CS 308 Embedded Systems Lab

Systems Requirements Specification

The Hilfskraft Roboter

Submitted in the partial fulfillment of the requirements for the degree of

CS 308 Embedded Systems Lab

By

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1. Introduction

1.1 Introduction and Rationale

The purpose of this document is to present a detailed description of the Hilfskraft. It will explain the purpose and features of the system, the interfaces of the system, what the system will do, the constraints under which it must operate and how the system will react to external stimuli. This document is intended for the developers of the system.

1.2 The Idea

Imagine a busy departmental clothing store; say a Westside or a Lifestyle. There exist a lot of discarded clothes outside the changing room. It is this problem that we want to address! Instead of making an employee sort these clothes and put them back in the correct racks, we envision a future where the entire process is automated!
Thus, we wish to automate the process of sorting clothes and placing back in the correct racks.

A **brief description** is as follows:
There will be a robotic arm which will sort the items from the dump box and put them into various baskets, depending on which section the item has to be returned too. When a basket contains the required number of items, the helper robot will pick up the basket and return it to the correction section of the store. Path planning needs to be done to optimize the path and prevent collisions between robots. This entire process being intelligent needs to be coordinated using an intelligent device like a laptop

This particular process can be a generalized to a simple sorting and delivering mechanism. Although we have used a departmental store as an example the same system can be used in garbage sorting and disposal, at factories and at many other places. Thus we are attempting to automate the generic problem of sorting and transporting.

1.3 References

1. E-Yantra WebSite: http://www.e-yantra.org/
2. ATMega16 datasheet
3. Zigbee Wireless: http://www.kanda.com/zigbee-wireless.html
4. RFid Tags: http://www.acs.com.hk, http://en.wikipedia.org/wiki/Radio-frequency_identification

1.4 Definitions, Acronyms and Abbreviations

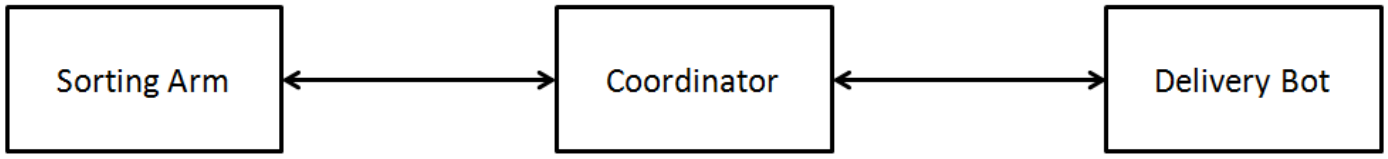
Term	Definition
Bot , Robot	The electro-mechanical machine that is guided by the user.
Coordinator	The electro-mechanical machine that is responsible for the major computations of the solution to the problem and transfers the data to the robot.
Robotic Arm	The electro-mechanical machine that looks like a arm and moves like a human hand and is guided by user. It has grips to pick and hold terms
Software Requirements Specification	A document that completely describes all of the functions of a proposed system and the constraints under which it must operate
User	The person that is currently controlling the bot.
SDK	Software Development Kit
Wifi	It is a mechanism which allows electrinoc devices to exchange data wirelessly
IDE	Integrated Development Environment
IR	Infra-Red
API	Application Programming Interfaces
AVR Studios	IDE for c programming for the robot.
X-CTU	Software used to configure ZigBee wireless module.
RFID	Radio Frequency Identification
RFID Tag	A unique Identification number is attached to each card
RFID Reader	Reads a RFID Tag and returns the tag to the coordinator

2) Overall Description

2.1 System Environment

The Hilfskraft Roboter has three systems, one sorting arm, delivery bot and coordinator. The main basket contains items with RFID tags on them. The RFID reader is connected to the coordinator via USB or Bluetooth. RFID reader can identify an item via its RFID tag. The coordinator communicates with the sorting arm and delivery bot on dedicated wireless frequencies.

