Petronics MicroMousr Project

Team 77/MUM - Andrew Betbadal, Nick Radler, Katelyn Schoedl

ECE 445 Project Proposal - Spring 2019

TA: Amr Martini

1. Introduction

1.1. Objective

As technology has evolved to become more capable and affordable, the world has seen a significant change in the way humans entertain themselves. While our entertainment has become more technologically advanced, the way we play with our pets has stayed relatively the same, despite there being plenty of room for improvement.

Petronics, a startup founded in 2014, looked to tackle this problem by creating an advanced robotic toy for cats. They accomplished this goal by creating Mousr, a cat toy that can operate autonomously or interactively through a user based app. This product contains cutting edge technology, but comes at a price point too high for the majority of consumers. After speaking with the team, we will be building a functional, scaled down product called MicroMousr, with comparable functionality at a lower price point.

1.2. Background

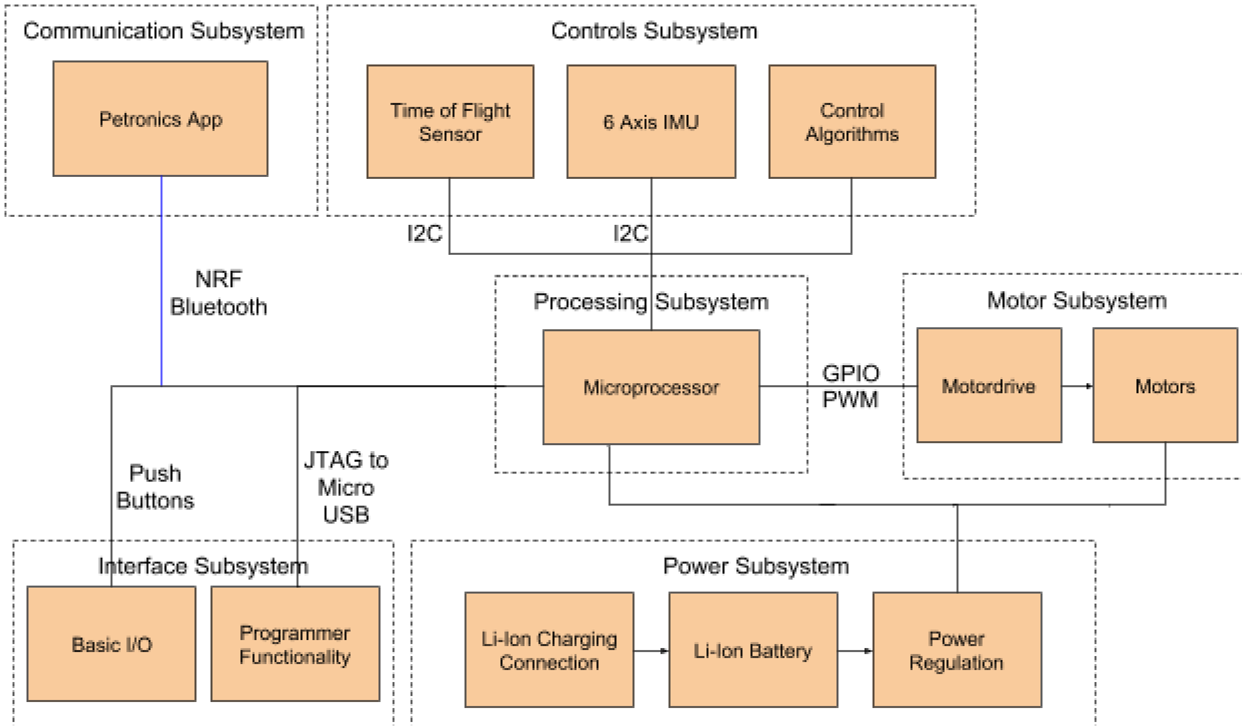
Petronics was founded with the goal of creating the best automated cat toy in the world. Their current product, Mousr, has had great success so far, but at its current commercial price of $149.99, it is only attractive to a relatively small market. This project is necessary to support the long term goal of the company by making this advanced technology available to a larger market.

1.3. High Level Requirements

1.3.1. Must link with existing Petronics app via Bluetooth.
1.3.2. Must be capable of operating for minimum 30 minutes on full charge.
1.3.3. Must have manual and autonomous driving capabilities.

