RimSim Visualization : An Interactive Tool for Post-event Sense Making of a First Response Effort

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ABSTRACT

Upon developing a software agent-based simulator for training roles in emergency response scenarios, the PARVAC team at the University of Washington has pursued building a tool for better investigative review and insight generation on the performance of an emergency response game session team. While our *RimSim Response* software included the opportunity to re-run a simulated team performance in order to review player and agent behavior, we did not provide our trainees the ability to visually query their performance outside of a sequential review of the emergency response effort. By integrating our RSR visualization components with an existing visual query software package called *Improvise*, we were able to construct highly-coordinated visualizations of our data model for the ability to apply a sense making approach in the investigation of live player and software agent-based behavior – both as individual players and as combinations of players working on tasks associated with an emergency response scenario. The resultant tool is now our primary visualization tool for discussing first responder team performance and supports the overall RSR objective of training teams to make the most effective, recognition-primed decisions when a real emergency crisis occurs in their community. This paper reviews our visualization tool and demonstrates its use.

Keywords

Emergency response, sense making, simulation, visualization.

INTRODUCTION

As part of the research and development agenda for visual analytics [1], we are developing integrated tools for improving analytic capabilities that facilitate application of human judgment to evaluate complex data and enable action. Actions through coordinated first response efforts to community disasters can save lives under immense time pressures. Responding to events of the scale of the Katrina hurricane disaster of 2006 requires a situation awareness not easily gained due to the sheer magnitude of data required across a wide geographical area. First responders attempt to gain necessary situation awareness in order to assess potential actions with the aid of visual artifacts. As coordinating artifacts, geospatial visualization assists in knowledge construction and decision support [2]. Once shared geospatial visualization is available to an emergency operations center, the team of response coordinators can improve their use of it through emergency drills and software-supported simulation use.

In 2006, the PARVAC team at the University of Washington crafted the RimSim architecture, seen in Figure 1, to build software to simulate emergency response scenarios and assess shared use of geospatial visualization over time [3]. We created a Response (RSR) simulator in order to gain experience with first response geospatial visualization, using software-based agents to simulate first responder behaviors that could be visualized in ways useful to scenario analysis [4]. The visualization products produced via simulations enable a team of responders to replay a response effort sequentially in order to review their decisions and the ramifications of decisions made in geospatial and temporal space. We were motivated to build the RSR simulator to help first response coordination teams explore four concepts in a large first response effort: recognition-primed decision-making

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[5], situation awareness [6], distributed cognition [7], and distributed intelligence [8]. All four suggest models relevant to the coordination of complex team activities under time-bounded conditions.

Our RSR software does not provide an optimal interactive visual query of coordinated views in an emergency response session that can be used for insight generation – instead, the focus is on real-time situation awareness rather than an after-game sense making activity. The RimSim Visualization (RSV) tool described in this paper helps response coordinators review communication patterns and response actions, discuss potential improvements, and then gain familiarity with better solutions based on reviewing other simulated emergency response sessions that are valued higher. Through the experience of visualizing coordinated actions in response to crises, event coordinators can improve their recognition of emergent event patterns and focus on the best response actions.

We visualize communication patterns between coordinators and actions taken in the field by coordinators alongside a geospatial visualization of all key components associated with an emergency response effort. The visualization can be interrogated through time controls that advance the state of the response effort from start to end of the evaluation period. By tagging each communication and action with a participant id, an in-depth analysis can be made of the team effort in order to help participants consider their contribution. By developing the RSV tool and introducing it to potential emergency response coordinators, we gain interface design feedback that suggests improvements we might implement for the RSR's user controls.

