Team Description Paper of the UvA Drone Team for the IMAV 2022 Nanocopter AI Challenge - Delft

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May 14, 2022

1 Introduction

The International Micro Air Vehicles Conferences and Competitions (IMAVS) [1] organisation is holding a series of competitions in September 2022 in Delft, the Netherlands. The UvA Drone team will compete in the "Nanocopter AI challenge" [2]. This challenge achieves to find solutions for more efficient autonomously flying drones and better path planning and obstacle avoidance in small indoor environments. It is the goal of this challenge to develop a nanocopter that can fly through an obstacle course autonomously and as fast as possible.

The UvA Drone team consists of two bachelor students supported by one staff member from the University of Amsterdam, The Netherlands. Previous participation in Micro Aerial Vehicle competitions [3, 4, 5] has resulted in several publications [6, 7, 8, 9] and theses [10, 11, 12, 13, 14, 15].

2 Team Members

The work is distributed over the team as follows:

- **Niels Sombekke** - Obstacle avoidance based on Monocular Depth Estimation.
- **Wim Pilkes** - Path planning using Virtual Force Fields.
- **Arnoud Visser** - Academic advisor.

3 Platform

The IMAV 2022 Nanocopter AI Challenge requires all participants to use identical hardware. This consists of the Crazyflie 2.1 nano quadcopter and the AI deck 1.1, both are produced by Bitcraze.

Figure 1: The Crazyflie 2.1 nano quadcopter.

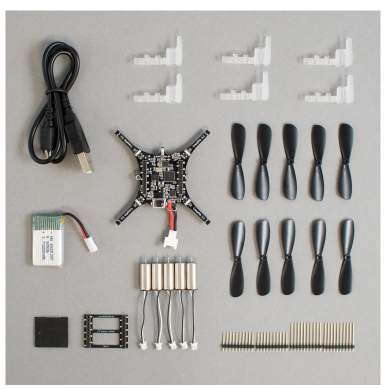

Figure 2: The components of the Crazyflie 2.1, including spare parts.

Figure 3: The AI-deck 1.1.

3.1 Crazyflie 2.1

The Crazyflie 2.1 is an open source flying development platform. This platform allows for efficient development and testing of autonomous drone software. The platform consist of an control board, a small LiPo battery, 4 DC coreless motors with motor mounts and propellers. This platform is designed to support expansion decks for further functionality, such as the AI-deck 1.1.

3.2 AI-deck 1.1

The AI-deck 1.1 is a processing board used for real-time complex AI processing. It can be attached above or under the Crazyflie. The main component of this deck is the GAP8 IoT processor, which can do efficient machine learning with ultra low power consumption. This makes it suitable to be used on a nanocopters. The deck also has an 320x320 monochromatic camera that is directly attached to the processor.

4 Our Approach

4.1 Obstacle Avoidance using Monocular Depth Estimation (MDE)

Monocular depth estimation is a field that has been widely studied and has seen major improvements with the introduction of Deep Neural Networks (DNN) [16]. Obstacle avoidance using these generated depth maps has proven to be successful [17], enabling the drone to move around an obstacle. It can be further improved by transforming the depth map, confidence values (obtained by a pCNN) and dynamic constraints to an Ego Dynamic Space (EDS) and using this to compute traversable waypoints and appropriate control inputs for the drone. [18]. These studies however are build on MDE models that are too complex to run on the hardware constraints of the AI-deck. Our approach for obstacle avoidance is inspired by these papers but simpler to adhere to the hardware constraints imposed by the AI-deck. A real-time and light-weight MDE model will be used to generate a depth-map from the monochromatic camera input, model candidates are the FastDepth [19] and PyDNet [20] model. The generated depth map will be used as input for the behaviour arbitration based control algorithm which enables the drone to steer away from obstacles. This steering angle will also be influenced by the direction of the target. [18] The complete pipeline will enable the drone to avoid obstacles by only using the input of the single monochromatic camera.

4.2 Path planning using Virtual Force Fields (VFF)

It is the goal of this challenge to be able to navigate the obstacle zone as efficient as possible without hitting the obstacles. To do so, an optimized path planning algorithm is needed. This algorithm has to operate with certain constrains. First of all, it is preferred that the algorithm is able to operate locally on the AI deck. Thus, a solution should be found that uses the least processing power possible, taking into account the processing power needed for the obstacle depth estimation. Second of all, the only information that the nanocopter observes is a 320x320 image feed. As a result, full mapping of the obstacle course is not a viable option. Thus the path planning must be able to operate on incomplete information.

Potential field methods (PFM) are widely used for path planning. These fields are determined by attracting forces and repulsing forces, such as goals and obstacles. The motion and direction of the drone can be calculated by the net force that is acting on it on any given moment. This results in a path in which the drone is attracted towards the goal, whilst being repulsed by obstacles.

Because the drone has incomplete information, a full force field of the whole course can not be mapped. Consequently, a potential field method called virtual force fields (VFF) is used. First used by Borenstein and Koren [21], VFFs create a certainty grid around a drone, where all cells are constantly updated with a certainty value, representing the certainty that there is an obstacle in the cell. This is then used to calculate a net force that acts upon the drone. This method is proven to be effective in both simulations and real world experiments.

5 Conclusion

The UvA Drone team has set out a framework for its approach of the "Nanocopter AI challenge". This consists of a combination of MDE and VFF to be used on the AI deck 1.1. The team aims to improve upon its earlier experience using the research done by several robotics teams in the Netherlands.

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