ME218c Smart Product Design

ME 218c Spring 2017 Project: Herding Hovering Ferrets

Grading Session on May 30, 2017 in SPDL starting at 6:00 PM.
Project Presentations on May 31, 2017 in the Atrium starting at 6:00 PM.

Goal:

The goal of this project is to provide a framework in which you can apply your knowledge of microcontrollers and multi-processor communications to a task that will provide an enjoyable experience for the users and the observers.

Purpose:

The underlying purpose of this project is to provide you with an opportunity to gain experience in integrating all that you have learned in the ME218 course sequence, with an emphasis on the new material in ME218c.

Background:

With the massive winter rains, Lake Lag has become host to a large population of salamanders. Unfortunately, the large population has attracted a gaggle of Frenzied, Erratic, Random, Ruckus Exciting Tormentors (FERRETs) who are feasting on the salamanders. We need a way to save the salamanders from these FERRETs.

The Task:

Design and build a teleoperated Device Of Guidance (DOG) vehicle and a companion Floating Animal Rescue Mechano-Electrical Remote (FARMER). Packs of DOGs will operate in the 'Wetlands' at the end of the Atrium in Building 550. During rounds of the game, a pack of three DOGS, through their FARMERs, will attempt to herd the FERRETs into the Safe Capture And Recovery Zone (SCARZ).

Specifications

General:

- ☐ Each team will construct a DOG and a FARMER.
- ☐ The DOGs are devices capable of navigating in wetland terrain while herding the FERRETs into the SCARZ.
- ☐ The FARMERs are the wireless remote controllers for the DOGs.
- ☐ SPDL will supply the fleet of hovering FERRETs to be herded.

Basic Game Play:

- ☐ A game round will be a cooperation among three FARMERs and a pack of three DOGs.
- ☐ The goal of the game is to herd the hovering FERRETs into the SCARZ.
- ☐ The game will continue until 218 seconds have passed or all FERRETs have been herded into the current SCARZ.

The Wetlands:

- ☐ The Wetland is comprised of a region at the West end of the building 550 Atrium, measuring approximately 16 ft. by 24 ft (see Figure 1).
- ☐ The boundaries of the Wetland are formed by a plastic wall 4" high.
- ☐ At the beginning of each game the participating DOGs will be placed in one of the four corners of the Wetland as shown in Figure 1.
- ☐ One end of the Wetland will be designated as the SCARZ.

