U.S. ARMY TANK AUTOMOTIVE RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

Tactical Behavior Mining of a Soldier-Based Gaming Environment

5/23/2016

…Plus Update on TARDEC's Virtural Experiment Capability and TRADOC Early Synthetic Prototyping Environment

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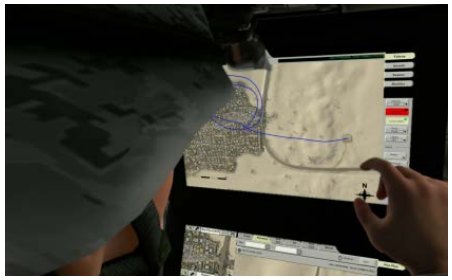
Any intelligent fool can make things bigger and more complex... It takes a touch of genius – and a lot of courage to move in the opposite direction.

Albert Einstein

Materiel Solutions Should Co-Evolve Simultaneously with User's Concept of Operation

Users at All Echelons



Soldier-centric battlefield performance at operational, strategic, and tactical levels.

Acquisitions

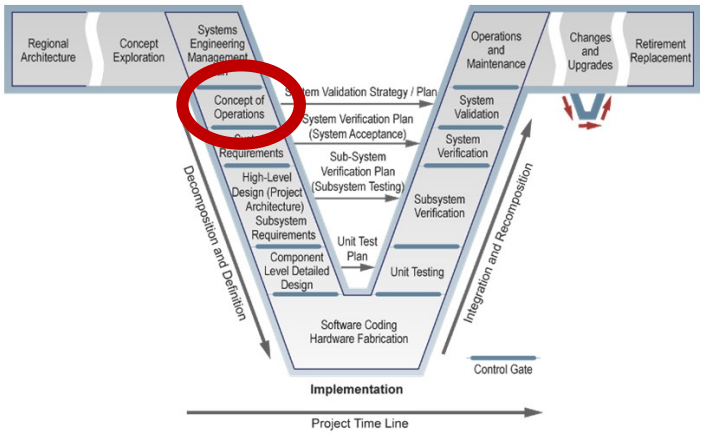
Finding the sweet-spot among competing objectives (performance, unit cost, O&S costs, development risk, and growth potential) is a non-trivial task.

- No Existing Way to Measure Battlefield Impact of Tradespace Choices
- We have only stochastic (non Soldier-in-the-loop) sims

...But they DON'T

How do you develop a system if you do not know what it is supposed to do?

CONOPS = Concept of Operation



108 SE's surveyed (18 DOD Orgs. and Major Contractors)

- 36% never worked a program with a CONOP
- 73% did not complete CONOPS by program start
- 50% did not update CONOPS
- 30% did not even involve a user

60 CONOPS examined:

- took 3-30 months to complete
- 25% did not state mission needs
- 80% did not discuss system risks
- 50% did not include operational scenarios

SOURCE: Roberts, N., & Edson, R. (2008). *System Concept of Operations: Standards, Practices and Reality.* NDIA Systems Engineering Conference, San Diego CA.

One Solution: Use a Physics-Based Game Environment

TODAY

TARDEC VIRTUAL EXPERIMENTS CAPABILITY

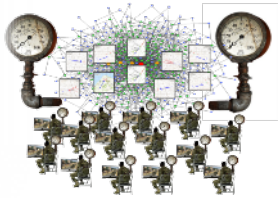
- VBS3 Training Game
- <75 Soldier Experiments
- 2-3 Days = Several Refights
- Lickert Subjective Questionaires

1-2 Years

FUTURE

[ESP] EARLY SYNTHETIC PROTOTYPING

- ESP Engine (Gov Owned)
- Thousands of Soldiers
- Many Refights = Statistical Significance
- Objective Data



Estimated 12 million hours per year

Virtual Battlespace 3 (VBS3)

- Drag-and-drop training game
- Hyper-realistic (i.e. physics)
- *https://bisimulations.com/*

Environmental Effects

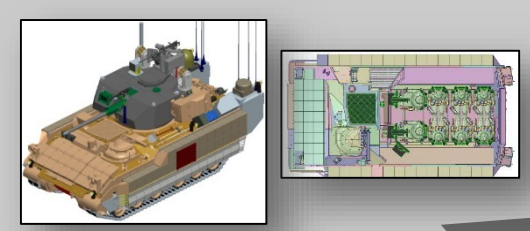
Lot's of canned content (40GB Install)

Detailed interiors/ crew positions

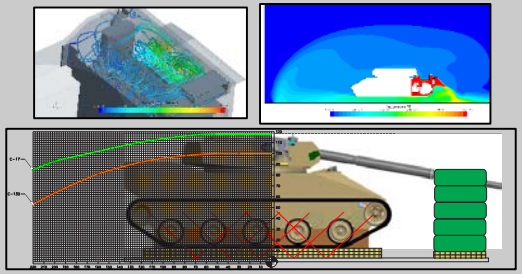
TARDEC's Digital-Prototyping Process

Soldier Innovation Workshop

Engineering Concepts



CAE Performance Analysis



Digital Prototyping and Experimentation

OBJECTIVE DATA
-and-
SUBJECTIVE SURVEYS

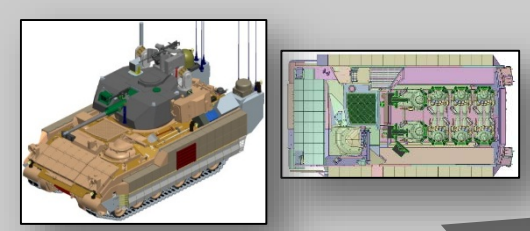
Soldier-Driven Program Requirements (ICD, CDD, ...)

TARDEC's Digital-Prototyping Process

Soldier Innovation Workshop

COMBAT EXPERIENCE IN FUTURE ENVIRONMENTS

Engineering Concepts



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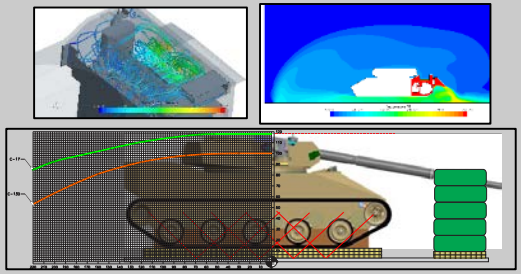


Digital Prototyping and Experimentation

HIGHER FIDELITY AS NEEDED (SMALLER DATASET)

OBJECTIVE DATA
-and-
SUBJECTIVE SURVEYS

Soldier-Driven Program Requirements (ICD, CDD, ...)

TVEC NEXT GENERATION CLOSE COMBAT VEHICLE STUDY VIRTUAL DEMONSTRATOR TEST.

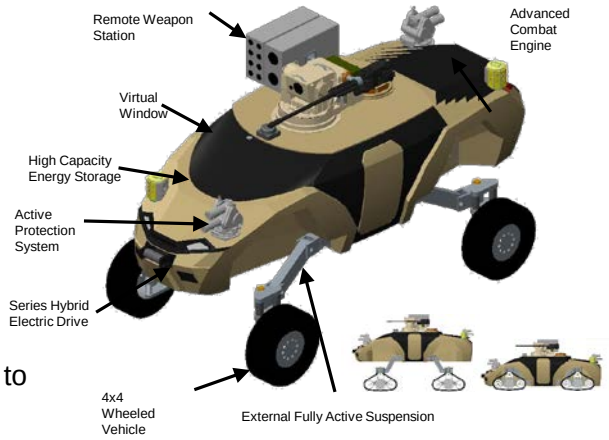
Ft. Bliss, Brigade Modernization Command, Dec. 2014

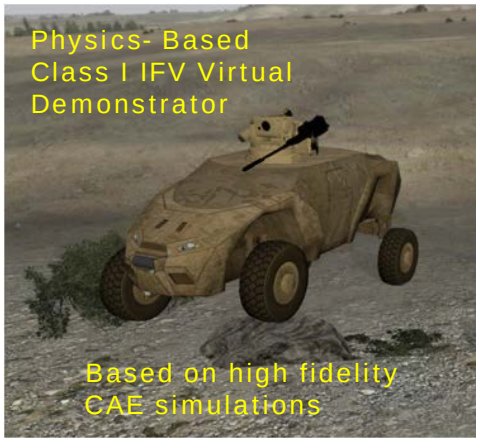
TEST DESIGN

- What would motivate Soldiers to participate?
- How to get data useful to concept developers?
- 76 Soldiers over two days
- Soldier vs. Soldier

AIRFIELD SEIZURE MISSION

- Airborne unit jumps in with NGCCVs
- Goal capture the airfield to land heavier assets
- Framed in a way that made it feel more like a game to participants





TEST EXECUTION

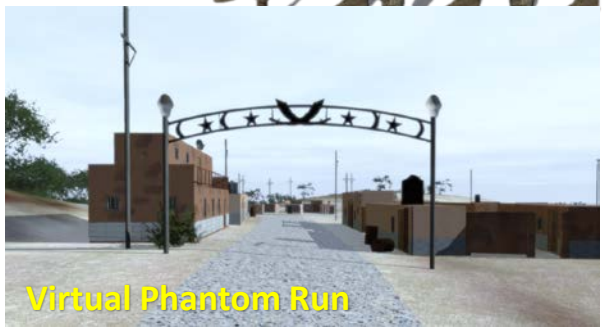
- 4 rows of 6 workstations
- BLUFOR on left, OPFOR on right
- Used either a mouse and keyboard or steering wheel and pedals, if driving

TVEC SQUAD CENTRIC MOUNTED MANUEVER (SCMM) VIRTUAL DEMONSTRATOR TEST

Ft. Hood 1st Cav, June 2015

Ft. Hood 1st Cav, June 2015

- Hands-on experience operating “Fire Team” vehicles
- Iterate between identical physical and virtual
- Explore how Soldiers might operate
- Soldier vs. Soldier



