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

Architectural Design Specifications
CSE 4316: Senior Design I
Fall 2021

Runtime Terrors
Turing Board

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Revision History

Revision	Date	Author(s)	Description
0.1	11.15.2021	SA	document creation

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1 Introduction

The Turing Board is a concept autonomous longboard which 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 and having the board summon itself to you from a parked location, in addition to functioning as a standard electric longboard capable of recording and analyzing all trip data. Users will also be able to use the Turing Board to function as a load carrier, relieving them from the burden of carrying everyday items like backpacks, boxes, etc. if desired. The main components of the Turing Board include a remote control via an app on the user's phone, the Jetson TX2 controlling the software signals and output to other components of the board, the motorized wheels and turning mechanism, computer vision, human-machine interface, and the board's power supply.

2 System Overview

The Turing Board consists of six architectural layers.

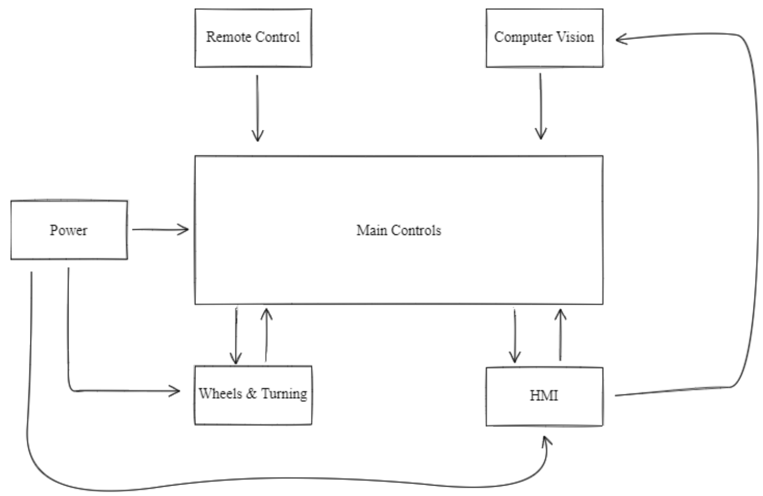

Figure 1: A simple architectural layer diagram of the Turing Board

2.1 Computer Vision Layer

This layer is the heart of the core autonomous functionalities of the Turing Board. We use computer vision and depth imagery to determine the board's surroundings and calculate the best path to move forward. The user will have, strapped around their ankle, an anklet-like contraption consisting of a pattern of ArUco markers for the *Follow Along* feature. This layer tracks the movement of the user through the anklet to determine how to instruct the combination of motors to move so as to follow the user at an appropriate pace. It is also responsible for detecting possible obstacles when operating on its own to find the user as part of the *Summon* feature. Data taken in from the cameras will flow from this layer into the Main Control Layer for the Main Control Layer to process to send out the appropriate signals to mainly the Wheels & Turning Layer. This layer also takes in data from the anklet component in the HMI layer specifically for the Follow feature.

2.2 Remote Control Layer

This layer is controlled directly by the user. It takes the form of an app that sends data to the Main Control layer for the appropriate signals to be sent to the other layers. The app requires an authentication process to log into it. It will also provide the user with ride data analysis after a trip on the board is completed. This app is available on iOS and Android.

2.3 Power Layer

This layer is responsible for controlling the power distributed to the electrical components on the Turing Board. It directly powers portions of both the HMI layer and the Wheels & Turning layer. This layer ensures power is not over-distributed by way of a Buck converter. It also provides data on how much charge is left in the battery at any given time. This data is sent to the Main Controls layer for the appropriate signals to be sent out to the other layers as needed.

Each layer should be described separately in detail. Descriptions should include the features, functions, critical interfaces and interactions of the layer. The description should clearly define the services that the layer provides. Also include any conventions that your team will use in describing the structure: naming conventions for layers, subsystems, modules, and data flows; interface specifications; how layers and subsystems are defined; etc.

2.4 Main Controls Layer

This layer is in charge of processing and sending out the majority of the signals on the Turning Board. It receives data from the Computer Vision layer, the Remote Control Layer, and the Power layer. With these inputs, it sends data to the HMI layer as well as the Wheels & Turning layer. The Jestson TX2 is the computing power in this layer and will process all of these needs. It will also fetch data from a real-time database and directly interact with a separate micro-controller that is in charge of a few other systems on the Turing Board.

