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

Architectural Design Specification
CSE 4316: Senior Design I
Spring 2016

SMART CART
Autonomous Tool Cart

Team Hawt Wheels
Smart Cart

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Revision History

Revision	Date	Author(s)	Description
0.1	03.11.2016	DH, DO, PS, BW, OZ	Document creation
0.2	04.08.2016	DH, DO, PS, BW, OZ	Complete draft

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1 Introduction

1.1 Product Concept

The Smart Cart will provide assistance by being an autonomous carrier. The cart needs to be able to do the following things:

- Follow a ”master” to the designated destination
- Avoid collision with obstacles such as walls and other people
- Include an integrated power supply
- Holonomic mobility

1.2 Scope

The main function of the Smart Cart is to help its user carry tools from one point to another. It will also have an integrated power supply to allow its user to charge or power his or her tools. A unique feature of the Smart Cart is that the cart will identify and follow its "master" by using the Intel RealSense. Another unique feature of the cart is its holonomic wheels. This allows the cart to easily maneuver and avoid collisions with objects by using image processing from a camera. The Smart Cart will require external input from the user. The user must wear a colored band that is provided with the Smart Cart. This band is used by the cart for tracking its "master". External outputs produced by the cart will be messages to let its user know whether it has succesfully identified its master. There are no other external inputs or outputs. A simple user interface may be implemented for identification of master depending on the availability of time.

1.3 Key Requirements

The Smart Cart shall have four layers that work in unison to allow the cart to autonomously navigate and follow a specified user. The four layers in the system are the Smart Cart layer, Power Supply layer, Imaging and Navigation layer, and Crab Drive layer. The four layers will be discussed more in the following sections.

2 System Overview

This section should describe the overall structure of your software system. Think of it as the strategy for how you will build the system. An architectural "layer" is the top-level logical view, or an abstraction, of your design. Layers should be composed of related elements of similar capabilities, and should be highly independent of other layers, but should have very clearly defined interfaces and interactions with other layers. Each layer should be identified individually and should be unique as to its function and purpose within the system. This section should also contain the high-level block diagram of the layers, as shown in the example below, as well as detailed descriptions of the functions of each layer.

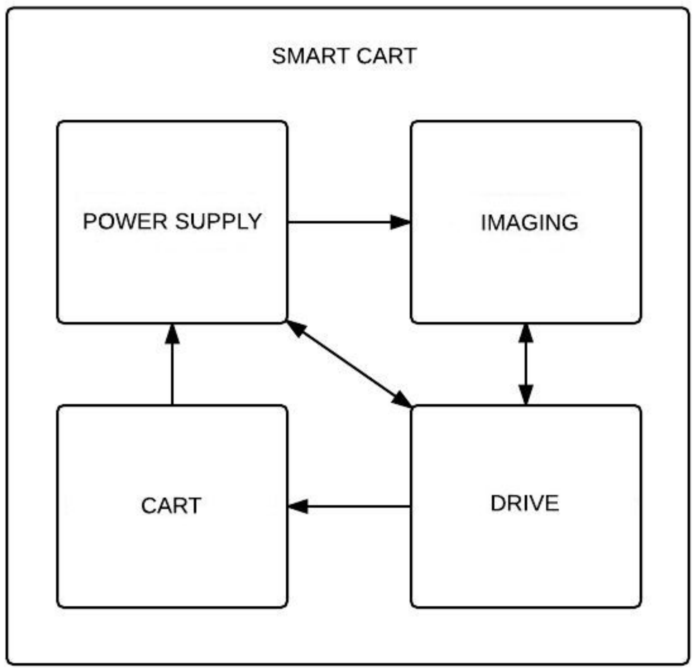

Figure 1: A simple architectural layer diagram

2.1 Power Supply Layer Description

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.

2.2 Cart Layer Description

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.

2.3 Crab Drive Layer Description

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 Imaging and Navigation Description

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.

3 Subsystem Definitions & Data Flow

This section breaks down the simple architectural layer diagram with another level of detail. The logical subsystems that compose each layer and its interactions and interfaces between the subsystems are graphically represented. Even though the power supply layer does not have data flow, it is still a key layer to the system. The following data flow block diagram shows a high level diagram of all the layers in the Smart Cart.

