February 08, 2010

Dr. Andrew Rawicz
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Re: ENSC 440 Functional Specifications for a Flame Extinginuishing Intelligent System

Dear Dr. Rawicz,

Enclosed is our document, “Function Specifications for a Flame Extinginuishing Intelligent System”, which describes the functional specifications and requirements of our product. Our Flame Extinginuishing Intelligent System (FlexiSys) product will be able to address current inefficient methods of extinguishing flames. By utilizing motors, sensors, and algorithms, FlexiSys will be detect and sense a flame, then proceed to extinguish the flame.

Our functional specification will outline and define top-level requirements for our system design and our working model, and, for future possibilities. Furthermore, the enclosed document will specify requirements for the three main sub-systems: the motor configuration, the sensor configuration, and the extinguisher configuration.

The purpose of our funcational specifications is to will establish a working model which will be the basis for future research, development, and evolution for further iterations. If any there are any questions or concerns, please feel free to contact me.

Sincerely,

Kelvin Ho

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Functional Specifications

For a Flame Extinguishing Intelligent System

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Executive Summary

Sprinkler systems and other similar fire extinguishing systems all share three critical flaws: the inability to correctly determine a flame, the inability to aim the extinguishing material, and lastly, the inability to control the amount of extinguishing material. All these factors lead to several important and damaging consequences:

- Sprinklers can only suppress flames, not extinguish.
- Sprinklers will not stop if the flame is extinguished by human intervention.
  - Leading to excessive water damage.

FlexiSys' endeavor is to provide a solution to above problems that exist in residential, business, and industrial buildings. Development of FlexiSys will require three modular components, all to be integrated into a single system during the final phase. This final phase will have to follow several high-level functional minimum requirements:

- The system must be able to detect a flame in a hemi-sphere with a radius of 3m.
- The system must be able to control a nozzle to aim directly at the flame.
- The system must be able to extinguish the flame within 2 minutes.

Before our final phase, however, we will be creating a working model that will be able to detect a flame on a planar surface as a proof of concept. As the development for our final phase proceeds, these minimum requirements may be fine-tuned to greater detail. Furthermore, all requirements will conform to all standards and guidelines, such as those of the Consumer Safety Association. Additional requirements will be amended to our documentation as we proceed with our design specification and development of our working model.

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Glossary

ADC	Analog to Digital Converter
DTMF	Dual Tone Multi Frequency
FlexiSys	Flame Extinguishing Intelligent System
Hp	House Power
IC	Integrated Circuit
IR	Infrared
kP	kiloPascal
M1	Motor 1
M2	Motor 2
Psi	pounds per square inch
TRIAC	Triode Alternating Current Switch

1. Introduction

FlexiSys is a prototype flame extinguishing intelligent system which will detect flames in an area and proceed to extinguish the flames. Our product will ultimately be mounted on the ceiling, similarly to a passive fire sprinkler. Furthermore, we will try to minimize the power and space requirement, such that our product can replace current passive sprinkler systems with ease. We wish to obtain this goal, along with the following specifications and requirements by April 9th, 2010.

1.1 Scope

This document describes the minimal functional requirements that must be adhered to when we develop FlexiSys. Although we have created these functional requirements, they may and will most likely be altered as the project proceeds. This change in scope could be the result of funding, complexity, and most importantly, time. With this in mind, we will first and foremost design FlexiSys according to our requirements, with possible revisions during development.

1.2 Intended Audience

This functional requirements documentation is created primarily for our team members of FlexiSys. It will serve as a reminder and written measure during the entire life cycle of our product. In addition, it will provide those who are interested in our product, a quick and brief glance at the functionality of our flame extinguishing intelligent system.

1.3 Classification

For our requirements, we will use the following convention to classify them:

[Rn-p] – A functional requirement

n – Functional requirement number
p – Priority of the functional requirement, one of:

- **I** - Requirement applies to proof of concept system only
- **II** - Requirement applies to both proof of concept and final system
- **III** - Requirement applies to the final system only

2. System Overview

The Intelligent Flame Extinguishing System is a system that can be modeled at a high-level as shown in Figure 1.

