Plan Overview

A Data Management Plan created using HKUL DMPTool

Title: UAV's Navigation in Complex Environments Based on Learning Methods

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Template: HKU Template

Project abstract:

The proposed research aims to tackle the challenges of navigating through dynamic cluttered environments, where the key difficulties lie in efficiently perceiving environmental dynamics and generating evasive behaviors that consider obstacle motion. While previous methods have attempted to explicitly model dynamic obstacle movements, such approaches often suffer from inefficiency and limited reliability, especially under highly dynamic and occluded conditions. In contrast, the research seeks to bypass traditional object detection, tracking, and prediction pipelines by leveraging simto-real reinforcement learning (RL) based solely on single LiDAR sensing. The goal is to develop a fully autonomous flight system capable of going directly from point cloud input to motion command. Specifically, the research intends to design a depthbased distance map that encodes fixed-shape, low-resolution yet detail-preserving information from raw point clouds, as well as an environment-change-sensitive point flow extracted from multi-frame observations to capture motion cues. These two components will be integrated into a lightweight and trainable representation to describe complex dynamic scenes. For action generation, the system is expected to learn proactive avoidance behaviors implicitly, guided by a change-aware representation and a relative motion-modulated distance field used for policy optimization. The research framework will emphasize a deployment-friendly sensing simulation and a dynamicsmodel-free control scheme, with the anticipated outcome of achieving higher success rates and adaptability compared to conventional methods.

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Copyright information:

UAV's Navigation in Complex Environments Based on Learning Methods

Data Collection

What data will you collect or create?

The types of data generated by this project are field research data, laboratory research data, and simulated data.

The main source of these data is summarized below:

Point cloud data: Raw LiDAR point clouds (.pcd/.bin/.npy), approximately 1-2 MB per frame. During training, hundreds of thousands of frames will be accumulated. When conducting experiments, the point cloud will be collected from a lidar.

Image/video data: RGB images and videos exported from the real-world environment (.png/.jpg/.mp4), used for visualization and analysis.

Model training logs and policy files: RL policy network weights (.pt) and training logs (.txt/.json) trained using PyTorch, totaling approximately 5-10GB.

Intermediate feature representation data: e.g., point flow and distance maps (.mp4 format), approximately 1MB per frame, totaling approximately 10-30GB.

Rosbag data:

ROS bag files containing multi-topic sensor data, recording the perception and status information of the drone during flight in a simulation environment or real environment. Data Format: .bag/.db3, readable using the rosbag tool. Recorded and parsed using ROS Noetic and ROS2 Humble.

How will the data be collected or created?

The data used in this research will be obtained through a combination of simulation platform generation and real sensor collection, as follows:

1. Simulation Data Generation

- Use a three-dimensional simulation platform with physical accuracy (NVIDIA Isaac Sim and Gazebo) to construct complex dynamic obstacle scenarios, including moving pedestrians, vehicles, dynamic walls, etc.

- Deploy multi-line LiDAR models in the simulation environment to record the flight process of the drone under different task settings, while simultaneously collecting:

- Point cloud data (simulating LiDAR sensors)

- RGB images and distance maps (for auxiliary analysis and visualization)

- Flight state data (pose, velocity, control commands)

All data is published via the ROS interface and recorded in .bag format for subsequent processing and reproduction.

2. Real-world data collection

- Conduct real-world flight data collection using drones equipped with LiDAR and control modules in laboratory or outdoor environments.

- Use ROS to record perception inputs and control outputs during flight, maintaining consistency with simulation data formats for unified training and testing.

3. Data processing and intermediate feature extraction

- Generate distance maps and point flows from raw point clouds using custom algorithms for training reinforcement learning strategies.

- The extracted results are saved in .npy or .pt format for subsequent use in strategy training or performance evaluation.

4. Reinforcement learning data generation

- During training, the system automatically records the state, action, reward, and changes in strategy network parameters at each step, forming reinforcement learning training trajectory data.

This data is used to analyze strategy convergence and behavioral stability.