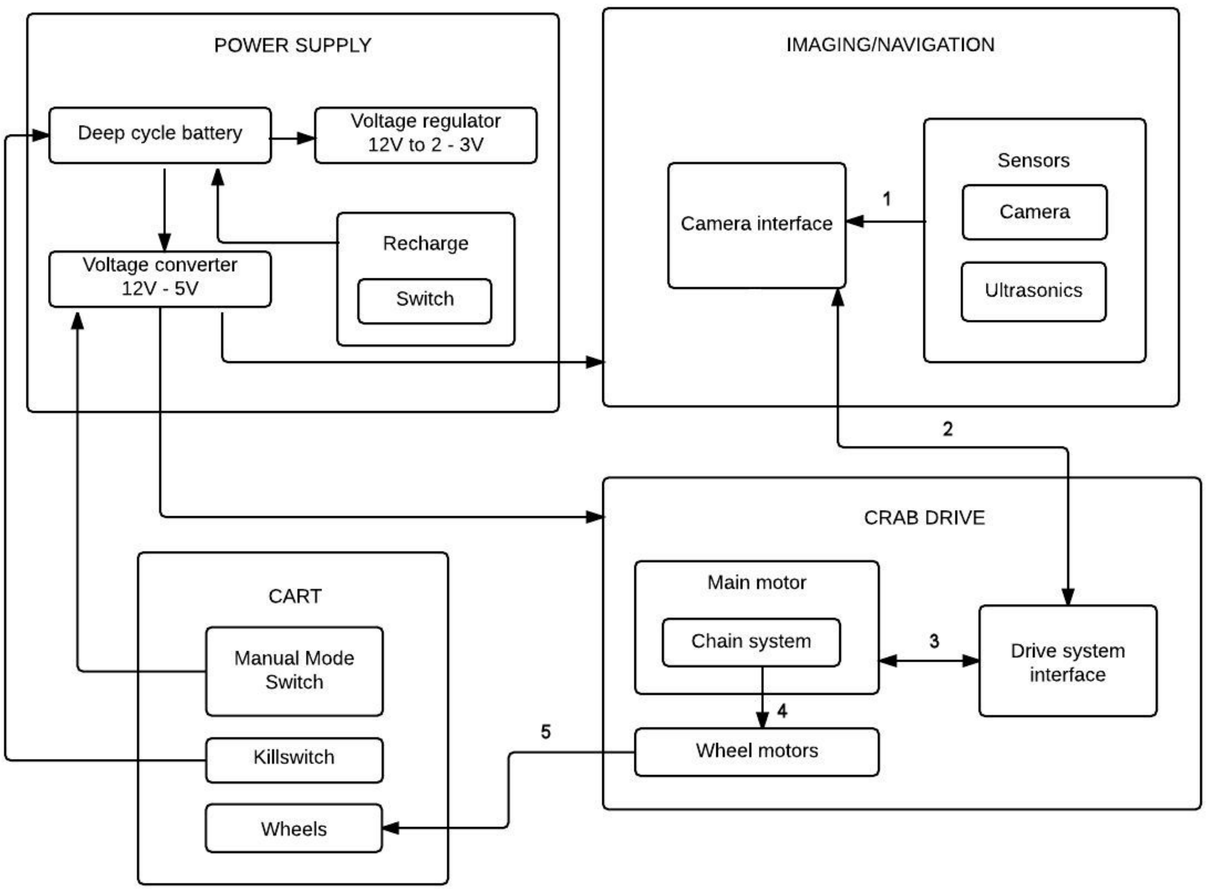

Figure 2: A simple data flow diagram

4 Power Supply Subsystems

The power supply layer is one if not the most important layer because it provides stable power supply to the cart. The parts in this subsystem are responsible for powering every other subsystem and any external tools or equiment.

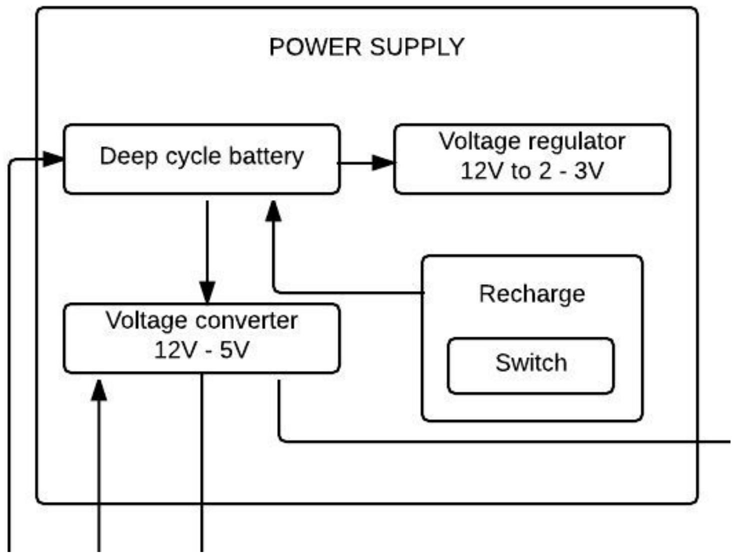

Figure 3: Power supply layer

4.1 Deep Cycle Battery

The deep cycle battery is designed to power everything. Once the cart's switch is turned on, the deep cycle battery will then begin to power the other subsystems on.

