Design Project Proposal

EECE 401 Senior Design I
Department of Electrical and Computer Engineering
Howard University

MEMORANDUM

12/1/2009

TO: Dr. Charles Kim
Instructor

FROM: Tolulope Kupoluyi ________________________ {Signature}
Oluwayemisi Sonoiki ________________________ {Signature}
Danah Warren ________________________ {Signature}

SUBJECT: Design Project Proposal Submission

Enclosed is our group's design project proposal for the Lunar Satellite Attitude Determination System. This proposal is submitted for partial fulfillment of the Senior Design requirement outlining the plan for the project pursuit through the problem formulation with functional requirement, alternative solution generation with electrical and computer engineering approaches, project management and milestones, and task assignments and deliverables. We understand this proposal, in written report as attached and oral presentation upon scheduled, would undergo a rigorous Proposal Review Panel assessment, and we are willing to accept recommendations from the Panel Review and modify and resubmit for final approval.

Design Project Proposal

Lunar Satellite Attitude Determination System

Submitted by

Tolulope Kupoluyi
Oluwayemisi Sonoiki
Danah Warren

Approved by

Proposal Review Panel Representative:

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Name Signature Date

Senior Design I Instructor:

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Name Signature Date

Lunar Satellite Attitude Determination System

Introduction

Developing a very simple system for Lunar Satellite Attitude Determination is an engineering problem that is highly encountered by astronauts, cosmologists, and agencies that actively participate in space navigation and studies. However, relatively little is known on how this problem could be solved. Although scientists have in the past tried to solve this problem, the solutions that they have derived still utilize complex algorithms, and thus, there is a need for a much simpler approach. The major objective of our Senior Design Project is to design a very simple prototype, tested on earth, for Attitude Determination that would provide an easier and less complex solution to the current problem.

The main purpose of this project would be to simulate a prototype that would be able to determine the attitude of a system by following a light source. The idea behind this 'box-on tripod simulation' solution could then be used to build the attitude determination system to be used by an actual satellite during a mission. According to Honeywell, the actual satellite may be just a simple and low-cost Lunar Satellite flying near the moon for a period of up to three years without any on orbit maintenance. Some of the basic questions that we plan to consider in the design of our prototype to ensure that the same idea could be used for an actual satellite includes: where the actual satellite is located, the direction of the actual satellite, and the time. Throughout this proposal, we explain how we plan to achieve the objectives of this project, the timeline, roles for each group member, current state of art and design requirements.

Problem Definition

The main objective of our system is to determine the orientation of a box that would be suspended by a tripod. This box would be used to represent the actual satellite. It should however be noted that in an actual satellite, Attitude determination and control is needed because there are various torques affecting a body in space. These include the gravity gradient (torque due to variation of gravity acting on different parts of the spacecraft), solar radiation (due to solar radiation forces acting on the spacecraft surfaces), atmospheric drag (atmospheric molecules colliding with the spacecraft, similar to solar radiation pressure), and magnetic torque (interaction of any residual spacecraft magnetism with the earth's magnetic field). Micrometeorites impacts and internal forces also affect the attitude of a spacecraft in space.

Our solution must determine the attitude of a box using optical sensors. The system should also have an interface for presenting the attitude information. The probable constraints in this design are cost, available technology, and the already existing standards that must be met. In addition to these constraints, there are also safety rules and regulations that must be followed. In this project, we are constrained by a budget of approximately $1000 and an inability to test our final prototype on an actual spacecraft that would be orbiting the moon. This is the main reason why the team would attempt to solve the problem by providing a solution that is formulated in such a way that we test the final prototype from earth. Also, the team would have to find a way to compare the obtained attitude information with a more accurate method to check the system's accuracy.

Current Status of Art

Currently available Attitude Determination Systems that are relatively similar with what we are trying to build utilizes large algorithms to determine the attitude of a satellite. There are currently two main methods for attitude determination:

1. Deterministic Method
- Measure two vectors in body frame
- Know these vectors in the reference frame
- Ephemeris, calculations (need to know position in orbit)
- Find the rotation matrix, i.e. the attitude

2. Estimation Method
- Measure one vector in body frame
- Recursive process
- State estimation
- Facilitated by gyros measurements

A specific example of a system currently in use would be the Lunar Reconnaissance Orbiter (LRO) which is the first mission in NASA's Vision for Space Exploration, a plan to return to the moon and then to travel to Mars and beyond. It must be noted that the LRO has an objective that is broader than attitude determination alone. The LRO objectives also include finding safe landing sites, locate potential resources, characterize the radiation environment, and demonstrate new technology. These satellites have an advantage of possessing a very high degree of accuracy. The goal of this project, however, is to come up with a design that would perform the function of attitude determination to a relatively coarse degree of accuracy.