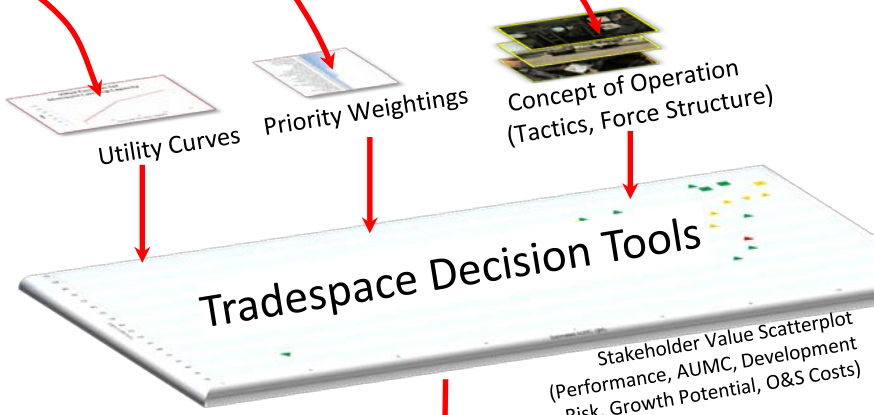
[ESP] Systems Engineering Construct

High-Fidelity CAE Models
And Concepts **(PHYSICS)**

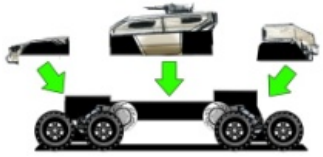
Mission Set

NEW Tactical Utility =
Probability Mission Success / Total Burden

EARLY SYNTHETIC PROTOTYPING



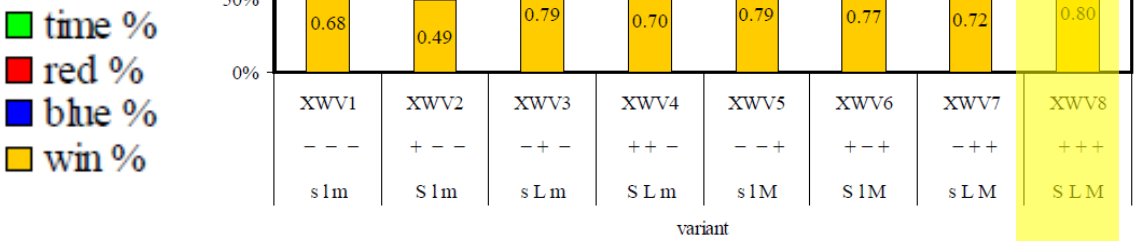
Robust / Adaptable System



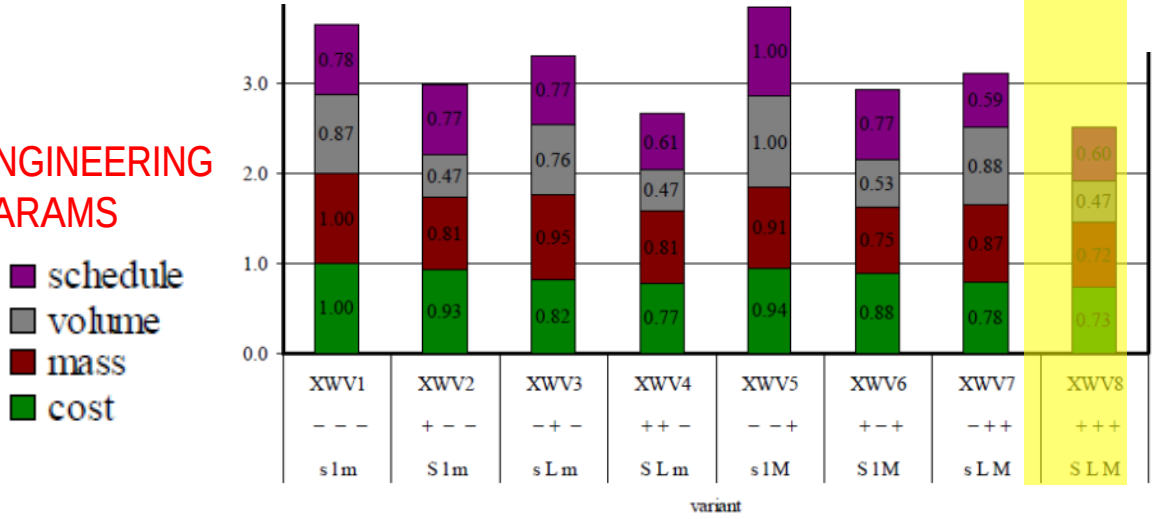
Example Tactical Utility Analysis of Alternatives
(Based on 1400 MindRover Runs by Cadets)

Highest tactical performance per cost/mass/schedule/etc

EFFECTIVENESS MEASURES



ENGINEERING PARAMS



DOE Parameters

s	S
Acceptable Survivability	Enhanced Survivability
rolled homogeneous (steel) armor aluminum body	depleted uranium armor steel body

l	L
Acceptable Lethality	Enhanced Lethality
2× heavy machine gun laser range finder communications suite ground penetrating radar	2× guided missile pods 2× heavy machine gun laser range finder communications suite ground penetrating radar

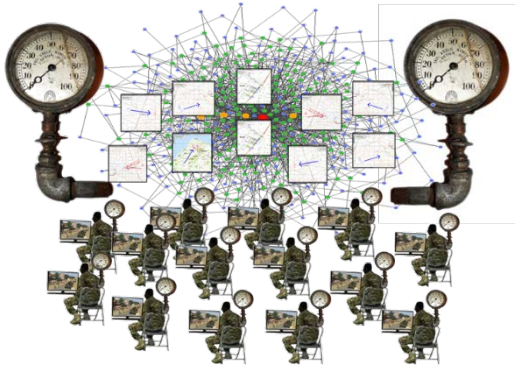
m	M
Acceptable Mobility	Enhanced Mobility
low output powerplant aluminum frame	high output powerplant composite frame

Each Variant was Fought Very Differently

Source: "Demonstration of Decision Support Tools for Evaluating Ground Combat System Survivability, Lethality, and Mobility at the Tactical, Operational, and Strategic Levels of War." MAJ Joshua Keena PhD Dissertation. University of Texas as Austin, August 2011. https://repositories.lib.utexas.edu/handle/2152/ETD-UT-2011-08-3781

Deeper Understanding Requires Game Analytics

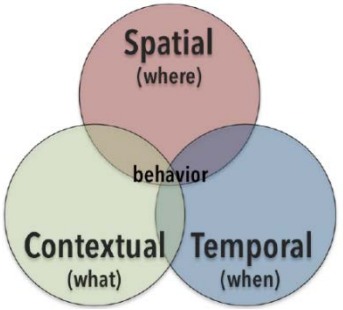
Virtual Physics-Based Gaming Environment



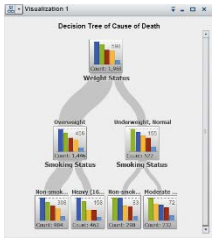
~12 million hours of Soldier gameplay per year

Data Mining

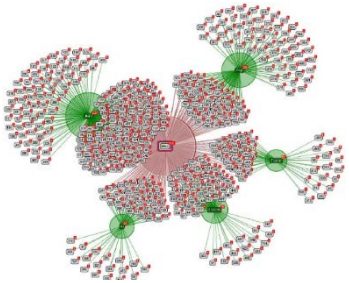
- What are they doing?
- Where are they doing it?
- Why they are doing it?
- How effective is this?
- Terrain versus movement choices
- What are they talking about/ when/ how often
- Optimal Force structure



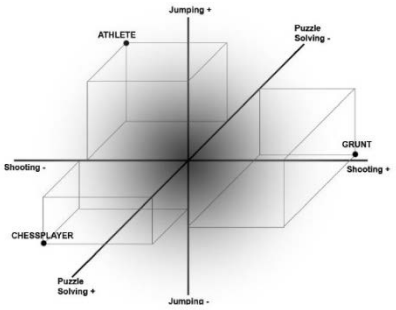
Visualization



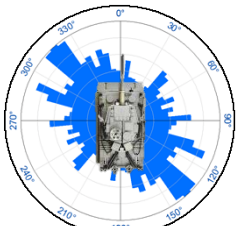
Decision Trees



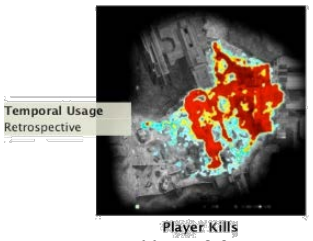
Clustering Cause of Death



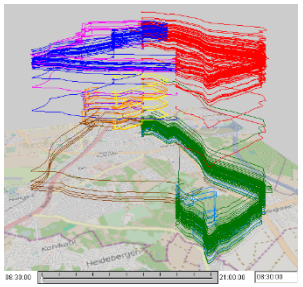
Player Personas



Engagement Sector Cardioid



Heat Maps



Multi-Run Movement Plots

Game Image Source: Game Metrics and Biometrics: The Future of Player Experience Research.
http://www.slideshare.net/acagamic/game-metrics-and-biometrics-the-future-of-player-experience-research

Aspects of Data Mining / Visualization

Filtering the Data
- Tracking player experience levels and play styles (preferences)
- “Seriousness” detection versus screwing around
- Learning curves on technologies

Labeling the Data
- Annotating the gameplay (painful)

Analyzing the Data
- Level 0: Directly visualizing data (human finds the “so-what”)
- Level 1: Machine learning for individual group goals / tactics
  (example: inverse reinforcement learning)
- Level 2: Machine learning for group goals / tactics

Next Slides: SBIR Research (Small Business Innovative Research Grants)
- Decisive Analytics
- SoarTech / USC Institute for Creative Studies/ Northeastern University
- Creative Technologies Inc. / UtopiaCompression Inc.

NOTE: SBIR TOPIC is A15-086 “Tactical Behavior Mining of a Soldier-Based Gaming Environment”
https://sbirsource.com/sbir/topics/91575

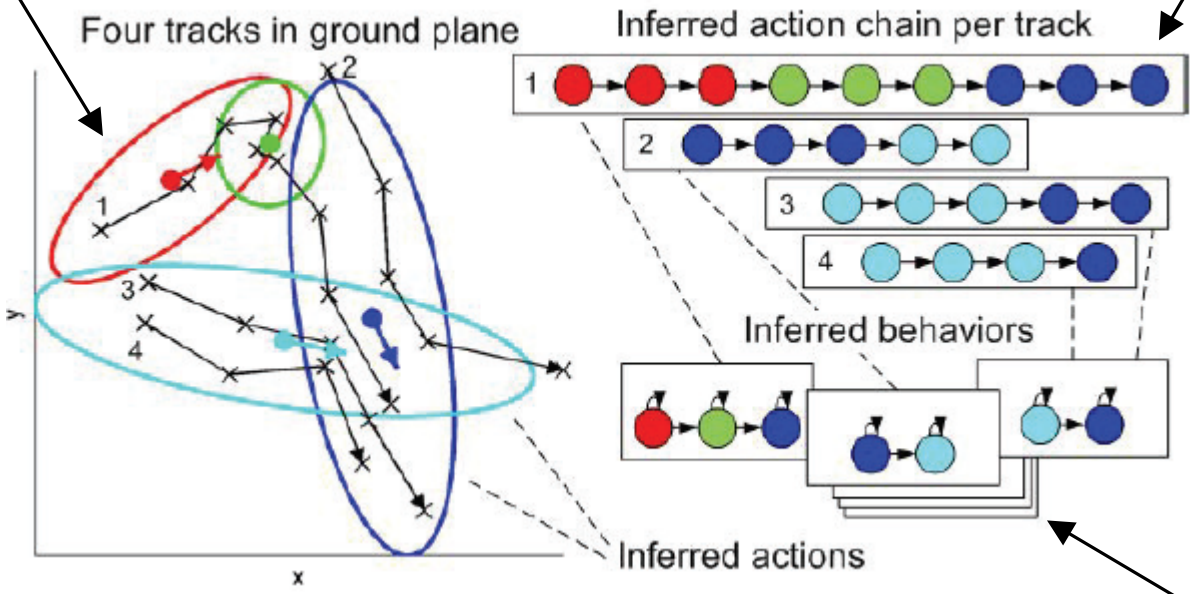
SBIR Examples:
Surrogate Dataset: DOTA-2 Commercial Game

- DOTA-2
  - Objective
    - 2 teams (Dire and Radiant)
    - 5 players each
    - Each team defends an “Ancient” building
    - 3 main “Lanes” between strongholds
  - Game player description
    - Players are called Heroes
    - 111 different Heroes available
    - Each Hero has different
      - Items (~equipment)
      - Spells (~skills & capabilities)
      - Gold
    - Players typically assigned a specific role within the team
      - Similar to the different roles soldiers have within a unit

Example Spatio-Temporal Machine Learning (Decisive Analytics)

Actions are inferred from trajectory/state data
- Standing
- Walking
- Walking with weapon drawn
- …

