Team 1: U-TRACKR

Vision-Based Tracking & Collision Avoidance System
Preliminary Design Review

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1. Problem summary

When Amazon purchased the Kiva robots from Kiva Systems in 2012, the face of warehousing forever changed. These mobile robots enabled Amazon to greatly improve their Prime services, promising the delivery of items within two days. Years later, the demand for autonomous mobile robotic systems began to grow as manufacturing, production, and shipping companies noticed the increased levels of performance and efficiency. However, these industrial robots come at a cost and warehouses have to be designed around them. For example, floors need to have custom grids so that the robots can move, and workers are at risk of getting hit if they are in the way. Our system is a solution to these flaws. We aim to provide real-time vision-based navigation for these blind robots, and enable trajectory control in indoor, GPS-denied spaces.

2. Statement of project objectives

The *U-Trackr* camera system will be designed to solve the tracking and control needs of shipping warehouses for mobile industrial robots. Our key objectives are to:

- Use real-time vision-based tracking to accurately locate a moving autonomous robot vehicle
- Locate the vehicle, as well as obstacles, within an indoor space
- Track the three-dimensional trajectory of the vehicle
- Predict the path for collisions with any obstacles
- Notify the vehicle of an oncoming collision (through an alarm or vibration)
- Predict the correct path to avoid the collision

Our (more advanced) objectives in the future are to:

- Control and correct the trajectory of the vehicle to avoid collision
- Adjust the program to account for the pitch, roll, and yaw of UAVs

The automation and design of the mobile vehicle is beyond the scope of the system. Our system will also be constrained by the type of components that we purchase. We plan to locate targets solely by using the image frames from the camera. We may use infrared technology for testing, but it will not be part of our system. Furthermore, the size of our system is constrained to lab spaces available to ENG 4000 students. While we would like to build our system to be used in large warehouses, for now we can only build a prototype that can be tested within York campus labs. Lastly, we are constrained by the budget, timeline and scope of the project.

3. System breakdown

The main components making up the *U-Trackr* camera system are illustrated in Figure 1.

