

Posture Transfer Method on Pre-Scanned Full-body Geometry for Space Architecture Design

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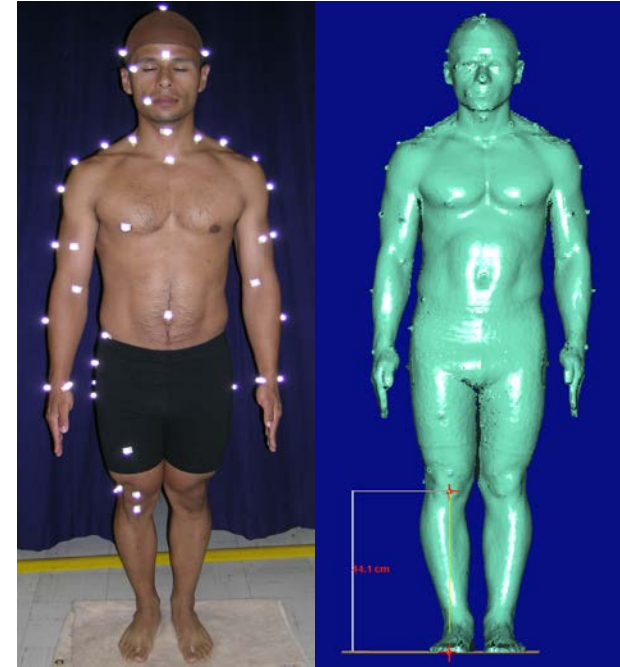
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Background

- Fit and sizing of the crewmembers are critical for spacesuit and space architecture design
 - Must accommodate a diverse population of current and future astronauts
- Current space architecture design aims to incorporate 3d body geometry
- At NASA, 3D full body scans are collected from numerous people in various postures



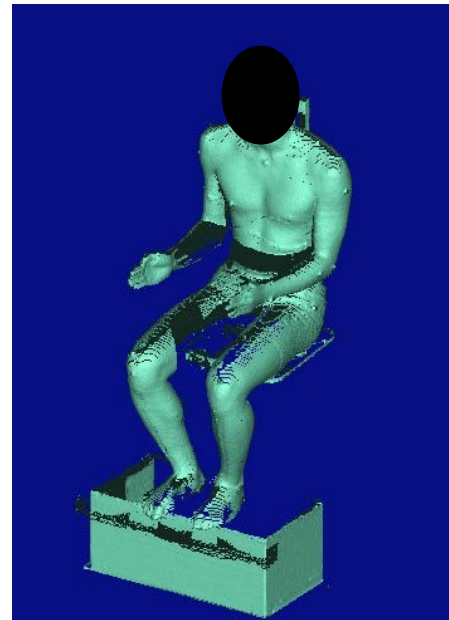
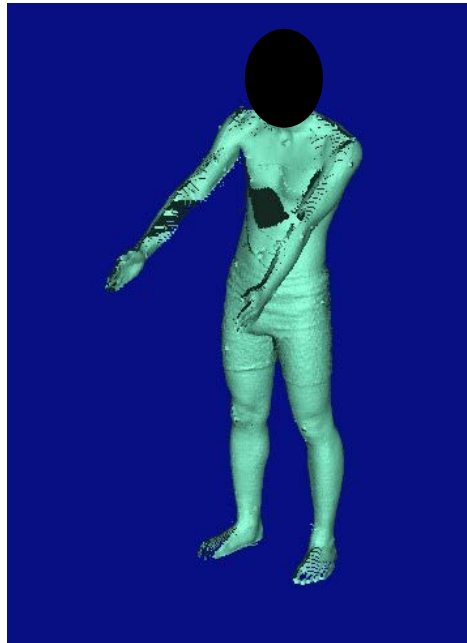
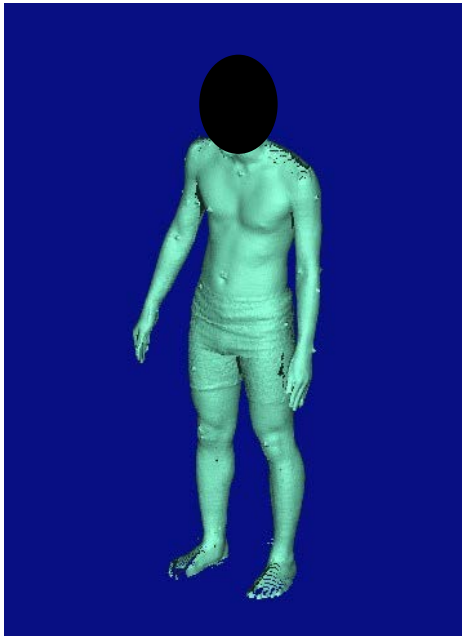
Problem

