Department of Computer Science & Engineering
The University of Texas at Arlington

Project Charter
CSE 4316: Senior Design I
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Runtime Terror
Turing Board

Sahaj Amatya
Sarker Nadir Afridi Azmi
Kendall Buchanan
Keaton Koehler
Happy Ndikumana
Lydia Sarver

Revision History

Revision	Date	Author(s)	Description
0.1	10.04.2021	SA	Document creation
0.2	10.08.2020	SA, NA, HN, LS, KK, KB	Complete draft
0.3	10.10.2020	LS, KB	Spelling/grammar check
0.4	10.11.2021	KB	Proof read
1.0	10.11.2021	SA	Official release

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1 Problem Statement

The need for autonomy has existed for all of human history. Combined with the growth of the AI industry, it has led to autonomous vehicles such as Teslas, self-flying drones, and more. The idea for Turing Board was inspired by these technologies with a goal to create an electric longboard with a certain level of autonomy. We present a solution for the task of carrying a longboard around and the also provide the flexibility of using a free to use app to control it. The prototype would have the ability to be summoned by the user to their current location and follow a target.

2 Methodology

Our primary goal is to solve the problem stated above while minimizing cost and maximizing efficiency. Using open source libraries such as OpenCV for object detection, low-over protocols like MQTT for IoT, and low-cost development boards including the Teensy for controlling motors and collecting data, we aim to create an autonomous longboard centralized by a discrete Jetson TX2 compute unit. All these technologies were picked due to their ease of use and the tremendous amount of work which has gone into their documentation to give us granular control of each feature.

The first feature would be implemented to address the problem of carrying the board around vis-a-vis an option to summon the longboard. The goal is to reach a level of autonomy where the longboard would be able to navigate its way toward a target location while avoiding obstacles with the aid of computer vision. The second feature allows the longboard to lock on to a target and follow the them around using computer vision, potentially carrying a load on top of it.

3 Value Proposition

Due to the nature in which the project is being implemented, new features can easily be added. All the software will be free, mitigating the cost of buying expensive, proprietary libraries which would only be able to solve one problem at a time. Not only does this encourage future updates to the software, it allows for modification by enthusiasts wanting to join in on the fun of owing a battery powered longboard, potentially creating a new sector to the already existing market of longboards.

4 Development Milestones

Milestones and completion dates:

- Project Charter First Draft - October 2021
- System Requirements Specification - October 2021
- Architectural Design Specification - November 2021
- Detailed Design Specification - TBA
- CoE Innovation Day Project Poster Presentation - TBA
- Final Project Demonstration - May 2022

5 Background

Currently, on the longboard market, there are two options: a normal longboard and an electric longboard. What we are introducing is a better version of an electric longboard. In addition to being controlled like an electric longboard, this product will add a level of autonomy to the longboard.

There are a few issues that come with owning a longboard. One of these issues is having to carry the board around when it is not is use. A longboard is fairly large and it takes effort and energy to carry it. Another issue is having to remember where a long board is placed when it is not in use. The product we are introducing tackles these problems. One of the features our product introduces is the ability to summon the board from wherever it may be within a certain radius. This eliminates the problem of not knowing where a board has been left when it is no longer in use. Another feature our product introduces is the ability to lock onto a target and follow them as they move. This feature solves having to carry the board everywhere you go.

Most electric longboards are controlled by little remotes. There are a few issues that can come with remote controllers. Remotes can be lost and the internal batteries can be drained. To alleviate this, we are introducing an app that would control the longboard. With an app to control the board, the user will not have to worry about charging/changing the batteries or losing their remote as it will be integrated in their phones, an important part of everyday life.

6 Related Work

At the time of the document being published there is no automated longboard commercially available. All longboards, at the moment, are either manual or electrical. Electrical longboards fix issues that come with a manual longboards. An example would be the need to constantly push the longboard in order for it to move. This is fixed by putting motors on the board and using them to push the board instead. Commercially, there are various electrical boards available [3]. Manual longboards simplify the process of traveling on a longboard. Electrical longboards automate the "push to move" action. Our product will add on to this feature. By introducing this product, we would be walking into uncharted territories.

