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Manipulating the Geometric Computer-aided Design of the Operational Requirements-based Casualty Assessment Model within BRL-CAD (v.2)

by Joshua Baker and Eric Murray

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14. ABSTRACT
This report (an update to ARL-TR-8336) outlines how to manipulate the Operational Requirements-based Casualty Assessment (ORCA) geometric model within BRL-CAD and includes best practices for overlap removal. It is written for those already versed in base BRL-CAD use and commands.

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geometry, conversion, BRL-CAD, Operational Requirements-based Casualty Assessment, ORCA, Modular UNIX-based Vulnerability Estimation Suite, MUVES, Advanced Joint Effectiveness Model, AJEM

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Table of Contents

List of Figures

1. INTRODUCTION

The Operational Requirements-based Casualty Assessment (ORCA) model is used for modeling personnel vulnerability and injury metrics within the Advanced Joint Effectiveness Model (AJEM) vulnerability/lethality (V/L) analysis environment. The interface between the geometric model and the vulnerability model has specific requirements that must be followed to ensure the proper geometric representation of the ORCA personnel. This report discusses the process to manipulate the ORCA 3-D geometric model for use in BRL-CAD and AJEM. It is a revised version of a report initially published in 2018 (Baker & Murray, 2018). This version has been updated to outline the current method of scaling ORCA. BRL-CAD is an open-source computer-aided design (CAD) program initially developed in-house by the U.S. Army Ballistic Research Laboratory (BRL), later maintained by the U.S. Combat Capabilities Development Command Army Research Laboratory and currently by the U.S. Army Combat Capabilities Development Command Data & Analysis Center. For further detail on the development of ORCA and its uses, reference the *ORCA within MUVES-S2 Analyst Guide and User Manual* (Gillich et al., 2013).

The ORCA geometric model is maintained by the Material Modeling & Simulation Branch CAD Team. Updates to the model are conducted as needed, with the most current model being orca_w_ppe_apr2021.g at the time of this report's publishing.

The **dbconcat** command can be used to incorporate ORCA geometry (Figure 1) into an existing database. This command also has the functionality of prefixing imported names, allowing for the addition of multiple, unique ORCA geometries. When using **dbconcat**, ensure that the file is placed in the current directory: type `pwd` from the Multi-device Geometry Editor (MGED) command line to determine the current directory. You can use the **cd** command to change directories.

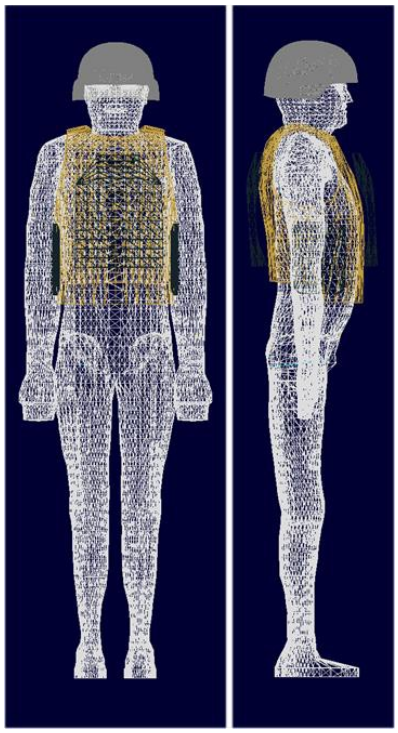

Figure 1. ORCA geometry

2. ARTICULATING THE ORCA GEOMETRIC MODEL

The ORCA geometric model can be manipulated into any posture; however, it must reference the original, unedited configuration when calculating injury insults. Because of this requirement, the ORCA geometric model manipulations must be preserved within the hierarchy as transformation matrices. Thus, the MGED **push** command should never be used on the ORCA geometry.

