Opportunities in Shipbuilding Ergonomics & Training through Deep Learning and Simulation, with Applications to Garment Design

PROJECT INFORMATION

Prime/Lead: Michel Audette, Ph.D., Old Dominion University (ODU)

Team Members: Newport News Shipbuilding, Virginia Digital Maritime Center.

Academic Members: MyungHee Sohn Ph.D. Cal State University Long Beach (clothing design), Hunter Bennett Ph.D., ODU (musculoskeletal simulation), Emiel DenHartog (comfort modeling, textile engineering), North Carolina State University.

Duration: 12 Months

Financial/Cost: $200,000

DELIVERABLES/BENEFITS/ROI

Deliverables: Tangible output of this project will be in the form of white papers describing:

- Development of digital, simulation-based pipeline for personalized welding clothing design, based on canonical welder poses.
- Application for this pipeline for designing clothing for female welders.
- Software methodology for motion capture and musculoskeletal simulation of welders.

Benefits: The initial benefit of this Panel Project is to develop a rigorous software methodology for producing personalized protective clothing equipment (PPE) for female welders. This approach will lead to improved productivity and ergonomics. The methods could also lead to better fitting PPE for welders of all shapes ill-served by commercial PPEs.

1. PPEs for female welders, leading to better performance, while reducing injury risk.
2. PPEs for welders of all shapes and sizes currently ill fitted by existing products.
3. Methodology for tracking and reconstructing musculoskeletal (MS) pose of welders.
4. Foundation of interactive skinned MS simulation, which can later be coupled with interactive deep learning-based simulation of welding processes.

ROI: potential game-changer for NSRP in performance & retention of female welders.

ISSUE / OBJECTIVE

Women in shipyard environments need properly fitting protective clothing equipment (PPE) for safety, productivity, and retention. Existing gear is often designed around male body shapes and scaled down, leading to poor fit, discomfort, or hazards. Designing and manufacturing PPE across the full range of women's body sizes and shapes is seen as complex and expensive. According to Culpepper, 89% of tradeswomen report difficulty obtaining properly fitting PPE, while 77% have been exposed to safety hazards due to gear designed for men. Also, 20% have suffered injuries because their equipment didn't fit their bodies, and finally, 65% say badly fitting PPE hampers their ability to do their jobs effectively .

Project Goals and Objectives: This project centers on the development of a personalized musculoskeletal simulation-based digital pipeline for welder clothing design, featuring specific garment designs for female welders.

Business Objectives:

- For Newport News Shipbuilding, this project represents a means of improving the productivity and health profile of female welders, through well-adapted clothing. It may also result in improved clothing for all welders, like a tide that raises all ships.
- For Virginia Digital Maritime Center, this project advances its mission of promoting improved productivity and safety in the maritime industry.

Technology Objectives:

- To develop a simulation & deep learning pipeline for personalizing and assessing garment design and production for welders ill-served by current PPEs, specifically female welders.
- To develop & refine motion capture-based musculoskeletal simulation of welders in their professional environment, for garment design and further simulation applications.
- To establish a foundation of MoCap-based MS welder simulation suitable for coupling with deep learning-mediated real-time simulation of welding processes.

Cost Share: Significant value will be provided in making public the software methodology developed in this project, for consumption by NSRP members.

Potential for applying musculoskeletal simulation in Shipyards Processes

ADDITIONAL INFORMATION

How does MoCap-based musculoskeletal (MS) simulation inform garment design?

Motion capture (MoCap) involves tracking a human subject's pose, either through fiducials affixed to specific locations on the body or through passive computer vision algorithms, imaged by a configuration of digital cameras. The MoCap dataset then constrains piecewise-affine scaling of a skeletal model to each subject. This scaling process can also exploit a digital atlas of the human body via Anatomy Transfer and priors of typical human shape through statistical shape models. MoCap-based personalized skeletal model time series will then be input to a MS dynamic simulation program such as OpenSim, which then interpolates this series of welder poses over time through interactive biomechanical simulation.

