Milestone Report I

Autonomous Thermal Camera EE449

April 9, 2010

Ramses Eduardo Alcaide Aguirre, John Thomson, Adrian Haruta

Executive Summary

The purpose of this milestone was to ascertain a controls project and begin the initial steps toward completing the project. This consisted of finding a customer, understanding the project of the costumer, compiling the specification asked by the costumer and planning the work that will be done. Additionally, preliminary system modeling was done and identification of the required electrical and mechanical components was done.

Contents

1 Introduction

One of the contributors to global climate change and forest ecosystem deterioration are wildfires. To study wildfires researchers use cameras to record the fire and retrieve information. Currently, this form of information gathering has flaws that cause information loss. To solve this an autonomous thermal camera is being developed for Dr. Ernesto Alvarado at the University of Washington School of Forest Resources. The specification needed to engineer the thermal camera are shown below:

- Camera must be able to rotate toward fire as it approaches
- Camera must be able to turn on automaticly when fire is 50 meters away
- Camera must be able to film in the infrared wavelengths from $8\mu m - 15\mu m$
- Camera must be able to operate in 800-1000° Celsius with peak spikes of 1930° Celsius
- Camera must be able to withstand 50mph winds

To accomplish this we plan on shielding the thermal camera from the heat by developing a thermal energy retardant box with IR windows to allow the camera to monitor the wildfire from within. A stand will be constructed that the thermal energy retardant box will be mounted on that can handle 50 mph winds without falling. Additionally we will use thermopiles as sensors to determine the direction of the fire and turn on the camera when the fire is 50 meters away. A DC motor with an encoder will be used to orient the camera to the correct orientation of the approaching fire. A micro-controller will be used to control the motor depending on data received by the thermopiles.

2 List of Symbols

- Motor winding resistance R_m (Ω)
- Motor winding inductance L_a (H)
- Torque constant K_T (N-m/A)
- Motor constant K_v (V-sec/rad)
- Back-emf voltage e(t)
- Nonlinear friction B_m (N-m)
- torque delivered by the motor T(t) (N-m)
- Armature voltage $V_a(t)$ (V)
- A disturbance torque $T_L(t)$ (N-m)
- motor drive inertia J_m (kg-m2)
- Change in current $\frac{di(t)}{dt}$
- Initial Angular Acceleration $\ddot{\theta}(0^+)$

3 Identification of The Plant

The plant consists of a tripod stand with a mounted thermal energy retardant box. Internally the box consists of a quadrature DC motor controlled by a micro-controller receiving inputs from six thermopiles. The electrical side of the DC is governed by Kirchkoff's voltage law as shown in equation 1. Using Faraday's law we get equation 2 where $K_v(V - sec/rad)$ is the motor constant.

$$V_a(t) - e(t) = L_a \frac{di(t)}{dt} + R_m i(t) \tag{1}$$

$$e(t) = K_v \omega(t) \tag{2}$$

Respectfully the mechanical side of the DC Motor is governed by newtons second law as shown in equation 3.

$$J_m \frac{d\omega(t)}{dt} = T(t) - T_L - B_m(\omega)(t) \tag{3}$$

Thus our DC motor is determined by the motor drive inertia J_m (kg-^{m}) which can be expressed as shown in equation 4.

$$J_m \approx \frac{K_T V_a(0^+)}{\ddot{\theta}(0^+)(R + R_m)} \tag{4}$$

This is the inertia of our motor which is determined by the transient response depending on the initial angular acceleration of our motor.
More details on the model will be added as parts lists are finalized and further investigation is done.