- Evaluation of design concepts often requires body geometry in target population anthropometry in specific postures
- However, the body geometry in that specific posture may not have been collected
 - Cost and time prohibitive to rescan subject
- A method to transform a body geometry into desired poses is needed
- Case Example:
 - Historically scanned a small number of subjects in one posture
 - Later scanned a large number of subjects in a new posture
 - How can we retrofit the old scans into the new posture, if subjects are unavailable for additional scanning?

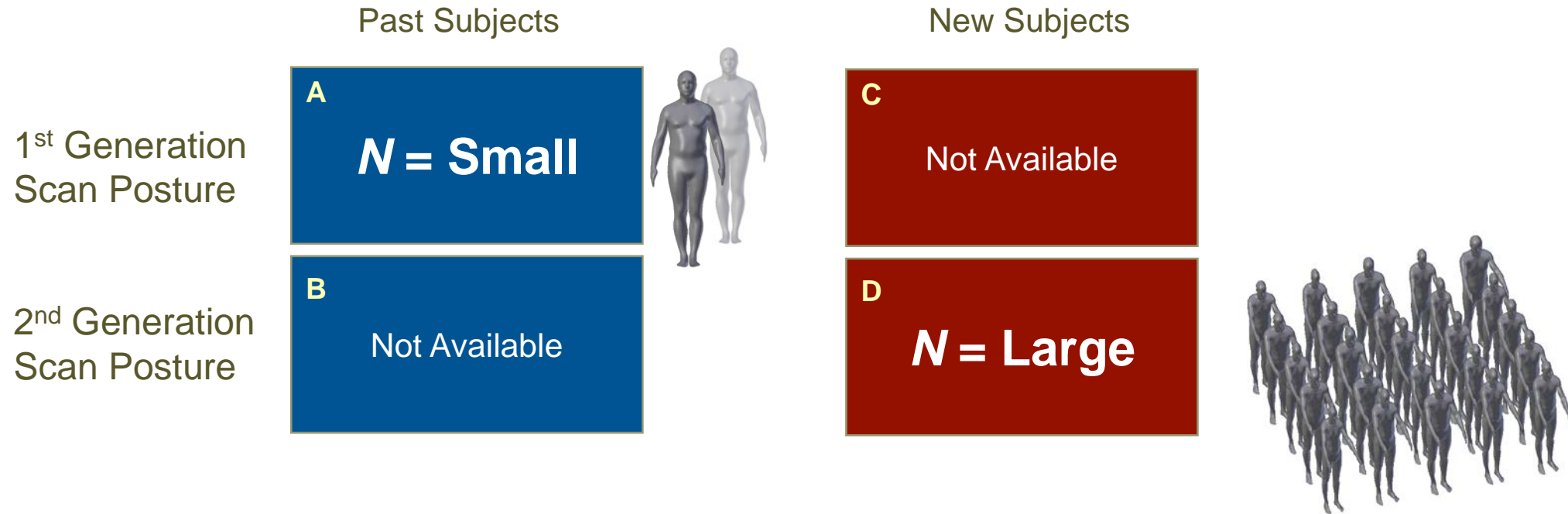


Objective

- Develop a method to assimilate the existing scans to new postures without needing to physically rescan the subject in the desired postures
- Discuss specific applications in spacesuit and space architecture design