A subset of these simulated poses can be covered with a digital skin, through a digital process known as skinning, which in conjunction with a static high-resolution range acquisition of the subject, then achieves a suite of personalized canonical poses of the welder.

Each canonical welder pose can then serve as a digital avatar for garment design, on a digital platform such as CLO3D. This pipeline is illustrated in figure 1 shown at right. The garment design can then be assessed either through iterative textile prototypes and welder-based feedback or alternately serve as input to a rigorous finite elements analysis (FEA) study that can quantify comfort, which can be defined in terms of pressures simulated on the subject's anatomy or a thermal model. Either is feasible through FEA studies planned in the future.

Related Work (ongoing project areas):

- Anatomical modeling: motion capture; human pose estimation; range-sensing.
- Musculoskeletal simulation; dynamic skinning, shape statistics models; Anatomy Transfer.
- Digital garment design; simulation of drape and appearance.
- Textile engineering; finite elements analysis; comfort modeling (mechanical, thermal).

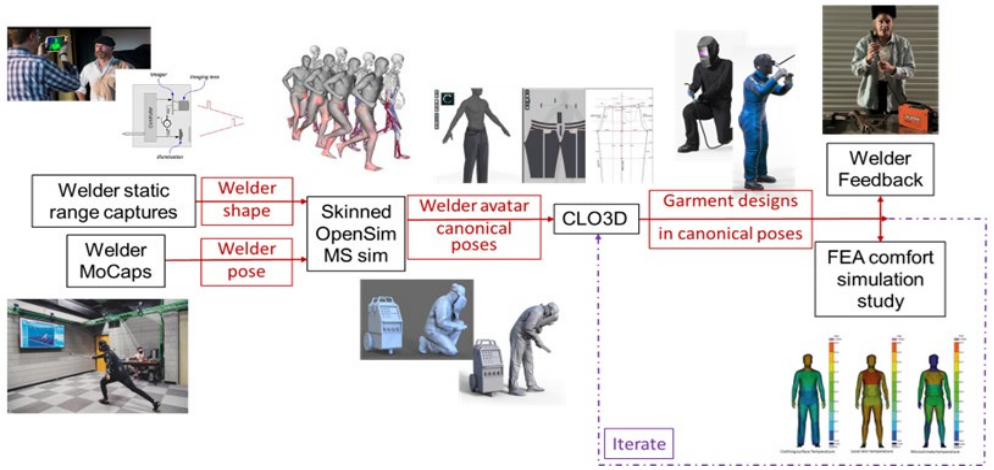
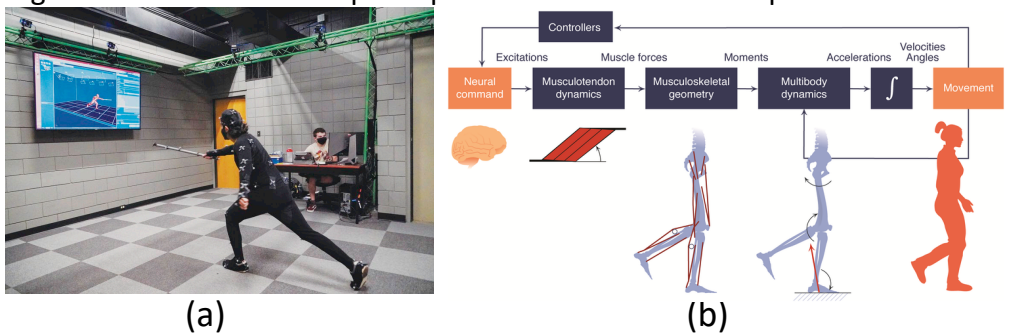


Figure 1. Static 3D + MoCap to OpenSim to Clo3D to FEA Pipeline



(a) (b)

Figure 2. Key technologies: (a) Motion capture acquisition. (b) Elements of a typical musculoskeletal simulation in OpenSim. Movement arises from a complex orchestration of the neural, muscular, skeletal, and sensory systems.