Trajectory Planning for Formations of Unmanned Micro Aerial Vehicles

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***Abstract*—A model predictive control based algorithm designed for guidance of formations of unmanned Micro Aerial Vehicles (MAV) is presented in the paper. The proposed method is suited for flight of multiple quadrotor MAVs in changing environment while maintaining the predefined shape. The formation is stabilized using the onboard relative visual localization, which puts additional constraints to the planning. The main advantage of the presented method is that it does not rely on global motion capture system. Multiple experiments verifying the method functionality are presented in the paper.**

I. Introduction

Motion coordination of large teams of Micro Aerial Vehicles (MAVs) requires precise positioning, which is usually provided by external localization systems [1]. However, multi-robot systems have to be cooperatively deployed in large areas in a short time and may not rely on such a pre-installed global localization infrastructure in the real-world applications. Moreover, most of available systems (like GPS) are not reliable in urban and indoor environments, and lack the required precision for teams of small robots.

We present a novel formation driving approach based on Model Predictive Control (MPC), which is adapted for onboard visual relative localization of formation members - quadrotor MAVs. The formation of multiple MAVs have to reach a desired target region in a complex environment with obstacles, while keeping predefined relative positions between the robots, in the investigated scenario. The desired shape of the formation can be temporarily broken if it is enforced by the environment (e.g. in narrow passages). The proposed system provides an efficient solution, which may act as an enabling technique for utilization of MAVs in severe applications. The presented paper focuses on the formation driving mechanism suited for the real-world deployment of formations of autonomous robots relying on the onboard visual relative localization.

In the paper [2], we utilise a leader-follower method, where the team of robots is stabilized by sharing knowledge of the position of the leader within the formation. The basic principles of the leader-follower approach are described in [3], more details are presented in papers [4], [5] and references reported therein. Recently, research has been aimed mainly at tasks of formation stabilization [6] and formation following a predefined path [4] in the formation driving community.

The paper shows that the computational power of microprocessors available onboard unmanned helicopters enables the employment of MPC techniques also for the formation control of these highly dynamic systems, as is formation of quadrotor MAVs.

In our approach, we apply the MPC technique for the stabilization of followers in the desired positions behind the leader, as well as for the trajectory planning into a desired goal area with obstacle avoidance ability. We do not rely on following a given trajectory, as in most of the state-of-the-art methods. The global trajectory planning is directly integrated into the formation control mechanism. This is necessary for finding a feasible solution for the relative visual localization of team members, where the constraints of direct visibility have to be satisfied. We propose a new MPC concept combining both, the trajectory planning into the desired goal region and the immediate control of the formation in a single optimization process. The method can continuously respond to changes in the vicinity, while keeping the cohesion of the immediate control inputs with the directions of movement of the MAV formation in the future.

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