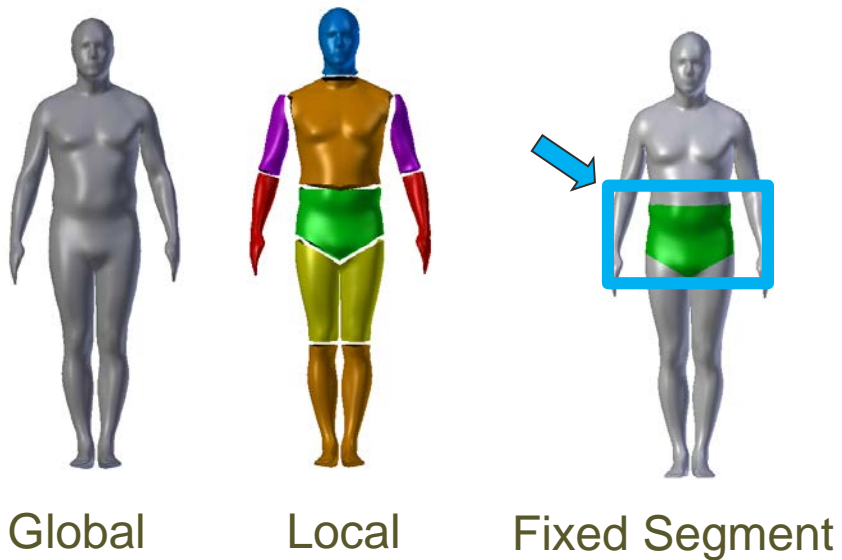
Overview of Goal and Methodology



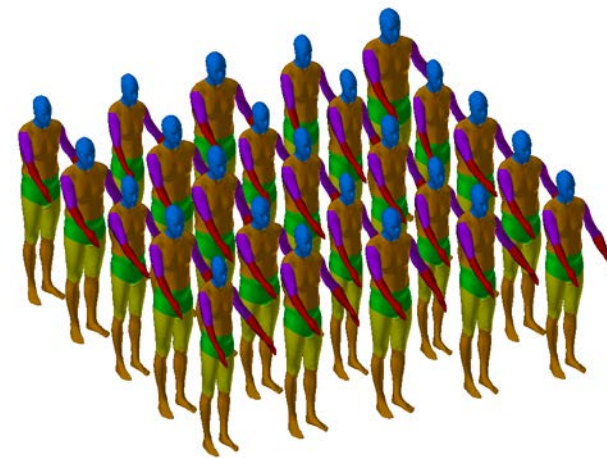
- Original posture (A): past subjects in old posture requiring transformation
- Goal posture (D): new subjects in new desired posture
- Objective is to retrofit past scans A (original posture) into B (goal posture)
- Accomplished by iteratively transform **A** to assimilate with **D** while maintaining the unique body physique of **A**

Scan Geometry Decomposition

- Global and local coordinates with respect to segments were calculated for the original and goal scans
- A priori identified fixed body segment where localized shape changes are hypothetically minimal
 - Used to preserve the shape of scan invariant to posture changes during transformation
- Principal component (PC) analysis was used to reduce data dimensions