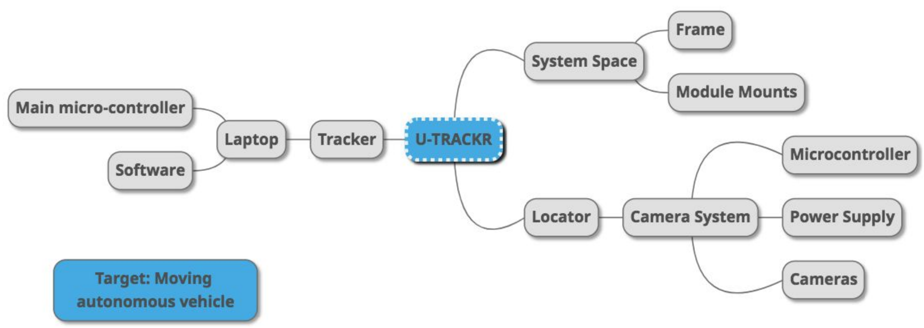

Figure 1: Top level diagram of the *U-Trackr* system

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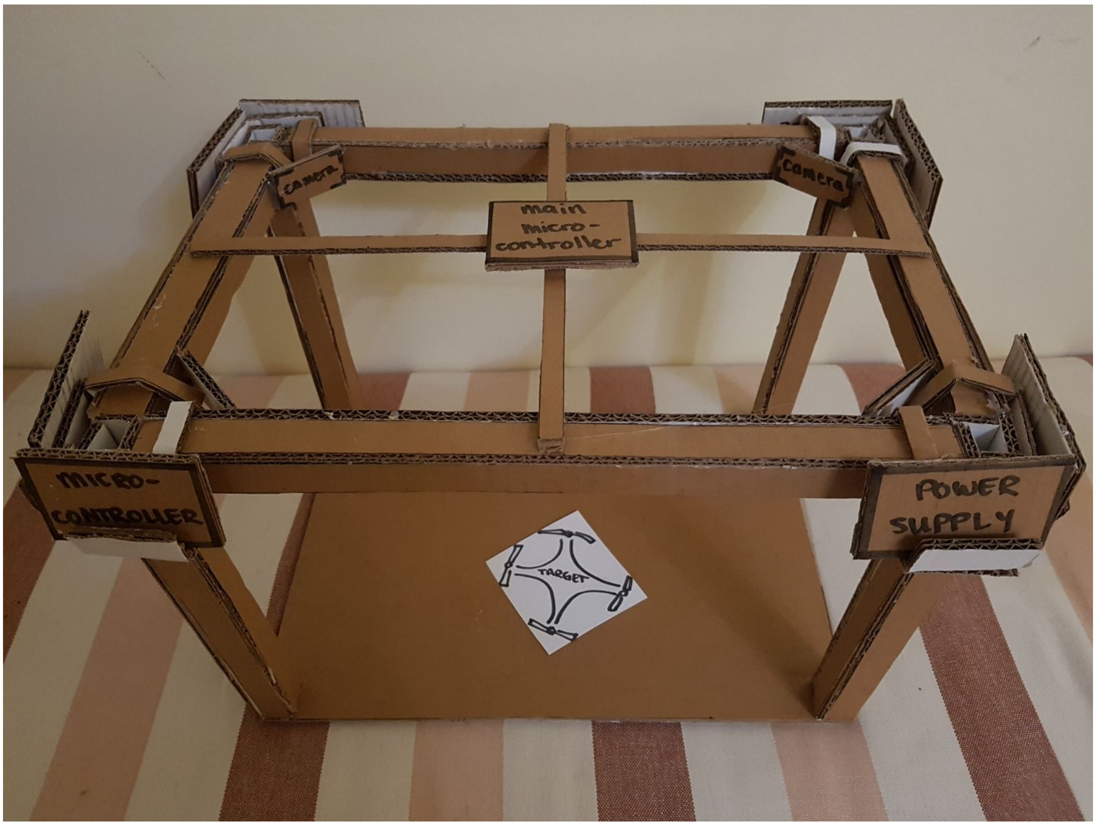
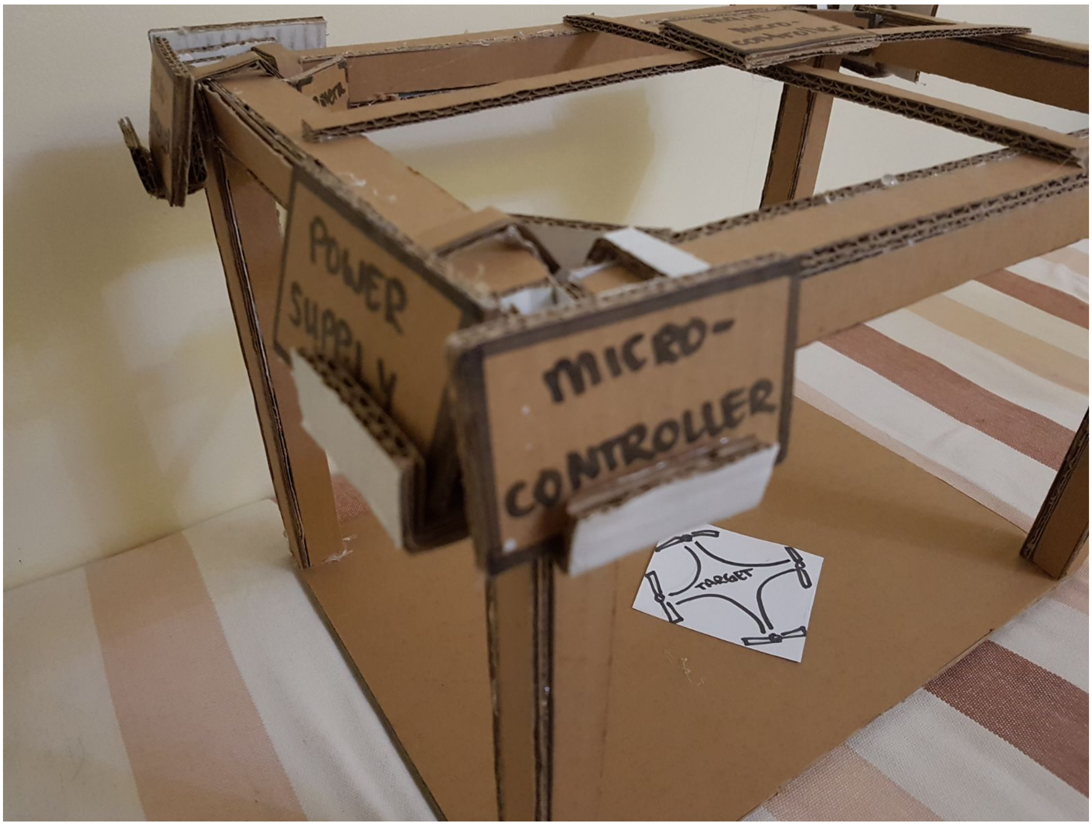
4. System requirements