An electric board that comes close to what we are trying to accomplish is the Audi's longboard that comes with the purchase of one of their vehicles. The Audi longboard offers one of the features our longboard will offer: the ability to follow a user [2]. Their longboard can also be configured to be used as a scooter. As nice as their board is, it only offers the "follow user" feature. The board itself is extremely expensive because it comes with the purchase of a car.

Another commercially available product that has features similar to what our boards will offer is the Ovis suitcase. This suitcase has the ability to lock onto a user and follow them around while avoiding obstacles [1]. The Ovis suitcase uses computer vision to navigate just like our board will.

7 System Overview

The Turing board will have two primary modes of operation: rider mode and autonomous mode. While in rider mode the electric long-board will be controlled entirely by the rider who is responsible for speed control. In autonomous mode the board will have the capability of being summoned from a parked location and self navigating to the user. Following the user is another function that will only be available while the electric long board is autonomous.

Rider Mode

The user will provide acceleration and deceleration commands through a mobile app connected to the hardware on the board with Internet of Things (IoT) software. An electronic speed controller will be used to receive the commands from the rider and adjust the speed of the electric motor accordingly. There will be no automation while in rider mode.

*************************** *IMAGE TO BE INCLUDED HERE* ***************************

Autonomous Mode
While in autonomous mode the commands for acceleration and deceleration will come from software analyzing real time environment data from board mounted cameras and sensors. An additional force sensor will be placed on the long board to ensure autonomous mode is only functional with a limited weight load on the board.
Turning without a rider present will require a unique hardware solution. During rider mode the user creates a bias in the wheel direction by leaning on either side of the board, this movement compresses the bushing component of long board trucks and allows the board to change direction. To solve this issue during autonomous mode a new hardware component will be created that will allow a stepper motor to spin the front trucks independent of the boards direction. The mechanism will fit between the truck and the board, acting as a conventional riser that separates the trucks from the deck. Using a stepper motor to drive a bevel gear, the lower component of the mechanism will spin along a vertical axis no more than thirty degrees in either direction. Solenoid pins will be used to lock the mechanism in place when not in use or when the user has switched to rider mode.
*************************** *IMAGE TO BE INCLUDED HERE* ***************************

8 Roles & Responsibilities

This being a non-sponsored, non-competition based project, the sole shareholder is Dr. Christopher Conly, who also acts as a "customer/sponsor." Team members include:

- Kendall Buchanan - Hardware, CV/OCR ML, Embedded
- Lydia Sarver - Embedded, Software, Scrum Master
- Sarker Nadir Afridi Azmi - Embedded, IoT, Circuit Design
- Sahaj Amatya - CV/OCR ML, Web Development, Software Development
- Happy Ndikumana - Embedded, Electromagnetic Sensors, Hardware
- Keaton Koehler - Electromagnetic Sensors, Embedded, 3D Modeling/Printing

As of now, we have no dedicated product owner until the time we pull together the efforts of all team members into a prototype, at which point a product owner will most likely change periodically or the product will remain available to all at the Senior Design Lab. Lydia Sarver has been chosen to be our Scrum Master. A secondary Scrum Master will be chosen if necessary.

9 Cost Proposal

The preliminary major expenses we have acquired were provided by the CSE Department including:

- 1x Jetson TX2 AI Computing Module
- 1x Intel RealSense Depth Camera D435 (Possibly 2x to be acquired total)

More major expenses yet to be acquired include:

- Li-Ion Battery Package (Specs TBD)
- Motor Controller IC

- Longboard Deck
- Brushless Motorized Longboard Wheels & Trucks
- Custom Machined Parts for Turning Mechanism
- Protective Housing(s) for Delicate Hardware

9.1 Preliminary Budget

Expenditure	Cost Estimation (USD)	Time Frame
Longboard Deck	\$200.0-300.0	1 Week
Longboard Motors and Hardware	\$100.0-200.0	2 Days
High-Grade Li-Ion Battery Pack	\$200.0-500.0	1 Week
Custom Machined Parts for Turning Mechanism	\$35.0-40.0/hour + cost of materials	2 Weeks
Motor Controller IC	\$100.0-150.0	2-7 Days

Table 1: High Level Preliminary Budget

9.2 Current & Pending Support

Funding Sources:

Source	Amount Provided (USD)
UTA CSE Senior Design Budget	\$800.0+
TBD	TBD

Table 2: Current Monetary Support

10 Facilities & Equipment

We will need a lab space for construction, a makerspace with a 3D printer, and a large space with obstacles (will most likely be outside) for testing. More may be added to this section as we continue to develop our project.