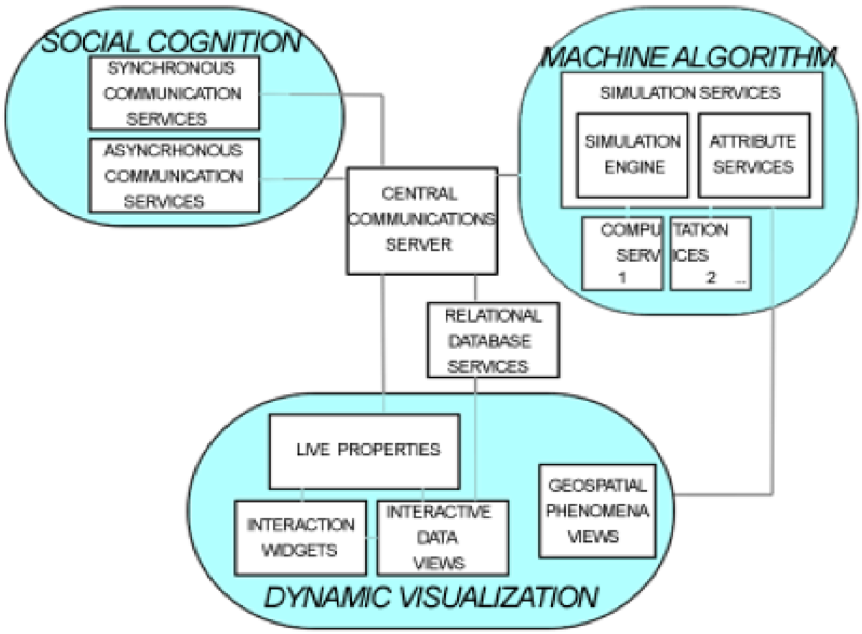

Figure 1. RimSim Architecture

BACKGROUND

The RSR software allows a user the opportunity to design and implement a basic emergency response scenario without needing to extend the base RSR software. To do so, the scenario designer uses the editor tool shown in Figure 2.

As the designer can draw scenario details anywhere on the Java World Wind-based virtual globe that appears in the tool, the scenario can take place anywhere on the surface of Earth. The designer draws responsibility jurisdictions as n-sided polygons, as well as n-sided polygons for out of bounds regions in which no simulation activity can take place. The designer drags and drops emergency response incidents geospatially and sets a begin time for each. The designer geospatially places the emergency response resources that a simulation participant can use to meet incident demand, by hand or by using one of many menu-driven distributions built into the software. For more specific scenarios, a developer can extend the software before providing it to the emergency response user. A community of developers builds the base RSR tool, including the scenario editor that we describe in [4], and makes it available for download and exploration at *www.oworld.org/parvac/rsr.html*.

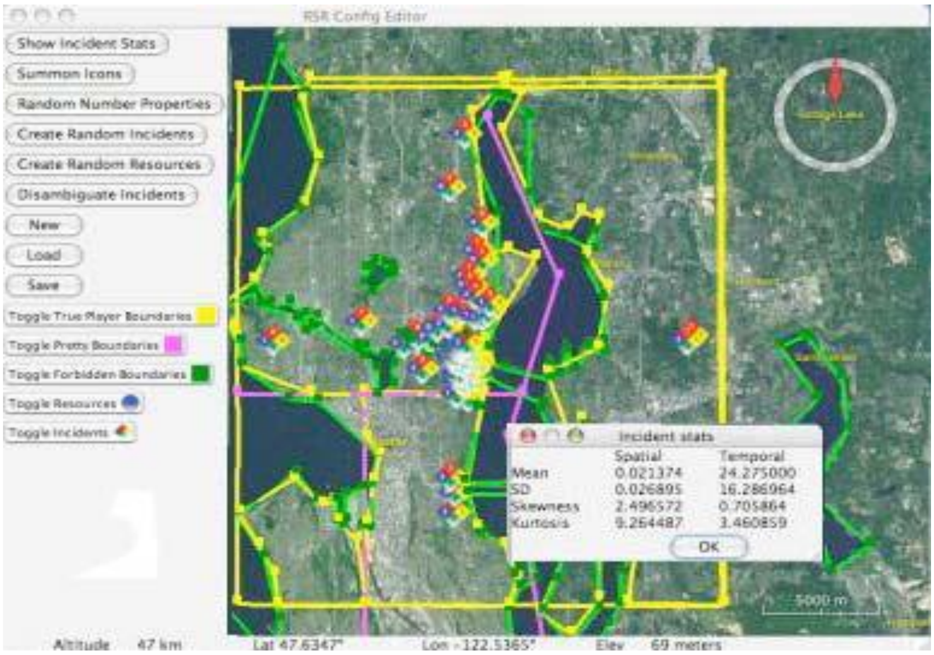

Figure 2. RSR Scenario Editor

At that address we provide the opportunity to substitute a software-based agent for each regional simulation participant, but each live participant can participate in an active simulation over the Web by using the available controls at any time during which a simulation session runs. The RSR development community runs many simulated sessions with software-based agents playing jurisdictional roles in order to debug agent behavior and to experience the visualization as game players will experience it. These sessions are open for anyone to play.

