University of Florida
Department of Electrical and Computer Engineering
Fall Semester 2008

EEL 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 Benton 327. See the Fall 08 Lab Schedules in class and on 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. For example, you must have your electronic board(s) ordered by 9/2/08, the board(s) built & tested by 9/8/08. Weekly reports are due every Thursday in class, starting 8/28/08. Lab notebooks will be checked every Monday in lab.
- Your robot must have a special system/sensor {not IR, Cds cells or bump}. 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 Thursdays
- Check the Web Site daily!!! Much information is distributed electronically.
- Your robot must have LCD feedback.
- You must create, maintain and update your own IMDL website posting your weekly and progress reports as appropriate.

Reading List

You will want to pay close attention to the hardware and software hints in reference [1] and [2]. Many of your questions can be answered there. References [3] and [4] provide a sense of the new, reality based, machine intelligence and robotics. Read [3] and [4] as bedtime stories to inspire and direct your own discovery and implementation of an intelligent robot. Reference(s) [5] are required reading for all students.

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

[2] Joseph Jones, Bruce Seiger & Anita Flynn, *Mobile Robots: Inspiration to Implementation*, 2nd edition, A.K. Peters Publishers, Natick, MA, 1998.

[3] Pattie Maes, *Designing Autonomous Agents: Theory and Practice from Biology to Engineering and Back*, MIT Press, Cambridge, MA, 1990.

[4] Kevin Kelly, *Out of Control: The New Biology of Machines, Social Systems and the Economic World*, Addison Wesley, April 1995. ISBN 0201483408

[5] http://onlineethics.org/ & http://www.iit.edu/departments/csep/PublicWWW/codes/coe/ieee-c.htm

Course Options

1. Design, build, and program an autonomous mobile robot using kit parts combined with novel circuits and mechanics of your design.
2. Build a completely pre-designed robot kit and then program sophisticated machine intelligence behaviors.

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, Mekatronix

Course Objectives

The *Intelligent Machines Design Laboratory (IMDL)* constitutes a capstone undergraduate laboratory and 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 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, and communications.

Pedagogical Philosophy

This course is non-competitive in nature. Your grade will be determined from how you meet the course performance objectives, not by how well you perform compared to a fellow student. If you meet the performance objectives, you make a grade of 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 always give credit to the student in your documents (reference the author's work)* and discussions about those concepts. This course encourages and teaches the practice of sound Engineering 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 mine field sweeper, tile laying, wall building, construction site materials handling, map making and navigation, etc. (By the way, the instructors and teaching assistants are tired of security robots and cats, so unless you have some really interesting ideas…).
2. Possess at least 4 types of sensors: 1) IR proximity detectors, 2) Bump switches, 3) A sensor of your own design, 4) anything you want, or can afford (e.g., wheel encoders, voice chip, GPS, 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 always give verbal and written credit to the classmate for that sensor!
3. Four integrated behaviors that use your 4 sensor types and accomplish the task or tasks established by you.

In addition you must

1. Write a one page proposal and two reports,
2. Submit weekly (due every Thursday, starting 8/28/08) reports detailing your progress,
3. Present three talks, and
4. Give weekly in-lab demonstrations concerning your robot and its development.

At the end of week three, most of you will have implemented two sensory systems (IR proximity and Bump detection) and one behavior, collision avoidance, on the robot. Now your job is to come up with two more sensors, one of your own design, and three more behaviors. We encourage you to enable 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*.

Course Structure

Three lectures 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. Readings from the literature [3,4] will supplement those from the main text [2] while Fred Martin's *The 6.270 Robot Builder's Guide* will help students to learn basic hardware fabrication and assembly skills. Advanced students with the appropriate background may, if they choose, investigate topics involving short-term perceptual memory, environmental modeling, or cognition and learning. Since the course emphasizes hands-on experience, the reading material will only play a supporting role and not the lead. EEL-5840 & EEL-6841, Machine Intelligence I & II, and EEL-6935 Machine Learning in Robotics I & II are available as follow-on courses to EEL-5666 to help you investigate the theory and applications of autonomous mobile robot in intelligence and learning so you can apply these principles to the robots you build in EEL5666.

