KAEFI

October 13, 2011

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
Burnaby, BC
V5A 1S6

Re: ENSC 305 Functional Specification for an Office Automated Delivery Robot

Dear Dr. Rawicz,

Attached document contains functional specifications for KAEFI's Office Automated Delivery Robot system. Our system will provide convenience at office spaces while securely delivering important documents and other packages from one cubicle to another. This is possible by having lockable compartments with software controlling them. An application installed on PC will offer easy-to-use User Interface which will be used to put in query for the delivery. QR barcodes embedded on the floor will be scanned by the robot for localization of itself. Path finding algorithm will be developed to find its way through the office spaces.

Our functional specification encompasses system requirements for functionalities that we will implement. Such document will provide guidance to our software and hardware developers through various development stages.

KAEFI is composed of five senior engineering students with experiences through numerous Co-op(s) in the industry and research projects. We strongly believe that our product will not only be educational but competitive and beneficial, we are Gyu Han David Choi (CEO), Jin Sun Ahn (CTO), Hongbae Sam Park (CFO), Kyu Seo Lee (CMO), and Yongho Choi (COO). Should you have any question about our system, attached functional specifications, please contact us by email at kaefi-support@sfu.ca

Sincerely,

Gyu Han David Choi

KAEFI, Chief Executive Officer

Functional Specification

For An Office Automated Delivery Robot

Dr. Andrew Rawicz – ENSC 440
Mr. Mike Sjoerdsma – ENSC 305

School of Engineering Science
Simon Fraser University

Gyu Han David Choi
Jin Sun Ahn
Hongbae Sam Park
Kyu Seo Sam Lee
Yongho Choi

kaefi-support@sfu.ca

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KAEFI

Executive Summary

We live in a world of efficiency. Companies strive to increase the efficiency of their operations in a quest to step up their financial performance. In doing so, companies have made vast advances in various fields to increase the speed of just about anything and decrease the downtime of any automated machine.

Work efficiency can be best increased by making use of time more effectively, especially in an office regime; workers are abound a finite time (i.e. 9-to-5), and hence they are required to finish their work for the day before leaving the office. In an attempt to assist employees meet their daily work quota, some companies go as far as actively preventing their employees from wasting time, for example, surfing the internet, by blocking work-unrelated websites such as Facebook. Our solution can help employees manage their time more effectively by relieving them of certain unnecessary burdens like delivering of documents.

In this report the functionality of the systems and their components that comprise the robot will be discussed. The purpose of this report is to serve as a guideline for estimated development requirements and time, and to make sure proper requirement goals are reached during the course of development. As project progresses, our team members will refer back to this report to stay on the right course.

The robot requires first and foremost the ability to run for a prolonged time; most offices are active between 9am to 5pm, so we aim for 9 hours of operation at the minimum, of which 1 hour is a safe margin. The user interface will be simple and text-based. The server-client communication will employ existing office infrastructure such as Wi-Fi network, so that the setup would be easy. The required software and hardware development topics are listed as below.

Software	• User Interface (Including Website) • Server-Client(User and Robot) Communication • Way-finding Algorithm • QR Detect and Decode • Camera Snapshot Taking
Hardware	• Motor Control and Propulsion System • Chassis Construction • Collision Avoidance Sensor • Storage Compartment Locking Mechanism

The product development will be largely divided into two phases; first phase will encompass propulsion system development including motor control, collision evasion and system, user interface, and server-client communication. The second phase will be attributed to the integration of aforementioned systems, testing, and debugging. The robot will comply with relevant CSA, FCC, ANSI and RIA standards. We aim to complete the development by December 2011.

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Glossary

ANSI	American National Standards Institute
CSA	Canadian Standards Association
Facebook	Social Networking Service
FCC	Federal Communications Commission
Microcontroller	The "brain" of the robot. Provides centralized processing capability
PC	Personal Computer
PWM	Pulse Width Modulation. Method of controlling motor
QR	Quick Response. A type of barcode that can store information in a two-dimensional graphical form
RIA	Robotic Industries Association
Server-Client	A model of computer network
OADR	Office Automated Delivery Robot

1. Introduction

The office delivery robot will deliver packages and things in primarily office spaces. By doing so, we hope to aid in saving time and increase work efficiency in offices. The requirements of the robot to achieve its main goal will be discussed in proceeding topics.

