Empirical data sets for agent based modeling of crowd scenarios

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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14. ABSTRACT
The presentation will focus on the quantitative analysis methods for "understanding human behavior", specifically how to describe a crowd, through the analysis of the locomotion of individuals in a crowd under various control force conditions. This data set represents actual behavior of humans under group conditions and can be used to inform simulations and potentially for validation of models. These empirical data were used to generate a vector field model of the interaction forces between members of the crowd and the control force. Subjects participated in an experiment investigating crowd behavior and response to a control force in a stop approach and an area clearing scenario. Level of threat from the control force was manipulated throughout the experiment. The location and orientation of all individuals and the crowd as a whole were recorded throughout the experiment using motion capture technology and then were quantified using a variety of metrics derived from these measures. Of all the derived measures, the centroid and average leading edges demonstrated the most sensitivity to differences in weapon type and tactics. Therefore, these metrics can be used to assess and compare effectiveness of different non-lethal weapons and systems and their tactics, techniques, and procedures. Vector fields were also generated to describe the locomotion of crowd members under each condition. These vector fields describe the most likely motion of a crowd member based on their location relative to the control force and can be used in dynamic situations. This demonstrates that the Lewinian Field Theory can be directly applied to crowd science. The presentation will conclude with a discussion on applications to crowd behavior modeling.

15. SUBJECT TERMS
non-lethal weapons, vector fields, quantitative analysis, crowd, control force, stop approach, area clearing, motion capture, laboratory human experimentation, centroid, leading edge, effectiveness testing, Lewinian Field Theory

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Agenda

- Crowd Research
- Experimental Method
- Metrics
- Results Discussion
- Conclusion

Crowd Research

- Large numbers
- Heterogeneous
- Individual Actors
- Interdependence
- Language Barriers
- Empirical testing is difficult
- Simulations require models based on real data, otherwise they are fiction

Methods

Gather empirical data on

real people and

real groups in tactically relevant situations

TBRL

Malcolm Baldrige National Quality Award 2007 Award Recipient

Method

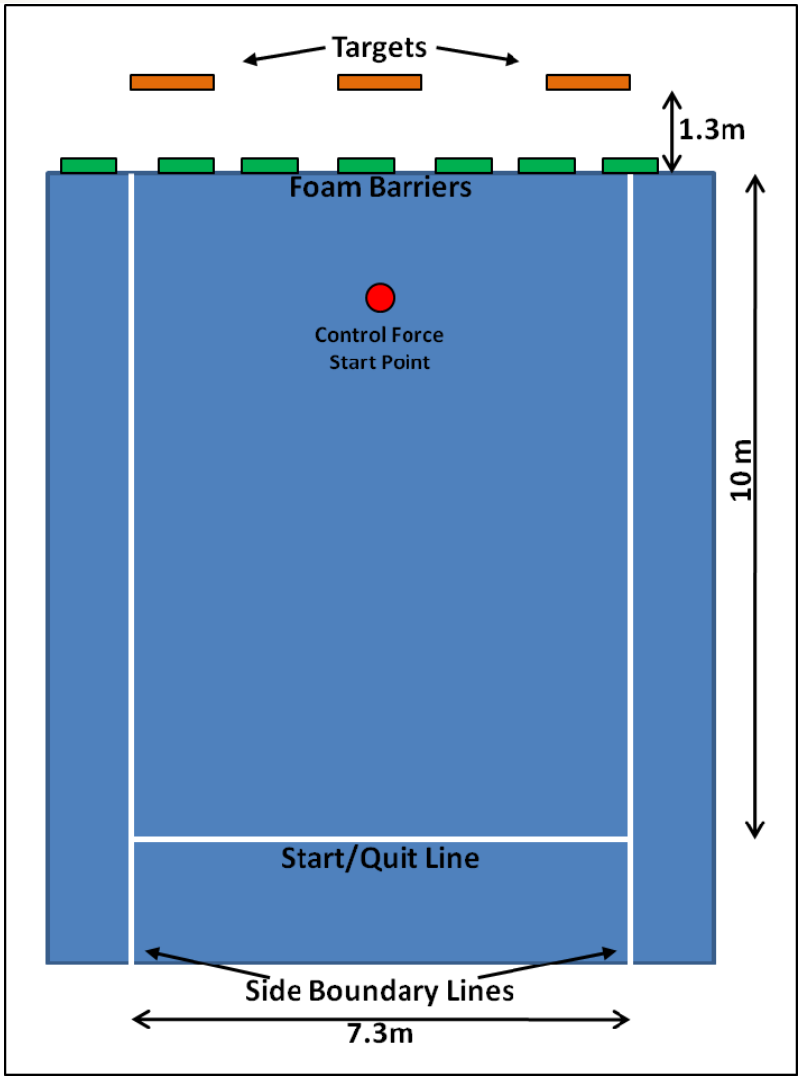
- Groups of 12-19 individuals
- Controlled motivations toward goal & away from control force with money
- Manipulated type of weapon and the ROE
- Approach / Keep away
  - ("Deny access into/out of an area to individuals" JNLE/CBA)
- Recorded spatial data
- Video recording

Test Setup

Slide 6

MD1 Suggest captions on all pic slides.
Administrator, 7/22/2009

Test layout


Targets
1.3m
Foam Barriers
Control Force
Start Point
10 m
Start/Quit Line
Side Boundary Lines
7.3m

Data Measurement

- Vicon V8i system
- 24 cameras
- 120 fps
- Optical tracking of retro reflective markers (ø14mm)
- Marker error <10mm
- Subjects
  - Unique Helmets
  - XYZ location + 3DOF orientation of head
- Control Force
  - Head & Torso
  - Capability for weapon

