PROJECT IDEA SUBMISSION –
BACKPACK MOBILE MAPPING SYSTEM

LABORATORY INFORMATION

Name: __Institute for Digital Forestry___________________ Date: _9/7/2024_____

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PROJECT NAME

BackPack Mobile Mapping System

GENERAL PROJECT DESCRIPTION

This project is the continuation of the earlier-proposed crew-carried mobile LiDAR mapping system. The system consists of a 3D LiDAR, a global navigation satellite system-inertial navigation system (GNSS/INS) georeferencing unit and RGB frame cameras. All these components are rigidly mounted on a common base frame that was designed following extensive topology optimization through finite element analysis (FEA). The current proposal is for the implementation of a LiDAR rotating mechanism with precisely-timestamped encoder output that will be logged along with other sensor messages.
At the core of its purpose, the developed system will be able to acquire 3D scans and RGB imagery along with GNSS/INS raw data in diverse outdoor/indoor environments such as forests, agricultural fields, historic sites, and building infrastructures. The post-processed information from these input data sources will be georeferenced point clouds and imagery, and the derived product may include, but not limited to, individual tree segments, crop growth profiles, digital surface models, stockpile volumetric information, to mention a few. All sensors onboard the system are controlled using a lightweight low-power computer (Raspberry Pi 5), and the entire system is powered by a multicell lithium polymer (Li-Po) battery. The project poses an interesting yet challenging task for evolving engineers, particularly senior undergraduates.*
**Post-processing of the data is not part of the project.*

WHAT IS THE MECHANICAL ENGINEERING PROBLEM (APPARATUS) YOU ARE WANTING SOLVED (BUILT)?

Over the past few years, our research group has built multiple backpack prototypes to test different sensing technologies in mapping different environments. Undoubtedly, these have proven immensely useful in advancing our research goals. With the growing interest among peers in academics and industries, we now realize the need for improving the overall design of these systems. Before the current version, all of the existing systems were bulky and inconvenient for long data acquisitions and transportation. Moreover, the integration of various sensors and data acquisition procedures were rudimentary (some of which have been improved in the first version). To handle these systems in their current form, a person must undergo sufficient training. Therefore, we are interested in simplifying both the physical and technical aspects of these systems. We believe redesigning these prototypes will be both an interesting as well as challenging task for undergraduate research, particularly for students in their final years, who, by that time have gained sufficient knowledge of most mechanical engineering sub-majors.

As this project continues over the new semester, the student group would study the existing system, then work together to redesign, analyze, build, and test an upgraded prototype that addresses some or all the shortcomings of its predecessors.

WHY IS THIS PROBLEM (APPARATUS) WORTH SOLVING (BUILDING)?

(Value Proposition)

We would like to add a motor stage that rotates the LiDAR unit during data collection. A rotating LiDAR will increase its overall field of view. From our findings, this has a huge impact on the point cloud quality and, ultimately, on any information that we derive from those point clouds.

WHAT ARE THE MOST IMPORTANT FUNCTIONAL REQUIREMENTS AND SPECIFICATIONS FOR THIS PROJECT?

Req 1: Addition of a LiDAR rotating mechanism
Spec 1: The rotating LiDAR stage will support subsequent post-processing of sensor data. Therefore, it will be crucial to maintain a precise motor control and encoder (pose) output throughout the operation (i.e., during an active mission). The encoder output will need to be accurately timestamped such that LiDAR pose is synchronized with other sensors.

Req 2: Optimizing weight, size, and transportability
Spec 2: Any backpack redesign should maintain an overall small system footprint so that the backpack fits in a small case allowing easy transportation as a carry-on or checked-in baggage on a commercial aircraft. Note that the choice of frame material (likely, metal) and backpack straps will be up to the team.
Req 3: Environmental protection
Spec 3: Organizing cables and connectivity among sensors that makes the system less prone to environmental hazards, such as dust and moisture.

Req 4: Power control system
Spec 4: A single Li-Po battery will power the entire system, which will involve various voltage conversions (for example, 12v to 5v) depending on individual component's voltage requirements. A control unit will be essential to power up/down each sensor through a power relay. On the operator side, the control unit should be interfaced together with data control/monitoring system, as described below.

Req 5: Sensor and data control/monitoring
Spec 5: Currently, the activation, control, and continuous monitoring of sensor health and data are performed through wireless consumer devices such as a cell phone or tablet. Any addition of a new feature (such as motor activation) should be made to either existing interface or another equivalent interface of choice.

WHAT DO YOU ANTICIPATE THE STUDENTS DESIGNING, ANALYZING, BUILDING/PROTOTYPING AND TESTING? BE AS SPECIFIC AS POSSIBLE.

Design: The design aspect can be classified into the following:

1. *Machine design – this will include designing 3D layout of the frame to house various components as stated earlier (LiDAR, rotation stage, GNSS/INS unit, antenna, RGB camera, computer, batteries, cabling etc.).*
2. *Control system design – this includes writing control scripts for microcontrollers and relays for sensor and motor activation, deactivation, data logging, and monitoring, throughout the operation of the system. The objective is also to reduce any occurrence of vibration-related damage to electronic wirings.*

Analyze: The analysis of the proposed design may consist of the following:

1. *Stress-strain analysis of the 3D design: through computational simulation (such as finite element analysis) considering various load and deflection tolerances.*
2. *Heat-induced stress: Given the diverse applications of the mapping platform, its components and structure are subject to wide temperature variations (such as -20 C to +40 C). An analysis of heat-induced deformation of the base frame will therefore be needed.*

Build:
This consists of the actual fabrication of the proposed design at a machine shop. The design report should include the basis for various machine tolerances used, along with any cost trade-off, if any.

Test:
Field test of the built prototype.

WHAT IS YOU BEST ESTIMATE OF THE COST OF THE HARDWARE, COMPONENTS, MATERIALS, … OF THE PROPOSED PROTOTYPE?

Total < $3,000
Hardware/Tool Costs: $1,000
Component Costs: Sensors to be lent by sponsor. The design team bears machining and frame material costs.
Material Costs: $1,000
Machining Costs: $1,000

HOW MUCH TIME AND EFFORT WOULD YOU EXPECT TO SPEND ON THIS PROJECT IF YOU WERE DOING IT INTERNALLY?

Calendar Months: 1-2 months *Total Hours (Engineering, Shop, …):*

DO YOU BELIEVE THE PROJECT CAN BE COMPLETED WITH EXISTING TECHNOLOGY, IF NOT, ELABORATE ON NEEDED DEVELOPMENTS?

The project can be completed with existing technology.

CONCERNS OR OTHER RELATED INFORMATION ASSOCIATED TO THE PROPOSED PROJECT?

Concerns:

Other Info:

ATTACH ANY APPROPRIATE SKETCHES, DRAWINGS, STANDARDS, DATA, PHOTOS, … USEFUL IN JUDGING APPROPRIATENESS AND SCOPE OF PROPOSED PROJECT.

Presentation with details of the existing prototypes is included for the reference.

ARE YOU WORKING WITH ME SENIORS WHO YOU WOULD LIKE ON THIS PROPOSED PROJECT? YES/NO (If YES, provided what information you can.)

NAME	PUID	PHONE	EMAIL

To submit this document for consideration, please complete the survey using either the QR code or the link below.

https://purdue.ca1.qualtrics.com/jfe/form/SV_bkCjo7jyE5Wb7ro

If you have any questions concerning a proposed project or completing this form, please contact Professor Greg Jensen.

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