UNIVERSITY OF BRITISH COLUMBIA
MECH 421 – Mechatronic Systems Instrumentation
MECH 423 – Mechatronic Product Design
Design Project – Handout #1
Overview, Logistics, Proposal, and Potential Projects

Overview

The MECH 421-423 design project aims to motivate students through the process to design and build a mechatronic product of their own invention. Students work in teams of two to formulate a product idea; develop a work plan; and then design, manufacture, and test their product. Students are free to develop any product that appeals them, as long as the development of the product could be divided into a set of reasonable functional components (FCs). A major exception is that projects aimed to develop weapons, even benign weapons, are prohibited! Each project is required to have at least five FCs. Standards for what constitute a valid FC for MECH 421-423 will be discussed in class. Students may choose to invent a new product or to develop their own version of an existing product. The major deliverables include a concept proposal, full proposal, interim demo, final demo, video, and final report.

The MECH 421-423 design project can be sponsored by a UBC or external sponsor. However, the MECH 421-423 student team must retain creative control. Specifically, the sponsor can present the problem, but the student team must, within reason, be allowed to explore the full solution space. Sponsored projects must be approved.

Students are encouraged to be creative and ambitious in their project proposal, but they are also encouraged to be prudent in designing a project compatible with their technical ability, time availability, and resource constraints. Specifically, students should aim to find projects that maximize the impact for their efforts, which is to say that students should aim to use minimum engineering effort to achieve maximum effect. For example, a project to create a remote-controlled toy car is unlikely to have this property since it is very difficult for students to make something better or more interesting than a well-designed, mass-manufactured toy car. An important part of the exercise is for students to estimate the challenges associated with developing robust and reliable mechatronic products.

Materials and Supplies

MECH 421-423 will provide each student team with up to $200 in materials purchased from Digikey, McMaster, and Amazon. The TAs will make orders from these suppliers once a week. Student teams are expected to acquire some basic supplies from available sources, such as fasteners from the Mech shop and maker space, materials from surplus, and components from e-waste. Student teams planning to incorporate specialized components in their project are expected to provide these components themselves.

A parts library is available for student teams to borrow components for their project. Student teams must obtain permission from the TAs to borrow components. Borrowed components must be returned at the end of the semester in usable condition.

The final projects, with the exception of components from the lab kit and parts library, are for the students to keep after the completion of MECH 421-423.

Schedule and Due Dates

Dates	Activity / Deliverables	Grade
11/3 – 11/15	Project conception, discuss with prof and TAs	
11/17	Project concept proposal due	5% in 421
11/3 – 12/8	Develop data infrastructure & most critical module	
12/8	Interim project demo and presentation (concept, data infrastructure, & MCM)	15% in 421
12/20	Full project proposal due Grading: FCs 50%, MCM 10%, Data infra 10%; Test plan 30%	5% in 423
11/3 – 2/27	Project work period	
2/27	Final project demo – graded by alumni, TAs, and prof.	40% in 423
3/9	Project video due	10% in 423
3/9	Final report due Grading: Concept 10%, FCs 40%, Testing 40%, Reflections 10%	10% in 423

Concept Proposal

Part I (50%): Use text and graphics to explain the overall concept of your design project. What is the overall goal and vision? What will the final product look like? What is conceptually interesting about your project? Why is it worth your time to do it? List the functional components of your product and give a brief description of each.

Part II (50%): copy the following questions and answer each using one paragraph:

1. What is the value of your product to the end-user? Note 1: the end-user is not the developer (i.e. you). Note 2: there may be many forms of value, including economical, utility, artistic, emotional, educational, and others. Please pick the most relevant one to explain.
2. What is the closest alternative to your product? Discuss the similarities and differences between your product and this alternative in terms like concept, mechanism, performance, cost, etc.
3. What is the metric of success for your product? How will you measure it?
4. Pick one aspect of your project that you will develop to a polished finish product? For example: mechanical housing, motion mechanism, software interface, and user experience. Describe the meaning of a finished product using both positive and negative attributes. For example: finished exterior; fast and smooth motion control; no rattling; error-free U/I; repeatable performance.
5. Which aspect(s) of your project will you not develop to a finished product?
6. What is your most critical module and why? For example, most risky, most difficult, least understood.
7. What kind of data infrastructure will you need? How will you test this infrastructure? What kind of mock data will you need to generate?

T1 Development and Interim Project Demo

In term 1, you will develop the data infrastructure and the most critical module (MCM) for your product. The data infrastructure enables the flow of information from the ADC to the user, or to an actuator control signal. A robust data infrastructure is typically required both for development and operation of your product. Start your project by developing the data infrastructure. Generate mock data and design experiments to test your data infrastructure at the maximum data rate.