Courtesy Vicon

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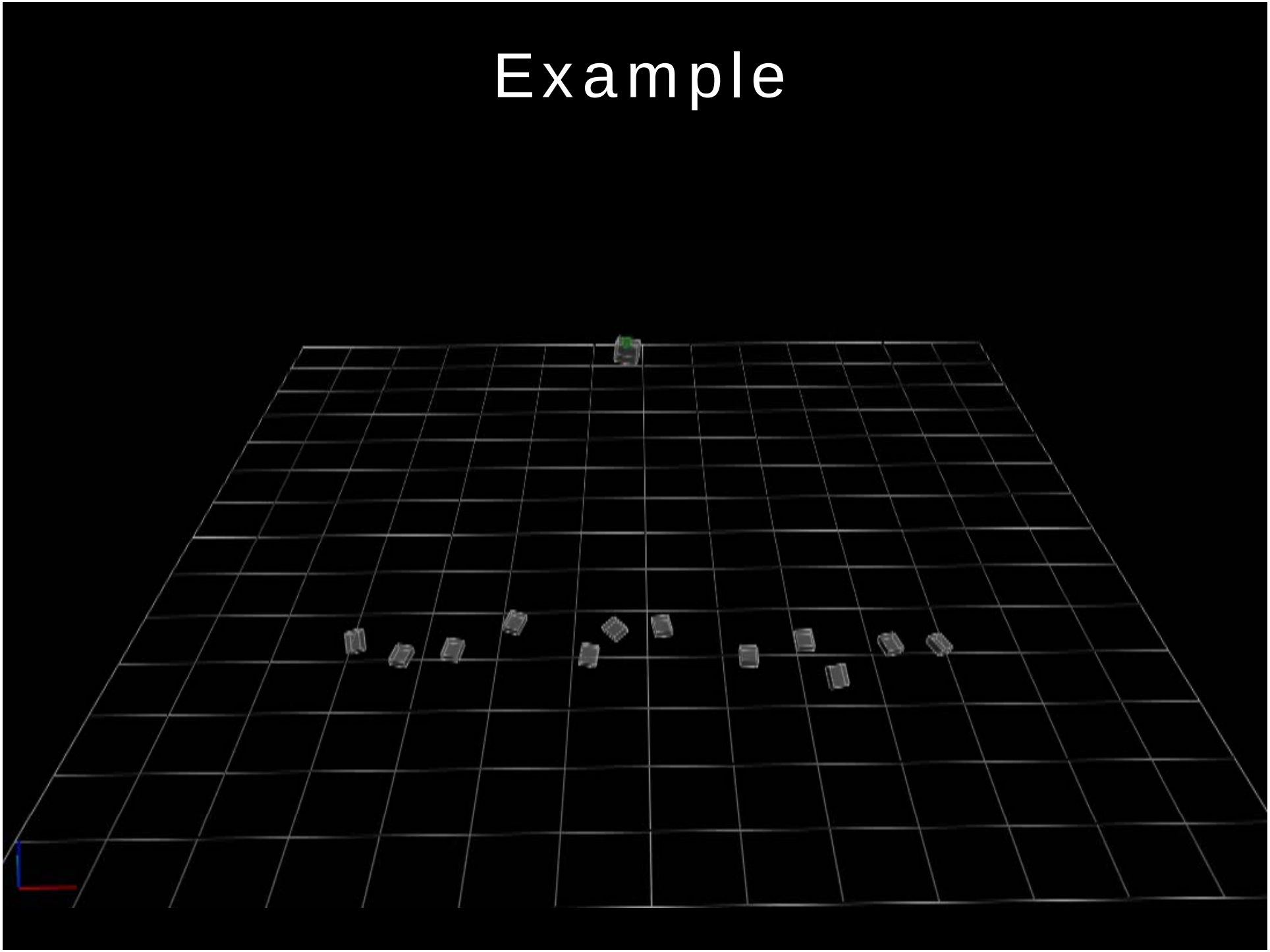
Example



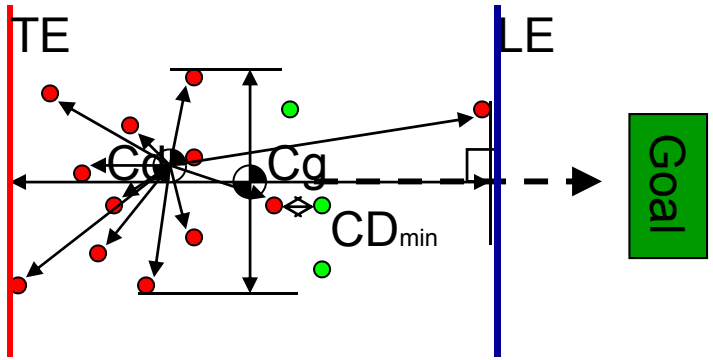
Individual Metrics

$S_{t,Sa}$	Distance covered in interval
$V_{t,Sa}$	Instantaneous Velocity
$ID_{t,Sa,Sb}$	Interpersonal Distance between any pair of subjects
$CD_{t,c,Sa}$	Distance between control force-subject pairs
$CID_{t,c,c}$	Interpersonal Distance between any pair of control force

Crowd Metrics

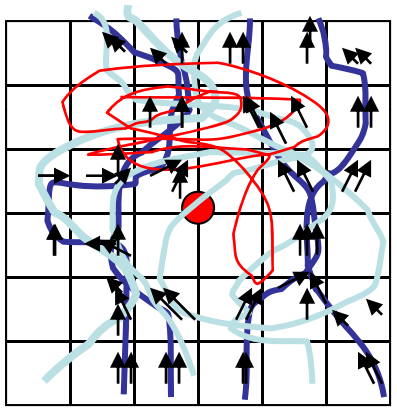
Cg_t	Geometric Center- middle of extrema
Cd_t	Centroid- mean of subject positions
D_t	Dispersion- mean subject radii from centroid
LE_t TE_t	Leading/Trailing edge- max/min along the approach axis
ρ_t	Density- $\rho_t = N / \pi D_t^2$
$CDmin_t$	Minimum distance between any subject-control force pair
σO_t σV_t	Deviation of Orientation/Velocity- StDev of all subjects head orientation or velocity
Vc_t	Bulk velocity of crowd- rate of change of centroid

Defined time periods based on events dependent on the construct or scenario used.



Vector Fields

- Each subjects path of movement considered separately.
- Coordinate conversion so Control Force is origin.
- Subject locations grouped into cells.
- Resulting vector for a cell is the average vector from all data in that cell.
- Stream lines built from Vector Field.