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. 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 will allow the student to utilize various resources under instructor/TA supervision. During assigned 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 persons, on a specific 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 rest with the students and their individual preferences and creativity.

Course Syllabus

The *IMDL* course content and experimental activity will include the following four phases. In all phases of your work acknowledge your peers who have helped you with a specific idea, data, design, or have provided you with a specific circuit or algorithm. When you develop original solutions, or at least believe you have, share your knowledge with the rest who will then give you credit if they decide to use the same.

PHASE 1
(4 Weeks)

1. Propose a robot application area (see list below for suggestions).
   Purchase electronic board & other items (IR cans, servos, wheels, batteries, etc.) (1 Week).

2. Motor Control Algorithms and Bump Sensing (1 Week)
   Verify electronic board operation: install Power Pack, Microcomputer, Bumper switches. Code bumper operation. Design actuation algorithms for controlling the motion of the robot. Code a simple motion trajectory. Test, debug, and verify motion and bump behavior.

3. Mobile Robot Platform and Bumper Development and Fabrication (1 Week).
   Platform design and assembly including bumpers, wheels, motor actuation and gear reduction.

4. IR Sensors and Collision Avoidance Behavior (1 Week).

Mount the IR emitters and detectors on your robot platform. Develop a collision avoidance algorithm and integrate with bump algorithm. Test, debug, and verify collision avoidance/bump behavior.

At the end of *Phase 1* you will have a simple functioning robot that can move about and avoid collisions. Students taking more unusual approaches will be evaluated differently. We want to encourage exploration and creative designs.

PHASE 2

(4 Weeks)

1. Sensor Suite Development (2.5 Weeks)
   Each student or team must adopt, design, develop, prototype, test, and mount on the robot platform at least one sensor type of their own design, or a substantial modification or novel use of some existing design. The sensor must be powered by onboard batteries and apply to the robot's overall operational tasks. Test, debug, and verify your design on the robot. Characterize your sensor with appropriate experiments, charts, graphs, etc. You will be asked to share your sensor design with classmates.

   Alternatively, students might develop external systems such as smart charge stations and ranging beacons. Talk to the instructor if you wish to pursue such an idea for your "sensor" requirement.

2. Sensor Algorithms (1.5 Weeks)
   Develop machine perception algorithms to interpret the sensor data in some useful way. Test, debug, and verify at least one behavior requiring your sensor in your robot application. This behavior must be integrated with the collision avoidance and bump sensors.

PHASE 3

(4 Weeks)

1. Behavior Algorithms (2.5 Weeks)
   Develop a second behavior algorithm for your robot relative to its task objectives. Integrate with the first one or some other behavior you have devised. At this point you should have a minimum of three sensor types (IR proximity, bump, your design) and three integrated behaviors.

2. Integrated Behavior Algorithms (1.5 Weeks)
   Integrate 4 behavior algorithms into some overall task objective using a software state machine controller. For example, the robot moves about the environment looking for a nook to hide in while avoiding potential collisions or well-lit areas. While hidden, the robot will exit the nook if an object (predator!) gets too close.

PHASE 4

(3 Weeks)

Complex Behavior Algorithms (3 Weeks)

Develop additional task algorithms, as time permits, supplementing the one you developed in *Phase 3.2*. Devise a method based on environmental or internal robot states that switch the robot from one task objective to another. For example, a simple rule based system could arbitrate between the behaviors based on internal and external stimuli.

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 three demonstrations of your hardware. You will also keep course laboratory notebook and write short weekly progress reports.

The proposal should not be more than three to five 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 5-minute talk on your proposal.

During the third week you will demonstrate your robot executing collision avoidance in the laboratory. For students taking creative, high-risk projects, the expectations of this demonstration will be negotiated with the instructor.

The sensor design report will present theory of operation, circuits, software and experimental data on your own 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 5-minute talk to the class about your design. You can extract your talk directly from your report. You will also present a 5- minute hardware demonstration of your sensor in the laboratory.

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. 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 will be placed on the IMDL web site and exposed to the Planet, so make them good!

Weekly Reports

Each week (every Thursday starting on August 28, 2008) each student must submit a typewritten progress report stating the immediate past week's activity and accomplishments. 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 effort involved. Word counts should not be interpreted as absolutes. The objective of all reports should be effective communication, not word counts. Table 1 depicts the percent of the final grade contributed by each assignment.

