Camera Positioning System

Team 79

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1 Introduction:

1.1 Objective:

This project will be a continuation of a MechSE senior design project from the last semester.

The current prototype lacks several important features. The first one is homing and auto-calibration of the XY traversing mechanism. Currently, the in-plane positioning system does not have a homing function and calibration is done manually. The second feature is angular position feedback from the pan-tilt heads. The control is completely open-loop currently and is not very accurate in angular positioning.

The previous mechanical team has completed the physical construction of the platform. Minimum software and hardware development were done to manipulate the gantry table and pan-tilt heads. For example, at current stage, a user is able to translate and pan & tilt a camera from a computer user interface in LABVIEW.

Next Step is to add in sensors and design circuits to achieve more advanced and essential features for the product. The features include auto-calibration, homing and position feedback from both the linear movement and angular movement. These functions were not included in the prototype due to the lack of electrical engineers on the team.

A central power unit is also needed to power the different electronics in the system. Currently the stepper motors and servo motors are powered separately from the wall. As more sensors and circuits are being added to the system, a compact central power unit is necessary to make the setup easier.

1.2 Background:

The University of Illinois's Renewable Energy & Turbulent Environment (RETE) research group with sponsorship from John Deere has been tasked with designing a camera positioning system for particle tracking research. The system must be able to operate with the same functionalities as the current particle tracking equipment but with additional scalability, precision, robustness, and ease-of-use in mind. The current equipment includes the use of a high resolution, high speed recording camera and a view splitter which produces four different views, converging them on the volume of interest. It is relatively small and thus limited in experimental range. Manual calibration of the four independent view splitting mirrors is very tedious and requires a minimum of two people to set up. It is also important to note that the total experiment set up time from scratch requires up to four hours.

The previous team completed a camera positioning system prototype with supporting design documents. The camera positioning system is consisted of two frames, holding two quadrants each. Each of the quadrant has two aluminum tracks in a “+” configuration as the XY traversing mechanism. On the vertical track, the pan-tilt head is mounted on the gantry plate which holds the camera. In terms of controls, an Arduino Mega is used for the microprocessor. A PWM add-on board is connected to control eight servo motors which in turn controls the pan and tilt motion. Eight stepper motor drivers are connected to the stepper motors, allowing control of the system’s translational motion.

A user interface was created using the LABVIEW program. There are four main types of inputs for the system’s user interface: calibration, absolute distance for stepper motors, incremental distance for stepper motor, and pan-tilt for servo motors.

1.3 High-level requirement list:

- **Homing and auto-calibration of the gantry table:**

The circuit should signify the controller whenever desired position is reached and also cut off the operation if physically limit is reached, and once powering up the XY mechanisms should perform an auto-calibration test and resume to user defined positions.

- **Pan-tilt head angle positioning:**

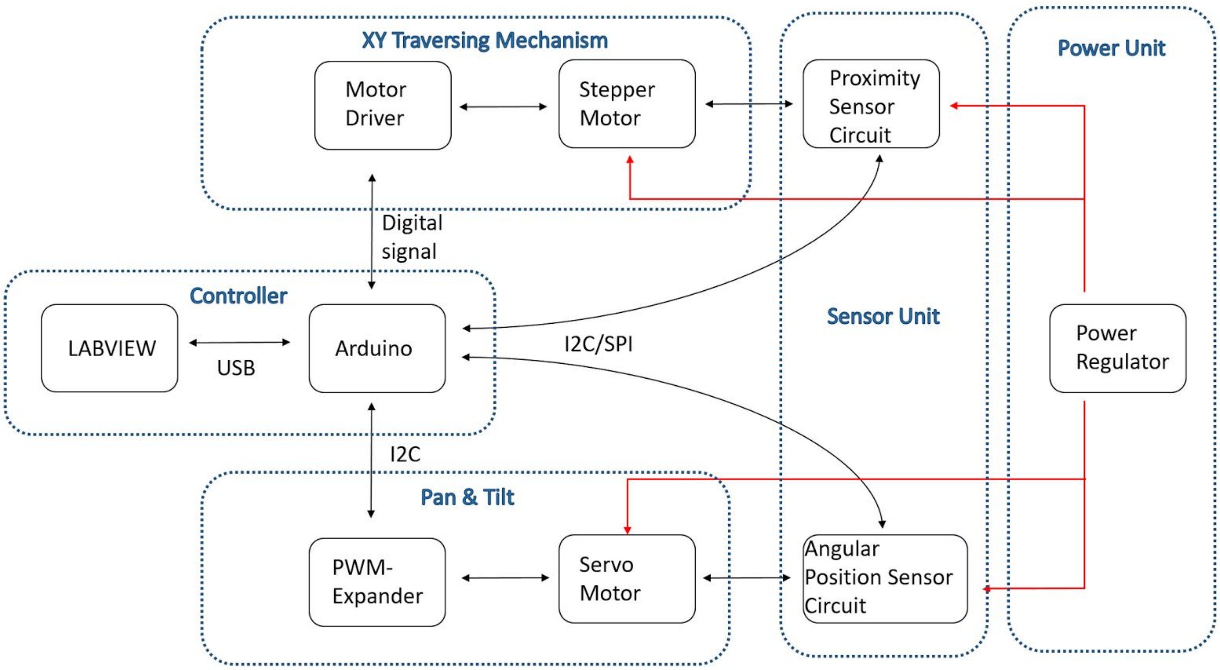
A control circuit will be implemented with either a inclinometer chip (ADS16201) or angular position chip (HMC-1501) to achieve angular position feedback of the pan-tilt heads.