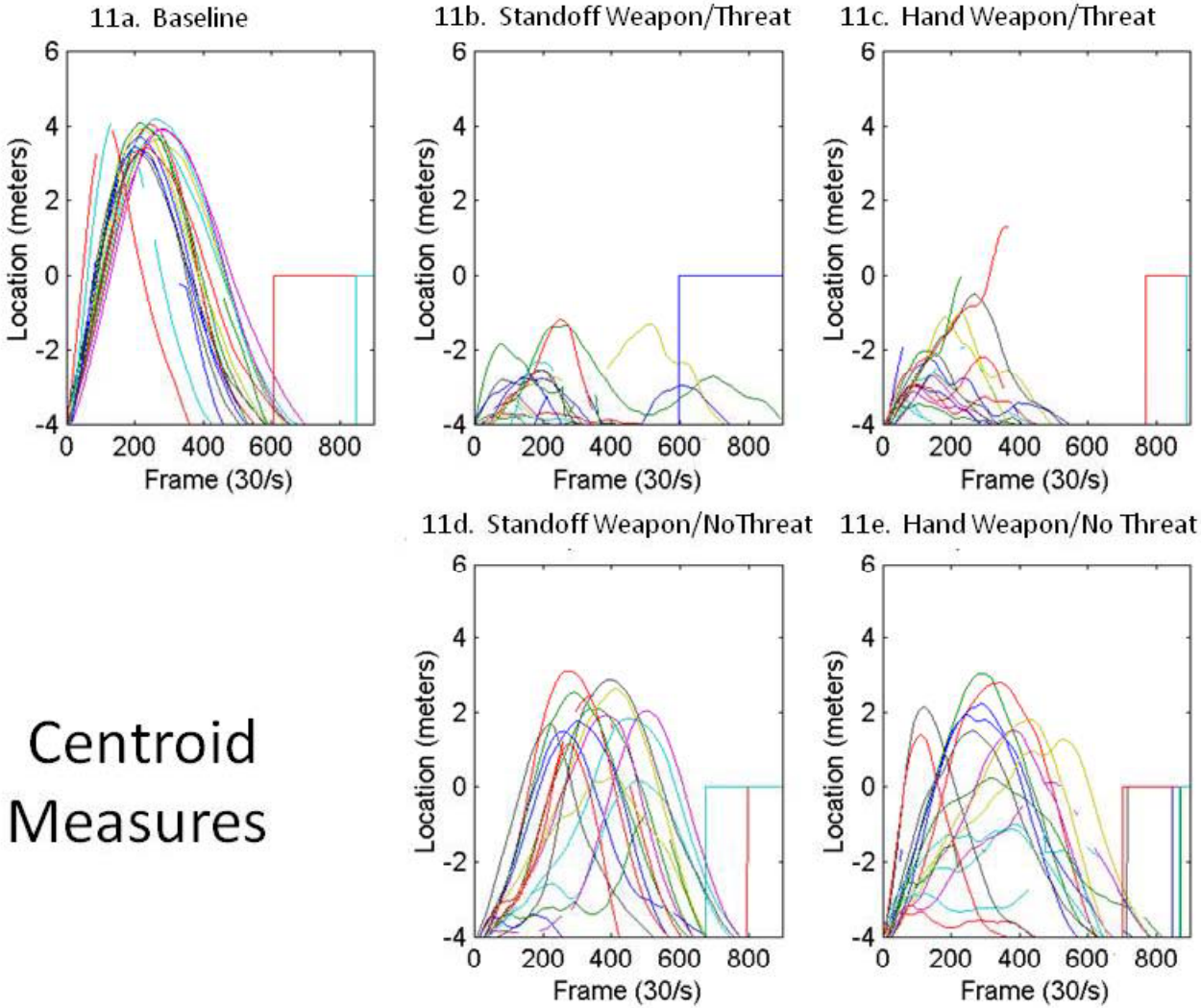
Results and Discussion

90 trials of data

Recorded from 5 groups

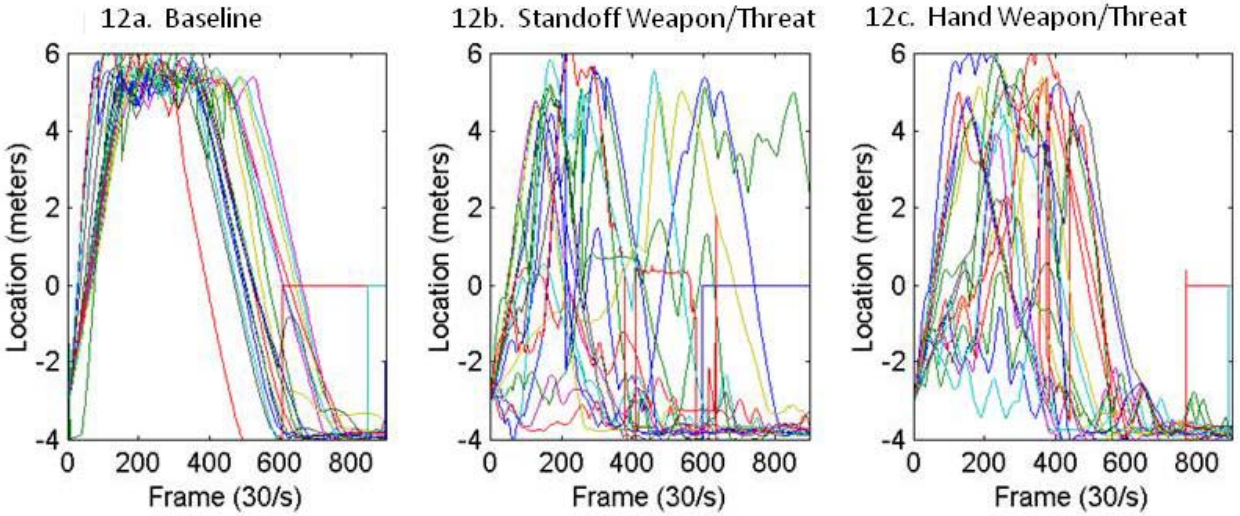
each made up of 12-17 individuals

Centroids

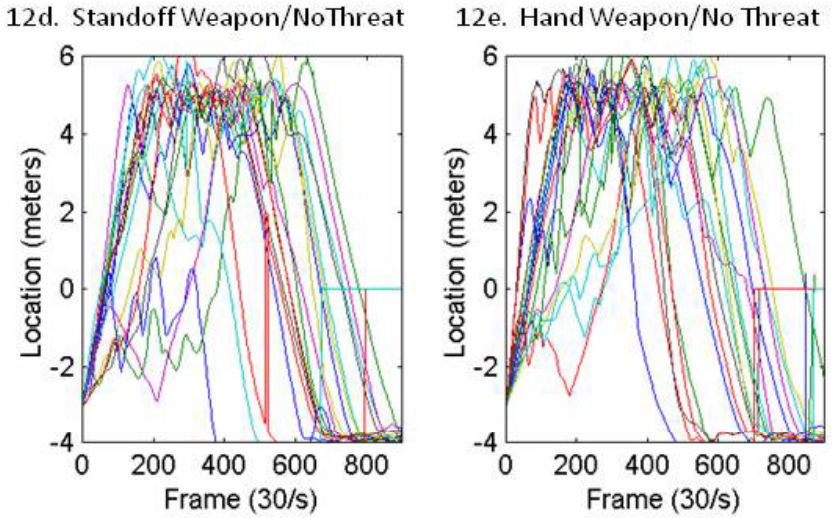


Centroid Measures

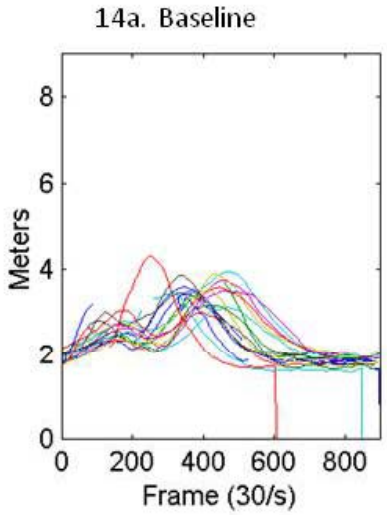
Leading Edge