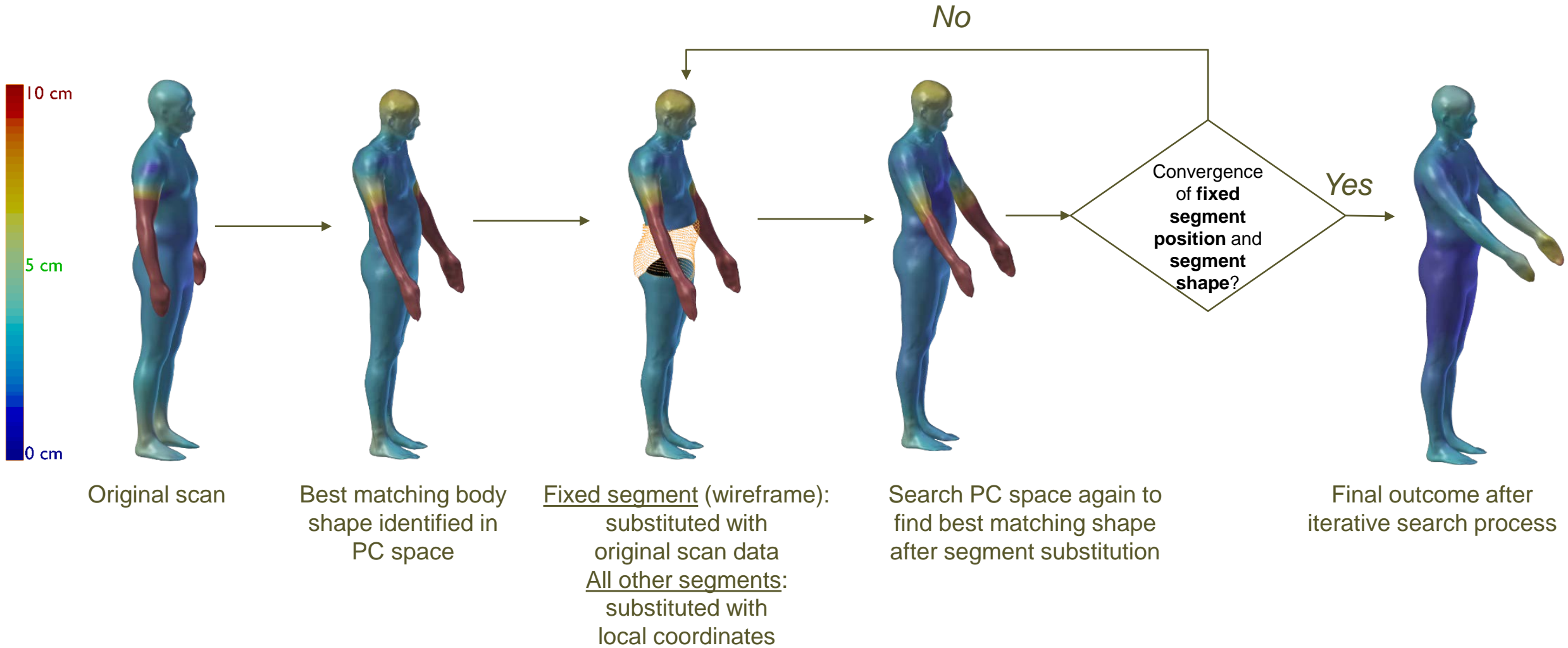


Original Posture Scan



Goal Posture Scans

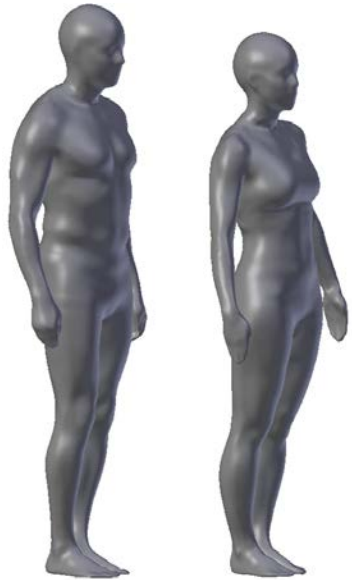
Methods: Iterative substitution algorithm



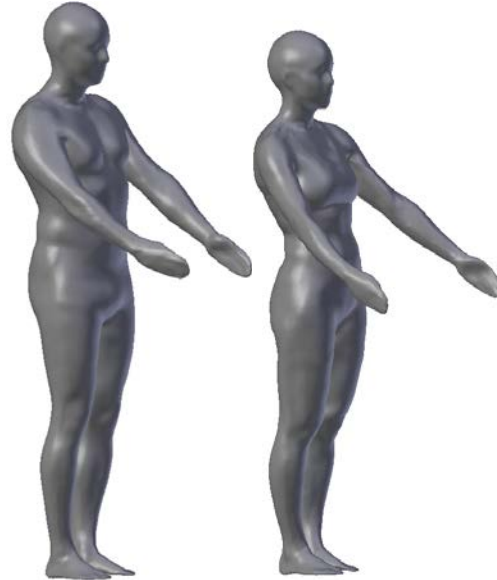
Outcome Validation

- Estimation accuracy was tested using leave-one-out validation for selected male and female subjects ($N=15$) that had both an original and goal posture scans
- Average RMSE: 2.28 cm (SD: 0.99 cm)