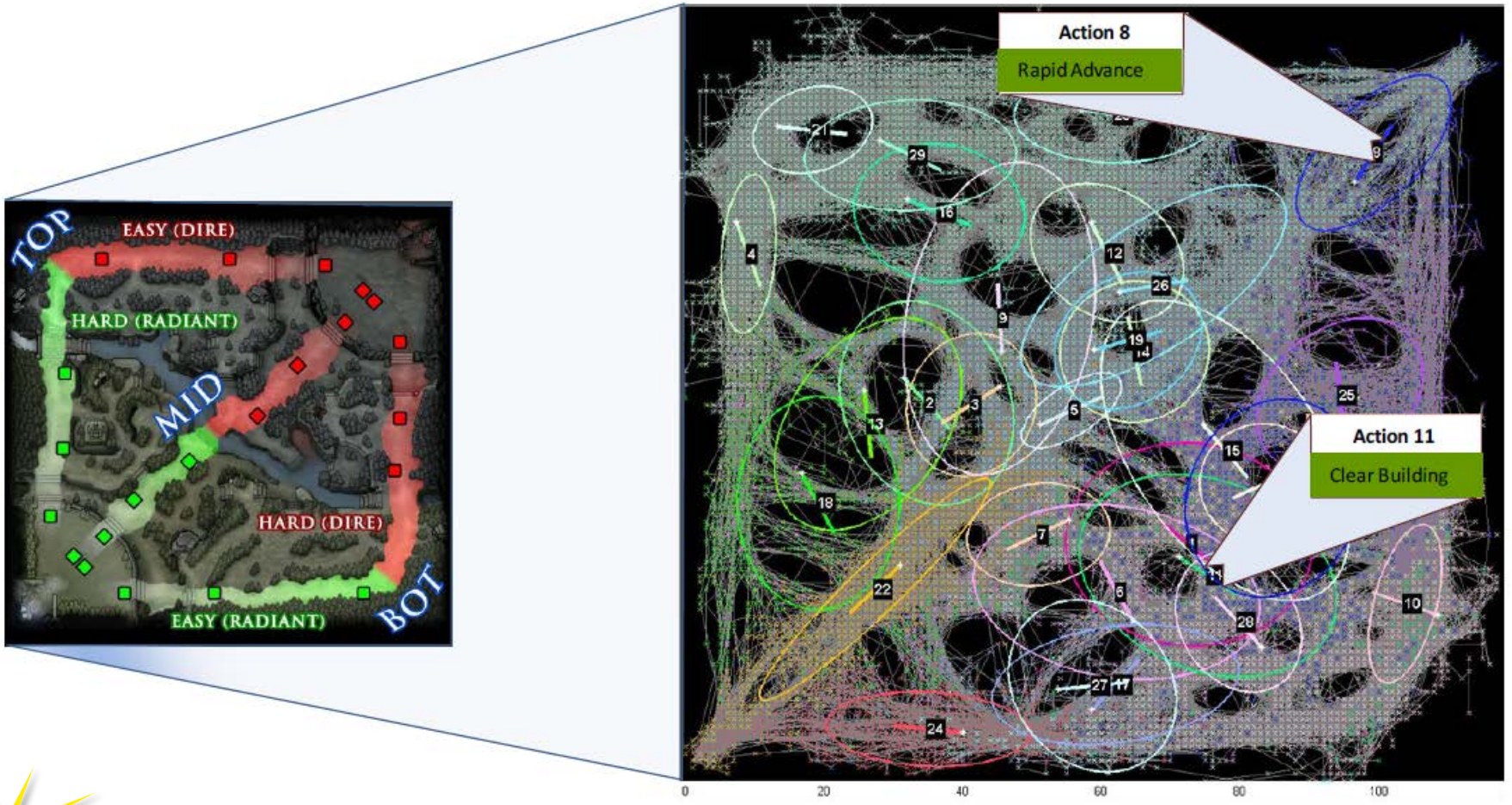
Tracks are sequences of Actions



Behaviors are clusters of similar Action chains

SOURCE: Decisive Analytics Corporation Phase I SBIR. Contract W56HZV-15-C-0190. http://www.dac.us/

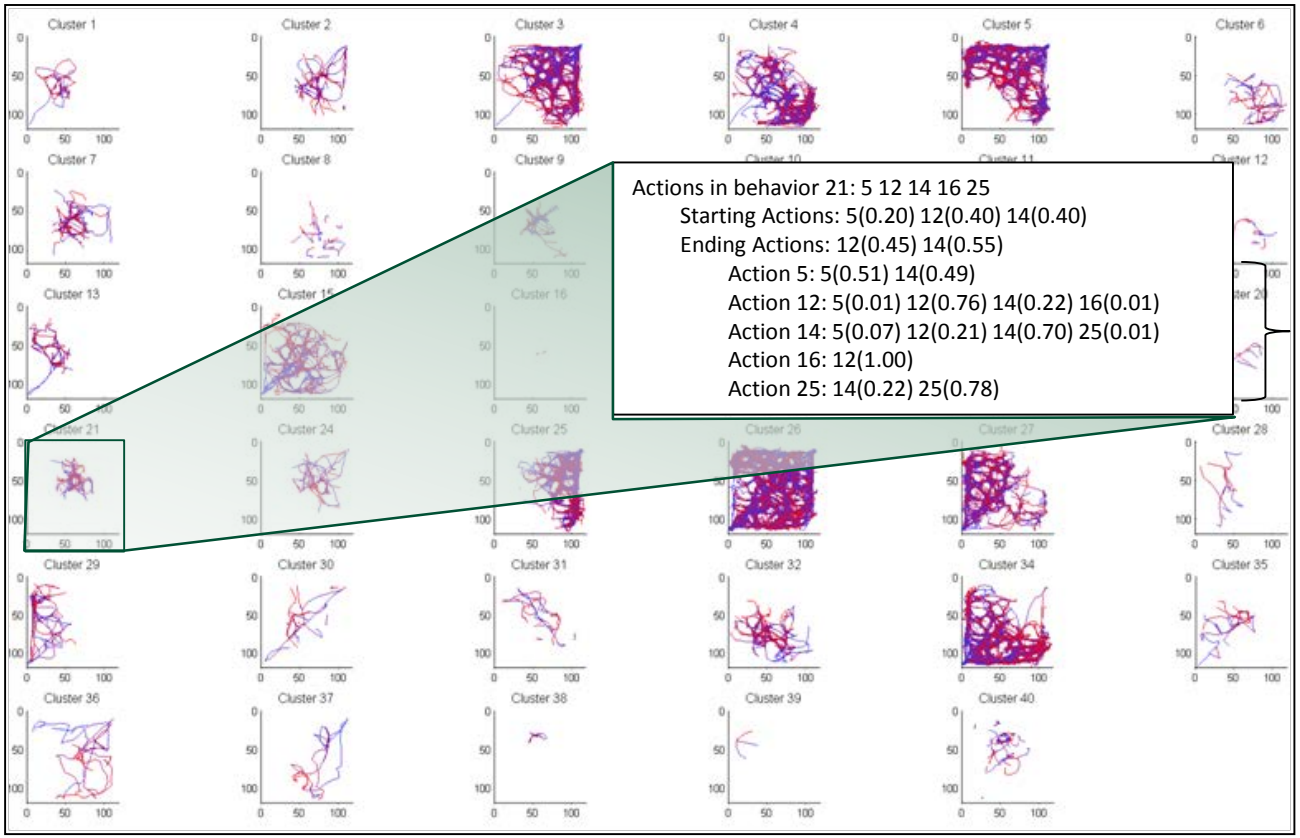
Behavior Spatio-Temporal Clustering (Decisive Analytics)



DECISIVE ANALYTICS

SOURCE: Decisive Analytics Corporation Phase I SBIR. Contract W56HZV-15-C-0190. http://www.dac.us/

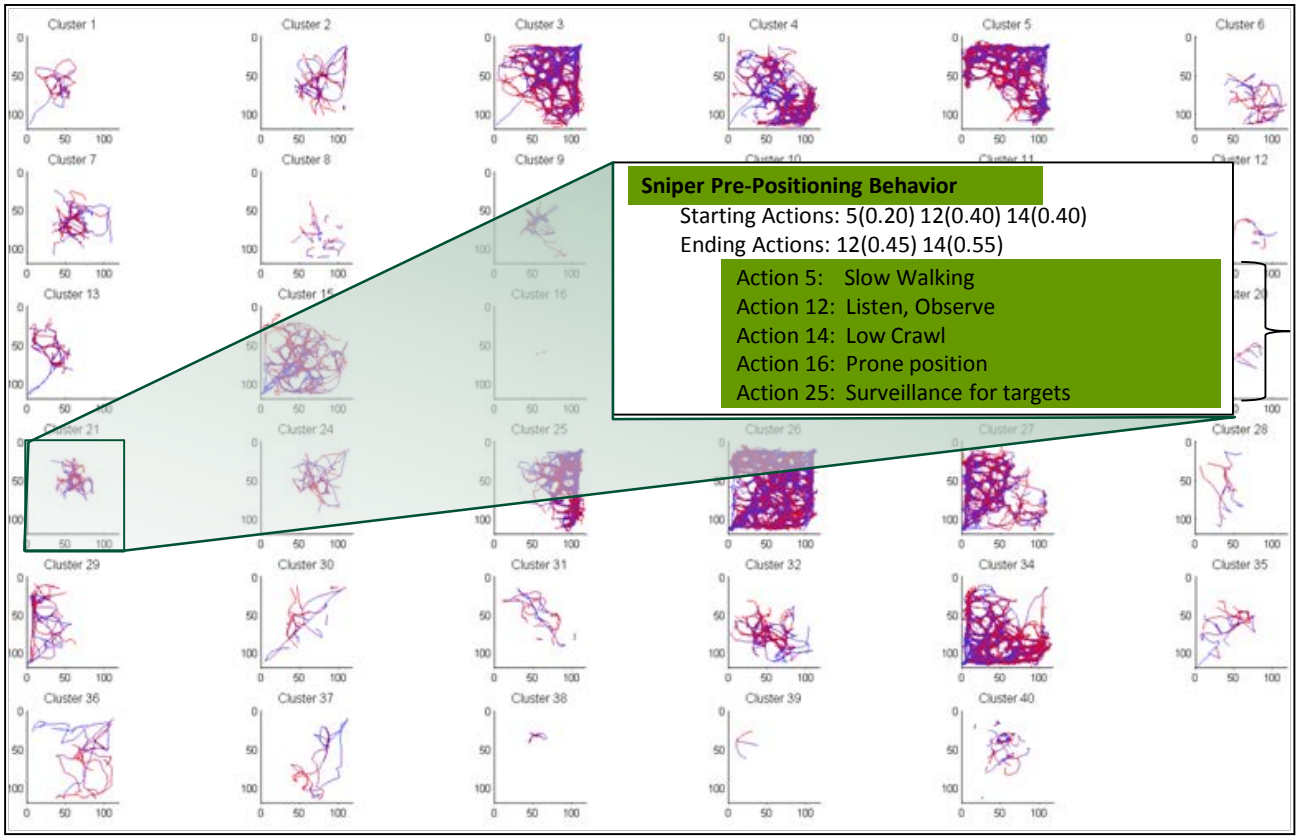
Learned Behaviors (Decisive Analytics)



- Each chart represents a Behavior
  - Sequences of Actions
  - Derived from Actions, tracks and state data

SOURCE: Decisive Analytics Corporation Phase I SBIR. Contract W56HZV-15-C-0190. http://www.dac.us/

Learned Behaviors (Decisive Analytics)



