Department of Computer Science & Engineering
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Architectural Design Specification
CSE 4316: Senior Design I
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Arm Solutions
Pack Man

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REVISION HISTORY

Revision	Date	Author(s)	Description
0.1	11.11.2020	IR	document creation
0.2	11.17.2020	GF, IR, DP	Completed Introduction & Parcel Sorter Sub system layer: Vision)
0.2	11.18.2020	KP	Completed Parcel Sorter Layer Subsystem: Arm and Controls
0.3	11.20.2020	MZ	Completed GUI Layer Subsystem
0.4	11.17.2020	DP	Completed Parcel Sorter Sub system layer: Comms)
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1.0	11.22.2020	GF, KP, DP, IR, MZ	Complete Draft
1.1	11.23.2020	GF, KP, DP, IR, MZ	Official Release
1.2	5.10.2021	GF, KP, DP, IR, MZ	Updated ADS

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1 Introduction

The overlying idea of Arm Solutions is to reduce contact between people and packages. This will be achieved through an automated robotic arm that picks up packages and moves them to an area within the work cell.

1.1 Purpose and Use

The ongoing global pandemic is an issue that affects many aspects of society, including supply chains. Companies are adapting to new conditions to allow for social distancing and more hygienic work environments. The goal of Arm Solutions is to reduce contact between people and mediums of transmission. By automating parts the movement sorting of packages, exposure is reduced.

1.2 Intended Audience

The intended audience includes all major shipping and acquisitions companies. This includes not only postal companies, but companies that have high volumes of incoming and/or outgoing materials. Additionally, this can apply to companies it large amounts of internal mail. This reasoning is, because of Arm Solutions' goal to reduce personnel required to handle packages.

Figure 1: Conceptual drawing

2 System Overview

The system of UR5 parcel sorter machine is divided into two high level layers: Graphical User Interface (GUI) and Parcel Sorter robot as seen in Figure 2. This will allow users to understand what the Parcel Sorter is currently doing and to control it. The communication between these two layers can easily been shown in the figure below.

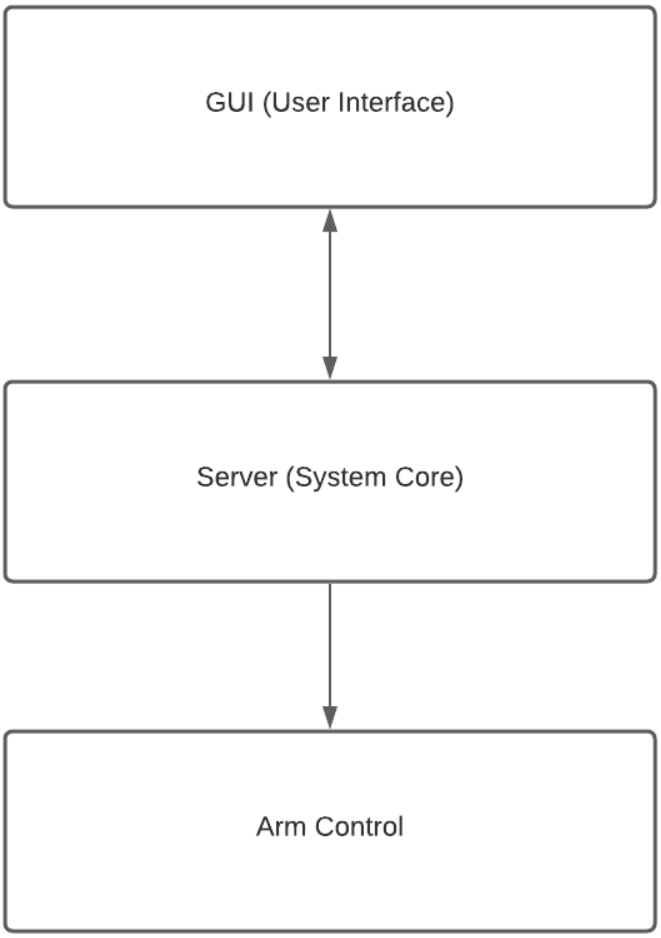

Figure 2: UR5 Parcel Sorter Robot Architectural Layer Overview

2.1 Graphical User Interface (GUI) Description

The GUI will be the interface between the Server and the user where it provides a status reports for the user to view and a command panel to control the Parcel Sorter for it to pause, reset, shutdown, etc. It will contain a Display and a Networking/Commands subsystem which will organize communications to and from the Server. As well, it will display a video feed from the work cell, allowing the operator to see what the system detects.