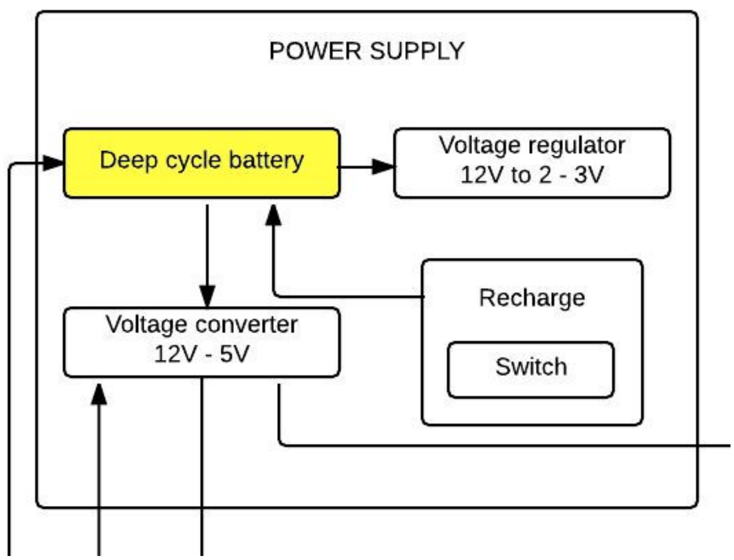

Figure 4: Deep cycle battery subsystem

4.1.1 Assumptions

Assumptions made are as follows:

- The battery is charged.
- The battery is properly connected to the cart.
- The battery is fully functional.
- The battery is connected to the cart at all times.
- The battery will be 12V.

4.1.2 Responsibilities

The deep cycle battery subsystem's responsibilities are as follows:

- Enable stable power to the other subsystems after being converted from 12V to 5V through the voltage converter.
- Enable stable power to external tools and equipment after being converted from 12V to 2 - 3V through the voltage regulator.

4.1.3 Subsystem Interfaces

Table 2: Deep cycle battery subsystem interfaces

ID	Description	Inputs	Outputs
N/A	Power integrated power supply	N/A	Voltage regulator
N/A	Power electronic components	N/A	Voltage converter
N/A	Safety killswitch	Killswitch	N/A
N/A	Safety manual mode	Manual-mode switch	N/A

4.2 Voltage Regulator

The voltage regulator is designed to convert the 12V voltage from the deep cycle battery to 2 - 3V and it will mainly be used to power up external tools and equipment.

4.2.1 Assumptions

Assumptions made are as follows:

- The voltage from the battery will be 12V.
- The voltage required for external tools and equipment will be between 2 - 3V.

4.2.2 Responsibilities

The voltage regulator subsystem's responsibilities are as follows:

- To enable and regulate constant voltage level for powering external tools and supplies.

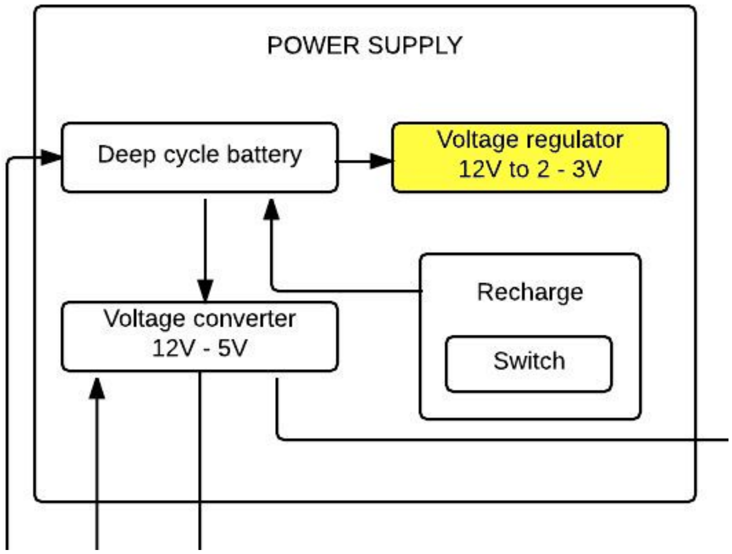

Figure 5: Voltage regulator subsystem

4.2.3 Subsystem Interfaces

Table 3: Voltage regulator subsystem interfaces

ID	Description	Inputs	Outputs
N/A	Receive power	Deep cycle battery	N/A

4.3 Voltage Converter

The voltage regulator is designed to convert the 12V voltage from the deep cycle battery to 2 - 3V and it will mainly be used to power up the Smart Cart's components.

4.3.1 Assumptions

Assumptions made are as follows:

- The voltage from the battery will be 12V.
- The voltage required for the cart's components will be 5V.

4.3.2 Responsibilities

The voltage converter subsystem's responsibilities are as follows:

- Enable stable power to the other subsystems, which include the crab drive system and image processing after being converted from 12V to 5V through the voltage converter.