When placing the ORCA geometric model within a target description, the top-level group (orca_system) should be translated and rotated using a matrix edit to achieve proper location and orientation and to ensure the entire personnel CAD remains intact. To enter matrix edit mode, draw ORCA at the orca_system level and type the following command:

```
oed / orca_system/orca_man/head/head.r/head.s
```

Manipulating the extremities is accomplished by rotation(s). It is essential that the correct geometric element and the correct location within the hierarchy is selected. Rotational values are expressed as X, Y, and Z axis components with degrees as the unit. There should never be matrices below the region level; to check, list out each region and make sure no matrices are present.

To manipulate the inner extremities (hips/upper legs or shoulders/upper arms), the arms and legs must be rotated in their entirety but independently from each other (rotate the entire left arm, then the right arm, but never both arms together). To appropriately rotate the arms and legs, matrix edit each arm and leg and use the pivot solids found in hips and shoulders as the reference solids. With orca_system drawn on the screen, type one of the following commands:

```
oed orca_system/orca_man/arms left_arm/shoulder_l/shoulder_l.r/shoulder_pivot_l.s
oed orca_system/orca_man/arms right_arm/shoulder_r/shoulder_r.r/shoulder_pivot_r.s
oed orca_system/orca_man/legs left_leg/hip_l/hip_l.r/hip_pivot_l.s
oed orca_system/orca_man/legs right_leg/hip_r/hip_r.r/hip_pivot_r.s
```

To manipulate the outer extremities (lower arms or lower legs), perform a matrix edit at the group level using the solid as the reference solid. To manipulate the left lower arm, use lower_arm_l.s as the reference solid and place the matrix above the lower_arm_l level. This can be accomplished by drawing ORCA at the orca_system level and using the first command listed below. All four commands for outer-extremity manipulation are listed for reference as follows:

```
oed orca_system/orca_man/arms/left_arm lower_arm_l/lower_arm_l.r/lower_arm_l.s
oed orca_system/orca_man/arms/right_arm lower_arm_r/lower_arm_r.r/lower_arm_r.s
oed orca_system/orca_man/legs/left_leg lower_leg_l/lower_leg_l.r/lower_leg_l.s
oed orca_system/orca_man/legs/right_leg lower_leg_r/lower_leg_r.r/lower_leg_r.s
```

To remove a matrix, either perform the matrix transformation in reverse or access the group above the matrix in the combination editor (found at **Edit** > **Combination Editor**). ORCA model articulation is shown in Figure 2.