Engineering Approach

As previously stated, it is our objective to provide a system for attitude determination for a box suspended by a tripod. In addition, the solution should provide a means to show such determined attitude information on an interface.

Proposed Solution

As highlighted in earlier sections, our project is to build a simulation of a Lunar Satellite Attitude determination System designed for a satellite orbiting the moon. This simulation would be in form of a small box with sensors following a light source. To effectively determine the attitude of our box, the system must comprise of both input (responsible for acquiring information form sensors, determining the object’s position in relation to a flash light, and determining if such an attitude is appropriate), and an output component (responsible for receiving information from the input and showing relevant details on a user interface). The use of a real satellite would have been preferred for this project but it is not very practical, hence the need for a ‘box-on-tripod simulation approach'. It would have been good to take advantage of the rotation of the Earth to simulate orbital motion however this would be too slow. We therefore simulate cylindrical motion using rotating device right under the box. In addition, we use some servos or stepper motors for attitude motion simulation.

Our primary approach is to construct a prototype that will exhibit the intended behavioral response to light input that will be the basis of attitude determination for an actual satellite. Therefore, we envision a prototype system that will respond to the position of a light source (input) by adjusting its position on a fixed axis (output). As stated earlier, due to the slow movement of earth with respect to the sun during the day and the unpredictable nature of the weather, natural light sources are not feasible input providers. To this effect, an artificial source of light (e.g. a flash light that we would be using) would be more realistic. Although specific dimensions of the box are still in consideration, a general description of the targeted prototype is given below:

1. The prototype will consist of a box (which will house the required hardware) and a tripod stand support to hold it in place but still allow free movement of the prototype.
2. The aforementioned object will be fixed with photo sensors on its six faces and a display on one face to show the change in attitude.
3. The control system, which comprises of the input processing system and the motion controlling hardware, will be contained within the box.
4. A flash light would serve as the artificial source of light.

The basis of the operation of the prototype will be as follows:

> The box will be mounted on its stand in such a way as to allow motion but still remain on a fixed axis. At this instance, the box will be at its reference frame position i.e. all planar coordinates will be at 0 degrees. The input sensors will respond to the external source of light by corresponding to the control system that it has detected a light source of recognizable intensity. As the light source is then moved (the speed of movement of the light source has to fall within a certain acceptable range), the input sensors will correspond the drop in intensity of the light source to the control system. The control system will then respond by enacting movement to achieve a position where the input sensors will again be receiving the optimal amount of light intensity. The planar deviation of the box from its original position (reference frame) will be tracked and reported on a display on the unit. This will effectively show the attitude change of the box.

Tasks and Deliverables

Our tasks and deliverables are as follows:

• Research even more on the topic of actual attitude determination in a spacecraft (possible factors/torques acting on an object in space near the moon, most common circumstances under which a problem might occur in the process of attitude determination and how such problems could be simulated on earth and countered)

• Brainstorm on different ways to determine the position of a box suspended by a tripod:
   1. With respect to a light source
   2. The co-ordinate systems to be observed

• Develop a problem formulation containing such factors as:
   1. Devices to be used
   2. Proposed problem to be solved through implementation of prototype
   3. Cost
   4. Environmental effects
   5. Regulation requirements

• Carry out research on US Patents to determine which kinds of attitude determination and/or systems are already available for both actual satellites and small suspended bodies here on earth.

• Brainstorm and derive ideas on more ways to tackle this problem

• Determine what prototype design would be the best option for the project, team, and eventual user (Honeywell in this case)

• Determine the dimension of the box that would best represent a satellite

• Order sensors and additional parts

• Determine standard that the box prototype would be compared with.

