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GENERATIVE GLOBAL SEARCH FOR CRITICAL POINTS IN ASTRODYNAMICS

Abstract

A number of problems in astrodynamics, from the design of optimal interplanetary trajectories, to the identification of period orbits in complex dynamic environments, can be formulated as a global search for critical points, and extrema, of a cost function. This is generally a difficult global search problem for two reasons: i) multiple critical points can exist and some extrema can be at the boundaries of the search domain, ii) more than one critical point can correspond to interesting solutions, thus it is desirable to find more than one local critical value or extremum rather than only the global one. This is for example the case of periodic or quasi-periodic solutions in a complex dynamic environment.

This paper proposes an approach that combines recent advances in machine learning with stochastic optimisation to build a model of the distribution of the critical points and extrema in some typical problems of astrodynamics. In most of the literature on the use of machine learning for global optimisation, authors have tried to build a surrogate, local or global, of the cost function. Only a few examples exist where authors have used machine learning to learn the relationship between a sampled point, in parameter space, and a neighbouring local optimum. In one case Support Vector Machines were used to decide a priori whether a first guess was promising or not. In another case authors proposed a, so called, Boltzmann generator, to automatically generate equilibrium states of a multi-body dynamical system.

The idea proposed in this paper is reminiscent of the concept of Boltzmann generator and aims at building a probabilistic model of the distribution of critical points, so that new points can be generated by drawing samples from the model. The idea is similar to the use of Kriging surrogates in bi-level min-max optimisation where a model of the space of the maxima of the lower level is progressively built so that the upper level can search directly among the maxima. The procedure proposed in this paper trains a machine learning model with a relatively small number of local solutions computed with a stochastic global search algorithm and then use the same machine learning model to generate new ones. By doing so one would be able to generate multiple local solutions at zero cost without running any new global search. The paper will introduce the general methodology and will illustrate its use with some simple examples.