# Estimating Parameters in Optimal Control Problems – Numerical Methods and Computational Results for Identifying Cerebral Palsy Gaits

**K. Hatz**[1], **J. P. Schlöder**[1], **and H. G. Bock**[1]

**Abstract:** We are interested in numerical methods for estimating parameters in optimal control problems, where we have a least-squares objective on the upper level and an optimal control problem (OCP) with mixed path-control constraints on the lower level. The OCP can be considered as a model (a so-called optimal control model) that describes optimal processes in nature, such as human gait, or in particular, the gait of cerebral palsy patients. The optimal control model includes unknown parameters that have to be determined from measurements. We present an efficient direct all-at once approach for solving this new class of problems. The main idea is the following: We discretize the infinite dimensional bilevel problem, replace the lower level nonlinear program (NLP) by its first order necessary conditions (KKT conditions), and solve the resulting complex NLP, which includes first order derivatives and a complementarity constraint, with a tailored sequential quadratic programming (SQP) method. The performance of our method is discussed and compared with the one of alternative approaches. Furthermore, we present an optimal control model for a cerebral palsy patient which has been identified from real-world motion capture data that has been provided by the Gait Analysis Laboratory of the University Hospital Heidelberg.

[1] Interdisciplinary Center for Scientific Computing
University of Heidelberg
Im Neuenheimer Feld 368, 69120 Heidelberg, Germany
Corresponding author: *kathrin.hatz@iwr.uni-heidelberg.de*