# Accurate Off-Road Path Following Control for a Small Agricultural Vehicle

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Future demands in the agricultural food production will increase the need for more production efficiency and environmental protection. Autonomous small agricultural vehicles can potentially respond to these challenges. In this work, we lay down the basis for exploring systematically these potentialities. Therefore a platform for path following control of small agricultural vehicles was developed and tested. 1

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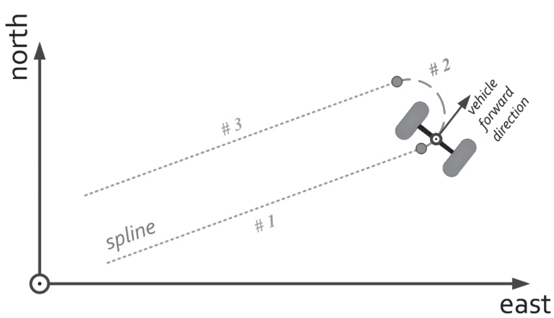
## Motivation

The United Nations Organisations predicts that more food has to be produced over the next 50 years, than has been during the last 10 000 years. To increase the agricultural food production, machines have to be more productive and environmental damages have to be reduced. Heavy agricultural vehicles are efficient but, due to their great weight, they compact the soil and thereby reduce the plant's growth. A possible solution is the use of small agricultural vehicles with partial autonomy. In this way, productivity gaps can be reduced and user safety can be increased at the same time.

## Objectives

The goal of this thesis is to design and implement a complete path following controller on a small, agricultural and commercially available differential-drive vehicle. Therefore the entire control loop, including sensor interface, coordinate system transformation, filter, path planer, path guidance and accurate robust control strategy, will be developed and implemented. Finally, empirical tests on hilly agricultural fields will be performed, to analyse the performance of the path following software and the control strategies.




A typical agricultural path with a headland turn

## Approach

The actual implementation is done on a real-time target, which can be programmed with MATLAB/Simulink. Among other sensors, a precise Differential Global Positioning System (DGPS) with Real Time Kinematic (RTK) and an Inertial Measurement Unit (IMU), are included in the control loop. Sensor signals are corrected, transformed into the desired coordinate system and fused within Kalman-Filter techniques. The vehicle is guided along a desired path, which is represented as a piecewise cubic B-Spline. The nearest spline point is evaluated within a numerical algorithm, called Newton-Raphson, which approximates the minimal orthogonal distance between spline and vehicle. Once this point is found, all error states and a desired forward velocity are computed and delivered to the control algorithms. For the implementation we focused on two control strategies, the first is a simple pure pursuit algorithm realized with a classic proportional controller. The second strategy is a velocity independent linear feedback controller, based on a linearized kinematic error model.

## Results

Field tests for the complete software and control strategy evaluation are planned. Therefore, the reference path, situated orthogonal to the slope (~10°), will consist of two parallel straight lines connected with a 1.5 m radius headland turn. First results on flat pavement showed a path following accuracy of ±9 cm lateral error and ±4° heading error on the straight path segments, obtained with the linear feedback controller at a velocity of 1.5 m/s.

## Outlook

Based on this work, better sensors, advanced filters and other control algorithms can be easily tested. We have seen, that an estimation of a suitable heading is difficult, the use of a dual antenna GPS system is promising therefore. This effort is necessary to get a suitable off-road path following behaviour at optimal cost.