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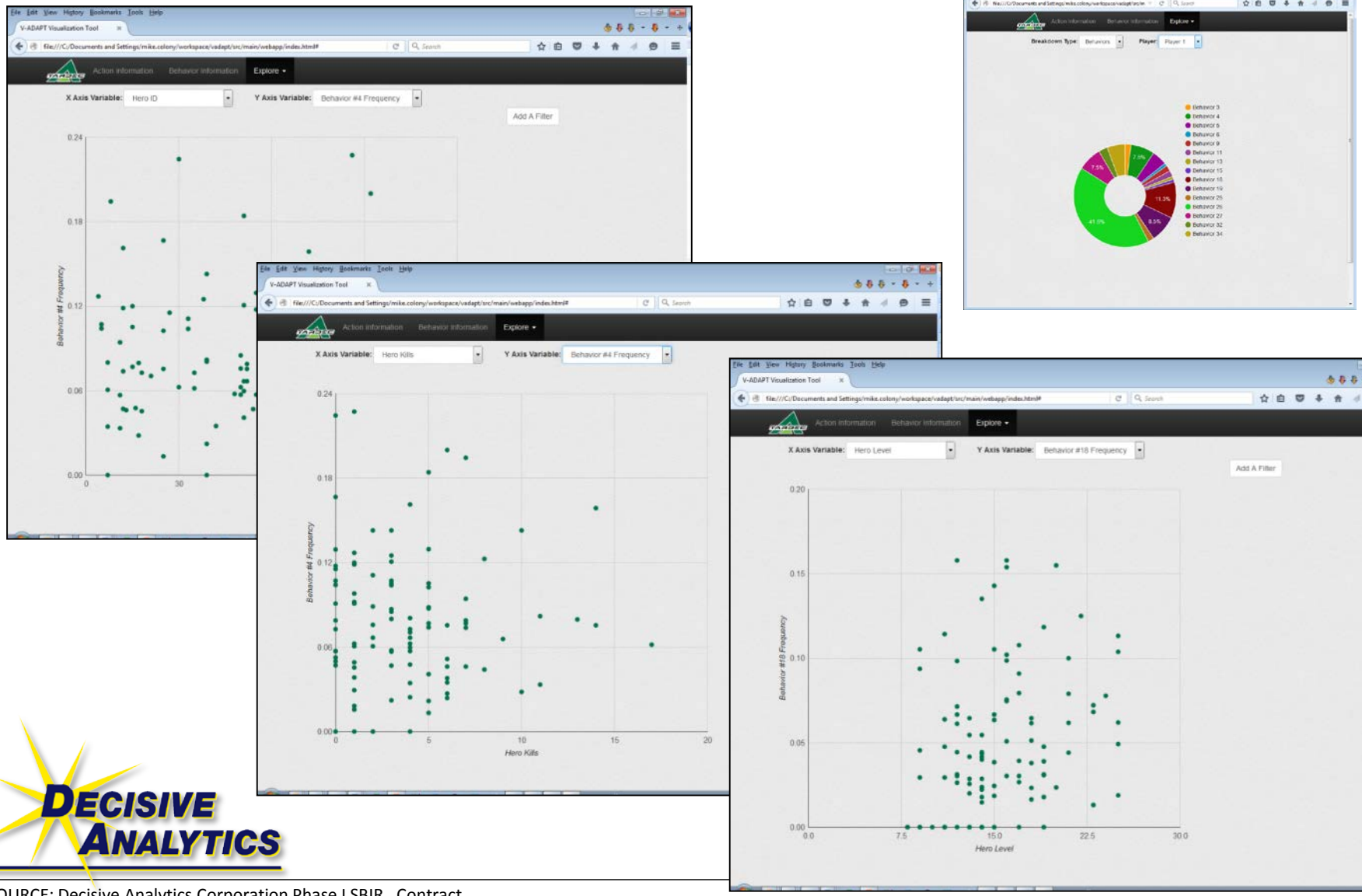
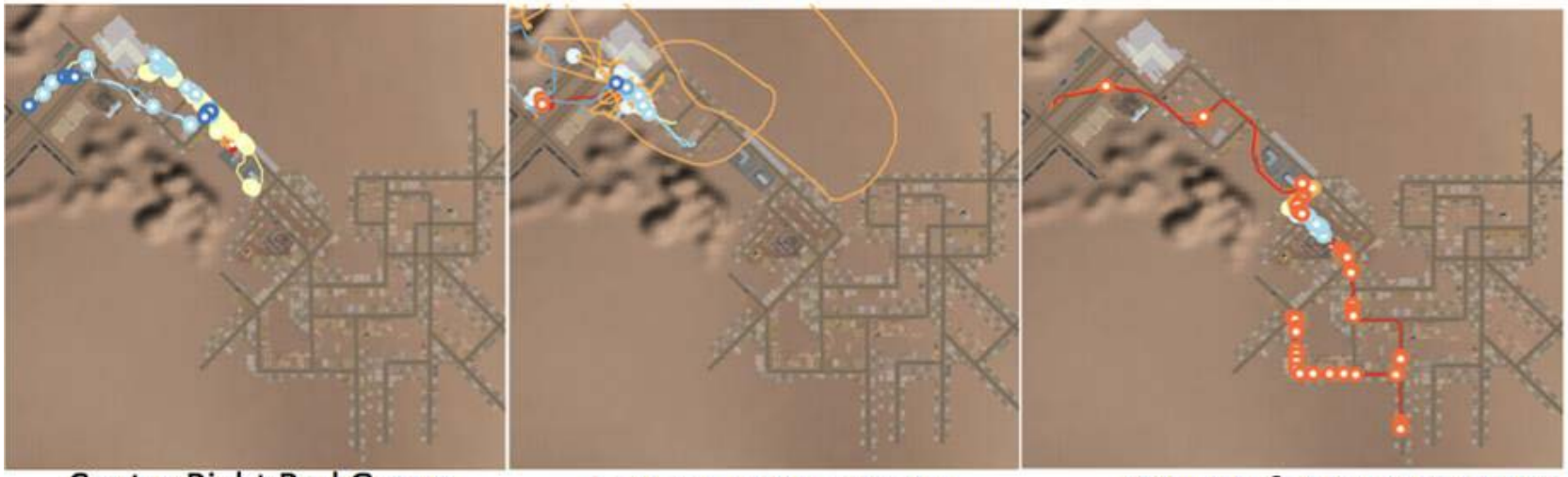
Slice/Dice the Data (Decisive Analytics)



SOURCE: Decisive Analytics Corporation Phase I SBIR. Contract W56HZV-15-C-0190. http://www.dac.us/

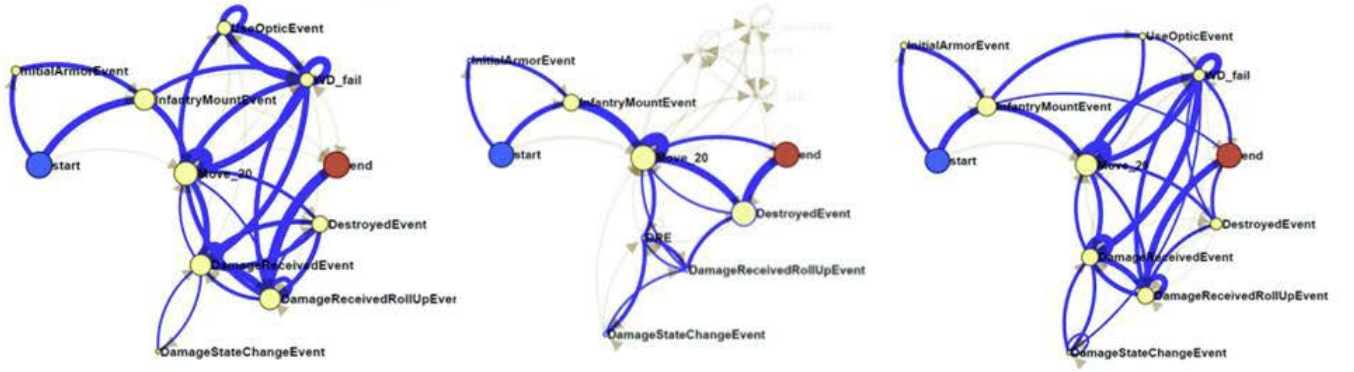
Gplayer/ Glyph Tools from Northeastern Univ. (SoarTech)

G-Player Cluster Spatial Visualization



Center Right Red Group | Lower Left Blue Group | Upper Left Magenta Group

Glyph Cluster State Visualization

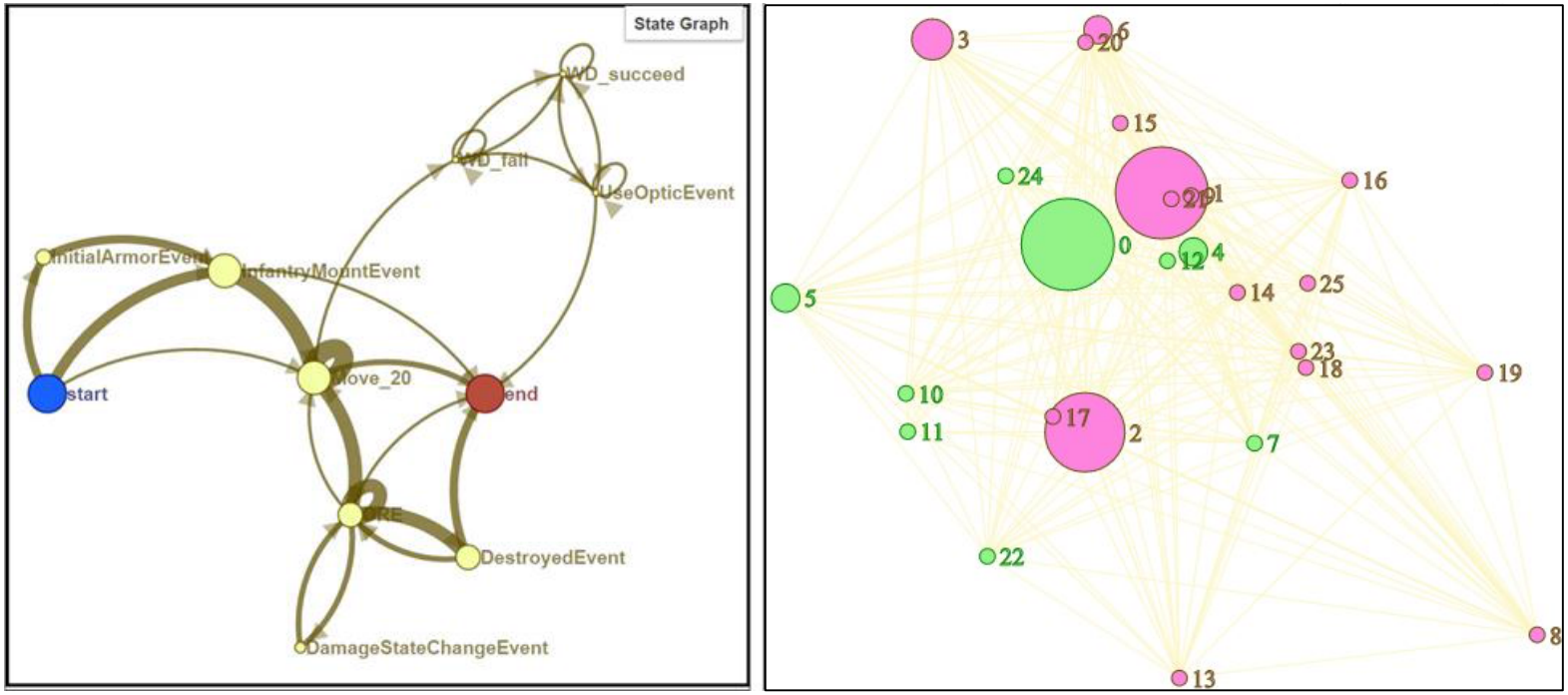


Center Right Red Group | Lower Left Blue Group | Upper Left Magenta Group

SOARTECH
Modeling human reasoning.
Enhancing human performance.

