Digital Human Modeling for Optimal Body Armor Design
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Abstract

Personal protective equipment (PPE), which includes traditional body armor, is a critical component for Warfighter survivability and performance. Designing a suitable PPE system is a complex and time consuming task with multiple design variables and constraints. To date most effort with PPE design, especially regarding body armor, has centered on materials development in response to necessary blast and ballistics requirements. Thus, most research and development has focused on experimental and computational evaluation and design of materials. Recently, however, the design focus has started to shift towards the complete body-armor system, not just the material(s) of a single plate or component. Improvement in survivability, stemming from incremental changes in material properties, can be minimal, and increased mobility can often be more advantageous than slightly stronger and lighter materials. Consequently, human-factors is starting to play an increasingly important role. Accordingly, although digital human modeling (DHM) has not yet been used to evaluate PPE, it offers significant opportunities for improved body-armor system design with potential reductions in developmental cost and timing.

Often, the design of PPE can be task specific. There are situations in which the armor must be as lightweight as possible, thus sacrificing coverage, and other scenarios require increased coverage, which may lead to reduced range of motion. Thus, new capabilities have been developed for virtually importing body armor and parenting it to the Santos DHM. Santos can then execute a variety of tasks like reaching, aiming, walking, etc. Concurrently, the virtual armor is automatically tested with respect to weight, coverage, bulk, geometric encumbrance, range of motion, joint torque, balance, and performance. This allows one to compare various PPE systems from a human-factors perspective.
We propose leveraging these new evaluation capabilities and implementing an optimization-based filter that automatically evaluates and selects the most advantageous PPE system. First, a library of employable, applicable armor systems is compiled. The user then indicates which metrics are used as objectives (i.e. minimize weight) and which metrics are used as constraints (i.e. ensure that weight is no more than twenty pounds). Then, the user sets up a task or set of tasks during which the armor is evaluated. Finally, the optimization filter automatically selects the system that optimizes the specified objectives while satisfying the specified constraints. Initial tests have shown realistic results with minimal computational demands.

Ongoing work involves approaching the problem of armor design from a more dynamic standpoint by actually creating new armor systems on the fly. Using the above-mentioned metrics, armor components will automatically be created or deleted, and moved over Santos’s surface. Eventually, higher fidelity models pertaining to damage of internal organs can be used to provide additional objective functions. As new and successful armor systems are found, they can then be added to the library filtering system, which can provide optimal designs more quickly. The proposed capabilities can be used, not just with body armor, but with other types of equipment as well, and thus pave the way for automatic human-centric optimal design.