Table 1 Grade Accounting

Topic	Written Report	Oral Presentation	Demonstration in Lab
Proposed Robot Purpose, Function, Structure & Design	5%	5%	**10**% (Base-Line Robot)
Sensor Development	5%	5%	5%
Demo Day Final Design and Performance	**10%**	**10%**	**30%**
Laboratory Notebook & Quizzes	5%		
Weekly Progress Reports	5%		
Web site	5%		

EEL 5666 Reading, Report and Demo Schedule

WEEK #/DATE	**PROJECT PHASE**	**WEEKLY PROJECT GOALS** **READING** **PATTIE MAES**	**READING** **6.270** **NOTES**	**READING** **JONES SEIGER & FLYNN**
1. 8/25	1.1	pp. 1-35	Chap. 1,4	Chap. 1,2,3,10,11
2. 9/2	1.2	pp. 71-88 **Boards Ordered {9/2}**	Chap. 2,3; Sec B2	Chap. 4,6,12 Appendix C,D,E,F
3. 9/8	1.3	pp. 145-186 **Boards Functional {9/8}** **Written Proposal {9/11}**	Chap. 6; Sec B3	Chap. 7,8, Appendix A
4. 9/15	1.4	**Oral Report 1 {9/16}** **Written Rept 1 {9/18}**	Chap. 7	Chap. 9,13
5. 9/22	2.1	**Boards functioning w/ sensor and/or actuator w/ software control {9/22}**	Chap. 5	Chap. 5
6. 9/29	2.2	**Platform Fully Assembled {9/29}**		Appendix B
7. 10/6	2.3	pp. 35-71 **Electronics functioning & mounted in the platform {10/6}**		
8. 10/13	2.4	pp. 123-145 **Collision Avoidance of robot {10/13}**		
9. 10/20	3.1	**All Sensors in hand {10/20}**		
10. 10/27	3.2	**Written Rept 2 {10/28}** **Extra / Special Sensor / System working under software control {10/28}** **Oral Report 2 {10/30}**		
11. 11/3	3.3	Ethics Lecture / Discussion **Tweak & Finalize Design {11/3}**		
12. 11/10	3.4	**Software Demo {11/10}**		
13. 11/17	4.1, 4.2	**Finalize Design {11/17}, Pre-Demo Day {11/20}**		
14. 11/24		**Final Talk {11/25}**		
14. 12/1	***DEMO DAY***	**Final Demo {12/2}**		
15. 12/8	***Media Day***	**Final Report {12/9}**		

Read references [4] at your leisure. Warning! This book is extremely entertaining and hard to put down!

Individual Robot Applications

1. Vacuum Cleaner Robot
   Picks up dust bunnies, navigates a room, avoids objects, recharges itself.
1. Lawn Mower Robot
   Detects grass, cuts grass, navigates the lawn, avoids objects, recharges itself.
2. Game Playing Robot
   Plays an action game with its Master or other robots! For example: A Laser Tag Robot
3. Detect and Collect Items
   Paper collector, construction site cleanup (pickup nails, metal scraps, soda cans), golf ball fetch, tennis ball fetch.
4. Acrobat Robot
   Flips and jumps and….
5. Predator Prey Robots- Synthetic Ecosystem
   Predator detects, pursues, and captures prey. Prey avoids predator. Both must recharge periodically.
6. Walking Robots
   Six legged insects. Four legged herbivores. Two legged rascals.
7. Mapping and Navigation Robots
   Robot identifies approximate location and size of objects within a room.
8. Flying robots: Winged vehicles, balloons, helicopters.
10. Water robots: Surface, submerged.
11. Hovercraft Land-Sea Robot
12. Racing vehicles
13. Construction vehicles
    Build bean-bag dikes to stem the flow of water, construct drywall for house interiors, layout tile floors.
14. Military vehicles
    Tanks, scouts, mine field 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 provide emergent behaviors.
20. Mule Robot
    Follows you around on campus carrying your books and supplies. Take it camping to serve as a pack animal.

