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Subject Area	Sensor, Actuator and Communication Systems
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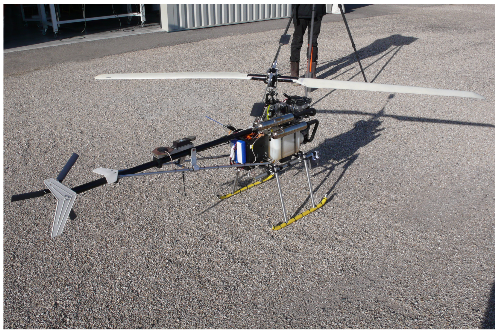
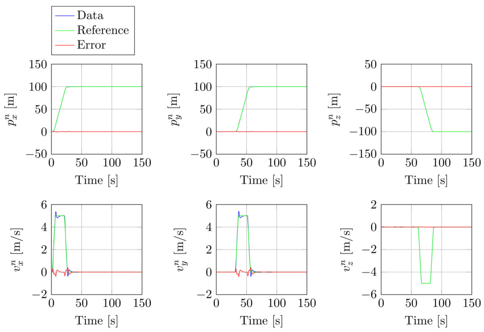
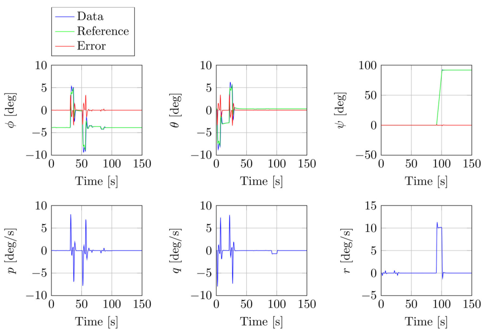
Nonlinear Control

Nonlinear Controller for a Rotary-wing Aircraft


Helicopter Ready to Fly



Simulated Response (Position and Speed)



Simulated Response (Attitude)

Introduction: weControl SA is developing and selling control systems for unmanned helicopters and airplanes. The software is implemented in Oberon on their own hardware. Together with SURVEY Copter SA, they offer fully automatic surveillance helicopters and planes. Up to the present, the control system used for helicopters is based on a linearized model. There are three controllers, one for the north and east speed and position, one for the heading and one for the vertical position. This control system is mainly optimized for hovering. Using robust control, the flight envelope is extended to moderate speed. With the coordinated turn feature, it is possible to follow a curved trajectory. But fast dynamic flying is not possible.

As a simple example for a nonlinear model, the forward and downward acceleration is connected to the pitch angle (here simplified for roll and yaw = 0°) by the following equations: a_x = T/m*sin(pitch) and a_z = T/m*cos(pitch) + g where T is the thrust generated by the main rotor. The linearized model is a_x = - g*pitch and a_z = T/m + g. The acceleration resulting from thrust T/m is approximated by -g because the thrust needs to compensate earth's gravity to maintain height. The linearized model works good for small angles which means also small accelerations. There is a well established theory for controlling linear systems. But for the above example, a controller working with a linearized model would ask for an angle of -180° to achieve an acceleration of 3.141 g. This clearly won't work out well!

Solution: In this work, a nonlinear transformation is used which was presented by Heiges M. W. et al. in «Synthesis of a Helicopter Full-Authority Controller» and applied to an acrobatic plane by Möckli M. in «Guidance and Control for Aerobatic Maneuvers of an Unmanned Airplane». After transforming the nonlinear system to a linear one, a linear controller is used. For the above example, the transformation would ask for pitch = - 72° and T/m = $-32 m/s^2$ to achieve the horizontal acceleration while holding the vertical position. The controller itself sets just the acceleration. This is basically how the used approach works. The full control system is implemented and tested in Matlab. The parameters for the new helicopter model are identified. When the simulation was stable, the controller was implemented in Oberon and tested. Finally, the controller is successfully tested on a real surveillance helicopter.