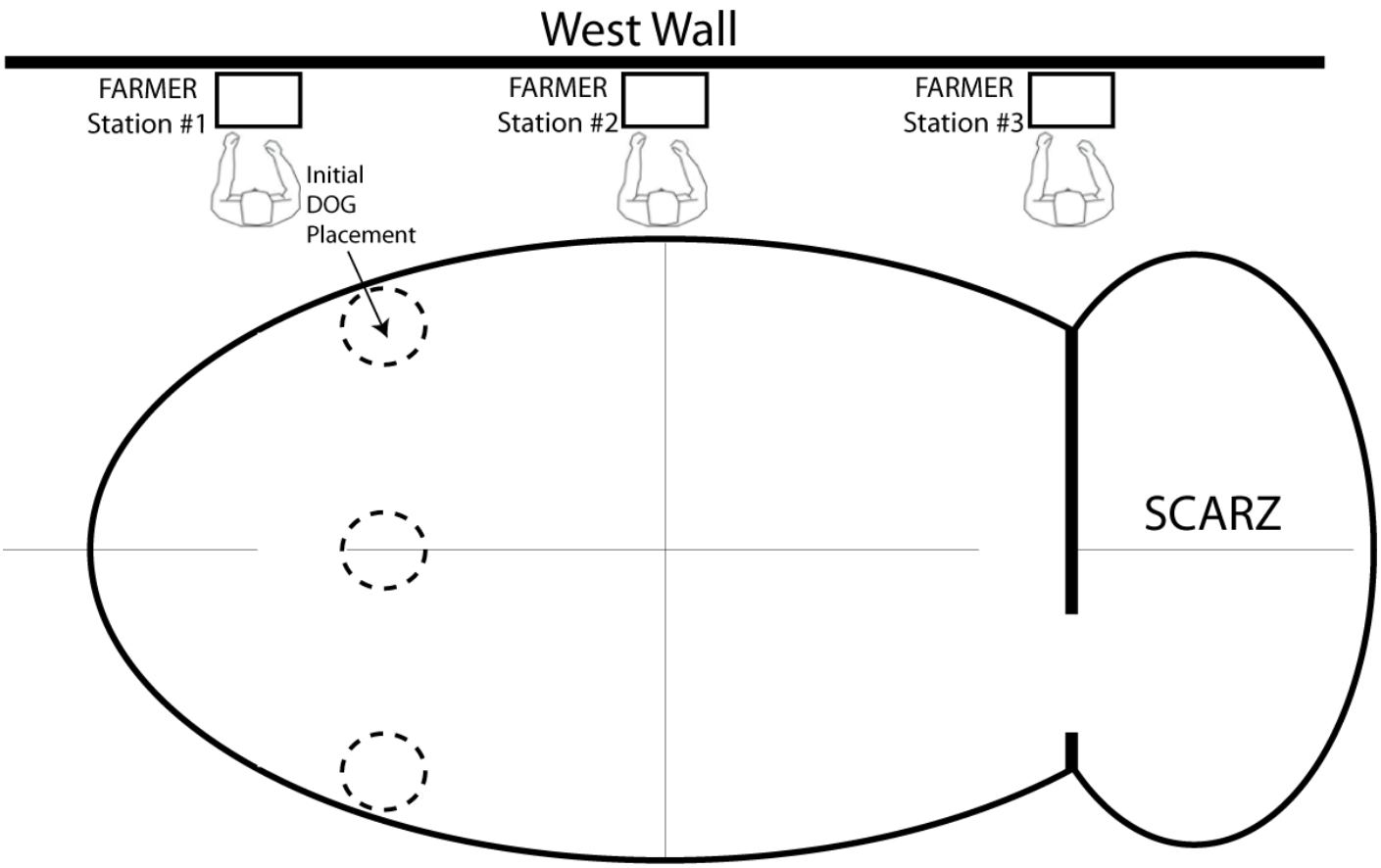

Figure 1: The Wetland

The DOGs:

- ☐ Each DOG must be capable of moving under its own power within the Wetland.
- ☐ The DOG must hover above the surface of the Wetland, and the only source of lift allowed is the lift fan provided by the SPDL.
- ☐ DOGs must be battery powered and operate without a leash. NiCd or NiMH batteries are the only approved power sources.
- ☐ The lift fan must only be powered through the series connected pair of SPDL supplied diodes. Do Not connect the lift fan directly to batteries or the power supply. The lift fan is not rated for the battery voltage of a pair of series connected 7.2V NiMh or NiCd batteries.
- ☐ Design and function of the propulsion and steering systems are unconstrained with the caveat that they may not directly apply force to the Wetland floor. An exception to this rule allows for dragging an element against the Wetland to brake or steer. This will be acceptable as long as the contact mechanism would, if deployed while the DOG was not moving, create approximately equal drag in all directions and is not capable of supporting the vehicle.
- ☐ Control of DOG functions must be achieved via a FARMER using the provided RF hardware (XBee24 modules).
- ☐ The DOG must contain an electromechanical display indicating that communication with a FARMER is currently active.
- ☐ Each DOG must carry and communicate with an SPDL supplied 6-DOF Inertial Measurement Unit. Information from the IMU will be reported to the FARMER to aid in controlling the DOG.
- ☐ DOGs must incorporate an easily accessible switch that disables all moving systems.
- ☐ The perimeter of the largest normal projection of the DOG into the plane of the Wetland must not exceed 72”. The entire vehicle, projected vertically onto the field, must lie within the perimeter. Height

is not restricted.

