AUTONOMOUS OBJECT-TARGET NAVIGATION USING UAV CONTROL

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Abstract: *Unmanned aerial vehicle (UAV) autonomous control has drawn a lot of attention from researchers over the past ten years. Drones are widely used in the public, private, and military sectors for a variety of tasks, including delivery, search and rescue, and surveillance, as well as for securing sensitive areas and resolving problems that call for movement. The use of UAVs for navigational tasks that require complete autonomy in terms of control, planning, localization, and mapping, however, is still an unresolved issue. Information on using autonomous UAVs for object-target navigation is provided in this article. With the exception of estimating the target's location, object-to-target navigation inherits the same navigational issues as steering and navigation. Understanding which object to look for and where to find it is necessary for the task of finding something. In this regard, research taxonomies on UAV navigation and target location tasks and methods are identified. The reliance on autonomous navigation tasks, as well as the shortcomings in UAV development and framework standardization, are significant issues that are brought to light by this review.*

Keywords: *object-target navigation, UAV control, autonomous systems, and thorough literature review.*

Introduction

The use of autonomous unmanned aerial vehicles (UAVs) for business, industry, and recreational purposes has recently increased [1]. When a large area needs to be covered, autonomous UAVs offer a significant advantage by allowing the human pilot to concentrate on other tasks and use the vehicle to speed up procedures. Therefore, a vehicle needs to be equipped with the ability to move around safely and effectively. This requires a well-designed autonomous system. Vehicle control, step planning, environment mapping, and surrounding perception are the four main problems that an ANS must solve [2]. Understanding movement dynamics and using perturbations to guide the vehicle to the desired location are the responsibilities of vehicle control. Step planning proposes a trajectory for moving around and arriving at the target's location while assessing the current vehicle state. In order to plan where to move next, it is necessary to first understand where the vehicle is located within the environment. By projecting the vehicle's surroundings and spatially locating the vehicle as well as various objects or obstacles, the mapping stage helps with planning. Finally, surrounding perception processes sensory data to determine the current state of the vehicle and identify potential objects of interest.

UAV navigation techniques

In contemporary UAVs, autonomy and precise flight stabilization are becoming more and more crucial. Autonomous UAV navigation systems and their supporting subsystems are essential. Figure 2 illustrates how a navigation system uses data from various sensors to estimate a UAV's position, speed, and orientation.

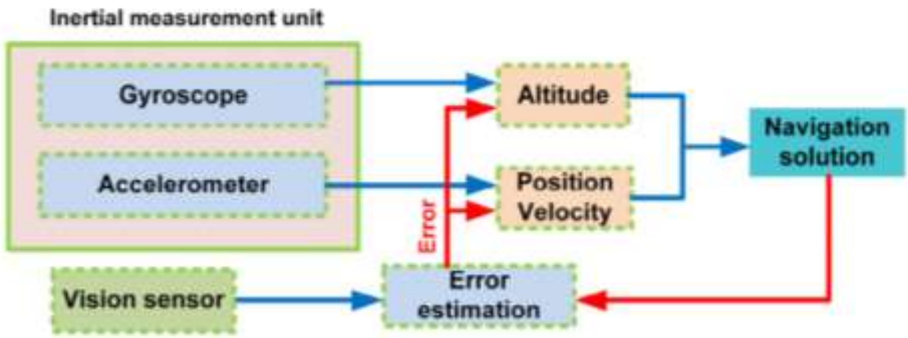

Figure 2. Typical configuration of a UAV navigation system.

Auxiliary systems also carry out related duties like static or dynamic detection, tracking, and obstacle avoidance. A trustworthy and effective navigation system is necessary for increased autonomy and flight stabilization [3]. Computer vision algorithms can be used with monocular cameras to enhance navigation. There are three primary subsystems that make up navigation systems: A UAV's position and orientation can be estimated using two- and three-dimensional (3D) representations. Other systems include obstacle detection and avoidance, which locates and relays the position of obstacles the UAV runs into, visual servo control (VS), which directs maneuvers to keep the UAV stable and on course, and position estimation.

Navigational tasks for autonomous targets

The primary distinction between each behavior is the underlying planning goal. The challenge of getting a vehicle from point A to point B quickly and safely is known as navigation behavior. On the other hand, gathering information from the environment's hidden areas while also moving the vehicle to a more advantageous position was described as reconnaissance behavior. In an object-to-target navigation task, the location of the target object is the main consideration when selecting a destination.

Four fundamental tasks necessary for autonomous navigation have been identified within these two fundamental behaviors, as shown in Figure 4.