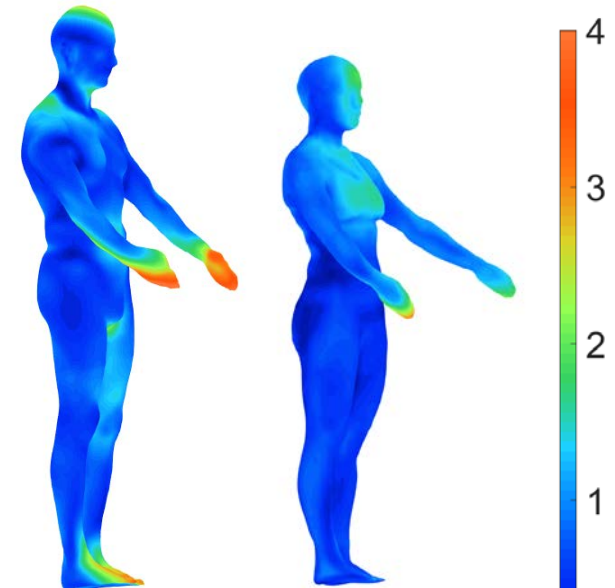
Subject	RMSE (cm)	SD (cm)
Male	3.17	0.51
Female	1.40	0.31
Average	2.28	0.99