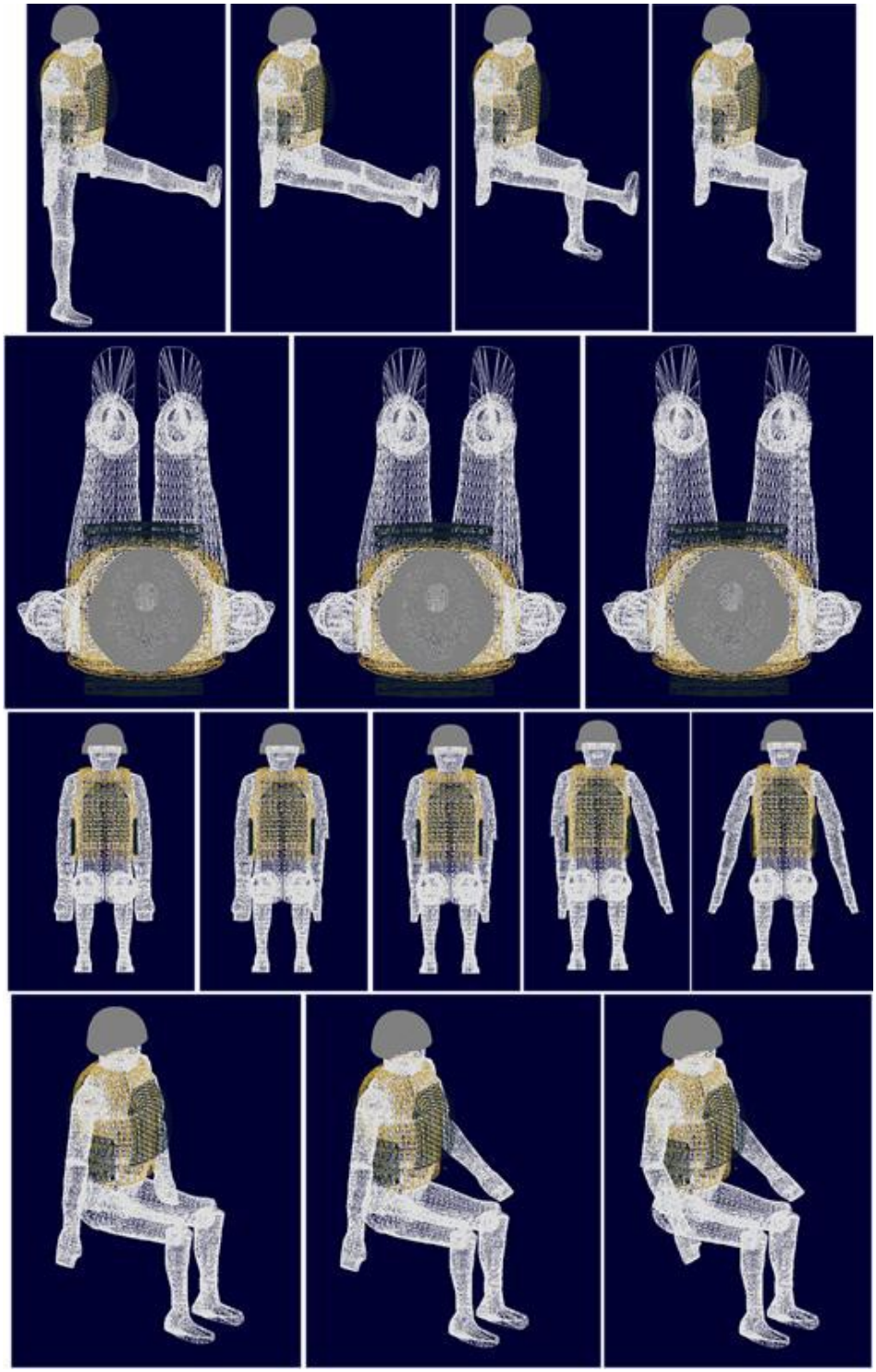

Figure 2. Progression of articulation

3. SCALING THE ORCA GEOMETRIC MODEL

The ORCA geometric model can be scaled to represent a larger or smaller person. While it is possible to scale in only one or two dimensions, it is recommended ORCA be scaled in all three dimensions by a single universal scaling factor. Scaling is done using the **sca** command. Like articulation, the scaling factor must be preserved within the transformation matrix to allow the geometry to map back to the original, unedited ORCA configuration. Use the following steps to scale ORCA:

1. Draw ORCA Man at the orca_system level.
2. Matrix select ORCA Man at the orca_system level using the following command:

```
oed / orca_system/orca_man/head/head.r/head.s
```

3. Use the **sca** command to scale ORCA by a given factor.
4. Accept the edit.
5. To check: list ORCA Man at the orca_system level and verify the matrix is followed by “scale α”, where α is the inputed scaling factor.

The following is a set of commands to scale ORCA Man using a 0.95 scale factor.

```
oed / orca_system/orca_man/head/head.r/head.s
sca .95 accept
```

4. REMOVING ORCA GEOMETRIC OVERLAPS

The matrices present at various levels in the ORCA hierarchy make overlap removal a challenge. A script has been created to remove the overlaps that are often created during articulation (Figure 3), as follows:

1. Once ORCA Man is placed, run the script in Section 5 to create Boolean solids and subtract them from the appropriate regions.
2. Draw up ORCA Man and ensure there are no double solids (if he appears to have three arms, there is a problem). This can be caused by rotating arms or legs together rather than independently.
3. If you need to rearticulate ORCA Man, remove the Boolean solids, move ORCA Man, and then rerun the script. Removing the Boolean solids requires deleting the solid and removing it from the region. This can be accomplished with the **killall** command (i.e., `killall hip_l.s-bool`).