- ☐ DOGs must incorporate a class standard foam bumper around their perimeter, and must be tolerant of moderate bumping from other DOGs and FERRETs. The bottom edge of the foam bumper must be at a height between 0" (the Wetland surface) and 1.25" above the Wetland surface while hovering. The bumper must follow the same perimeter that is measured to fit the 72" requirement.
- ☐ Every DOG must be controllable through any of the FARMERs via the class-wide protocol (See Radio Communications in a later section).
- ☐ The DOG may issue messages to the FARMER at a rate no greater than 5 Hz.
- ☐ If the DOG fails to receive a message from its controller for 1 second, it will assume that there is a problem and revert to the controller search process described under Game Details.
- ☐ During a game, each DOG will carry an SPDL supplied DogTag indicating which of the DOGs (1-3) it currently represents. The DogTag will include a 2-pin electrical connector (Molex KK256) to a resistor (1-3k) that can be used by the DOG to determine which DogTag it is currently carrying.
- ☐ Each DOG must provide a standard ¼"-20 screw to attach an SPDL supplied smartphone mount. This screw should be positioned to provide the best location for the smartphone camera to provide a DOG's-eye view to the FARMER for use in controlling the DOG. In the event that your team does not have a smartphone that can be used for testing, SPDL will have a small number of phones available to check out. They will also be available for use on the evening of the public show.

The FARMERs:

- ☐ Each team will design and construct a FARMER that will relay commands from a human operator to a DOG, and receive and display connection status with the DOG and attitude reports from the IMU mounted on the DOG.
- ☐ The FARMER must be capable of displaying to the operator an indication of active communication with its associated DOG.
- ☐ The FARMER must provide a method for the operator to use to indicate which DOG (1-3) the operator would like to control.
- ☐ FARMERs must be battery powered, and shall have sufficient battery capacity for at least 8 hours of continuous operation. The report should show documentation and calculations to support meeting this requirement.
- ☐ FARMERs must be un-tethered and portable by one person.
- ☐ Input to the FARMER should involve at least 3 sensing modalities (e.g. position, force, audio, acceleration, etc.). Use of unusual interface methods is encouraged as the DOGs are used to responding to unique signals.
- ☐ The actions required by the user of the FARMER to issue commands to the DOG should be inventive and interesting for the audience to watch. Use of actions that make the operator look and feel foolish is encouraged.
- ☐ The FARMER may issue commands to a DOG at a rate no greater than 5 Hz.
- ☐ FARMERs should be intuitive to operate, and/or have sufficient visual instructions that a typical spectator (even a non-engineer) would be able to learn its controls within the time span of a single game round.

The Fan Controlling TREAT:

- ☐ Each DOG must have a Tenacious Reward and Encouragement for Accurate Tracking (TREAT).
- ☐ The TREAT will consist of a PIC12F752 programmed in assembly language that receives instructions from the main processor of the DOG to control the level of lift created by the lift fan.
- ☐ Communication between the TREAT and the main processor of the DOG will take place over an asynchronous serial communications channel.

Game Details:

- ☐ Three FARMER stations will be arrayed along the west wall of the Atrium. These stations will consist of an SPDL-supplied workstation and monitor, connected to the internet and capable of running Skype. The FARMER stations will be positioned with their monitors facing the wetlands. The FARMERs will be positioned in front of the stations, facing the monitors and therefore facing away from the wetlands. A Skype connection between the DOG-mounted smartphone and the FARMER station will provide the DOG's-eye view of the world for use by the person operating the FARMER. The person operating the FARMER should be discouraged from turning to face the Wetlands.
- ☐ Upon power-up or in the event of a loss of communication with its current FARMER, the DOG will activate its electromechanical indication that it is searching for a controlling interest, deactivate its lift fan and wait for a request for control from a FARMER.
- ☐ The operator of a FARMER that wishes to control a particular DOG must select that DOG (1-3) using the FARMER and make a unique control action to initiate taking control of the DOG. This action will result in the FARMER sending a message to the DOG requesting control of the DOG. The details of the request process will be defined in the class-wide communications protocol.
- ☐ The DOG will respond to requests for control from its assigned FARMER by sending a message back to the requesting FARMER confirming receipt. At this time, the DOG will also de-activate its electromechanical indication of searching for a controller. After completing this process, the DOG remains loyal to that FARMER until all FERRETs are contained or 218 seconds have passed.
- ☐ If a DOG receives a request for control while it is already under control, it will silently ignore the request.
- ☐ Within 100 ms of losing communication, the DOG must activate its electromechanical indication that it is searching for a controlling FARMER and deactivate its lift fan.

Radio Communications:

- ☐ Communications between the DOGs, and FARMERs will take place over an SPDL-supplied 802.15.4 radio (Xbee24) using the Non-Beacon API mode of operation.
- ☐ To prevent eavesdropping on the conversations between the FARMERs and their DOGs command communications between them will be encrypted using the algorithm described in Appendix A of this document.
- ☐ Any FARMER should be capable of controlling any DOG.
- ☐ Once a game begins, communication will take the form of bi-directional communications between a DOG and its bound FARMER.
- ☐ Each DOG and FARMER will be assigned a unique ID in the form of the source address of each SPDL-supplied radio.
- ☐ The details of the communications protocol will be defined and specified by a Communications Committee, which will consist of one member from each project team. The specification must be in a written form and with sufficient detail that someone sufficiently skilled in ME218 material could implement it.
- ☐ In order to better balance the workload and learning among team members, each of the following tasks must be completed by a different member of the team: serve on the communications committee, implement communications on the DOG, and implement communications on the FARMER.
- ☐ The class communications protocol must include a procedure for validation of communication between the DOG and FARMER. The DOGs must provide an electro-mechanical indication of when a functioning communications link between the DOG and FARMER exists.

General Requirements:

- ☐ At a minimum, either the FARMER or the DOG must contain two actively communicating processors. There is no class imposed upper limit on the number of processors employed.
- ☐ You are limited to an expenditure of **$200.00/team** for all materials and parts used in the construction of your project. Materials supplied to each team by SPDL, from the lab kit, or the Cabinet Of Freedom

do not count against the limit. All other items count at their fair market value.

- ☐ A project logbook must be maintained for each group. An online blog is appropriate to meet this requirement as long as it is made available to the teaching staff for review. This log should reflect the current state of the project, planning for the future, results of meetings, designs as they evolve etc. The project logbook will be reviewed at irregular intervals for evaluation.
- ☐ A report describing the technical details of the system will be required. The report should be of sufficient detail that a person skilled at the level of ME218c could understand, reproduce, and modify the design. The report must be in website format, and be suitable for posting on the SPDL site.
- ☐ FARMERs or DOGs based substantially on purchased platforms are not allowed.
- ☐ All projects must respect the spirit of the rules. If your team is not sure if something will violate the spirit of the rules, you must consult a member of the teaching staff.

Safety:

- ☐ Both the DOGs and the FARMERs should be safe, both to the user and the spectators.
- ☐ Propulsion fans must be suitably shrouded to prevent injury from the fan blades.
- ☐ Intentionally disabling or damaging other DOGs is not allowed. Prohibited actions include, but are not limited to, the following: ramming at excessive speed (as determined solely at the discretion of the teaching staff).
- ☐ No part of the DOG may become ballistic.
- ☐ Approved small portable electronic devices may now be used during taxi, take-off, and landing.
- ☐ The teaching staff reserves the right to disqualify any device considered unsafe.

