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

System Requirements Specification
CSE 4316: Senior Design I
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Runtime Terrors
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	10.22.2022	SA	document creation
0.2	10.28.2022	SA	completed sections 1 and 2
0.3	10.05.2015	AT, GH	complete draft

CONTENTS

List of Figures

1 PRODUCT CONCEPT

This section describes the purpose, use and intended user audience for the Turing Board.

The Turing Board is a concept autonomous longboard that is capable of exhibiting self-driving capabilities using computer vision. Users of the Turing Board will be able to take advantage of various features such as having the board follow you autonomously, having the board summon itself to you from a parked location, all on top of functioning as a standard electric longboard capable of recording and analyzing all trip data. Users will be delighted to observe that the Turing Board may also function as a load carrier, relieving them from the burden of carrying everyday items like backpacks, boxes, etc. if desired.

1.1 PURPOSE AND USE

The purpose of the Turing Board is to improve the overall user experience of an electric longboard with highly interactive software as a catalyzing agent. The user interfaces with the board via either a native Android or iOS app on their mobile device. It is through the mobile app that the user will be able to control the speed of the board when in manual mode, and send requests to the board to perform tasks it is able to do autonomously.

1.2 INTENDED AUDIENCE

The intended audience of this board is the electric longboarding community who share a passion for technology. Since this is an open source project, users are invited to tinker with their own forks of the code to optimize the board to their own standards, all the while furthering the light of knowledge to solve self-driving vehicles.

2 Product Description

This section provides the reader with an overview of the Turing Board. The primary operational aspects of the the Turing Board, from the perspective of end users, are defined here. The key features and functions found in the Turing Board, as well as critical user interactions and user interfaces are described in detail.

2.1 Features & Functions

When desired, the Turing Board will follow the user side by side at a walking pace. When called upon, it will summon itself to the user's location from a parked spot. However, users will not be able to take advantage of the autonomous features when they mount the board. The change in inertia spawned by a computer generated movement of the longboard puts the user at great risk of losing balance when taking off, braking, and especially turning. This changes the balance of the system as a whole. Such a problem is not an issue in household autonomous vehicles such as a self-driving car because the change in inertia only affects the balance of the user and not the car in any significant way.

The feature set of the Turing Board also consists of the collection and display of ride analytics.

Visually, the Turing Board is anticipated to share the form of any regular electric skateboard, with the only difference being that it is going to have a camera mounted on the nose end. The parts will consist of a deck, underneath the deck will comprise of an encasing that will house the battery, computation module, turning mechanism hardware, trucks and motorized wheels. The placement of the camera module is anticipated to be on the top of the board.

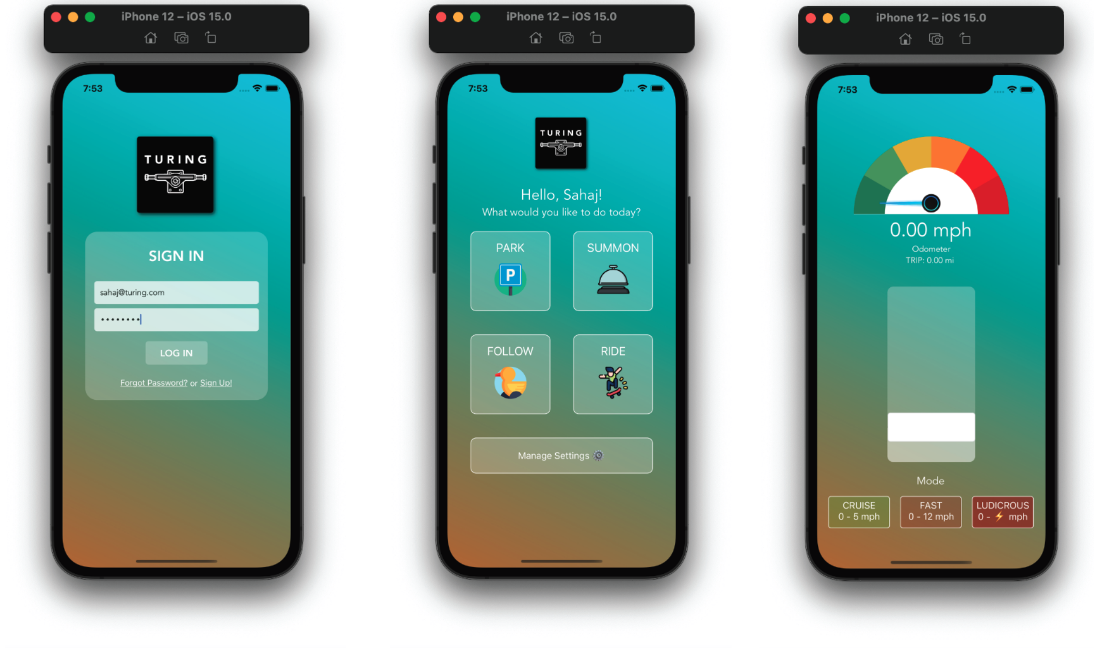
On the software side, the items include native Android and iOS apps to interface with the Turing Board.