Source: SoarTech/ ICT/ Northeastern University Phase I SBIR. Soldier Sourcing Insights Early with a Game Environment (SSIEGE). W56HZV-15-C-0188

State transition graph + Cluster of Sequences Graph (SoarTech)



Glyph visualization for 8 entities in an ESP session

Glyph: Visual Analytics

State graph – shows transition between states in the game

Cluster of Sequences – shows how patterns cluster in space where distance is how similar they are (the more similar the closer)

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Modeling human reasoning.
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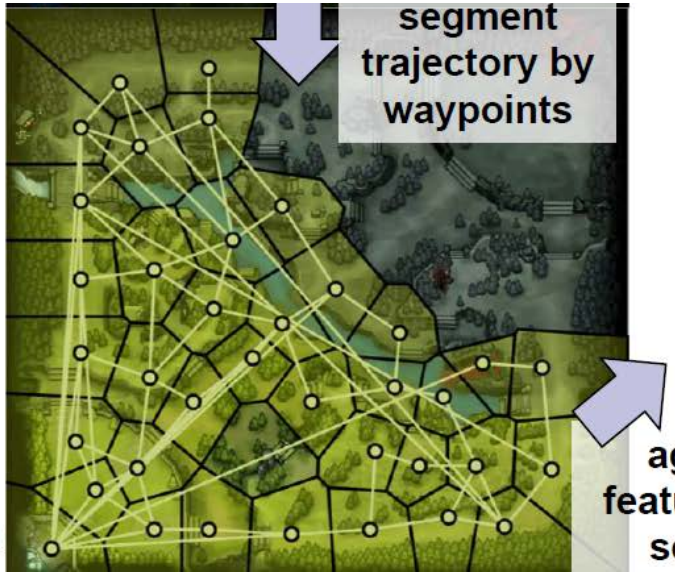
Source: SoarTech/ ICT/ Northeastern University Phase I SBIR. Soldier Sourcing Insights Early with a Game Environment (SSIEGE). W56HZV-15-C-0188

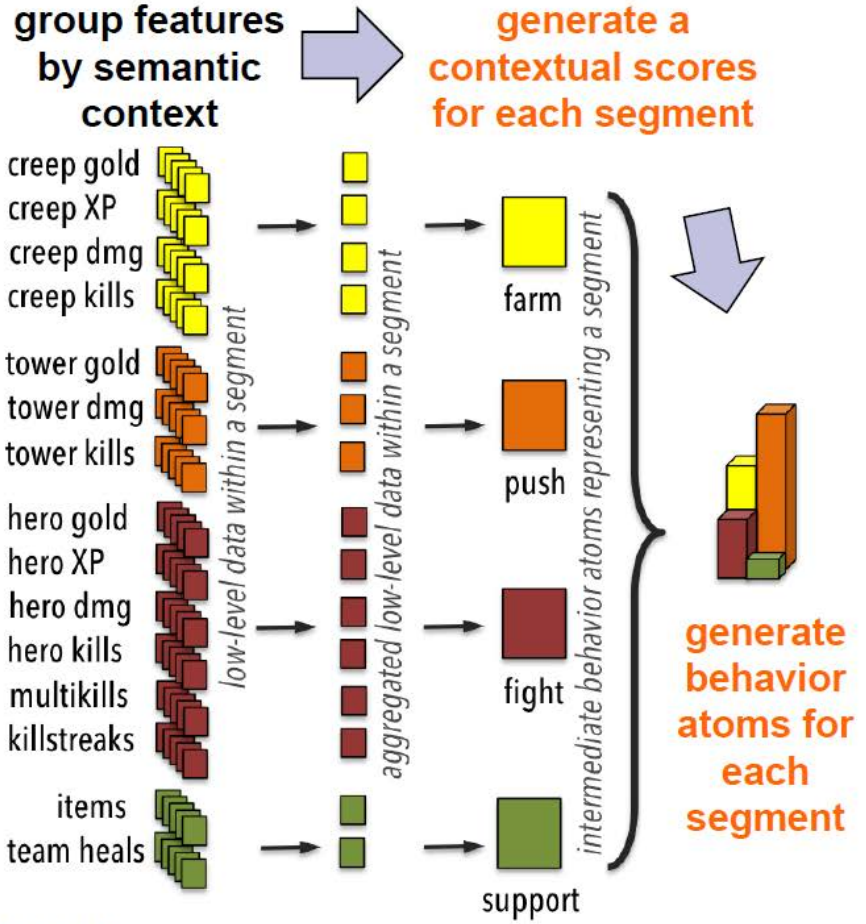
Spatio-Temporal Machine Learning (CTI/ UtopiaCompression)

Semantic context tells us **what a player did** within a segment.

Two approaches to obtain semantic context for data:

- **Supervised labeling**: show SMEs/crowd images, video and ask them to label player actions;
- **Unsupervised labeling**: Ask SMEs to list behavior atoms of interest and corresponding low-level features and try to label context autonomously.





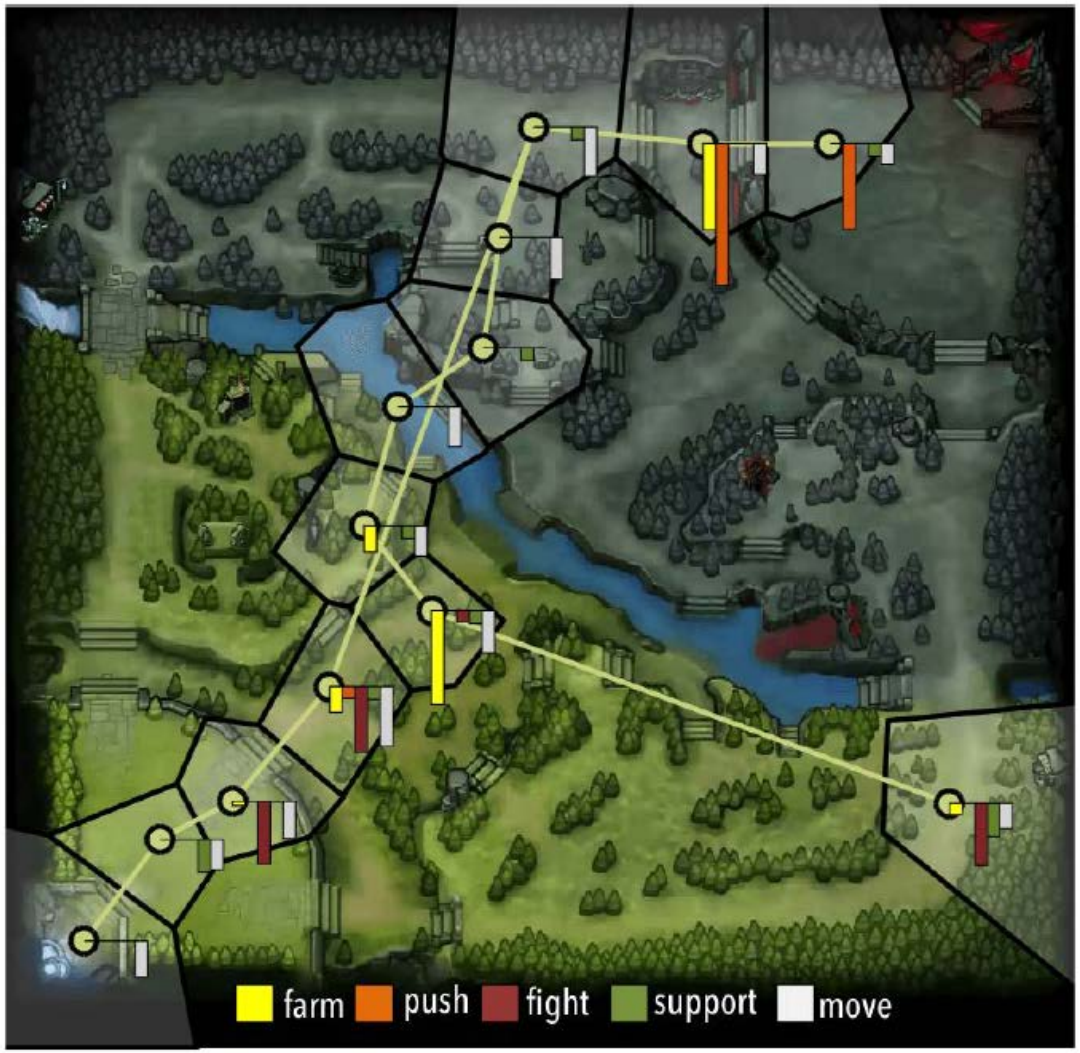
UTOPIACOMPRESSION Intelligent Technologies & Innovative Solutions

CTI CREATIVE TECHNOLOGIES INC

12

Source: Creative Technologies Inc.. W56HZV-15-C-0189. Tactical Behavior Mining of a Soldier-Based Gaming Environment.

Spatio-Temporal Machine Learning (CTI/ UtopiaCompression)



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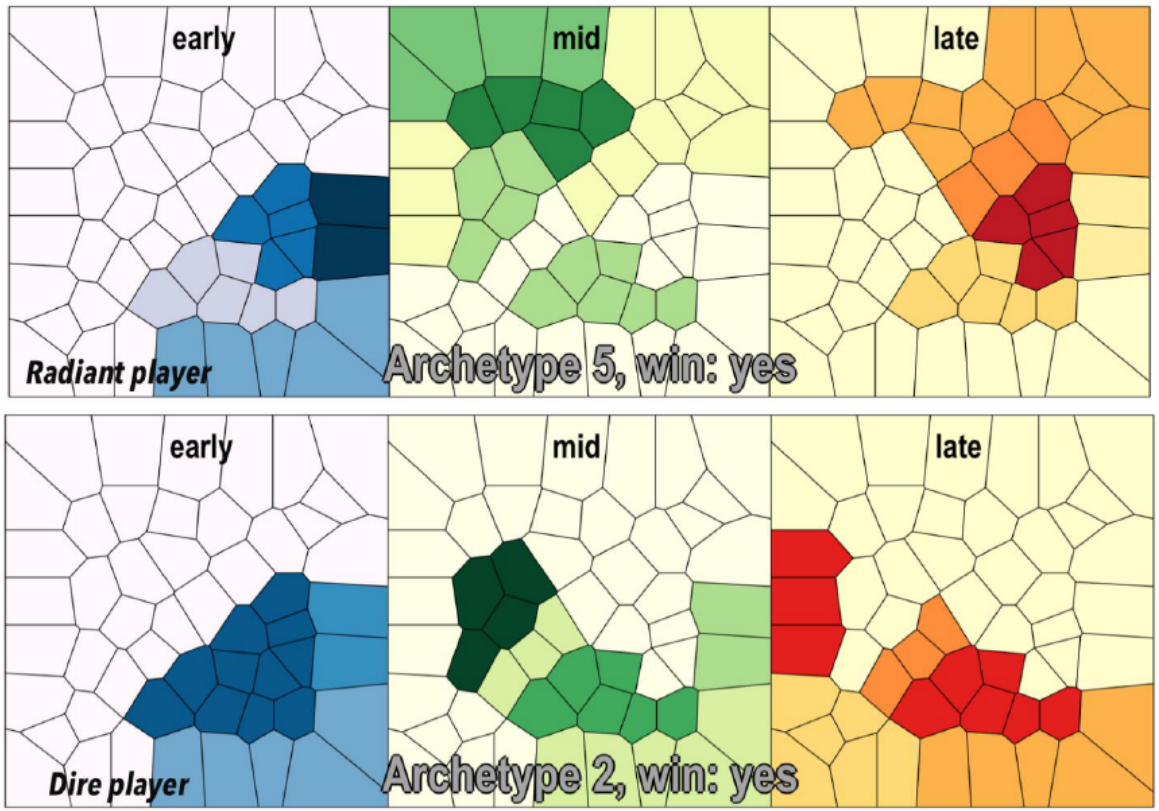
Source: Creative Technologies Inc.. W56HZV-15-C-0189. Tactical Behavior Mining of a Soldier-Based Gaming Environment.

Positional Analysis Over Time (CTI/ UtopiaCompression)



Archetypes: *(top, Archetype 5) Radiant player who's strategy is early:safe, mid:hard and late:Dire. Switching lanes is an unusual behavior as it leads to lane imbalance making a win harder.*
(bottom, Archetype 2) Dire player who is unusually aggressive, spending most of the game in the Radiant half.

