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Abstract

LIDAR-equipped drones represent a groundbreaking innovation in the field of remote sensing and environmental monitoring. These drones combine the advantages of LIDAR technology, which uses laser pulses to measure distances and create highly detailed 3D maps of the terrain, with the mobility and accessibility of unmanned aerial vehicles (UAVs). This integration allows for rapid and cost-effective data collection in various domains. LIDAR drones have found applications in forestry management, where they aid in assessing forest health, carbon storage, and tree species identification. They are also used in land surveying and archaeology, providing archaeologists with the ability to uncover hidden structures and ancient landscapes with unprecedented precision. Additionally, LIDAR drones play a crucial role in urban planning by helping to create detailed urban maps, identify infrastructure vulnerabilities, and improve disaster response and recovery efforts. Despite their many advantages, the technology does come with challenges such as data processing complexity and the need to navigate evolving regulatory frameworks. However, LIDAR drones are poised to become an increasingly essential tool in addressing environmental and societal challenges, making further research and development in this field vital for continued progress. In summary, LIDAR-equipped drones offer a powerful synergy between LIDAR technology and UAVs, enabling efficient and highly detailed data collection for a wide range of applications. Their impact is particularly evident in fields like forestry, archaeology, urban planning, and disaster response, where the high-resolution 3D maps they generate provide valuable insights and facilitate informed decision-making. While there are challenges to overcome, the potential benefits of LIDAR drone technology are undeniable, making it an area of ongoing research and innovation that promises to address critical environmental and societal issues.

Keywords

Lidar, 3D Map, Drone , Flight

Introduction

Applications of drones ranges from filming, thermal inspections and now in agriculture. The major issues of the drones is the cost. Generally speaking drones are costly purchase and there is a huge risk of damage while flying them that is why drones are still not a very common gadget. Mostly large drones make a lot of noise and need a lot of clear space to fly. They cannot be flown in dense forests or areas with many trees. So here we build a micro drone with an obstacle detection feature using LIDAR sensor. Hence this drone helps you understand drone flying as well as how obstacle sensing can be done using drones. And, its small size and lower cost makes it less risky to fly it in dense forest of places. The mini drone consists of 4 drone motors, propellers and Arduino Pro Mini F3 EVO controller and a LIDAR sensor and buzzer. IR used by the LIDAR sensor is for detecting any obstacles in front of it. If any obstacle is detected the LIDAR signal are decoded by controller to operate a buzzer and led for indication of obstacle in front of it. The user is constantly alerted with about the proximity by changing the led and buzzer frequency so drone can be controlled accordingly to avoid collision.

Scope and Motivation

The scope and motivation behind using LiDAR technology in drones are driven by the need for precise and comprehensive data collection and analysis in various industries. LiDAR, which stands for Light Detection and Ranging, is a remote sensing method that uses laser pulses to measure distances and create highly detailed 3D maps of the environment. When integrated into drones, LiDAR technology allows for the efficient and accurate scanning of landscapes, structures, and natural resources. This capability finds applications in fields such as agriculture, forestry, urban planning, environmental monitoring, archaeology, and more. The motivation behind its use is to obtain high-resolution data for decision-making, resource management, and risk assessment. LiDAR-equipped drones can capture information not easily accessible through traditional means, making them a valuable tool for a wide range of applications, ultimately enhancing our ability to better understand and interact with our surroundings.

Review of Related Literature

- Joseph P. Hupy, Cyril O. Wilson: “Modeling Streamflow and Sediment Loads with a Photogrammetrically Derived UAS Digital Terrain Model: Empirical Evaluation from a Fluvial Aggregate Excavation Operation”, Multidisciplinary Digital Publishing Institute, Vol 5, Issue 1, PP 20, (Mar 2021) Arnold Chi Kedia, Christopher Updike, Amy E. Frazier: “An Integrated Spectral– Structural Workflow for Invasive Vegetation Mapping in an Arid Region Using Drones”, Multidisciplinary Digital Publishing Institute, Vol 5, Issue 1, PP 19, (Feb 2021)
- Kuangyu Zheng, Zimo Ma, Mingyue Zhao: “Joint Efficient UAV Trajectory and Velocity Optimization for IoT Data Collection Using a New Projection Algorithm”, Multidisciplinary Digital Publishing Institute, Vol 6, Issue 12, PP 376, (Nov 2022)
- Hao Gu, Jie Yang, Chenhan Hu: “Deep Complex- Valued Convolutional Neural Network for Drone Recognition Based on RF Fingerprinting”, Multidisciplinary Digital Publishing Institute, Vol 6, Issue 12, PP 374, (Nov 2022)

Objective

The primary objective for a LiDAR-equipped drone can vary depending on the specific application, but a general objective might be:

"To utilize LiDAR technology on a drone to capture high-resolution, three-dimensional geospatial data with precision and efficiency, enabling accurate terrain mapping, environmental monitoring, infrastructure inspection, or archaeological surveying, among other applications. The goal is to provide invaluable insights, improve decision-making, and enhance resource management in various industries by harnessing the power of LiDAR technology integrated into unmanned aerial systems.".

Problem Statement

This study employed the Delphi method which structures and facilitates discussion among groups of experts on complex topics through iterative rounds of questions with the goal of arriving at a consensus about a particular outcome. The method is commonly used in policy development, technology forecasting, medical and education planning. It is primarily used as a planning or forecasting tool and is most applicable to deal with uncertainty in an area of imperfect knowledge. As there are no “correct” or verifiable answers, a consensus is considered an acceptable second choice. Experts are carefully selected based on specific criteria related to the field of interest so that a broad spectrum of opinion on the topic can be examined. The group typically involves competing stakeholders so that conflicting demands can be considered by other group members. With the guidance of a facilitator (i.e., moderator or researcher), the group ultimately makes predictions about some future direction as it relates to the area of discussion

Proposed Work

The proposed work for a LiDAR-equipped drone depends on the particular goals and requirements of the project or application, but here's a general outline of the steps and tasks involved:

1. Project Planning and Objectives:
   - Clearly define the project's objectives, including what specific data needs to be collected and why LiDAR technology is the best choice for the task.