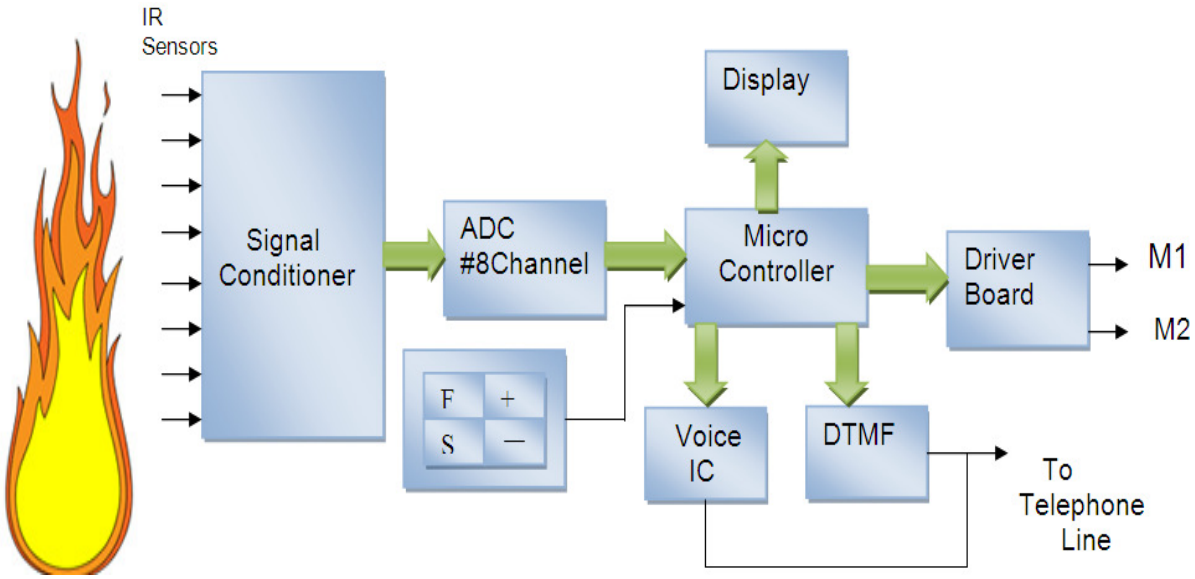

Figure 1: Block Diagram for the Completed Fire Fighting System

Due to time and budget constraints in the first stage of development, the components for voice IC, DTMF, FS keypad, display and telephone line will not be integrated into our fire fighting system, which means the main components of our system will consist of IR sensors, a 8-channel ADC, a microcontroller, a motor driver board, step motors, a water pump and nozzle.

The IR sensor is initially in standby mode when there is no fire. When a fire starts, there is significant infrared light emitting from the source. When the infrared light enters the monitoring range of an IR sensor, the IR sensor will send an analog signal to the ADC, which will convert the analog signal to digital signal. This digital signal will then be sent to the microcontroller informing that there is a fire. By controlling step motor M1 and M2 which are connected to the nozzle, the microcontroller will direct the nozzle to the location where the fire is. Once the nozzle turns to the right location of the fire, the microcontroller switches on the water pump immediately to drive water to the nozzle. When the fire is extinguished, the IR sensor will notify the microcontroller. In order to ensure the fire is totally extinguished, the microcontroller will keep the water pump on for an extra thirty seconds after it receives the kill signal from the microcontroller. Unlike current sprinkler

systems which will still splash water even if the fire is off, our fire fighting system will reduce the water damage to the building.

With more time and money, we could develop a more sophisticated system. For example, we can integrate an additional sub system that will dial 911 or any pre-stored number to report a fire.

3. System Requirements

General requirements applicable to the Intelligent Flame Extinguishing System as a complete system are presented in this section.