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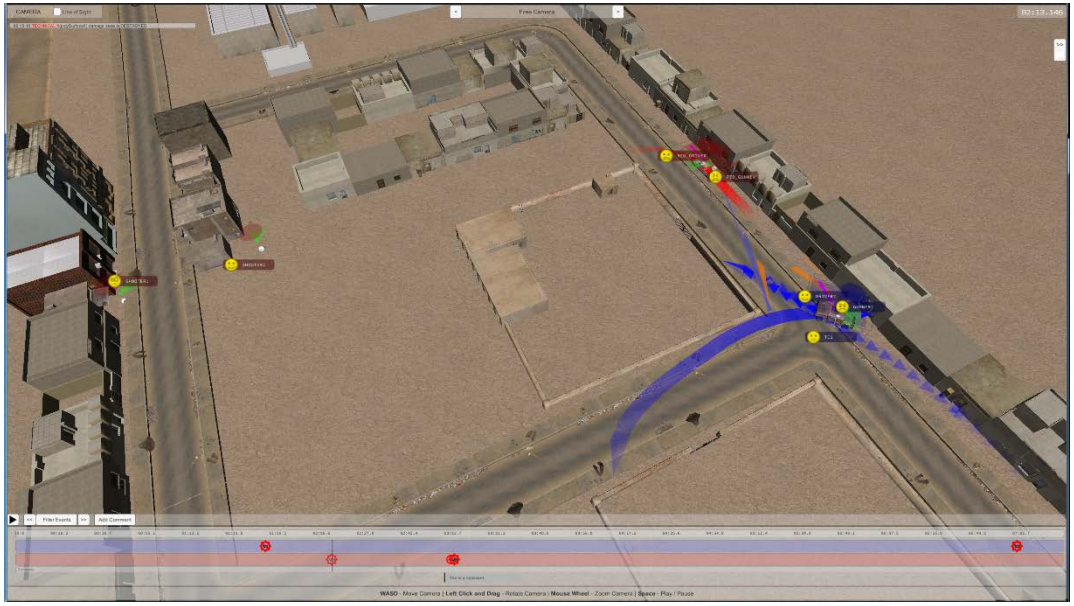
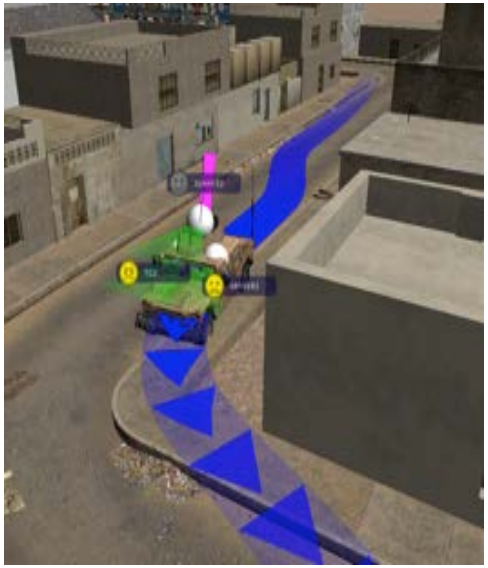
Intelligent Technologies & Innovative Solutions

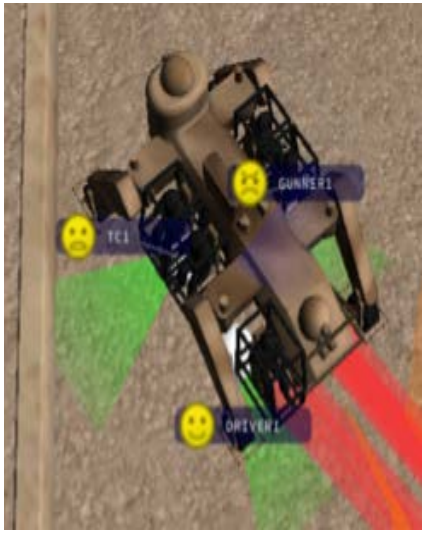
CTI CREATIVE TECHNOLOGIES INC

Source: Creative Technologies Inc.. W56HZV-15-C-0189. Tactical Behavior Mining of a Soldier-Based Gaming Environment.

ICT Demo ESP Environment – Emotion Tracking







- Players on laptops w/ webcam
- Intel's Perceptual Computing SDK captures data about the user's emotional state
- Seven emotions (anger, contempt, disgust, fear, joy, sadness, and surprise) and three sentiments (positive, neutral, and negative).
- Also record voice annotation of events

USC Institute for Creative Technologies

More info: http://ict.usc.edu/prototypes/early-synthetic-prototyping-esp/

ICT Demo ESP Environment – Other Prototypes

Let Soldiers make cost-constrained tradespace optimizations over a mission set

Immersive reality impact

- How does the physiology of the eye play into detections?
- How does play change?

USC Institute for Creative Technologies

More info: http://ict.usc.edu/prototypes/early-synthetic-prototyping-esp/

Labeling Data: Retrospective Interviewing

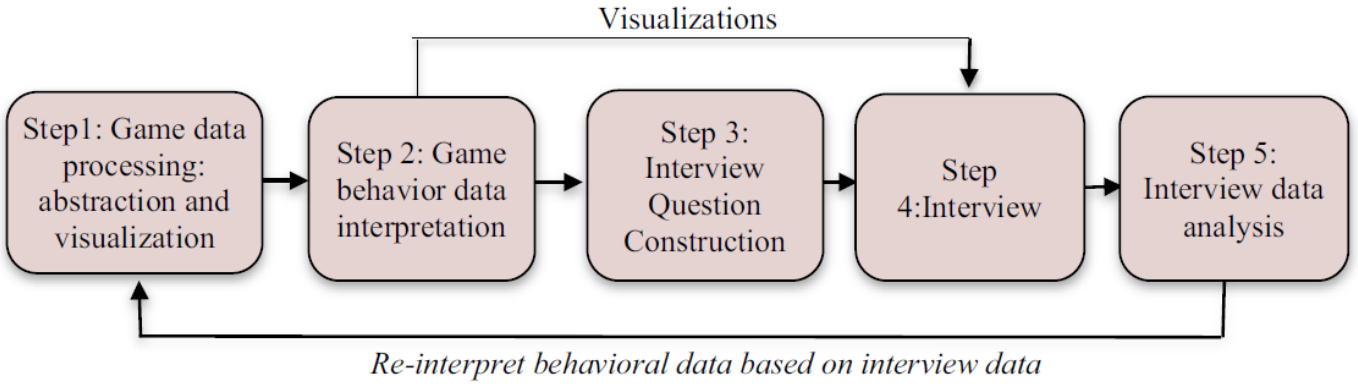
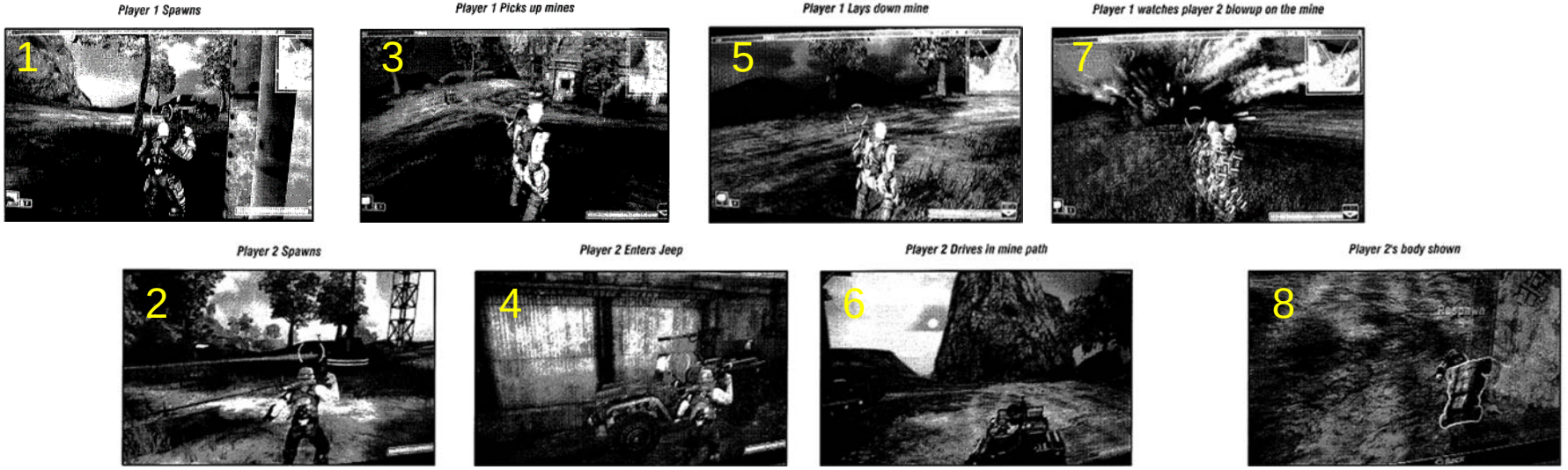


Fig. 1. Data-driven retrospective interviewing method overview.

Seif El-Nasr, M., Durga, S., Shiyko, M., and Sceppa, C. (2015). Data-Driven Retrospective Interviewing (DDRI): A Proposed Methodology for Formative Evaluation of Pervasive Games. Elsevier Entertainment Computing Journal. Impact Factor 1.65

How I See this Working w TVEC (Autonomous Highlight Reel):



System and method for automated creation of video game highlights. Sony Entertainment. D Cottrell - US Patent 8,515,253, 2013.

Autonomous Generation of Mission Graphics

- Closely related, it would be useful to communicate the battle overview via military graphics discovered by data mining (combined with retrospective interviewing).

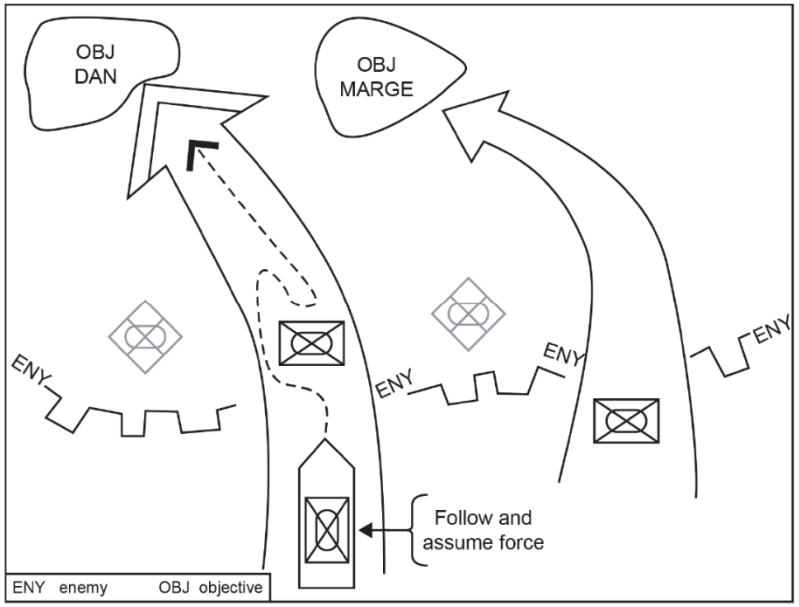


Figure B-6. Follow and assume tactical mission graphic

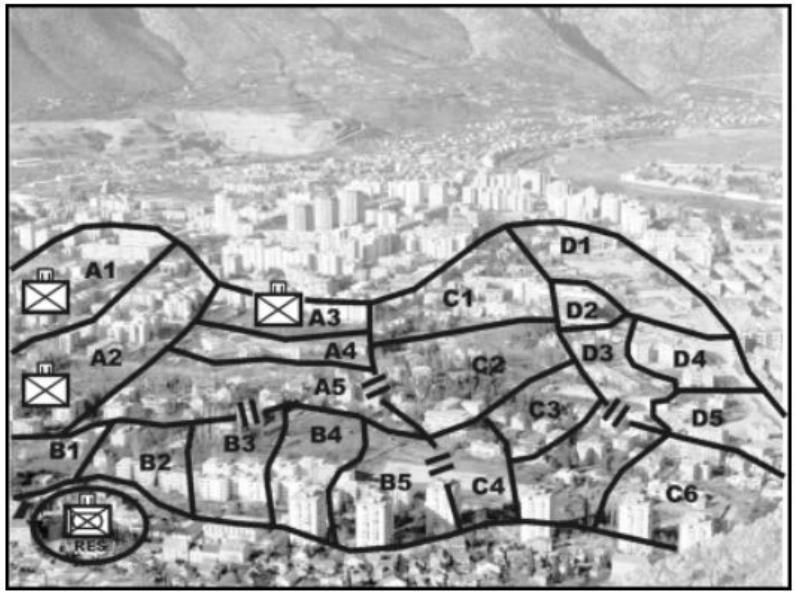


Figure 4-10. Search and attack technique.