Table 1: System requirements for the *U-Trackr*

	Requirement	User Need	Plans to achieve requirements
Functional Requirements	• The system shall ensure all objects in motion in a defined indoor space are identified. The system shall record the area at various angles and write the videos onto a server. • The system will process the videos from the server, frame by frame, to identify the objects in motion and identify the location of the objects in the indoor space. • The system shall predict and determine if object in motion will collide with any obstacles. Based on that, it will either sound the alarm or, (future scope) communicate to object in motion to steer away.	• Workers are at risk of getting hit if Kiva robots are in the way. • Ditto. • A form of alert to notify the object in motion that a collision will occur, and alert the object or control and correct its path to avoid collision.	• First phase of testing will consist of identifying one object in motion, and identifying its location in the indoor space. This will be further expanded by adding more moving objects. • Remote control cars will be used for initial testing of the parts of the system's operations. • Communication with the object in motion will be integrated to the system, provided we have the time. Else, an alarm will sound to alert that a collision is about to occur.
Performance Requirements	• The system shall be able to identify objects in motion within an indoor space in York University. • The system shall be able to identify at least 2, if not more objects in motion. • The system shall identify to 90% accuracy the exact location of the objects in motion in the indoor space. The system shall 90% identify if a collision shall occur between the objects in motion, and create the alert.	• Based on the size of the room, and how much area our cameras can cover. • There are many Kiva robots in Amazon's warehouse. • Approximately 90% of exact location will aid in providing real-time vision based navigation for objects in motion, and approximately 90% chance of predicting collision will cause less collisions to occur.	• A room in York University will be used for early system testing, when not in use. • The initial goal for the system is to identify at least 2 objects in motion. The system can further be expanded to identify more objects. • This will rely on the final system results.
Interface Requirements	• The system shall sound an alarm, if a collision, were to happen, or communicate with one of the object's in motion via a shared server.	• The communication with the object in motion is currently out of scope.	• An alarm in the center of the indoor space will sound. • Currently not in scope, however if possible, we will expand our scope by allowing the microcontroller on the moving object to constantly read from a server to check if any changes must be made to the track of its motion.
Regulatory Requirements	• The system shall comply with the Workplace Safety and Insurance Board(WSIB) policies. • The system shall comply with the Worker Health and Safety - Ontario Ministry of Labour policies. • The system shall comply with the privacy policies in place due to recording a defined area. • The system shall comply with York University's policy with regards to Temporary Use of University Space.	• http://www.wsib.on.ca • https://www.labour.gov.on.ca/english/hs/sawo/pubs/fs_manufacturing.php • Privacy policies of the manufacturing plant will be in effect while using this system. • http://secretariat-policies.info.yorku.ca/policies/temporary-use-of-university-space-policy/ . York University's policy.	• The system shall be reviewed by our user to ensure the system complies with the WSIB policies. • The system shall be reviewed by our user to ensure the system complies with the Worker Health and Safety regulations. • The system shall be reviewed by our user to ensure the system complies with privacy policies. • Our supervisor will ensure that the system shall be implemented and operated following the policy by York University.
Process Requirements	• The system shall be ready for first phase of testing by mid-February 2018.	• It is preferred to have preventative measures to ensure a collision does not occur.	• The timeline currently shows an end of January readiness date, keeping in mind some margin for contingencies. Also, this will allow for ample time to expand our scope (if needed) to integrate communication with the moving object.

5. Point design (cardboard mockup)





Before the critical design review, some of the technical questions that came up following the completion of the cardboard prototype are:

- What is the flow of operations and how will the variables be determined during setup?
  - How can we determine the variables such as the camera angle, height, the frame of axis and the position of the camera system?
  - How does the system process information in real time and how will it be translated into commands?
  - How can we transfer the data collect from a micro-controller to a server computer?

- How can the main purpose be delivered?
  - How can we track motion and how do we translate the movement into usable data?
  - How can we control these systems (motion tracking and control) and make autonomous operations?
  - Do we need a main micro-controller? And does it have to be in the center of the frame?

