Large-Scale Online Constructive Simulation as a Response Training and Education Platform

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ABSTRACT

Massive multiplayer online games (MMO's) have given rise to 3D worlds that are amazingly realistic. What if you could use MMO concepts to train and educate every team and organization involved in emergency response plans? In this presentation, ATS explores its research using GIS mapping and game engines coupled with large online constructive simulations to virtually train response teams, across multiple organizations and locations at the same time. This research includes population behavior modeling aimed at giving large population actors in these simulations attributes that affect their autonomous behavior. The simulation can be placed anywhere in the world with both 2D maps and 3D game engine terrain. Participants simply need a computer connected to the internet and they can join and participate in the constructive simulation. The training simulation can be designed around any scenario, whether it be a hurricane, nuclear blast, or earthquake. Each participating organization will have a chance to interact and practice its role in the response. Participating organizations can be distributed across any physical location. Currently, response training is expensive and cumbersome due to the high travel and venue costs associated with a physical gathering for training. With large-scale online constructive simulations, these costs are eliminated. With these cost savings, organizations can now include in their plans a large-scale training exercise for their most likely scenarios. This new approach to training will fill the education and preparation gap and help organizations be more prepared, trained, and response ready.
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ABOUT THE AUTHORS

David Spriggs graduated from the University of Missouri Columbia with a BA in Geography. Post education, David worked at Esri for seven years. While at Esri, David worked in Professional Services helping clients solve real world problems with GIS technology. David took this experience and knowledge overseas to Saudi Arabia for six years working for Aramco. There he built an enterprise mapping platform. David now works at ATS as Director of Software Engineering helping ATS train response communities to be more prepared using GIS technologies.

Schawn E. Thropp graduated with a Bachelor of Science in Computer Science and Mathematics from the University of Pittsburgh at Johnstown along with a Master of Science in Computer Science at Johns Hopkins University. Post education, Schawn has over 23 years of research and development, application development, and program management within the Training, Education and Learning domain. Schawn has spent the last 7 years focused on the modeling and simulation domain.

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MMO CONCEPTS TO TRAIN EMERGENCY RESPONSE PLANS

Disasters, natural or manmade, can strike at any time. Preparing for disasters requires an all-hazards approach by emergency management officials, starting with training and exercise. Over the years, exercises have evolved into complex events using new technologies to simulate realistic events, allow for multiple partners, and track actions for comprehensive after-action reports.

As emergency managers know, all disasters are local. It is important for training and exercises to start at the local level. As disasters increase in complexity, a response or recovery could include state or national disaster response agencies. States conduct annual exercises to test the capabilities of their teams in coordination with local partners and, at times, other states (Sanjay Jain and McLean, 2003).

National-level exercises may include local, state, and federal emergency management teams, military components, private sector partners, and academia. New training and exercise tools will allow partners to collaborate over multiple days and multiple locations simultaneously. Applied Training Solutions (ATS) aims to do this with the ATSsim training and exercise platform.

ATSsim is a web-based, versatile disaster training and exercise constructive simulation tool. It provides users with a simulated training environment that is realistic and scalable to meet the needs of the organization. ATSsim integrates Homeland Security and Department of Defense requirements to provide disaster management teams the ability to train their teams at the same time while meeting national requirements.

To make constructive training simulations more realistic and support population scenarios, ATS experimented with two new technologies. First, population behavior models inside ATSsim simulations. Can we accurately model and then display large populations and their behavior? Second, ATS won an Epic Games grant to research the possibility of extending these simulations into a 3D game engine, immersing participants into a 3D world. Do these environments enhance a participants' training and make it more effective?

RESEARCH AND DEVELOPMENT

Our research and development efforts were defined by a specific set of constraints and requirements to continue to evolve our ATSsim web-based constructive simulation. These included the following focal areas and questions:

- GIS Mapping
- Game Engines
- Population Behavior Modeling

The goal was to research and develop a solution that leveraged these concepts to train and educate teams and organizations involved in emergency response plans. In this paper, ATS describes its research, findings and lessons learned using GIS mapping, game engines, large online constructive simulations and population behavior modelling to virtually train response teams, across multiple organizations and locations simultaneously.

