***. These final reports, still pictures and a video will be placed on the IMDL web site and exposed to the Planet, so make them good!

Weekly Reports

Each week (every Tuesday starting on January 17, 2012) each student must e-mail a formatted progress report stating the immediate past week's activity and accomplishments. The e-mail submission should contain "IMDL Weekly Report #" as part of the subject of the e-mail. Further, please name your report file as follows: Your_Full_Name_IMDL_Weekly_Report_# .docx or .pdf (example: Tim_Tebow_IMDL_Weekly_Report_1.docx). Please add your e-mail address to the body of the report.

Please use MSWord or pdf or if you must, text. Attach the report to your e-mail and do not embed the report in the e-mail text. The weekly report may typically vary from 100 to 250 words. You should be able to easily derive all documents from your *Laboratory* notebook. The document word counts above should only serve as guidelines and provide you a measure of the required effort. Word counts should not be interpreted as absolutes. The objective of all reports should be effective communication, not word counts. Table 1 depicts final grade percentage allotted to each assignment.

Table 1 Grade Accounting

Written and Oral Assignments – 20%	Breakdown
Written and Oral Reports	10%
Weekly Progress Reports	5%
Web site & Laboratory Notebook	5%
Demonstrations in Lab – 10%	
Demo Collision Avoidance {Sense/React} (3/2)	5%
Pre-Demo Day Demonstration (4/10)	5%
Failure to Check Off In-Lab Demo by Friday's Lab ea.	-2% each week
DEMO DAY {4/17} – 70% (70 grade points**)**	70%
TOTAL	**100%**

EEL 5666 Reading, Report and Demo Schedule

WEEK #/DATE	PROJECT PHASE	WEEKLY PROJECT GOALS	READING 6.270 NOTES	READING BRAUNL
1. 1/9	1.1	**Boards Considered {1/9}**	Chap. 1,4	Chap. 1
2. 1/17	1.2	**Boards Ordered {1/17}**	Chap. 2,3; Sec B2	Chap. 2
3. 1/23	1.3	**Boards Functional {1/23}** **Informal Written Proposal {1/26}**	Chap. 6; Sec B3	Chap. 3
4. 1/30	1.4	**Oral Report 1 {1/31-2/2)** **Written Report 1 {2/2}** **Boards functioning w/ sensor and/or actuator w/ software control {2/3}**	Chap. 7	Chap. 5
5. 2/6	2.1	**Platform Component Cutout Group 1{2/10}**	Chap. 5	Chap. 4, 6
6. 2/13	2.2	**Platform Component Cutout Group 2{2/17}**		Chap. 7-10
7. 2/20	2.3	**Platform Fully Assembled with Electronics functioning & mounted in the platform & all Sensors in hand {2/24}**		Chap. 14, 15
8. 2/27	2.4	**Collision Avoidance (Sense/React) on the completed platform {3/2}**		Chap. 16, 17
3/3-3/11		**Spring Break**		
9. 3/12	3.1	**Oral Report 2 {3/13}** **Written Rept 2 {3/13}**		Chap. 22
10. 3/19	3.2	**Preliminary Special Sensor / System working under software control {3/23}**		
11. 3/26	3.4	**Tweak & Finalize Design & Final Special Sensor Demo{3/30}**		
12. 4/2	4.1, 4.2	**Software Demo {4/6},**		
13. 4/9	**Pre-Demo Day**	**Pre-Demo Day {4/10}**		
15. 4/16	***DEMO DAY***	**Final Presentations {4/17}, Final Demo {4/19}**		
16. 4/23	***Media Day***	**Final Written Reports {4/24}; Media Day {4/25}**		

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.

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

Laboratory Times (Location NSC407) in Time

	Mon	Tues	Wed	Thur	Fri
Tim		10:30am-1:30pm		10:30am-1:30pm	
Ryan					12pm-3pm
Josh			4pm-7pm		

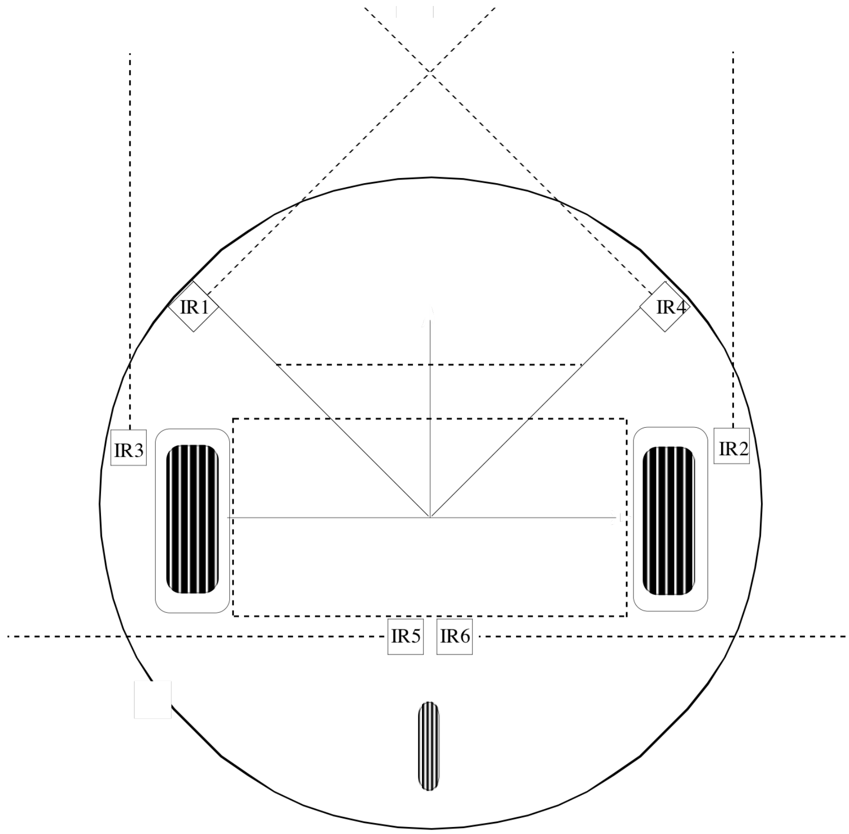

Figure 1. Example mobile robot platform.