2.2 External Inputs & Outputs

GPS information is a critical entity that will be involved in both external input and output scenarios. We will need the account for the GPS information of both the user and the board. The user authentication is handled by the Google Firebase Authentication API paired with the Google Firebase Cloud Firestore API acting as a cloud database.

2.3 Product Interfaces

Here are some of the screenshots of what the application interface will look like for the end-user.



Login Screen UI   Dashboard Screen UI   Throttle Screen UI

Figure 1: User Interface Screenshots

3 Customer Requirements

Specific requirements for the Turing Board were established with the enjoyment and convenience of the user in mind. In order to have an electronic longboard with autonomous capabilities the majority of the customer requirements are based on functionality. Users will be able to propel the board forward and backward using a mobile application to adjust the speed of electric motors embedded into the trucks. For safety, all autonomous features will be disabled while a rider is on the board. To determine if a rider is present a weight sensor will be included on the Turing Board. While in autonomous mode the user can expect the board to know and remember its location using GPS. While within a limited range the user will be able to summon the board to their location. The user will also be able to enable a follow mode that will keep the board within close proximity while the user is mobile. Both summon and follow features will need computer vision and path finding algorithms to detect and avoid any object.The board must also be able to turn without the assistance of a riders weight compressing the bushings within the trucks. To accomplish this the longboard will have a 14mm turning mechanism sit between the front trucks and the board, allowing forty-five degree rotation in either direction. The following customer requirements were developed to ensure the user's experience matches their expectation's of an autonomous longboard.

3.1 Forward Propulsion System

3.1.1 Description

Two six-hundred watt brush less DC motor's are embedded into the rear truck and will be powered through the on board battery. Utilizing an electronic speed controller the motors will be driven to a specific RPM that corresponds to the users desired speed.

3.1.2 Source

This requirement comes from the user and is the key component in making this an electronic longboard.

3.1.3 Constraints

The forward propulsion system must use a control loop that takes environmental factors into account and adjusts the torque to accommodate any change in variables. Within reason the user should expect to go the same speed regardless of body weight or slight changes to terrain.

3.1.4 Standards

Conforms to the Texas state motor-assisted scooter laws.

3.1.5 Priority

Critical

3.2 Turning mechanism

3.2.1 Description

The Turing board has a turning mechanism that will be utilized during autonomous mode. Normally, to turn a normal long-board, the user must lean toward the side they want to turn towards. To mitigate and simplify the turning mechanism for the Turing board during autonomous mode, we decided to have a rotating front truck, controlled by a stepper motor and a gear box. The turning mechanism has an inclusive rotation range of -45 to 45 degrees, with 0 degrees being the universal normal front truck position. When the Turing board is in user mode, the turning mechanism rotated back and is locked at 0 degrees, using solenoids, and the user is in charge of turning the board by leaning toward the desired side, like on normal long-boards.

3.2.2 Source

Specifics and mechanics of the turning mechanism were specified by team members.
Gear box 3D printed by team member Keaton Koehler.
Stepper motor ordered online.

3.2.3 Constraints

The turning mechanism has a turning range of 90 degrees. With 0 degrees being the origin, the range of this mechanism will be 45 degrees in either directions.

3.2.4 Standards

An inclusive turning range of -45 to 45 degrees

3.2.5 Priority

Critical

3.3 Weight sensor

3.3.1 Description

The Weight sensor's main role is to determine if a user, a small load or nothing is on top of the Turing board. With the provided information from the sensor, the appropriate mode will be set. If a user is on the Turing board, then the autonomous mode will be disengaged. This means the turning mechanism will be rotated and locked at 0 degrees. In any other case, a small load or nothing on the Turing board, then the autonomous mode can be engaged if it is needed.

3.3.2 Source

The role and mechanics of the weight sensor were specified by the team.
The sensor will be ordered online.

3.3.3 Constraints

For small loads, we will have a maximum weight to never exceed. If exceeded, the Turing board will consider it as a person and the autonomous mode will be disengaged.
For user weight sensing, we will set a minimum weight to always exceed in order for the autonomous mode to be disengaged.