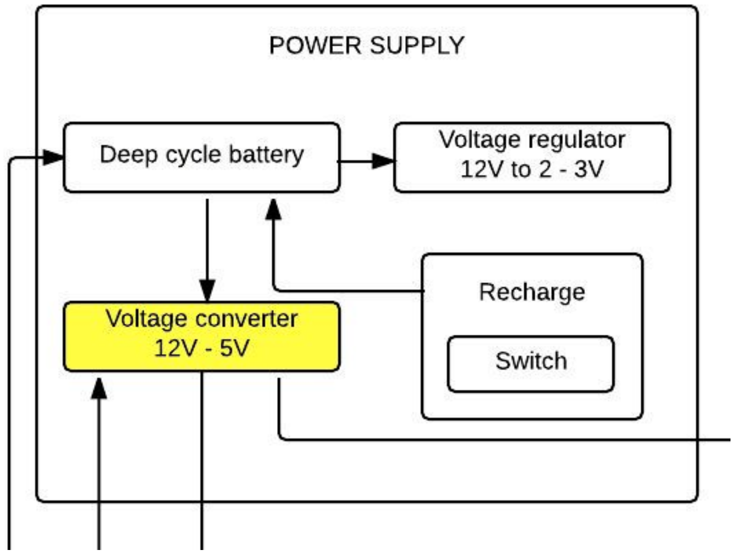

Figure 6: Voltage converter subsystem

4.3.3 Subsystem Interfaces

Table 4: Voltage converter subsystem interfaces

ID	Description	Inputs	Outputs
N/A	Receive power	Deep cycle battery	N/A
N/A	Safety manual mode	Manual-mode switch	Crab-drive system Imaging and navigation

4.4 Recharge

The recharge subsystem will be used to ensure that the Smart Cart will be charged without having too much electricity going to the electronics or the other battery and cause problems.

4.4.1 Assumptions

Assumptions made are as follows:

- The recharge subsystem will ensure the safety of the tools and equipment.

4.4.2 Responsibilities

The recharge subsystem's responsibilities are as follows:

- A switch will disable the battery from powering the Smart Cart components while it is being recharged.

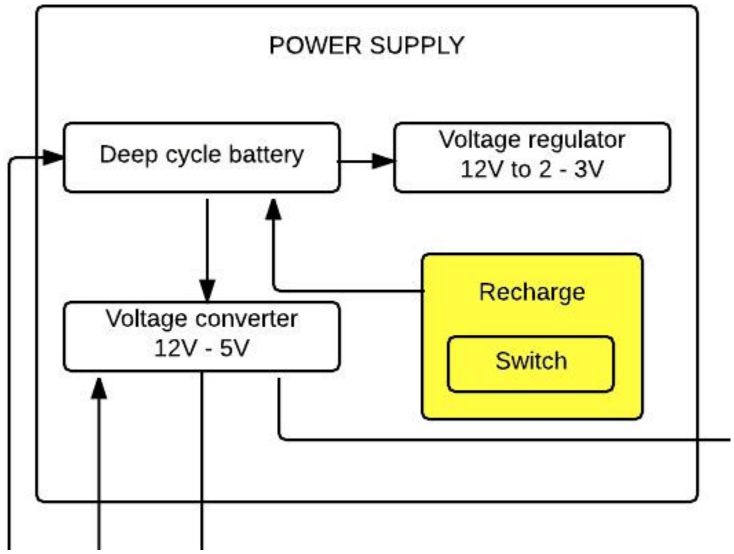

Figure 7: Recharge subsystem

4.4.3 Subsystem Interfaces

Table 5: Recharge subsystem interfaces

ID	Description	Inputs	Outputs
N/A	Switch on safety	Switch	Deep cycle battery

5 Cart Subsystems

The cart layer consists of the hardware components of the cart as well as the switches. The switches include a manual mode switch to remove autonomous activity and a killswitch to immediately unpower the cart.

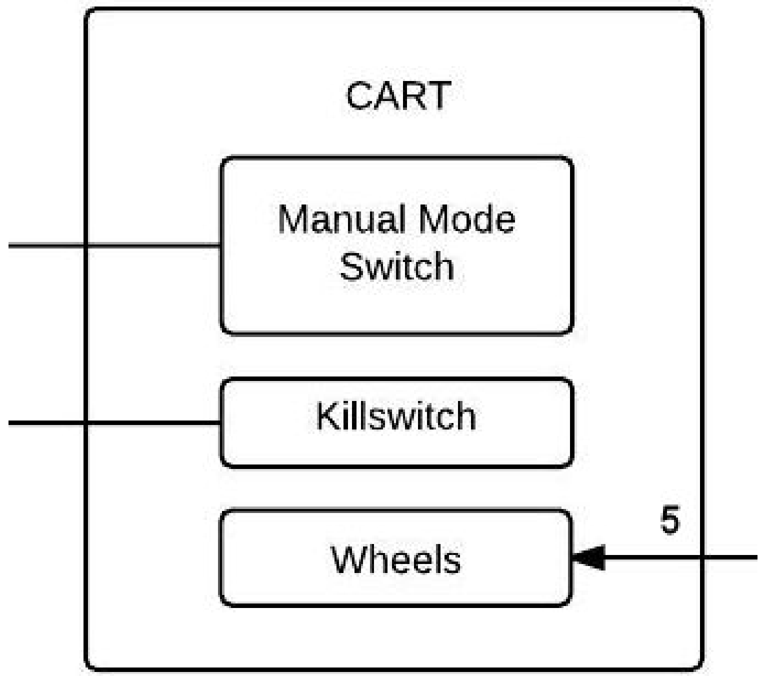

Figure 8: Cart layer

5.1 Manual Mode Switch

The manual mode switch subsystem will be used to ensure that the Smart Cart will not be autonomously moving.