1.1 Scope

This document (i.e. the functional specification) will describe the office delivery robot. All technical aspects of the robot system and testing approach will be discussed in the following topics, and ultimately this document will serve as an outline which can be referred back to ensure desired functionalities are within specification.

1.2 Intended Audience

This document is primarily intended to be used internally by the members of KAEFI. The members of the KAEFI shall use this document as a guideline which shall be referred to as necessary during the course of the development. Also, external audiences such as project supervisors, legal consultants, and standards organization shall use this document in the events such as certification of the proposed robot system or there arise any legal issues.

1.3 Classification

The following notation will be used to indicate the categorized functional requirements.

[R – n – p] Functional Requirement

Where R refers to the requirements, n refers to the number of the requirements, and p refers to the importance of the requirement in completing the project.

2. System Overview

The high-level scheme of the secure office automated robot can be described with the system flow chart provided below.

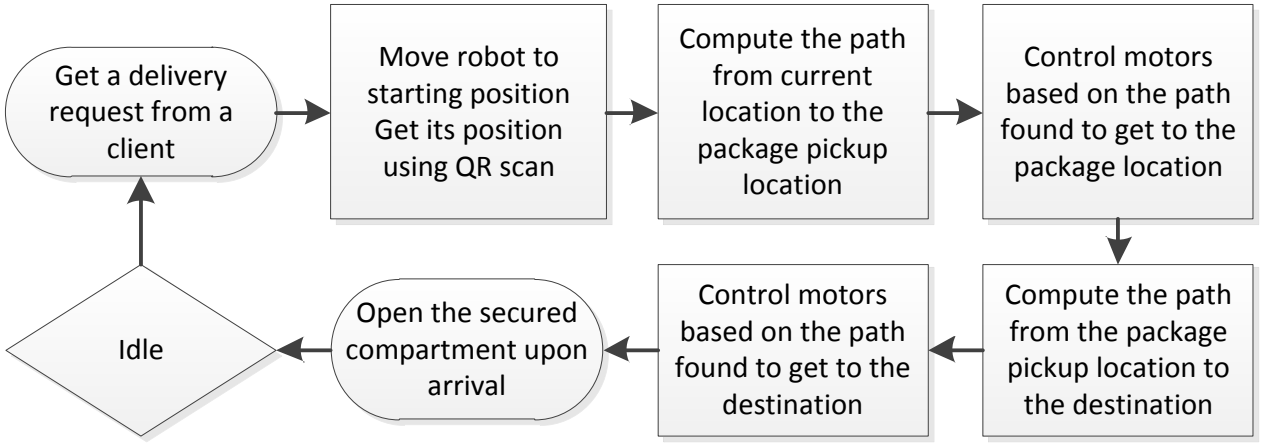

Figure 1: Robot's Delivery Flow Chart

With a tight deadline being the nature of this project, there may be some features excluded from the initial development such as obstacle detection and return-to-charging-station function. Without these functionalities implemented, our prototype will still be able to perform our goal of delivering packages.

The robot will start from the starting station where it can be a potential location for charging the robot. Upon a delivery request from a client PC, the robot will first scan the QR code embedded on the ground to obtain the current position in the office space. When at idle, the robot will be positioned on the top of the QR code, so the robot always knows where it is. Once its current location and destination for delivery are submitted to the database from the client PC, the algorithm running in the background will use this information as an input to compute the shortest path from current location to the pickup location (client's location). Another motor-controlling application programmed on microprocessor will move the robot to desired location inputted from the algorithm. The same algorithm will be applied to move the robot from pickup location to the destination while carrying the package in the compartment. After the package has been successfully delivered to the target client, the robot status will become "idle" until new query is submitted to the database.

