CRITERIA FOR A DIGITAL HUMAN MODELING AND ANALYSIS SOFTWARE TOOL

Kent W. McKee and David W. Tack

Prepared By:
Human*systems*® Incorporated
111 Farquhar Street
Guelph, ON N1H 3N4

PWGSC Contract Number: W7711-088136/001/TOR; Task No. W7719-45O0905734
Project Scientific Authority: Linda Bossi, CD,416-635-2197

Contract Report
DRDC-RDDC-2015-C231
March 2012

CRITERIA FOR A DIGITAL HUMAN MODELING AND ANALYSIS SOFTWARE TOOL

by:

Kent W. McKee and David W. Tack

Human*systems*® Incorporated
111 Farquhar Street
Guelph, ON N1H 3N4

Project Manager:

David W. Tack
(519) 836-5911

PWGSC Contract No. W7711-088136/001/TOR Task No. W7719-45O0905734

On Behalf of
Department of National Defence
As represented by

Defence Research and Development Canada - Toronto
1133 Sheppard Avenue West
Toronto, ON, M3K 2C9

Project Scientific Authority:

Linda Bossi, CD
416-635-2197

March, 2012

Table of Contents

This page intentionally left blank.

List of Figures

1. Background

1.1 Introduction

The Comprehensive Ergonomics Tools and Techniques (CETTs) project team requires performance-based specifications and evaluation criteria that would enable DRDC Toronto to acquire (through competitive bidding) the most suitable integrated anthropometry & biomechanical modeling and analysis software tools. These tools could be modified to incorporate many needs such as the impact of warfighter encumbrance on warfighter dismounted and mounted mobility, field of view, task performance, fit/accommodation, and health and safety implications of mis-accommodation.

The evaluation criteria are to include minimum mandatory criteria that are available through COTS software tools, and rated criteria for the desired tool functionality. The purpose of this report is to present a framework for establishing the mandatory and rated criteria, and to develop draft performance-based specifications with proposed evaluation criteria.

1.2 Bid Evaluation Strategy

Industry will provide COTS software for competitive bidding. The software will be evaluated based on cost, and the ability of the software to meet mandatory and rated criteria. In consultation with the CETTs project team, a strategy for determining the criteria was formed. A flowchart is presented in Figure 1 below.

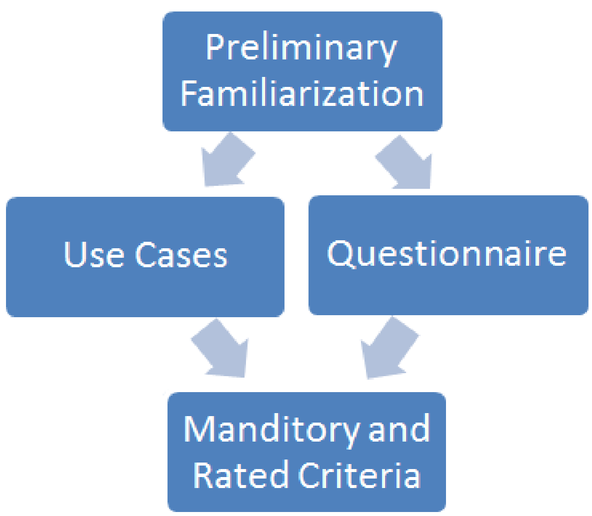

Figure 1: Strategy for Creating the Mandatory and Rated Criteria for Digital Human Modeling Software

Preliminary familiarization with the features of digital human modeling software has been done by completing a State of the Art Review (Tack and McKee, 2011), by reviewing a comparison of digital human modeling software with focus on lifting applications (Lafiandra, M), and by attending web software demonstrations. This preliminary familiarization was used to build Use Cases and the Questionnaire, as presented in Section 2 and Section 3 of this report.

It is proposed that each software package be tested against Use Cases for bid evaluation. For the draft list of performance-based specifications with proposed evaluation criteria (Section 4), the CETTs project team was consulted by using the questionnaire.

2. Use Cases

The following four (4) Use Cases are proposed to be tested with each of the software packages. The Use Cases were determined by considering the scope of current digital human modeling software and CF needs. It is not expected that any one software package will be able to perform all four Use Cases. However, the Use Cases should identify the abilities and functionality of each software package.

2.1 Use Case 1: Physical Demands - Equipment on the Body

Context: The digital human is fitted with a digital prototype CF rucksack. The digital human will be required to stand upright (statically), and perform dynamic tasks of walking and running while wearing the rucksack.

Analysis:

- Forces on the body: The software determines the amount of compression force and torque exerted on the lower back while standing upright, walking, and running.
- Muscular exertion: The software determines the amount of joint torque required by the knee joint, with and without the rucksack, while walking and running.
- Health parameters: The software provides insight into health parameters such as muscular expenditure over time, endurance, and fatigue.