- Will our system be efficient and how do we improve on the system ?
  - How fast does the system of micro-controllers process and what is the runtime on the code?
  - How important is the camera frame rate important for image-processing?
  - Are the components of the camera and control system economically efficient?
  - How can we make our system portable?

The list of questions we presented demonstrate the use of a cardboard mock up. The question identified in the process of making the cardboard prototype revealed some of the unknowns, variables, and constraints that may come up immediately or in the later stages of the project. These questions will be answered later on in the design process and may have a single solution or no immediate solution. For instance, the variables such as *the angle, the height, the frame of axis and the position of the camera system can all be determined* by a specific grid system to translated photo coordinates into 3D cartesian coordinate. From there, the coordinate system will allow us to track the motion of the moving target, with respect to its position.

Another question that was answered from the point design: *Do we need a main micro-controller? Does it have to be in the center of the frame?* The position of the main controller enables communication between the individual micro-controllers using wireless methods. If the frame of the system was bigger, the range of the devices will matter. In our case, the position of the main micro-controller does not matter.

The programming efficiency, process speed and runtime will be determined during the system prototype stage. These factors define the properties of a real-time processing and command system.

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6. Breakdown of tasks

A breakdown of scheduled tasks can be found below. (Dates are subject to change). This can also be seen using Microsoft Project with various views by following the link.

	Task Name	Grade Percentage	Duration	Start	Finish	Predecessors
1	**U-TRACKR**	**100%**	**169 days**	**Mon 10/16/17**	**Mon 4/2/18**	
2	**Preliminary Design Review (PDR)**	**10%**	**8 days**	**Mon 10/16/17**	**Mon 10/23/17**	
3	PDR Draft		2 days	Mon 10/16/17	Tue 10/17/17	
4	Meeting with Industry Advisor		1 day	Wed 10/18/17	Wed 10/18/17	3
5	PDR Final Report		5 days	Thu 10/19/17	Mon 10/23/17	4
6	**Critical Design Review (CDR)**	**25%**	**28 days**	**Tue 10/24/17**	**Mon 11/20/17**	**2**
7	Prototyping (Microcontroller and frame setup)		10 days	Tue 10/24/17	Fri 11/3/17	
8	Prototyping (Development of a preliminary motion tracking program)		9 days	Fri 11/3/17	Mon 11/13/17	7
9	CDR Draft		1 day	Mon 11/13/17	Wed 11/15/17	8
10	Prototype Review w/ Technical Supervisor		1 day	Thu 11/16/17	Thu 11/16/17	9
11	CDR Final Report		4 days	Fri 11/17/17	Mon 11/20/17	10
12	**Test Readiness Review (TDR)**	**10%**	**77 days**	**Tue 11/21/17**	**Mon 2/5/18**	**6**
13	Build microcontroller, camera, and frame setup		14 days	Tue 11/21/17	Mon 12/4/17	
14	Semester Break		31 days	Tue 12/5/17	Thu 1/4/18	13
15	Development of the primary motion tracking program		13 days	Fri 1/5/18	Wed 1/17/18	14
16	Design Review w/ Technical Supervisor		1 day	Thu 1/18/18	Thu 1/18/18	15
17	Define test plan for full system testing		8 days	Fri 1/19/18	Fri 1/26/18	16
18	TRR Draft		7 days	Sat 1/27/18	Fri 2/2/18	17
19	TRR Final Report		3 days	Sat 2/3/18	Mon 2/5/18	18
20	**Test Review (TR)**	**10%**	**21 days**	**Tue 2/6/18**	**Mon 2/26/18**	**12**
21	Unit Testing		6 days	Tue 2/6/18	Sun 2/11/18	
22	Integration Testing & Continuous Refinement		5 days	Mon 2/12/18	Fri 2/16/18	21
23	Acceptance Testing		5 days	Sun 2/18/18	Thu 2/22/18	22
24	TR Draft		2 days	Fri 2/23/18	Sat 2/24/18	23
25	TR Final Report		2 days	Sun 2/25/18	Mon 2/26/18	24
26	**Final Formal Documentation (FFD)**	**25%**	**15 days**	**Tue 2/27/18**	**Tue 3/13/18**	**20**
27	FPD Draft		7 days	Tue 2/27/18	Mon 3/5/18	
28	FPD Final Report		8 days	Tue 3/6/18	Tue 3/13/18	27
29	**Product Release Presentation/Exhibits**	**10%**	**20 days**	**Wed 3/14/18**	**Mon 4/2/18**	**26**
30	Demo Materials Preparation (Bristol Boards, Videos, etc)		10 days	Wed 3/14/18	Fri 3/23/18	
31	Demo Practice Preparation		9 days	Fri 3/23/18	Sun 4/1/18	30
32	Demonstration		1 day	Mon 4/2/18	Mon 4/2/18	31
33	**In-class Feedback**	**5%**				
34	**Weekly Reports (On-going)**	**5%**				