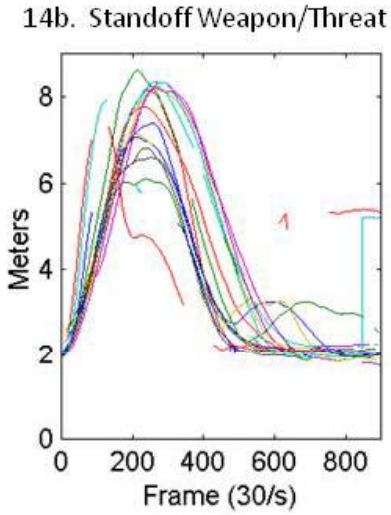


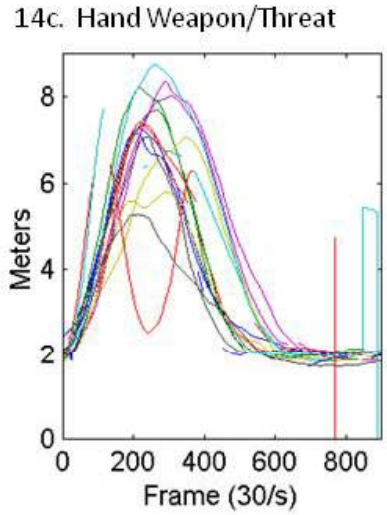
Leading Edge Measures

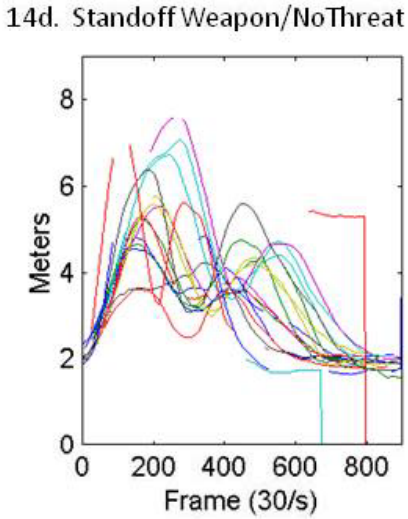


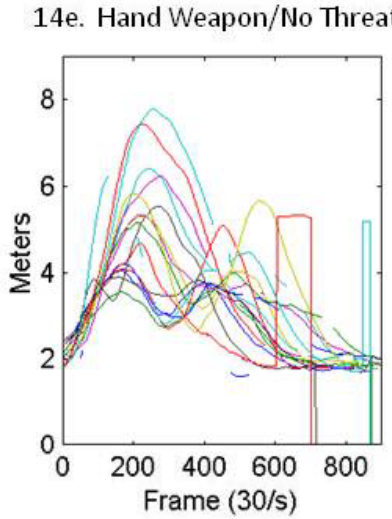
Dispersion





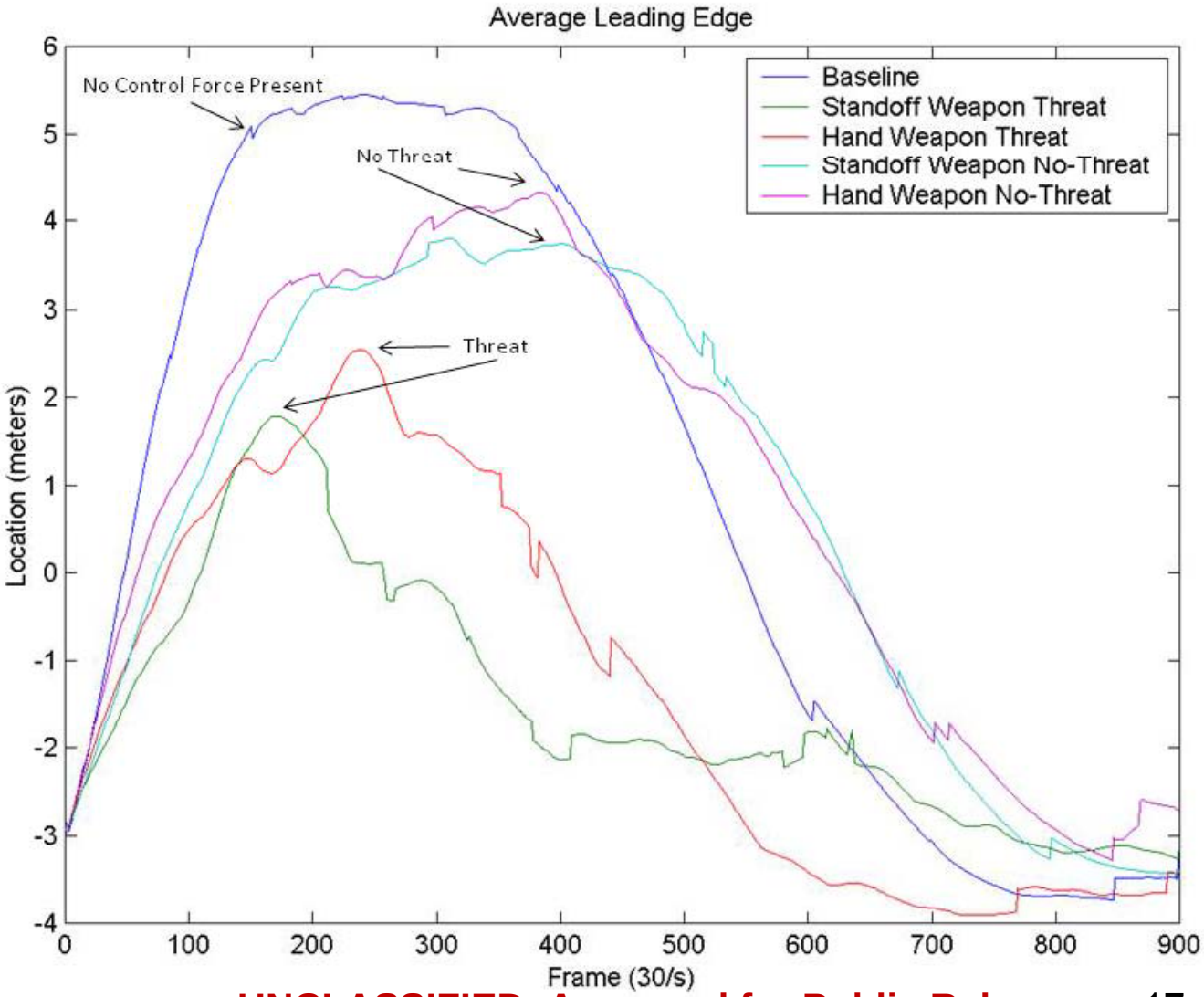




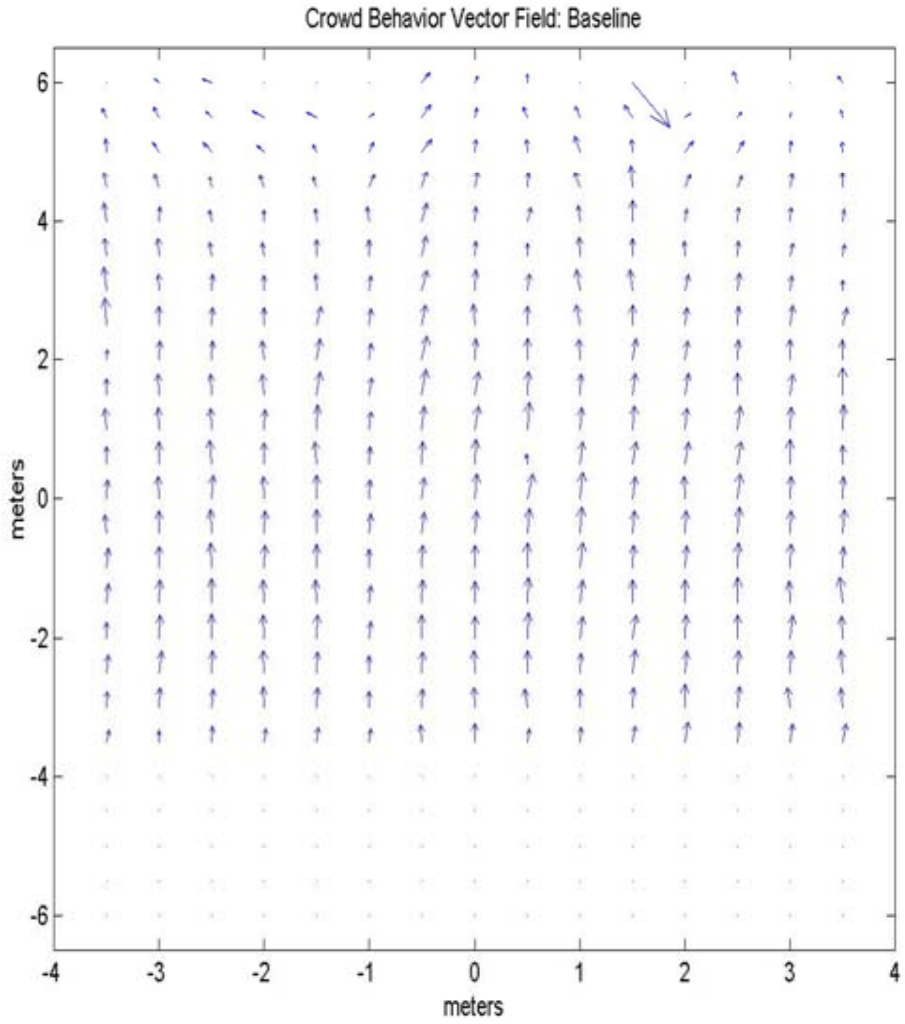


Dispersion Measures (Average Radius)