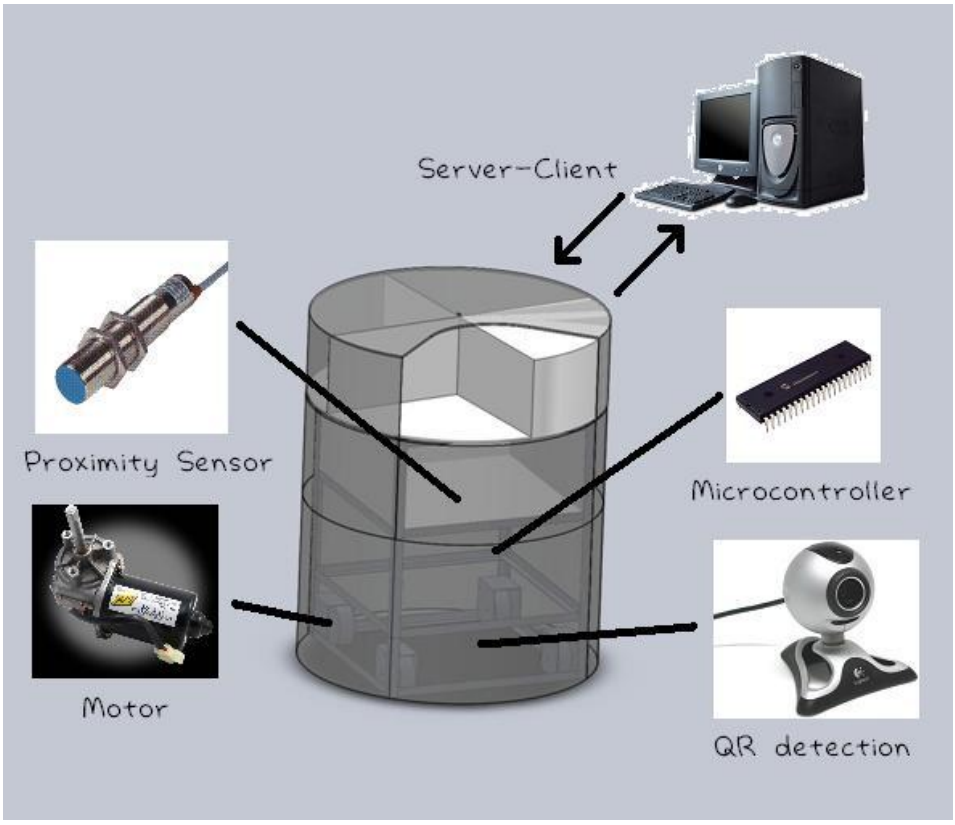

Figure 2: Description of System Components

Complex computations such as picking up a new package while delivery is in process and a traffic controlling algorithm amongst more than 2 automation robots won't make it to this part of development stage since they are very time consuming implementations which we can't afford to do. Another important thing to consider is the complexity of the map we want our robot to move in. For the development purposes, we will implement easier map; furthermore, robot's path finding has a higher accuracy during demonstration.

3. Overall System Requirements

3.1 General Requirements

[R – 001 – 2] When the robot is in operation, it must notify its presence and that it is in an operational state to its clients.

[R – 002 – 2] When the robot is NOT in operation, it must also notify it's in a non-operational state to its users.

[R – 003 – 1] At all times, person(s) that gets in the way of the robot, whether voluntarily or involuntarily, has the right of way. The robot must stop until path is cleared.

[R – 004 – 2] All self-diagnostics must be performed automatically when the power is on, or when the robot completes the recharging cycle

[R – 005 – 1] The robot shall have an emergency kill switch, which can disable the robot in the case of emergency.

3.2 Physical Requirements

[R – 006 – 1] The QR Code panel placement on the floor shall not be altered from its original position.

[R – 007 – 1] The robot shall NOT have a height greater than 1.5m.

3.3 Mechanical Requirements

[R – 008 – 1] The left and the right wheels must be powered independently to accommodate turning about its vertical central axis.

[R – 009 – 2] The chassis shall be constructed from lightweight metal.

[R – 010 – 2] The combined total weight of the robot shall not exceed 30kg.

[R – 011 – 2] The center of gravity shall be as low as possible.

3.4 Electrical Requirements

[R – 012 – 1] The robot shall be powered by a 12V battery source with minimum 100 amp-hour capacity.

[R – 013 – 1] The electrical system shall be enclosed and must be out of touch from its users.

