Optimal Control and Trajectory Estimation of Nonlinear Quadrotor

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***Abstract*—We present an optimal control problem to estimate the rotor speed inputs and state sequences to drive a nonlinear model of a quadcopter through a race track in a minimum time. We show how to solve this problem by using GPOPS-II, a matlab-based general purpose optimal control software.**

***Index Terms*—Optimal Control, Drone Racing**

SUPPLEMENTARY MATERIAL

Videos of the experiments: **TODO:** Add video url
Open-source code: **TODO:** Add code url

I. INTRODUCTION

THE advent of drone racing competitions such as **TODO:** cite alpha pilot requires the estimation of the fastest possible trajectory through a given race track. Finding this optimal trajectory can be useful for human pilots, and their tacticians, to evaluate their performance and improve upon it. For example, the teams in the Red Bull Air Race **TODO:** cite redbull and SH make extensive use of such information to train and perfect their manouevers. In this same way, drones can autonomously follow a dynamically feasible trajectory with high accuracy. Therefore being able to infer the optimal feasible trajectory could potentially make fully-autonomous drones beat human pilots. We are still not there, but great progress in this direction is being made.

Contributions.

- Formulation of the minimum-time problem for the specific problem of drone-racing through multiple gates.
- Presentation of a means to solve the problem using readily available software.

Paper Structure. Section III presents the mathematical formulation of our approach, and discusses the implementation of Section IV reports and discusses the experimental results and comparison against related work. Section V concludes the paper.

II. RELATED WORK

A. TODO

B. Optimal Control

III. APPROACH

The minimum time optimal control problem can be generically formulated as follows:

Cost:

$$J = \int_{t_0}^{t_f} dt$$

Nonlinear Dynamics:

$$\dot{x}(t) = f(x(t), u(t), t)$$

Constraints:

- Input constraints:

$$M_i^- \leq u_i(t) \leq M_i^+$$

- Path constraints: $\forall t, t_0 \leq t \leq t_f$

$$c(x(t), u(t), t) \leq 0,$$

Boundary Conditions: Given

- Initial: $n(x(t_0), t_0) = 0$
- Final: $m(x(t_f), t_f) = 0$

Transversality Condition:

A. Front-end

1) Calculus of Variations:

2) 3D Mesh Propagation:

IV. EXPERIMENTAL RESULTS

V. CONCLUSION

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