Multirotor aerial vehicle control combining different actuation principles

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1. Introduction

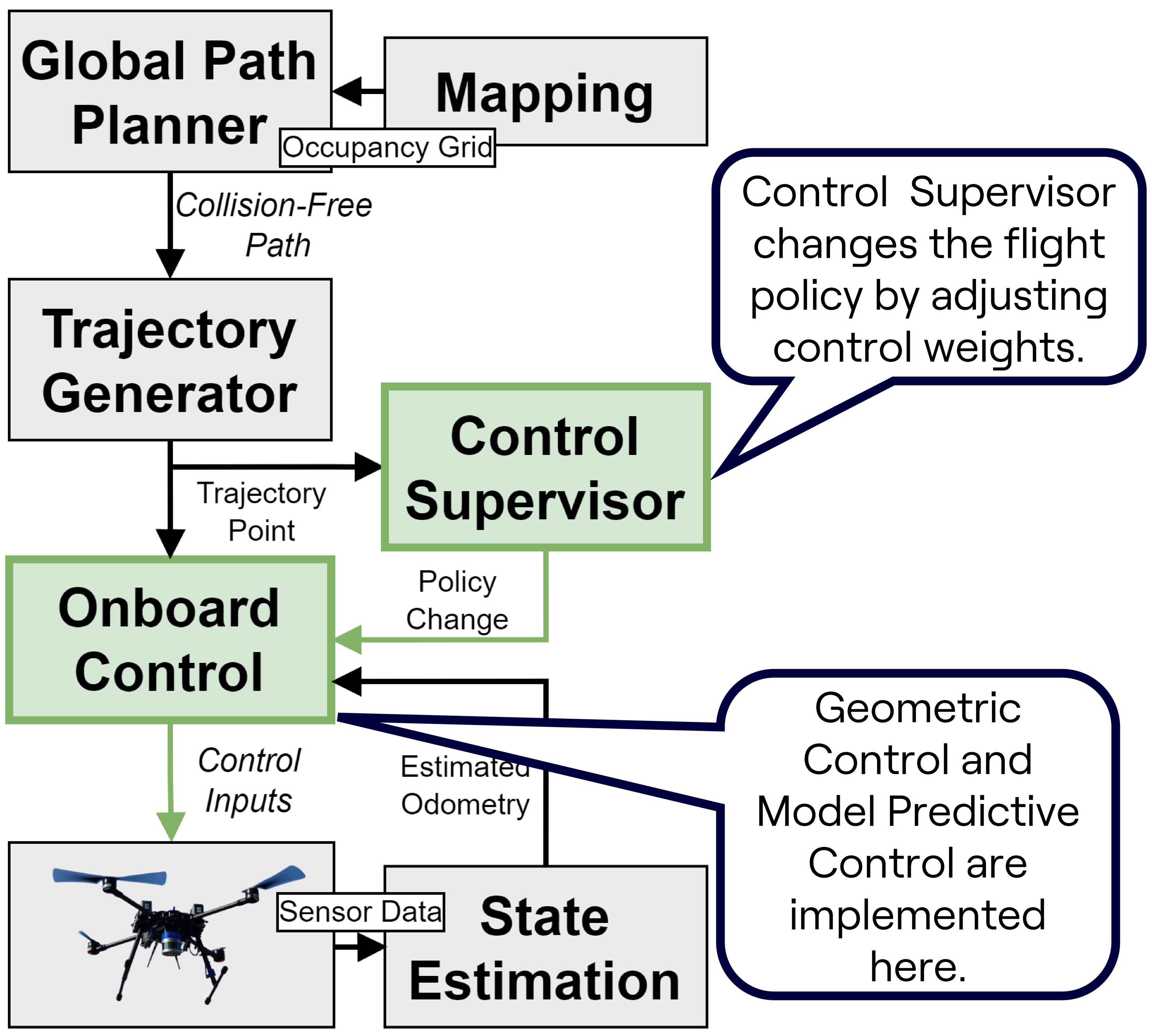
The main goal of this research is to explore and develop novel control methods for multirotor unmanned aerial vehicles with multiple control inputs. A standard multi-rotor vehicle relies on rotor variation to govern its body frame, while the aerial vehicles considered in this research may include additional control inputs. Actuated rotors, which tilt along the arm axis, are introduced to provide a more subtle influence on the body frame while endowing the UAS with a tilted hover ability. A varying center of mass, caused by moving masses or an aerial manipulator, is also considered in the control problem formulation.

2. Problem Description

In this research, both a geometric[1] and a model predictive control approach is proposed for aerial vehicles with multiple actuation methods. Furthermore, an adaptive algorithm is introduced to supervise the model predictive controller and to ensure stable flight in various mission scenarios, e.g. aggressive, contact-based or payload transportation flights. Finally, an experimental validation is performed along with a potential application in a surface-based inspection scenario[2].

