



# Advancing the Behavior Modeling and Visualization of Entities in the Ground Vehicle Simulation Laboratory

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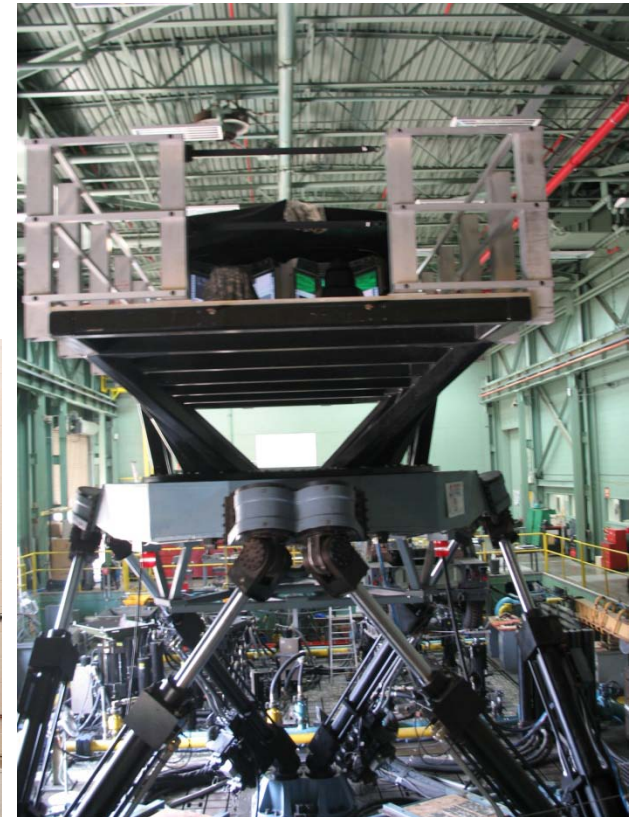
- TARDEC Ground Vehicle Simulation Laboratory (GVSL)
  - Designs and executes soldier-in-the-loop distributed virtual simulations.
    - Goal: To Improve Army ground vehicle systems.
- Recent Experiments
  - Obtained physiological data on situational awareness decision-making. [1]
  - Created vehicle usage profiles (duty cycles) for hybrid electric combat vehicles. [2]

# Introduction

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- TARDEC and CAVS Simulators
  - Different hardware
  - Software parity



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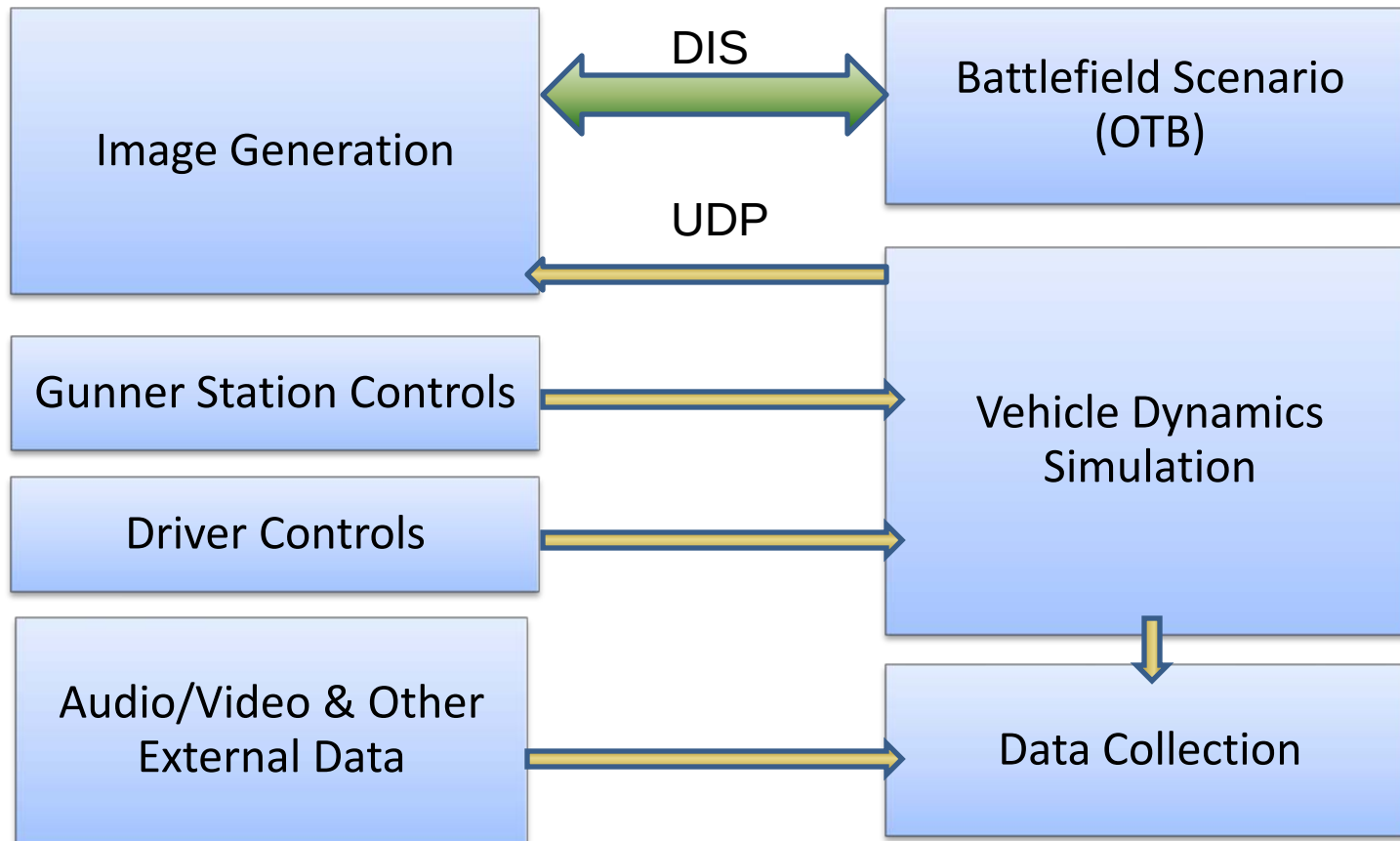


