Intelligent Decision Support System for NEO Impact Scenarios Identification and Deflection Strategies Selection under Uncertainty*

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Abstract. Near Earth Objects (NEO) impact poses a major threaten to all life forms on Earth. In the planning and decision making process that precedes the implementation of a NEO deflection mission, such as identifying hazardous NEO and selecting deflection strategies, there is a considerable amount of uncertainty affecting any decision [1]. In addition to the aleatory uncertainties which derive from the inherent randomness that are irreducible, the epistemic uncertainties that are caused by the lack of knowledge and limited experimental opportunities cannot be ignored. Previous studies [2] showed that by including epistemic uncertainties in the optimisation process, one can observe that in the worst case scenario the effectiveness of the whole concept can be severely compromised. For this reason, a number of past studies proposed robust optimisation methods for NEO deflection missions. However, computing a robust and globally optimal solution under mixed aleatory and epistemic uncertainty is computationally expensive and the cost rapidly grows with the number of uncertain quantities. The cost further increases with the fidelity of the deflection action and associated uncertainty model. Furthermore, the development of a deflection mission is expected to go through different phases of growing complexity in which the appropriateness of a deflection action has to be re-assessed multiple times given the level of uncertainty and maturity of the deflection technology and the knowledge of the target NEO.

To quickly respond to a NEO impact scenario, an Intelligent Decision Support System (IDSS) is proposed to automatically decide if a deflection mission is necessary, and then select the most effective deflection strategy. The diagram of IDSS is shown in Figure 1. IDSS consists of two sub-systems: the first one is named as NEO Impact Scenarios Identifier, and the second one is named as NEO Deflection Strategies Selector. The input to the NEO Impact Scenarios Identifier is the warning time, the orbital parameters and the diameter of the NEO and the corresponding uncertainties. According to the Probability of Collision (P_c) and the corresponding confidence, the output is the decision of action: the deflection is needed, no deflection is needed, or more measurements need to be obtained before making any decision. If the deflection is needed, the

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NEO Deflection Strategies Selector is activated to output the deflection strategies that are more likely to offer a successful deflection.
The training dataset is produced by generating thousands of virtual impact scenarios, sampled from the real distribution of Near-Earth Objects. A robust optimization is performed, under mixed aleatory/epistemic uncertainties, with five different deflection strategies (Nuclear Explosion Device, Kinetic Impactor, Laser Ablation, Gravity Tractor and Ion Beam Shepherd). The robust performance indices are considered as the deflection effectiveness, which is quantified by the Probability of Collision post deflection P_c'. We demonstrate the capabilities of Random Forest at classifying impact scenarios and deflection strategies. Simulation results suggest that once trained the Intelligent Decision Support System, does not require re-running expensive simulations and is, therefore, suitable for the rapid prescreening the impact scenarios and deflection options.

Keywords: Near-Earth Objects · NEO Deflection · Aleatory/Epistemic Uncertainty · Robust Optimisation · Machine Learning.

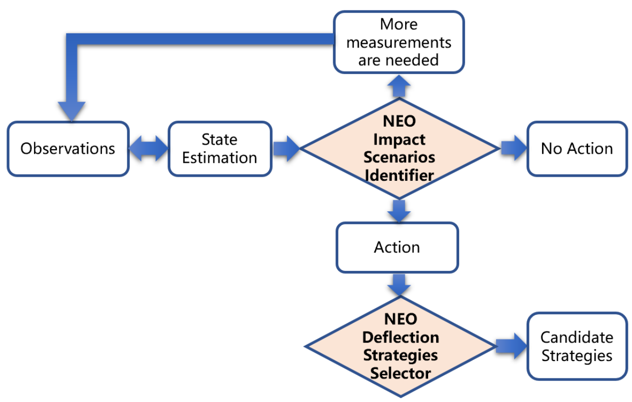

Fig. 1. Diagram of Intelligent Decision Support System for Planetary Defense.

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