3.1 System requirements – General

[R1-I] The system shall actively detect fires.
[R2-I] The system shall spray water towards the direction of the fire.
[R3-I] The system shall respond in less than 5 seconds.
[R4-III] The system in standby mode shall be silent.
[R5-II] The system shall not leak water.
[R6-I] The water shall be able to reach the fire within 3 meters.
[R7-III] The system shall be easily installed in place of a traditional sprinkler.
[R8-I] The system shall stop spraying water after 30 seconds when the sensors determine that the fire has been extinguished.
[R9-III] The system shall revert to standby mode after the fire is extinguished.
[R10-I] The system shall (in standby mode) still be able to detect a fire.

3.2 System requirements – Physical

[R11-I] The system shall have aesthetic qualities.
[R12-I] The system footprint shall not be larger than an A4 paper.
[R13-I] The system shall hide all internal circuitry and motors from users.
[R14-I] The system shall weigh less than 5 kilograms.
[R15-I] The system shall have IR sensors.
[R16-I] The system shall have step motors.
[R17-I] The system shall have metal linkages.
[R18-I] The system shall have a water nozzle.

3.3 System requirements – Electrical

[R19-I] The power supply shall support all sensors, circuits and motors.
[R20-I] The power adapter shall be usable with a wall supply of 110v/120v at 60Hz AC according to North America standards.

[R21-III] The system in standby mode shall only have sensors active.

[R22-III] The system in active mode shall have sensors, circuits and motors active.

[R23-II] The system shall sound the alarm if no power is provided to the system.

[R24-II] Two size AA batteries shall be sufficient to provide power for the system's alarm.

3.4 System requirements – Mechanical

[R25-I] All moving parts shall be controlled by step motors.

[R26-I] The base of the system shall be able to rotate 360 degrees.

[R27-I] The water hose of the system shall be able to go between 0 and 90 degrees.

[R28-I] All motors shall have enough power to move the mechanism they are attached to in less than 5 seconds.

[R29-III] The motors shall be inside the enclosure.

[R30-III] The water hose shall be the only mechanism visible to the users.

3.5 System requirements – Environmental

[R31-I] The system shall be able to operate in an indoor setting.

[R32-I] The system shall operate within an elevation range from sea level to 2000m above sea level.

[R33-I] The system shall be able to operate normally between 15 to 300 ^{o} C.

3.6 System requirements – Standards

[R34-I] The system shall conform to all related CSA standards.

[R35-I] The system shall conform to CAN/ULC-S508-02 and CAN/ULC-S503-05 and any other ULC standards.

[R36-I] The system shall conform to ANSI Z21.40.1/CGA 2.91-96 and any other ANSI standards.

[R37-I] The system shall conform to National Fire Code of Canada.

3.7 System requirements – Reliability and Durability

[R38-III] The system shall be able to communicate a critical failure to the user.
[R39-III] The system shall be easy to replace.
[R40-I] The system shall last for at least 10 years.
[R41-II] The system shall be resistant to water.
[R42-III] The system shall be resistant to lightning.
[R43-I] The system shall be able to detect fire in all scenarios.
[R44-III] The system shall not respond to false positives.

3.8 System requirements – Safety

[R45-I] The failure of any electrical or mechanical component of the system will not cause any danger to the user.
[R46-I] The electronic components shall not cause interference with other devices.
[R47-III] The system shall be able to detect mechanical and electrical failure. Any error shall be notified to the user. In error mode, the system shall not allow water to leak out of the hose.
[R48-I] The system shall not spontaneously combust.
[R49-I] The pressurized water shall not cause harm to the user.

3.9 System requirements – Performance

[R50-I] The system shall be able to accurately detect a fire within 1 minute.
[R51-I] The system shall be able to extinguish the fire after detection in 1 minute.
[R52-I] The pressurized water shall reach the fire within 3m.
[R53-I] The pressurized water shall stop spraying 30 seconds after fire has been extinguished.

3.10 System requirements – Usability

[R54-III] The system shall be user friendly.
[R55-III] The system shall include a user manual.
[R56-I] The system shall not interrupt the daily activities of the user.