2.5 HMI Layer

This layer contains all of the hardware parts of the Turing Board that interacts directly with the user. This layer includes LEDs, a pressure sensor, a buzzer/speaker, and an anklet. The LEDs let the user know what mode the board is in (Summon, Follow, or Electric) based off of the color they are emitting at the time. The pressure sensor determines how much weight is currently on the board and transmits this information to the Main Controls layer to control what mode the board is in. The buzzer or speaker will make a sound if the user steps onto the board when it is not in Electric mode to notify them of improper usage. Finally, the anklet is to be worn by the user to give data to the Computer Vision layer when the board is in Follow mode.

2.6 Wheels & Turning Layer

This layer contains the components needed to cause the board to move and turn. It contains the ESC, brushless motors, stepper motors, optical sensors for the stepper motors, solenoids, optical sensors for the solenoids, the micro-controller, and the turning mechanism. The ESC will control the speed at which the brushless motors inside of the wheels turn at as determined by signals sent from the Main Controls layer. The stepper motor will turn the turning mechanism a certain amount of degrees no exceeding 30 as determined by the Main Controls layer. The optical sensor for the stepper motor will track how many degrees the turning mechanism has been turned and send this data to the Main Controls layer. The solenoids will be responsible for locking the turning mechanism in place when it is in Electric mode. The optical sensors for the solenoids will determine if the solenoids are properly locked in place or not and transmit this data to the Main Controls layer. The micro-controller will receive data from the Main Controls layer and use that to output the necessary signals to the motors.

3 Subsystem Definitions & Data Flow

This section breaks down your layer abstraction to another level of detail. Here you grapically represent the logical subsytems that compose each layer and show the interactions/interfaces between those subsystems. A subsystem can be thought of as a programming unit that implements one of the major functions of the layer. It, therefore, has data elements that serve as source/sinks for other subsystems. The logical data elements that flow between subsystems need to be explicitly defined at this point, beginning with a data flow-like diagram based on the block diagram.