Checkpoints

Design Review:

On **05/09/17** between 9:30am & 2:30pm we will conduct a design review, one team at a time. Each team should prepare a few images showing your proposed designs for both the DOG and the FARMER. You will have 5 minutes to walk us through your ideas. **The focus should be on system level concepts, not detailed hardware or software.** We will spend the balance of the time-slot giving feedback and asking questions. In addition to your concepts, at this time you must present, in printed form (soft copy), your plan for the development, integration and testing steps that you will follow to complete the project. The plan must describe what hardware you will show (deliverables) and what functionality you will demonstrate at the two check-points and the project preview along with the detailed test procedures that we (the teaching staff) can follow to prove that your team has met the check-point. Check-point tests must follow an incremental integration strategy with each successive check-point demonstrating all of the functionality of the prior checkpoint(s) as well as the new functionality. This plan must be approved by the teaching staff. If we feel that it is flawed, we will ask you to revise and resubmit. Sample plans are available in `_Samples\SampleCheckpointDeliverablesTestingPlans`. The presentations and review will take place in 550-122 AKA 'The Fishbowl')opposite the Design office).

There was a time I thought I was a ferret.

Cassandra Clare

First Draft of Communications Standard:

Due by 9:00 pm on **05/10/17**. Ed will provide feedback on the specification on 5/12/17. Sample protocols and input documents are available in `_Samples\CommProtocolSpecArchive`

Slicing a warm slab of bacon is a lot like giving a ferret a shave. No matter how careful you are somebody's going to get hurt.

Alton Brown

Communications Standard:

Due by 5:00 pm on **05/13/17**. This is the working draft of the communications standard.

Old dogs, like old shoes, are comfortable. They might be a bit out of shape a little worn around the edges, but they fit well.

Bonnie Wilcox

First Checkpoint:

On **05/16/17**, you must demonstrate your approved 1st check-point functionality according to your defined testing procedure.
The final working version of the communications standard is due. No further changes are allowed to the standard. This protocol will be evaluated with respect to its completeness and suitability for the proposed system. Note: this is a functional evaluation only. The focus should be on demonstrating functional hardware and software. You may submit for approval a final revision of your check-point plan at this time.

The farmer has to be an optimist or he wouldn't still be a farmer.

Will Rogers

Second Checkpoint:

On **05/22/17**, you must demonstrate your approved 1st check-point and 2nd check-point functionality according to your defined testing procedure. The functionality demonstrated at this time must include full implementation of the communications protocol.

If a ferret bites you it is nearly always your own fault.

Phil Drabble

Project Preview:

At the Project Preview on **05/26/17**, each team must demonstrate (in addition to the 1st & 2nd checkpoints' functionality) your approved project preview functionality. The functionality demonstrated at this time must include a demonstration of interoperability between at least 2 teams' DOGs and FARMERs.

I believed that I was a salamander and it seems that I am nothing but an impediment.

Zelda Fitzgerald

Grading Session:

During the Grading Session on **05/30/17**, each team will be required to demonstrate the ability to successfully participate in a game. This will include
1) Establishing communications between your DOG and FARMER and between your DOG and the FARMER from another team.
2) Navigating a DOG from the initial position and successfully inducing at least one FERRET to move into the designated SCARZ.
3) Displaying on both the FARMER and the DOG the correct status of communications.
A detailed grading check-off procedure will be published at a later date.

That's not a rat, that's my ferret.

Jennifer Aniston

Public Presentation:

This will take place on **05/31/17** starting at 6:00 pm in the Atrium of Building 550. At this event, members of the public will be encouraged to act as operators of the FARMERs.

Nothing in the world is friendlier than a wet dog.

Unknown

Report:

Draft due on **06/05/17** by 4:00 pm. The final version (with revisions incorporated) is due by 5:00 pm on **06/09/17**.

Anybody who doesn't know what soap tastes like, never washed a dog.