To remove overlaps with ORCA Man and non-ORCA geometry (such as seat cushions), use the **copyeval** command to create a solid that can be subtracted from the region. In the following example, a subtraction solid has been created to resolve an overlap with ORCA Man's right hip:

```
copyeval orca_system/orca_man/legs/right_leg/hip_r/hip_r.r/hip_r.s  new_solid.s
```

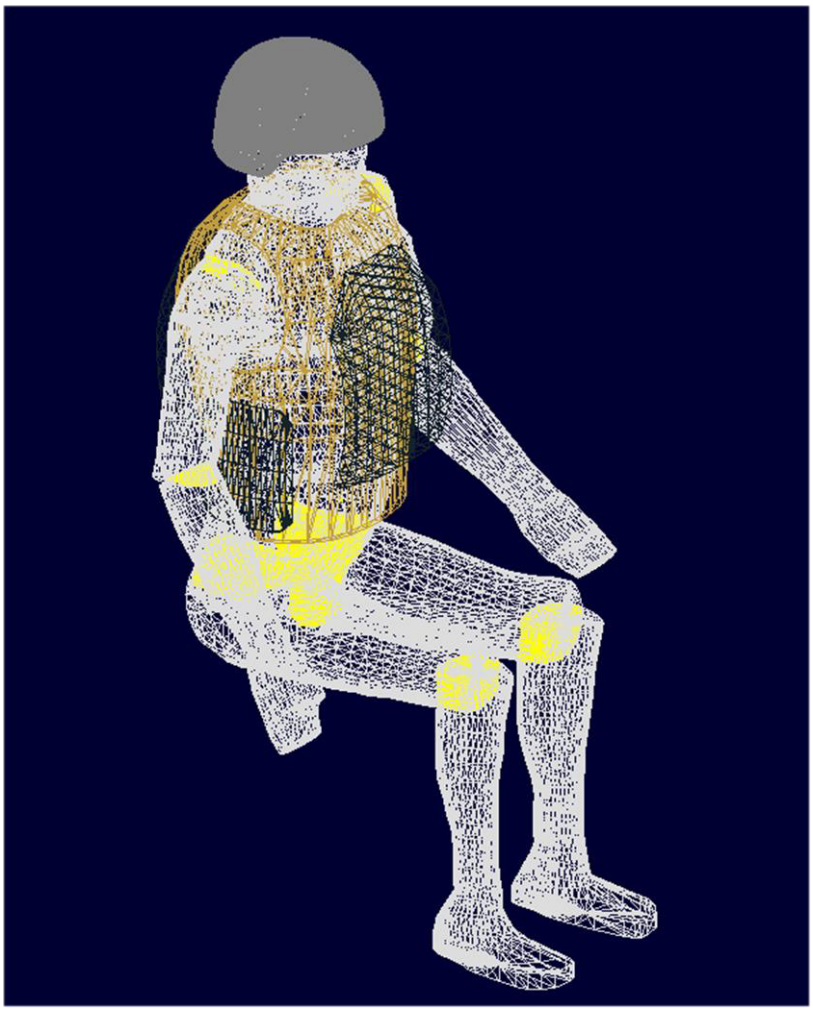

Figure 3. ORCA overlaps

5. OVERLAP REMOVAL SCRIPT

This overlap removal script can be placed into a file or simply copied and pasted into MGED. You may need to modify the names if you added prefixes or suffixes to accommodate multiple ORCA Men. The script can be run by typing `source filename.txt` from the MGED command line. Ensure the script is placed in the current directory: type `pwd` from the MGED command line to determine the current directory. You can use the **cd** command to change directories.

```
copyeval left_leg/lower_leg_l/lower_leg_l.r/lower_leg_l.s lower_leg_l.s-bool
copyeval right_leg/lower_leg_r/lower_leg_r.r/lower_leg_r.s lower_leg_r.s-bool
copyeval right_arm/lower_arm_r/lower_arm_r.r/lower_arm_r.s lower_arm_r.s-bool
copyeval left_arm/lower_arm_l/lower_arm_l.r/lower_arm_l.s lower_arm_l.s-bool
copyeval legs/left_leg/hip_l/hip_l.r/hip_l.s hip_l.s-bool
copyeval legs/right_leg/hip_r/hip_r.r/hip_r.s hip_r.s-bool
copyeval legs/left_leg/upper_leg_l/upper_leg_l.r/upper_leg_l.s upper_leg_l.s-bool
copyeval legs/right_leg/upper_leg_r/upper_leg_r.r/upper_leg_r.s upper_leg_r.s-bool
copyeval arms/left_arm/shoulder_l/shoulder_l.r/shoulder_l.s shoulder_l.s-bool
copyeval arms/right_arm/shoulder_r/shoulder_r.r/shoulder_r.s shoulder_r.s-bool
copyeval arms/left_arm/upper_arm_l/upper_arm_l.r/upper_arm_l.s upper_arm_l.s-bool
copyeval arms/right_arm/upper_arm_r/upper_arm_r.r/upper_arm_r.s upper_arm_r.s-bool

r upper_leg_l.r - lower_leg_l.s-bool
r upper_leg_r.r - lower_leg_r.s-bool
r upper_arm_r.r - lower_arm_r.s-bool
r upper_arm_l.r - lower_arm_l.s-bool
r pelvis.r - hip_l.s-bool - hip_r.s-bool - upper_leg_l.s-bool - upper_leg_r.s-bool
r thorax.r - shoulder_l.s-bool - shoulder_r.s-bool - upper_arm_l.s-bool - upper_arm_r.s-bool