3.3.4 Standards

0 kg to Turing board's weight - considered "no load"
Turing board's weight to 23 kg (50lbs) - considered "a small load"
23 kg (50lbs) upwards - considered "a person"

3.3.5 Priority

Critical

3.4 GPS

3.4.1 Description

As part of the autonomous navigation system, the GPS would provide coordinate data which would allow the program to know the position of the longboard which would be used to draw vectors to aid with navigation to a target coordinate.

3.4.2 Source

The GPS built into the phone will be used to get the current location of the longboard.

3.4.3 Constraints

The GPS coordinates provided by the phone should be precise without jumping from one value to another too much.

3.4.4 Standards

Conforms to the standard Global Positioning System.

3.4.5 Priority

High

3.5 Remote

3.5.1 Description

Instead of having a separate remote, a free-to-download app will be made available which can be used to summon the board, enable the follow-me feature, and control the speed of the wheels. The app currently uses React as the framework of choice for the front-end and is hosted publicly on Netlify. It uses sockets for communication, but a better approach we found is Bluetooth which would make the process of data transfer very simple and easy. The app will soon be changed to using React Native to support both Android and iOS. The reason for this is to ensure full compatibility without having to worry about browser versions.

3.5.2 Source

Native Android and iOS application making use of Bluetooth to communicate with the longboard.

3.5.3 Constraints

Since the rider of the longboard will be going quite fast, the transmission of data needs to be reduced as much as possible. Latency should be minimized.

3.5.4 Standards

Bluetooth 4.0/5.0 for maximum compatibility.

3.5.5 Priority

High

3.6 Computer Vision

3.6.1 Description

The Turing Board utilizes an Intel RealSense Depth Camera D435. It has two that will be used for detecting objects to avoid and detecting a specific maker in its view to command the board to follow (see "Other" section for more information on this feature). The object detection is handled by Single Shot Detectors (SSDs). An SSD-MobileNet V2 model on a 91 class COCO dataset will be deployed.

3.6.2 Source

Sahaj Amatya Sarker Nadir Afridi Azmi

3.6.3 Constraints

The pre-built library for the computer vision only works on x86 architecture. Since our controller, the NVIDIA Jetson TX 2, was built to work with Intel ARM architecture a kernel has been built to allow communication between the two. Also, due to the nature of what the computer vision of the Turing Board will do, the Jetson TX 2 will need to use it's CUDA cores to process the input appropriately. For this reason, a kernel was also built for OpenCV.

3.6.4 Standards

N/A

3.6.5 Priority

High

3.7 Path finding

3.7.1 Description

The Turing Board will utilize a greedy best first search for its path finding algorithm. The board generates a trapezoidal trajectory map in front of it with progressive width equal to its own width plus some padding width. If an object is detected with the trajectory, the path finding algorithm will seek a path to avoid the object.

3.7.2 Source

Sahaj Amatya & Sarker Nadir Afridi Azmi

3.7.3 Constraints

The camera used on the board is able to only see up to 20ft ahead. This will need to be taken into consideration with considering how to best avoid an object.

3.7.4 Standards

N/A

3.7.5 Priority

High

4 Packaging Requirements

The product will be shipped pre-assembled which would include the turning mechanism, camera, and Jetson already screwed onto a standard longboard. The only thing not plugged in would be the batteries which the user has to connect themselves. The firmware for the product will come pre-installed where the user would only be required to pair the device with the mobile app to make use of it. An ankle bracelet with ArUco Tags for the follow me feature and a power supply for charging the batteries would also be included as part of the purchase.

4.1 Requirement Name

4.1.1 Description

Due to the nature of the product, the main point of failure is the turning mechanism which needs to be protected using bubble wrap with zip ties holding it in place to prevent it from shaking during shipping. Anything electrical which might not be inside of an enclosure will be contained inside of ant-static bags to prevent static from killing the parts. The Ankle bracelet will be packaged separately in a hard casing to prevent it from bending or being compressed during shipping. The batteries would come packaged inside of an insulated bag alongside the power supply. All the components would be placed inside of the delivery box which would have dedicated sections for each part.

4.1.2 Source

These are some of the locations from which the parts are being sourced:

1. Adafruit
2. Amazon
3. eBay

4.1.3 Constraints

One of the major constraints is to make sure that the board does not move around too much whilst shipping as it contains sensitive components which might get chipped off in a scenario where a screw comes loose, and the PCB hits the inside of the casing. Also, the shipping environment should have a fairly constant temperature as electrical components are heavily affected by temperature which might cause the parts to degrade. The latter scenario is an extreme case.

