3D SCANNING SYSTEM TO ASSESS GRAVITY-DEPENDENT BODY SHAPE CHANGES

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The human body shows unique physiological and morphological changes when exposed to different gravity conditions, including muscle atrophy, fluid shift, spinal elongation, and body posture adjustments. Such changes need to be incorporated for human-system integration in the vehicle habitat, garment, and spacesuit designs, as inaccurate body measurements can result in suboptimal crew protection that can potentially decrease injury tolerance. However, the traditional linear measurements, such as stature, segment lengths or circumferences measured using a caliper or tape measure, often show limited consistency and are unable to capture the nonlinear characteristics of the human body. While 3D body scanning can provide significant advantages over linear measurements, the technologies have not been fully developed or customized for in-flight scanning. For ground laboratory use, several different scanner types are commercially available. However, in-flight scanning requires additional technical considerations, such as minimal scan time, simplified calibration, and sufficient capture volume.

This work aims to develop a prototype 3-D body scanning system that is customized for in-flight use to scan crewmembers, with the configuration and performance optimized for detecting known gravity-dependent body shape and posture changes. A hardware system will be custom built using a network of commercial off-the-shelf 3D sensors. The sensor parameters and settings will be optimized to detect the targeted body shape changes, specifically using body manikins of which the shape and size are iteratively permuted to simulate the known changes by fluid shift and spinal elongation. The capture volume will be also matched for a range of body sizes from a 1st percentile female to 99th percentile male. Unintentional body motions or floating in microgravity will be also simulated and incorporated. A data acquisition software will be developed for efficient in-flight operations with minimal overhead and easy-to-use user interface. A simplified calibration procedure will be designed for robust scanning against frequent vibration or unexpected sensor position shifts.

The system will be tested in the ground laboratory for accuracy and reliability against a reference scanning system. New anthropometry measurements will be also identified to sensitively capture the gravity dependent body shape changes, in addition to the traditional anthropometry measurements. A novel landmark-based technique will be tested for consistent anthropometry measurements across posture variations. If successfully developed and deployed, the new system is expected to provide previously unavailable body shape and size data from different gravitational environments, including 0-g, 1/6-g, and 1-g. Such data can improve suit fit, habitat design, exercise efficacy quantification and sizing of orthostatic intolerance garments.

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