Leading Edge Comparison



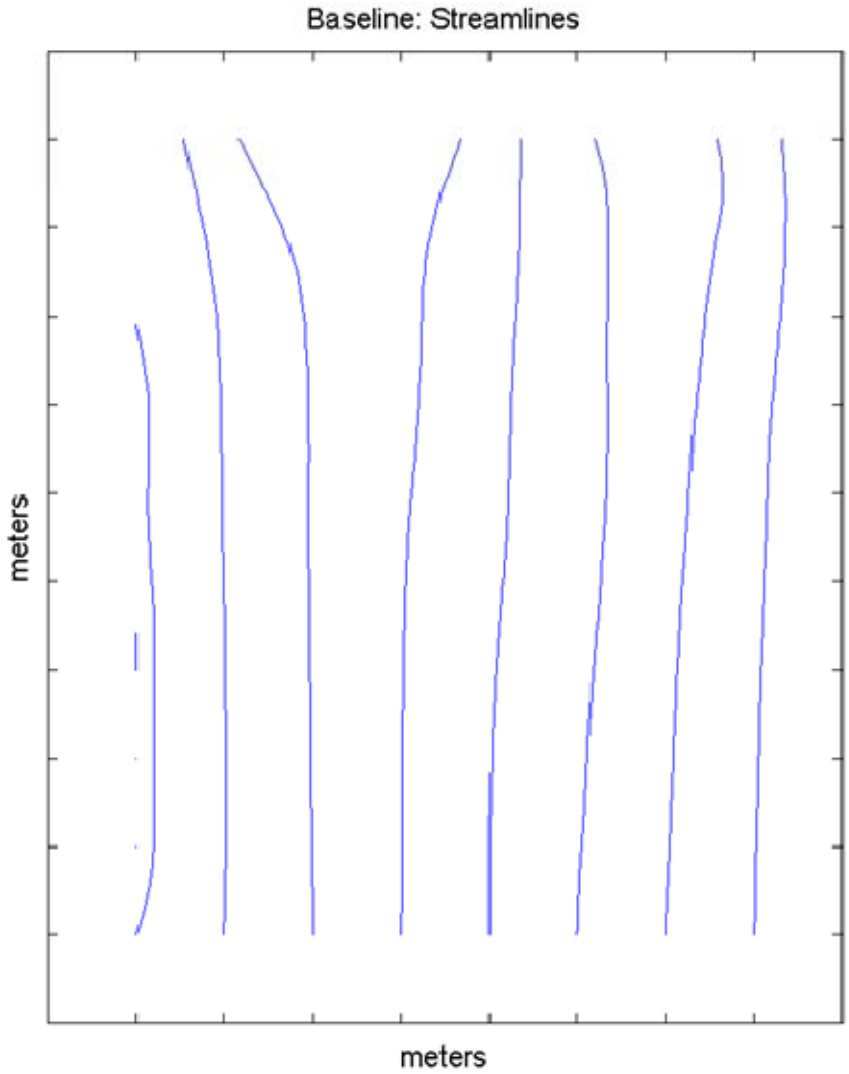
Baseline Vector Field



Goal End

Start End

Baseline Vector Field

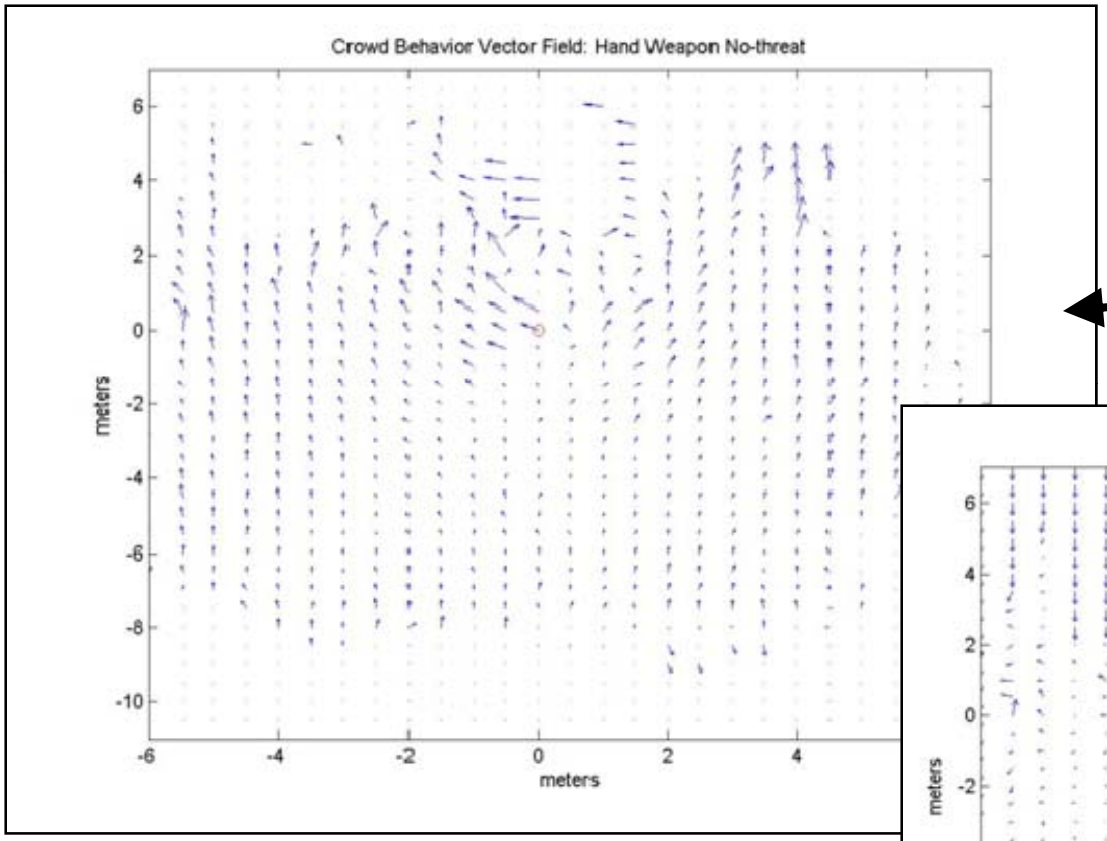


Goal End

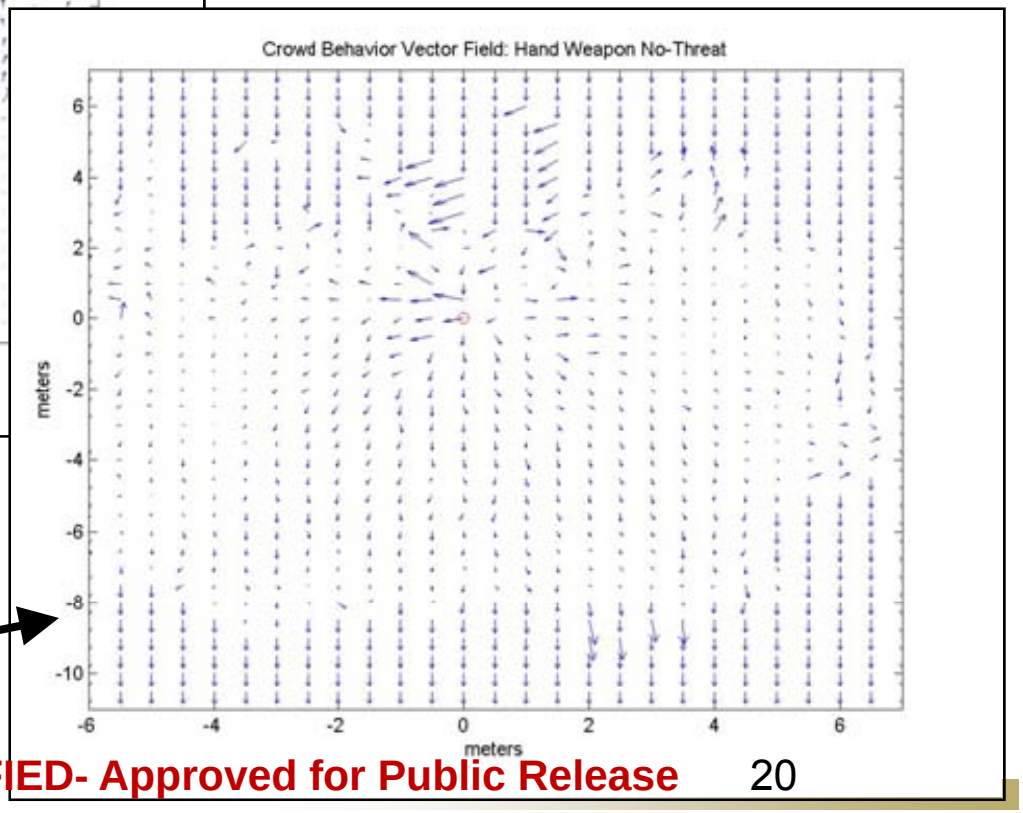
Streamline View

Start End

Vector Fields



