REU Proposal

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1 Project Title

GPS-Free localization, object tracking, and path-planning for secure navigation in GPS denied Battlefield Scenarios using computer vision and deep learning.

2 Description of the Project

This project includes designing a path planning algorithm for secure navigation of moving military forces in a GPS-denied environment where using GPS is denied due to tactical reasons or it is intermittently available due to unusual terrain, signal blockage, and interference. We will study and discuss the current state-of-the-art path planning algorithms and design a novel algorithm for battlefield application. A significant component of this work involves GPS-free localization of moving objects, which is crucial for tracking and navigation applications. So, we will also discuss the GPS-free object localization algorithms and will design and implement a unique solution that will be feasible for our application. In this project, we will use a stereo vision system and deep learning model to build a landmark-based localization system. The model will be able to detect and identify the geographical landmark objects in the surroundings and a stereo vision system will be used to determine the distance to the detected landmarks.

To achieve the above objectives, we will incorporate our real-world landmark datasets and enhance them by gathering, processing, and labeling new image data of real-world landmarks. This comprehensive approach aims to devise a practical solution that addresses the unique challenges of navigating in GPS-denied environments.

3 Tasks for the project

3.1 Literature Review and State-of-the-Art Analysis

Task 1.1: Conduct a comprehensive literature review of existing path planning algorithms, with a focus on those designed for GPS-denied environments.

Task 1.2: Review current methodologies and technologies in GPS-free localization and object tracking, particularly those using computer vision and deep learning.

3.2 Algorithm Development for Path Planning

Task 2.1: Identify limitations and gaps in current path-planning algorithms for battlefield applications.

Task 2.2: Design a novel path-planning algorithm that is specific for GPS-denied battlefield environments.

Task 2.3: Simulate and evaluate the designed path planning algorithm using synthetic battlefield scenarios.

3.3 Development of GPS-Free Localization System

Task 3.1: Investigate and select appropriate computer vision and deep learning techniques for landmark detection and identification.

Task 3.2: Design and implement a stereo vision system for distance measurement to identified landmarks.

Task 3.3: Integrate landmark detection with the stereo vision system to create a cohesive localization system.

3.4 Dataset Acquisition and Enhancement

Task 4.1: Be familiar with existing real-world landmark datasets and be able to process them using cv libraries.

Task 4.1: Plan and execute the collection of new image data for real-world geographical landmarks, considering diverse environments and conditions.

Task 4.2: Process and label the collected image data to prepare it for training deep learning models.

3.5 Deep Learning Model Training

Task 5.1: Design deep learning models for landmark detection and identification.

Task 5.2: Train models using the prepared datasets, adjusting parameters for optimal accuracy and performance.

Task 5.3: Validate and test the models under varied scenarios to ensure robustness and reliability.

3.6 Integration and Testing

Task 6.1: Integrate the developed path planning algorithm with the GPS-free localization system into a unified navigation solution.

Task 6.2: Conduct comprehensive testing in simulated GPS-denied environments to evaluate system performance and reliability.

Task 6.3: Iterate on feedback, refining the system for improved accuracy and efficiency.

3.7 Documentation and Publication

Task 7.1: Document the development process, algorithm designs, system architecture, and testing results in detailed technical reports.

Task 7.2: Prepare publications manuscripts and presentations about findings and methodologies to present at conferences or journals.

4 Required Skills and Abilities

1. Good Experience in Python Programming.
2. Knowledge of Neural Networks, Deep Learning.
3. Familiar with Computer Vision and some Image processing skills.
4. Some experience on Computer vision libraries such as OpenCV, Pillow etc.
5. Familiar with TensorFlow, PyTorch, or similar frameworks for designing and training deep neural networks.
6. Understanding of version control Tools (e.g., Git, Github)
7. Strong analytical and problem-solving skills to navigate challenges that arise during the project.
8. Ability to learn new technologies and adapt to new information.

5 Material to be Study

1. G. Sapkota and S. Madria, "Landmark Stereo Dataset for Landmark Recognition and Moving Node Localization in a Non-GPS Battlefield Environment," 2023 IEEE Applied Imagery Pattern Recognition Workshop (AIPR), St. Louis, MO, USA, 2023, pp. 1-11, doi: 10.1109/AIPR60534.2023.10440690.

2. Ganesh Sapkota and Sanjay Madria, "Landmark-based Localization using Stereo Vision and Deep Learning in GPS-Denied Battlefield Environment", 25th IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM), Perth, Australia, 2024.

3. C. -L. Li, N. Wang, J. -F. Wang and S. -y. Xu, "A Path Planing Algorithm for Mobile Robot Based on Particle Swarm," 2023 2nd International Symposium on Control Engineering and Robotics (ISCER), Hangzhou, China, 2023, pp. 319-322, doi: 10.1109/ISCER58777.2023.00064.

4. Google Landmarks Dataset v2 - A Large-Scale Benchmark for Instance-Level Recognition and Retrieval T. Weyand*, A. Araujo*, B. Cao, J. Sim Proc. CVPR'20

PS: Reading any recent literatures on vision-based navigation, path planning and geographical landmark recognition will be beneficial before starting to work on the project