- **Power Unit:**

Eight stepper motors, eight servo motors and the main controller will be powered with a single power regulator circuit.

2 Design:

2.1 Block diagram:



This is a block diagram of the whole system. The red lines are the power lines and the black lines are the data lines. The system is split into five major blocks, the Controller, XY traversing mechanism, Pan&tilt, Sensor unit, and the Power unit. Users should be able to enter inputs on a PC in a LABVIEW environment. The commands will be processed and send to the Arduino board which serves as an I/O board. The proximity sensors and angular positioning sensors will provide feedback to LABVIEW to a\make adjustment and calibration. The motors and sensors will all be powered by an integrated power circuit.

2.2 Functional Overview (explaining the block diagram):

2.21 Controller Block

After communicating with John Deere and Prof. Chamorro, the previous team decided to develop a LABVIEW interface as a virtual control panel for the system. LABVIEW provides support for Arduino communication. This made the development of the interface much easier. By adopting a software solution, the control panel is able to include more useful features such as incremental traversing, absolute traversing and calibration, etc. These features are tailored to suit specific needs proposed by potential users. For x and y movements, LABVIEW is able to do incremental traversing, absolute traversing with numerical input or arrow key input. For the pan and tilt movements, it can accept angles in degrees. LABVIEW also allows for easy calibration and has safety features such as finger pinch safety zone.

The Arduino Mega board runs at 16 MHz and has 54 digital I/O pins, out of which 15 are PWM ports. It provides sufficient pin connections to other peripherals. The controller mainly serves as an I/O device. All the processing and control happen inside the LABVIEW program on the host computer.

2.22 Pan & Tilt

there are 8 Hitec HS-785HB servo motors for pan and tilt movements. Each servo motor provides a maximum 183 oz/in torque. The Hitec HS-785 servo motor is a continuous rotation motor with effective rotations of 8 revolutions. The gearbox of the pan & tilt head has a 7:1 ratio. Therefore, the servo is able to turn the head more than 360 degrees. An 8-channel PWM servo add-on board from FeatherWing is used to control the servo motors. Because the Arduino board does not have enough PWM outputs to support all 8 servo motors, the add-on is necessary. The add-on communicates with the Arduino via I2C protocol and commands the servo motors connected to it.

2.23 XY traversing

There are 8 high torque NEMA 23 stepper motors for x and y movements. Each motor provides 175 oz/in torque and has a native step size of 200 steps/rev. The load was estimated to be around 24.5 N so the motor torque needed to raise it is about 10.62 oz-in and the torque to lower it is around 2.4 oz-in. A safety factor of 16.5 can be achieved with this setup. 8 industrial grade motor drivers are used to drive the stepper motors. The DQ542MA is a two-phase hybrid stepper motor driver and is widely used in numerical control devices such as CNC machines. It also provides micro-stepping options to further increase positioning accuracy.