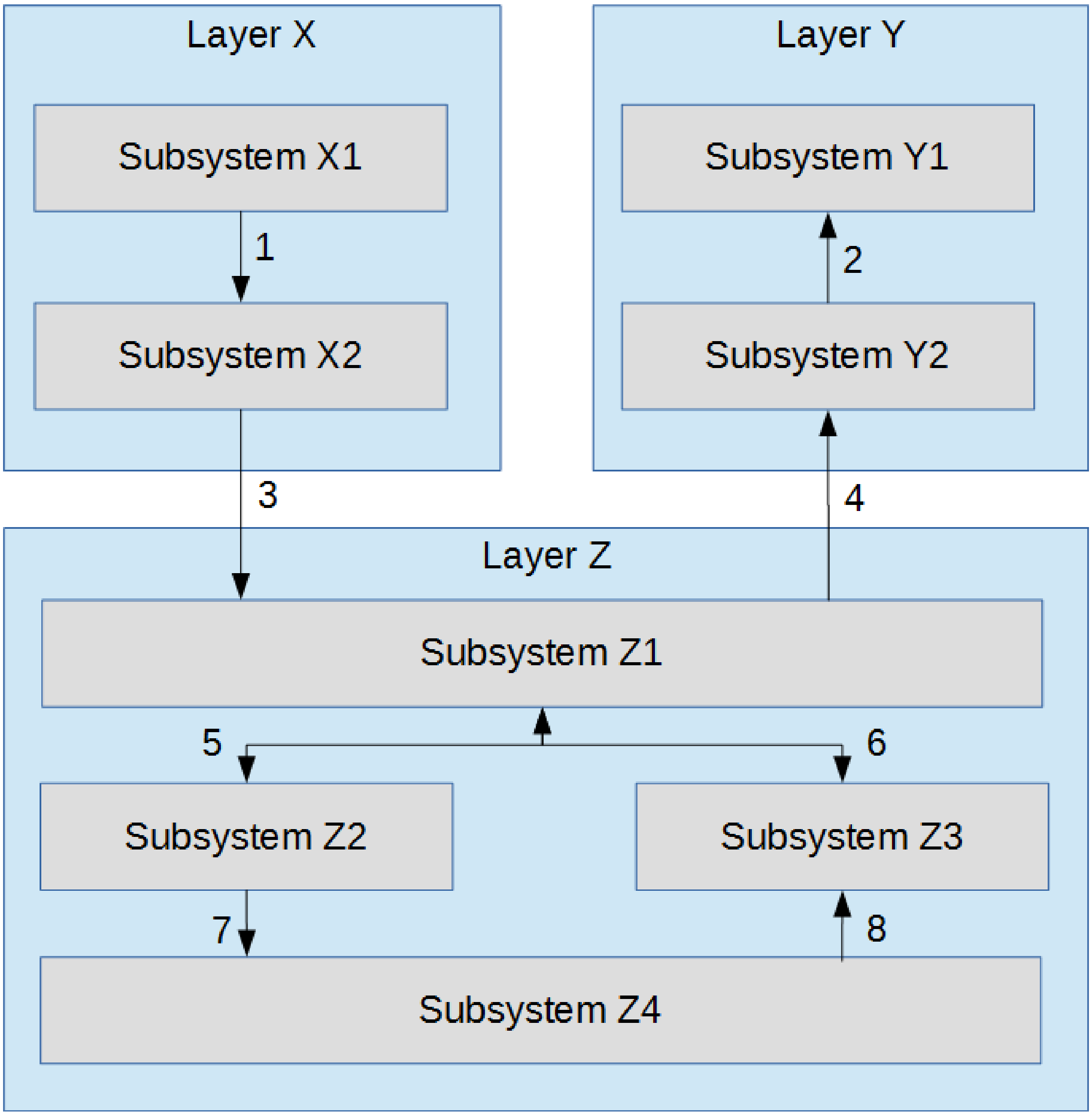

Figure 2: A simple data flow diagram

4 Remote Control Layer Subsystems

In this section, the layer is described in some detail in terms of its specific subsystems. Describe each of the layers and its subsystems in a separate chapter/major subsection of this document. The content of each subsystem description should be similar. Include in this section any special considerations and/or trade-offs considered for the approach you have chosen.

4.1 Subsystem 1

This section should be a general description of a particular subsystem for the given layer. For most subsystems, an extract of the architectural block diagram with data flows is useful. This should consist of the subsystem being described and those subsystems with which it communicates.

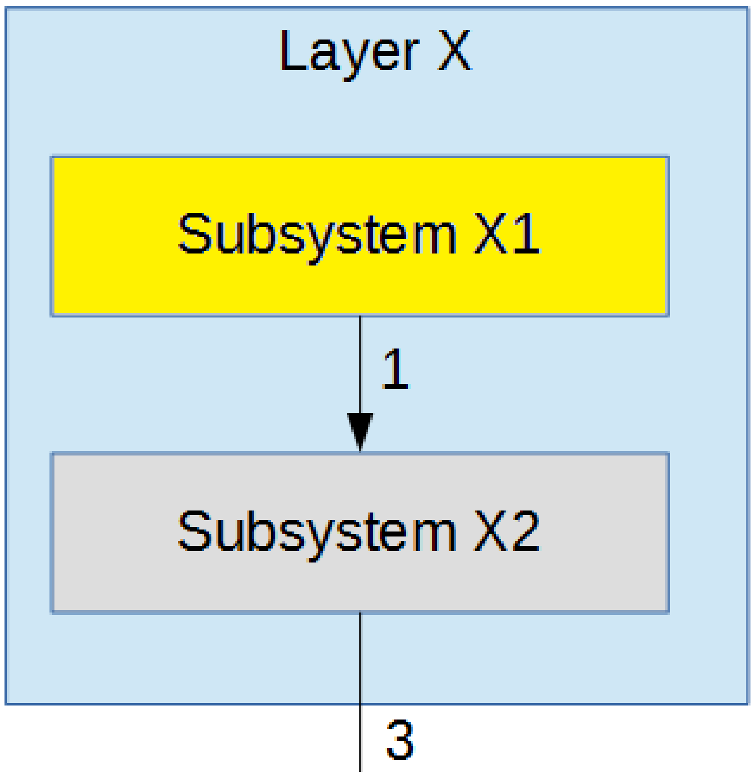

Figure 3: Example subsystem description diagram

4.1.1 Assumptions

Any assumptions made in the definition of the subsystem should be listed and described. Pay particular attention to assumptions concerning interfaces and interactions with other layers.