2.2 Server (System Core) Description

The Server (System Core) includes the Vision system and is the networking backbone for the entire system. Furthermore, it contains the vision system data extraction subsystems, data this used by the

Arm Control System. The operator can control these actions via commands from the User Interface.

2.3 Arm Control Description

The Arm Control will be the main system performing the physical sorting and be able to automatically find parcels in the environment and sort them using the data provided by the server. All arm movement will be automated, and the user can only control the drop location of the parcel.

3 SUBSYSTEM DEFINITIONS & DATA FLOW

Once the Operator starts up the system (from the User Interface), the flow of data starts at the Vision subsystem where it gathers information from its camera. This information then is passed to the Data Extraction subsystem to make the data usable for the Arm Control System. Then Vision subsystem will decide on actions for the Arm Control system to control the arm to successfully grab a parcel and move it to its final sorted position and repeats. While this cycle is progressing, the networking subsystem in the User Interface will receive a video stream from the server, showing the work cell and the detection of any possible parcels (if parcel detected, bounding box will appear around it).

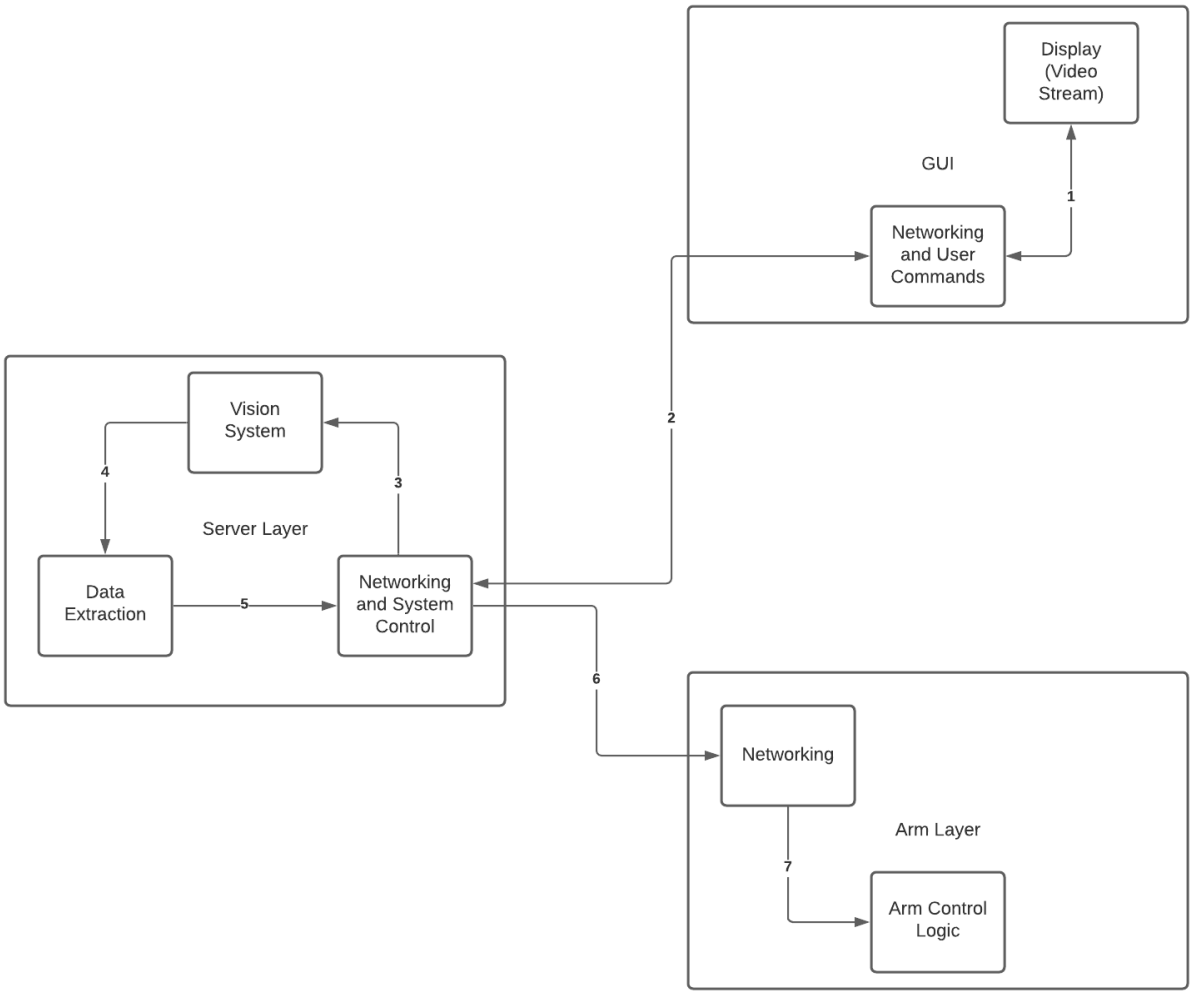

Figure 3: A simple data flow diagram for UR5 Parcel Sorter Robot

4 GUI Layer Subsystems