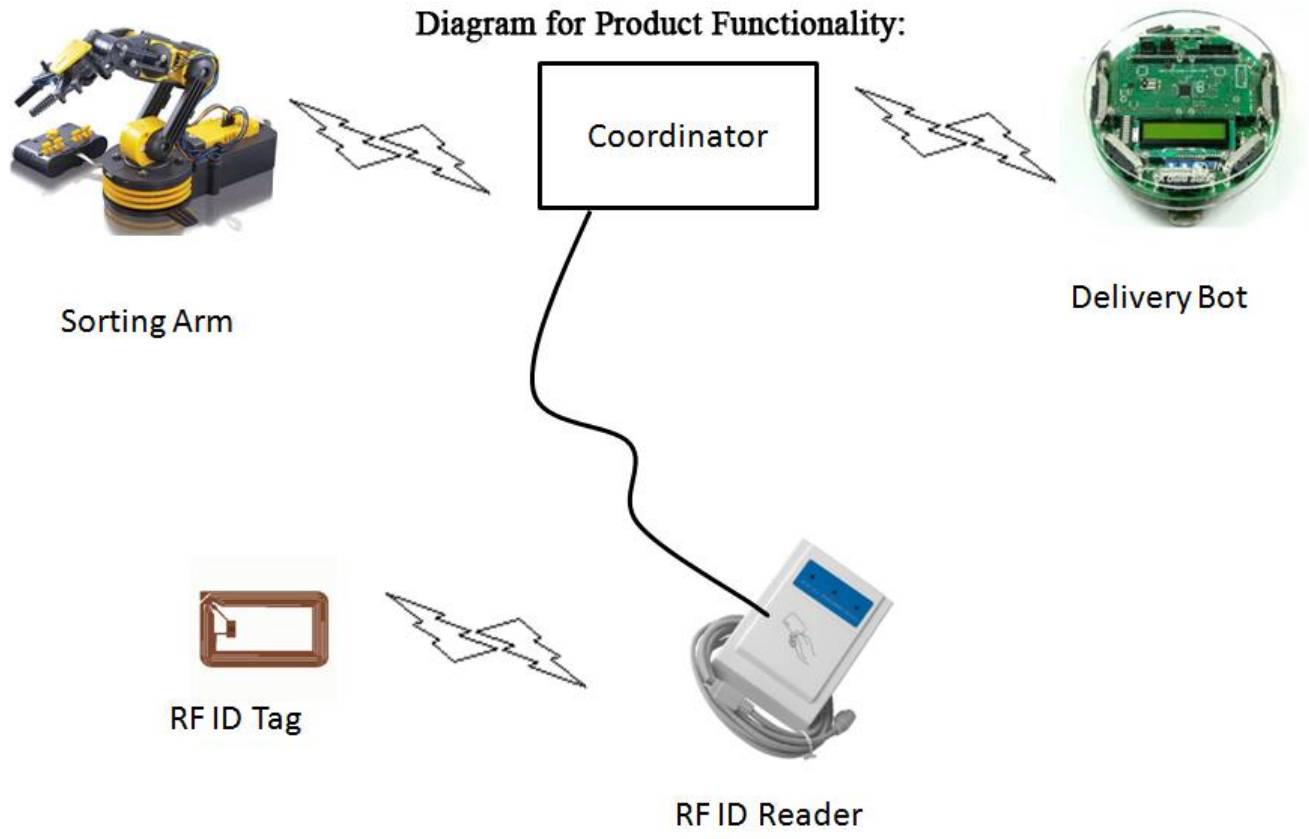
The user is able to view the problem if any are reported by the sorting arm , delivery bot and RFID reader on the coordinator.



2.2 Product Perspective:

All robots (Firebird V) are controlled remotely by the coordinator using the ZigBee wireless interface. The sorting arm picks up an item from the dump box. Based on the scanned RFid, the coordinator instructs the arm to place it in a particular basket.

When a particular basket is full, the coordinator instructs a delivery robot to deliver the basket to the desired location. The path of the delivery robot is decided by the coordinator to minimize delivery time and prevent collisions.