4.1.4 Standards

The shipment should be handled with care and not thrown around which moving from one shipment container to another.

4.1.5 Priority

High

4.2 Dampeners

4.2.1 Description

Excessive vibrations within the electronic housing can cause destructive resonance and render the board non-functional. In order to absorb these vibrations foam dampeners will be installed around all essential parts of the internal components.

4.2.2 Source

This requirement comes from the hardware engineers responsible for designing the internal components.

4.2.3 Constraints

Foam that is rigid enough to absorb vibrations caused by fast movement over uneven terrain but will not compress enough to cause damage to the internals.

4.2.4 Standards

No standards will be used.

4.2.5 Priority

High

5 Performance Requirements

This section highlights an overview of the Turing board's performance. More precisely, this section will explore task requirements. Further along in this section, each task requirement will be examined in details: its constraints, standards and priority.

The Turing board should be able to follow a target user and it should be able to be summoned from a parking location. The board should be able to use computer vision, the turning mechanism and the propulsion mechanism to navigate. The board should also be able to function as a normal electric long-board when a user is on it.

5.1 Battery

5.1.1 Description

A 2500 KW hour, 24 V battery will provide power to the entire system. For the preliminary design, the voltage will be stepped down using a Buck Converter providing 19V to the Jetson TX2. There will be an open 5V and 3.3V terminal if there is a need to connect external power to sensors and microcontrollers.

5.1.2 Source

Specified by the team member (Sarker Nadir Afridi Azmi)

5.1.3 Constraints

The power used by the entire system should be minimized to ensure the the longboard can operate for at least an hour with a rider before it needs to be charged.

5.1.4 Standards

2500 KWh

5.1.5 Priority

High

6 Safety Requirements

Include a header paragraph specific to your product here. Safety requirements might address items specific to your product such as: no exposure to toxic chemicals; lack of sharp edges that could harm a user; no breakable glass in the enclosure; no direct eye exposure to infrared/laser beams; packaging/grounding of electrical connections to avoid shock; etc.

6.1 Laboratory equipment lockout/tagout (LOTO) procedures

6.1.1 Description

Any fabrication equipment provided used in the development of the project shall be used in accordance with OSHA standard LOTO procedures. Locks and tags are installed on all equipment items that present use hazards, and ONLY the course instructor or designated teaching assistants may remove a lock. All locks will be immediately replaced once the equipment is no longer in use.

6.1.2 Source

CSE Senior Design laboratory policy

6.1.3 Constraints

Equipment usage, due to lock removal policies, will be limited to availability of the course instructor and designed teaching assistants.

6.1.4 Standards

Occupational Safety and Health Standards 1910.147 - The control of hazardous energy (lockout/tagout).

6.1.5 Priority

Critical

6.2 National Electric Code (NEC) wiring compliance

6.2.1 Description

Any electrical wiring must be completed in compliance with all requirements specified in the National Electric Code. This includes wire runs, insulation, grounding, enclosures, over-current protection, and all other specifications.

6.2.2 Source

CSE Senior Design laboratory policy

6.2.3 Constraints

High voltage power sources, as defined in NFPA 70, will be avoided as much as possible in order to minimize potential hazards.

6.2.4 Standards

NFPA 70

6.2.5 Priority

Critical

6.3 RIA robotic manipulator safety standards

6.3.1 Description

Robotic manipulators, if used, will either housed in a compliant lockout cell with all required safety interlocks, or certified as a "collaborative" unit from the manufacturer.

6.3.2 Source

CSE Senior Design laboratory policy

6.3.3 Constraints

Collaborative robotic manipulators will be preferred over non-collaborative units in order to minimize potential hazards. Sourcing and use of any required safety interlock mechanisms will be the responsibility of the engineering team.

6.3.4 Standards

ANSI/RIA R15.06-2012 American National Standard for Industrial Robots and Robot Systems, RIA TR15.606-2016 Collaborative Robots

6.3.5 Priority

Critical

6.4 Weather Proof Casing

6.4.1 Description

A water proof case is needed to protect the sensitive electronic components of the Turing board from environmental conditions. In addition to keeping out moisture the case will act as a barrier from any debree that could cause damage while the board is at high speeds.

6.4.2 Source

This requirement is from the hardware engineers.

6.4.3 Constraints

The profile of the container must be slim enough to not touch the ground while the board is turning. The case must be strong enough to withstand limited physical stress. A rubber gasket or seal is necessary to prevent liquid from touching the sensitive equipment.

6.4.4 Standards

No standards were used.