Original Scans



Goal Posture Scans

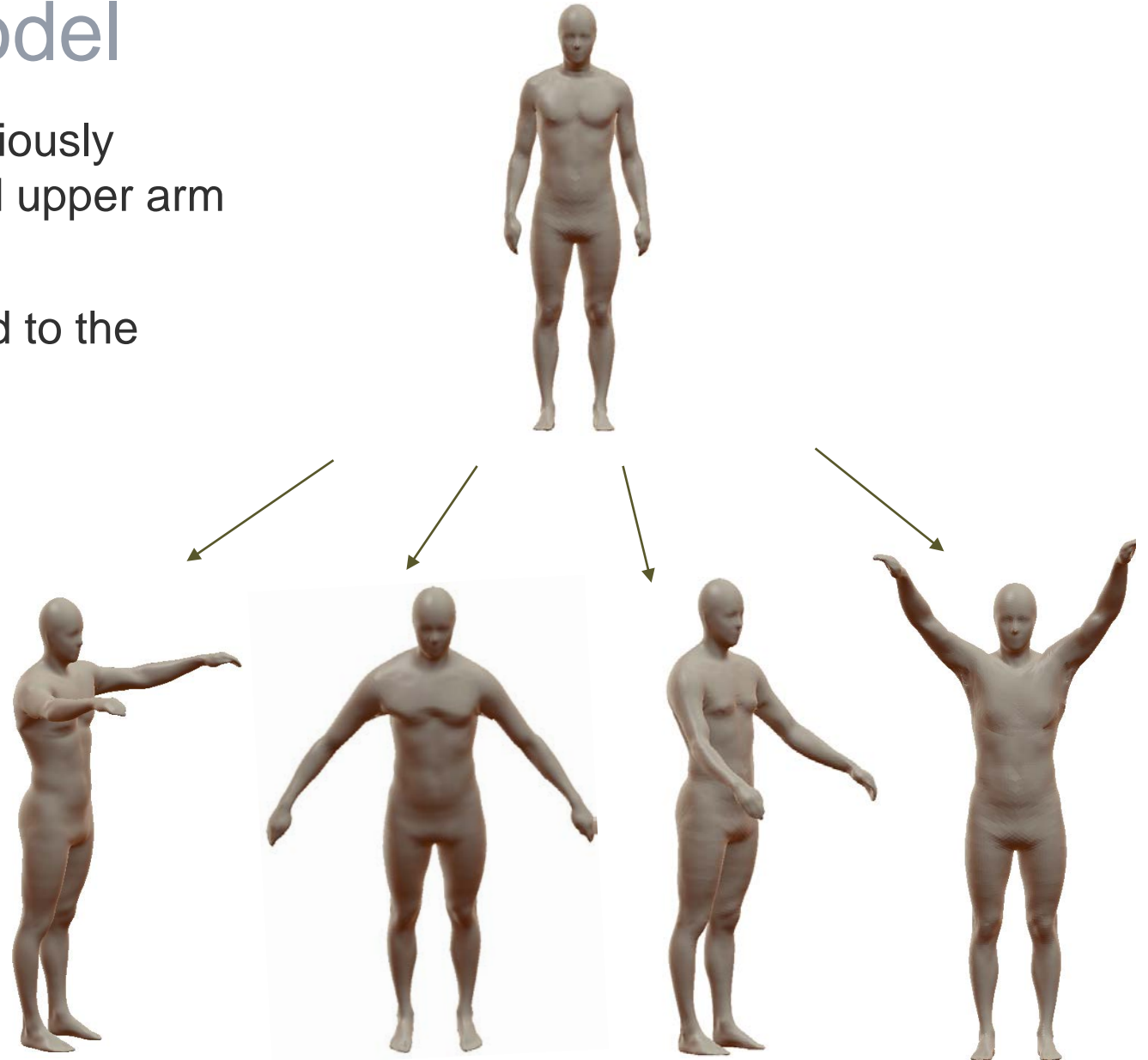
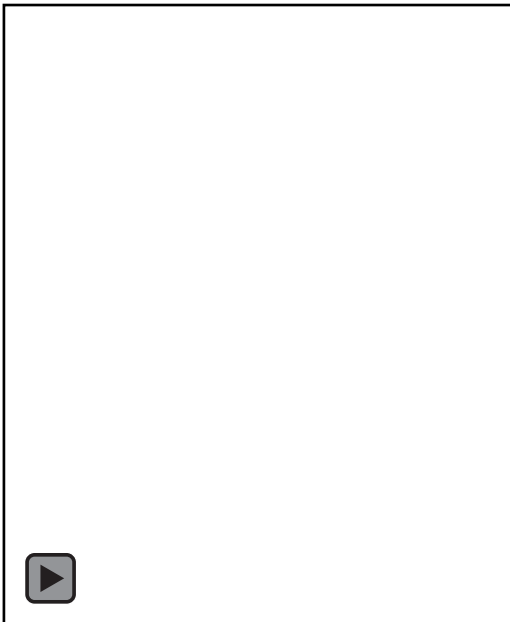