GIS Mapping

ATSsim is map centric and utilizes GIS base maps and operational data layers to present the audience with a geographic-based simulation. Entities are placed on the map and can be given attributes to represent their current state. These entities can be human assets like civilians, troops, law enforcement, rescue crews, etc. Entities can also be physical assets like cars, trucks, airplanes, supplies, etc. Entities start with a given state and an entity's state can change over time. For example, a car that is driving from one location to another, will consume fuel and eventually run out of gas if not refueled.

Other entities, like civilians, can be contaminated by areas built to simulate chemical or radiation disasters. These entities can then be cleaned in a decontamination zone. These entities have state which includes a location and can therefore be injected into the simulation at a given place and time, in response to simulation injects or movement orders (Applied Training Solutions, 2020). The geographic map is the hub around which the simulation is organized, just like in the real world. This approach gives the participant's the advantage of being "present" at that geographic location during the scenario. Data layers can also be used to analyze infrastructure that may be damaged. Such as bridges or cell towers. This aids in disaster planning and helps participants make informed decisions.

Game Engines

ATS also experimented with 3D in constructive simulations. Step one was to find a good candidate for a 3D sub-system. With a grant from Epic Games, ATS built a decontamination site game using Unreal engine. The idea was to build a traditional National Guard decontamination site as a 3D game. Entities in the ATSsim simulation that were contaminated by a disaster, would make their way to a decontamination area. When this happens in the simulation, the entity will then be transferred into the 3D decontamination game simulation for processing. While in the 3D decontamination simulation, operators can practice via game technology their abilities to

- interact with various avatars with different personalities through ATS built decision tree conversation algorithm
- practice wash and rinse down procedures
- and chemical monitoring after wash and rinse to approve entities to be released back into the simulation

Outside of the research and development of the Decontamination site, ATS also experimented with creating a "Virtual Operating Picture." This was done with Unreal Engine and was a 3D twin of the ATSsim constructive simulation. ATSsim was modified to send a data stream to the Unreal environment, consisting of each entity's location and state. This data stream was real-time and mirrored the simulation in the web interface. Each user in the application had the ability to fly around the scene in a drone mode. This allowed observers to watch the simulation in the 3D environment.

Population Behavior Modelling

Another goal of our research and development efforts was to define a way to dynamically simulate various population behaviors. The main behavioral area was on conflict escalation and de-escalation. We took a preliminary look at various conflict escalation models (Jordan, Thomas 2000). There were several different models that went into detail on how conflicts escalate out of control and techniques on how to deescalate. For our purposes we were looking for a means to model and simulate this escalation overtime and to find a way to dynamically change the circumstances or parameters to the model.

The next challenge was to define an algorithm that would suit our needs to simulate this escalation and de-escalation process on individual entities in the simulation (Jordan, Thomas 2000). To define this algorithm, we started by breaking down the pieces (or stats) we needed to model. During our initial work, we decided to define an overall anger stat of $0 \rightarrow 1$, a political compass stat between $-1 \rightarrow 1$ (political x and political y), and a temperament stat of $0 \rightarrow 1$. These were just artificial limits we set to allow for number balancing as we processed the overall results. Anger is used to generally represent the sense of unrest an entity has. The other personality metrics are strictly used to help skew anger adjustments. They could be dynamically adjusted in the future if we determine things like political position is a changing metric in a person. In the future it would be easy to add more stats that can help influence anger calculations however the algorithms used will become more and more complex; For example, entities could also potentially be given unique personality traits that affect how anger is calculated, limited, and lessened.