4.1.2 Responsibilities

Each of the responsibilities/features/functions/services of the subsystem as identified in the architectural summary must be expanded to more detailed responsibilities. These responsibilities form the basis for the identification of the finer-grained responsibilities of the layer's internal subsystems. Clearly describe what each subsystem does.

4.1.3 Subsystem Interfaces

Each of the inputs and outputs for the subsystem are defined here. Create a table with an entry for each labelled interface that connects to this subsystem. For each entry, describe any incoming and outgoing

data elements will pass through this interface.

Table 2: Subsystem interfaces

ID	Description	Inputs	Outputs
#xx	Description of the interface/bus	input 1 input 2	output 1
#xx	Description of the interface/bus	N/A	output 1

4.2 Subsystem 2

Repeat for each subsystem

4.3 Subsystem 3

Repeat for each subsystem

5 Main Controls Layer Subsystems

In this section, the layer is described in some detail in terms of its specific subsystems. Describe each of the layers and its subsystems in a separate chapter/major subsection of this document. The content of each subsystem description should be similar. Include in this section any special considerations and/or trade-offs considered for the approach you have chosen.

5.1 Subsystem 1

This section should be a general description of a particular subsystem for the given layer. For most subsystems, an extract of the architectural block diagram with data flows is useful. This should consist of the subsystem being described and those subsystems with which it communicates.

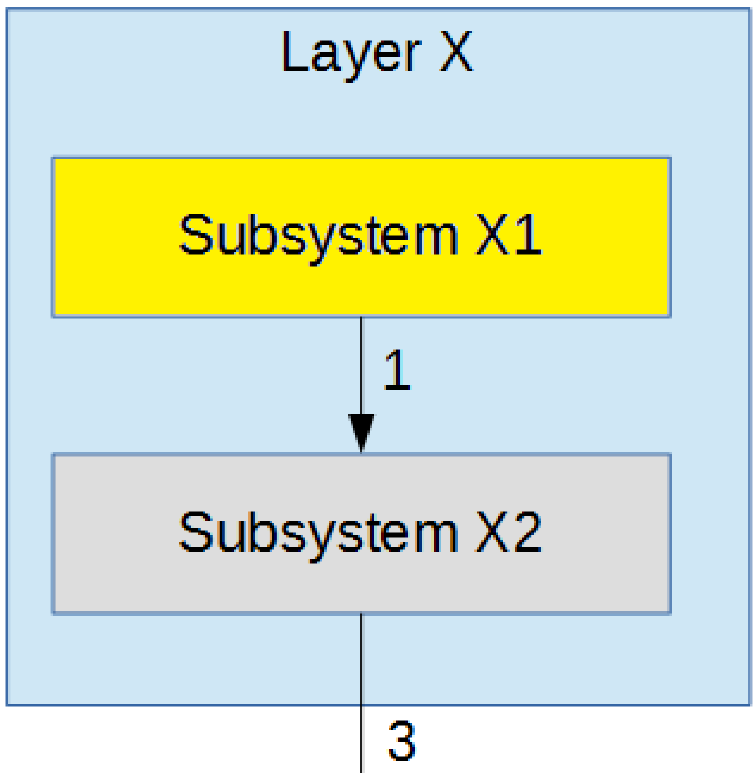

Figure 4: Example subsystem description diagram

5.1.1 Assumptions

Any assumptions made in the definition of the subsystem should be listed and described. Pay particular attention to assumptions concerning interfaces and interactions with other layers.

5.1.2 Responsibilities

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#xx	Description of the interface/bus	N/A	output 1

5.2 Subsystem 2

Repeat for each subsystem

5.3 Subsystem 3

Repeat for each subsystem

6 Wheels & Turning Layer Subsystems

In this section, the layer is described in some detail in terms of its specific subsystems. Describe each of the layers and its subsystems in a separate chapter/major subsection of this document. The content of each subsystem description should be similar. Include in this section any special considerations and/or trade-offs considered for the approach you have chosen.

