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VERSION 2.0

# ROBOTIC PLANT MEASUREMENT SYSTEM

## PROJECT PLAN


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## PROBLEM STATEMENT

While conducting agricultural experiments, researchers must take a variety of measurements of every research specimen. Currently this process is done manually by research technicians walking the fields. This process requires extra personnel, time and money for the project. Our clients wish to develop a system that could automate these agricultural measurements using a robotic platform. An automated system would then reduce the personnel required, and the time spent by researchers gathering information about their specimens.

In this project, our group is designing a cooperative robotic system containing a ground vehicle and an instrumentation arm connected at a single pivot point. This instrumentation arm will then be balanced primarily by four propellers located at its top, with some assistance from the movement of the ground robot. Our main goal is to design and construct a laboratory proof of concept for such cooperative system to demonstrate its feasibility.

## DELIVERABLES

### FIRST SEMESTER

- Spherical inverted pendulum stabilized using the propeller balancing system
  - 1-Degree of freedom (only able to rotate around the Y-axis)
  - 2-Degrees of freedom (freely able to rotate around the X-axis and Y-axis)
- Ground vehicle
  - Have a reliable ground platform
  - Ability to compile software for the platform
  - Get a stable base for mounting of pendulum
- Log and analysis of data
  - Measure flight data from quadcopter
  - Measure data from robot
  - Have a uniform format for log data from quadrotor system and ground vehicle

### SECOND SEMESTER

- Cooperative system between the quadrotor system and ground vehicle
  - On-vehicle sensing to provide positional feedback
  - On-vehicle control processing
- Two-Degrees of freedom instrumentation arm balanced on a moving ground vehicle
  - Balanced primarily using the propeller system, with assistance from movements of the ground vehicle
- Control GUI for ground vehicle
  - GUI can assist with data logging

## SPECIFICATIONS

The systems designed by this project will be expected to meet the following criteria.

### INSTRUMENTATION ARM SYSTEM

- Allow measurements above the top of the corn (up to 12ft high)
    - Our development environment restricts us to ~6-7ft high - if we prove that this project can be completed, a future team will develop the larger system
- Stabilization of self with top-heavy system of propellers attachment
    - Feedback regarding position and orientation of the instrumentation arm should be provided by sensors installed on the Instrumentation arm and it's components
- Should automatically rebalance in response to disturbance and error
- Continually stay balanced above the ground vehicle while the vehicle moves over uneven ground (slow speeds ~ 1.3 m/s)
- Utilizes a real-time linear feedback controller
- The Instrumentation arm will ideally be attached to the ground vehicle through a joint that gives full range of motion in 2D, but does not allow yaw of the system (spinning)
    - An actuated gimbal sensor may require custom design, but it would best fit our needs
    - A fallback system is a joint similar to a universal joint, but this is not ideal

### GROUND VEHICLE SYSTEM

- The system should reliably receive commands and translate them into motion
- The vehicle structure should be able to provide a sturdy support base for the Instrumentation arm
- On vehicle processing should handle computing for the ground vehicle as well as the system of propellers
- Receive commands from a user interface
- Contain battery source for the entire system (system of propellers, Instrumentation arm, and the ground vehicle)

### DATA LOGGING AND ANALYSIS SYSTEM

- Log the values of run-time parameters and variables during the experiment
    - Collect relevant data from both the quad-rotor and the ground robot
- Analyze runtime data post experiment
- System is easily reconfigurable to account for new variables or discard current ones
- Quick and simple in generating analysis to primarily serve debugging and/or development purposes

## CONCEPT SKETCH

The system consists of four main parts, the ground vehicle, the Instrumentation arm, the system of propellers, and a computer for wireless control and data logging. Figure 1 shows a simplified image of how everything interacts with each other.