To calculate the anger escalation of an entity in a simulation we began by assuming that the angrier an entity becomes the faster the entity would continue to escalate in anger. Knowing this, we started by creating a simple exponential function in a graph and adjusting from there between a value of 0 and 1. We then applied some of the other personality stats to the equation to help change anger over time. For example, when entities in a simulation are near (geospatially) each other, their political difference is calculated, then resulting value is used to affect the change in anger. One of the biggest factors used in anger calculations is the temperament stat. Temperament is used to scale the rate of change in anger. An entity with a high temperament value will get angry faster from a given stimuli than an entity with a low temperament. The number of entities in an area (e.g., crowd size) also affects anger; this is used to simulate the concept of mob mentality, so an entity surrounded by many angry entities will get angry faster than an entity next to only one other entity.

$$y = \left(1 + 0.5\ \left(\frac{c}{100}\right)\right) * \left(\frac{3}{8}\ t + \frac{5}{8}\right) p\ \left(0.25x^2 + 0.25 + \frac{1}{2}\ a_2\right) \quad (1)$$

Equation (1) represents the base equation we defined in the model to calculate the overall anger of an entity over time. In this equation *y* represents the anger gained.

$$\left(1 + 0.5\left(\frac{c}{100}\right)\right) \quad (2)$$

Equation (2) is used to scale the result set based on crowd size. This part of the equation is used for simulating mob mentality. As with the rest of the equations, there is a lot of trial and error to come up with the value we needed to simulate crowd size impacts on the equation. The variable ‘c’ is the number of entities that the current entity is near. 100 was used a crowd unit size, meaning that for every 100 entities nearby, a result of 1.0 is received. A crowd size of 200 would appropriately scale this even higher. The result is then halved and offset by 1 to balance the anger gain based on crowd.

$$\left(\frac{3}{8}t + \frac{5}{8}\right)p \quad (3)$$

Equation (3) is used to scale political difference based on temperament. Temperament (t) is the average temperament of all the entities near the current entity. As of the current implementation, this is a raw average, meaning that it is not weighted or curved. Political distance (p) is similarly the raw average political distance of all entities nearby. Political distance is determined by taking the current entity’s position on the political compass and finding the distance with the average of the entities nearby. This distance is calculated with axis scaling to keep the result from being too high. The current implementation has the x-axis scaled by 0.5 and the y-axis scaled by 0.35. This keeps the result in between 0 (completely similar) and ~1.2 (completely different). This was done to simulate the phenomenon observed in US politics where the terms “Left” and “Right” are the most used terms when discussing someone’s political views. Temperament (t) is scaled by 3/8 and offset by 5/8 to balance the result.

$$\left(\ 0.25x^2 + 0.25 + \frac{1}{2}\ a_2\right) \quad (4)$$

Equation (4) is used scale anger gained based on current anger values. This simulates how once someone is already angry, they are more likely to get angrier as well as anger others more quickly. The current entity’s anger (x) is curved with an exponent and scaled by 0.25, then offset by 0.25. Then, half of the weighted average anger of the colliding entities (a2) is added on top of that. A weighted average is an average that has its input values scaled and then the result is divided by the sum of the weights.

To counter anger gain and prevent angry entities from becoming permanently angry, we needed to define a de-escalation algorithm. De-escalation happens for every effected entity, but the amount of de-escalation is scaled based on many of the same factors that affect anger gain in the previous sections.

$$y = \left(\frac{7}{8}\ t - 1\right) * \left(-0.125x^2 + 0.25 + (1 - \ a_2)\frac{1}{6}\right) \quad (5)$$

In the anger de-escalation equation (5) y: represents the anger de-escalated, x: is the current anger of the entity (does not account for anger gain in the same time frame), t: is the entity’s temperament, a2: is the weighted average anger of all colliding entities.

The result of this anger de-escalation equation is always negative but can get close to zero. This is then added to the accumulated anger, resulting in the net change in anger over time. The constants used in the function above, like anger gain, are similarly arbitrary and adjusted based on trial and error to meet the overall simulation effect we needed.

APPLYING THE RESEARCH AND DEVELOPMENT

ATS implemented this research with custom software development. ATSsim was chosen as the parent component. ATSsim offers the context of a constructive simulation that can then be extended with this new functionality. ATSsim also provides a way to visualize the population behavior modeling in a geospatial context.

Decontamination Simulation

The decontamination game simulated a real-world National Guard decontamination site. Game players use a controller and player to fill a role within the site. Contaminated human entities enter the site from the ATSsim constructive simulation. The player then tests the entity for contamination levels and precedes with an initial washing. The entity precedes to drying and the retesting. If needed the entity may be washed again. After testing clean, the entity is then released and can return to the constructive simulation.

