ARC Cluster of Activities at Clemson University

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A central theme of the efforts of rapid modernization of the U.S. Army includes virtual prototyping supporting the rapid transformation of U.S. Army fleets. This requires advanced modeling and simulation combined with unprecedented collaboration across disciplines, departments, and facilities. A cluster of ARC projects have started this year at ClemsonUniversity to address this issue. The research in this cluster focuses on autonomy-enabled ground vehicles, including digital engineering, energy systems, and human-autonomy teaming in unknown off-road environments. Six exploratory and translational projects have been stared. This presentation will introduce these efforts with the goal of eliciting synergies with other ongoing ARC efforts. Specifically, the following projects will be discussed:

- **Deep Reinforcement Learning Approach to CPS Vehicle Re-envisioning** (ARC Thrust Area 1): Modern-day cyber-physical ground vehicle systems permit superior performance (reconfigurability, robustness, reliability) by exploiting underlying capabilities offered by multi-modal sensor-actuator networks mounted on the electromechanical vehicle bases and orchestrated by algorithmic-intelligence. We explore a Deep Reinforcement Learning enhanced Decision-Support framework to empower superior mobility and information gathering in a range of outdoor terrains.
- **Integrated Transient Control and Thermal Management of Autonomous Off-Road Vehicle Propulsion Systems** (ARC Thrust Area 4): This research focuses on real-time optimization strategies that account for individual component and system response and ensure fast and efficient torque delivery and high-quality electrical power within the thermal constraints of the powertrain. Of particular focus is the management of components to lower thermal footprint while meeting powertrain objectives, thereby minimizing needed package space and cooling requirements. The control methodologies developed will take advantage of forward-looking information, when available from autonomous sensing systems, to better optimize powertrain efficiency, cooling, and electrical energy delivery.

- **Energy Management of Multi-Scale Vehicle Fleets** (ARC Thrust Area 5): This project's objective is to research and develop energy sharing strategies for mixed fleets of vehicles of varying scales (UGVs and UAVs) operating in a resource-constrained environment. It specifically considers the optimal design and operation of mobile/movable microgrids involving diverse energy sources. It explores modeling and computational schemes for robust and optimal energy utilization plans for UGVs and UAVs.
- **Computational Representation and Analysis of Mission and System Requirements** (ARC Thrust Area 5): The goal of this project is to develop computational reasoning tools to aid in the definition of system-level requirements. The current requirements modeling and management approaches at GVSC and in industry will be studied to identify opportunities for developing new reasoning tools, not currently available. We will first target change prediction and robustness assessment of requirements using established approaches for historical-based modeling and reasoning using networks of requirements. To support this activity, a requirement extraction and definition tool is being developed that can read requirements documents, filter individual requirements, and link requirements into a network of the specifications. Future work will include exploring requirement target setting through systemized gamification of mission simulation, developing a formal logic to requirements, and developing machine learning to identify missing requirements.
- **Model Interface Specification and Environment to Support Model Integration** (ARC Thrust Area 5): The development of next-generation ground vehicles requires the use of models across multiple disciplines, domains, organizations, and software environments. While this is a necessary characteristic of the vehicle development process, it causes information exchange and model integration challenges. To alleviate the challenges associated with model reuse, composition and integration, an ontological approach and the associated model integration framework will be researched, and recommendations will be made to overcome current GVSC challenges. This goal will be achieved by 1) developing an approach to catalog simulations and analysis, 2) formalize a standardized model interface specification, and 3) evaluate existing model integration frameworks.
- **Best Practices for Computational Tradespace Exploration, Analysis and Decision-Making Tradespace Exploration, Analysis and Decision-Making** (ARC Thrust Area 5): In this project, we will refine the overall requirements by establishing project viability in technological, risk, and budgetary spaces. Our approach to enhancing these capabilities include incorporation of tradespace characterization metrics, technical maturity models, Bayesian estimation of requirement prioritization and thresholding, and the demonstration of best-practices for human-in-the-loop decision-making practices for tradespace analysis.

These projects support a collaborative Ground Vehicle Alliance that includes the Clemson Virtual Prototyping of Ground Systems (VIPR-GS) center and the Autonomous Vehicle Mobility Institute (AVMI) at the University of Alabama Birmingham.