Selected Online References

Government Publications

- Smith, Robert E., and Brian D. Vogt. *A Proposed 2025 Ground Systems, Systems Engineering Process*. DEFENSE ACQUISITION UNIV FT BELVOIR VA, 2014. http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA608885
- Murray, Kate L. *Early synthetic prototyping: exploring designs and concepts within games*. NAVAL POSTGRADUATE SCHOOL MONTEREY CA, 2014. http://calhoun.nps.edu/bitstream/handle/10945/44627/14Dec_Murray_Kate.pdf
- Early Synthetic Prototyping (ESP) Page at USC Institute for Creative Technologies. http://ict.usc.edu/prototypes/early-synthetic-prototyping-esp/

Great Industry Resources

- Game Metrics and Biometrics: The Future of Player Experience Research. http://www.slideshare.net/acagamic/game-metrics-and-biometrics-the-future-of-player-experience-research
- MIT Sloan Sports Analytics Conference. www.sloansportsconference.com/
- Disney Research Modeling and Recognising Team Strategies, Tactics and Tendencies in Sports https://www.disneyresearch.com/project/modeling-sports-tendencies/

Interesting TED Talks

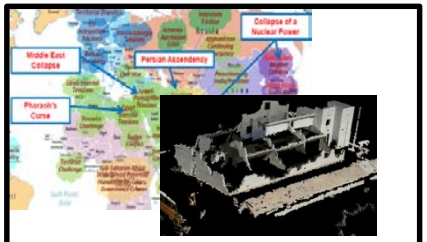
- The new positions of basketball. http://tedxtalks.ted.com/video/The-new-positions-of-basketball
- How augmented reality will change sports ... and build empathy https://www.ted.com/talks/chris_kluwe_how_augmented_reality_will_change_sports_and_build_empathy

A 1st Armored Division "Old Ironsides" Soldier familiarizes himself with the M249 Squad Automatic Weapon user interface for Virtual Battle Space 3 during an Early Synthetic Prototyping pilot test held on Fort Bliss, Texas. (Photo by Sgt. Brooks Fletcher, 16th Mobile Public Affairs Detachment/Released)

BACKUP MATERIALS

How We'll Design and Manufacture Systems in 2025

Innovation / Training / Inception



3D Virtual World
Acquired on Demand

Persistent Synthetic
Gaming Environments
(Soldier Crowd Sourcing)

Pre-Engineered Plug and
Play Vehicle Templates

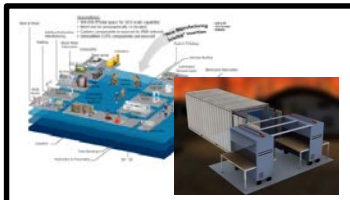
Detailed Engineering

Collaborative 3-d
Immersive Design
Environment

Semi-Autonomous
Virtual Prototype
Engineering
(proactive M&S that does
design and optimization)

Physical M&S and
Prototypes (Full Physics)

Manufacture/ Deployment



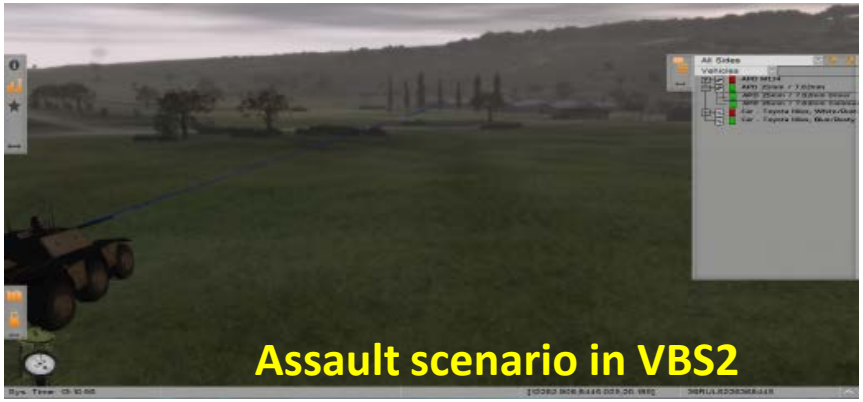
Layered Manufacturing, Repair,
and Logistics
(FOB Instant, Regional Rapid)

Customized Mission-Optimal
Ground System

Smith, Robert E., and Brian D. Vogt. *A Proposed 2025 Ground Systems, Systems Engineering Process*. DEFENSE ACQUISITION UNIV FT BELVOIR VA, 2014. http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA608885

NPS Pilot Study: Robotic Wingman

- Robotic wingman based on actual demonstrator system
- Three scenarios:
  1. Track a red convoy (AI) to a specific location, then eliminate it. 4 blue
  2. Assault a defended, fixed location to free prisoners. 2 blue/ 2 red
  3. Defend an urban location for five minutes. 2 blue/ 2 red



Game Physics Based on Autonomous Platform Demonstrator

Big Takeaways:

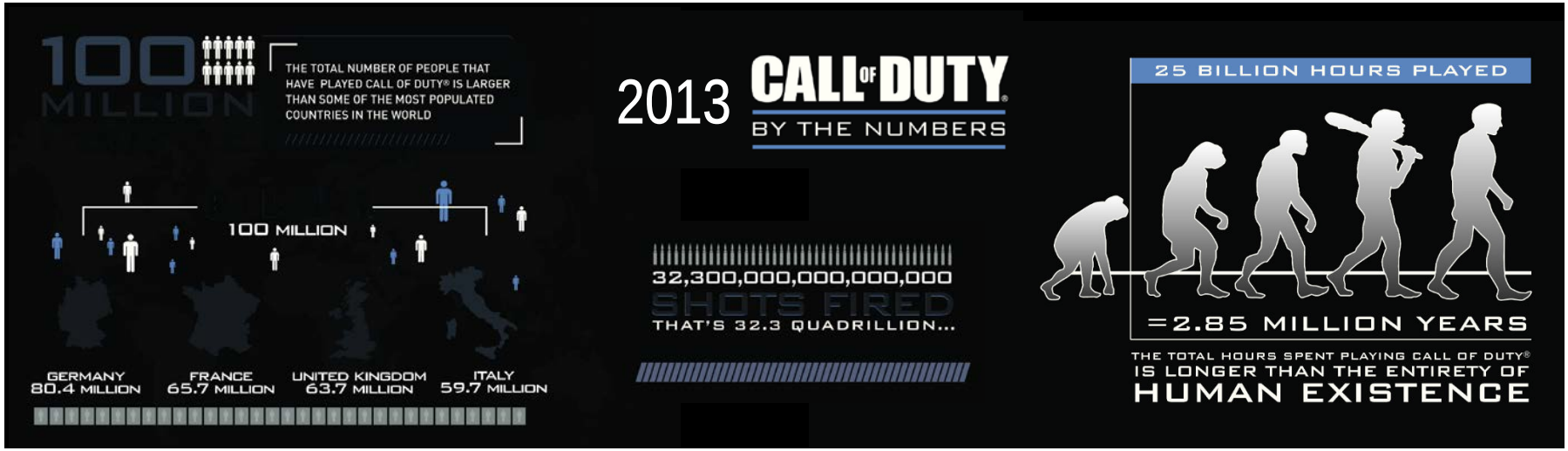
- Soldiers very enthusiastic about playing game – especially head-to-head
- Game interface is very important (which key does what)
- Scenarios showed definite desire to **tailor platform for mission**

Source:
http://calhoun.nps.edu/bitstream/handle/10945/44627/14Dec_Murray_Kate.pdf

Commercial Gaming Example – Call of Duty

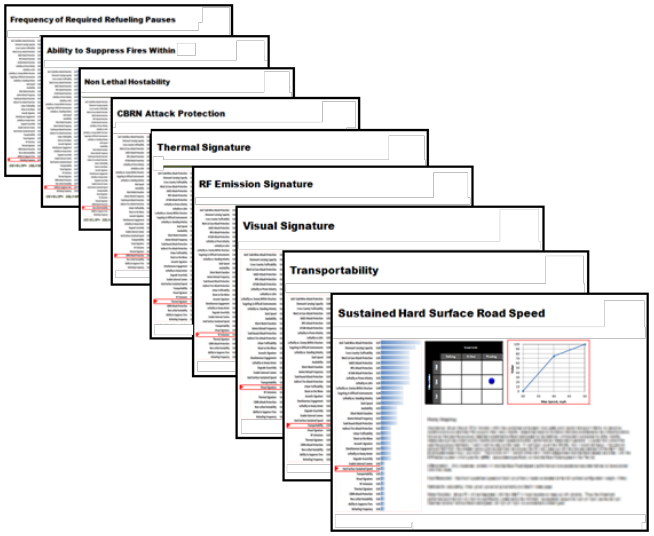
Per Activision (2013):

- **100 million players** **(larger than the population of the UK, Germany, or France)**
- **2.85 million years have cumulatively** **been played**
  (longer than the entirety of human existence.)
- **NOT PHYSICS BASED / REALISTIC!!!**



http://games.mxdwn.com/news/over-100-million-people-have-played-call-of-duty/

Relative Feature Priority / Value Functions



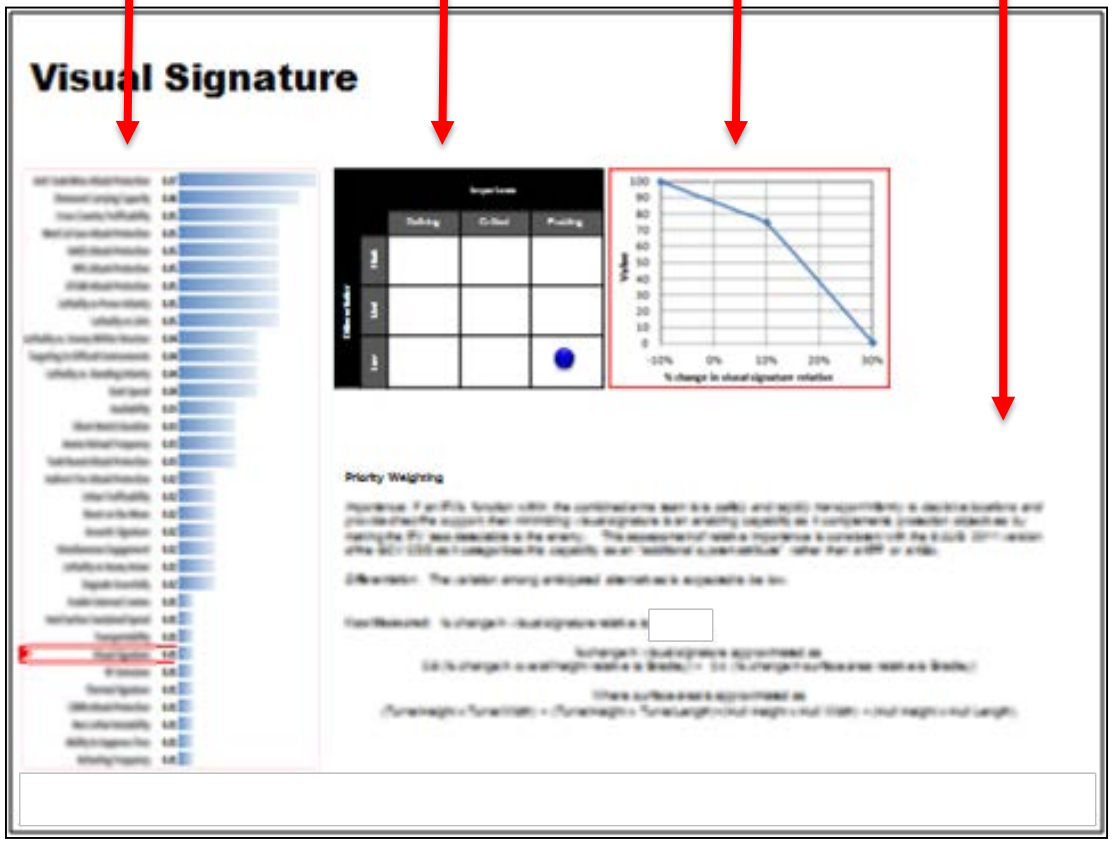
Priority weightings and value functions for each objective are well reasoned based on SME input and gaming data.