- Subject Feedback from Experiments
  - Improve wandering behavior of human entities.
  - Develop behavior code for civilian interaction to map-based points of interest.
  - Improve red force human entity engagement response to blue force entities.
  - Improve human entity response to fire, ambush, and Improvised Explosive Device (IED) events.
  - Add animal entities to the virtual environment.

- Simulation-based Reliability and Safety (SimBRS)
  - TARDEC GVSL partners with SimBRS researchers in Starkville, MS to address gaps.
- Key Areas of Work
  - Record realistic motions using a motion capture system.
  - Generate animations to be implemented into TARDEC GVSL.
  - Develop behavior simulation code that shows improved adaptive behaviors for human entities.
  - Demonstrate animations and behaviors with a scenario.

- Project Highlights
  - 2009:
    - Procedural pipeline developed to streamline animation process.
  - As of August 2010:
    - Human model motions have been collected, cleaned, and added to the simulation framework.
    - New Behavior: Civilian entities join a path at a point closest to their current location.
- Additions and modifications will improve the visualization and behavior modeling capability under TARDEC GVSL's current simulation framework.

# Simulation Framework





- Used to demonstrate new animations and behaviors.
- Convoy escort mission
  - 2 participants
    - Driver of the lead vehicle.
    - Controller of simulated CROWS station.
  - Red Force Ambush location
    - As blue force lead vehicle approaches location, an Improvised Explosive Device (IED) detonates in the road.
      - Civilians flee the scene.
      - Red force entities move in and begin firing on blue force vehicle.
      - CROWS station participant engages the red force entities, as the driver heads through the contact zone.



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# Human Entity Visualization

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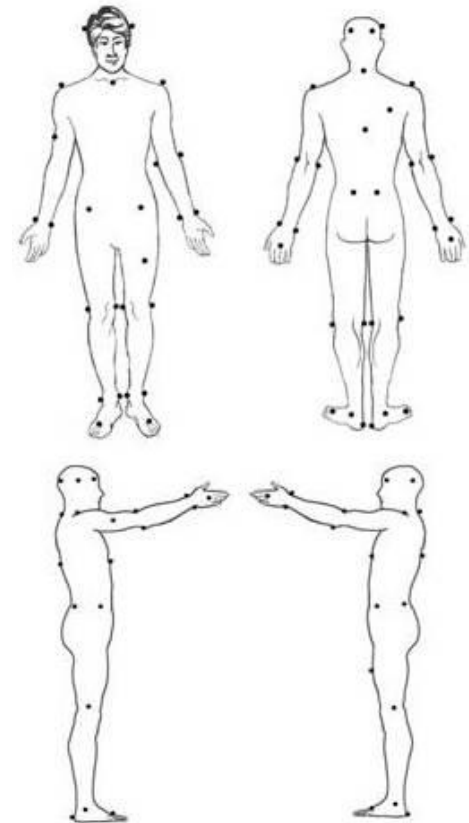
- Limited set of animations in character models
  - This constrains the ability to properly visualize human entity activities in the GVSL IG.
- To alleviate constraints, SimBRS researchers implemented an animation pipeline to generate animations compatible with existing character models using motion capture and commercial-off-the-shelf software.



