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Robust nonlinear trajectory tracking and control of quadrotor UAV

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2014-09-03
http://hdl.handle.net/10539/15373

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Abstract

Unmanned Aerial Vehicles(UAVs) provide a versatile platform for the automation of a wide variety of tasks such as powerline inspection, border interdiction, search and rescue e.t.c. The success of these UAV platforms relies heavily on the development of control algorithms that can cope with the harsh and uncertain environments in which the UAVs will operate in. This dissertation focuses on the development of robust trajectory tracking control algorithms for a quadrotor UAV platform. Robustness in this context refers to the ability of the controller to guarantee system performance in the presence of uncertainties such as unknown system parameters or some other unmodeled effects. By exploiting the strict feedback form of the quadrotor dynamics a backstepping based control strategy for the system which comprises of two sub-controllers namely a translational controller and an attitude controller is developed. For the translational controller of the UAV a novel robust bounded controller is developed. This novel controller is developed by combining A.R Teel's nonlinear saturated controller with sliding mode techniques to achieve bounded error tracking in the presence of disturbances while at the same time ensuring bounded control which captures the limited nature of the UAV's thrust actuators. Additionally conditions on the controller parameters are identified which ensure that the UAV does not overturn during flight. The controller for the vehicle attitude is based on a modified backstepping method. Conventional backstepping control is formulated under the implicit assumption of a perfectly known system, thus in instances where uncertainty exists the performance of conventional backstepping deteriorates. To improve on the robustness of conventional backstepping control, methods of combining it with

adaptive and/or sliding mode techniques are considered. Adaptive backstepping control is robust against parametric uncertainty however its performance deteriorates in the presence of disturbances. An adaptive backstepping controller with nonlinear damping is proposed as a solution to this problem, Lyapunov based analysis shows that this controller achieves bounded error tracking in the presence of parametric and non-parametric uncertainty. A second modification of the backstepping method that is considered involves combining sliding mode control with conventional backstepping control. Sliding backstepping control is a powerful control method in that it is able to achieve asymptotic tracking in the presence of uncertainty. However this is only achieved if the upper bounds of the uncertainty are known *a priori*, this requirement is very difficult to meet in practice. Thus an adaptive sliding backstepping controller is proposed which removes the requirement of *a priori* knowledge of the upper bounds. In conclusion the key features of this work are a novel robust bounded translational controller, an adaptive backstepping attitude controller with nonlinear damping and an adaptive sliding backstepping attitude controller with guaranteed asymptotic tracking. Thus a comprehensive robust trajectory tracking controller for a quadrotor UAV is developed.