Estimation with color-coded error

0
1
2
3
4
cm

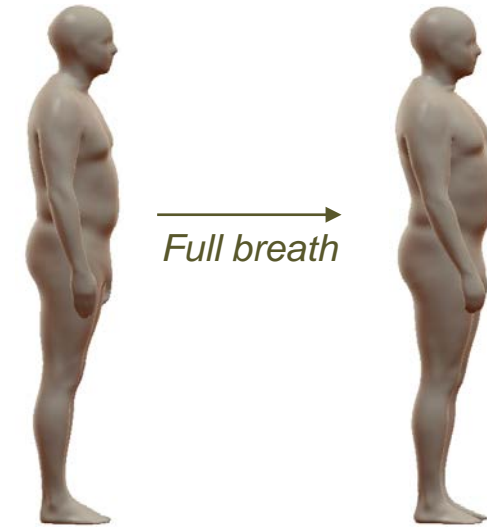
Application Example (1): Parametric shoulder model

- A reusable & resizable model was previously developed to represent the shoulder and upper arm posture (NASA, 2016)
- The present methodology can be applied to the existing scans to diversify postures

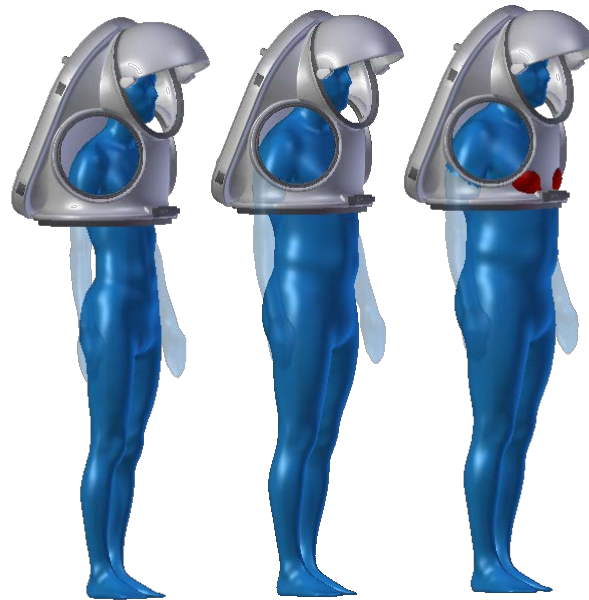


Application Example (2): Spacesuit fit assessment

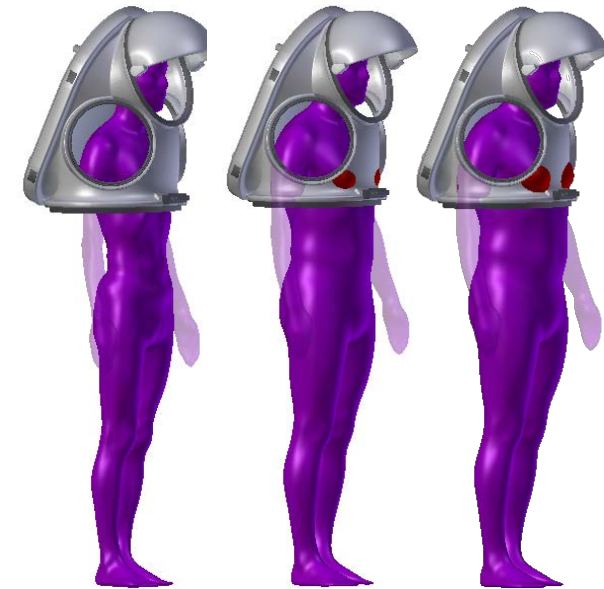
- Hard Upper Torso (HUT) design needs to be verified for fit across different body sizes in relaxed and full-breath postures
- Scans with diverse anthropometry dimensions can be reposed to evaluate HUT clearance



Original Scans (Relaxed Posture)



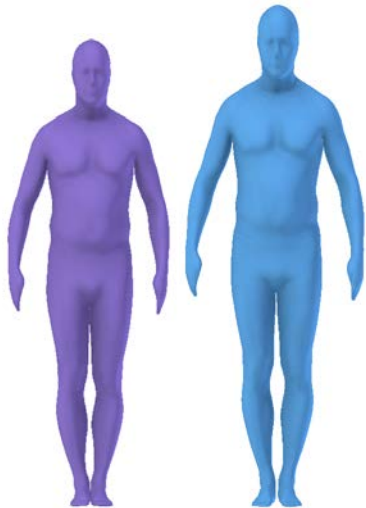
Overlaid with HUT (Relaxed Posture)



