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Mathematical Capture Of Human Data For
Computer Model Building And Validation

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14. ABSTRACT The model development process created at the TBRL has successfully created models from LVC simulation data, simulated models over time to generate simulated crowd data per condition, performed analysis of observed and simulated data, and compared simulated and observed data against crowd behavioral measures. The process allows for quantitative means for validation of both the mathematical (statistical) and computational models against empirical data. These findings support the claim that more accurate human behavioral models may be derived using laboratory observed data. Furthermore the findings support the necessity of a continuation of the work to explore ways to improve the model development and validation processes.						
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Overview

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Military Need for Crowd Behavior Research

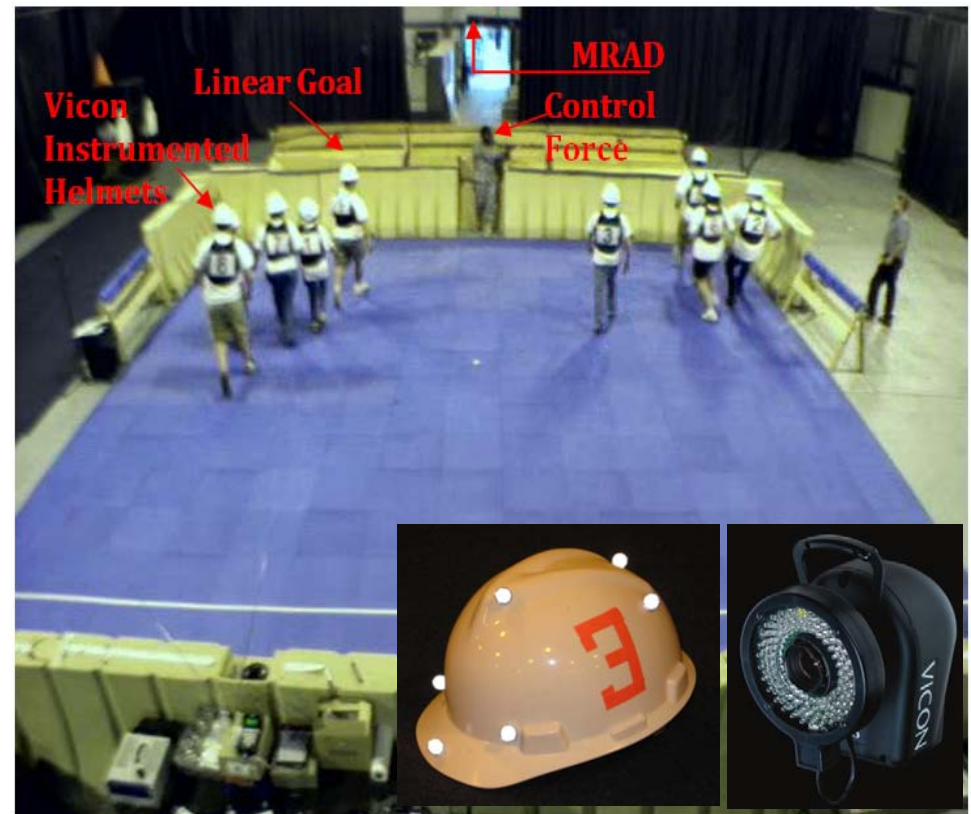
- The motivations underlying adversarial behavior
- Behavior of contested populations
- How the behavior of populations vary cross-culturally
- What is innate human behavior that extends across cultural boundaries



Introduction

Crowd Behavior Research at TBRL

- Human behavior can be explained as attractions and repulsions toward and away from goals (Lewin, 1935)
- Crowd Behavioral Test-Bed used to gather:
 - locomotive
 - psychosocial
 - effectiveness data
- Data gathered to develop models that use vector regression methods to identify attributes of a crowd that influence predictive variables.