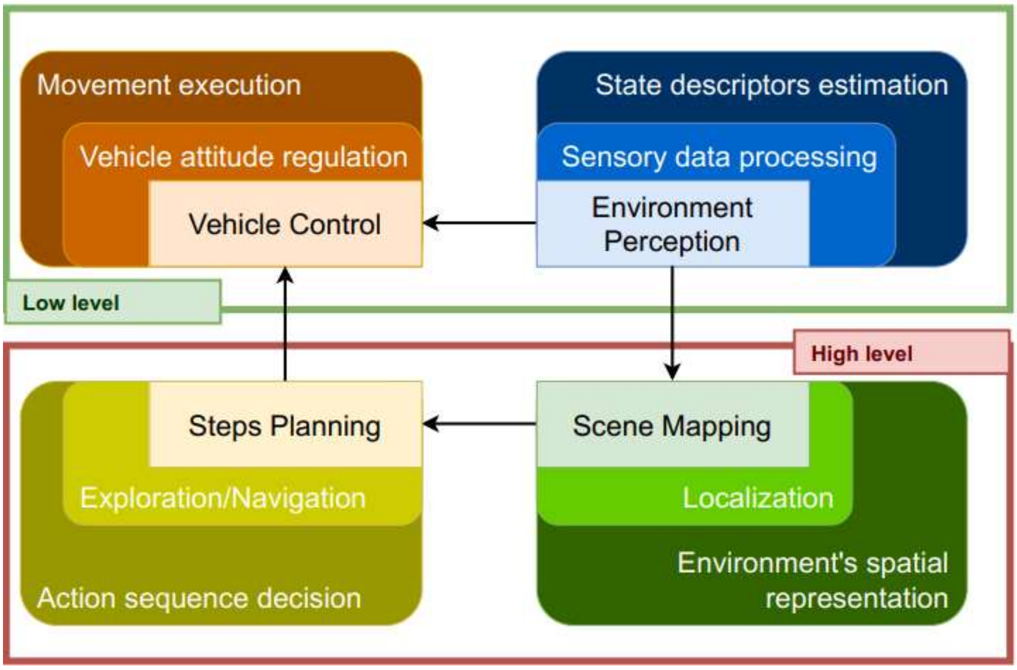

Figure 4 depicts the main tasks for autonomous UAV control, focusing on low-level tasks such as vehicle control and environmental perception, as well as high-level tasks such as scene mapping.

In order to suggest a trajectory and movement to the desired location, these operations process both internal and external data while controlling the fundamental UAV characteristics. The primary point of distinction is the localization task, which is a mapping sub-task. There is also a perception task that utilizes all of the vehicle's sensor data. The descriptions of each of the listed tasks are provided below.

• Vehicle control modifies actuators to carry out movements in accordance with the target coordinates and the current posture, necessitating real-time processing to ensure safety. Depending on the dynamics and degrees of freedom of the vehicle, different methods are used.

• Step-planning establishes a sequence of points that the vehicle must pass through and determines the subsequent coordinates to be followed. The trajectory is chosen in order to establish the most effective path to the destination.

• Scene mapping depicts the surroundings of the vehicle by highlighting open spaces, uncharted territory, and nearby objects. To ascertain the current positions of the vehicle and other objects in the scene, this task is typically carried out concurrently with localization. The map representation is designed using various sensory data from the detected methods.

• Environment perception records the most recent sensory data in order to gather pertinent information about the environment for other tasks to process later. Accurate environmental knowledge will improve task performance by making it more resistant to noise.

Control Techniques

Pixhawk 4 advanced autopilot hardware and PX4 software. Pixhawk Autopilot is a hardware-based vehicle control platform that simplifies development with easy-to-connect peripherals and their control. PX4 is software designed to control a vehicle with its sensors and actuators, providing low-level control of the vehicle. This hardware control must be performed in real time to ensure the safety and stability of the vehicle. Other methods are proportional-integral-differential regulator (PID), linear-quadratic regulator (LQR) and learning methods such as reinforcement learning and fuzzy algorithms[4]. These methods aim to develop a suitable control policy for moving the vehicle around the scene of an accident. The resulting policy is directly dependent on how the control task has been modelled, most of which learns to move from one point to another as an end-to-end solution. Predictive or probabilistic methods for control tasks. These methods process the state of the vehicle to derive a possible next state, bounded by reaching the target position. There are interesting implementations of the dual control cycle method[5]. The first focuses on vehicle stability and attitude control, while the second manages high-level movements, controlling how the UAV must behave in order to reach a certain target point.

Planning methods

In order for the vehicle to get to the following waypoint of the route, the planning method is a waypoint-following problem. The planning method is focused as a graph-based approach, choosing which point to reach by applying a cost function over the graph's vertices. Tree-search algorithms were discovered among the graph-based techniques, including the Dijkstra algorithm[6], Rapidly Exploring Random Tree (RRT)[7], and its improved version RRT*[8]. The main goal of graph-based methods is to move from one node to another using vertex cost analysis to find the shortest, most direct path without encountering any obstacles. an optimization algorithm that aims to get to the final, well-known point through intermediate goals. The majority of the custom implementations were mathematical models that planned the pose, velocity, or required future state using positional data from the UAV and the target location. In contrast to graph-based techniques, which are more closely related to the exploration behavior, the majority of waypoint-following papers only discuss navigational behavior. Finding the shortest route to a target location would seem to be a natural application of the planning methods, which are focused on optimizing a score value given a function or constraints. When the target is an object, however, it becomes necessary to use a planning method to determine where it might be located.