The GUI Subsystem layer's primary usage is for the user to know what the software and hardware is doing and to alter its current instructions. It does so through two distinct parts, an input (4.1 Networking/User Commands Subsystem) for allowed commands, and an output for relevant information (4.2 Display System), both of which are in a Graphical User Interface. When designing this, available GUI packages and their limitations are considered.

4.1 Networking and User Commands Subsystem

The Networking/User Commands Subsystem receives input from the user and alters the current operations of the system via sending commands over the network to the server.

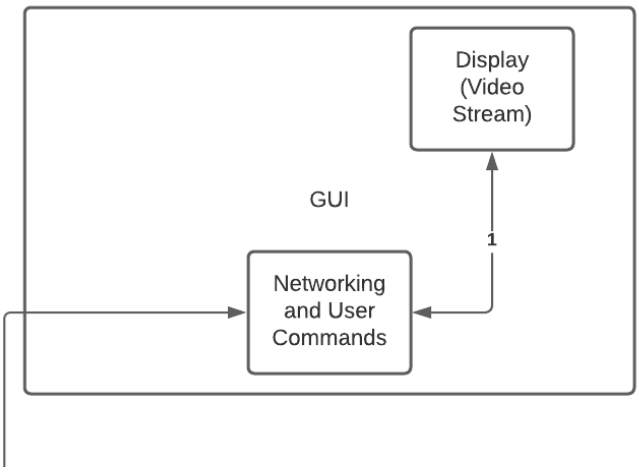

Figure 4: User Commands subsystem description diagram

4.1.1 Assumptions

- The primary assumption of this section is that the Networking part of this subsystem will have easily accessible APIs that will effectively work with the controls.

4.1.2 Responsibilities

- Receive and communicate user input outside of standard, user-less operations.

4.1.3 Subsystem Interfaces

- This subsystem relies on an API for the commands interface. How exactly this will occur is not yet know. In theory, a command queue or a command override function could be implemented. 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: User Commands Subsystem interfaces

ID	Description	Inputs	Outputs
#1	Graphics package input methods & programmed outputs/function calls	GUI Buttons and Text Inputs	Networking/Commands Subsystem API

4.2 Display Subsystem

The Display Subsystem is the layer between the Networking/Commands Subsystem and the operator to easily display information to the user. Its goal is to organize, abstract, and display key information.