We need a NVIDIA Jetson TX2 and an Intel RealSense Depth Camera D435, which are being provided by UTA's CSE department for us to borrow. As we continue to develop our project, more may be added to this section.

11 Assumptions

The following list contains critical assumptions related to the implementation and testing of the project:

- We will be allowed to keep the loaned equipment in our possession for the full duration of the project, namely the NVIDIA Jetson TX2 and the Intel RealSense Depth Camera D435.
- The NVIDIA Jetson TX2 is trusted to be powerful enough to send instructions to the motors and perform the required live image based computations necessary for path planning.
- Given the nature of our project, it is important that we protect the equipment we have from any collisional damage.
- We must obtain the main components such as the board deck, motors, batteries, etc. before end of 2021.

- There may be no changes to team composition.

12 Constraints

The following list contains key constraints related to the implementation and testing of the project:

- The board must not be used under rainy or wet conditions. User must also be aware of the surface the board is going to operate on, lest the board suffers hardware damage.
- The user must have a handheld mobile device which is capable of Wi-Fi and cellular connectivity to take advantage of the web app remote for the board.
- The user must be familiar with operating a skateboard.
- The summon feature of the board may only be used when both the user and the board are on the same tier terrain (e.g., same floor in a building).
- Final prototype demonstration must be completed by May 1st, 2022.
- Total development costs must not exceed $800.

13 Risks

The following high-level risk census contains identified project risks with the highest exposure. Mitigation strategies will be discussed at a later date.

Risk description	**Probability**	**Loss (days)**	**Exposure (days)**
Turning mechanism does not function as intended	0.10	120	12.0
Delays in shipping from vendors	0.40	30	12.0
Hardware/Software Interface response time	0.15	42	6.3
Exceeding Budget	0.20	21	4.2
Internet access not available at demonstration site	0.10	1	.1

Table 3: Overview of highest exposure project risks

14 Documentation & Reporting

14.1 Major Documentation Deliverables

14.1.1 Project Charter

The initial version of the Project Charter will be delivered on 10/8/2021, with a final draft of the initial document completed on 10/10/2021. After that, Lydia Sarver will be responsible for updating the document as needed for items changing. Some items that may change include:

- Current and pending support
- Milestone date changes

The absolute final version of this document will be completed on or before the Final Project Demonstration Day, which is to be held in May 2022.

14.1.2 System Requirements Specification

The initial version of the System Requirements Specification document will be completed on 10/22/2021, with a final draft of the initial document completed on 10/24/2021. The team will be responsible for updating this document if the requirement they are working on at the time has to be changed for any reason. The absolute final version of this document will be completed on or before the Final Project Demonstration Day, which is to be held in May 2022.

14.1.3 Architectural Design Specification

The initial version of the Architectural Design Specification document will be completed on 11/12/2021, with a final draft of the initial document completed on 11/14/2021. The team will be responsible for updating this document if the design specification they are working on at the time has to be changed for any reason. The absolute final version of this document will be completed on or before the Final Project Demonstration Day, which is to be held in May 2022.

14.1.4 Detailed Design Specification

The initial version of the Detailed Design Specification document will be completed on (Friday before due date), with a final draft of the initial document completed on (Sunday before due date). The team will be responsible for updating this document if the design specification they are working on at the time has to be changed for any reason and as the design becomes more detailed. The absolute final version of this document will be completed on or before the Final Project Demonstration Day, which is to be held in May 2022.

14.2 Recurring Sprint Items

14.2.1 Product Backlog

After we decide the items for the System Requirements Specification document, they will be added to our Jira project (the software we are using to monitor our sprints and sprint items). The items will be prioritized by people's availability and group vote as to what is the next most important items. If multiple people have a large availability during a given sprint, multiple items can be worked on during said sprint.

14.2.2 Sprint Planning

Each sprint will be planned the week between sprints during our weekly group meetings. We will look through our backlog, consider what the best next steps are and what assignment is due next, and decide accordingly. We will have 9 sprints during our project.

14.2.3 Sprint Goal

We will decide the sprint goal based off of the next best step for our project as well as the assignment due dates for our Senior Design Class. This goal will be decided on as a group. We do not have a customer to involve in this process.