Next, start working on your MCM. Plan to make successive improvements over multiple versions.

Each student team will give an interim project presentation to explain the concept of their project, demo the data infrastructure, and present progress on their MCM. The presentation will be on **Dec. 8 1-4 pm CEME 1202**. Each team will have 6 minutes for the presentation and demo, and 4 minutes for questions and feedback.

Full Project Proposal

The full project proposal expands on the Concept Proposal to provide a detailed work plan for each module. Use the following outline to write the full project proposal. Detailed descriptions of each proposal section are provided subsequently.

1. Concept
2. Answers to Questions in the Concept Proposal
3. Overview of Functional Components
4. Functional Component #1
   - 4.1. Approach and Design
   - 4.2. Inputs and Outputs
   - 4.3. Parameters
   - 4.4. Development Plan
   - 4.5. Test Plan
5. Functional Component #2
   …
6. Functional Component #3
   …
7. Functional Component #4
   …
8. Functional Component #5
   …
9. Data Infrastructure Development
10. Most Critical Module Development
11. System-level Test Plan

Grading: Functional Components (section 3-8) 50%, Data infrastructure 10%, MCM 10%, Test plan 30%

Detailed Description of Proposal

1. Concept

Revise from the concept proposal based on feedback

2. Answers to questions from the concept proposal

Revise from the concept proposal based on feedback

3. Overview of Functional Requirements

Briefly describe the purpose and scope of each FC. Use graphical illustrations as appropriate. List your FCs in a table. For each, assign a lead team member and estimate % effort.

Functional Requirements	% Effort	Responsible Person
FC#1: Sensor interface circuit	15	Calvin

FC#2: Mechanical stage design and manufacturing	30	Calvin
FC#3: MSP430 code for signal processing and motor control	15	Hobbes
FC#4: Motor driver and interface electronics	20	Hobbes
FC#5: C# User interface program	20	Calvin and Hobbes

4. Most Critical Module

Identify the most critical module (MCM) of your project and explain the challenges involved (e.g. difficulties, unknowns, risks). Describe the work done so far to develop the MCM. Describe any work remaining to complete development of the MCM (reference later sections if appropriate).

5. Functional Component #1

For each functional component in your system create subsections that address the following.

5.1 Approach and Design

Describe the objective of the FC. Describe the hardware and/or software that will be developed to address the FC. Present preliminary designs and work done to-date including circuit diagrams, algorithms and pseudo-code, mechanical sketches, solid models, block diagrams, and screen-shots from user-interface software.

5.2 Inputs and Outputs

Describe the inputs and outputs of the hardware and/or software module developed to address the FC. Examples include voltages representing physical parameters, serial data streams, and user-interface outputs. Present details such as the transfer function and range for analog signals, the format of serial message packets, and text and graphics presented to the user.

5.3 Parameters

Identify the parameters of this FC. (*i.e.* what are the knobs that can be adjusted on this module?) Examples include sensor bias voltage, values of key circuit components, motor operating speed, dimensions of mechanical elements. Describe how these parameters affect the operation of the module. Discuss how you will optimize these parameters.

5.4 Development Plan

Describe the development process as a series of incremental steps.

5.5 Test Plan

Describe tests that will be performed to evaluate the functionality of the FC, as well as key developmental steps.

6-9. Functional Component #2-5

10. System-level Testing

Design system-level tests that will be used to evaluate the function and performance of your product. Describe specific metrics of success and what you hope to achieve. Describe tests you will perform to evaluate the one aspect of your product that you intend to bring to a polished finish. If appropriate, describe hardware or software that you'll develop for testing.

Project Ideas (very old)

The projects listed below are designed to be starting points for students to develop a proposal. Feel free to modify any parts for your own proposal, or preferably, create a proposal from scratch.

Motion and Light Activated Bicycle Light

LED lights are a nice bike accessory in case you had to do some nighttime riding. However, they have to be turned on, which slows you down and can run down the battery if you forget to turn them off. Design a bicycle LED that only turns on while the bike is in motion and in low-light environments. Keep manufacturing costs to a minimum by using a low-cost microprocessor, light sensor, and devising your own low-cost motion sensor. Develop strategies to keep parasitic power consumption to a minimum. Estimate the battery life of your device. Student teams should produce a polished final product.

Remote Weather Station

Develop electronics and software for a remote weather station to measure the temperature and wind speed at the top of Whistler. Use the MCP9700-E/TO-ND sensor to measure temperature. Build a thermal anemometer using precision resistors as heating elements. Calibrate wind speed and direction in the wind tunnel. Report the temperature and speed to a C# user-interface. Use the C# program to send periodic emails or tweets of current weather conditions with time and date stamp.