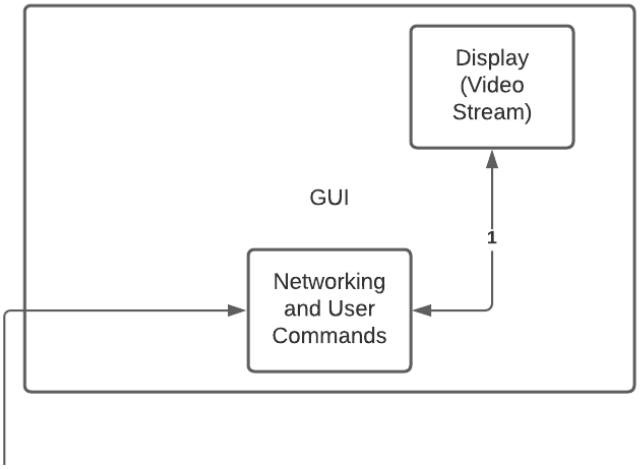

Figure 5: Display subsystem description diagram

4.2.1 Assumptions

- The primary assumption is that the server will transmit updated information over the network to display for the operator.

4.2.2 Responsibilities

- The subsystem will update and display current and relevant information.

4.2.3 Subsystem Interfaces

- The GUI object will have the functionality to receive information from the server. This allows us to display real time information to the operator. Following this, the ability to request information will also be implemented, but not necessarily activated.

Table 3: Display Subsystem interfaces

ID	Description	Inputs	Outputs
#2	GUI API & Display	Data received from the server	GUI

5 Server (System Core) Layer Subsystems

The Parcel Sorter Layer contains the Data Extraction, Vision System, and Networking/System Control which will work together to dynamically to plan arm movements. Although this system layer may operate slower, the many subsystems will allow for dynamic controls with easier development and maintenance.

5.1 Vision Subsystem

The Vision system will capture data about the work-cell environment. Its primary function is to collect this data and process the data about the parcel location and type. This be will be done by using a CNN and marker detection in conjunction, to improve accuracy and fault-tolerance. This data is then provided for the AI for parcel identification. This will allow the system to sort parcels without the need for human intervention.

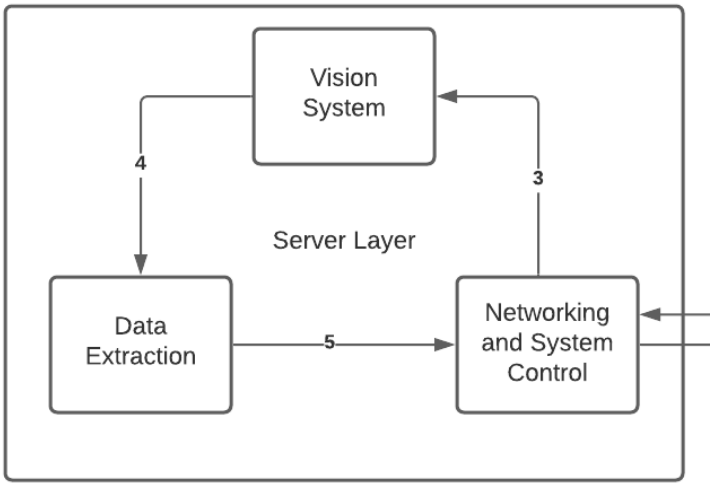

Figure 6: Vision subsystem description diagram

5.1.1 Assumptions

- This subsystem will be capturing data using some type of stereo camera (e.g. Intel Realsense), other types of depth sensors will not be supported.
- The Vision subsystem will not be GPU accelerated.

5.1.2 Responsibilities

- This subsystem is responsible for relaying accurate (and ideally noise free) data about the work-cell environment to the Data Extraction subsystem.

5.1.3 Subsystem Interfaces

- This subsystem will have one interface that connects to the Data Extraction Subsystem.