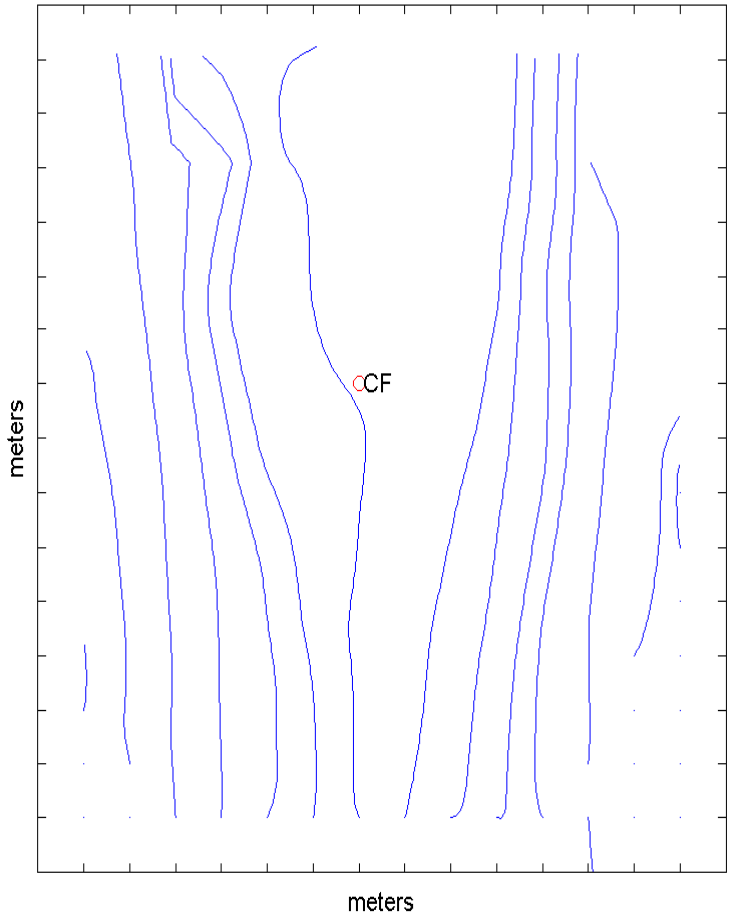
Recorded vector fields are combined behavior towards the goal and avoid the control force.



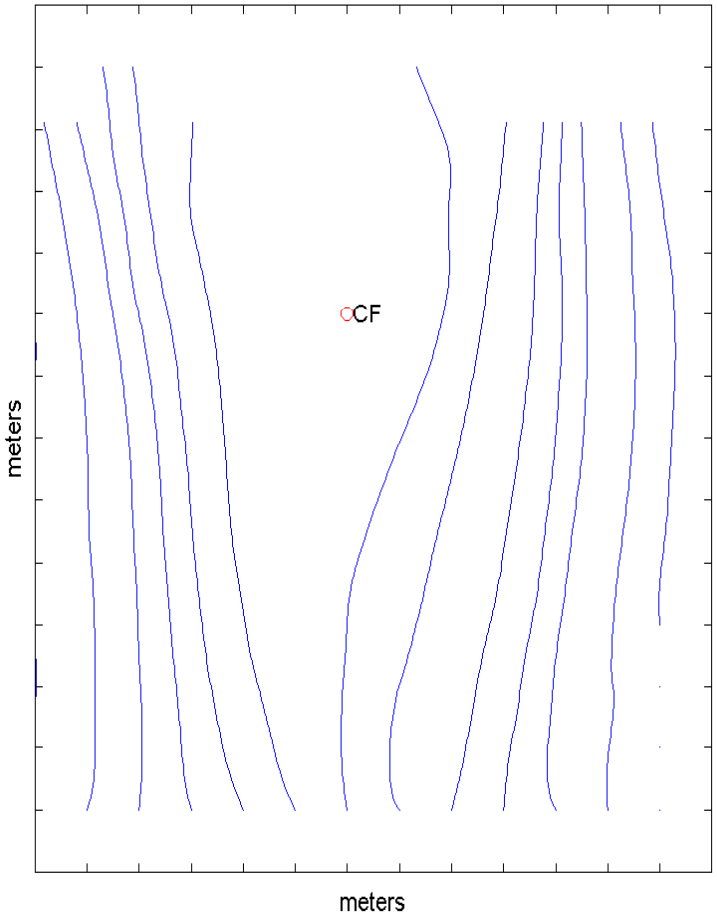
Can subtract baseline (towards goal) to find the vector field only avoiding the control force.