2.2 Use Case 2: Physical Demands - Equipment in the Workspace

Context: The digital human lifts a truck wheel from the ground to a mounting bracket on the side of a vehicle.

Analysis:

- Forces on the body: The software determines the amount of compression force and torque exerted on the lower back.
- Muscular exertion: The software outputs the amount of force required by the arms at various stages throughout the lift.
- Endurance and Fatigue: The software provides insight into health parameters such as muscular expenditure over time, endurance, and fatigue.

2.3 Use Case 3: Workspace Accommodation (Individual and Crew)

Context: The digital human will be fitted with digital prototype body armour: helmet and ballistic vest (with plates). The digital human will be seated (statically) in a LAVIII passenger seat. The digital human will dynamically ingress and egress the vehicle through passenger doors and hatches. In addition, multiple digital humans will be encumbered with body armour and tested (statically) in LAVIII passenger seats.

Analysis:

- Volumetrics (Clothed): The software measures the accommodation of the 5th percentile female to 95th percentile male in the seated passenger position.
- Crew Volumetrics (Clothed): The software measures the accommodation of 5th percentile females to 95th percentile males in seated passenger positions and analyses any overlap.
- Hatch and door sizing: The software analyses the ability of the encumbered digital human to ingress/egress doors and hatches of various sizes.

2.4 Use Case 4: Crewstation Accommodation (Individual and Crew)

Context: The digital human will be seated in a Griffon pilot cockpit. The reach envelope of the digital human's arms and legs will be compared with the location of controls (static). The digital human will dynamically reach for a button. The digital human will grasp a control with the right hand, and when the seat is adjusted (in height and forwards/backwards) the digital human will assume the optimum posture. The visual field of view will be assessed statically when the digital human is facing forwards. Virtual immersion will be used with a Head Mounted Display (HMD).

Analysis:

- Reach: Static reach envelopes, dynamic optimization of control positions through reach comfort.
- Spatial accommodation: Assist with the design of the seat, by recommending the optimum dimensions of a seat track (fore/aft and height) that accommodates 5th percentile female to 95th percentile male. Export 3D solid geometry with the seat in maximum positions.
- Vision: Visual field of view for various windshield design concepts
- HF field trials: participant evaluation using visual immersion in real time with HMD.

3. Questionnaire

The following questionnaire was filled out by five members CETTs project team to determine the importance of software capabilities. It was anticipated that if a capability was rated at "Very Important" or higher, the capability should be mandatory.

DIGITAL HUMAN MODELING SOFTWARE

Rate the importance of the following capabilities for digital human modeling software. Leave a question blank if it is not applicable. Add any other capabilities at the end.

Digital Human Modeling Capabilities	No Importance	Slight Importance	Little Importance	Some Importance	Moderately Important	Very Important	Extremely Important
Equipment on the Body							
Import of scanned files and 3D CAD files	O	O	O	O	O	O	O
Able to attach objects to the digital human	O	O	O	O	O	O	O
Standard dynamic motion: walking and running	O	O	O	O	O	O	O
Static force analysis	O	O	O	O	O	O	O
Dynamic force analysis	O	O	O	O	O	O	O
Muscular expenditure over time	O	O	O	O	O	O	O
Endurance and Fatigue limits	O	O	O	O	O	O	O
Injury limits (NIOSH lifting equations)	O	O	O	O	O	O	O
Equipment in the Workspace							
Stationary objects in the virtual environment	O	O	O	O	O	O	O
Movable objects in the virtual environment	O	O	O	O	O	O	O
Able to manually adjust dimensions of solid objects	O	O	O	O	O	O	O
Able to manipulate position solid objects	O	O	O	O	O	O	O
Automatic Posture Update based on environmental changes (e.g. seat height)	O	O	O	O	O	O	O
Custom dynamic motion from motion capture	O	O	O	O	O	O	O
Custom dynamic motion from XSens	O	O	O	O	O	O	O
Custom dynamic motion from position tracking	O	O	O	O	O	O	O
Gravity and weight in the virtual environment	O	O	O	O	O	O	O
Static Output – Biomechanical Demands	O	O	O	O	O	O	O
Dynamic Output – Biomechanical Demands	O	O	O	O	O	O	O
Output: overall metabolic energy expenditure	O	O	O	O	O	O	O

