Predicting Apophis' Earth Encounter in 2029 using Differential Algebra and Taylor Models: Part 1

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The application of differential algebra and Taylor models to the analysis and prediction of Apophis close encounter is presented. The high order expansion of the flow of ordinary differential equations obtained by differential algebra is exploited to develop tools for the prediction of planetary encounters and potential impacts, taking into account the uncertainties due to measurement accuracy. A computationally efficient Monte Carlo simulation, an algorithm for the computation of the minimum distance between Earth and all the virtual asteroids belonging to the initial uncertainty cloud, and an impact leading algorithm capable of computing the initial conditions leading to an Earth impact are presented.

Furthermore, a set of tools based on resonant distance minimization and resonant period constraint are enabled by differential algebra. Taylor model integrators are used to rigorously integrate all the possible Apophis initial conditions expressed as interval boxes. It is shown that the Taylor model based integration outperforms the validated integration tools based on interval arithmetic and that long-term integrations of the heliocentric phase can be addressed. Furthermore, an automatic box splitting algorithm and a particular attention with the coding of the dynamical system enable the validated integration of Apophis close encounter phase, which is a particularly challenging problem due to the high nonlinearities of the dynamics.