3.5 Operating-Environment Requirements

[R – 014 – 1] The robot shall not be subject to a greater impact force than either chassis or enclosure can tolerate.

[R – 015 – 1] The robot shall not be incinerated deliberately.

[R – 016 – 1] The robot shall not be subject to any liquid spillage on its enclosure.

[R – 017 – 1] The propulsion system (i.e. wheels) may require periodic cleaning as they may pick up dirt from floor.

3.6 Performance Requirements

[R – 018 – 2] The robot shall not exceed a maximum speed of 60cm/s at any moment.

[R – 019 – 2] The self-diagnostic sequence shall not exceed 5 minutes.

[R – 020 – 3] The speaker (used for emitting sound to notify its presence) loudness shall exceed 60dB unless otherwise manually set by the operator for use in quiet areas.

3.7 Usability Requirements

[R – 021 – 1] The robot's status indicator shall be simple and straight-forward that any user can instantly distinguish which state (i.e. operational, in-operational, activated, or deactivated) the robot is in.

[R – 022 – 2] The user shall not be required, in most cases, more than a push of a button, or a similar action, to bring the robot up to an operational state.

3.8 Reliability and Durability

[R – 023 – 3] The storage compartments shall be liquid-tight and leak-proof.

[R – 024 – 3] The robot, when subject to a full usage (i.e. minimum 9 hours of use every day), shall out-perform its minimum requirements and operate in a safe and predictable manner for at least 2 years.

3.7 Safety Requirement

[R – 025 – 2] The robot shall not overheat, and even in the unlikely case that it does, the heat shall not be transferred to the enclosure. The enclosure temperature shall not exceed 40° C.

[R – 026 – 2] The robot shall NOT have sharp corners, and ground clearance of at most 6 cm.

3.8 Standards

[R – 027 – 1] The system shall comply with relevant CSA standards.

[R – 028 – 1] The system shall comply with relevant FCC standards.

[R – 029 – 1] The system shall comply with relevant ANSI standards regarding machinery.

[R – 030 – 1] The system shall comply with relevant RIA standards.

4. Camera and QR Decoding

4.1 General Requirements

[R – 031 – 1] The camera must be set to focus to clearly scan the QR code.

[R – 032 – 2] The camera must start scanning the QR code upon delivery order request.

[R – 033 – 2] The camera must be turned on if delivery order request exists in the database query.

[R – 034 – 1] The camera must detect the QR code.

[R – 035 – 1] The camera must decode the QR code.

[R – 036 – 2] The QR code must dominate 85% of the viewfinder frame.

4.2 Environment Requirements

[R – 037 – 2] The camera must have enough lights.

[R – 038 – 2] The camera must not be shaken while scanning QR code.

4.3 Reliability and Durability

[R – 039 – 2] The QR code should be uniquely defined for each intersection.

[R – 040 – 2] The QR code shall not be defected easily.

5. Motor

5.1 General Requirements

[R – 041 – 1] At least two motors shall be used to drive left and right side wheels independently.

5.2 Physical Requirements

[R – 042 – 1] A motor must be able to fit within a box with a volume of 6000cm^3 (20cm x 20cm x 15cm).

5.3 Electrical Requirements

[R – 043 – 1] A motor must be DC (Direct Current) compatible, and must be able to run from a 12V DC source [6].

5.4 Mechanical Requirements

[R – 044 – 1] A motor with built-in gear-head shall be used.

[R – 045 – 2] Motor shaft length shall be greater than 1cm.

5.5 Operating-Environment Requirements

[R – 046 – 1] The motor, because they require greater than 5 amps of current at all times during operation, shall be kept away from users.

5.6 Reliability and Durability

[R – 047 – 1] The motor and the gear-head must be made from durable materials such as metal.

5.7 Safety Requirement

[R – 048 – 1] The motor shall not overheat beyond 50° C.

5.8 Performance Requirement

[R – 049 – 1] Each motor that power either left or right wheel(s) must be able to provide a minimum of 150Nm at the wheel.

[R – 050 – 1] Motor must be able to spin in the reverse direction [6].