No Threat Streamlines

Hand-to-Hand Combat Weapon

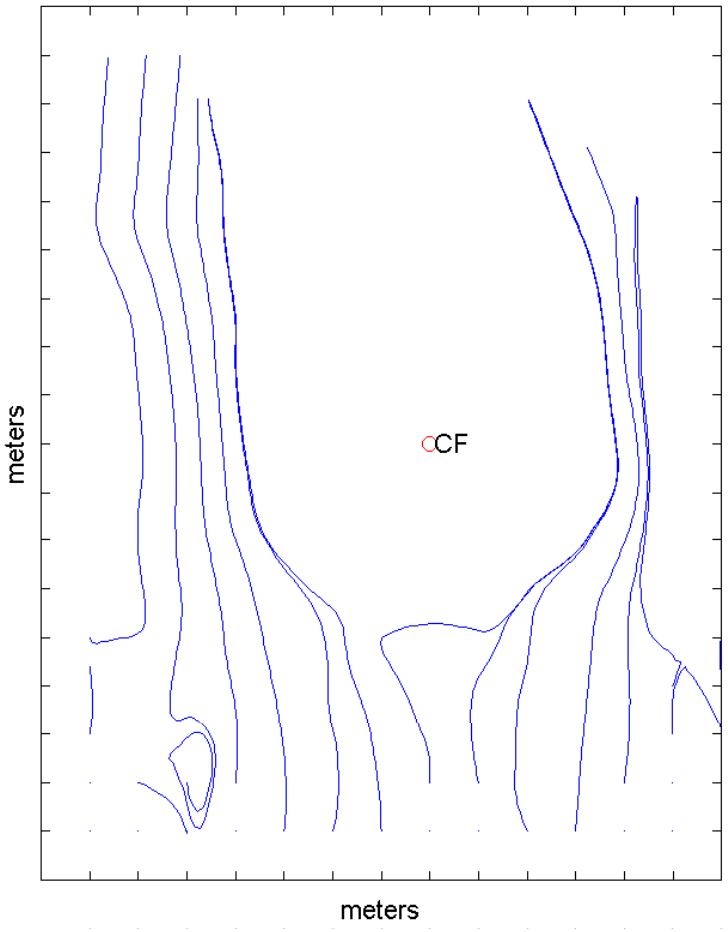


Stand-off Weapon

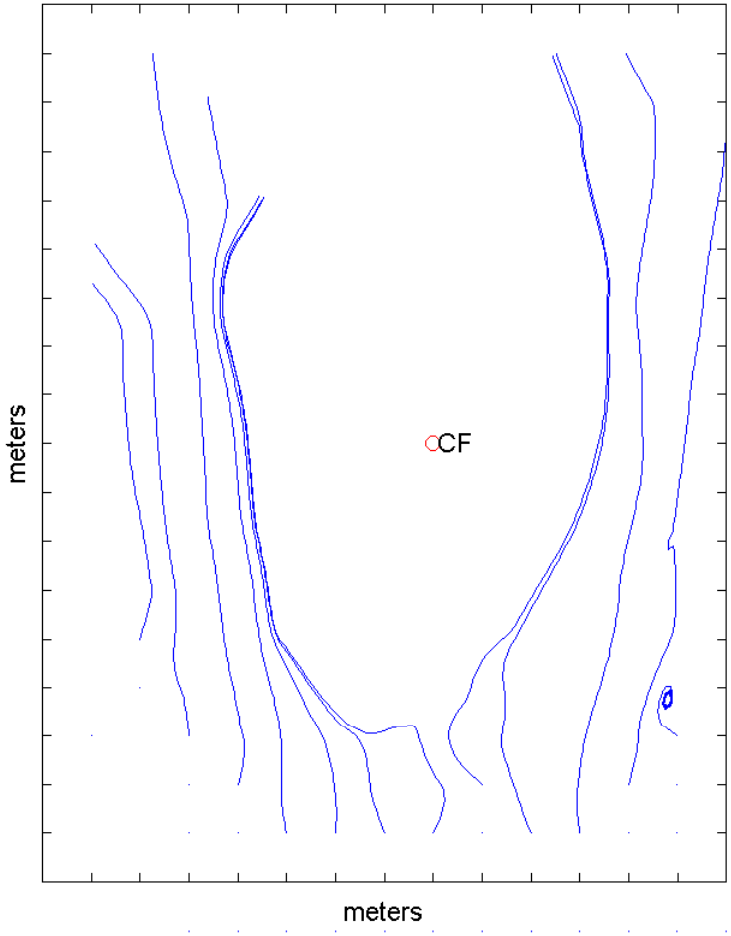


Threat Streamlines

Hand-to-Hand Combat Weapon



Stand-off Weapon



Conclusion

- It is possible to capture empirical data from real humans in group/crowd situations.
- Behavior of crowds seems rather consistent without control force.
- Centroid behavior shows difference between baseline, no-threat, and each weapon type.
- Leading edge might be used to quantify delays caused under different conditions.

Conclusion

- Possible to create vector fields of actual crowd motion to use in models.
- Simulations could use this model to determine most likely motion of an individual.
- Using known vector field of a goal and a control force, could simulate behavior in a situation with two goals and multiple control forces.
- Simulations would be well suited for expanding the situation to large crowds of 100s to 1,000s.

Impact on M & S

- These results demonstrate the capability of the testbed to quantify the subtle differences exhibited by crowds as they react to changes in their environment. This ability translates to an immediate jump to in the level of fidelity available for modelers and simulators. Leveraging this type of information should help in fulfilling the potential of M&S. Work should be conducted immediately to transform the current vector fields into a mathematical model of the repulsive field around the control force.