Major Goals

1. Project must be completed by March 2010
2. Final product must be ready for demonstration ECE Day.

Deliverables

Final product would include:

1. Program
   a. User interface
   b. Computer (to provide the control loop driving a servo to track the Sun or Moon.)

2. Prototype
   a. Box
   b. Digital Sensors
   c. Coarse Sensors
   d. Servos or stepper motors for attitude motion
   e. Tripod Stand
   f. Light Source
   g. Device to allow for cylindrical motion of box (to simulate rotation of a satellite)

Project Management

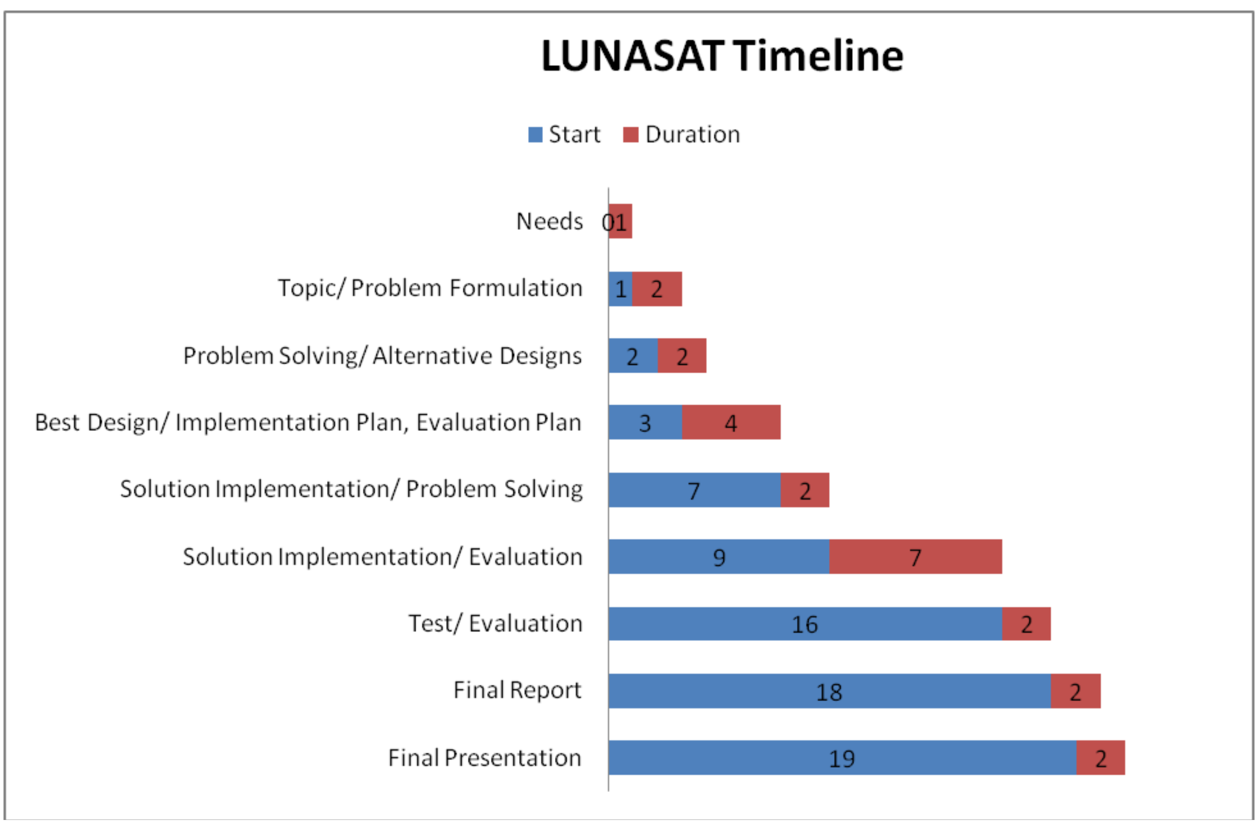
Roles have been divided as follows to increase team productivity.

Danah – *Project Manager*. Ensures deadlines are met; checks up on individual tasks. Enforce project timeline and determines when it should be adjusted. Determines if team is making progress and success and decides when things need to be done differently to ensure goals are achieved. Keeps track of minutes of meetings and other written documents related to the project. Makes sure that all individual assignments are combined together appropriately.

Oluwayemisi – *Lead Researcher*. Responsible for researching problems, constraints and how to implement solution.

Tolulope– *Lead Developer*. In charge of all simulation and code writing.

To complete our project, we will need to constantly keep in touch with the project advisors, professors from the Physics department, and the instructor of the class. We will also need to use the internet sources and the library to further research our design topic. This project is a typical non-trivial engineering problem that if solved properly would contribute greatly to the engineering world. However, safety precautions must be taken while choosing a method of designing the prototype. The team mould endeavor to build a simple and creative solution that meets all the necessary safety rules and regulations to ensure that our final product is useful, efficient, and safe for use during space navigation.