5.1.1 Assumptions

Assumptions made are as follows:

- The manual mode switch subsystem will ensure the safety of the users and people around the user.
- The manual mode switch subsystem will not power the Smart Cart off, but simply disable autnomous smovement.

5.1.2 Responsibilities

The manual mode switch subsystem's responsibilities are as follows:

- The switch will disable the autonomous movement of the cart.
- The switch will ensure the safety of the user and surrounding people.

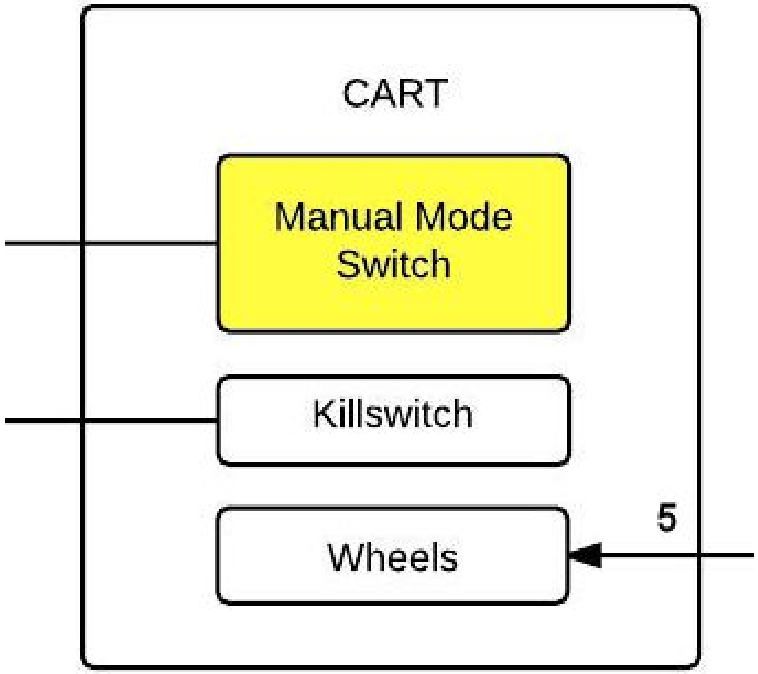

Figure 9: Manual mode switch subsystem

5.1.3 Subsystem Interfaces

Table 6: Manual mode switch subsystem interfaces

ID	Description	Inputs	Outputs
N/A	Disable converter	N/A	Voltage converter

5.2 Killswitch

The killswitch subsystem will be used to ensure that the Smart Cart will be immediately turned off.

5.2.1 Assumptions

Assumptions made are as follows:

- Power to the Smart Cart components will be disabled.
- Power to external tools and equipment will be disabled.

5.2.2 Responsibilities

The killswitch subsystem's responsibilities are as follows:

- The switch will disable the battery from powering the Smart Cart and its components.

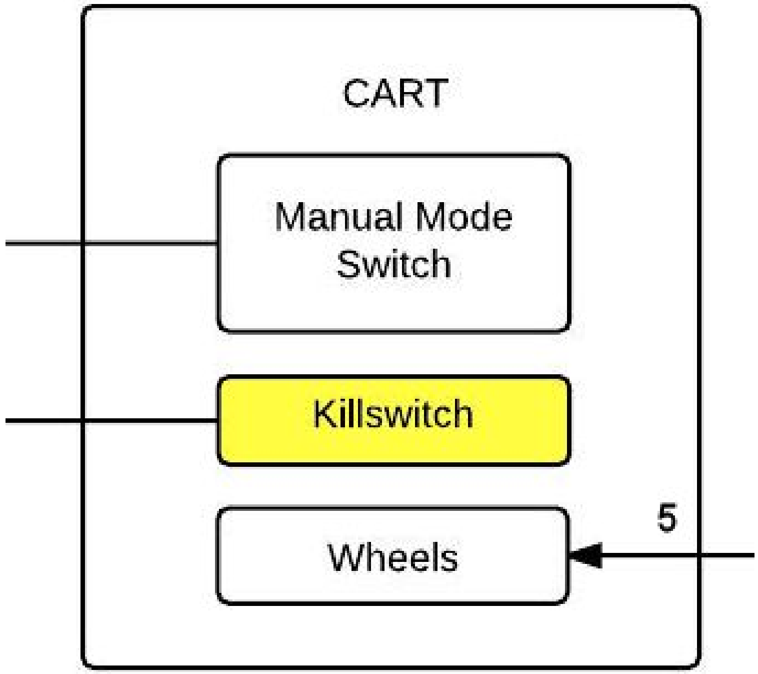

Figure 10: Killswitch subsystem

5.2.3 Subsystem Interfaces

Table 7: Killswitch subsystem interfaces

ID	Description	Inputs	Outputs
N/A	Disable battery	N/A	Deep cycle battery

5.3 Wheels

The wheels subsystem will be used to provide movement to the Smart Cart. The wheels will be controlled by the Crab Drive layer.

5.3.1 Assumptions

Assumptions made are as follows:

- The wheels must be able to turn in any sort of direction.
- The wheels will move together as a whole.