CETT Questionnaire – Digital Human Modeling 1

DIGITAL HUMAN MODELING SOFTWARE

Workspace Accommodation:							
Able to attach multiple pieces of body armour	O	O	O	O	O	O	O
Automatic positioning in the seat via reference planes	O	O	O	O	O	O	O
Dynamic ingress and egress	O	O	O	O	O	O	O
Automated posture positioning based on seat and control positions	O	O	O	O	O	O	O
Automated posture positioning based on clothing (i.e. adjust clothing thickness)	O	O	O	O	O	O	O
Compression of clothing	O	O	O	O	O	O	O
Comfort analysis (e.g. between 2 different positions for a control)	O	O	O	O	O	O	O
Multiple digital humans	O	O	O	O	O	O	O
Ingress and egress hatches	O	O	O	O	O	O	O
Automated accommodation for various hatch sizes	O	O	O	O	O	O	O
Analysis of body offset (e.g. from a seatback due to body armour)	O	O	O	O	O	O	O
Spatial measuring – point to point	O	O	O	O	O	O	O
Spatial measuring – point to plane	O	O	O	O	O	O	O
Spatial measuring – automated indication of overlap	O	O	O	O	O	O	O
Crewstation Accomodation:							
Reach envelopes – hands and feet	O	O	O	O	O	O	O
Reach comfort (to optimize control positions)	O	O	O	O	O	O	O
Vision – sight limits, sight lines from mannequin eyes	O	O	O	O	O	O	O
Vision – sight lines from vehicle mirrors	O	O	O	O	O	O	O
Built-in joint ROM limits	O	O	O	O	O	O	O
Hand Grasping	O	O	O	O	O	O	O
Multiple grasping modes (hard grasp, soft grasp)	O	O	O	O	O	O	O
Reach envelopes based on comfort	O	O	O	O	O	O	O
Immersive HMD to see the 3D environment	O	O	O	O	O	O	O
Immersive HMD to see and move in the 3D environment	O	O	O	O	O	O	O

DIGITAL HUMAN MODELING SOFTWARE

Finger and digit manipulation	O	O	O	O	O	O	O
Common Use Functionality							
Able to draw on 3+ anthro databases	O	O	O	O	O	O	O
Able to draw on 5+ anthro databases	O	O	O	O	O	O	O
Able to draw on 7+ anthro databases	O	O	O	O	O	O	O
Able to resize specific segments	O	O	O	O	O	O	O
Male, Female	O	O	O	O	O	O	O
Able to import directly from body scanner	O	O	O	O	O	O	O
Wealth of scanned person data	O	O	O	O	O	O	O
Able to import a typical population sector (e.g. able to select age group)	O	O	O	O	O	O	O
Body segments: 15+	O	O	O	O	O	O	O
Body segments 20+	O	O	O	O	O	O	O
Body segments 25+	O	O	O	O	O	O	O
Standard postures	O	O	O	O	O	O	O
Ease of posing	O	O	O	O	O	O	O
Standard automatic motions (grasping, ingress, egress, etc.)	O	O	O	O	O	O	O
Able to track motion (from motion capture system) in real time	O	O	O	O	O	O	O
Able to track motion (from Xsens) in real time	O	O	O	O	O	O	O
Impact injury analysis	O	O	O	O	O	O	O
Immersive HMD and haptic devices for feedback	O	O	O	O	O	O	O
Immersive HMD and manipulate objects that correspond to the 3D environment	O	O	O	O	O	O	O
Export 3D model of Digital Human in a universal file type (e.g. IGES)	O	O	O	O	O	O	O
Export 3D models of certain components in a universal file type (e.g. IGES)	O	O	O	O	O	O	O
Export 3D models of certain components in a universal file type (e.g. IGES)	O	O	O	O	O	O	O
	O	O	O	O	O	O	O
	O	O	O	O	O	O	O
	O	O	O	O	O	O	O
	O	O	O	O	O	O	O

CETT Questionnaire – Digital Human Modeling 3

DIGITAL HUMAN MODELING SOFTWARE

Comments

CETT Questionnaire – Digital Human Modeling 4

4. Draft Specifications and Evaluation Criteria

This project required consultation with the CETTs project team to draft performance-based specifications with proposed evaluation criteria. The list of specifications was developed through preliminary familiarization and development of the use cases. The questionnaire was used to scrutinize the list of specifications and determine which specifications should be mandatory and which ones should be rated. This was done by considering that capabilities rated “very important” or “extremely important” should be considered as mandatory requirements, and capabilities rated “moderately important” or less should be considered as rated requirements.

It was found that some of the capabilities that were rated by most CETTs project team members as “very important” or “extremely important” are only known to be available on one particular software program (e.g. injury impact analysis is unique to MADYMO, automated posture positioning based on seat and control positions is unique to RAMSIS, and compression of clothing is unique to a module of Santos). For these instances, the specification was changed to “rated” so that more software packages could pass the minimum mandatory requirements.

Comments from the questionnaire and scrutiny by the CETTs project team also suggested some new criteria and changes to the wording of some of the criteria. This was updated as best as possible.