To date, we have been logging key game session variables needed to replay an emergency response simulation session. We can replay any session that has been run if provided its log file for loading. Replaying a wide variety of simulated emergency response attempts enables a participant to observe patterns of resource allocation across the whole emergency crisis time and place extent. Klein's recognition-primed behavior theory predicts that repeated exposure to emergency response patterns should help with situation awareness should a community-wide emergency ever develop in which the participant has response responsibilities [5].

Sense making v. Situation Awareness

We have built RSR to help first responders gain deeper cognition with the data they need to be aware of during a response effort and the data others need in order to help suggest future actions given present situation awareness. By replaying a software-supported visual simulation in sequence, first responders can investigate when and where their situation awareness was gained or lost – and the future accuracy of their awareness at any time. But, evaluating situation awareness is not the only analysis that can be performed to help improve future efforts. Response teams can perform additional analyses facilitated by coordinated query-driven, less sequential, interactive visualization tools.

Many analysis tools enable analyses consistent with the process of sense making, which, as Mica Endsley suggests, is performed by a subset of the processes that humans use to maintain situation awareness, but "in a more explicitly effortful manner than those processes that are naturally performed in achieving situation awareness" [9]. She and others suggest that sense making is the process of gaining a situation awareness for a process or system that spans a much longer time period than what is within access of immediate sensory perception. Intelligence analysts perform sense making on a regular basis when looking for long-term patterns of human activity and events that might suggest a terrorist event is likely in the future. Financial analysts perform sense making on a regular basis to look for long-term trends that might suggest future behavior of financial markets. Interactive visualization tools support visual querying, a process that lets an analyst use gained spatial and temporal analysis skills to investigate a train of thought or interact with data serendipitously to suggest an interesting research direction.

One instructive example of supporting a sense making activity with interactive visual tools is the visual exploration and analysis of historic hotel visits performed by Weaver et al. [10]. To enable an interactive visual query tool for performing sense making on hotel guest book records from the 19th century, Weaver transcribed the hotel guest data into electronic views that could be queried using visual widgets that responded quickly to filtering, sorting, aggregating, and connecting patterns in the data that demonstrated hotel activity trends at a time when transportation, social, and lodging norms were different from the current day. Situation awareness could only be accessed through analysis over years worth of data – providing deep insights that could not have been anticipated in the course of one week or month and allowing history experts to test hypotheses regarding societal changes to hotel use norms in comparison to current day.

Given this and other documented successes of sense making through visual query, we predicted that a similar approach to analyzing first responder teams could prove to be extremely useful to a team, a command center, or an individual investigating their own performance within a team effort. We are developing our RSV tool for use by our RSR community. We require tight integration with RSR as a result.

DATA MODEL DRIVEN DATA ACQUISITION AND ANALYSIS

In order to facilitate RSR and RSV integration, we designed the same data model for use within both tools. Working backwards from the types of queries we wanted to support, we generated the data model in Figure 3 that could support the RSV tool with three types of data: communications between first response coordinators, actions requested by first response coordinators, and attributes of physical phenomena in the field (specifically incidents, response resources, and responders). The three types are connected in a causal manner such that communications between first responders can lead to actions being taken which can then lead to changes to tracked attribute values of objects in the field. Alternatively, actions taken by a member of the response team can lead to updates to key attributes in the field and communications with or between other key first responders.

Whenever analysis desired by a first responder team cannot be performed because the software does not have needed data attributes available, we revisit our data model and, if warranted, update the data model to incorporate the identified attributes. Then, the model drives software changes to both the RSR and RSV tools.