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7. Expenses

Table 2: Preliminary Expenses for the U-Trackr prototype

Item (Problem Space)	Item (Prototype Solution Space)	Estimated Cost	Description
Microcontroller (x4)	Raspberry Pi Zero (x2)	($34.99 * 2) = **$69.98**	Controls and processes information from the camera modules. (Two Raspberry Pi modules are provided by the team for prototyping)
Cameras (x4)	Raspberry Pi Camera Module V2 (x4)	($30.99 * 4) = **$123.96**	Takes high-definition videos in real time for vision based tracking.
Frame	PVC Pipes and Fittings	($8.73 * 2) = **$17.46**	Holds the camera modules in opposite and equidistant positions.
Primary Processing System	Personal Laptop	-	Tracks, locates, and models the moving object(s) programmatically using image sequences. (Provided by the team for prototyping)
Portable Power Supply for Microcontrollers (x4)	USB Power Banks	-	Provides an external power source for the microcontroller. (Provided by the team for prototyping)
TOTAL ESTIMATED EXPENSES = $211.40 PROTOTYPING BUDGET = $250			

The group plans to spend roughly $211.40 on prototyping the preliminary system.

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8. Self-assessment (Rubric)

RUBRIC CRITERION FOR PDR	SELF-EVALUATION RANKING	OUR JUSTIFICATIONS
Identify and document design requirements (e.g., goal, objectives, constraints, functions, and specifications) from a given set of customer needs.	*Exceeding criterion (4/4):* Fully identifies and documents design requirements from a given set of customer needs	Requirements in section 4 captures all the key elements in great detail.
Conceive design solutions to solve the defined problem.	*Exceeding criterion (4/4):* Conceives elegant/ innovative/ creative/ professional standard solutions to solve the defined problem	The team presented an innovative solution to a current problem and has narrowed down a target market as stated in section 1 and 2.
Decompose complex systems into smaller, more manageable sub- systems.	Meeting criterion (3/4): Able to decompose complex systems into smaller, more manageable but suboptimal sub-systems	The system has been decomposed into subsystems in Figure 1 and 2. However the top level blocks of the software implementation has not been adequately covered.
Identify criteria to compare and evaluate various design solutions.	Meeting criterion (3/4): Resolved some of the criteria that is needed in both hardware and software aspect of the project.	The point design with cardboard mockup illustrate and provide immediate solution into some problems that will arise in the develop of the prototype.
Incorporate appropriate considerations of ethical, social, environmental, legal, and regulatory factors into an engineering design.	Meeting criterion (3/4): Incorporates key appropriate and adequate consideration of ethical, social, environmental, legal and regulatory factors into an engineering design.	Requirements table includes the requirements for collision prevention, and laws our system with comply with when implementing and operating the system in a manufacturing plant for example. Also, taking into consideration the pre-existing policies and regulations maintained by the manufacturing plant.
Determine the necessary schedule and timelines to complete a project.	*Exceeding criterion (4/4):* Determines the necessary schedule and timelines to complete a project making good use of resources.	A full breakdown of tasks for each deliverable is presented in section 5. Each task is given an appropriate amount of time to complete.
Formulate a strategy for solving an engineering problem.	*Meeting criterion (3/4):* Formulates a strategy for solving an engineering problem.	Section 2 and 3 state the project goals and requirements. The schedule presented in section 5 provides a list of tasks that help formulate the strategy to solve the engineering problem.
Identify the problem variables, unknowns, and constraints.	*Exceeding criterion (4/4):* Determined the necessary variable unknowns and constraints of the project and how they affect the overall performance of the system	List of questions answers some of the problem that needs to be tackle between the preliminary design report and the critical design report.