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Enhance Concurrent Design Approach through a Design Methodology Based on an Artificial Intelligence Framework: Guiding Group Decision Making to Balanced Preliminary Design Solution

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Abstract : This paper presents a design methodology in which stakeholders are assisted with the exploration of a so-called negotiation space, aiming to the maximization of both group social welfare and single stakeholder's perceived utility. The outcome results in less design iterations needed for design convergence while obtaining a higher solution effectiveness. During the early stage of a space project, not only the knowledge about the system but also the decision outcomes often are unknown. The scenario is exacerbated by the fact that decisions taken in this stage imply delayed costs associated with them. Hence, it is necessary to have a clear definition of the problem under analysis, especially in the initial definition. This can be obtained thanks to a robust generation and exploration of design alternatives. This process must consider that design usually involves various individuals, who take decisions affecting one another. An effective coordination among these decision-makers is critical. Finding mutual agreement solution will reduce the iterations involved in the design process. To handle this scenario, the paper proposes a design methodology which, aims to speed-up the process of pushing the mission's concept maturity level. This push up is obtained thanks to a guided negotiation space exploration, which involves autonomously exploration and optimization of trade opportunities among stakeholders via Artificial Intelligence algorithms. The negotiation space is generated via a multidisciplinary collaborative optimization method, infused by game theory and multi-attribute utility theory. In particular, game theory is able to model the negotiation process to reach the equilibria among stakeholder needs. Because of the huge dimension of the negotiation space, a collaborative optimization framework with evolutionary algorithm has been integrated in order to guide the game process to efficiently and rapidly searching for the Pareto equilibria among stakeholders. At last, the concept of utility constituted the mechanism to bridge the language barrier between experts of different backgrounds and differing needs, using the elicited and modeled needs to evaluate a multitude of alternatives. To highlight the benefits of the proposed methodology, the paper presents the design of a CubeSat mission for the observation of lunar radiation environment. The derived solution results able to balance all stakeholders needs and guaranteeing the effectiveness of the selection mission concept thanks to its robustness in valuable changeability. The benefits provided by the proposed design methodology are highlighted, and further development proposed.

Keywords : concurrent engineering, artificial intelligence, negotiation in engineering design, multidisciplinary optimization
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