2. Design

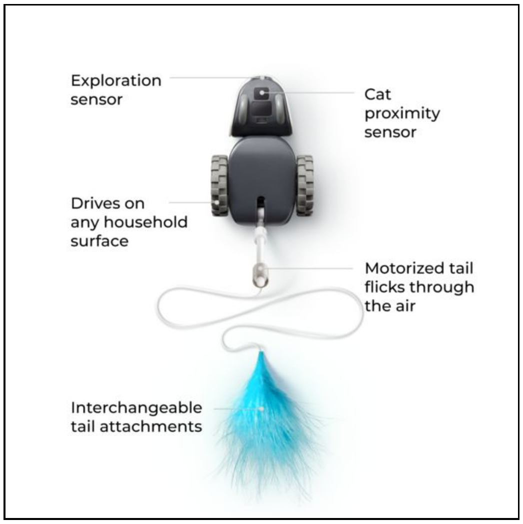
2.1. Block Diagram



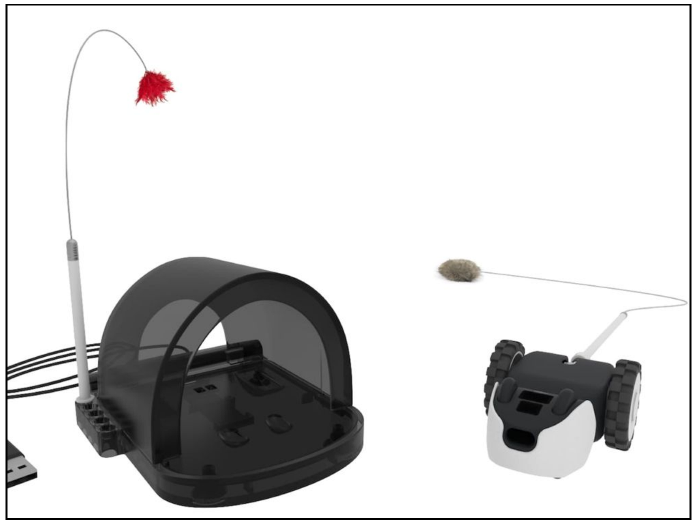
2.2. Physical Design

Following the design of a working electrical system, we will work with Petronics to develop a polycarbonate casting of the MicroMousr body. As this is ultimately a product for cats, the product will be designed to look like a mouse so there is a “head” and “body” portion of the device. We can use the current Mousr as reference for the mouse shape we plan to achieve. Mousr is 7.5cm x 5.8cm x 3.5cm. In MicroMousr, the physical design restraints of the charging dock will not apply, but we would prefer to keep the design at the same scale.

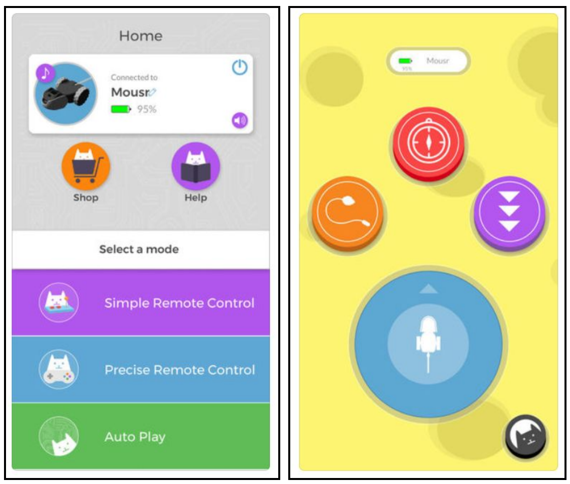
We plan to use the same durable wheels and tail components as the original Mousr. MicroMousr must work “on any common household surface including high pile carpet” and must be “highly durable - can stand up to even the toughest cats.” (Amazon.com). The shipping weight of MicroMousr should be less than 10 ounces. When considering the shell of the body, wheels, tail, and packaging, the electronic components of MicroMousr should weigh no more than 3 ounces.



Mousr Design (Source: Petronics.io)



Mousr with Charging Block (Source: TheGadgetFlow.com)



Petronics App (Source: apple.com)

2.3. Functional Overview/Block Requirements

2.3.1. Processing Subsystem

The processing subsystem is responsible for much of the system management within MicroMousr. A functional subsystem should be able to operate low energy Bluetooth communication, receive data transmission from sensor systems, and correctly drive a PWM signal to the Motor subsystem.

2.3.1.1. Microprocessor

The Microprocessor will be a Cortex M4 with an embedded NRF Bluetooth chip set. This chip is capable of communicating with Petronic's pre existing Mousr app and will be able to drive a PWM for the motor control subsystem by handling sensor readings.

Requirements :

1. *Step down voltage to supply 1.7-3.8 volts to power individual sensors.*
2. *Must be able to process information fast enough to respond to Time of Flight sensor 400kHz serial bus.*
3. *Transmit PWM signal via GPIO connection to motor drivers*

2.3.2. Controls Subsystem

The controls subsystem consists of an array of sensors that communicate environmental changes to the processing subsystem. In order to function effectively, the subsystem must be able to transmit real time changes with minimal latency using firmware that allows for powering on or off with minimal recalibration.

