The University *of* Western Ontario
Faculty of Engineering
Mechatronic Systems Engineering Program

MSE 2202 — Introduction to Mechatronic Design
Term Project 2016

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1 Problem Description

The Southwestern Ontario Tessaract Co. is in disarray. Due to the stocastic nature of creating tessaracts, they appear simultaneously in random locations of the factory floor. To complicate matters, not all tessaracts are fully formed. In an effort to mitgate this problem, the goal is to design an autonomous mechatronic device that can collect "good" tessaracts and manipulate them for subsequent use. Good tessaracts have outside dimensions of $2 \times 2 \times 2$ cm and may be distinguished from the others by the presence of strong magnetic flux density.

The device must be able to operate in two modes:

1. In Mode 1, the device works within a square room, collecting good tessaracts and placing them in a holding area for subsequent processing. The tessaracts must be collected one at time. Once collected, each tessaract must be placed in a distinct section of the holding area, as identified by black stripes. The available space for each tessaract is 5 cm and only one tessaract is allowed in each section. Six good tessaracts will be in the room at a time, with two devices operating simulataneously. The devices will have a selectable "home" position, located in opposite corners of the room. The corners may be identified by either positive or negative magnetic flux. Ideally, each device collects 3 good tessaracts; however, if one device outperforms the other, it may collect more.
2. In Mode 2, the device takes tessaracts from the holding area and places them on a raised platform for pickup by delivery drones. The task is complicated by the need to manoeuvre through an opening that is approximately 19 cm high and 25 cm wide. The tessaracts are positioned on a platform that is approximately 43 cm from the ground. The tessaracts may be placed anywhere on the platform, so long as they do not overlap.

It is expected that the device will operate autonomously. Navigation should be achieved using an internal "map" of the key objects in each area in combination with real-time sensor data. While the production room will always be square, the device should be robust to changes in the room geometry (length and width). The tessaract locations will be random, as will be the number of defective tessaracts. The platform dimensions will not change.

The overall dimensions of the device must allow it to fit within one of the MSE lockers without disassembly. The device should be able to move over any smooth floor and must be able to operate without painted/taped lines, markers, wires or any other installed guides. In addition, the design must incorporate features to ensure the safety of the other device operating simultaneously. That is, the devices must not drive into each other or otherwise cause harm, but rather should stop and/or seek an alternate route. This is not Battlebots.

The following items will be left to the discretion of each group:

- Map representation and method of input
- Method of manipulating tessaracts

- Type and robustness of collision avoidance

To take advantage of concurrent engineering practice, each student will work in a team of four members. Each team must consult potential end users of the product when establishing the design requirements and evaluating product performance. These consultations may introduce additional design constraints such as durability, ergonomics, simplicity of the user interface, ease of battery charging/replacement, etc. It is expected that each team will utilize accepted product design principles and techniques to progress along the following steps:

- Establish customer needs
- Establish relevant design specifications
- Develop project plan
- Generate and evaluate several design concepts
- Develop detailed design with CAD
- Develop manufacturing-ready design documentation
- Use design simulation to analyze product performance
- Develop prototype of design
- Evaluate prototype performance

The design must be evaluated in terms of product function, design for manufacturing and/or assembly, failure modes, and other relevant performance criteria. The design team must be able to provide sufficient and relevant documentation to justify all critical design decisions.

2 Deliverables

There will be a number of deliverables for this project:

1. Design notebooks
2. A product development file (PDF) documenting the design process
3. A report describing and justifying your design
4. A prototype of your design

2.1 Design Notebooks

Each student is to keep a hard-cover notebook that shows all individual work concerning design project. This includes all sketches, notes, experimental data, and design ideas. Each page must be numbered and no pages are to be removed from the book. At the beginning of each laboratory period, the prior week's entries in the design notebook will be evaluated by the course instructor or teaching assistants. The design notebook will be collected at the end of the term and graded on the number of “quality entries” it contains. A quality entry is a significant sketch or drawing of some aspect of the design; a listing of functions, ideas, or other features; a table such as a morphology chart or decision matrix; or a page of text.

2.2 Product Development File

Each group is required to create a Product Development File (PDF). This is a series of documents that cover the entire history of the design. In practice, this includes all documents generated throughout the design process, including: quality function deployment charts, product design specification lists, Gantt charts, function decomposition diagrams, system models, sketches of concepts, calculations, go/no-go screening, decision matrices, detail and assembly drawings, circuit drawings, program flowcharts and code, bill of materials, prototype construction notes, failure modes and effects analysis (FMEA), analytical and physical modelling, operating instructions, description of experimental tests, test results and analysis.

The first or cover page for each document in the PDF must be dated and signed. The file should be kept in a single three-ring binder. The material should be organized according to the different phases of the design process:

1. Specification and Planning Phase
   (a) Statement of Need/Problem Statement
   (b) Product Design Requirements (Understanding the problem)
   (c) Program Plan (Planning and scheduling)
2. Conceptual Design Phase
   (d) Conceptual Design Development (Concept generation)
   (e) Concept Evaluation (Concept selection)
3. Product (Detail) Design Phase
   (f) Product Generation (Refine design concepts)
   (g) Product Evaluation (Product design vs. requirements)

The information contained in the PDF is complementary to, and provides the basis for, the final report.

2.3 Product Design Report

A technical report is to be submitted at the end of the term. The report must clearly describe a single solution for the design problem. Proper specifications and engineering drawings must be included. General *guidelines* are provided below.

Cover/Title Page: Outside jacket of the report—contains the name of the course, title of project, and identifying information.

Abstract/Executive Summary: Abridged version of the entire report written in nontechnical terms; short and informative; normally describes salient features of the report, draws a main conclusion and makes a recommendation; should be written last, after the remainder of the report has been drafted.