Table 4: Vision Subsystem interfaces

ID	Description	Inputs	Outputs
#6	Data Extraction System	NA	output 4
#2	Networking/System Control	Input 3	NA

5.2 Data Extraction Subsystem

The Data Extraction subsystem will pull the parcel data from the Vision system. This data is critical for the entire system, both the pick points of the parcel and sorting application will use this data.

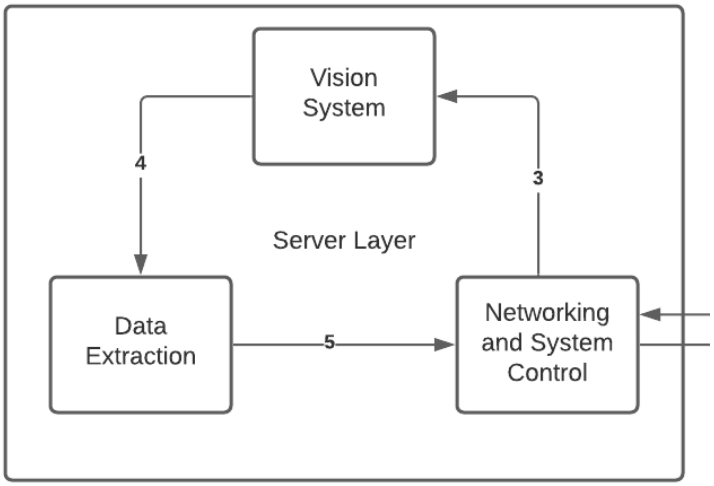

Figure 7: Data Extraction subsystem description diagram

5.2.1 Assumptions

- The data processing will be performed on a Linux OS (e.g. Nvidia Jetson).

5.2.2 Responsibilities

- The Data Extraction subsystem is responsible for providing the data for the pick points for the Arm Subsystem.

5.2.3 Subsystem Interfaces

- This subsystem will interface with Arm Control Logic sub-system

Table 5: Data Extraction Subsystem interfaces

ID	Description	Inputs	Outputs
#1	Vision subsystem	Input 4	NA
#2	Networking/System Control	NA	Output 5

5.3 Networking/System Control Subsystem

The Networking/System Control Subsystem serves as the main bridge for communications between the user and the entire system. The subsystem will iteratively receive user commands and status updates and sends them to their respective receivers. It will also send a confirmation message upon receiving user commands to help prevent user spam.

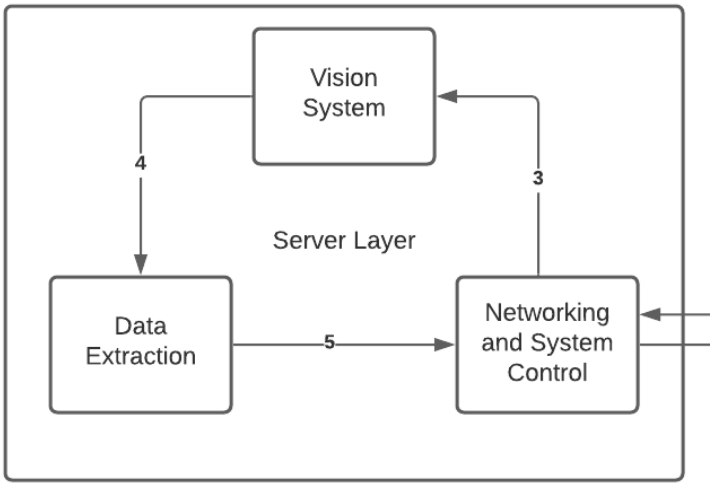

Figure 8: Comms subsystem description diagram

5.3.1 Assumptions

- Messages will be in a specific byte format for processing
- Network connection is stable and reliable.

5.3.2 Responsibilities

- To handle user commands for the Server from the user
- To handle sending status updates to the user

5.3.3 Subsystem Interfaces

- Interfaces with the Networking/Commands and Display subsystems for the operator.
- Interfaces with Arm Control Logic to control the arm.