6.1 Subsystem 1

This section should be a general description of a particular subsystem for the given layer. For most subsystems, an extract of the architectural block diagram with data flows is useful. This should consist of the subsystem being described and those subsystems with which it communicates.

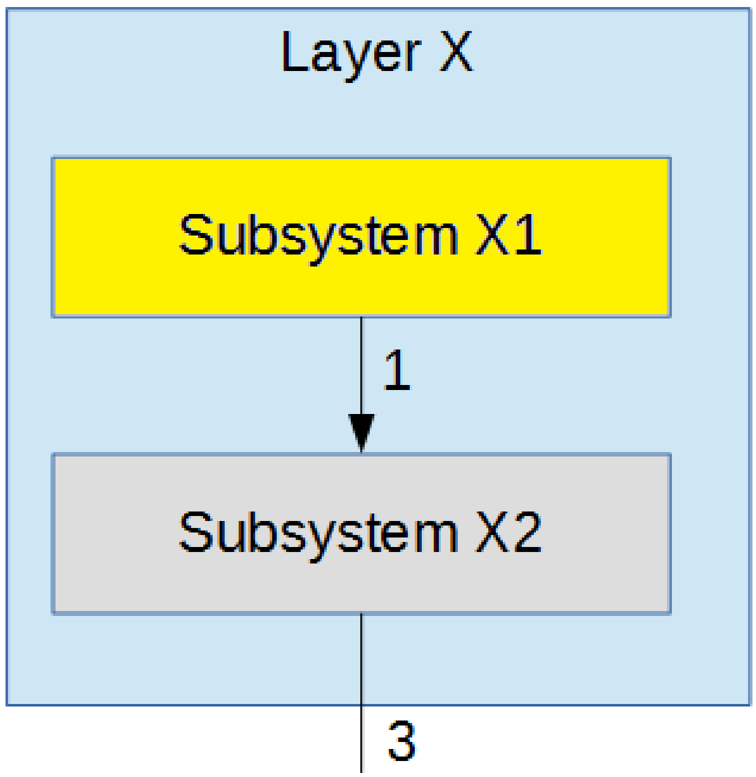

Figure 5: Example subsystem description diagram

6.1.1 Assumptions

Any assumptions made in the definition of the subsystem should be listed and described. Pay particular attention to assumptions concerning interfaces and interactions with other layers.

6.1.2 Responsibilities

Each of the responsibilities/features/functions/services of the subsystem as identified in the architectural summary must be expanded to more detailed responsibilities. These responsibilities form the basis for the identification of the finer-grained responsibilities of the layer's internal subsystems. Clearly describe what each subsystem does.

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Each of the inputs and outputs for the subsystem are defined here. Create a table with an entry for each labelled interface that connects to this subsystem. For each entry, describe any incoming and outgoing

data elements will pass through this interface.

Table 4: Subsystem interfaces

ID	Description	Inputs	Outputs
#xx	Description of the interface/bus	input 1 input 2	output 1
#xx	Description of the interface/bus	N/A	output 1

6.2 Subsystem 2

Repeat for each subsystem

6.3 Subsystem 3

Repeat for each subsystem

7 Computer Vision Layer Subsystems

This layer is the heart of the core autonomous functionalities of the Turing Board. We use computer vision and depth imagery to determine the board's surroundings and calculate the best path to move forward. The user will have, strapped around their ankle, an anklet-like contraption consisting of a pattern of ArUco markers for the *Follow Along* feature. This layer tracks the movement of the user through the anklet to determine how to instruct the combination of motors to move so as to follow the user at an appropriate pace. It is also responsible for detecting possible obstacles when operating on its own to find the user as part of the *Summon* feature.

7.1 RGB Imagery Subsystem

RGB Imagery of the front of the board is used as input in making various position specific calculations pertaining to navigation.