3. Methodology

Before designing the control approaches, the aerial vehicle model needs to be considered. For the geometric control, a nonlinear variant with SE(3) configuration is derived, while a linearised form is used for the model predictive control approach. On top of the onboard control, as seen on the system diagram, an adaptive control supervisor is designed, based on *a-priori* knowledge of the flight mission. Its job is to adapt the control weights depending on the mission requirements.



System diagram for aerial vehicle navigation integrating the proposed control supervisor approach.

4. Results

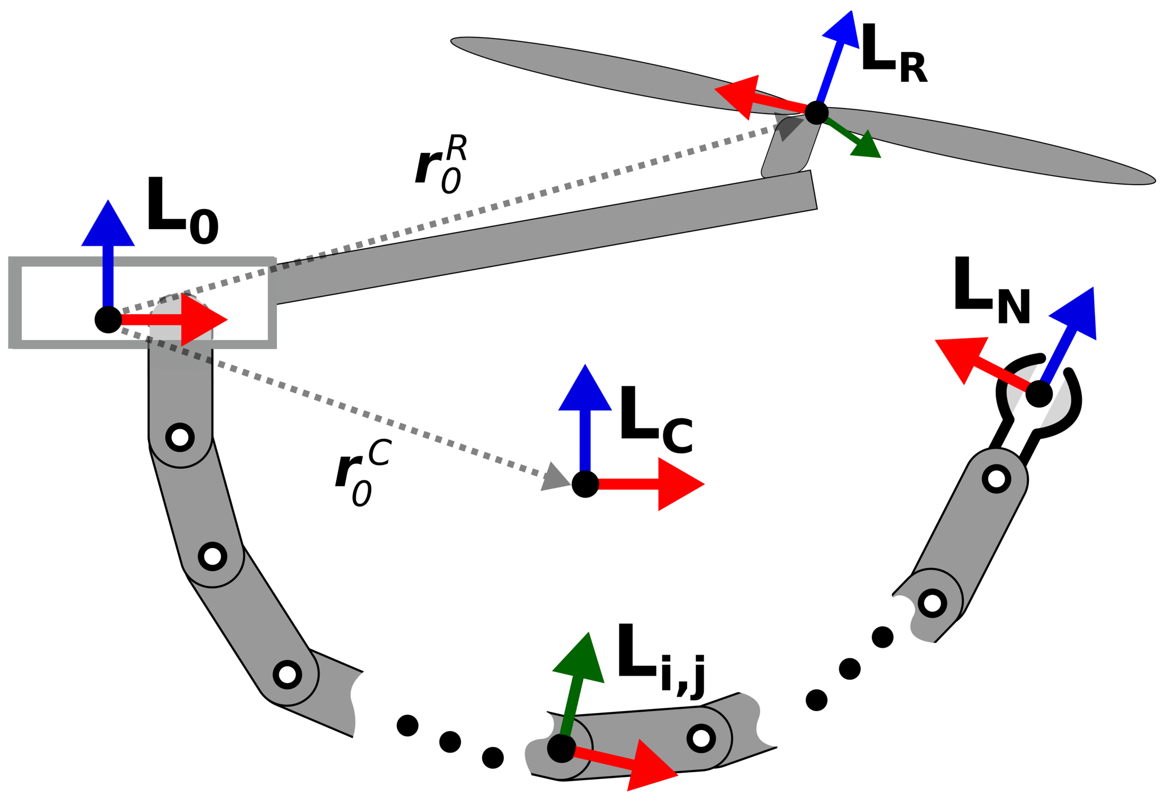
The results shown are from the first approach, geometric control with centroid vectoring[1]. Based on the derived nonlinear model, the control terms are selected which guarantee system stability wrt. the Lyapunov criterion. The obtained control system is validated in a Gazebo simulation environment using the Robot Operating System (ROS). Centroid vectoring is induced with two separate principles: the mass displacement on the vehicle arms and the payload transportation using a robotic manipulator.

Nonlinear model for a vehicle with a variable center of gravity evolving on the SE(3) configuration space.