4. Motor and Nozzle Requirements

This unit is composed of two step motor drivers, two step motors and a nozzle. The main function of this unit is to direct the water to the fire when a fire has been detected, and to stop spraying water after the fire is extinguished. The requirements listed in the following subsections refer to terms that are defined below.

Azimuthal control motor, M1, is the motor that will rotate the nozzle with the rotation freedom of 360º azimuthally.

Altitudinal control motor, M2, is the motor that will rotate the nozzle with 90º of freedom in the altitude direction.

4.1 General Requirements

[R57-II] The two step motors must be in standby mode when there is no fire.

[R58-I] When there is a fire, M1 should rotate the nozzle to the correct azimuthal direction of the fire.

[R59-II] After M1 locates the azimuthal direction of the fire, M2 will rotate the nozzle to the right altitudinal direction.

[R60-I] Before M1 and M2 direct the nozzle to the right location of the fire, there should be no water coming out of the nozzle.

[R61-I] The nozzle should spray water at the fire right after it is directed to the right fire location.

[R62-I] The nozzle should stop spraying water 30 seconds after the fire is extinguished.

4.2 Physical Requirements

[R63-II] The two step motors must be able to generate enough torque to rotate the nozzle.

[R64-III] The nozzle must be able to rotate in both altitudinal direction and azimuthal direction after it is connected to the water pipe.

[R65-II] The water pressure in the nozzle must be strong enough so that the water coming out of the nozzle will be able to shoot within 3m.

[R66-III] The precision of the step motors will be 3 degrees maximum per step.

5. Water Pump Requirements

The water pump's primary function is to pressurize the water, such that all the nozzles in a building will be able to shoot water far enough to cover a room of approximately 5m by 5m. In order to reduce noise and pollution, the water pump is installed outside of the building.

The requirements in the following subsections reflect the guidelines prescribed by Saskatchewan Environment [1].

5.1 General Requirements

[R67-II] The water pump is only on when there is fire.

[R68-I] Max water pressure should not exceed 700 kPa (100 psi) to protect the water pipes.

[R69-III] Water pipes should be designed to withstand the transient pressures due to pump starts and stops.

[R70-III] The minimum mainline size should not be less than 50 mm (2 in) nominal diameter and the minimum lateral size should not be less than 38 mm (1.5 in) nominal diameter.

5.2 Physical Requirements

[R71-I] The water pump should have at least 0.5 horsepower.

[R72-I] The water pump should have short circuit protection for safety issue.

[R73-II] The water pump should be switched on and off by a TRIAC so that its state can be controlled by the digital signal coming from the microcontroller.

6. Flame Detection Sensor

Flame detection sensors are the “eyes” of the system. The purposes of these sensors are:

- To detect heat signatures (infrared light) from a burning object.
- Locate board direction and location of the fire or burning object.
- Base on heat signature, send signals to activate or de-activate extinguishing system

In general these sensors are used to locate the fire, send signals to a microcontroller to extinguish it and at the same time, try to minimize the water damage to the burning area only.

6.1 General Requirements

[R74-II] The sensors shall be reasonably small.
[R75-II] The sensors shall be light-weight.
[R76-III] The sensors shall be hidden from the user.
[R77-I] The sensors shall operate in room temperature from 15^{o} C to 300^{o} C.
[R78-I] The sensors shall be active all the time to detect fire.

6.2 Reliability Requirements

[R79-I] The sensors shall be able to detect fire or burning object within 1 minute.
[R80-I] The sensors shall be able to detect temperatures between 0^{o} C to 200^{o} C.
[R81-I] The sensors shall not fail to locate the direction of fire from the water hose location.
[R82-III] The sensors shall be guaranteed to be working for at least 10 years

6.3 Electronic Requirements

[R83-I] The sensors shall work with supply voltage less or equal than +5 VDC.
[R84-I] The sensors shall not drive more than 100mA.
[R85-I] The sensors shall give out serial output to decode into temperature.
[R86-III] The sensors shall be able to easily communicate with various microcontrollers.