6.4.5 Priority

High

6.5 Alarm or Buzzer for Improper Use

6.5.1 Description

The Turing Board's autonomous capabilities are not intended for use with a rider on the long board. A weight sensor will trigger a buzzer to sound if the user attempts to ride while under autonomous operations or if a change in weight is detected while the turning mechanism is engaged.

6.5.2 Source

This requirement is from both the hardware and software engineers.

6.5.3 Constraints

The buzzer will need to be loud enough to catch the attention of the user despite environmental distractions.

6.5.4 Standards

No standards were used.

6.5.5 Priority

Low

6.6 Board response in accidents

6.6.1 Description

The Turing board's response in an accident is necessary. In the regretful case a user should fall off the board, the board must take the appropriate measures to make the user's life easier. There are two main response expected if a user falls off the board. If the user falls of the board and the Turing board is still in the user's vicinity, then the moment the sensor reading changes from "user weight" to "no weight", the Turing board stops. This same mechanism applies in the case the user falls off and lands far away from the user. The board should autonomously find its way back to the user.

6.6.2 Source

These responses were specified by the group.

6.6.3 Constraints

The board must have a reliable weight sensor that will always return the right weight. A faulty reading could cause an accident itself by suddenly stopping the board.

6.6.4 Standards

If the Turing board is within 3 meters of the user after the user falls off, the board will automatically stop.
If the Turing board is outside of a 3 meters parameter of the user after an accident, the board must autonomously roll back to its user.

6.6.5 Priority

Low

6.7 Kill switch

6.7.1 Description

The role of the Kill switch is to disengage autonomous mode. With the help of the weight sensor, it will be determined if a user, a small load or nothing is on top of the board. When a user is on the Turing board, we must prioritize their safety. The way we will do this is by disengaging autonomous mode and making sure the turning mechanism is locked at 0 degrees. This will make sure the Turing board can be operated as a normal electric long-board and prevent any accidents that could be caused by a misaligned front truck.

6.7.2 Source

The role and mechanics of the kill switch were specified by the team.

6.7.3 Constraints

When a set weight is exceeded, meaning a user is on the board, autonomous mode will be disengaged and the turning mechanism will be rotated and locked at 0 degrees for the user's safety.

6.7.4 STANDARDS

If a weight greater than 23 kg (50 lbs) is detected, the "kill switch" will be triggered. It will disengage autonomous mode, rotate the trucks back to 0 degrees and the trucks will be locked at that position using solenoids.

6.7.5 PRIORITY

Critical

7 Maintenance & Support Requirements

The Turing Board is ultimately meant to be a full product sent to a customer ready to ride basically out of the box. For this reason, the majority of the maintenance and support items are abstracted from the user's view. We will provide a user manual to the user, but other than that it would largely be up to the supporting team to resolve any technical issue with the board. For the app, we are hosting our login admin portal on Google's Firebase Authentication.

7.1 Firebase Authentication Admin Portal

7.1.1 Description

The Turing Board's authentication is hosted through Google's Firebase. It currently uses the free Spark Plan. Through this portal, an admin would have the ability to manage users, reset passwords, and monitor authentication usage.

7.1.2 Source

Sahaj Amatya & firebase.google.com/pricing

7.1.3 Constraints

The Spark Free plan for Firebase only allows for 10,000 authentications per month.

7.1.4 Standards

N/A

7.1.5 Priority

Moderate

8 Other Requirements

Include a header paragraph specific to your product here. In this section specify anything else that is required for the product to be deemed complete. Include requirements related to customer setup and configuration if not specified in a previous requirement. Add any known requirements related to product architecture/design, such as modularity, extensibility (for future enhancements), or adaptation for a specific programming language. Consider requirements such as portability of your source code to various platforms (Windows, Linux, Unix Mac OS, etc.).

8.1 Requirement Name

8.1.1 Description

Detailed requirement description...

8.1.2 Source

Source

8.1.3 Constraints

Detailed description of applicable constraints...

8.1.4 Standards

List of applicable standards

8.1.5 Priority

Priority

9 Future Items

In this last section, you will reiterate all requirements that are listed as priority 5. This is repetitive, but necessary as a concise statement of features/functions that were considered/discussed and documented herein, but will NOT be addressed in the prototype version of the product due to constraints of budget, time, skills, technology, feasibility analysis, etc. Use the following format for this section.

9.1 Requirement Name

9.1.1 Description

Detailed requirement description...

9.1.2 Source

Source

9.1.3 Constraints

Detailed description of applicable constraints...

9.1.4 Standards

List of applicable standards

9.1.5 Priority

Priority

References