2.3.2.1. IMU

The inertial measurement unit (IMU) will be composed of a gyroscope and accelerometer. The gyroscope measures device rotation rate and the accelerometer measures the rotational position around those axes, giving the device 6 degrees of freedom.

Requirements :

1. *The IMU must be able to communicate with the M4 processor via I2C or SPI interface.*
2. *The IMU must accurately detect when the MicroMousr is lifted, tilted, or rotated, and transmit sensor readout with minimal latency (100-150 Hz sample rate).*

2.3.2.2. Control Algorithms

To achieve expected vehicle operation, the algorithms driving the motor subsystem must balance sensor input with appropriate motor performance.

Requirements :

1. *Algorithms should allow the moving vehicle to self-adjust based on sensor data.*

2.3.2.3. Time of Flight Sensor

The time of flight (ToF) sensor should be able to accurately sense cat activity and obstacles at a 2 meter range with no blind spots. The sensor should rest in a location at the top portion of the body for full visibility of surroundings.

Operating the device in shadows, darkness, or intense sunlight should not be a concern. The sensor emits a laser invisible to the human eye coupled with internal infrared filters. These considerations make the sensor data independent of obstacle reflectivity.

Requirements :
1. *The ToF sensor should be capable of detecting objects including cats, humans, and other obstacles at a range up to 2 square meters from the device with no blind spots.*
2. *Must be able to fit on board without losing distance capabilities and without requiring excessive PCB layout adjustment.*

2.3.3. Communication Subsystem

Full functionality of our device requires proper communication with the Mousr smartphone application.

2.3.3.1. Petronics App

The device can connect to the existing Petronics app via low energy Bluetooth (BLE) connection. BLE allows the device to operate with minimal power consumption as the device is kept constantly in sleep mode until a connection is initiated.

Requirements :
1. *Communicate signals at 2.4 GHz frequency while transferring data at rates up to 1 Mb/s.*
2. *Use Bluetooth to communicate user input signals to operate controls subsystem.*

2.3.4. Power Subsystem

We will be charging via microUSB with a modified JTAG connection to allow charging capabilities as well as programmer debugging capabilities.

2.3.4.1. Charging Connection

The device will be charged via a USB micro connection. Redesigning the power cable is also an opportunity to make the firmware more accessible for debugging.

Requirements :
1. *Must be capable of connecting with and charging the Li-Ion battery.*
2. *Cable must be able to debug through micro USB-JTAG redesign.*
3. *Charging connection can deliver 5W (standard Apple block charger).*

2.3.4.2. Li-Ion Battery

The Li-Ion battery will supply the rest of the system with charge and should be able to deliver enough power to support “ON” mode for an extended period of time.

Requirements :

1. *Reach full charge level after maximum 20 minutes.*
2. *Able to store enough charge to deliver 3.6-5 V for 30 minutes.*

2.3.4.3. Power Regulation

We will require two modes of operation. The first, “ON” mode, will fully power all components of the system. The second, “Low-Power” mode, will be considered the “OFF” mode to the customer. We will cut all power to peripheral components, and only power the M4 microprocessor in its low-power mode. In this state, the processor is in standby and awaiting an interrupt signal.

Requirements:

1. *Safely step down from maximum 6 Volts to power components in ON mode from 3.5-4.5 Volts and 250 mA.*
2. *Power the M4 processor with approximately 3 volts and .7 microAmps in low power mode.*

2.3.5. Motor Subsystem

The power subsystem consists of motor drivers that take in a PWM signal from the processor subsystem and convert this into real time signals for the motors on the product. In order to have full functionality, this subsystem must be able to receive PWM signal from the microprocessor and accurately direct the motors.

2.3.5.1. Motordrive

The motor drive system will accept a PWM signal from the microprocessor via GPIO connection and will consist of an H-bridge circuit capable of driving 2 DC motors

Requirements:

1. *Deliver motor control signal with latency of less than 500 ms*
2. *Can convert a 1-3.3 V PWM signal to 5V DC motor control*

2.3.5.2. Motors

We will be using two DC motors capable of moving the physical body of MicroMousr at a high velocity with minimal response latency

Requirements:

1. *Vehicle speed capacity in range of Mousr product line*
2. *Device maintains close to maximum speed on rough surfaces*

2.3.6. Interface Subsystem

2.3.6.1. Basic I/O

The device will include a mechanical push button for switching between on and off states. The button should be located in an accessible position on the body of the device without requiring significant electrical redesign.

Requirements:

1. *Robust and accessible push button able to switch between power modes with no delay.*
2. *Button circuit should be debounced to prevent oscillation of power states*

2.3.6.2. Programmer Functionality

The motherboard of the device will contain a JTAG port for debugging firmware. JTAG is a standard serial wire debug (SWD) for accessing the debugging interface of the microprocessor. Customers will never interact with the debugging features, but they will use the same port for charging the device.