Table of Contents: Shows the content and arrangement of the report; includes a list of appendices, a list of figures, and a list of tables; sometimes followed by nomenclature (set of terms or symbols).

Introduction:	Identifies the design problem and indicates the scope of the report; summarizes key design specifications; provides background information.
Discussion:	Provides all of the details, evidence, and data needed to understand how the process was developed and evaluated; includes a brief description on alternative concepts and why they were rejected; may also describe the adjustments made the prototype phase and the impact of these on the device performance.
Conclusions:	Concise statement of the outcome; evidence that the design objectives have been met.
Recommendations:	If the discussion and conclusions suggest that a specific action needs to be taken, the recommendations state categorically what must be done.
Bibliography/References:	A list of references which were used to conduct the project and which the author considers useful for the reader; follows accepted stylistic conventions and contains sufficient information for the reader to obtain the documents.
Appendices (Optional):	Supporting data, which rightly belong in the Discussion, but if included, would disrupt and clutter the narrative; inserted in the order that they are referenced in report.

2.4 Prototype

Each group must produce a functional prototype of their design. The prototype should approximate the final design as closely as possible, but need not be exact. It is expected that certain compromises, modifications and adjustments will be required such that the prototype can be constructed with the resources available to each team. Remember that each group must design a *product*; not a *prototype*. The following resources may be used for prototype construction:

1. VEX kits—All components available in a single VEX toolbox are available for use (if required, additional servo motors are available on request).
2. Rechargeable battery packs—Standard MSE battery packs will be available. It is expected that the device will operate within the energy budget permitted by one of these batteries.
3. Arduino-based microcontroller—It is expected that the MSEduino boards constructed during Lab 1 will be used; however, alternate Arduino-compatible boards may also be used if desired.
4. Electronic components—Electronic components in addition to those available in the VEX and the MSEduino kits may be obtained through the Electronics Shop. Each group will be provided with a budget of $50. These components must be returned at the end of the term.
5. Rapid prototyping machine—Two fused-deposition modelling (FDM) systems that can construct parts from layers of extruded ABS plastic are available in the Mechatronics Lab. Build costs are $1.50/m of material. Each group will be provided with a budget of $80. Note that, the turnaround time on component builds (especially for large parts) may be up to one week.

6. Laser cutter—A 60 W CO_2 laser is available in the Mechatronics Lab. It is capable of cutting 2D profiles from a variety of sheet goods including acrylic, plywood, pressboard and corrugated plastic up to 1/4” thick. For safety reasons, only approved materials will be cut. As with the rapid prototyping machines, the turnaround time to have parts fabricated may be up to one week.

7. Additional components purchased or salvaged—Each group can add any additional components required by their design. The total cost of all additional components cannot exceed $100. To ensure fairness, receipts are required; for salvaged components, the fair-market value, as determined by advertised prices in catalogs or on websites, must be provided.

3 Design Review Meetings

The purpose of the design review meetings is to provide an opportunity for each design team to meet with the course instructor and teaching assistants during the design process. There will be two design review meetings held during the lab periods. The specific dates are as follows:

Design Review	Section 003	Section 004	Section 002
1	March 7, 2015	March 8, 2015	March 10, 2015
2	March 21, 2015	March 22, 2015	March 24, 2015

At each meeting, the design team will give a short *informal* (i.e., no PowerPoint slides) presentation (5–10 minutes in length) that clearly states the design problem, the progress made, and any problems that have been encountered. The meeting will also provide an opportunity for both parties to discuss any questions and concerns arising from the project and related course material.

In addition, each group must submit a one to two page summary report that provides a complete synopsis of the state of the project during the reporting period. This summary report should include the following sections:

Progress: Discussion of the activities and developments in the reporting period that have advanced the design project to a higher or better stage.

Prognosis: A forecast or prediction of the probable course and outcome of the design project.

Plan: Description of the proposed course of action for the next time period and its relationship to successful completion of the project. The plan should include a schedule developed by the responsible parties for each task.

These reports and the design meetings are formative in nature. That is, to receive full credit for the final design project, the meetings and associated summary reports must be completed satisfactorily; however, no grade will be assigned.

4 Mark Distribution

To make the grading process fair, each member of the design team will evaluate every member of the group (including themselves) for the percent of his/her contribution to the design project. These confidential evaluations must be justified and supported by written commentary. The resultant evaluations will be averaged to find each student’s contribution and to determine the student’s individual grade.

For example, if there are four students in a group and each student makes an equal (25%) contribution then all members will receive the same grade for the project. However, if the individual contributions vary then the grades will be corrected by the difference from 25%. For example, if the group mark for the project was 80% and student A makes a 40% contribution to the project then his/her mark will be 95% (i.e., 80+(40 - 25)). Furthermore, if student B in the same group makes a 30% contribution then that student will be assigned a mark of 85% (i.e., 80+(30 - 25)). Finally, if students C and D make contributions of 20% and 10% then their individual marks will be 75% and 65%, respectively. Note that the maximum possible mark for the project is 100%.

5 Project Deadline

A showcase of the devices developed by each group will be held on Monday, April 4 from 5–8 pm in SEB 3109. The showcase will provide each group with an opportunity to demonstrate the efficacy of their device with respect to each of the tasks outlined in the problem description.

Individual design notebooks, the PDF, the prototype, and a final design report are due no later than 4 p.m. on Wednesday, April 6, 2016. *Late submissions will not be accepted.* Marks will be assigned on the basis of innovation, correctness of solution, thoroughness of analysis, clarity of presentation, and neatness.

Note: The above design requirements are subject to adjustments and changes as necessary.