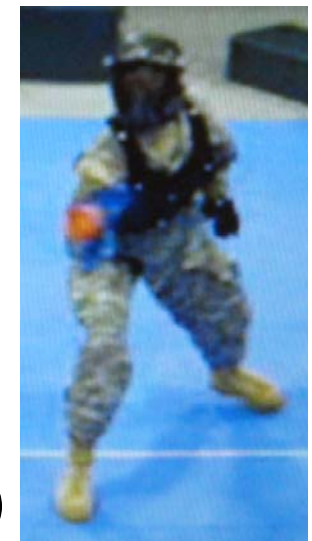


Data Collection



Experimental Conditions

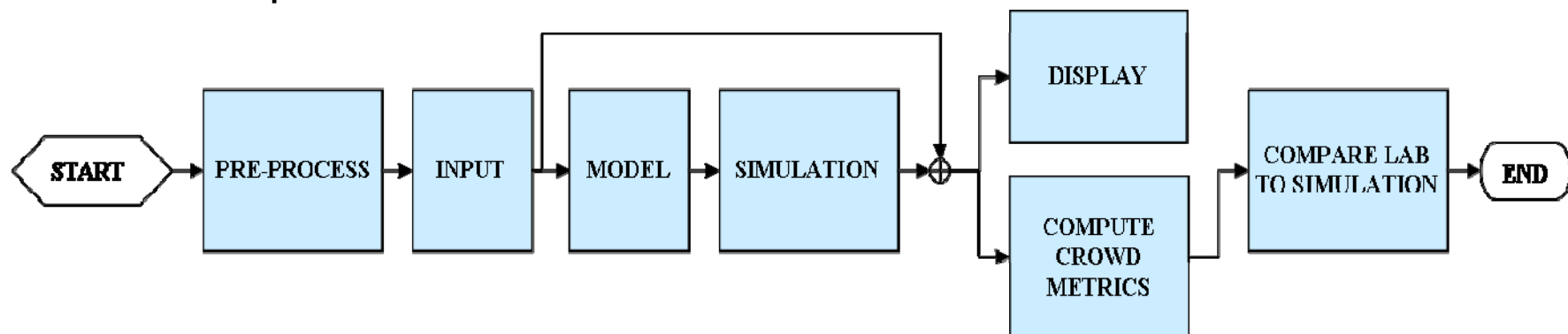
- Crowds with up to 25 subjects during a trial throwing simulated rocks into a linear target while the target was defended by a non-lethal device:
 - No Defense (Baseline)
 - MRAD
 - Handheld stand-off NLW operated by Control Force
 - Simulated Projectile Weapon
 - Simulated Handheld Directed Energy NLW (VDE)
 - Simulated Invisibly located Directed Energy NLW (IDE)



M&S Process

Model Building

- **MATLAB** modules for developing software to:
 - Automate the creation of mathematical models for motion of individuals in a crowd from the data collected in TBRL crowd experimentation
 - Run simple simulation of the above model to generate simulated data
 - Calculate crowd level metrics from laboratory and simulated data
 - Compare simulated data with observed data



M&S Process

Model Building

- **Pre-Process Module**

- Separate modeling and validation data
- Restructures the location data file
 - Data for each participant at sample time is grouped and appended to preceding time steps.

- **Input Module**

- Parses the formatted data from the previous step into three elements:
 - Header vector
 - Output matrix
 - Predictor matrix

M&S Process

Model Building

- **Modeling Module**

- Accepts the predictor and output matrices
- Performs non-linear regressions to determine the relationship between predictor/input and predicted/output variables.
 - $[\text{beta}, r, J, \text{COVB}, \text{mse}] = \text{nlinfit}(X, y, \text{fun}, \text{beta0})$
 - Regression of velocity vectors in both 'X' and 'Y' axes against the predictors, generating model coefficients for change in location in 'X' and 'Y' coordinates
- Model errors were fit to Weibull distribution

M&S Process

Simulation

- **Simulation Module**

- Execute a time stepped simulation of each subject's location based on:
 - derived model
 - starting conditions
 - average time between samples
 - duration of simulation
- Calculate the following for each subject at each time step and appended to a simulated data file
 - delta distance traveled
 - delta position
 - velocities
- Incorporate Control Force effects by transforming the coordinates of the baseline model to fit that of the CF model,

Crowd Metric Analysis

- **Crowd Metric Module**

- Calculates aggregate metrics of crowd behavior as a whole
 - Leading edge (LE): location of the forward most crowd member
 - Trailing edge (TE): location of the crowd member that is furthest back
 - Centroid: location of the crowd member that is midway between the LE and TE
 - Geometric center: mean of the LE & TE
 - Dispersion: average displacement in the 'X' and 'Y' direction