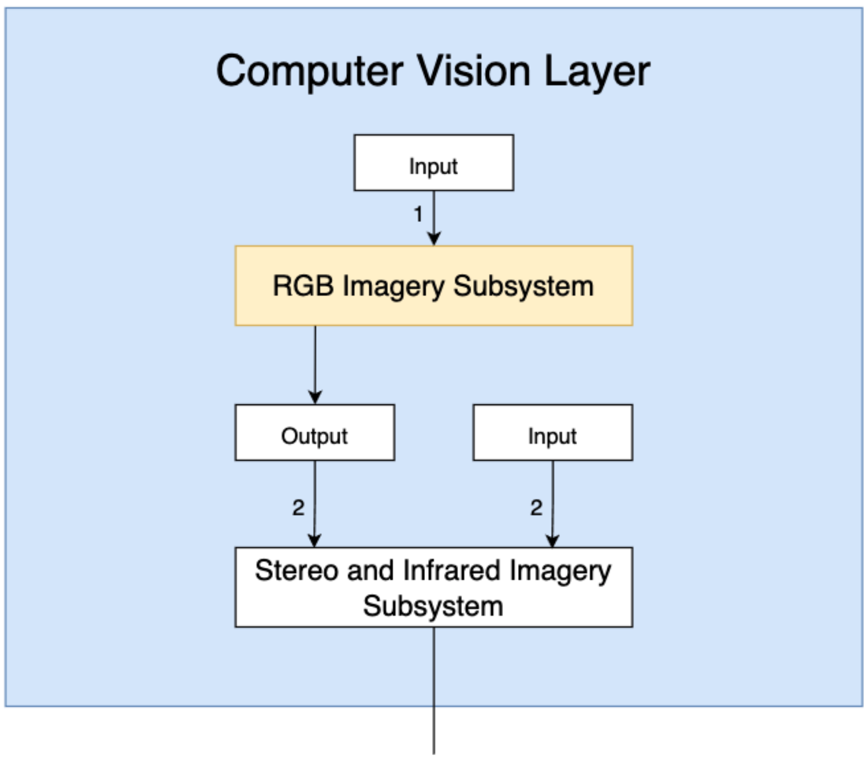

Figure 6: RGB Imagery subsystem description diagram

7.1.1 Assumptions

This layer is triggered by the user via the native iOS/Android application. It is assumed that the layer is being called upon in terrain with sufficient lighting conditions so that the RGB camera is able to produces images of good quality. For the *Follow Me* feature, it is assumed that the user has their anklet put on and proceeds to start with the anklet within the frame of the camera.

7.1.2 Responsibilities

RGB imagery is responsible for powering the *Follow Along* and the *Summon* features. For the *Follow Along* feature, this subsystem calculates the position of the user in 1D space along the horizontal axis to determine whether to turn left, right, or straight. For the *Summon* feature, this subsystem is responsible for helping identify patterns for possible obstacles ahead.

7.1.3 Subsystem Interfaces

Each of the inputs and outputs for the subsystem are defined here.

Table 5: RGB Imagery Interfaces

ID	Description	Inputs	Outputs
1	RGB Imagery	RGB Frame	Position of target object(s)

7.2 Stereo and Infrared Imagery Subsystem

Stereo and Infrared Imagery of the front of the board is used as input in making various depth specific calculations pertaining to navigation.