Mapping methods

The majority of planning techniques require prior spatial knowledge in order to suggest a movement scheme. Three main types of methods are used to address the spatial information problem in the mapping task. The mapping task might have been viewed as reconstruction, combining sensory data to produce a spatial projection for each component of the scene. This reconstruction issue is resolved by simultaneous mapping and localization (SLAM)[9], a popular navigational technique. SLAM combines data from internal and external sensors to produce a map that includes structural information about lanes, objects, and the vehicle itself. The iterative closest point (ICP)[10] method is another option for improving the relationship between a point cloud and a sensor-generated image. This relationship gives the map additional visual depth information. Quadtree decomposition[11], oblique photogrammetry, and laser sensor-based implementation are additional methods for map reconstruction. Similar to ICP, these techniques attempt to combine depth sensor and visual data to produce a map that includes distance information about the environment's structure and the objects nearby. The representation category for the mapping task was also established. The use of sensor data is the primary distinction between the earlier introduced representation and reconstruction methods. Reconstruction entails compiling a map of the entire environment, whereas representation entails using that data to create a spatial projection of the surroundings. Simply put, the map's representation is clearer and only includes the details that are absolutely necessary to solve the navigational issue. The majority of map representation techniques make use of occupancy grid maps, which divide up various cell scene regions. Occupancy maps can be modified by adding cell priority based on a calculated score or by adding OctoMap[12], which incorporates the Octree data structure for effectiveness. With SLAM, additional variations were used to fuse sensory data. The reference map is the last classification for the mapping task, where the techniques use environmental data as a reference for spatial data. After sensing the reference data, this mapping technique enables a vehicle to determine its location. With this type of mapping, there were only two methods discovered. The first one makes use of visual landmarks to identify an intriguing spatial region in the scene. The second locates objects of interest using a radio frequency (RF) signal[13], producing a signal fingerprint of the separation between the vehicle and various objects' beacons in the scene.

Conclusion

Over the last decade, an increasing number of UAV-based solutions have demonstrated diverse area implementation and diverse methodologies for achieving appropriate applications. This article's main goal was to identify actual development using UAVs in the context of an object-goal navigation problem. Autonomous navigation is only possible if the UAV can solve control, planning, mapping, and perception tasks without relying on external assistance. The two main behaviors of exploration and navigation, as well as the four tasks required to achieve an autonomous approach, could be identified. The behavior is determined by the processing form of each task.

REFERENCES:

1. Liu Y, Dai HN, Wang Q, et al (2020) Unmanned aerial vehicle for internet of everything: Opportunities and challenges. Computer communications 155:66–83

2. Yasuda YD, Martins LEG, Cappabianco FA (2020) Autonomous visual navigation for mobile robots: A systematic literature review. ACM Computing Surveys (CSUR) 53(1):1–34

3. Dong, J.; Ren, X.; Han, S.; Luo, S. UAV Vision aided INS/odometer integration for Land Vehicle Autonomous Navigation. IEEE Trans. Veh. Technol. 2022, 71, 4825–4840.

4. de Plinval H, Morin P, Mouyon P (2017) Stabilization of a class of underactuated vehicles with uncertain position measurements and application to visual servoing. Automatica 77:155–169.

5. Helgesen HH, Leira FS, Bryne TH, et al (2019) Real-time georeferencing of thermal images using small fixed-wing uavs in maritime environments. ISPRS Journal of Photogrammetry and Remote Sensing 154:84–97.

6. Bershadsky D, Johnson E (2013) Indoor gps-denied context based slam aided guidance for autonomous unmanned aerial systems. AIAA Guidance, Navigation, and Control (GNC) Conference

7. Dang T, Papachristos C, Alexis K (2018) Autonomous exploration and simultaneous object search using aerial robots. IEEE Aerospace Conference Proceedings 2018-March:1–7

8. Alarcon EPH, Ghavifekr DB, Baris G, et al (2021) An efficient object-oriented exploration algorithm for unmanned aerial vehicles. 2021 International Conference on Unmanned Aircraft Systems, ICUAS 2021 pp 330–337.

9. Bachrach A, Winter AD, He R, et al (2010) Range - robust autonomous navigation in gps-denied environments. Proceedings - IEEE International Conference on Robotics and Automation pp 1096–1097.

10. Li Y, Wang Y, Wang D (2018) Multiple rgb-d sensor-based 3-d reconstruction and localization of indoor environment for mini mav. Computers & Electrical Engineering 70:509–524.

11. Peake A, Mccalmon J, Zhang Y, et al (2020) Wilderness search and rescue missions using deep reinforcement learning. 2020 IEEE International Symposium on Safety, Security, and Rescue Robotics, SSRR 2020 pp 102–107

12. Dang T, Papachristos C, Alexis K (2018) Autonomous exploration and simultaneous object search using aerial robots. IEEE Aerospace Conference Proceedings 2018-March:1–7.

13. Wang J, Hinton J, Liu JC (2017) Rf based target search and localization with microuva. Proceedings - 2016 International Conference on Computational Science and Computational Intelligence, CSCI 2016 pp 1077–1082.