Conclusion

In this project, we present a system which has the potential to reduce the dependence on a very complex and expensive system for attitude determination in satellites if the idea behind our box solution is carried unto satellite systems and replicated there. On an actual satellite, the functioning of the system will be to constantly determine the attitude of the satellite (as it does for the box in our prototype), and provide relevant information in an easy to understand way on a user interface (just like in a prototype). Several other factors would have to be considered for an actual satellite. These include more torques, the yaw-pitch-roll factor, and how safe, reliable and accurate the system would be. It must be noted that while building our prototype, not much emphasis is placed on the accuracy of the system but this is a very important factor for real satellites.

In addition, if the design presented in this proposal is implemented successfully on a real satellite, it may also serve as a back up to existing attitude determination systems in satellites in the event that existing systems unexpectedly fail while on a mission. This would be important in serving such a back-up role because in this project, we make use of technologies that are not currently utilized, making it very difficult for the system we build to fail whenever existing systems unexpectedly fail. For example, the use of GPS (although not used in space) and magnetic fields to determine the attitude of the spacecraft would not be utilized in this project. The successful completion of this project shall require our knowledge in Programming, Astronomy, Optics, Electronics and Interface of computers to hardware, data processing, filtering, and state estimation algorithms.

The team comprises of both Electrical and Computer Engineering majors that are competent enough and possess the fundamental engineering knowledge required to meet the objectives of the project. The cost of this project is limited to $1000 and this would be a major constraint however, the team would work hard to keep total cost to this minimum. The main goal is to have the project ready by March 2010. Everything in this report is subject to change after review and feedback which we eagerly look forward to.

Attachment: Final Design Requirement Form

DESIGN REQUIREMENT LIST

The design requirements are as follows:

Design Project Title:	Lunar Satellite Attitude Determination System
Team Name:	Epoch
Team Members:	Oluwayemisi Sonoiki, Tolulope Kupoluyi, Danah Warren
Date:	12/1/2009
Version No.	3

Requirements	Descriptions	Sources
Overall Function	To design and simulate a prototype that would be able to determine the attitude of a system. The idea behind the selected solution should be	Honeywell

	replicable in building a "simple" attitude determination system for an actual low-cost satellite.	
Performance	❖ Prototype would consist of a box which will house the required hardware and a tripod stand support to hold it in place but still allow free movement of the prototype. ❖ Box would be fixed with photo sensors on its six faces and a display on one face to show the change in attitude. ❖ Control system comprising the input processing system and the motion controlling hardware, will be contained within the box. ❖ Flash light would serve as the artificial source of light.	Team Epoch
Cost	❖ The prototype shall cost less than $1000.00 ❖ The following must be procured for a total cost less than the aforementioned amount: a. Box b. Servos or stepper motors for attitude motion c. Tripod Stand d. Light Source e. Required Interface f. Sensors (Optical)	Team Epoch
Safety	❖ Safety to be ensured by making the planar deviation of the box from its original position (reference frame) to be tracked and reported on a display on the unit. ❖ Accuracy however, would not be a focus in the design process as only a coarse degree of accuracy is needed. ❖ Final prototype must be tested continually for one month prior to ECE day to verify performance capabilities are operationally safe. ❖ Device would be used only when weather is conducive to prevent possible hazards.	Team Epoch
Compliance	Must be designed in accordance with recognized standards and regulations.	-
Interfaces	❖ The system would have an interface for presenting the attitude information. ❖ An output component would be responsible for receiving information from the input and showing relevant details on the user interface. ❖ The solution should provide a "means" to transmit such determined attitude information to the selected interface.	Team Epoch
Energy, Power, and Environment	❖ The system shall use less than 10 watts of power. ❖ The prototype shall operate in an urban campus outdoor environment.	Honeywell
Lifespan	The lifespan shall be a minimum of 3 years.	Honeywell
Size, Weight, Maintenance	❖ The system shall weigh less than 10 lbs ❖ The system shall not require any maintenance for at least 1 year.	Honeywell, Team Epoch.
Timeline and Schedule	❖ Meetings would be held at least once a week during the fall semester, and twice a week during the spring semester beginning January 2010. ❖ A prototype will be completed by March 2010 to allow for further testing of performance capabilities and any necessary modification.	Team Epoch