Building Ventilation Controller

Ventilation is a major source of energy consumption in public buildings. Develop a building ventilation controller that changes the amount of ventilation depending on the level of activity in the building. Use a microphone to estimate the activity level in the building. Use the motor as your ventilation fan. Use the building activity level to control the motor speed. Create a user interface using C# or a LCD screen to show the building activity level and the fan speed. Allow the user to vary the relationship between activity level and fan speed.

Home-made Pen Plotter

Bubblejet printers are an incredibly cheap way to obtain a precision 2-axis stage. Find an old bubble jet printer. Open the printer and remove the cable to the stepper motors from the control board while keeping the stage intact. Build a motor controller for the two stepper motors. Use MSP430 to generate control sequences for moving the motors forwards and backwards. Use C# to send commands like “forward 100 steps” or “left 20 steps”. Replace the bubblejet cartridge with a pen or pencil. Demonstrate plotting simple figures on a sheet of paper. Other modes of artistic patterning include wood-burning and foam cutting.

New Interfaces for Musical Expression

An often heard complaint at electronic music concerts is that the artists are simply “playing” their laptop. Develop new interfaces for musical expression as a means to connect physical gestures with music and enable new ways to generate and improvise music. Develop a platform for generating music using physical gestures. Use Ableton Live to create electronica melodies and then use signals from the accelerometer, motor/encoder, and push buttons to trigger MIDI inputs on your computer. Use the LCD screen and soft-keys to add trigger dynamic content (changing with song content).

Colour-changing kinetic sculpture (Heavy mechanical component)

Kinetic sculptures are moving art displays. Create a kinetic sculpture using one or more motors. Change the sculpture depending on the ambient light-level, temperature, and noise level in the room picked up a microphone. Add LEDs to the sculpture and change their colour and brightness output depending on the state of the sculpture.

The sculpture could be a designed as a permanent system or perhaps as a flashing toy that is tossed around (i.e. at a party or a concert).

Lie Detector

Create a lie detector that monitors various physiological signals when a person is asked a series of questions. Potential measurement parameters include heart rate, motion (fidgeting), face and hand temperature, and skin response (sweating). Potential ways to measure heart rate include ECG sensor, pulse oximetry, and microphone. The ECG sensor is potentially a difficult circuit to build. A shortcut is to purchase an ECG sensor and extract the ECG waveform by hacking a wire to the amplified output. Motion could be measured using accelerometers. Skin response could be measured using galvanic skin response sensors or home-brew versions that measure skin conductivity.

Simon Says (Heavy mechanical component)

The game “Simon Says” game is a pattern matching game, where an increasingly difficult pattern is displayed and the player of the game must repeat that pattern in order to go to the next level (more elements are added to the end of the pattern each level). Create this game with a new twist: use visual indicators, sensors (buttons or touch sensors), and haptic feedback to enhance the player’s experience.

Knock Pattern Door Lock

Forgetting your keys and calling up a roommate to let you in is always frustrating, or trying to find a place to hide keys that’s not as obvious as under the door mat. Inspired by the “What’s the secret knock?” days of our childhood, develop a door lock that will activate when a specific knocking pattern is detected. Commercially available solenoid door locks can be used as a starting point. Use a contact microphone to pick up the knock pattern from a door. The knock pattern could have a temporal component (time between knocks), as well as a spatial component (location on door). Make sure this system cannot be easily fool by random knocking.

Whack-A-Mole Game

Re-make the classic game or the following new version: There are a number of tiles, any of which could be indicated (for example with a light). The player then has a certain amount of time to activate that tile using a sensor of your choice, and then another tile is activated. This repeats, with the time between tile activation decreasing until the player makes a mistake and the game is over. Create a version of this game, and optionally keep track of high scores through a Windows interface.

Additional Project Ideas

- Persistence of vision display
- Hack an existing display device to display your own messages
- Energy harvester
- Run-away alarm clock
- Animatronic dancing robot
- Self-balancing machine
- Ultrasonic wood stud finder
- Capacitive metal stud finder
- Home-away program
- Office temperature controller controlled using an Internet calendar (i.e. gmail calendar)
- Labyrinth-playing robot (start with a simple version!)

- Low-cost electrode-discharge machining tool
- Home-brew laser scanner display
- Automated pet food dispenser
- Location based games using a GPS chip
- Puzzle alarm clock (must solve the puzzle to disarm the alarm)
- Unuseless machine (electromechanical Rube Goldberg machine)
- Escape room
- Maze solving robot
- 3D block builder (like a 3D printer)
- Smartphone app to control hardware via Bluetooth
- Part picker/sorter
- Sunlight finding planter
- AR video game with motion sensing control