Figure 1. Decontamination Site

Figure 2. Player testing and monitoring an entity for contamination.

Population Behavior Simulation in Constructive Simulation

To demonstrate the Population Behavior algorithms for escalation and de-escalation, ATS integrated the algorithms with ATSsim as a proof of concept. ATSsim added the missing components to demonstrate the conflict escalation R&D describe earlier. ATSsim provided an entity-based constructive simulation environment where populations could be injected into the training and observed by participants over time.

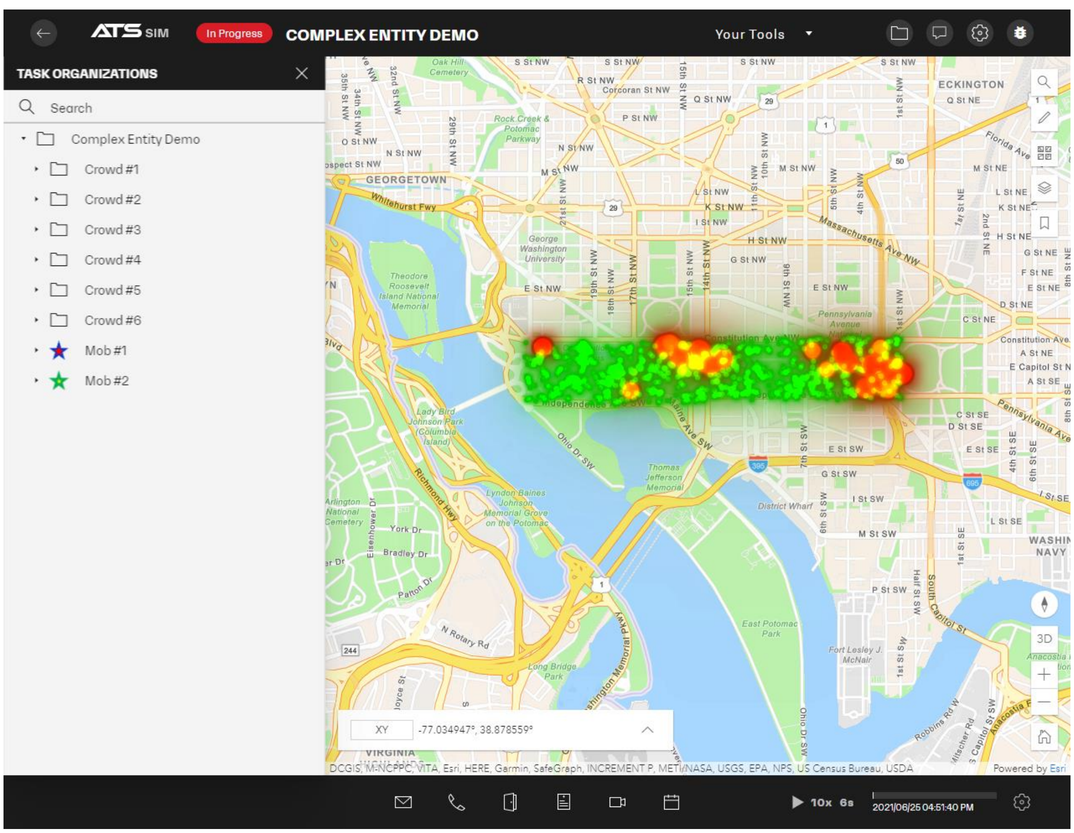

Figure 3. National Mall protest simulating spreading anger.