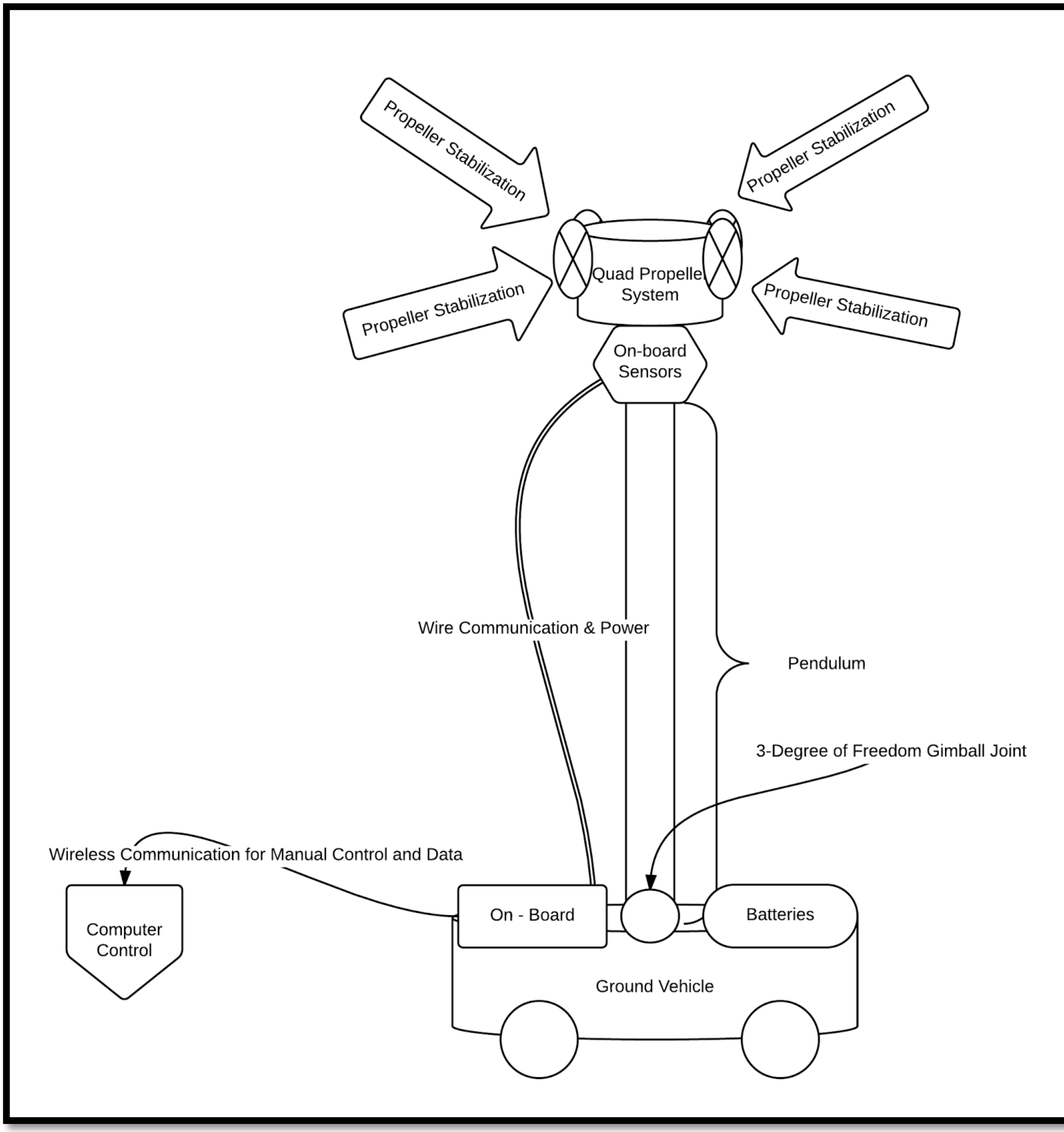


**FIGURE 1: HIGH-LEVEL DIAGRAM OF SYSTEM**

## SOFTWARE AND CONTROLS

The cooperative system will be designed so that the propeller system will follow the movements of the ground vehicle in order to keep the instrument arm balanced. The commands to move the entire system will come from a GUI that transmits them to the ground vehicle. The ground vehicle will then handle the computation of the entire system and send commands to the stabilizing propeller system.