7. Microcontroller

For this project, we need a “brain” to coordinate sensors and motors to be able to identify and extinguish the fire. The microcontroller will collect temperature readings from sensors and perform the condition evaluation to control motors for appropriate action. The general requirements of micro-controller we will need are:

7.1 General Requirements

[R87-I] The microcontroller will be able to transmit serial data.
[R88-I] The microcontroller should be able to create PWM output.
[R89-I] The microcontroller will have both digital and analog pins.
[R90-I] The microcontroller will be able to supply 20mA at least per pins.
[R91-I] The microcontroller will need at least 16 KB flash memory.
[R92-I] The microcontroller will need at least 1 KB SRAM.
[R93-I] The microcontroller will need at least 512 bytes of EEPROM.

8. System Test Plan

This section will outline the test plans to prove the functionality of FlexiSys system. In order for the system to work as a whole, each separate component is required to perform its job according to the requirements. Each unit is required to follow the functional requirements mentioned above and will be tested at different development stages. After ensuring that each unit works as they are supposed to, more thorough tests will be performed on the complete system. Many different user scenarios will also be considered during testing.

For mechanical components including motors, water pipes, nozzle, and pumps, tests shall include functionality tests and stress tests. Extreme scenarios will be manually inspected (high water pressure, motors frictions, nozzle friction,…) If any adjustments are made throughout the development process, functionality tests and stress tests will be repeated. After the mechanical system assembled, it will be tested as a unit before integrated with other subsystems.

For electronic units including sensors, circuits, and the microcontroller, functional tests will also be performed. Other tests such as power tests are also needed to obtain the power consumption of whole system. The power required by each electronic component will also be taken into calculation.

There will be software programs that will have unit tests and will produce flow charts to help debug the system. Any errors will be carefully examined to ensure safety.

8.1 Overall system basic functional test:

FlexiSys's endeavour is to bring a safe and reliable system as our products can save lives, therefore, our product will be carefully tested. Some basic functional tests we are planning to perform with our whole system are:

- Completely extinguishing a flame.
- Excessive water tests after extinguishing a flame.
- Extinguishment of an extremely hot object.

In addition, the overall system will have more tests such as different sizes of flames, different location of flames. Failed performance tests will be carefully studied and repeated multiple times for debugging.

9. User Documentation

FLEXISYS system is automatic. User interface is minimal. Information on products will be available to customers as well as following requirements:

9.1 General Requirements

[R94-III] User manuals will be available with the product in English.
[R95-III] Support should be available for repair, debugging.
[R96-III] Installation guide will be available with the product in English.
[R97-III] User manuals will be written for a customer with no technical expertise.

10. Conclusion

The functional specifications in this document clearly assign the necessary requirements of both the entire system, and the sub systems that are indicated. In brief, we hope to complete our first build, which will be a working model that will be able to detect a flame on a planar surface, and then extinguish it. Our second and final build will consist of a working model which will be able to detect a flame in a sphere followed by extinguishment. While our second build may not cover all necessary demands for our final production model, we expect it to establish a low price point for a complex system. We are expecting our final working model to be completed by April 9th, 2010.

11. References

[1] Arduino, *Arduino Duemilanove*, Feb 05th, 2010, http://arduino.cc/en/Main/ArduinoBoardDuemilanove

[2] Robotshop, *Parallax MLX90614 Infrared Thermometer Module (10 FOV),* January 31st, 2010, http://www.robotshop.ca/parallax-mlx90614-infrared-thermometer-module-10-fov-3.html

[3] Robotshop, *Parallax MLX90614 Infrared Thermometer Module (90 FOV),* January 31st, 2010, http://www.robotshop.ca/parallax-mlx90614-infrared-thermometer-module-90-fov-3.html

[4] Saskatchewan Environment, *Water Pipeline Design Guidelines,* January 31st, 2010, http://www.saskh2o.ca/DWBinder/EPB276WaterPipelineDesignGuidelines.pdf