5.3.2 Responsibilities

The wheels subsystem's responsibilities are as follows:

- The wheels will be able to withstand movement through rough terrain.
- The wheels' movement and direction will be controlled by the wheel motors.

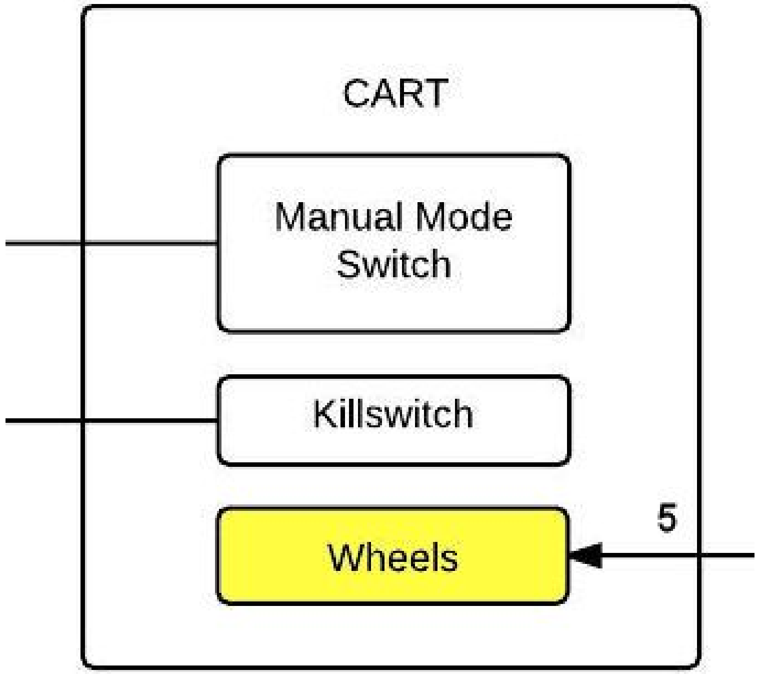

Figure 11: Wheels subsystem

5.3.3 Subsystem Interfaces

Table 8: Wheel subsystem interfaces

ID	Description	Inputs	Outputs
#5	Move wheels	Wheel motors	N/A

6 Crab Drive Subsystems

The crab drive layer consists of the hardware components that include a main drive motor that is responsible for steering the wheel motors that move the wheels. The drive system interface is responsible for communicating with the camera interface in the imaging subsystem, supplying directions to the main motor, and providing the cart with holonomic capabilities.

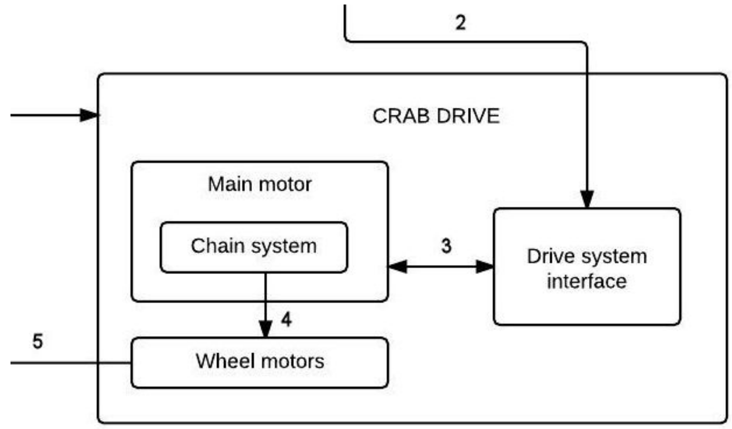

Figure 12: Crab drive layer

6.1 Drive System Interface Subsystem

The drive system interface is designed to communicate with the navigation subsystem's camera interface. it will get navigation data from the camera interface to steer the main drive motor as well as receiving feedback information for the wheel orientations.

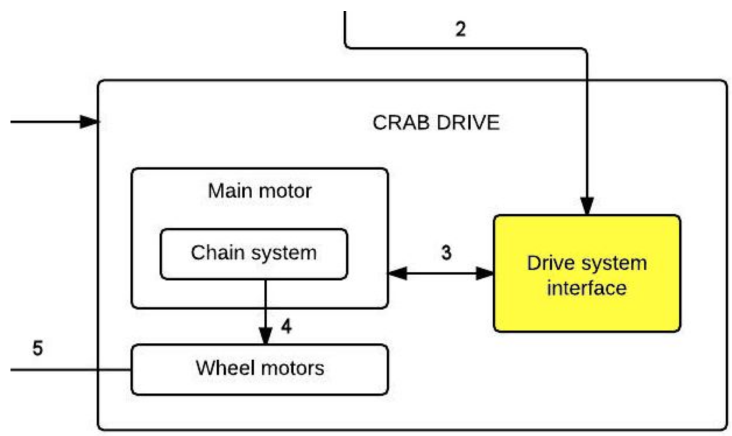

Figure 13: Drive system interface subsystem

6.1.1 Assumptions

Assumptions made are as follows:

- The drive system interface will receive accurate navigation data from the camera interface.