M&S Process



Model Validation

- **Model Comparison**

- Compares, statistically, the crowd metrics of simulated and observed data
 - two sample Kolmogorov-Smirnov (K-S) goodness of fit (GOF) test
 - Determine if the simulated data follows the same distribution as the observed data, the asymptotic p-value, and k-statistic.
- 5% significance level
- Unequal alternative hypothesis test



Results

Model Verification

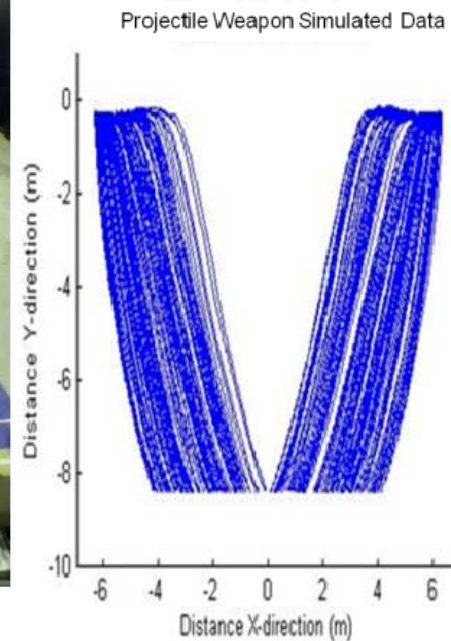
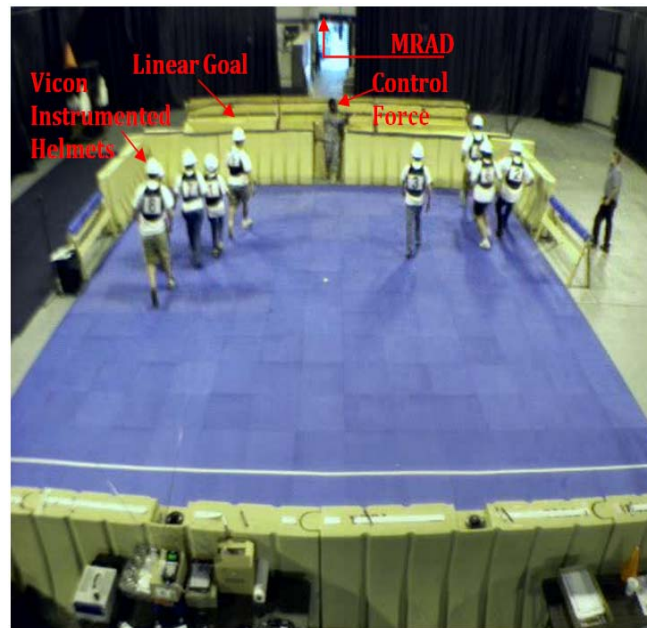
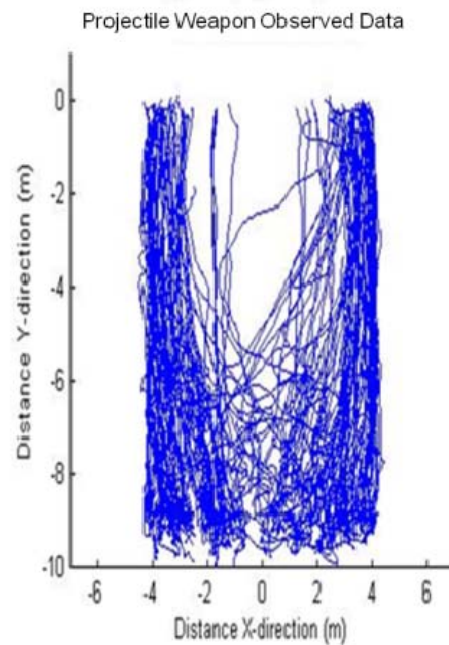
- **RMSE comparison**
 - Comparison between the expected values calculated from the regression equation and the data observed in the laboratory.