5.9 Usability Requirement

[R – 051 – 2] The motor must be easy to work with; it shall not require further physical modification to any part of the motor. The motor must be plug-and-play ready. Negative, positive, and ground wires shall be the only wires required for the motor to run.

6. Database

6.1 General Requirements

[R – 052 – 1] The database must establish the connection with the robot.

[R – 053 – 1] The database must store the starting point and the destination point of the robot.

[R – 054 – 2] The database must be private and secured.

[R – 055 – 2] The database must store the result, so it can track that the robot has successfully finished its duty.

[R – 056 – 2] The database must track the robot's current location.

[R – 057 – 1] The database must check the order priority.

6.2 Environment Requirements

[R – 058 – 1] The database must be connected to the same network as the robot.

[R – 059 – 2] The database must be set with Oracle or MySQL for compatibility.

6.3 Reliability and Durability

[R – 060 – 3] The database must be infinite in size.

[R – 061 – 2] Once the system is set up, the database must be permanently durable.

6.4 Safety Requirement

[R – 062 – 1] The database must pass the order to the robot precisely.

7. User Documentation

[R – 063 – 1] The user document will include detailed operation instruction

[R – 064 – 1] The user document will contain detailed description of components

[R – 065 – 2] The user document will be available on the internet and in hard copy

[R – 066 – 3] The user document will be available in multiple languages of specific target markets

[R – 067 – 2] The user document will accommodate users with no technical background

[R – 068 – 2] The user document will include warranty details

8. System Test Plan

As a delivery robot, achieving 100% successful delivery rate is a major challenge. To ensure this, the general approach of testing will consist of individual module testing, integration testing, and prototype testing. Modules will be tested first and integration testing will ensure that different modules will work together. The prototype testing will simulate the robot in normal operation conditions. Also, it will contain massive numbers of tests to make sure that the robot will not break down in any situations.

8.1 Individual Module Testing

1. Connectivity Module
   a) Ping Server's IP address from the client's computer
   b) Observe that packets are sent and received properly

2. KAEFI Order Website
   a) Turn on the client's computer's internet explorer
   b) Type Server's IP address
   c) Observe that KAEFI order website is opened

3. KAEFI Order Website Functionality
   a) Within the website, place an order with an input of a starting point and a destination point
   b) Observe the order is placed properly with a success message on the website
   c) Observe that the robot starts moving right after the order is placed

4. Database Module
   a) After order is placed, observe that the database is filled with inputted data
   b) Observe the database can record results sent from the robot

5. Camera Module
   a) Turn on the QR code
   b) Detect the QR code
   c) Observe that the QR code is decoded successfully
   d) Pass the decoded value to the database and the Robot Module

6. Motor Module
   a) Feed Identical 50% duty-cycle PWM signal for 2 seconds to the positive terminal of the left and right motors via H-bridge
   b) The robot must move forward and the displacement of the robot must be 10cm; if the robot veers to either side, one of the motors is not functional. If the displacement is less than 10cm, motor performance or battery performance is compromised
   c) Feed 50% duty-cycle PWM signal to the negative terminal of both motors for 2 seconds to move the robot back to original position

8.2 Integration Testing

After numerous times of individual parts of testing, KAFEI has planned to test in pairs. First, the network between databases needs to be set and camera and motor will be pair to be integrated. Since operating system is based on motor control motion and simultaneous camera's detection. They need to be in a stable in order to run office robot properly. The integration between pairs is most sensitive part that could have many error and exceptions because the language used in motor and others are different.

8.3 Prototype Testing

KAFEI has planned to do various scenarios to complete prototype test. Firstly, runs motors maximum hours to find out the battery problem and QR camera's functional .Secondly, from network calls robot in every station at the same time to figure out if the database crashes or mixes up. Thirdly, tests in exceptions cases that have been planned before and normal planning system. Lastly, the robot's safety, there could be unlike situation that people can hit the robot or unexpected things blocking the ways.

9. Conclusion

This Functional Specification includes the description of the core functions, requirements and reliabilities OADR. The prototype and the proof of concept devices are under development phase. The functional requirements marked as 2 will be included in the prototype of the product, targeted to be released on December 10, 2011. For the further development, if the time permits, the requirements marked as 3 will be included.

10. References

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