Documentation and Metadata

What documentation and metadata will accompany the data?

1. Data Description Document (Data README)
   Each dataset (such as point cloud data, simulation environment output, reinforcement learning logs, rosbag records, etc.) will be accompanied by a README.md file containing the following information:
   - Brief description of the dataset (purpose, source, generation method)
   - File structure and naming conventions

- Explanation of data fields (e.g., meaning of each column in point cloud data, image dimensions, control command units, etc.)
- Sensor parameters used (e.g., lidar scan frequency, field of view angle, resolution)
- Sample code snippets (demonstrating how to read and visualize the data)

2. Metadata files (Metadata JSON/XML/YAML)
   To facilitate automated retrieval and processing, each type of data will also be accompanied by a standardized metadata file (e.g., .json or .yaml), containing:
   - Data generation time and location (simulation or field)
   - Simulation platform and version information used (e.g., Isaac Sim 2024.1)
   - Relevant hardware and software configurations (e.g., sensor model, drone control frequency)
   - Environmental settings (number of dynamic obstacles, movement modes, etc.)
   - Data format and volume specifications
   - Sampling frequency and time synchronization method
   - Data responsible party, author, and contact information
   - Data license agreement (e.g., CC BY 4.0)
3. Script Documentation
   All scripts used for generating, preprocessing, and analyzing data will be accompanied by Chinese or English comments, with separate documentation explaining usage methods and dependencies.
   - Scripts include:
     - Point cloud encoding script
     - Multi-frame point stream extraction module
     - Reinforcement learning training log recording script
     - Rosbag data processing and visualization script, etc.

Ethics and Legal Compliance

How will you manage any ethical issues?

This study does not involve clinical or personally identifiable data. The primary data sources are simulation-generated data and non-personalized drone status information. However, during data collection, use, and sharing, we will adhere to research ethics guidelines and manage the following aspects:

1. Consent for data preservation and sharing
   All data used in this project were either created by the research team or sourced from open-source simulation platforms and do not include human subject participation or human data requiring ethical approval.

- If public datasets or third-party simulation models are used in the future, their open-source licenses (e.g., MIT, Apache 2.0) will be followed for attribution and use. All data will be used for research and academic exchange purposes, and will be published with a clear data usage agreement (e.g., CC BY 4.0).

2. Identity protection and anonymization
   All data does not contain audio, facial images, GPS coordinates, or other information that can identify individuals.
   - If future expansions involve recording images or videos in real-world scenarios, all individuals involved will be required to provide prior written consent, and anonymization measures will be implemented prior to data collection, such as blurring, obscuring, or cropping of facial features.
   - Drone status data (e.g., pose, velocity) is solely used for flight analysis and does not contain any personally identifiable information.
3. Secure handling of sensitive data
   Data processing and storage devices are configured with access rights management and are restricted to project team members.
   - All experimental data will be backed up on encrypted hard drives (or NAS systems) and transferred between devices using secure transfer protocols (such as SCP or SFTP).
   - If deployed in the cloud, data service platforms with GDPR or ISO/IEC 27001 certification will be selected to ensure that data is not leaked during transmission and storage.

How will you manage copyright and Intellectual Property Rights (IP/IPR) issues?

This study will strictly adhere to copyright and intellectual property rights (IP/IPR) regulations throughout the creation, use, and sharing of data and code, and will implement the following management measures:
1. Ownership and Licensing Statements for Data and Code
- All datasets, model parameters, and analysis scripts generated independently by this research team are the intellectual property of the research team/affiliated institution. By default, an open-source license agreement (such as CC BY 4.0 or MIT) will be attached when the research results are made public.
- Prior to public sharing, all content will be accompanied by clear copyright statements and usage terms, including:
a.Whether the data and models are commercially usable;
b.Whether users need to credit the original author;
c.Whether modification and redistribution are permitted.