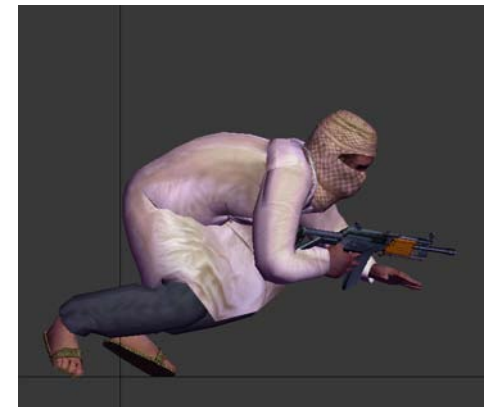
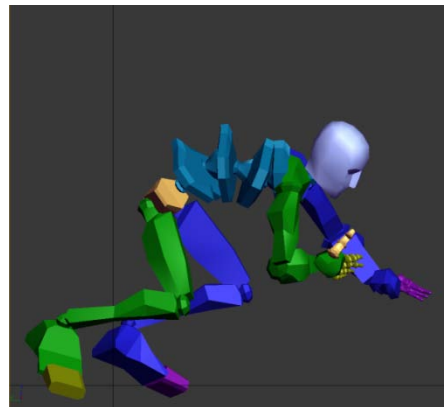
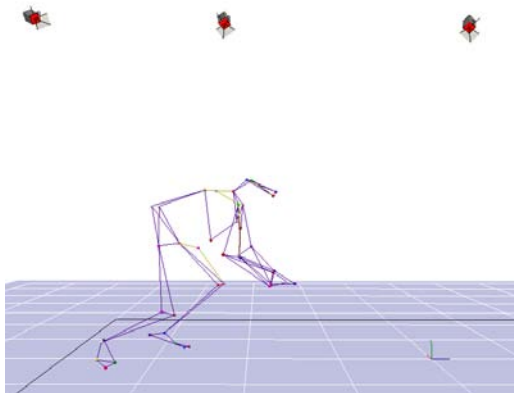
- Characters consist of 5 files types:
  - Configuration file
    - Describes how a collection of file represents a character.
  - Skeleton file
    - Defines hierarchical bone system describing the character's structure.
  - Animation files
    - Describes the animation of the character.
  - Mesh files
    - Describes 3D geometry representing the character's form and relationships between surface geometry and underlying skeleton.
  - Material files
    - Describes material and texture data for painting a surface of the geometry.