- The drive system interface will receive accurate feedback data from the main motor about wheel orientation.

6.1.2 Responsibilities

The drive system interface subsystem's responbilities are as follows:

- Send navigation data to the main motor.
- Receive wheel feedback data.

6.1.3 Subsystem Interfaces

Table 9: Drive system interface subsystem interfaces

ID	Description	Inputs	Outputs
#2	Receive navigation data	Camera interface	Main motor
#3	Receive wheel data	Main motor	Camera interface

6.2 Main Motor Subsystem

The main motor will contain a chain system that is responsible for steering the cart and maintaining a consistent orientation for all of the wheels.

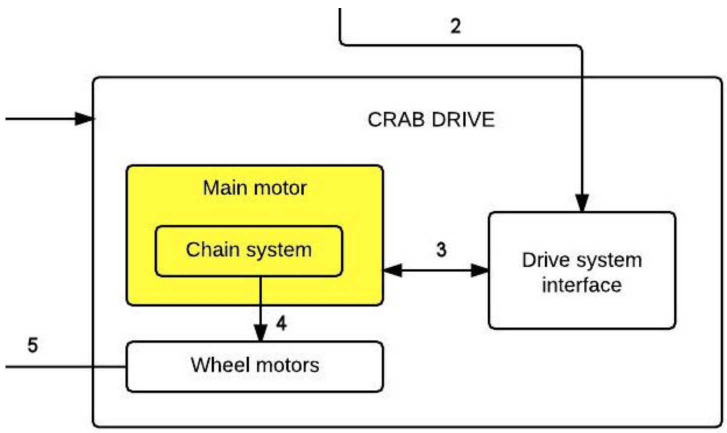

Figure 14: Main motor subsystem

6.2.1 Assumptions

Assumptions made are as follows:

- The main motor will correctly steer the wheels with the chain/belt system.
- The main motor will have a method to accurately keep wheel orientation data.

6.2.2 Responsibilities

The main motor subsystem's responbilities are as follows:

- Receive steering instructions from the drive system interface and accurately perform instructions.

6.2.3 Subsystem Interfaces

Table 10: Main motor subsystem interfaces

ID	Description	Inputs	Outputs
#4	Steer wheels	Drive system interface	Wheel motors
#3	Feedback data	N/A	Drive system interface

6.3 Wheel Motors Subsystem

The wheel motors is designed to drive the wheels at an appropriate speedt to follow the user using information sent by the main motor.

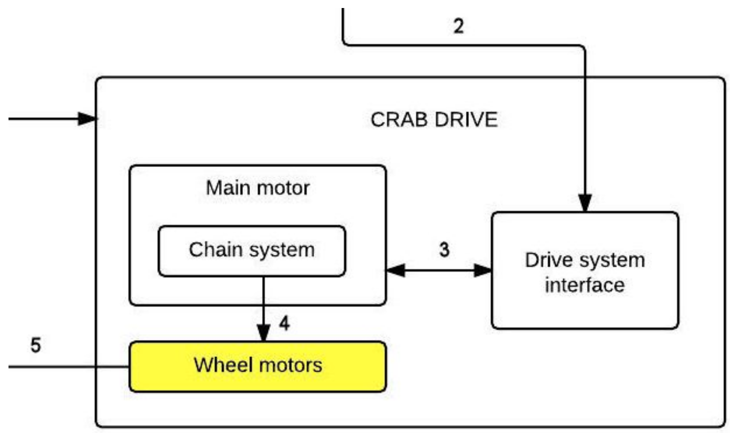

Figure 15: Wheel motors subsystem

6.3.1 Assumptions

Assumptions made are as follows:

- The wheel motors will be able to decide how fast to spin to achieve an appropriate speed.
- The wheel motors will only spin in one direction as the chain/belt system will control steering.

6.3.2 Responsibilities

The wheel motors subsystem's responbilities are as follows:

- Drive the wheels to follow a user at an appropriate speed.

6.3.3 Subsystem Interfaces

Table 11: Wheel motors subsystem interfaces

ID	Description	Inputs	Outputs
#5	Receive drive data	Chain system	Wheels

7 Imaging and Navigation Subsystems

The imaging and navigation layer consists of the Intel Realsense camera, ultrasonic sensors, and imaging software to produce navigation data to be sent to the drive system interface. The navigation data that will direct the crab drive system to follow a user as well as obstacle avoidance.