Relative Priority Weighting Indicator

Swing Weight Matrix (Performance Gap vs. Importance)

Value Function (knee in the curve)

Supporting Narrative



Source: WSTAT (Whole Systems Trades Analysis Tool) Web:http://www.sandia.gov/CSR/_assets/documents/WSTAT.pdf

TARDEC Man or Hardware in-The-Loop Facilities

US Army TARDEC's Ride Motion Simulator (RMS) is an example of a man-in-the-loop physical simulation.

US Army TARDEC's N-post shaker is a hardware-in-the-loop simulation.

Further References Related to Tactical Behavior Mining / Spatio-Temporal Pattern Recognition

- Ayers, Jeanine, and Nick Caler. *Automated Support for After Action Review (AAR) Presentation*. No. AP-R-1456. APTIMA INC WOBURN MA, 2009. *www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA507982*
- Bialkowski, Alina, et al. "Identifying team style in soccer using formations learned from spatiotemporal tracking data." *Data Mining Workshop (ICDMW), 2014 IEEE International Conference on*. IEEE, 2014. https://s3-us-west-1.amazonaws.com/disneyresearch/wp-content/uploads/20150122055122/Identifying-Team-Style-in-Soccer-using-Formations-from-Spatiotemporal-Tracking-Data-Paper.pdf
- Bialkowski, Alina, et al. "Representing Team Behaviours from Noisy Data Using Player Role." *Computer Vision in Sports*. Springer International Publishing, 2014. 247-269. https://s3-us-west-1.amazonaws.com/disneyresearch/wp-content/uploads/20150307075804/Representing-Team-Behaviours-from-Noisy-Data-using-Player-Role-Paper.pdf
- Bosc, Guillaume, et al. *Strategic pattern discovery in rts-games for e-sport with sequential pattern mining*. Tech. Rep. RR-LIRIS-2013-012, 2013. http://liris.cnrs.fr/Documents/Liris-6365.pdf
- Bowman, Brian, Niklas Elmqvist, and T. J. Jankun-Kelly. "Toward visualization for games: Theory, design space, and patterns." *Visualization and Computer Graphics, IEEE Transactions on* 18.11 (2012): 1956-1968. http://www.umiacs.umd.edu/~elm/projects/visgames/visgames.pdf
- Canossa, A., M. S. El-Nasr, and THD NGUYEN. "Beyond Visualization: Democratizing Access to Game Analytics Through Interactive Sense-making." *CHI PLAY Game User Research Workshop*. 2014.
- Centieiro, Pedro, Teresa Romão, and A. Eduardo Dias. "Enhancing Remote Spectators' Experience During Live Sports Broadcasts with Second Screen Applications." *More Playful User Interfaces*. Springer Singapore, 2015. 231-261.
- Cheong, Yun-Gyung, et al. "Automatically Generating Summary Visualizations from Game Logs." *AIIDE*. 2008. https://www.aaai.org/Papers/AIIDE/2008/AIIDE08-028.pdf
- Cottrell, David. "System and method for automated creation of video game highlights." U.S. Patent No. 8,515,253. 20 Aug. 2013. https://www.google.com/patents/US8515253
- Dominguez, Mike, R. Michael Young, and Stephen Roller. "Design and Evaluation of Afterthought, A System that Automatically Creates Highlight Cinematics for 3D Games." *AIIDE*. 2011. https://www.aaai.org/ocs/index.php/AIIDE/AIIDE11/paper/download/4059/4425
- Drachen, Anders, et al. "A comparison of methods for player clustering via behavioral telemetry." *arXiv preprint arXiv:1407.3950* (2014). http://arxiv.org/pdf/1407.3950.pdf
- El-Nasr, Magy Seif, Anders Drachen, and Alessandro Canossa. *Game analytics: Maximizing the value of player data*. Springer Science & Business Media, 2013.
- El-Nasr, Magy Seif, et al. "Data-Driven Retrospective Interviewing (DDRI): A proposed methodology for formative evaluation of pervasive games." *Entertainment Computing* 11 (2015): 1-19.
- Gonzalez, Avelino J., and Patrick Brézillon. "Comparing two context-driven approaches for representation of human tactical behavior." *The Knowledge Engineering Review* 23.03 (2008): 295-315. http://www-sysdef.lip6.fr/~brezil/Pages2/Publications/KER-2008-CxG-CxBR.pdf
- Gonzalez, Avelino J., and Robert Ahlers. "Context-based representation of intelligent behavior in training simulations." *Transactions of the Society for Computer Simulation* 15.4 (1998): 153-166. https://www.researchgate.net/profile/Avelino_Gonzalez/publication/234791270_Context-based_representation_of_intelligent_behavior_in_training_simulations/links/55563f5208ae6fd2d8236110.pdf
- Gonzalez, Avelino J., Jose Castro, and William Gerber. "Automating the acquisition of tactical knowledge for military missions." *The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology* 2.3 (2005): 145-160. http://www.scs.org/pubs/jdms/vol2num3/Gonzalez-Castro-pp145-160.pdf
- Good, Owen. "Dota 2 is Steam's first game with 1 million users playing at the same time". Polygon. http://www.polygon.com/2015/2/15/8042171/dota-2-concurrent-users-million-steam-pc
- Ha, Eunyoung, et al. "Goal Recognition with Markov Logic Networks for Player-Adaptive Games." *AIIDE*. 2011. http://www.aaai.org/ocs/index.php/AIIDE/AIIDE11/paper/download/4077/4409/
- Hsueh, Pei-Yun, Prem Melville, and Vikas Sindhwani. "Data quality from crowdsourcing: a study of annotation selection criteria." *Proceedings of the NAACL HLT 2009 workshop on active learning for natural language processing*. Association for Computational Linguistics, 2009. http://www.aclweb.org/website/old_anthology/W/W09/W09-19.pdf#page=37
- Jensen, Randy, et al. *Visually based timeline debrief toolset for team training AAR*. STOTTLER HENKE ASSOCIATES INC SAN MATEO CA, 2006. https://www.stottlerhenke.com/papers/IITSEC-06-visual-timeline-debrief-team-training-aar.pdf
- Johnson, Cynthia, and Avelino J. Gonzalez. "Automated after action review: State-of-the-art review and trends." *The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology* 5.2 (2008): 108-121. *http://www.scs.org/pubs/jdms/vol5num2/Johnson-AAR-final.pdf*

Further References Related to Tactical Behavior Mining / Spatio-Temporal Pattern Recognition Continued

- Kooij, Julian FP, Gwenn Englebienne, and Dariu M. Gavrila. "A non-parametric hierarchical model to discover behavior dynamics from tracks." *Computer Vision–ECCV 2012*. Springer Berlin Heidelberg, 2012. 270-283. http://www.lookingatpeople.com/eccv12.pdf
- Korfiatis, Peter, and Robert Cloutier. "Using 3D gaming technologies to improve the Concept of Operations (CONOPS) process." *Presentation to the National Defense Industrial Association's Ground Vehicle Systems Engineering and Technology Symposium, Troy, MI, August*. 2013. http://serc2cdn1.mannadesignworks.netdna-cdn.com/wp-content/uploads/2014/03/94_Using-3D-Gaming_NDIA_Final-paper.pdf
- Lasecki, Walter S., et al. "Real-time crowd labeling for deployable activity recognition." *Proceedings of the 2013 conference on Computer supported cooperative work*. ACM, 2013. http://ftp.cs.rochester.edu/u/ysong/papers/cscw-ar.pdf
- Leban, Gregor, et al. "Vizrank: Data visualization guided by machine learning." *Data Mining and Knowledge Discovery* 13.2 (2006): 119-136.
- Leece, Michael A., and Arnav Jhala. "Sequential pattern mining in starcraft: brood war for short and long-term goals." *Tenth Artificial Intelligence and Interactive Digital Entertainment Conference*. 2014. http://www.aaai.org/ocs/index.php/AIIDE/AIIDE14/paper/viewFile/9082/9011
- Lucey, Patrick, et al. "Assessing team strategy using spatiotemporal data." *Proceedings of the 19th ACM SIGKDD international conference on Knowledge discovery and data mining*. ACM, 2013. http://www.disneyresearch.com/wp-content/uploads/PROJECT_AssessingTeamStrategy_kdd2013_paper.pdf
- Lucey, Patrick, et al. "Representing and discovering adversarial team behaviors using player roles." *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*. 2013. https://s3-us-west-1.amazonaws.com/disneyresearch/wp-content/uploads/20141125022728/Representing-and-Discovering-Adversarial-Team-Behaviors-Using-Player-Roles-Paper.pdf
- Mahlmann, Tobias, Matthias Schubert, and Anders Drachen. "Esports Analytics Through Encounter Detection." *MIT Sloan Sports Analytics Conference*. MIT Press, 2016. www.sloansportsconference.com/wp-content/uploads/2016/02/1458.pdf
- Miyamori, Hisashi, and Shun-ichi Iisaku. "Video annotation for content-based retrieval using human behavior analysis and domain knowledge." *Automatic Face and Gesture Recognition, 2000. Proceedings. Fourth IEEE International Conference on*. IEEE, 2000. ftp://ftp.cfar.umd.edu/.snapshot/nightly.0/pub/aravinds/00840653.pdf
- Nguyen, Truong-Huy Dinh, Magy Seif El-Nasr, and Alessandro Canossa. "Glyph: Visualization Tool for Understanding Problem Solving Strategies in Puzzle Games." *Foundations of Digital Games (FDG)* (2015).
- Sha, Long, et al. "Chalkboarding: A New Spatiotemporal Query Paradigm for Sports Play Retrieval." *Proceedings of the 21st International Conference on Intelligent User Interfaces*. ACM, 2016. https://www.disneyresearch.com/publication/chalkboarding/
- Stensrud, Brian S., Gilbert C. Barrett, and Avelino J. Gonzalez. "Context-Based Reasoning: A Revised Specification." *FLAIRS Conference*. 2004. http://www.aaai.org/Papers/FLAIRS/2004/Flairs04-104.pdf
- Sun, Guo-Dao, et al. "A survey of visual analytics techniques and applications: State-of-the-art research and future challenges." *Journal of Computer Science and Technology* 28.5 (2013): 852-867. www.cad.zju.edu.cn/home/ycwu/Files/va_survey.pdf
- Synnaeve, Gabriel, and Pierre Bessiere. "A Bayesian model for plan recognition in RTS games applied to StarCraft." *arXiv preprint arXiv:1111.3735* (2011). http://arxiv.org/pdf/1111.3735
- Tadjdeh, Yasmin, "New Video Game Could Speed Up Acquisition Timelines." *National Defense Magazine* blog post dated 12/3/2014: http://www.nationaldefensemagazine.org/blog/lists/posts/post.aspx?ID=1687
- Tastan, Bulent, and Gita Reese Sukthankar. "Learning Policies for First Person Shooter Games Using Inverse Reinforcement Learning." *AIIDE*. 2011. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.384.5902&rep=rep1&type=pdf
- TrueSight Visual Tool for Analyzing Video Game Play . http://tunglinwu.com/assets/portfolio/.../InfoVis_Mid_Phase_Project_Design_Report.pdf
- van Lent, Michael, and John E. Laird. "Learning procedural knowledge through observation." *Proceedings of the 1st international conference on Knowledge capture*. ACM, 2001. https://www.researchgate.net/profile/John_Laird/publication/2925010_Learning_Procedural_Knowledge_through_Observation/links/5464efa80cf2052b509f28a1.pdf
- Van Lent, Michael, and John Laird. "Learning by observation in complex domains." *Ann Arbor* 1001 (1998): 48109. http://web.eecs.umich.edu/~soar/sitemaker/workshop/19/vanlent-SWS-Thesis.pdf
- Van Lent, Michael, and John Laird. "Learning hierarchical performance knowledge by observation." *Ann Arbor* 1001 (1999): 48109-2110. http://ai.eecs.umich.edu/people/laird/papers/ML99-2.pdf
- Vondrick, Carl, Donald Patterson, and Deva Ramanan. "Efficiently scaling up crowdsourced video annotation." *International Journal of Computer Vision* 101.1 (2013): 184-204. http://cvrr.ucsd.edu/ece285/Spring2014/papers/Vondrick_IJCV2013.pdf