Franklin P Jones

Celebration:

A celebration of the past 3 quarters of ME218 will take place at the Alpine Inn on **06/01/17** starting at noon. Mark your calendars now and save the date.

Money can buy you a fine dog, but only love can make him wag his tail.

Kinky Friedman

Evaluation

Performance Testing Procedures:

One or more of the team members will demonstrate the DOG and FARMER during the first & second checkpoints and project preview. Members of the teaching team will operate the DOG via the FARMER during the grading session.

Grading Criteria:

- ☐ **Concept (15%)** This will be based on the technical merit of the design and coding for the machine. Included in this grade will be evaluation of the appropriateness of the solution, as well as innovative hardware, software and use of physical principles in the solution.
- ☐ **Implementation (15%)** This will be based on the prototype displayed at the evaluation session. Included in this grade will be evaluation of the physical appearance of the prototype and quality of construction. We will not presume to judge true aesthetics, but will concentrate on craftsmanship and finished appearance.
- ☐ **First Checkpoint (10%)** Based on the results of the performance demonstrated on 05/16/17.
- ☐ **Second Checkpoint (10%)** Based on the results of the performance demonstrated on 05/22/17.
- ☐ **Preliminary Performance (10%)** Based on the results of the performance demonstrated during the Project Preview.
- ☐ **Performance (15%)** Based on the results of the performance testing during the Grading Session.
- ☐ **Report (10%)** This will be based on an evaluation of the report. It will be judged on clarity of explanations, completeness and appropriateness of the documentation.
- ☐ **Report Review (5%)** These points will be awarded based on the thoroughness of your review of your partner team's report. Read the explanations, do they make sense? Review the circuits, do they look like they should work?
- ☐ **Log Book (5%)** This will be evaluated by the evidence of consistent maintenance as well as the quality and relevance of the material in the log book.
- ☐ **Housekeeping (5%)** Based on the timely return of SPDL components, cleanliness of group workstations as well as the overall cleanliness of the lab. No grades will be recorded for teams who have not returned all loaned materials.

Appendix A

Encryption Algorithm:

All commands from the FARMER to a DOG will be encrypted using a rotating XOR Cipher (described in detail below). Since the communications channel is essentially one-way (with the exception of acknowledgements), only one encryption key is necessary. This 32 byte randomly generated key will be provided by the FARMER to the DOG as part of the process of pairing between the FARMER and the DOG. All subsequent commands from the FARMER to the DOG through the end of the period of control will be encrypted using this key.

As part of the pairing process, the details of which will be defined by the class-wide communications protocol, the FARMER will provide to the DOG the current key (uint8_t EncryptKey[32]). For this application, all messages prior to pairing as well as the key may be transmitted in plaintext.

Once the receipt of the key is acknowledged, both FARMER and DOG will reset internal counters (uint8_t i) to zero. This counter will then count modulo 32 (so that it will rotate through the bytes of the encryption key) with every new byte encrypted and decrypted.

To transmit a message, XmitMsg = [a,b,c], the FARMER would construct an encrypted version using the encryption key: Encrypt =[a^Key[++i], b^Key[++i], c^Key[++i]] where ++i is understood to be an increment by 1 modulo 32 and i is incremented on every use. For example, if i=0 originally, then Encrypt = a^Key[1], b^Key[2], c^Key[3]. The DOG would decrypt this received message using the stored encryption key: Decrypt = RecvMsg[0]^StoredKey[++i], RecvMsg[1]^ StoredKey[++i], RecvMsg[2]^ StoredKey[++i] where, once again, ++i is understood to be an increment by 1 modulo 32 and i is incremented on every use.

At this point, the DOG would interpret the Decrypted message according to the protocol defined by the class-wide communications committee.

Note: because the encryption key is rotating it is critical that the transmitter and receiver stay in sync. Dropped or lost packets must be re-tried until success in order to remain in sync. It will be the responsibility of the communications protocol to provide for this robustness.