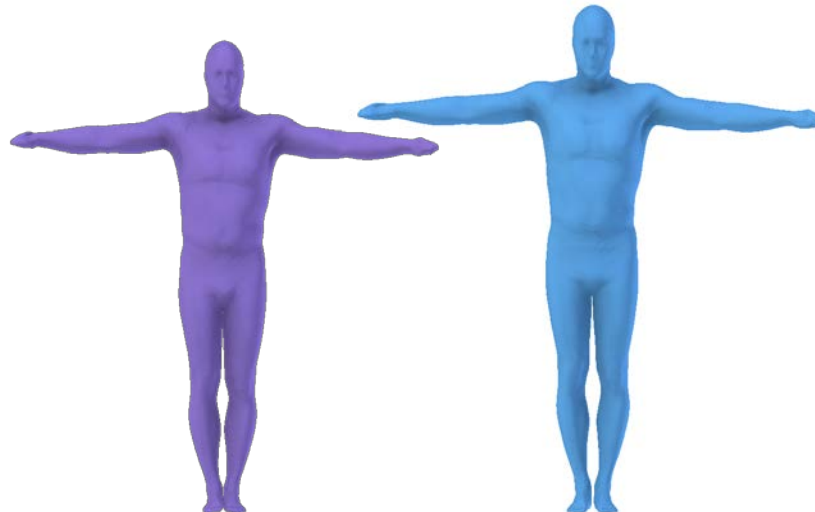
Full Breath Posture

Application Example (3): Habitat volume evaluation

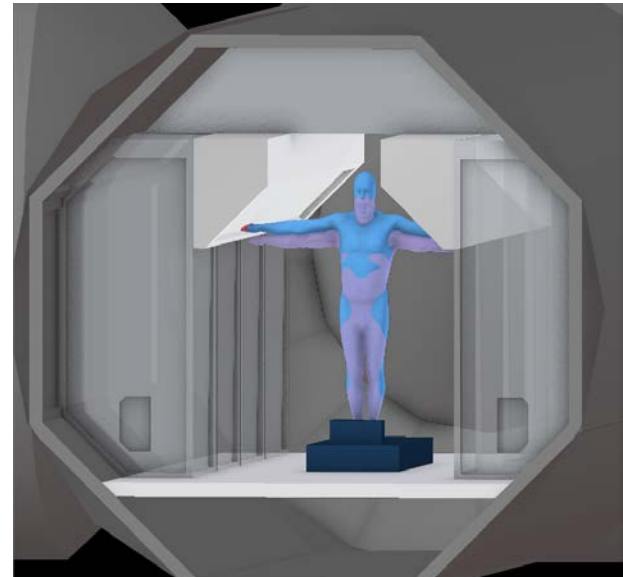
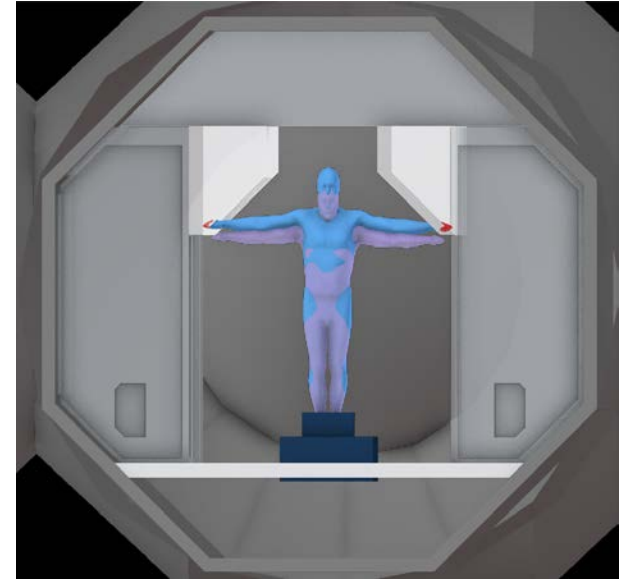
- A new habitat design needs to accommodate crewmembers during exercise
- Original scans can be reposed for critical exercise postures (e.g., stretched arms)
- This method can be particularly useful for crewmembers currently in orbit and unavailable for new scans



Original Scans



Reposed Scans



Discussion

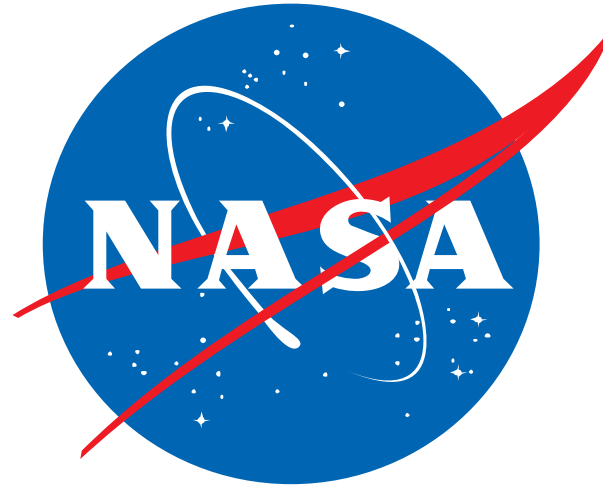
Advantages of the new method:

- Relatively simple and quick to use
- Data-driven approach
- May better characterize postures changes that are independent to body size and shape than direct extrapolation

Limitations

- PC space must be sufficiently large to represent different body variations
- There is some subtle variations in human physiognomy (musculature, soft tissue, bone geometry) that may not be completely represented in the transferred model
- The fixed segment definition may vary with posture

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