Conditions	RMSE (Radial) [meters]	RMSE (Tangential) [meters]
Baseline	0.5	
Projectile Weapon	0.65	0.54
Visible Directed Energy	0.47	0.36
MRAD	0.37	0.26
Invisible Directed Energy	0.37	0.38

Results

Model Verification

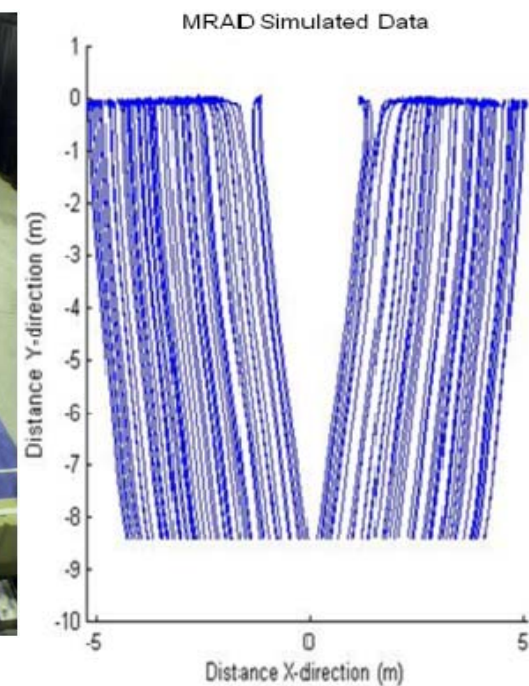
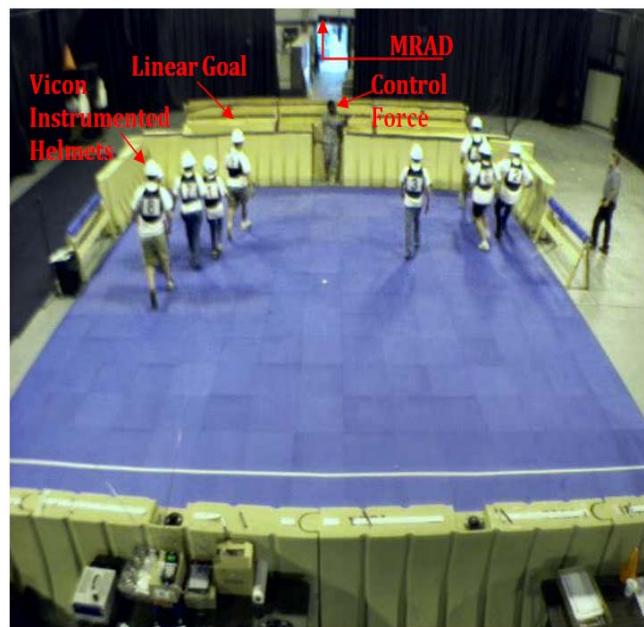
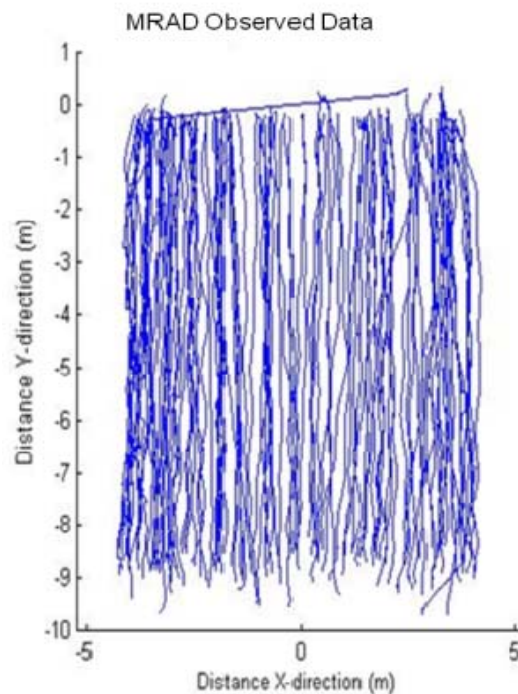
- Graphical Comparison



Results

Model Verification

- Graphical Comparison Cont'd



Results

Model Validation

- K-S GOF Test

Conditions	Measures	H [Accept(0) /Reject(1)]	P-value	K-S Statistic
Baseline	LE	0	0.188	0.500
	Centroid	0	0.519	0.375
	TE	0	0.519	0.375
MRAD	LE	0	0.883	0.286
	Centroid	0	0.883	0.286
	TE	0	0.883	0.286
Projectile Weapon	LE	1	0.001	0.714
	Centroid	1	1.19E-04	0.786
	TE	1	1.87E-05	0.857
Visible Directed Energy	LE	0	0.077	0.667
	Centroid	1	1.19E-04	0.786
	TE	1	1.87E-05	0.857
Invisible Directed Energy	LE	1	1.87E-05	0.857
	Centroid	1	2.50E-06	0.929
	TE	1	2.86E-07	1.000