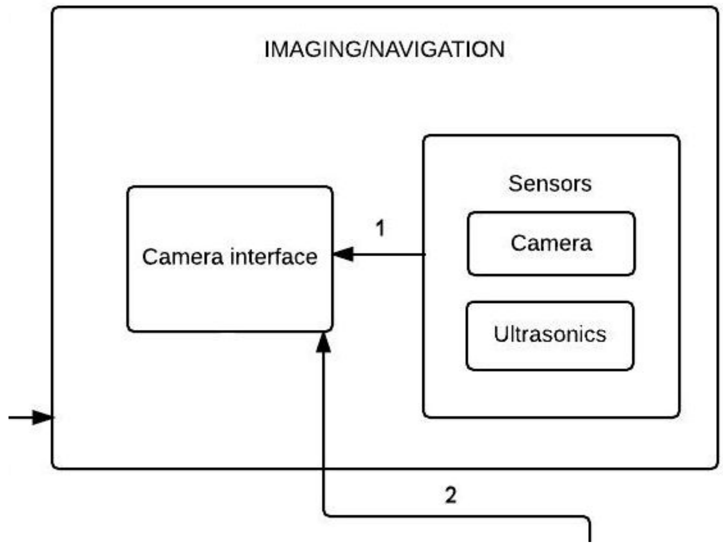

Figure 16: Imaging and navigation layer

7.1 Sensors Subsystem

Sensors include the Intel RealSense camera and ultrasonic sensors. The RealSense will identify a user to follow and the ultrasonic sensors will be used for obstacle avoidance. The sensors will provide the necessary information to the camera interface needed to create navigation data.

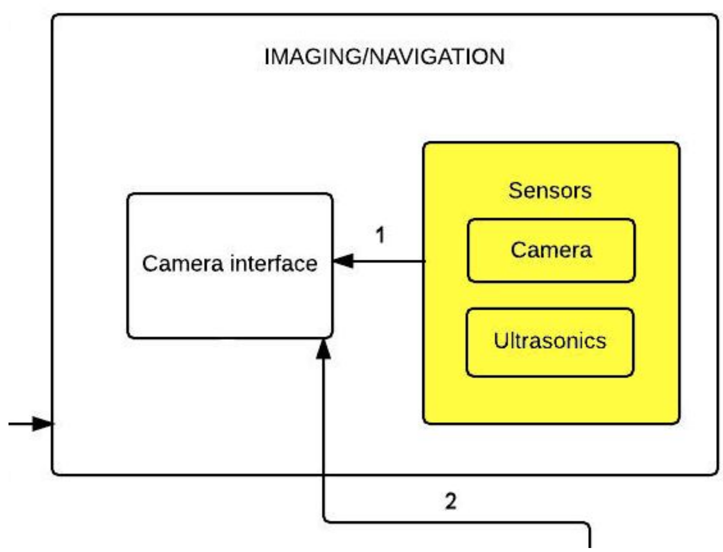

Figure 17: Sensors subsystem

7.1.1 Assumptions

Assumptions made are as follows:

- The user will be wearing a colored wristband that identifies them as the master.
- The user will stay in front of the Intel RealSense to avoid possible errors, such as the cart losing vision of its master.

7.1.2 Responsibilities

The sensor subsystem's responsibilities are as follows:

- Process image and ultrasonic data in real time.
- Keep the designated master within the image frame.
- Gather accurate data to send to the camera interface.

7.1.3 Subsystem Interfaces

Table 12: Sensors subsystem interfaces

ID	Description	Inputs	Outputs
#1	Send sensor data	Camera Ultrasonics	Camera interface

7.2 Camera Interface Subsystem

The camera interface is responsible for taking the data received from sensors to calculate accurate navigation data to send to the crab drive's drive system interface. The navigation data will include required speed, direction needed, and cart position for collision avoidance.

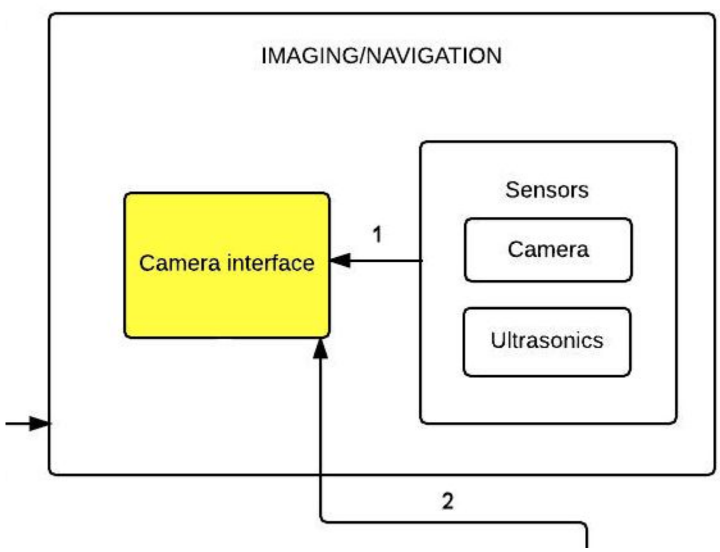

Figure 18: Camera interface subsystem

7.2.1 Assumptions

Assumptions made are as follows:

- Accurate data is being sent from the sensors.
- The camera interface will be able to communicate with the drive system interface.

7.2.2 Responsibilities

The camera interface subsystem's responsibilities are as follows:

- Calculate and process navigation data.
- Communicate necessary information to the drive system interface.

7.2.3 Subsystem Interfaces

Table 13: Camera interface subsystem interfaces

ID	Description	Inputs	Outputs
#2	Calculate navigation data	Sensors	Drive system interface