r otv.r - shoulder_l.s-bool - shoulder_r.s-bool - upper_arm_l.s-bool - upper_arm_r.s-bool
```

6. CHECKS

There are a few final checks to perform to ensure ORCA Man has been placed correctly:

1. Use the **l** command to list out each region and verify there are no matrices below the region level. You can use the following command to list all regions at once:

   ```
   search /orca_system -type region -exec l "{}" ";"
   ```

2. List ORCA Man's top-level group (orca_system or orca_man) and verify the matrix reads "scale 1", or, if scaled, ensure the matrix reads "scale α", where α is the desired scaling factor.

3. Draw all ORCA regions and confirm that ORCA Man appears in the standard, unarticulated standing position. You can use the following command to draw all regions (at the region level) at once:

   ```
   search /orca_system -type region -exec e -S "{}" ";"
   ```

7. CONCLUSION

The ORCA geometric model can be manipulated into a wide range of positions, but these manipulations must be performed in a specific manner that allows the regions to be referenced to ORCA Man's original standing position via transformation matrices. Matrices must be placed in the correct hierarchical location and be preserved in the final model.

8. REFERENCES

Baker, J., & Murray, E. (2018, March). *Manipulating the geometric computer-aided design of the operational requirements-based casualty assessment model within BRL-CAD.* (Report No. ARL-TR-8336). U.S. Army Research Laboratory.

Gillich, P., Eberius, N., Myers, T., & VanAmburg, R. (2013, April). *Operational requirement-based casualty assessment (ORCA) within MUVES-S2 analyst guide and user manual.* (Report No. ARL-TR-6416). U.S. Army Research Laboratory.

Appendix A – List of Acronyms

3-D	three-dimensional
AJEM	Advanced Joint Effectiveness Model
BRL	U.S. Army Ballistic Research Laboratory
CAD	computer-aided design
MGED	Multi-device Geometry Editor
MUVES	Modular UNIX-based Vulnerability Estimation Suite
ORCA	Operational Requirements-based Casualty Assessment
V/L	vulnerability/lethality

Appendix B – Distribution List

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