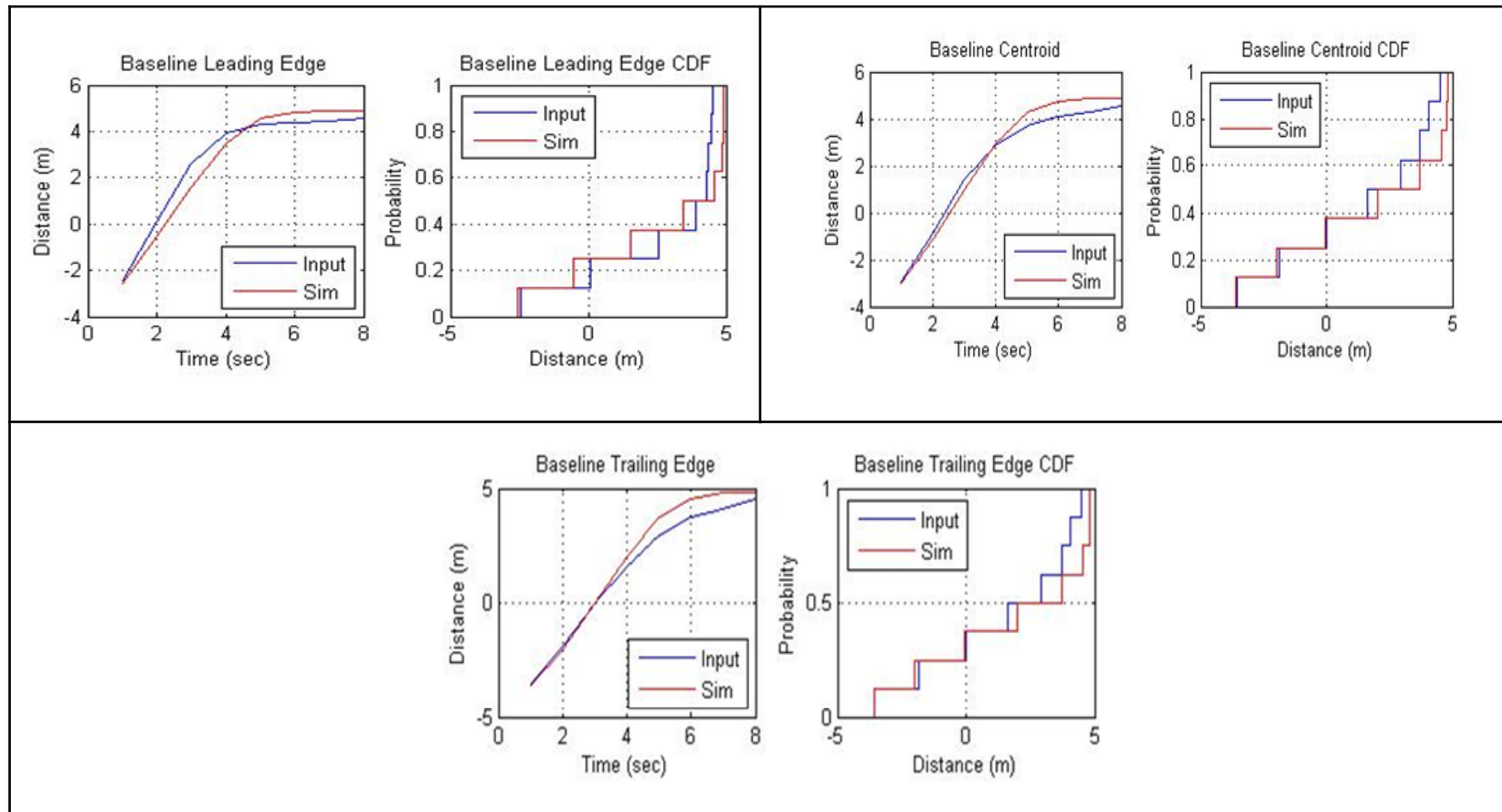


Results



Model Validation

- K-S GOF Test - Baseline



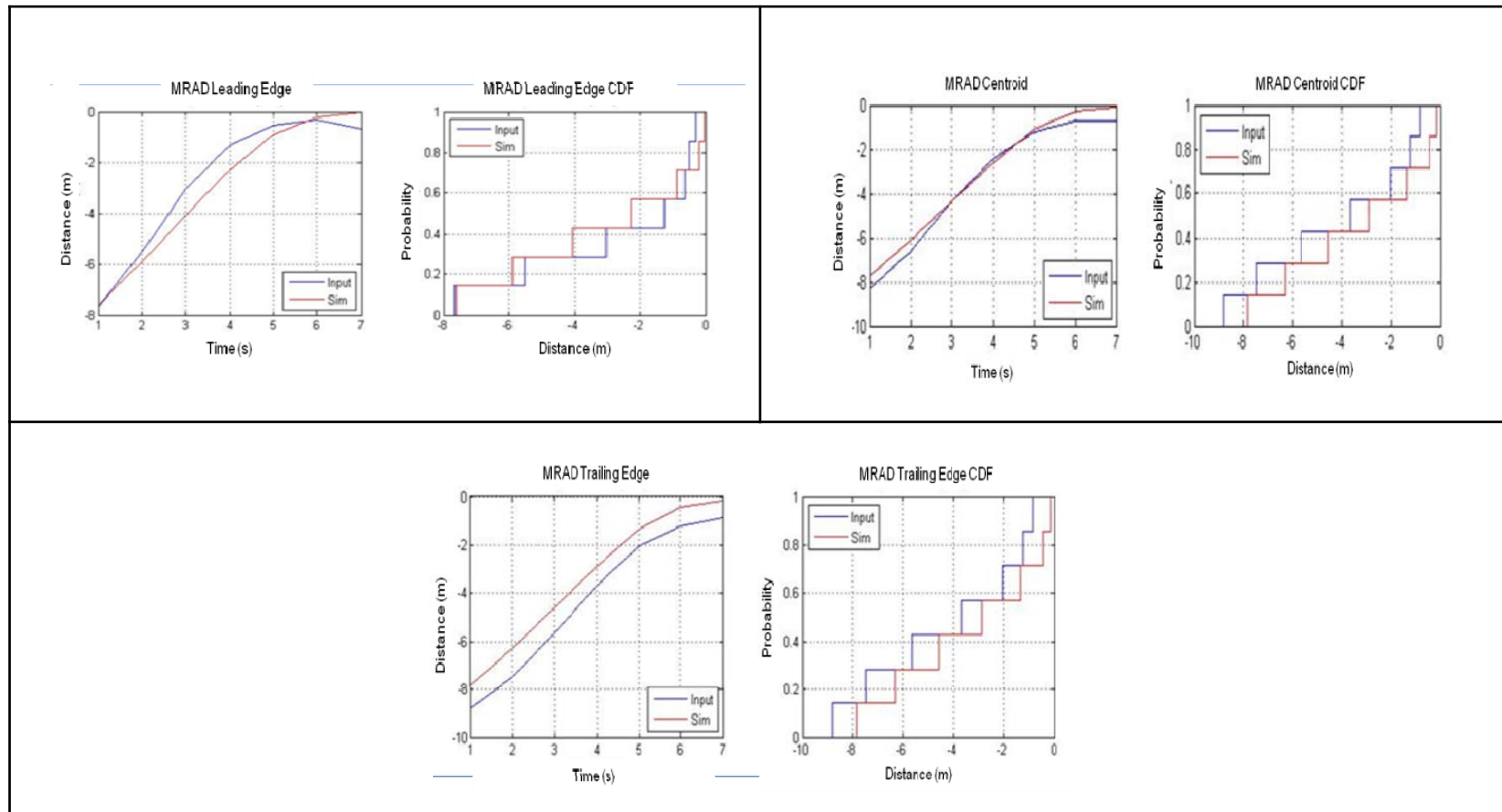


Results



Model Validation

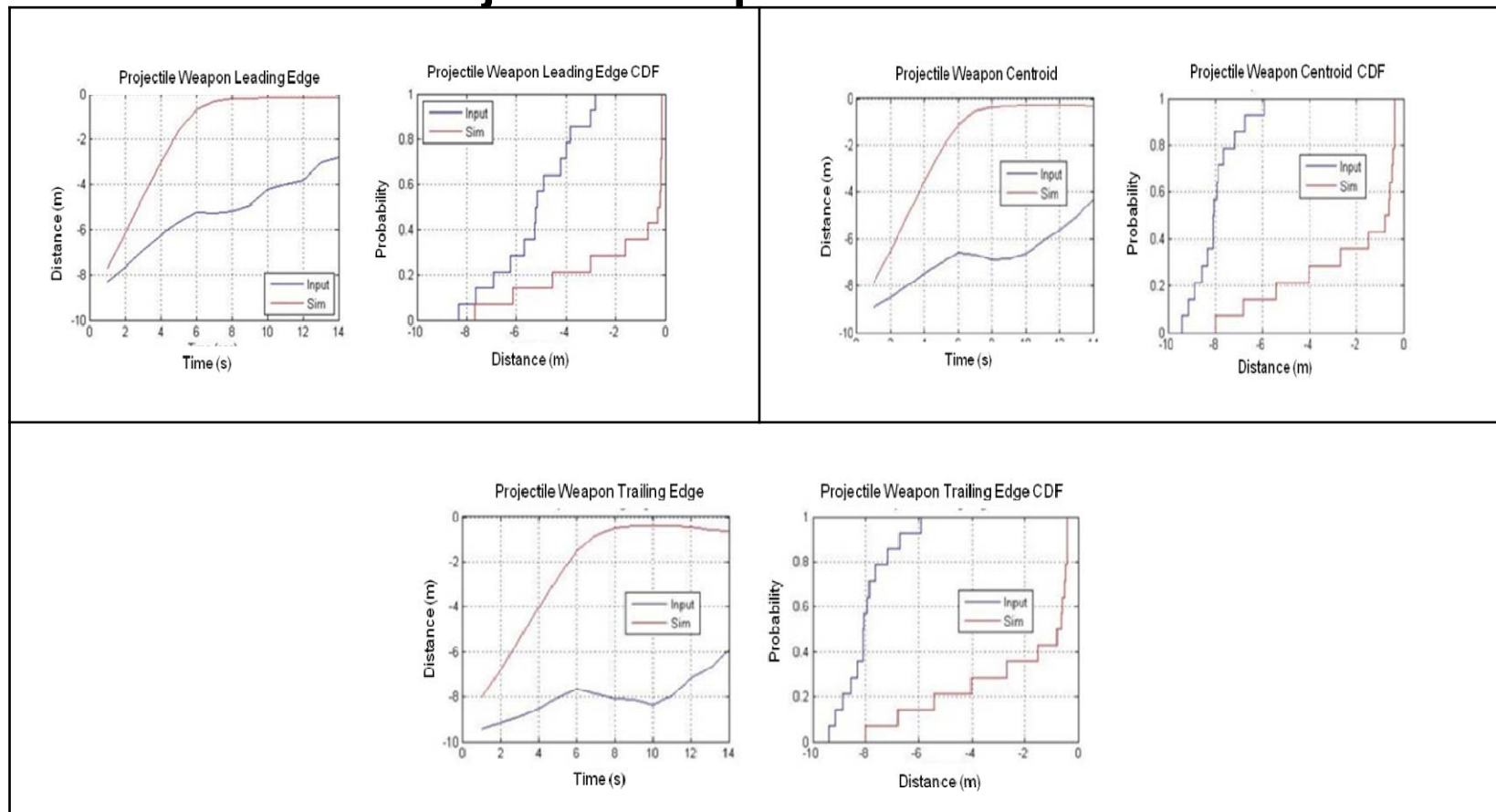
- K-S GOF Test - MRAD



Results

Model Validation

• K-S GOF Test - Projectile Weapon





Conclusion



- There are several identified areas for improvement which include:
 - Using additional or new regression methods that yield more accurate models reflected by smaller RMSE
 - Accounting for error during simulation and making necessary adjustments to produce data that more closely represent observed data
 - The incorporation of crowd metrics for the observed data set into the model development process to improve the goodness of fit for the observed and simulated data
 - Using additional goodness of fit test to validate the model

Summary

- The model development process created has successfully
 - created models from Laboratory collected data
 - simulate models over time to generate crowd data per condition
 - perform analysis of observed and simulated data
 - compared simulated and observed data against crowd behavioral measures
- The process allows for quantitative means for validation of both the mathematical and computational models against empirical data,
- The models created for the baseline and the MRAD weapon conditions successfully estimated crowd locomotive behavior
- Some of the models created still need refinement based on the graphical comparison of the simulated and observed data in addition to the K-S GOF test

Questions?