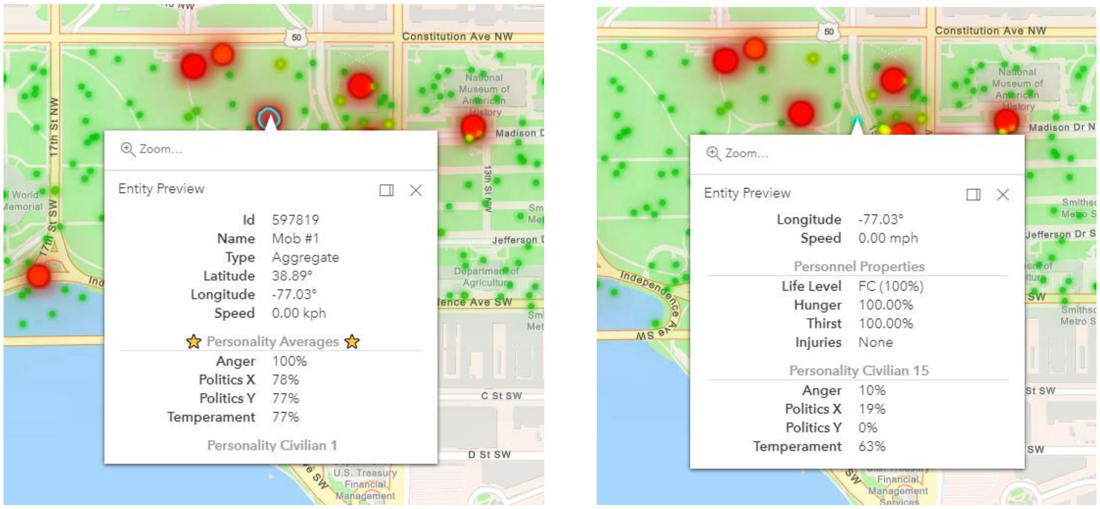

Figure 4. Entity Attributes.

Virtual Operating Picture

To implement the 3D Virtual Operating Picture viewer, ATS first had to construct 3D models of the training scenario area. This was achieved using open-source data from openstreetmap.org. Once the city scenes were created in Unreal, ATS then developed a "drone" style flying system that allowed the viewer to fly around the scene and observe from any angle or altitude.

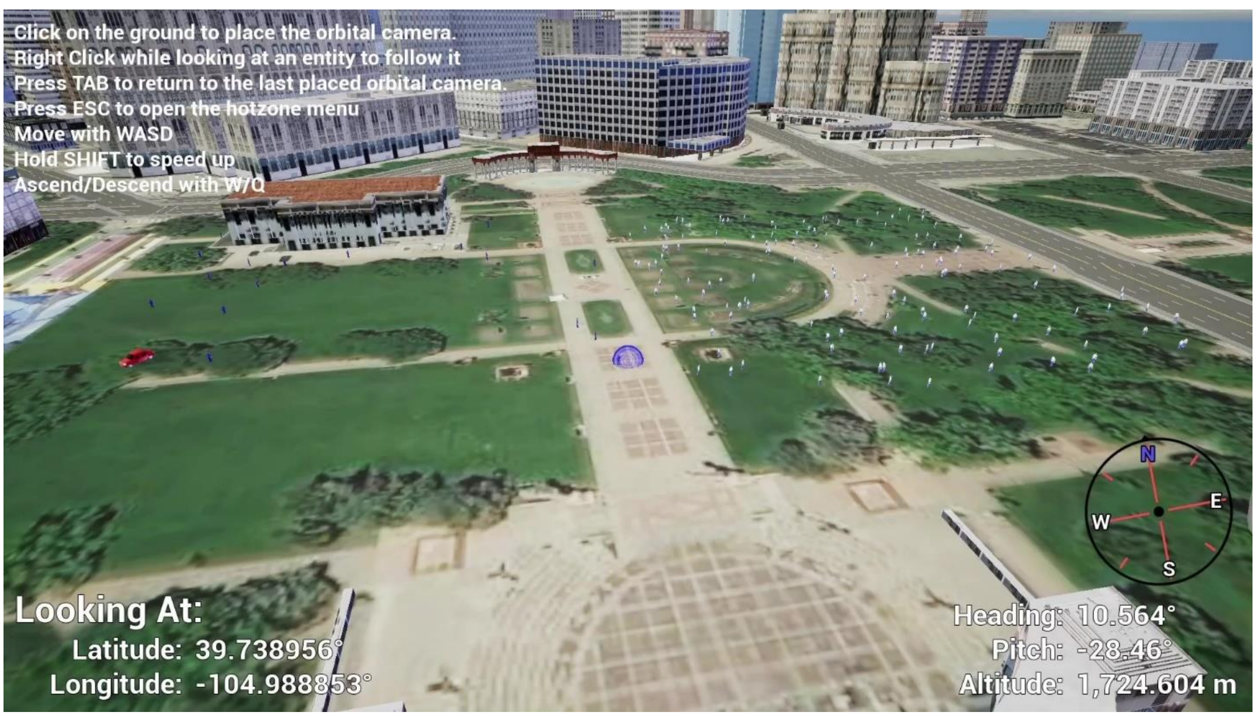

Figure 5. View of simulation entities in Virtual Operating Picture.