## DATA LOGGING AND ANALYSIS SYSTEMS

This system consists of log files that hold runtime data of individual experiments. A MATLAB environment reads the logged data and generates data in the form of graphs and matrices for analysis and computational purposes.

## ALTERNATE DESIGNS

- Actuation only on top of instrumentation arm
    - ➔ In the event that an actuated-gimbal joint cannot be adapted for use in this system, a universal joint fixing the yaw direction can be used. The actuation that was going to be supplied by the gimbal joint will then be supplied by the motor system on top of the instrumentation arm.

- Yaw control generated by motors on top of instrumentation arm
    - ➔ In the event that the gimbal joint between the robot and the instrumentation arm cannot provide yaw control, the four motors in the motor system can be angled slightly from vertical to provide the required yaw control.

# USER INTERFACE DESCRIPTION

## HARDWARE

Hardware includes:

- Quad Rotor System (DJI F450 Frame, Motors, ESC and sensors)
    - High strength polymer 4-winged frame: Necessary to house motors and any hardware required by motors as well as sensor hardware
    - ESC: powers motors and interprets data signal into motor instructions
    - Motors: Necessary to provide actuation (thrust in this situation) to stabilize
    - Sensors: Will require gyroscope and acceleration sensor. Also open to addition of GPS for location
- Ground Vehicle:
    - Pluto PC board running Linux
    - PCI bus adapter board
    - Mesa 4i68 motor controller board
    - Frame: Custom chassis from 2010 senior design
    - Motors: Four motors on four edges of the circular frame. Each motor is powering the movement of an omni-directional wheel.
    - Wheels: omni-directional wheels which allow for movement from side to side whether the wheel is turning or not.
- Gimbal Joint:
    - Joints: the gimbal joint is made up of two joints which are perpendicular to each other which allow for motion along two axes.
    - Sensors: May be included in the motors. If not, these must be added to measure angle of the instrumentation arm
    - Servo Motors: Motors will be used to assist in actuation so that all actuation is not dependent on the quad rotor system only.
- Instrumentation Arm:
    - Wiring:
    - Aluminum pole:
- External computer:
    - Communication System: Allows for communication to the system to send commands or reprogramming.
    - PC: external computer running software to enable transmission of commands to the system.

Figure 2 represents the “final” set-up of the propeller pendulum model. It consist of a ground robot running a Linux operating system, a system of propellers sitting on top of an instrumentation arm that is used for balance, and a computer for sending commands and receiving system feedback.