Table 6: Networking/System Control Subsystem interfaces

ID	Description	Inputs	Outputs
#1.1	User Stop	Stop packet	None
#1.2	User Start	Start packet	None
#2	Display Status	None	Status packet
#3	Direct Command	None	Command
#4	Sorter Status	Current Status	None

6 Arm Control Layer Subsystems

6.1 Networking Subsystem

The Networking Subsystem serves as the bridge for communications between the Arm Layer and the Server. The subsystem will iteratively receive user commands and data from the vision system on the Server.

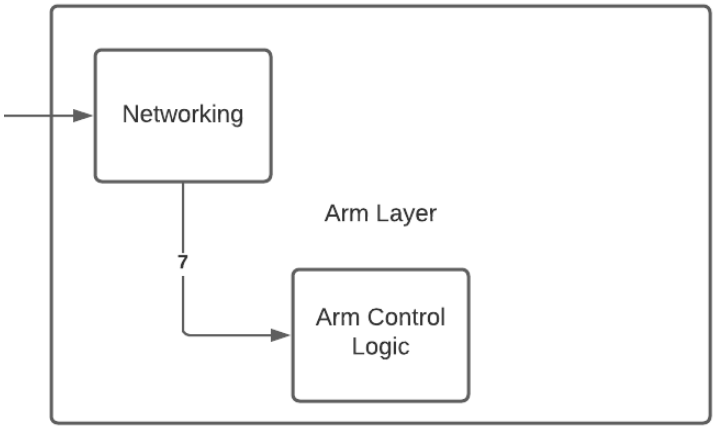

Figure 9: Comms subsystem description diagram

6.1.1 Assumptions

- Messages will be in a specific byte format for processing
- Connection between the Server and Arm is stable and reliable.

6.1.2 Responsibilities

- To handle user commands from the User Interface

6.1.3 Subsystem Interfaces

- Interfaces with Arm Control Logic Subsystem to control the arm.

Table 7: Networking Subsystem interfaces

ID	Description	Inputs	Outputs
#1.1	User Stop	Stop packet	None
#1.2	User Start	Start packet	None

6.2 Arm Control Logic Subsystem

This subsystem will move the arm accordingly from the data received from the Server. The Controls Subsystem will be used to send movement commands to the Arm based on data received by the Vision subsystem.

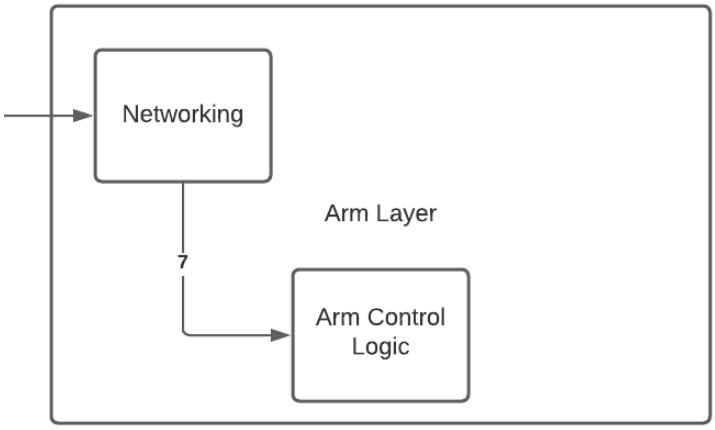

Figure 10: Controls subsystem description diagram

6.2.1 Assumptions

- This can be done using python scripts using RTDE.

6.2.2 Responsibilities

- Robot is operating in a safe manner.
- Managed command priorities between user and Vision system.

6.2.3 Subsystem Interfaces

- It will interface with the Arm.

Table 8: Controls Subsystem interfaces

ID	Description	Inputs	Outputs
#3	User Command	Command	None
#4	Status Update	None	Sorter Status
#5	Arm Command	None	Arm Command
#7	AI Update	None	New Parameters
#8	AI Command	Command	None

REFERENCES