US Army - Target Behavioral Response Lab

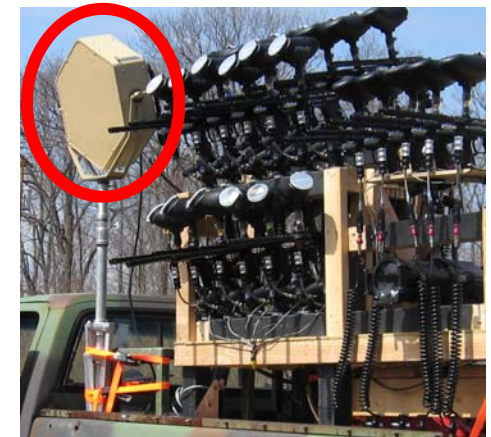
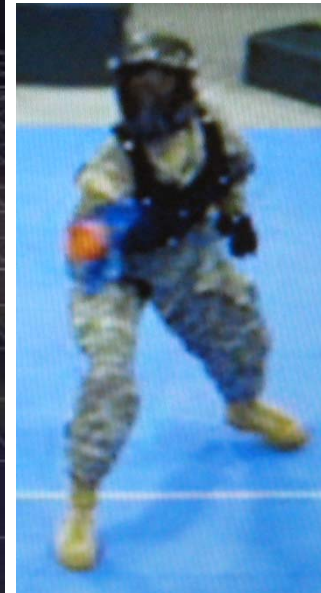
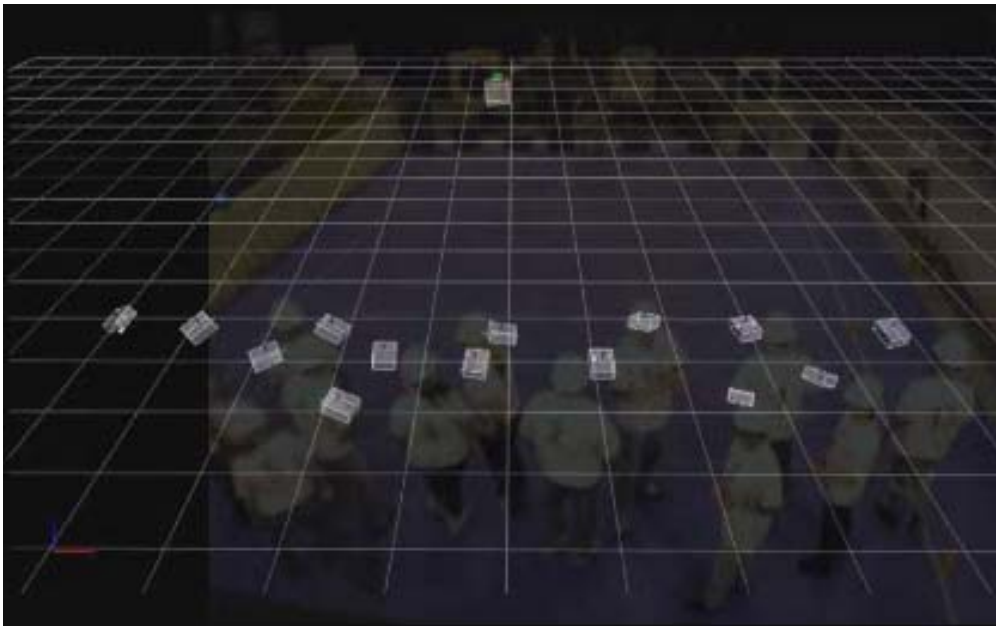
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BACKUP SLIDES

Data Collection



Crowd Behavior Testbed



Courtesy Vicon