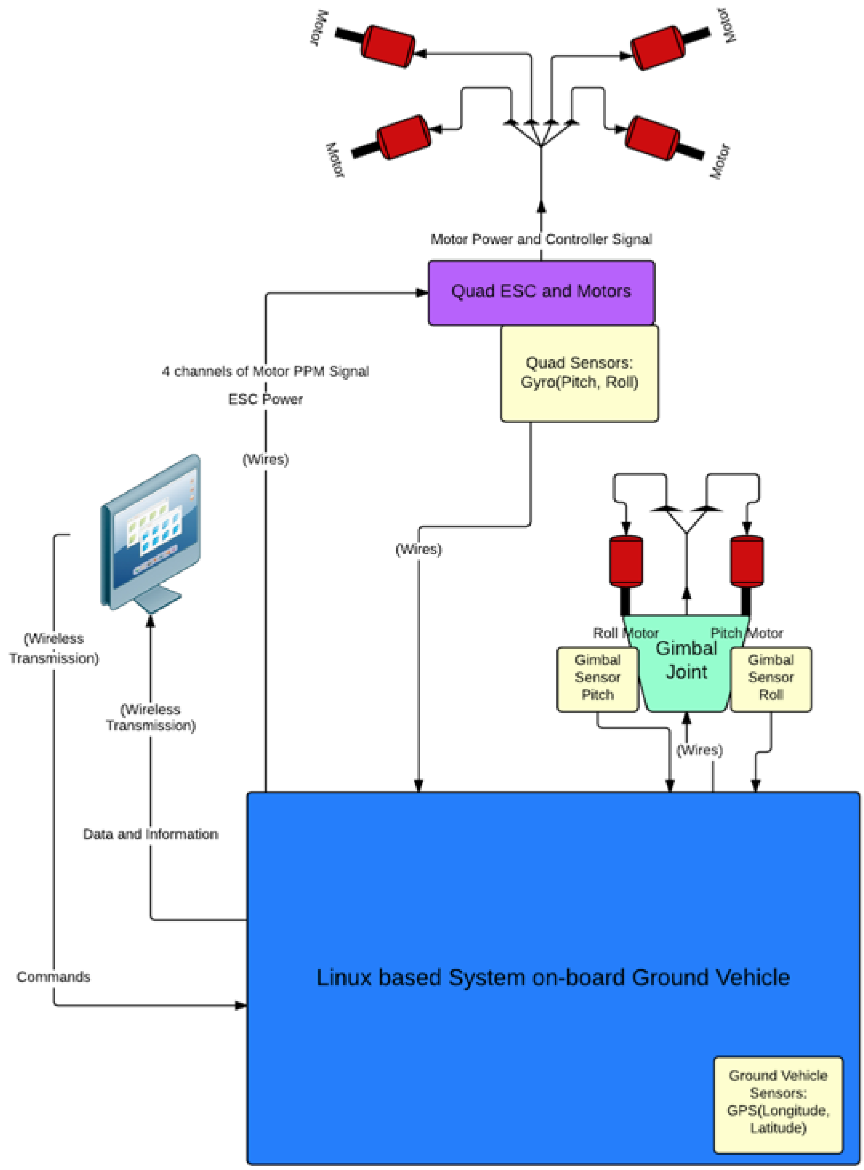


FIGURE 2: PROPELLER-PENDULUM SETUP

## SOFTWARE

The software will have a graphical user interface (GUI) which will be used to configure specific runtime settings, send commands to the ground vehicle, and access important logger data. The current GUI graphs real time data for the ground robot motors, but we are moving to a more easily expandable logger (see the data logging & analysis system section).

### FUNCTIONAL REQUIREMENTS

- Cooperative system between ground vehicle and quadrotor system
  - All processing should be completed on the ground vehicle
  - Should be independent of outside monitoring systems (camera system will act as a stand in for advanced GPS sensors used in the final version)
- Quadrotor system balances pendulum while moving above the ground vehicle
- Data logging system that can export data to MATLAB for quick and easy analysis
- GUI to control the movement of the cooperative system

### NON-FUNCTIONAL REQUIREMENTS

- Reliable system that performs commands in real-time
- Efficient power consumption
- Failure Management
- Upgradable hardware & control system

## WORK BREAKDOWN STRUCTURE

Every member of our team is expected to work closely and cooperatively even when working on different tasks. In order to ensure continuous progress as well as a well-structured team format, we designated a team role for each member to better organize us.

