Title: Multidisciplinary Design Optimization for Missile Design using Machine Learning Techniques

Background: The missile design process involves the integration of multiple engineering disciplines including aerodynamics, propulsion, structures, control systems, etc. Traditionally, these disciplines have been optimized sequentially or separately, unable to account for complex coupled interactions. This leads to prolonged design cycles and suboptimal performance. Multidisciplinary Design Optimization (MDO) holistically optimizes the integrated system by considering interdisciplinary couplings. However, application of MDO in missile design has been limited due to computational challenges in disciplinary analyses and system integration.

Recent advances in artificial intelligence and machine learning, especially deep neural networks, provide promising avenues to address these challenges. Some initial research has applied neural networks within MDO to enable concurrent multidisciplinary optimization for missile design. However, extensive research is still needed to develop advanced machine learning-driven methodologies that can substantially transform missile design using MDO principles.

Objectives:

Perform an extensive literature review to clearly identify limitations in existing research on MDO for missile design.

Develop novel deep learning architectures like Graph Neural Networks to accurately capture complex interactions between missile design disciplines.

Construct a flexible MDO framework with a system-level optimizer, disciplinary optimizers and machine learning approximators facilitating efficient data transfer.

Validate the MDO methodology through case studies on optimizing cruise missile and tactical missile designs. Compare against traditional sequential optimization approaches.

Perform trade-off analyses to study sensitivities between competing objectives like range, speed, stealth etc. Derive actionable design guidelines.

Establish a standardized procedure for integrating machine learning models within MDO for missile design, applicable across different missile types.

Methodology:

Comprehensively review research literature on MDO in missile design to precisely determine research gaps.

Work with subject matter experts to collect extensive datasets with labelled parameters spanning key missile design disciplines.

Preprocess data and divide into training and test sets for developing machine learning models.

Train, cross-validate and select the best deep neural network architectures for modeling each discipline.

Construct response surface approximations using the trained networks to enable rapid disciplinary analyses.

Develop a flexible MDO architecture with a central system optimizer connected to disciplinary optimizers through response surface models.

Implement test cases applying the MDO framework to concurrently optimize conceptual designs of cruise and tactical missiles.

Analyze results to quantify improvements over traditional sequential optimization methods. Study trade-offs between competing objectives.

Distill research findings into a standardized step-by-step procedure for integrating machine learning within MDO for missile design.

Significance: This research will pioneer the use of state-of-the-art machine learning techniques to advance MDO capabilities for missile design. It has the potential to:

Achieve orders-of-magnitude improvement in missile performance by holistically optimizing the coupled system behavior.

Radically enhance computational efficiency by using fast-running machine learning approximators.

Validate the proposed techniques through real-world case studies on contemporary missile systems.

Standardize the integration of machine learning within MDO to make the techniques accessible to missile design practitioners.

References:

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3. Zhong, Yi-fang. (2004). Intelligent optimization system for tactics missile scheme design. Computer Integrated Manufacturing Systems.