Requirements:

1. *Redesigned cable for micro USB-JTAG connection.*

2.4. Risk Analysis

The element in our design that poses the greatest risk to completing our project successfully is going to be designing a PWM system and the correct control algorithms to properly control the motors/wheels. To lower costs, Petronics has enforced that they no longer want encoders included in the motordrive system. Their control algorithms make use of data that the encoders provide to properly control Mousr's movements.

In order to have MicroMousr have the same basic functionality as Mousr, it is absolutely critical to have it move like the original product. Without the same data the original control algorithms used, we will have to come up with a new way to decide how to tell MicroMousr how to adjust to changes in its environment.

3. Ethics and Safety

We must pursue this project in good faith of ourselves, the engineering department, the external company, and their customers. As stated in the *IEEE Code of Ethics* Item 1, we must "hold paramount the safety, health, and welfare of the public, to strive to comply with ethical design and sustainable development practices, and to disclose promptly factors that might endanger the public or the environment." In light of this, there are several potential safety hazards involved **with designing and prototyping** the MicroMousr system.

We will prototype our device only in approved spaces with adequate equipment and supervision. We must exercise caution while soldering and working with components of the battery, as emphasized in the Safety Quiz and safety guidelines of this course. ECE 445 safety guidelines state that designs utilizing a lithium ion battery must work with extra caution. The *Safe Battery*

Practices documents states that the battery must always be stored in a secure location with the terminals covered by insulating material (Section III). Additionally, we "will be REQUIRED to find the Material Safety Data Sheet (MSDS) and data sheet" and we must keep this documentation on hand at all times in the laboratory (Section IV). We must ensure we NEVER over charge, over discharge, over heat, or short circuit the battery.

We must also ensure that **the final produc**t is safe, with no risk of the human or the cat exposing internal electronics or otherwise misusing the product in a way that could produce electrical harm. To do this, we need to consider all possible environments the product may be used in. The parts we choose should be able to withstand environments such as extreme temperature or humidity. The sensors we are considering are functional at temperature ranges at least -20°C ~ 70°C. Should the cat drop the device into a sink or toilet, the sensors may malfunction nobody should be harmed at a maximum charge of only 6 volts. There should be no risk of dropping the device in a way that could open the mechanical chasse and expose internal components. The strong polycarbonate casting should protect the device from external damage, and the electronics should be properly mounted to prevent internal damage. Leaving the device in front of a window should not cause issues for the product.

In addition to prioritizing physical design safety concerns, there are **ethical considerations** to be made when working closely alongside an established company. The *ACM Code of Ethics* Item 1.2 states "Examples of harm include unjustified physical or mental injury, unjustified destruction or disclosure of information, and unjustified damage to property, reputation, and the environment. This list is not exhaustive." To adhere to these guidelines, we must keep proprietary information out of reach of unauthorized parties and respect the donation of time and supplies provided by Petronics and the engineering department. We must respect the reputation of Petronics and be frugal with the resources they provide for us. Misuse of available resources may lead us to directly break *IEEE Code of Ethics* Item 9, "to avoid injuring others, their property, reputation, or employment by false or malicious action."

We must adhere to *ACM Code of Ethics* Item 1.7, "honor confidentiality." To protect the integrity of Petronics, the device should in no way allow customers or unauthorized authorities to gain access to any design information. This includes firmware and specific component pricing.

Throughout the development phase, our project team must work together "to assist colleagues and co-workers in their professional development and to support them in following this code of ethics" (*IEEE Code of Ethics* Item 10). We will each **support one another in our own development** and strive to make the design process as seamless as possible. We do this as we strive "to achieve high quality in both the processes and products of professional work" (*ACM Code of Ethics Item* 2.1).

4. References

ACM. "*Code of Ethics and Professional Conduct.*" June 22, 2018. https://www.acm.org/code-of-ethics

Amazon.com. “*Petronics Mousr Interactive Robotic Cat Toy.*” Product, 2018. https://www.amazon.com/Petronics-Interactive-Robotic-Automatically-Smartphone/dp/B07HBC5M6Q/ref=cm_cr_arp_d_product_top?ie=UTF8

IEEE. Policies, Section 7 - Professional Activities. “*Code of Ethics.*” February 2006. https://www.ieee.org/about/corporate/governance/p7-8.html

Petronics.io. *Mousr*. [Product, 2018.] https://petronics.io/products/mousr

Senior Design Project Laboratory. “*Safe Practices for Lead Acid and Lithium Batteries*.” April 13, 2016. https://courses.engr.illinois.edu/ece445/documents/GeneralBatterySafety.pdf

Timms, Ashley. Gadget Flow Inc. “*Petronics Mousr Robotic Cat Toy.*” August 20, 2018. https://petronics.io/products/mousr