2.24 Proximity sensor circuit

Homing and auto-calibration of the gantry table:

For each of the XY traversing rack, two proximity sensors will be placed at the end of two racks. The sensors will send back the information about the distances of the camera position on the XY rack to the LABVIEW user interface.

The tentative plan is to use 1128_0 - MaxBotix EZ-1 Sonar Sensor, since it’s capable of measuring the distance to the object (up to 6.5m) [1] and has relatively good accuracy.

Requirements:

1)The sensor must have accuracy tolerance within ±30 mm as indicated from its datasheet [2].

2)Power must supply within 3V-5V and has maximum 3mA current.

2.25 Angular position sensor circuit

Pan-tilt head angle positioning:

One angular position sensor will be attached to each pan & tilt for reading the angular position of the camera relative to the ground.

Angular position sensors attached to the camera holders will send the signals to LABVIEW user interface on computer via Arduino board. A small PCB will be used to mount sensors and connect to power.

Requirement:

1)The angular position sensors must achieve a precision of at least 0.05 degree.

2.26 Power regulating Unit

Power Regulating Module:

There are four kinds of electronic components that require different power supply: stepper motors, servos, proximity sensors and angular position sensor.

Our goal is to unite these four kinds of electronic components with one power cable, which can be plugged in a regular 110V power outlet. Therefore a power regulating module is needed to regulate the total input power and supply each component with power within appropriate range.

Requirement:

1)The 8 stepper motors each requires a voltage of 12V to 48V and a current of 187mA to 300 mA. The 8 camera servos each requires a voltage of 4.8V to 6V and a current of 12.5mA to 285 mA.

2)Each proximity sensor require a voltage of 3V to 5V. The power requirement for angular position sensors are to be decided.

2.3 Risk Analysis

Proximity sensor circuit

The successfulness of implementing the proximity sensor circuits heavily depend on the quality of the sensors and the way we mount them. The signals emitted by multiple sensors could interfere with each other, and the sensor's capabilities of identifying the correct object are the key factor to accurately measure the distances and report useful information to LABVIEW user interface. We will need to have a good design to account for multiple factors that may cause failure.

Pan-tilt head angle positioning:

Similar to proximity sensor circuit, the successful implementation of pan-tilt angular position sensing also depends on the quality and accuracy of the angular position sensors, the way we install the sensors, and the way we handle the raw signals from the sensors.

Power Regulating Module:

The whole system draws a lot of power, and different components requires different amount of power. Special care is needed in designing the power regulating module to ensure the regular functioning of the whole system, and a fail-safe mechanism is required to prevent overheating of the circuits.

3 Ethics and Safety

The whole system consumes a significant amount of power in operation. Especially, the 8 stepper motors require a relatively large amount of current supply. The datasheet of the specific model of NEMA 23 stepper motor indicates that the maximum current draw of the motor is 2.8 A/Phase. The current required to power the servo motors scales up with the load applied. The stepper motors draw current even when they are idle. We are aware of the fact that the power regulator not only needs to supply appropriate voltage but also tolerates the theoretically maximum current draw. Therefore, the power unit will be designed with the maximum current and voltage settings in mind .This is to prevent the system from overheating and damaging the power unit.

In accordance with the IEEE Code of Ethics, #6 "to undertake technological tasks for others only if qualified by training or experience,[3]" all group members will be trained and certified to use standard lab tools. Only members experienced with and trained to use prototyping machines such as laser cutter, milling machines, etc. will be in charge of manufacturing parts if necessary.

We will adhere to and honor the IEEE Code of Ethics, #7 " to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others [3]." The team will keep in contact with the users and listen to their feedback. We will accept honest criticism from our sponsors and try to improve upon current work. We appreciate all participants of this projects for their valuable suggestions and feedback.

4 Reference

[1] Phidgets, ‘Exploring the Many Methods of Object Detection.’ 2014, [Online]. Available: https://phidgets.wordpress.com/2014/05/23/exploring-the-many-methods-of-object-detection/

[2] Phidgets, ‘Products for USB Sensing and Control’ 2012, [Online]. Available: http://www.phidgets.com/products.php?category=2&product_id=1128_0

[3] IEEE,”7.8 IEEE Code of Ethics.”2017,[Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html