- Robert Larsen: Team Leader/Project Manager
- Ian McInerney: Team Key Concept Holder/Tech Lead
- Dylan Gransee:  Webmaster
- Alberto Di Martino: Webmaster
- Aaron Pederson: Team Communications
- Fengxing Zhu: Team Communications
- Rohit Zambre:  Data Logging and Analysis Lead

## RESOURCE REQUIREMENTS

| Resource | Provided by | Estimated cost |
|---|---|---|
| Gimbals | Client | $100 |
| Gyroscope/Accelerometer | Client | $50 |
| Brushless motors, Propellers, Electronic Speed Controllers | Client | $300 |
| Photo Tachometer | Client | $200 |
| Spektrum Transmitter & Receiver | Client | $250 |
| OptiTrak IR Camera System | Client | $15,000 |
| Digital Scale | Client | $50 |
| Omnidirectional Robot System | Client | $3,000 |
| FPGA system | Client | $500 |
| 2-cell LiPO batteries | Client | $75 |

**TABLE 1: RESOURCE REQUIREMENTS**

## PROJECT SCHEDULE

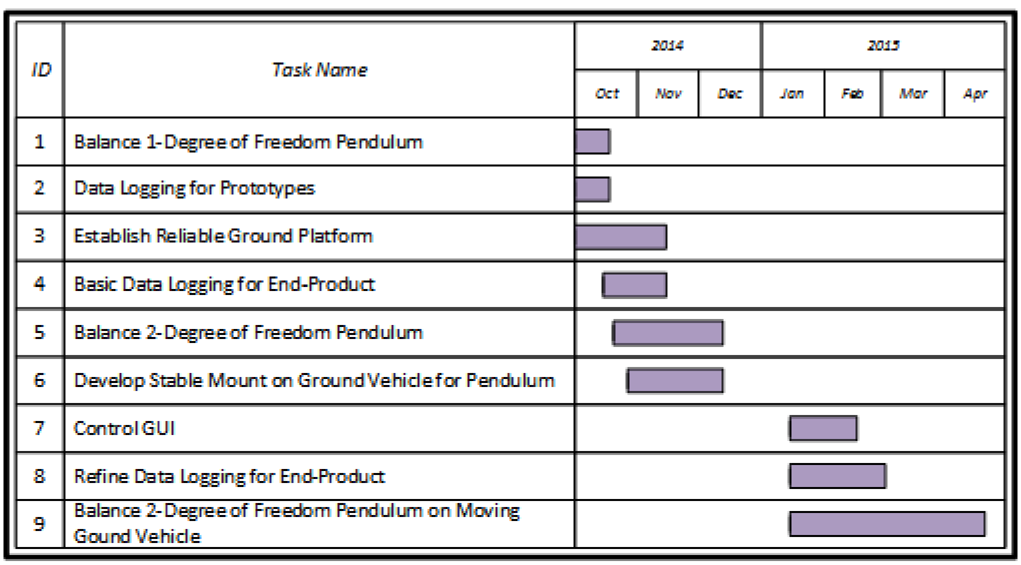


**FIGURE 3: GANTT CHART OF PROJECT SCHEDULE**

# RISKS

## RISKS TO THE PROJECT TIMELINE

Our project relies upon a past senior design project that requires some work to get back in shape. If we are unable to resurrect that project efficiently, then we must purchase a new ground vehicle. Since this project is a proof of concept, it may not work the way we are expecting, so our project could take a sharp turn at any time.

## PHYSICAL DANGERS

The main risk is with testing the propeller system. If it is not secured properly, there is a chance that it could break free and hit somebody. Other risks during construction of electrical circuits include being burned by solder. Since Electricity is used for many things in this project, electrical shock is always a danger.

# TESTING

## CONTROL SYSTEM

To test the control system, initial Simulink models of the physical system will be created. These will be used to design the controller before the actual hardware is used. Once the controller is designed, it will be tested using the actual hardware. Data collected for the control inputs and outputs are provided by the data analysis GUI. The collected data will then be used to refine the controllers and the Simulink models, leading to a final design at the end.

# LITERATURE SURVERY

This project is mainly focused on developing a research system to prove if the propeller-based balancing system is able to stabilize the instrument arm (which behaves similar to a spherical inverted pendulum). Other universities have conducted research and successfully balanced 1-degree of freedom spherical inverted pendulums on stationary objects. No current work on balancing a spherical inverted pendulum with 2-degrees of freedom using a propeller-based balancing system is known.