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BRANCH AND BOUND TECHINQUE TO EFFICIENTLY SOLVE CONTROL AND SYSTEM DESIGN PROBLEMS WITH MIXED-INTEGER VARIABLES DOMAINS

Abstract

The paper proposes an algorithm to identify the exact solution for optimization non linear problems on mixed-integer domains (MINLP). Within the space applications context, many real design challenges, from systems design up to the guidance profile and control law identification may be formalised as optimal solutions search for mixed variables constrained through non − linear dependencies. The problem's search space, may therefore turn out to be discontinuous and largely multi-modal. Several algorithms exist to find an approximate the solution, among which stochastic global optimizers keep being widely exploited in recent years. In contrast to those aforementioned approaches, the paper presents a strategy to find exact solutions of such a class of MINLPs. The algorithm merges the idea of Branch and Bound, first given by Land and Doig in1960, with other integer programmino ingredients. The non-linear problemi s faced by exploiting the Solver WORHP ("We Optimize Really Huge Problems") an SQP Solver specifically developed for aerospace applications Both the method and the implemented algorithm are presented. To show the effectiveness and validity of the proposed tool, results obtained on two different applicative scenarios are discussed: the control profile design for the descending and landing trajectory on the Moon surface with non-throtteable thrusters; a Multidisciplinary Design Optimization (MDO) problem applied to space transportation vehicles. The former is a trajectory control problem, highly non-linear even in the center of mass dynamics only. Discrete variables are represented by the admissible thrusting level the propulsion module can supply. Cost function is the typical fuel mass minimisation. The latter is part of the joint resaerch project between the Universität Bremen and Politecnico di Milano under the European Space Agency PRESTIGE grant (PRrogram in Education for Space, Technology, Innovation and knowledGE). The models employed for the branch and bound application are limited to the conceptual level design ofclassical expendable launchers, nevertheless constituting a complex, highly non-linear and large optimization problem. Discrete variables are mainly architectural parameters, such as the number of boosters, the number of engines in each stage/booster and others, whereas the cost function is constituted by a weighted sum of mass, cost and reliability indexes. The solutions obtained for both applicative cases with the branch and bound methodology are compared with other existing algorithms and the quality of the results is discussed in the paper, together with some ideas for further work on MINLPs for space applications.