As a result of this exercise, the following specifications should be considered minimum mandatory criteria:

1	**Equipment on the Body**
1.1	The software shall allow import of scanned files and 3D CAD files
1.2	The software shall enable the user to attach objects to the digital human
1.3	The software shall enable the user to attach multiple objects to the digital human
1.4	The software shall simulate standard dynamic motions: walking and running
1.5	The software shall enable the user to analyze static forces
1.6	The software shall enable the user to analyze dynamic forces
2	**Equipment in the Workspace**
2.1	The software shall support stationary 3D objects in the virtual environment
2.2	The software shall enable the user to move objects in the virtual environment

2.3	The software shall enable the user to manually adjust dimensions of solid objects
2.4	The software shall enable the user to manipulate the position of solid objects
2.5	The software shall support custom dynamic motion from a motion capture system
2.6	The software shall simulate custom dynamic motion from position tracking
2.7	The software shall simulate gravity and weight in the virtual environment
2.8	The software shall provide static output – Biomechanical Demands
2.9	The software shall provide dynamic output – Biomechanical Demands
3	**Workspace Accommodation**
3.1	The software shall enable the user to analyze body offset (e.g. from a seatback due to body armour)
3.2	The software shall enable the user to perform spatial measuring – point to point
4	**Crewstation Accommodation**
4.1	The software shall enable the user to analyze reach envelopes – hands and feet
4.2	The software shall enable the user to analyze vision – sight limits, sight lines from mannequin eyes
4.3	The software shall have built-in joint ROM limits
4.4	The software shall support an immersive HMD to see the 3D environment
4.5	The software shall support an immersive HMD to see and move in the 3D environment
4.6	The software shall enable finger and digit manipulation
5	**Common Use Functionality**
5.1	The software shall enable the user to draw on 3+ anthropometry databases

5.2	The software shall enable the user to able to resize specific body segments
5.3	The software anthropometry shall include Male and Female
5.4	The digital human shall have at least 20 body segments
5.5	The software shall enable the user to easily pose the digital human in standard postures
5.6	The software shall enable the user to export a 3D model of the Digital Human in a universal file type (e.g. IGES)
5.6	The software shall enable the user to export 3D models of certain components in a universal file type (e.g. IGES)

The following specifications should be considered rated criteria:

1	**Equipment on the Body**
1.1	The software should enable the user to analyze muscular expenditure over time
1.2	The software should enable the user to analyze endurance and fatigue limits
1.3	The software should enable the user to analyze injury limits related to lifting (NIOSH lifting equations)
2	**Equipment in the Workspace**
2.1	The software should automatically update posture based on environmental changes (e.g. seat height)
2.2	The software should provide output of overall metabolic energy expenditure
3	**Workspace Accommodation**
3.1	The software should enable the user to position the digital human in the seat via reference planes
3.2	The software should have automatic dynamic motion for ingress and egress
3.3	The software should have automated posture positioning based on seat and control positions
3.4	The software should have automated posture positioning based on clothing (i.e. adjust clothing thickness)
3.5	The software should simulate compression of clothing
3.6	The software should enable the user to analyze comfort (e.g. between 2 different positions for a control)
3.7	The software should support multiple digital humans
3.8	The software should have automatic dynamic motion for ingress and egress of hatches
3.9	The software should enable the used to perform spatial measuring by an automated indication of overlap
4	**Crewstation Accommodation:**
4.1	The software should enable the user to analyze reach comfort (to optimize control positions)

4.2	The software should enable the user to analyze vision – sight lines from vehicle mirrors
4.3	The software should have automatic dynamic motion for hand grasping
4.4	The software should have automatic dynamic motion for multiple grasping modes (hard grasp, soft grasp)
5	**Common Use Functionality**
5.1	The software should enable the user to draw on 5+ anthro databases
5.2	The software should enable the user to import directly from body scanner
5.3	The software should enable the user to import a typical population sector (e.g. able to select age group)
5.4	The digital human should have at least 25 body segments
5.5	The software should support motion capture (from motion capture system) in real time
5.6	The software should allow the user to analyze impact injury
5.7	The software should support immersive HMD and haptic devices for feedback
5.8	The software should support immersive HMD and allow the person wearing the HMD to manipulate objects that correspond to the 3D environment
5.9	The software should have a tool with links to visual models (low visibility)
5.10	The software should have a tool with links to audio models
5.11	The software should have a tool with links to task (cognitive) models

5. References

1. LaFiandra, M., Methods, Models, and Technology for Lifting Biomechanics. Handbook of Digital Human Modeling, p8-1 to 8-26, Taylor and Francis Group, 2009.
2. Tack, D.W., and McKee, K., Warfighter Integrated Physical Ergonomics Tool Development: Acquisition Stakeholder Needs Analysis and State-of-the-Art Review; DRDC Toronto Contract Report DRDC-RDDC-2015-C227 dated March 2011.