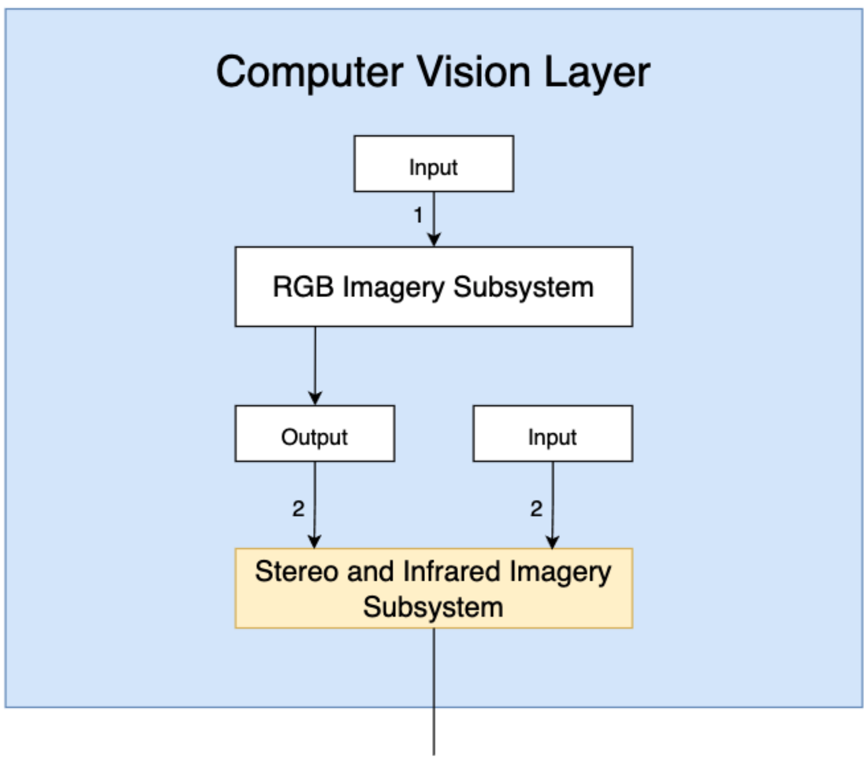

Figure 7: Stereo Imagery subsystem description diagram

7.2.1 Assumptions

This layer is triggered by the user via the native iOS/Android application. It is assumed that the layer is being called upon in terrain with sufficient lighting conditions so that the RGB Stereo cameras are able to produces images of good quality. For the *Follow Me* feature, it is assumed that the user has their anklet put on and proceeds to start with the anklet within the frame of the cameras.

7.2.2 Responsibilities

Stereo and Infrared imagery is responsible for powering the *Follow Along* and the *Summon* features. For the *Follow Along* feature, this subsystem calculates the position of the user in 1D space along the longitudinal axis to determine whether to move forward or stay put. For the *Summon* feature, this subsystem is responsible for helping identify how far objects detected by the RGB module are.

7.2.3 Subsystem Interfaces

Each of the inputs and outputs for the subsystem are defined here.

Table 6: Stereo and Infrared Imagery Interfaces

ID	Description	Inputs	Outputs
2	Depth Imagery	Depth Frame Position of target object(s)	Optimized distance of target object(s) from camera True position of target object(s) in 2D space

8 HMI Layer Subsystems

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8.1 Subsystem 1

This section should be a general description of a particular subsystem for the given layer. For most subsystems, an extract of the architectural block diagram with data flows is useful. This should consist of the subsystem being described and those subsystems with which it communicates.

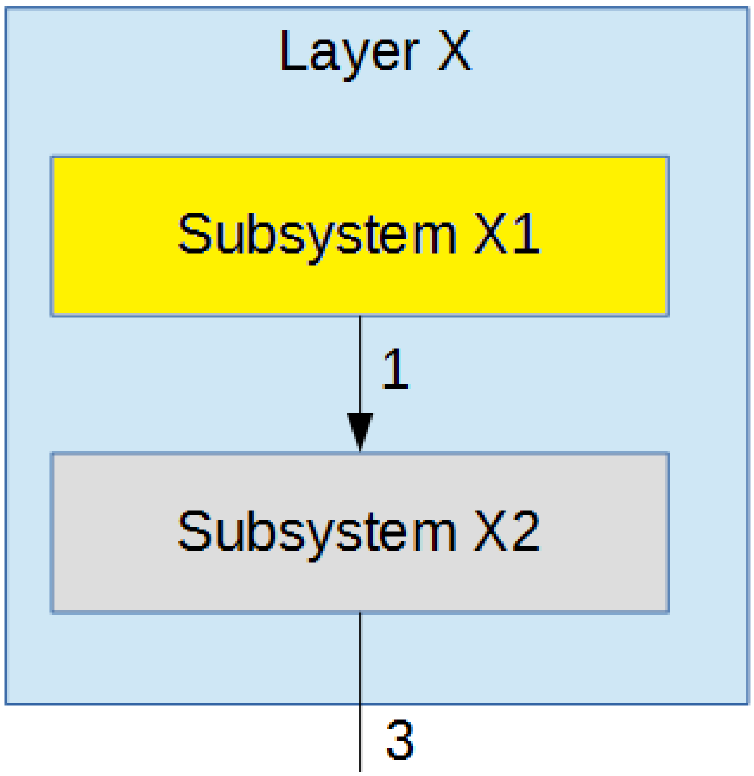

Figure 8: Example subsystem description diagram

8.1.1 Assumptions

Any assumptions made in the definition of the subsystem should be listed and described. Pay particular attention to assumptions concerning interfaces and interactions with other layers.