4 Electrical

The purpose of the [robotic camera housing] is to increase the probability of taking useful thermal footage of a wildfire versus leaving a stationary camera housing. To accomplish this goal, the [robotic camera housing] will point the thermal camera in whatever direction flame is detected, or in the case of lots of fire, in the general direction of the heart of the fire. For the initial prototype, the [robotic camera housing] will sport a single degree of freedom: rotation around the vertical axis. This capability should sufficiently accomplish the purpose of flame tracking. In order to control this system, the following hardware will be implemented:

- Actuators:
  - 1 rotational motor
  - Switching circuitry for enabling/disabling the camera
- Sensors:
  - Motor encoder
  - 6 thermopiles for directional flame sensing
- Controller:
  - PI controlling rotational position implemented using an Arduino

The proposed algorithm for flame tracking utilizes the six thermopiles in two modes. First, before a fire is detected, the [robotic camera housing] will operate in a low power mode, with only the microcontroller and sensors consuming power. When any thermopile detects a substantial rise in infrared radiation, the [robotic camera housing] will enter tracking mode, when the thermopile with a substantially larger reading than the others will trigger a rotation in that direction. With the camera window and the three forward thermopiles pointing in the general direction of the fire, the box will rotate until the central thermopile has the highest intensity of the three. This way, the [robotic camera housing] is guaranteed to be pointing at the most interesting part of the forest fire as it passes through. As soon as the fire engulfs the box itself, the inexpensive thermopiles will almost certainly be destroyed. At this time, since it's already looking at flame, the housing will stop tracking the fire and enter passive filming mode. This behavior will allow the camera to observe the burn process during and after the peak intensity of the wildfire.

5 Mechanical

The primary mechanical challenge for this project is protecting the camera that will record the wildfire. To achieve this a setup that can resist extreme heat is needed. To achieve this a thermal energy retardant box is being developed. The thermal energy retardant box must not degrade or change shape during extreme heat and must maintain an environment of less than 50 degrees Celsius within. The initial plan for the development of the thermal energy retardant box are as follows:

- Design a CAD Model
- FEA analysis 1 dimensional heat transfer through the box
- Research into microcellular phase change materials

The CAD model will created in solid works. A 3D model to scale and a blueprint will be created for water jet cutting well as visually displaying the design ideas. A Finite Element Analysis will be modeled in 1 dimension where to trace the propagation of heat through the materials as a function of time and insulation thickness. The information gathered during the Finite Element Analysis will be used choose the exact box dimensions and insulation thickness based on the material used. For additional cooling and to prevent the deformation of the thermal energy retardant camera a microcellular phase change materials and gold reflective file will be used.

6 Cost and Scheduling

Currently costs have not been finalized as the research is still being done regarding the final materials for the thermal energy retardant box, however the current budgetary constraint is of $3000 dollars. The current ongoing schedule is shown in table 1 and will be updated as parts of the project develop. Schedule constraints are to finish before lab visitation.

Table 1: Current Schedule

Week	Goals
1	ID Challenges
2	Mech. Modeling
3	Elec. Modeling
4	Mech. Development
5	Integration/Testing
6	Design Changes
7	Redevelopment
8	Testing

Table 2: Current Costs

Item	Quanity	Cost
Atmega	1	4.32
H-bridge	1	4.34
Thermo Piles	6	1.9
Motor	1	50
Titanium Sheets		0
Thermal Insulation		0
Phase Change Mat		0

7 Technical Obstacles

The primary technical obstacle is that of keeping the extreme heat outside of the box such that a temperature of less than 50 degrees Celsius can be maintained inside. This challenge includes not only the conduction of heat but also the radiation from the IR windows being used. Additionally the original design had problems keeping heat out because it used a connecting rod that runs directly from the tripod to the gear system inside of the box. This was solved using a separate tripod and box with male and female hexagonal pieces used to mount the box onto the tripod.
Furthermore, finding IR windows that can resist the heat requirements has proven difficult. Although glass can withstand the heat of wildfires, glass

blocks the wave lengths required in our specifications. One alternative currently being investigated is a Zinc Selenide(ZnSe) IR window. ZnSe has a melting point of 2000 degrees Celsius, allows light to pass within our required wave lengths and has very little thermal run away.

8 Team Management

Currently all progress has gone to schedule and communication has remained high. The primary challenge is the mechanical aspect of the project and work is being distributed as problems are encountered.