TECHNISCHE UNIVERSITÄT MÜNCHEN
LEHRSTUHL FÜR INFORMATIONSTECHNISCHE REGELUNG
ORDINARIA: UNIV.-PROF. DR.-ING. SANDRA HIRCHE

F O R S C H U N G S P R A X I S

Rotational Derivatives and Newton's Method in Robotics

Problem description:

Newton's method is a fundamental algorithm at the heart of most optimization tools [1]. Such optimization solvers can be used for control, for example model-predictive control (MPC), trajectory optimization, or in the numerical integration for dynamics simulation. The main concept of Newton's method is to iteratively linearize a nonlinear function at a current approximate solution and then take the root of this linearization as a better approximation of the solution to find the root of the nonlinear function. For the linearization it is necessary to calculate derivatives of the nonlinear function.
In robotic systems, typically rotating components are involved such as links in a robot arm, wheels on a car-like robot or the floating base of a humanoid. The orientation of such rotating components can be described in a variety of ways (for example Euler angles, rotation matrices) but an efficient and powerful parameterization is quaternions [2]. Quaternions are simply an extension of complex numbers with four components.
Quaternions can be treated as regular four-dimensional vectors in which case the derivatives in Newton's method are fairly standard. But the special structure of quaternions and rotations also allows for the application of different derivatives that have certain advantages [3].
The aim of this Forschungspraxis is to investigate the performance of different rotational derivatives in their application in Newton's method. As a result, advantages and disadvantages of different derivatives, for example in terms of required iterations, are obtained.

Work schedule:

- Literature research on quaternions and rotational derivatives
- Implementation of Newton's method with varying rotational derivatives
- Evaluation of performances for different problems
- Optional: Theoretical reasoning about results, i.e. convergence proofs

Bibliography:

[1] J. Nocedal and S. Wright. *Numerical Optimization*. Springer, 2006.
[2] J. Solà. Quaternion Kinematics for the Error-State Kalman Filter. *arXiv e-prints*, arXiv:1711.02508 [cs.RO], 2017.
[3] J. Stillwell. *Naive Lie Theory*. Springer, 2008.

Supervisor:	M. Sc. Jan Brüdigam
Start:	As soon as possible
Delivery:	After 9 weeks (full time) or 20 weeks (part time)

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