IMDL Robot Contest

{If available, it will be discussed in class}

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, microswitches, 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	Audiotropism, 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

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.

Laboratory Times (Location Benton 327) in Periods

	Mon	Tues	Wed	Thur
Mike				
Vermeer				
McDonley				

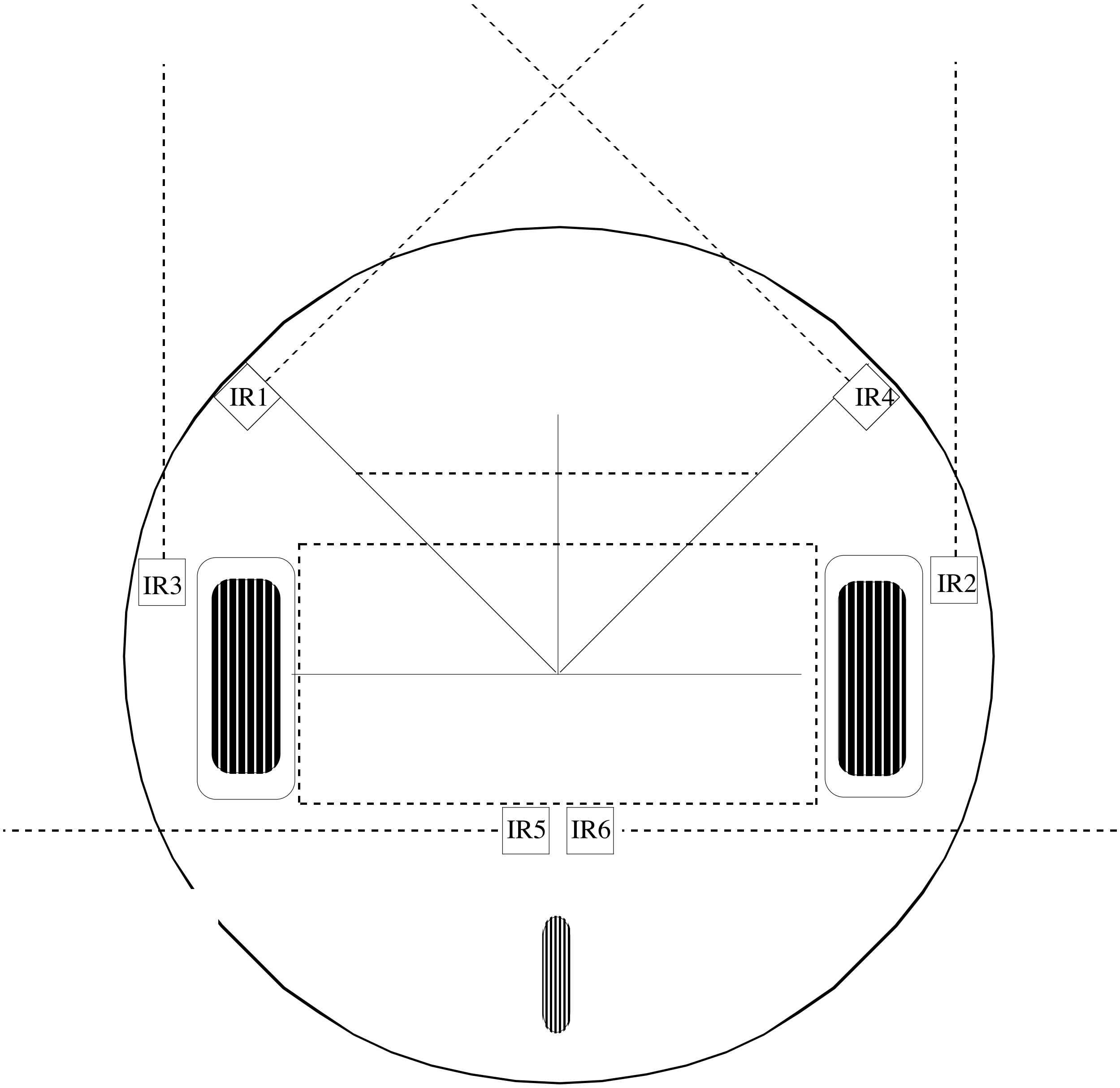

Figure 1. Example mobile robot platform.