8.1.2 Responsibilities

Each of the responsibilities/features/functions/services of the subsystem as identified in the architectural summary must be expanded to more detailed responsibilities. These responsibilities form the basis for the identification of the finer-grained responsibilities of the layer's internal subsystems. Clearly describe what each subsystem does.

8.1.3 Subsystem Interfaces

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Table 7: Subsystem interfaces

ID	Description	Inputs	Outputs
#xx	Description of the interface/bus	input 1 input 2	output 1
#xx	Description of the interface/bus	N/A	output 1

8.2 Subsystem 2

Repeat for each subsystem

8.3 Subsystem 3

Repeat for each subsystem

9 Power Layer Subsystems

In this section, the layer is described in some detail in terms of its specific subsystems. Describe each of the layers and its subsystems in a separate chapter/major subsection of this document. The content of each subsystem description should be similar. Include in this section any special considerations and/or trade-offs considered for the approach you have chosen.

9.1 Subsystem 1

This section should be a general description of a particular subsystem for the given layer. For most subsystems, an extract of the architectural block diagram with data flows is useful. This should consist of the subsystem being described and those subsystems with which it communicates.

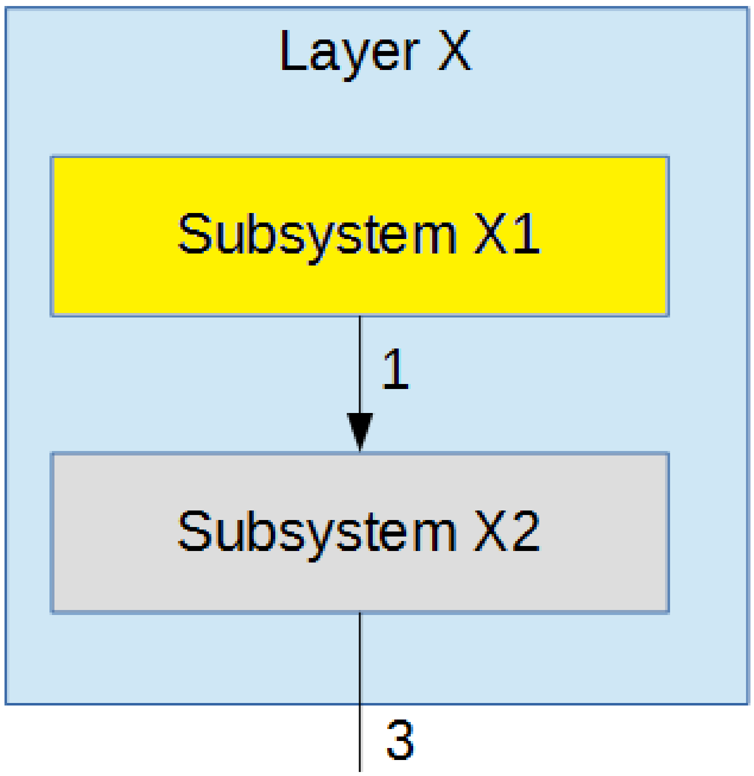

Figure 9: Example subsystem description diagram

9.1.1 Assumptions

Any assumptions made in the definition of the subsystem should be listed and described. Pay particular attention to assumptions concerning interfaces and interactions with other layers.

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Each of the responsibilities/features/functions/services of the subsystem as identified in the architectural summary must be expanded to more detailed responsibilities. These responsibilities form the basis for the identification of the finer-grained responsibilities of the layer's internal subsystems. Clearly describe what each subsystem does.

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Each of the inputs and outputs for the subsystem are defined here. Create a table with an entry for each labelled interface that connects to this subsystem. For each entry, describe any incoming and outgoing

data elements will pass through this interface.

Table 8: Subsystem interfaces

ID	Description	Inputs	Outputs
#xx	Description of the interface/bus	input 1 input 2	output 1
#xx	Description of the interface/bus	N/A	output 1

9.2 Subsystem 2

Repeat for each subsystem

9.3 Subsystem 3

Repeat for each subsystem

REFERENCES