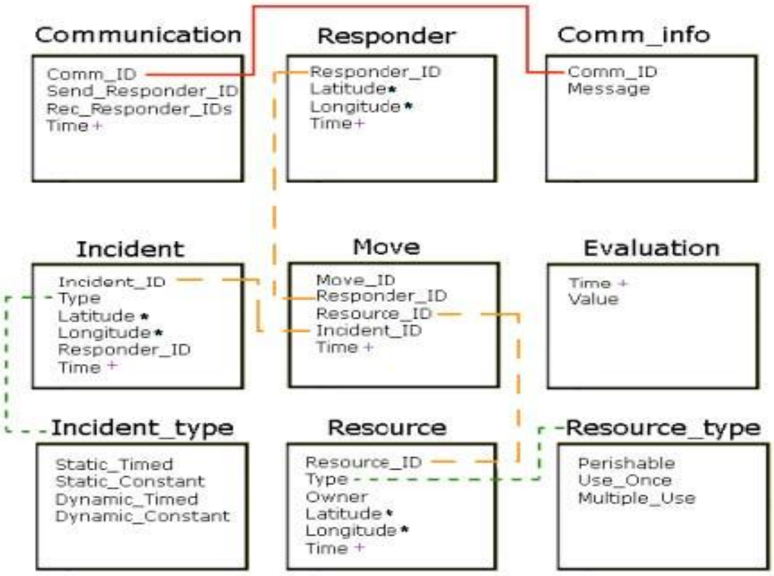

Figure 3. RSR and RSV Shared Data Model

In Figure 3, attributes with asterisks can be used to analyze data geospatially (Responder.Latitude, Responder.Longitude, Incdent.Latitude, Incident.Longitude Resource.Latitude, Resource.Longitude). Attributes with plus signs enable temporal analysis (Communication.Time, Responder.Time, Incident.Time, Move.Time, Resource.Time, Evaluation.Time). Objects connected with the short-dashed lines are related via a lookup procedure. Attributes connected with a solid line are related via expansion. Attributes connected with longer-dashed lines have a primary key – foreign key relationship.

The shared RSR and RSV data model supports evaluation of individual and team first responder behavior upon analysis. For example, by looking at an RSR session's data that complies with the data model for a response activity, we can ascertain that at 6:10pm two responders communicated about downed power lines. At 6:12pm a medical unit resource was dispatched to head to that location. The medical unit then makes its way from its base at the hospital to the downed power line incident location, affecting the incident and the resource entities. We choose representative entities and relationships from each first response effort to visualize. Scenario specific response resources such as police, fire, and medical units are tracked geospatially through the responder entity over time. Vehicles carrying medical supplies or medical patients are tracked as resource entities and supply levels for resources are tracked by separate resource entity tuples for each location.

In the case of a first response effort, first responders become critical attributes to track geospatially. Fire, police, medical, and other specialists are deployed by an event commander or report in from the field. We track the movement of first responder personnel through geospatial visualization that includes visual layers to identify location and the resources each first responder manages throughout the first response effort. By visualizing the results of actions taken in the field, first responders can review their actions and the communications that led to those actions.

RSV INTERFACE

The RSV tool enables interactive visual querying through a series of highly coordinated views. The underlying Improvise software platform [11] with which the RSV tool is built enables quick control widget and views construction.

Our interface provides two tabs to access the two pages of views seen in Figures 4 and 5. We allocate widgets such that one sheet provides an emphasis on geospatial analysis of responders, resources, and incidents, while the other provides emphasis on simulation participant communications and actions. Both sheets update dynamically when the user interacts through the interface in order to keep all views coordinated with each other.

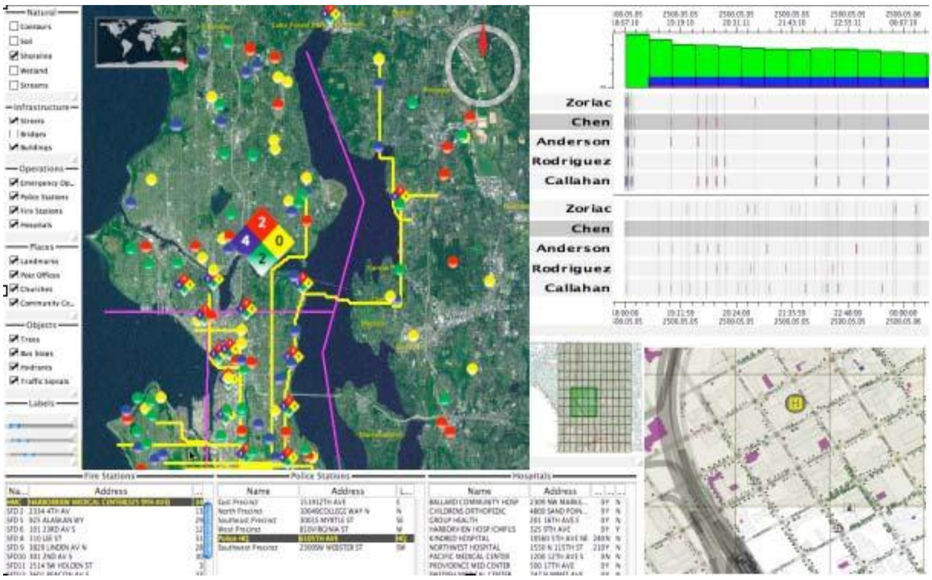

Figure 4. RSV Interface Tab One

RSV Coordinated Map Interface

The view in the upper-left in Figure 4 is taken right out of the RSR interface, but embedded within an Improvise-based view container in order to be able to communicate with all other RSV controls and views. The view in the lower right in Figure 4 allows an analyst to drill down on a map view of the community with visualization layers that show all community objects relevant to emergency response (fire hydrants, buildings, waterways, roads and highways, police stations, hospitals, etc.). The analyst can toggle the layers using the checkboxes that run in the left-hand margin of the page.