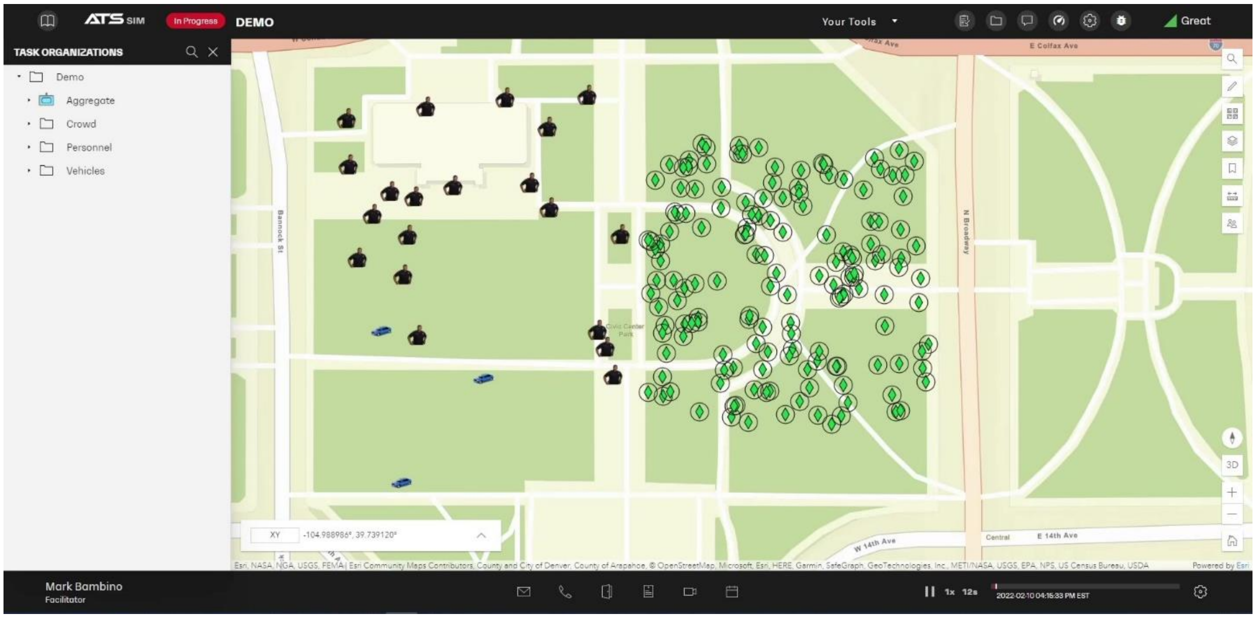

Figure 6. View of same entities in ATSsim (constructive simulation base platform).

CONCLUSION

Through this research, ATS believes that using large scale on-line web-based platforms, GIS map centric presentation layers, and integrating high quality modeling, will greatly increase quality and access to training. These training simulations can be placed anywhere in the world with both 2D maps and 3D game engine terrain. Participants in the training only need a computer connected to the internet, allowing them to fulfill their role in the constructive simulation. The training simulation can be designed around any scenario, natural or manmade. Each participating organization will have a chance to interact and practice its role in the response. Participating organizations can be distributed across any physical location.

Currently, response training is expensive and cumbersome due to the high travel and venue costs associated with a physical gathering for training. With large-scale online constructive simulations, these costs are eliminated. With these cost savings, organizations can now include in their plans a large-scale training exercise for their most likely scenarios. This new approach to training will fill the education and preparation gap and help organizations be more prepared, trained, and response ready.

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