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INVERSE-DYNAMICS PARTICLE SWARM OPTIMIZATION FOR REAL TIME OPTIMAL CONTROL: CHALLENGES AND OPPORTUNITIES

Abstract

Optimal control problems (OCPs) often arise in the aerospace field when maneuvers are required to satisfy specific requirements, as it happens for the minimum-time or minimum-effort planning. However, numerical techniques used so far to solve the parameters optimization problems associated to OCPs are often computational demanding and are implemented offline. The optimal trajectory is then given as input to a feedback control system. However, a new control philosophy has been proposed basing on the hardware improvements and the computational abilities of future platforms. Real time optimal control (RTOC) is based on the combination of efficient strategies to solve OCPs and the opportunity to use powerful on-board computers with enhanced computational capabilities.

In these last years, the authors of this paper have proposed the Inverse-dynamics Particle Swarm Optimization (IPSO) to solve different optimal control problems (OCPs) relevant in the astrodynamics field. In more details, it has been shown how constrained attitude maneuvers and spacecraft formation reconfiguration maneuvers can be planned using IPSO. The proposed algorithm is based on the combination of the particle swarm optimization (PSO) algorithm (to solve the parameters optimization problem) and the differential flatness formulation of the dynamics (to minimize the number of optimization variables and avoid numerical integration). In previous papers the reliability and the efficiency of IPSO has been proved, but the computational effort has been never thoroughly analyzed.

This paper will present an updated version of the IPSO software. It will be useful for on-ground planning of optimal maneuvers with a user-friendly interface. Moreover, it will be analyzed the opportunity to use IPSO for RTOC. Accordingly, the main contributions of this paper are:

1. To improve the approximation ability of IPSO, considering the opportunity to use NURBS curves instead of B-splines. It is expected an improvement is the ability to approximate the optimal control policy.
2. To discuss the computational effort considering a low-level programming language and hardware computational performances consistent with current or near-future OBCs used for spacecrafts.
3. To consider the opportunity to implement RTOC based on IPSO basing on computational effort analyses and comparisons with other strategies.

Results will show how to interface with the IPSO software giving some general guidelines to set an optimal control problem using the differential flatness formulation. IPSO performances will be commented and compared with those offered by other similar software, for instance pseudo-spectral optimal control software.