14.2.4 Sprint Backlog

The sprint backlog will be decided by the sprint goal and what tasks are both applicable to achieving the goal and feasible for the two week time frame. We are using Jira to maintain our sprint backlog as well as our Scrum board.

14.2.5 Task Breakdown

Individual tasks from the sprint backlog will be on a volunteer basis originally, but the Scrum Master may ask or delegate tasks as needed. The time we spend on tasks will be documented in Story Points because of the limitations of Jira. However, each story point will represent 30 minute intervals.

14.2.6 Sprint Burn Down Charts

Burn down charts will be produced by the Scrum Master at the end of each Sprint. Each group member will be responsible for estimating and tracking the time spent for each of their Sprint Issues. The burn down chart will be provided in the format Jira provides. The burn down chart for Sprint 2 will be added to this document as an example after it is created.

14.2.7 Sprint Retrospective

Our sprint retrospective will be held as an agenda point during our weekly meeting we will hold in between sprints. We will discuss what we finished, what was left, what we did well as a group and as individuals, as well as what we did not do well as a group and as individuals. We will document these in the notes we take for all of our meetings. Before this meeting, each member will be encouraged to consider these topics and bring them with them to that meeting.

14.2.8 Individual Status Reports

Individual status reports will be produced at the end of each Sprint. Key items reported in this are:

- Previous Sprint's Goal
- Previous Sprint's Backlog
- Individual Time Expenditures
- Team Burn Down Chart [Not relevant for Sprint 1]
- Individual Retrospective
- Peer Review

14.2.9 Engineering Notebooks

Our engineering notebooks will be updated everyday we do anything with the project. This should take place at least once a week, but will all most certainly happen more often. We will not keep a page number requirement for each person. They should track what is important to our project and the amount of pages required is expected to be different for each person. The engineering notebooks will be due in class periodically throughout the two semesters. We will sign off on each other's notebook pages as witnesses, but each person will be responsible for keeping up with their own notebook.

14.3 Closeout Materials

14.3.1 System Prototype

Our final system prototype will be an autonomous longboard as well as a web app remote. This final prototype will be demonstrated prior to the Senior Design Final Presentation day and videotaped to be shown to the reviewers due to safety concerns. There will not be any Prototype Acceptance Tests or Field Acceptance Tests.

14.3.2 Project Poster

Our poster will be a tri-fold board will be 48" x 36". It will be delivered on the CoE Innovation Day poster presentation as well as the Final Senior Design Presentation Day. It will have our board design schematic, a few specific parts of the board's schematics, and some problems we faced when building it. In front of our poster, we will have a laptop paying a soundless video of our longboard in use.

14.3.3 Web Page

Our web page will hold our web app when viewed on a mobile device. However, when viewed on a desktop pages about our board design, team, and more things to be decided at a later date will be found. Our final web page will be published in May of 2022. We will update the drafted version as we continue to develop our project, however the final web page will not be complete until May 2022. Sahaj Amatya will be in charge of updating our web page.

14.3.4 Demo Video

Our demo video will show our longboard in action with someone riding it, the board following someone, and it navigating to someone. We plan to include B-roll footage for future video cuts for the CSE department. The videos will be less than a minute in length and cover topics including autonomy, path finding, and turning mechanisms.

14.3.5 Source Code

Our source code is being maintained on GitHub. We will use their version control system. Our source code will not be open source.

14.3.6 Source Code Documentation

Our final documentation will be available in PDF format. We are following good code practices to ensure clean and understandable comments for our code.

14.3.7 Hardware Schematics

We will be wiring our components together. As we get our schematics for these wiring diagrams, they will be listed here.

14.3.8 CAD files

Our project will require mechanical design. We are using SolidWorks and TinkerCAD. Our closeout materials will be provided in OBJ, STL, and MTL files.

14.3.9 Installation Scripts

Our project will not require installation scripts. The board will already have the program to run it installed and the app is a web app and therefore updated on the server side of the app.

14.3.10 User Manual

We will provide a digital user manual for board and app use. It will walk the user through general setup of the board and how to use the web app.

References

[1] Henry T. Casey, 2018.

[2] T.S Fox, 2016.

[3] Bogdan Petrovan, 2021.