The smaller view, which appears between both map views, in Figure 4 lets the analyst consider the context of the current context of lower-right map relative to the whole scenario geographical coverage. The analyst can drag the green rectangle to move to a different location or can drag its corners to enlarge or shrink the extent (effectively zooming in or out while at the same time allowing distortion should the analyst so desire). The rectangle updates itself whenever action in another view changes the map in the lower-left (they are coordinated in both directions). Zooming and panning in the upper-left map view retains the same interaction behaviors the analyst is familiar with from using the RSR.

Tabular lists of those objects appear at the bottom of page one. Upon selecting a named object, both maps pan to orient with that object in the center (while maintaining the current zoom level). These short-cut navigation aids are very useful for an analyst. For example, if an analyst is curious about activity at a specific hospital, he can select the hospital by name and then drag and paint upon the time sliders in the upper-right to see events that occur in the area.

An analyst can track resource and incident properties over time, and can track player communications and actions using the three timelines in the upper-right of Figure 4. The uppermost timeline shows total incident demand for the scenario. The middle timeline shows each player's communications behavior over time. The lower timeline shows each action made by the players over time. Each timeline accepts typical Improvise dragging, painting, and clicking behaviors in order to adjust start and stop times, filter the visual time span, and choose a specific time step for detailed analysis in coordinated views.

The upper views visually show the connections between players for messages sent and actions taken. By scrolling the timeline for messages and zooming in and out of the time range represented, an analyst can get a visual sense of how much players communicate with other players. The analyst can also ascertain how often players work in unison to perform actions (such as allocated resources, for example). The views automatically change the position of player names in order to best show highest connectivity based on the range of messages or actions currently selected for viewing. The thickness of lines surrounding sets of players identifies the relative number of occurrences that combination of players participated in a communication event or other game action.

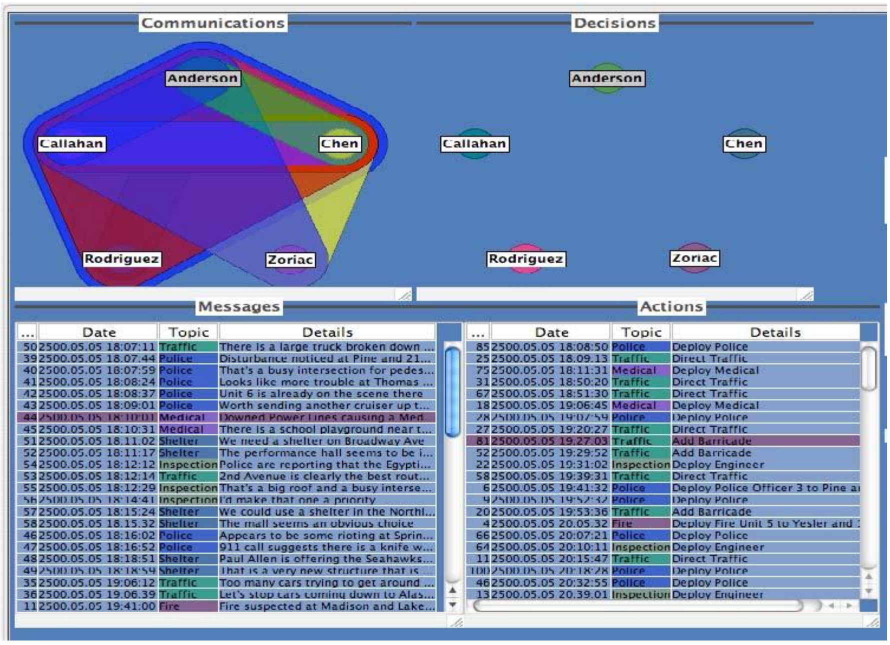

Figure 5. RSV Interface Tab Two

Example Use of the RSV

The emergency response scenario shown in Figure 4 requires significant focus within the south central area of downtown Seattle. Calahan, the coordinator for the south central region, does not have enough resources under his immediate control to handle all the incidents that are active in his region at various times during a simulated play session of that scenario.