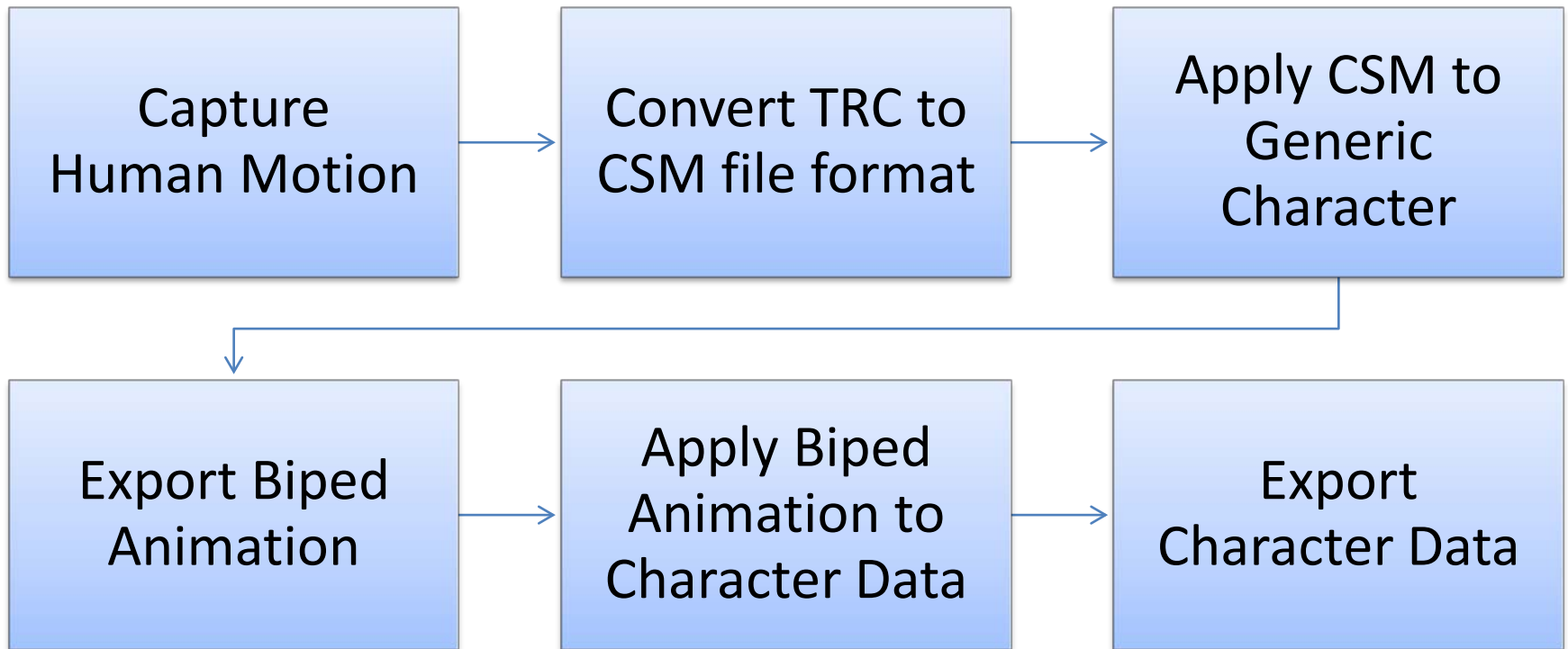
- Animations were collected using a custom marker set.
  - Actor was marked with 42 motion capture markers.
  - Generated 3D position data over time for each marker.



- Cleaning Position Data
  - Visual noise and environmental objects obscured and created duplicate markers.
  - Automated and manual procedures were used to clean marker data.



# Animation Generation



# Animation Summary

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Table 1: Animations Created for GVSL Characters.

| <i>Animation</i>             | <i>Type</i> | <i>Description</i>                                                                                          |
|------------------------------|-------------|-------------------------------------------------------------------------------------------------------------|
| Idle – Slow Shift            | New         | Entity stands in one location slowly shifting weight from one foot to the other.                            |
| Idle – Impatient             | New         | Entity stands in one location shifting weight from one foot to the other and occasionally tapping one foot. |
| Idle – Look at Watch         | New         | Entity looks at his/her watch.                                                                              |
| Walk                         | Replacement | Basic walking gait.                                                                                         |
| Run                          | Replacement | Entity appears to be on a quick jog.                                                                        |
| Limp                         | New         | Entity limps on his/her right leg.                                                                          |
| Crawl                        | New         | Entity moves while remaining prone.                                                                         |
| Firing Weapon while Standing | Replacement | Entity fires his/her weapon from a standing posture.                                                        |
| Firing Weapon while Kneeling | New         | Entity fires his/her weapon from a kneeling posture.                                                        |
| Stand/Kneel Transitions      | Transition  | Entity kneels down and entity stands up.                                                                    |
| Stand/Prone Transitions      | Transition  | Entity drops down into a prone position and stands up.                                                      |
| Hit by Gunfire               | New         | Upper body jerks in response to being hit by gunfire.                                                       |
| Fall Down                    | Replacement | Entity responds to being hit and falls down.                                                                |
| Dead                         | Replacement | Entity lays in the final position after falling down.                                                       |
| Kneel                        | Replacement | Static pose for kneeling. Replaced old kneeling static pose to match stand/kneel transitions.               |
| Prone                        | Replacement | Static pose for prone posture. Replaced old prone animation to match stand/prone transitions.               |

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- If many entities initiate an animation, the playback in the IG will be synchronized in an immersion-breaking manner.
- Two Methods for Animation Variability
  - Multiple animations for a given task.
    - Breaks up repeating animations and creates apparent activity.
    - Example
      - Stand idle: depicts avatar shifting weight slowly from one foot to other.
      - Idle look at watch: depicts avatar looking at watch to determine time.
  - Pseudo-random start delays.
    - Creates an offset in the animation playback across two characters.



