Mathematical Capture Of Human Data For Computer Model Building And Validation

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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.
• **Introduction**
  – Crowd Behavior Research at TBRL

• **Data Collection**
  – Experimental Conditions

• **Modeling & Simulation Process**
  – Model Building
  – Simulation
  – Crowd Metrics Analysis
  – Model Validation

• **Results**
  – Model Verification
  – Model Validation

• **Summary**

• **Conclusions**
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
• 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.
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)
**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
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
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.
    
    • \([\beta, r, J, \text{COVB, mse}] = \text{nlinfit}(X, y, \text{fun, beta0})\)
  
  • 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
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 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
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
Model Verification

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

<table>
<thead>
<tr>
<th>Conditions</th>
<th>RMSE (Radial) [meters]</th>
<th>RMSE (Tangential) [meters]</th>
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<tr>
<td>Baseline</td>
<td>0.5</td>
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Results

Model Verification

• Graphical Comparison

![Graphical Comparison Image]
Results

Model Verification

• Graphical Comparison Cont’d
Model Validation

- K-S GOF Test

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<tr>
<th>Conditions</th>
<th>Measures</th>
<th>$H$ $[\text{Accept}(0)/\text{Reject}(1)]$</th>
<th>P-value</th>
<th>K-S Statistic</th>
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Model Validation

• K-S GOF Test - Baseline

- Baseline Leading Edge
- Baseline Leading Edge CDF
- Baseline Centroid
- Baseline Centroid CDF
- Baseline Trailing Edge
- Baseline Trailing Edge CDF
Results

Model Validation

• K-S GOF Test - MRAD

Distribution A: Approved for Public Release
Model Validation

• K-S GOF Test - Projectile Weapon
• 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
• 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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Data Collection

Crowd Behavior Testbed

Courtesy Vicon