The yellow track lines seen in the upper-left of Figure 4 show resources coming in to the south central region from other areas in Seattle. The RSV interface enables an analyst to review communications and actions made by other players in response to the crisis and bottlenecks that occur based on the nature of the scenario. The timelines allow a coordinated view of the time lag associated with initiating help. The maps allow a coordinated view of the distances required in order to move resources to the south central region. Figure 5 suggests that Calahan has communicated with all other players, but has let the other players act independently in sending resources to his region during the time period visualized.

By dragging to paint upon the views, the analyst can find the maximum resource allocation bottlenecks that occur in this scenario across multiple attempts of the same team at the scenario or of other team attempts at the scenario. To date, we have found that finding bottlenecks visually with the available controls in the RSV is most often between two and four times faster than trying to find the bottlenecks by reviewing game sessions from within the RSR.

DISCUSSION

The RSV tool is available for game players and response coordinators to use to evaluate performance of first responders during a simulated emergency response game play session. Evaluation requires an evaluator to develop the metrics by which an emergency response effort is considered successful. Metrics vary greatly by the different constituents in a community. Some organizations in a community have significant investment in physical assets. Some organizations, like a museum, may have fewer assets but the assets may be of priceless value due to age or significance to human culture. Most constituents agree on the priority of saving human life, but don't agree on the relative priority of saving pets or livestock. Where does the cost of gasoline used to transport responders and resources fall within a list of response priorities?

The RSR tool allows a scenario developer to determine a scoring algorithm and show a team score at all times based on the algorithm at run-time. An analyst can refine the scoring algorithm by analyzing its impact on performance in order to determine its effectiveness in generating desired behavior from game players. Alternatively, an analyst can start with the RSV tool and find an example of team behavior that appears to be most successful and then use that example to build a scoring algorithm based on seeing scenario-appropriate behavior. Ideally, the RSR and RSV tools can be used in unison to iterate upon a better scoring algorithm with which a player can play with software-based agents and get a sense of how well he or she is doing.

We build the RSV tool to support one basic metric of insight generation – the more insights that are generated from interacting with the RSV, the better. Although this is a simple metric, it is consistent with goals of the visual analytics community in general. The RSV should allow anyone to get a deeper sense of how an emergency response effort performed just by interacting with simple widgets that accumulate value in their coordination in groups.

Our observation of RSV users that are already well familiar with RSR leads us to hypothesize that a single scoring algorithm is not sufficient for building an optimal perspective on an emergency response effort to any scenario. Instead, a visual tool like the RSV tool lets an analyst discuss a response team's performance with changing metrics associated with changes in the nature of the unfolding scenario being analyzed. We continue to fine-tune the RSR and RSV tools through a mid-size hospital evacuation scenario being run with hospitals and regional fire departments in the Seattle area.

We are building the RSR simulator with a long-term goal of scaling up to large crisis events such as a Cascadian Subduction zone earthquake scenario. To incorporate such a large and complex scenario, the visualization data model will need to be updated with more field data attributes as attributes are identified as critical to track in a simulation. The RSR visualization panel will likewise need keep pace with enhancements and the interactive RSV visualization tool will need to be enhanced to include coordinated views for those new attributes.

As the PARVAC office is located in Seattle and we collaborate with other institutions up and down the west coast, we are interested in the Cascadian Subduction zone earthquake threat to communities in the Pacific Northwest that looms as a potential disaster similar in scope to the Katrina hurricane. Workshops are held to help communities at risk share plans and coordinate mutual support agreements in preparation for a potential Richter 9 earthquake affecting communities along the length of the tectonic plate boundary from Northern California north to Vancouver Island [12]. Earthquake visualization techniques improve in lockstep with ground motion and structural response data simulators [13]. As a result, we foresee a challenging opportunity to include natural phenomena visualizations in our RSR and RSV tools to help with game play and evaluation.

CONCLUSION

Now that we've established a data model and built a process by which to perform a sense making analysis on any database filled with data that is based on that model, we can iterate on our RSV tool design in order to help analysts help simulation players improve their performance. In fact, we can generate specific versions of the RSV for specific analysts who require a different combination of visualization controls and views based on tools they have used in the past that have guided their thinking. Our RSR tool will continue to allow teams to play simulation sessions, which will continue to feed data into a format the RSV tool can use to let emergency response coordinators review the simulation and discuss potential improvements in strategy. Players can play a simulated scenario as often as necessary to enrich situation recognition, situation awareness, and distribute cognition among coordinators. Visual analytics techniques can be implemented within the RSV tool without having to change the RSR and yet allowing simulation play and analysis to be decoupled.

ACKNOWLEDGMENTS

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