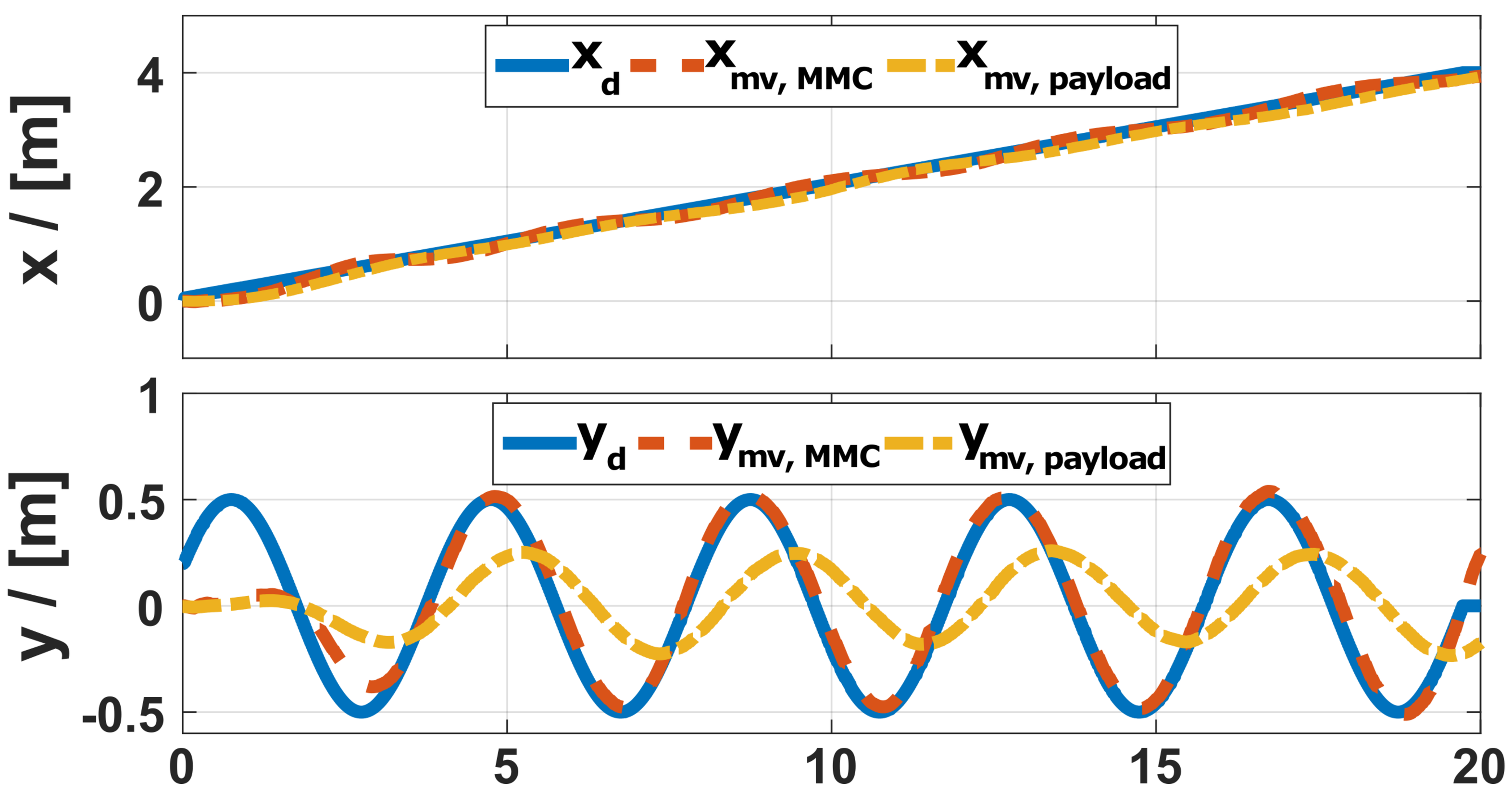
$$\dot{R} = R\hat{\Omega}$$

$$m\ddot{\mathbf{x}} - mR(\mathbf{r}_{CoG} \times \dot{\boldsymbol{\Omega}}) + mg\mathbf{e}_3 - mR[\boldsymbol{\Omega} \times (\mathbf{r}_{CoG} \times \boldsymbol{\Omega})] = fR\mathbf{e}_3$$

$$J\dot{\boldsymbol{\Omega}} + m\mathbf{r}_{CoG} \times R^T\ddot{\mathbf{x}} + \boldsymbol{\Omega} \times J\boldsymbol{\Omega} = \mathbf{M}$$



A generalised aerial vehicle model with multiple actuation principles. The robotic manipulator payload L_N induces changes in center of gravity L_c while the tilting propeller adjusts the thrust direction L_R.



Geometric controller's trajectory tracking performance using moving masses and a robotic manipulator with payload. Slow manipulator dynamics fail to produce the desired control moments.

5. Conclusion

In conclusion, the gemetric control terms are derived using the proposed nonlinear aerial vehicle model. The controller is validated in the Gazebo simulation environment. The results show that geometric control with centroid vectoring can track the desired trajectory, provided that the center of gravity actuator is able to meet the torque demand. A similar approach is taken with the model predictive control in the remainder of the research. The advantages of both control approaches for aerial vehicles with multiple actuation methods are compared. Lastly, the control supervisor is integrated to facilitate smooth execution of diverse flight missions with varying dynamic constraints.

Acknowledgments
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References

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[2] L. Markovic, M. Car, M. Orsag and S. Bogdan, "Adaptive stiffness estimation impedance control for achieving sustained contact in aerial manipulation"

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