2.3 Product Functions:

The **step-by-step algorithm** for the entire process is given by the following:

1. The robotic arm picks up an item from the dump box and places it on the RFid Reader.
2. The Arm communicates to the Coordinator that an item is placed on the reader.
3. If RFid is not scanned due to some error, the Coordinator instructs the Arm to return the item to the dump box. The algorithm then proceeds from step 1.
4. Based on the RFid scanned, the Coordinator checks if an empty basket is available. If no empty basket is available, the Coordinator instructs the Arm to return the item to the dump box. The algorithm then proceeds from step 1.
5. Based on the RFid scanned, the Coordinator instructs to place the item in a particular basket.
6. The Arm places the item in the correct basket and informs the coordinator about the same.
7. The Coordinator checks if any basket has required number of items. If a basket has the required number of items, the algorithm proceeds to step 8. Meanwhile the arm returns to step 1.
8. The Coordinator looks for a free delivery robot. If a free robot is found, the coordinator instructs it to deliver the basket to the desired location. It also plans the path for the delivery robot to minimize delivery time and prevent collisions.

2.4 User Characteristics:

Since the entire process is automated, the user will just be an observer of the entire process. He will ensure no errors occur in the entire process.

2.5 Constraints:

1. Only 1 item must be picked by the arm at a time. This is to prevent the RFid reader from reading multiples values at the same time
2. The item must be placed on the reader in such a way that the RFid card is close to the scanner so that the id can be scanned.
3. Currently, we plan to attach the RFid reader to the Coordinator. Thus the coordinator must be placed close to the robotic arm
4. The Robotic arm will be programmed to move a fixed absolute distance after picking up an item. Thus, the Scanner must be placed accurately at that point. Any change in the scanner position will make the entire system unusable.
5. The Delivery Bots must be within the Wireless network range of the Coordinator.
6. All baskets must be placed accurately at the respective pick up points
7. 2 successive RFid readings must have a time lag of at least 1 second.

2.6 Assumptions and Dependencies

The bandwidth of ZigBee Communication should be able to handle the load of communications i.e. downlink - the commands from the Coordinator to the robotic arm; Coordinator to the Delivery bots and uplink – Delivery Robot to Coordinator and Robotic Arm to Coordinator

2.7 Requirement Subsets

1. Wireless detection and communication
2. Driver support for RFID Reader on coordinator
3. Sorting arm movement,
   3.1) it should be able to pick one item at a time and place it on RFID Reader
   3.2) and again pick the item and place it in the correct bucket
4. Identification of items by their RFID tags
5. Sorting and placing of items in boxes based on information
6. Delivery Bot movement
   6.1) White line detection
   6.2) Path finding
   6.3) Collision detection and avoidance

3) Details

3.1 Functionality:

1. **The Robotic Arm:** Pick up an item from the box of dumped items and communicate the RFid to the master laptop. Depending on the master laptop's response, the arm will either drop the item in the required basket (which basket will be told to the robot by the laptop) or will return the item into the original dump box.
2. **The Delivery Robots:** The helper robots when not deployed are in a parking yard! They wait for a signal from the master laptop. On receiving a particular signal, the helper robots will pick up the required basket and drop it off at the needed point. This will be done based on the path told to the robot by the laptop. The helper robots will also respond to interrupts to prevent collisions with other robots.
3. **The Coordinator:** The master laptop controls the entire process. On receiving an RFid from the arm, it will look for an available basket. If no basket is available the laptop instructs the arm to return the item to the original basket. Otherwise it asks the arm to put the item in the correct basket. When enough items are present in a particular basket, the laptop instructs a free helper to carry the basket to the correct location in the store i.e. grid point.

3.2 Supportability

1. **Basis for future work**
    1. The RFid module will help future projects that use RFid based hardware in the coming years.
    2. The project itself can be used in other projects based on garbage disposal, warehouse automation and so on.
    3. A potential future application could be a complete automatic shopping experience i.e. users will use input devices (Android phones or any such device) to decide a list of items they want to buy. Delivery robots will collect the items and create a basket of the items for the user. The user will remove the unneeded items from the basket and place them in a dump box. A Robotic arm sorts the items. The delivery robots return the items to the correct section. Meanwhile a delivery robot delivers the items the user wants to the billing counter.

