

On the Challenges to Incorporate Active Muscles in Human Body Models to Simulate Motion

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ABSTRACT

Recent advances in computing power and modeling capabilities have enabled the use of advanced and detailed Human Body Models (HBMs) in the automotive industry to study crashworthiness, occupant protection, and pedestrian safety [1]. Passive HBMs, available since 2002 [2], allow analyses of kinematics and injury mechanisms during crash events but cannot represent muscle activity or reflexive responses.

Active HBMs (AHBMs) overcome these limitations by incorporating muscle models and neuromuscular control, enabling physiologically realistic, muscle-driven occupant responses, particularly relevant in pre-crash conditions where voluntary actions and reflexes influence posture and loading. Hill-type muscle formulations [3] have been widely adopted due to their efficiency and ability to reproduce fundamental muscle properties. Prior work demonstrated that combining Kistemaker's arm model [4] with the Extended Hill-Type Muscle (EHTM) model [5] provides an effective basis for studying control strategies grounded in the Equilibrium Point Hypothesis (EPH) [6]. However, the one-dimensional structure of the EHTM limits muscle representation to truss-like elements, preventing realistic modelling of three-dimensional geometry and transverse dynamics. Anatomically detailed finite element frameworks, such as the Ansys Hans Human Body Model, address these limitations by capturing realistic muscle morphology, deformation mechanics, and material behaviour. In this study, the model of Kistemaker was enhanced with EHTM muscles, resulting in a neuromusculoskeletal model comprising a musculoskeletal model of the arm with one degree of freedom that is actuated by four muscles, as well as a controller. The optimised control strategies derived were subsequently transferred to three-dimensional muscle representations in Ansys Hans, providing a foundation for more biofidelic AHBMs.

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