Back-up Slides

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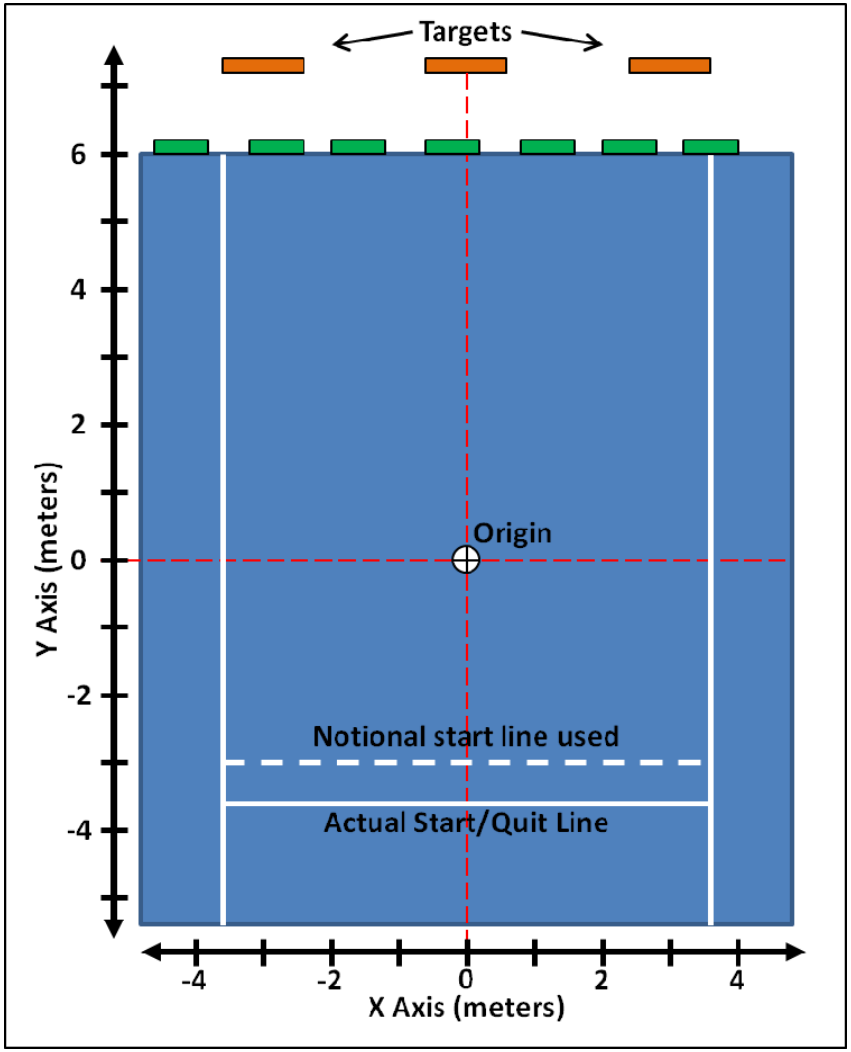
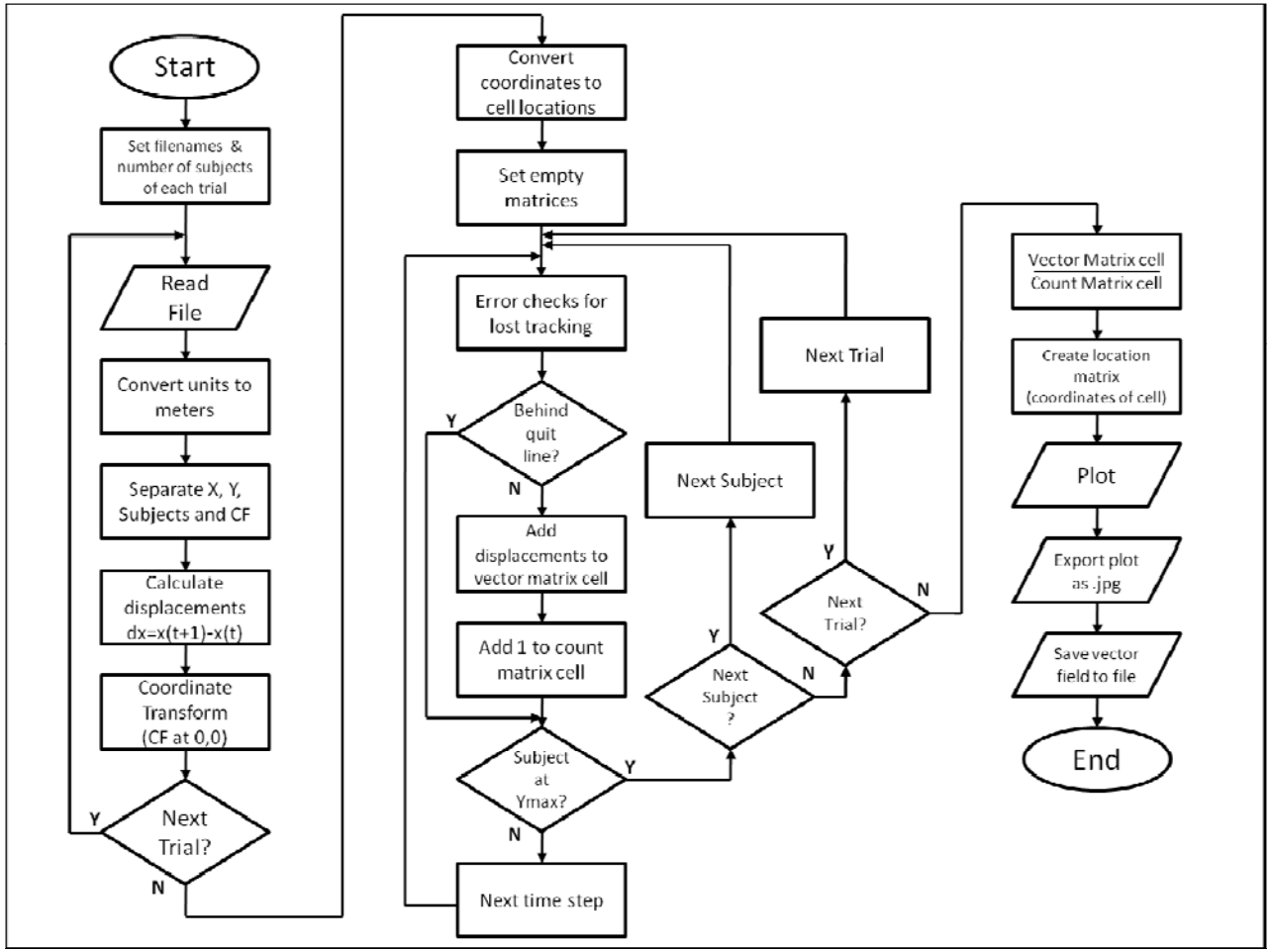
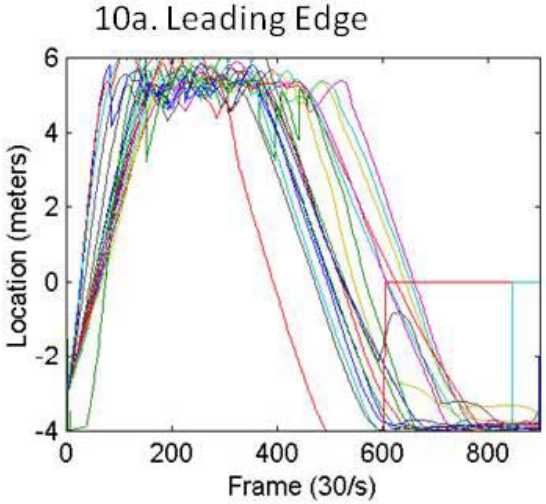
Coordinate System

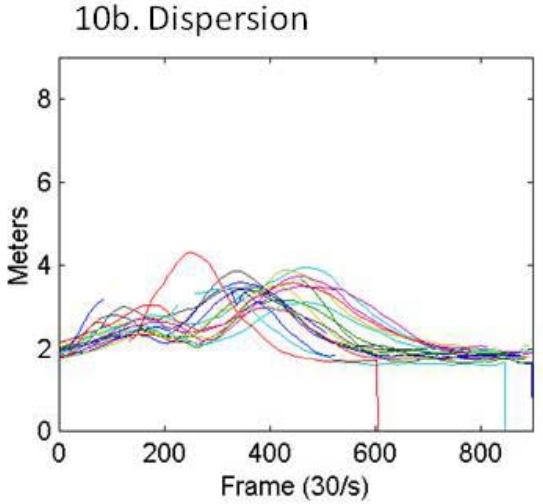


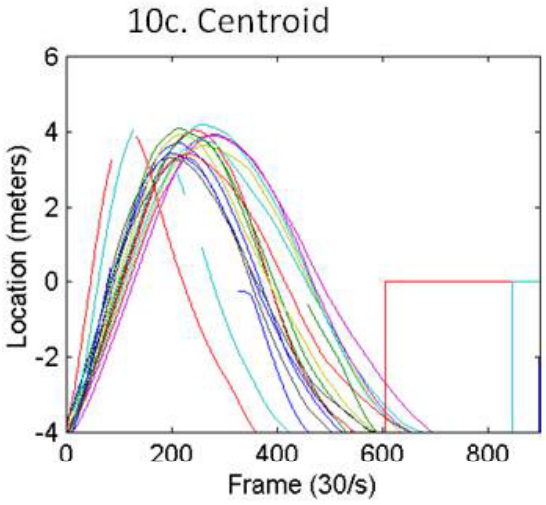
Vector Field Algorithm



Baselines







Baseline Measures
(No Control Force)