2. **Distinguished Modules of the Project**

    There are two distinguished modules of the project:

    1. Sorting Module: Arm picking up an item and placing it near the RFid Reader.
    2. Communication module between RFid Reader and Coordinator.
    3. ZigBee communication module for wireless communication between Sorting Robot and Coordinator.
    4. ZigBee communication module for wireless communication between Delivery Robots and Coordinator.
    5. Delivery Module: Delivery Robots place the basket at the given location and return the basket to the initial position.

    Any of these modules can potentially be used in other projects requiring their functionality.

3. **Documentation**

Documentation in terms of embedded comments and other explicit write-ups will help others in future.

3.3 Design Constraints

The restrictions being implemented in the code are primarily due to those imposed of the system by the hardware being used.

They are as follows:

1. The ZigBee Wireless Communication Module uses a Serial COM Ports. So, all the communication between the coordinator and the Robot will be via a serial port only.
2. The Robotic arm movement is a big challenge. Picking items, placing them in the baskets. This will require a lot of programming of the robotic arm.
3. The RFID Reader is only connected to the coordinator via a USB port and not to the sorting arm itself. So the items have to be brought near the Reader for scanning the tag.
4. Collision Detection and avoidance between
    a. Delivery bots themselves,
    b. Delivery bots and moving costumers.

3.4 Interfaces

1. **User Interfaces**

    There will be no user interface. The user is merely an observer to the automated process.
2. **Hardware Interfaces**

    This section states the essential physical equipment required to interact with the application designed.

    They are as follows:
    1. **Coordinator**: To coordinate the 2 major modules of the process – sorting and delivery.
    2. **Wireless Communication Module**: Used for communication between the delivery robot and the coordinator. Also used for communication between the sorting robot and coordinator
    3. **RFid Module**: Used for communication between RFid Reader and Coordinator for transmission of RFid Tags of items.
3. **Software Interfaces**

    This section states the requirements to development the application which will use the data feed from the various interfaces and use them to control the robot or display information for the user.

    They are as follows:
    1. Atmel AVR Studio
    2. AVR Bootloader
    3. RFid Hardware Driver
4. **Communications Interfaces**

    This section states the requirements to create a communication between the robot the coordinator.

    They are as follows:
    1. 6 ZigBee Wireless Modules
    2. X-CTU ZigBee Configuration
    3. 1 RFid Communication Module

4) Quality Control

For the sorting arm:

Quality needs to be ensured for the following functions:

1. From the heap of items, only one item should be picked up by the arm.
2. The item should be taken in enough proximity of the reader by the arm, so that the RF tag can be scanned easily.
3. After detecting the RF tag, the coordinator should communicate immediately to the arm, to avoid the tag being read multiple times.
4. The position of sorted containers should be accurate, so that the arm will drop the item at the correct location.
5. The item should be dropped only if the sorted container is not taken away by the delivery bot.

For the delivery bots:

Quality needs to be ensured for the following functions:

1. The path should be planned such that:
    a. Collisions are avoided.
    b. Minimum length path is chosen for all bots.
2. While returning the containers, the bot should position the container accurately.

5) Risk Management

This project can face the following runtime problems:

1. **RFid reader does not function properly**: The Reader needs to be replaced/ repaired. In the meanwhile, the delivery bot can still carry out its functions and the sorting of items will have to be done manually.
2. **RFid Tag does not get detected**: The Tag on the item need to be replaced and this item can be taken back to its original location manually. This will not affect anything else.
3. **Sorting arm does not function:** Sorting will have to be done manually till the arm is repaired or reprogrammed. In the meanwhile, the delivery bot can still carry out its functions and the sorting of items will have to be done manually.
4. **Delivery Bot does not work:** There will be several delivery bots, and hence one bot not functioning would hardly affect the system. In the meanwhile, the central computer should be instructed about this, and it will not schedule this bot for any kind of delivery.
5. **Wireless Communication does not work/Coordinator stops working:** The functioning of the sorting arm would not be affected. The delivery bots can be programmed to take the items to their locations if the sorting arm keeps the items in pre-specified locations after sorting. Collisions can be avoided using the proximity sensors around the delivery bots.