## Soldier models running after simultaneous start



## Soldier models running with start delay offset

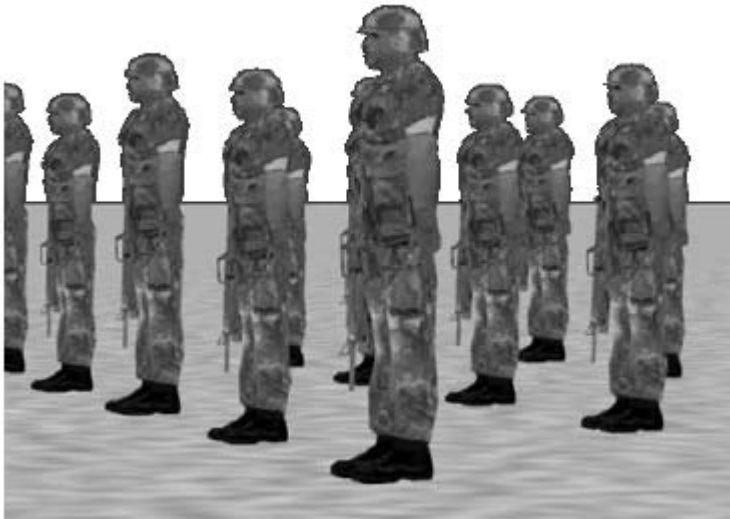


- When populating an environment with a limited set of digital human models, variation in height will be low.
  - One solution is to apply a scaling factor to the data representation of the entities.
- Human height is appropriately modeled using a normal distribution.
  - A Box-Muller transform can be applied to two linearly distributed pseudo-random numbers,  $U_1$  and  $U_2$ , to generate a standard normal deviate.

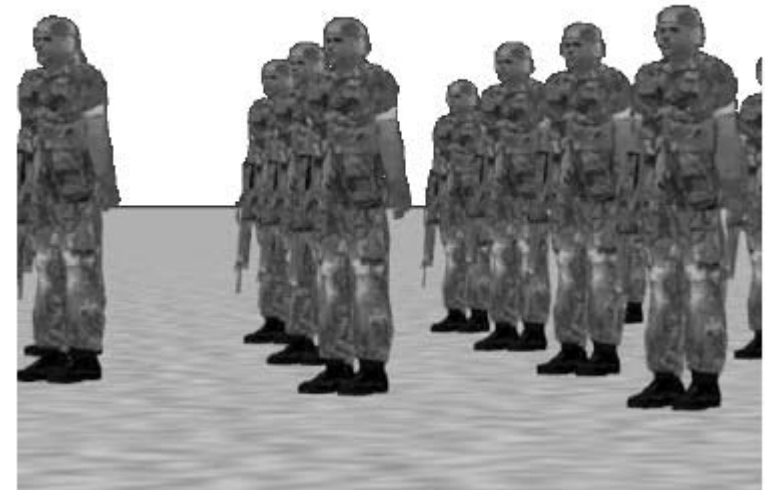
$$Z_0 = \sqrt{-2 \ln U_1 \cos(2\pi U_2)} \quad [3]$$



## Uniformly Distributed Height Variability



## Normally Distributed Height Variability





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# Human Entity Behavior Modeling

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- Identified gaps in available OTB behaviors.
- Move on Exact Path
  - Two Major Weaknesses
    - (1) Entities have limited awareness of events in the environment and do not react appropriately to combat-related events.
    - (2) Expects the entity to join the path at the beginning of the path.
  - Modifications
    - Corrected (2) by modifying task such that an entity, when assigned the task, would find the closest point along the path to its current position.
    - (1) will require combination of Move on Exact Path with additional behaviors.



- Major Goals for Improvement
  - Make the behaviors of the civilian units more natural.
    - Exploring integration of task behaviors into an all-encompassing autonomous task behavior that would prioritize goals and react to changes in the environment.
  - Inferred behavior visualization technique
    - Standard PDUs cannot fully describe an entity's actions in the environment.
    - By considering the IG and other events in the simulation environment, we can attempt to infer the intent of the behavior and visualize a richer representation of the entity behavior.

# Conclusion

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- TARDEC GVSL requires immersive simulation environments to ensure subject performance will generate valid and accurate data.
- Subject feedback from previous experiments has revealed the need for improved visualization and behavior modeling of entities.

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- Visualization
  - Implemented a pipeline for quickly generating new animations for existing character models from motion capture data.
  - Increased variability of character visualization through use of increased number of animations, variable character scale, and animation start offsets.
- Behavior Modeling
  - Improved capability to model ambient civilian traffic.
    - Modifications have reduced operator effort when defining paths and simplified the creation of paths for large numbers of entities.
- Efforts are underway to visualize context-dependent behaviors.



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Thank you for your attention.

Any questions?

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