2. LiDAR Sensor Selection:
   - Choose an appropriate LiDAR sensor that matches the project requirements, such as range, accuracy, and point density.

3. Drone Selection:
   - Select a suitable drone platform capable of carrying the LiDAR sensor and fulfilling mission requirements, considering factors like flight time and payload capacity.

4. Flight Planning:
   - Develop flight plans and mission parameters to ensure optimal coverage and data acquisition.

5. Data Acquisition:
   - Fly the drone over the target area while the LiDAR sensor records laser data, creating a point cloud of the terrain or objects of interest.

6. Data Processing:

- Post-process the raw LiDAR data to filter noise, correct for sensor errors, and generate 3D point cloud models.

7. Data Analysis:
   - Analyze the point cloud data to extract relevant information, such as topography, vegetation density, building structures, or any other specific data of interest.

8. Visualization and Reporting:
   - Create visual representations and reports based on the analyzed LiDAR data to communicate findings effectively.

9. Quality Control:
   - Implement quality control measures to ensure the accuracy and reliability of the collected data.

10. Data Integration:
    - Integrate the LiDAR data with other datasets or GIS (Geographic Information System) information to provide a more comprehensive view of the target area.

11. Application-Specific Tasks:
    - Depending on the application, conduct further analyses or modeling. For instance, in forestry, you might assess tree health and volume, while in urban planning, you may analyze building heights and land use.

12. Decision-Making and Action:
    - Utilize the insights derived from the LiDAR data to make informed decisions or take appropriate actions based on the project's objectives. This could involve land-use planning, disaster response, resource management, or infrastructure maintenance.

13. Regular Maintenance and Calibration:
    - Ensure that the LiDAR sensor and drone are properly maintained and calibrated to sustain data accuracy over time.

14. Documentation:
- Maintain detailed records of all processes, including flight logs, data processing steps, and any modifications to the system.

15. Training and Skill Development:
- Provide necessary training to personnel involved in operating the LiDAR-equipped drone and processing the data.

16. Continuous Improvement:
- Periodically review the workflow and technology to incorporate advancements and improvements in LiDAR technology or drone capabilities.

By following these steps, the proposed work for a LiDAR-equipped drone can be tailored to achieve specific goals and deliver valuable insights in various fields, such as environmental monitoring, agriculture, archaeology, forestry, construction, and more.

Software Requirements

The software requirements for a LiDAR-equipped drone project encompass a diverse set of tools tailored to various stages of data acquisition, processing, analysis, and visualization. Key software components include LiDAR data processing software such as TerraScan, TerraMatch, and TerraSlave, which enable the management, calibration, and processing of LiDAR data. Additionally, global software applications like Global Mapper and open-source options like QGIS facilitate LiDAR data manipulation and integration with Geographic Information Systems (GIS). For projects that combine LiDAR and imagery, photogrammetry software like Agisoft Metashape and Pix4D comes into play. Data visualization relies on tools such as Cloud Compare, Potree, and Fusion/LDV for rendering 3D point clouds. Data analysis and custom processing may require Python, R, or MATLAB. Furthermore, flight planning and control software, data storage solutions, quality control tools, hardware drivers, and firmware are essential for comprehensive LiDAR drone operations. Selecting the appropriate software suite, ensuring compatibility, and fostering a secure and efficient workflow are pivotal for the successful management and analysis of LiDAR data collected by drone platforms.

Hardware Requirements

The hardware components of a LiDAR-equipped drone are essential for ensuring the successful integration, operation, and data collection capabilities of this advanced technology. At the core of such a system is the drone platform itself, equipped with the necessary propulsion and stabilization mechanisms, a reliable GPS unit, and communication systems for real-time data transmission and control. The LiDAR sensor, a pivotal component, is mounted on the drone to emit laser pulses and record the time it takes for them to return, generating precise 3D point cloud data. To support this data acquisition, the drone typically requires a robust power supply system, including high-capacity batteries and efficient energy management systems. Furthermore, the onboard processing unit, often in the form of a computer or embedded system, manages the LiDAR data and, in some cases, combines it with other sensor inputs such as cameras or GPS data. A robust and lightweight drone frame, sturdy gimbal or mount for the LiDAR sensor, and adequate cooling systems ensure the safe and reliable operation of the entire setup. The hardware components must be carefully selected and integrated to match the specific needs of the LiDAR drone project, considering factors like payload capacity, flight time, and the environmental conditions in which the drone will operate.

Conclusion

This article presents a Detect and Avoid solution for UAV navigation in UAM corridors. A commercial LIDAR sensor was simulated including its operational characteristics to replicate the detection capabilities that an UAV would have with this technology. With this information, an avoidance algorithm based on SOCP programming was developed to compute trajectories in real time and modify the trajectory of the vehicle if a risk of collision is anticipated. The following goals were achieved: The position and speed of the obstacles were correctly measured employing the point clouds from the LIDAR sensor. UAV operational characteristics are considered for the computation of trajectories. A fast implementation was obtained that allows the calculation of trajectories practically in real time on a modern computer. In future works, the effect of meteorological phenomena such as wind gusts on the evasion capabilities of the algorithm will be studied. The influence of the speed and size of the intruders will be analysed to evaluate how the safety distance should be dynamically adapted with respect to them. In addition, the feasibility of adapting this implementation or developing a new methodology for fixed-wing aircraft will also be assessed.

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