2. Compliant Use of Third-Party Resources
- In this project, if open-source simulation environments (such as Isaac Sim), public datasets, or pre-

trained models are used, they will comply with their respective licenses (such as Apache 2.0, MIT, NVIDIA Omniverse License), and the sources and citation methods will be clearly noted in the documentation.
- Closed-source/restricted-license data, models, or software will not be used without authorization.
- For cited literature, images, or algorithms, sources will be strictly cited in accordance with academic norms to avoid copyright disputes.

3. Ownership and Protection of Results
- If important original algorithms, system frameworks, or training strategies are developed during the research process, an assessment will be conducted prior to formal publication to determine whether software copyright or patent protection is required, and the results will be registered within the university.
- In the event of joint development with other research teams/partner organizations, the details of result sharing and ownership will be clearly specified in the cooperation agreement to prevent disputes in the future.

Storage and Backup

How will the data be stored and backed up during the research? i. e. until stored in the final location (e.g. on your password protected laptop)?

During the research process, all data will be stored on encrypted and password-protected local workstations and external hard drives, with access restricted to research team members. Code will be manually backed up to GitHub daily to prevent accidental loss.

How will you manage access and security?

During the research period, data access is restricted to project team members, and all data is stored on password-protected local computers and encrypted hard drives.
- When collaborating remotely, data is transferred using VPN, SFTP, or private Git repositories to ensure secure transmission.
- Sensitive files are protected with AES encryption, and storage paths and access permissions are recorded and managed.
- Before public release, any potentially sensitive information is removed from the data, and a clear usage agreement is provided.
- Once the research is completed and archived, the data is stored in a controlled-access long-term storage platform, with the level of access determined by the licensing agreement.

Selection and Preservation

Which data are of long-term value and should be retained, shared, and/or preserved?

The following data in this project has long-term value and needs to be properly stored and shared:
- Raw point cloud data and multi-frame point stream features: basic perception data that supports subsequent algorithm improvements and reproducibility.
- Dynamic scene data and rosbag files generated by the simulation environment: complete flight records that are useful for verification and comparative research.
- Trained reinforcement learning strategy model weights and logs: demonstrate algorithm performance and training process, facilitating reuse and further optimization.
- Code and scripts for data processing and analysis: Ensuring research reproducibility and openness.
- The above data will be permanently stored on a secure storage platform and shared under an open-source license agreement to promote ongoing research and collaboration in related fields.

What is the long-term preservation plan for the dataset?

The dataset for this project will be archived in a school or nationally recognized long-term data storage platform (such as a research data center or institutional data warehouse) after the research is completed to ensure data integrity and accessibility.
The storage platform supports data backup, version control, and access permissions, ensuring the secure preservation of data for years to come.
Additionally, the data will be associated with a Digital Object Identifier (DOI) to facilitate citation and sharing.
Accompanying metadata and documentation will also be preserved in tandem, ensuring the long-term availability, understandability, and reproducibility of the data.

Data Sharing

How will you share the data?

After the study is completed, the data will be shared through the following channels:
- Uploaded to public academic data platforms (such as Zenodo and Figshare) and assigned a DOI for easy academic citation.
- Code and data processing scripts will be published simultaneously on public code hosting platforms (such as GitHub), accompanied by detailed documentation.
- Shared with a clear license agreement (e.g., CC BY 4.0) to specify usage rights.
- Sensitive portions will be anonymized as needed to ensure that shared data poses no privacy risks.

Are any restrictions on data sharing? If yes, Why?

No

Responsibilities and Resources

Who will be responsible for data management?

Me and my collaborators.

What resources will you require to deliver your plan?

To ensure the smooth completion of data collection, processing, storage, and sharing, this project requires the following resources:
a. Hardware equipment
- High-performance computing servers (including GPUs) for reinforcement learning training and data analysis
- High-capacity secure storage devices (local external hard drives) for data backup and long-term storage

b. Software tools:
- ROS and related robotics software platforms
- Python and deep learning frameworks (PyTorch)
- Point cloud processing libraries (Open3D, PCL)
- Data management and version control tools (Git, etc.)
