RimSim Response Hospital Evacuation:
Improving Situation Awareness and Insight through Serious Games Play and Analysis

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ABSTRACT

To aid emergency response teams in training and planning for potential community-wide emergency crises, two coordinated research teams centered in King County, Washington have developed software-based tools to provide cognitive aids for improved planning and training for emergency response scenarios. After reporting the results previously of using the tools in pilot studies of increasing complexity, the implementation teams have been searching out community-wide emergency response teams working on emergency response plans that might benefit from use of the tools. In this paper, the authors describe the tools, the application of them to a countywide hospital evacuation scenario, and the evaluation of their value to emergency responders for improving situation awareness and insight generation.

Keywords: *Crisis Management, Emergency Scenario Planning, First Responder Training, Simulation, Situation Awareness*

INTRODUCTION

Communities are preparing diligently for potential community-wide crises arising from natural and man-made causes. First responders are those people who train to fulfill emergency response roles on behalf of community residents, seeking to limit loss of life, protect property, and reduce the cost of long-term recovery periods associated with crisis scenarios. The cost of providing physical drills to train for participation in community-wide crises is exorbitant and the 24/7 demands for first responders can preclude participation in training even if a physical drill is made available. As a result, research teams are exploring the use of software-based simulation environments to help extend training and planning opportunities to synchronous and asynchronous activities using role-play interfaces to simulate the performance of activities independently as well as with other role-players. This paper reviews the activities and results of one research team attempting to evaluate the use of software-based simulation environments as

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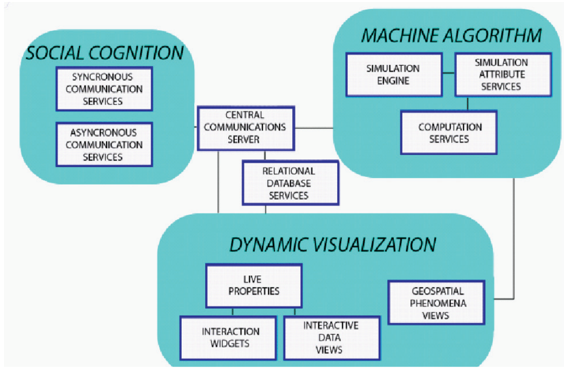
Figure 1. RimSim modular architecture



serious games for first responder training and planning purposes.

As part of the research and development agenda for visual analytics (Thomas & Cook, 2005), researchers have been developing integrated tools for improving analytic capabilities that facilitate application of human judgment to evaluate complex data associated with emergency response efforts. As coordinating artifacts, geospatial visualization assists in knowledge construction and decision support (MacEachren & Gahegan, 2004). In 2006 the Pacific Area Regional Visual Analytics Center (PARVAC) team at the University of Washington began working with regional emergency operation centers to explore the use of geospatial visualizations as a key component in an emergency response crisis scenario simulator, being built to allow first responders to plan and train for community-wide potential emergency scenarios. The team built a series of software components to support a modular architecture they call RimSim, seen in Figure 1, which advises development of simulation environments for first responder planning and training using emergency response scenarios identified by interested partners in the Pacific Northwest region of the United States.

The PARVAC team assesses shared use of geospatial visualization over time through iterations of scenario development tasks combined with simulated scenario game role-play (Campbell & Mete, 2008). The team builds supporting tools to help first response coordination teams explore four concepts in a community-wide emergency response effort: recognition-primed decision-making (Klein, 1998), situation awareness (Adams & Tenney, 1995), distributed cognition (Hutchins, 1996), and distributed intelligence (Pea, 1993). All four suggest models relevant to the use of interactive visual artifacts in the coordination of complex team activities under time-bounded conditions. By working closely with the emergency response community, the team has explored expedient methods for improving emergency response activities effectiveness, which can be attained by improving response behavior in association with any or all of the four models.

Through a series of pilot studies with medical logistics teams that contained a handful of participants, the PARVAC team observed that first response teams improved their emergency response activities performance by using two different methods of considering an emergency response scenario. Through software-supported simulators that used software-based agents to simulate first responder behaviors, first responders participated in simulation sessions that could provide experience with a scenario through repeated game role-play (Campbell, 2010). Simulator-support visualization products enabled a team of responders to play and replay a response effort sequentially in order to review their decisions and the ramifications of decisions made in geospatial and temporal

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space with constraints that would be typical of an emergency response effort. Through a separate tool development process, software-based sense-making and probing tools provided an emergency response team the opportunity to review an emergency response scenario effort as an information space that need not be queried or investigated sequentially, but instead selectively across time and space to look for interesting patterns that provide insights into the nature of the scenario.

To support the two observed methods of exploring a crisis-wide emergency response scenario in emergency operation centers, the PARVAC team iterated upon the development of two separate software tools they now call RimSim Response! (RSR) and RimSim Visualization (RSV). Although the RSR tool allows temporal investigation game play sessions, it does not provide an optimal interactive visual query of coordinated views in an emergency response session that can be used for insight generation – the focus is on role play to build a better real-time situation awareness rather than an after-game sense-making analysis for suggesting alternative approaches to the scenario. The RSV software, on the other hand, allows the team to visually query the team effort in non-sequential temporal investigations to discuss the ramifications of actions made by all participants.

The PARVAC team spent six months working closely with the King County Health Coalition (KCHC), in King County, Washington, to adapt the RSR tool for use in a countywide hospital evacuation scenario that the KCHC used as part of a five-part planning and training process that spanned a year of activities. The process involved an all-member brainstorming scenario-building exercise, an all-member paper-based tabletop exercise, a role-playing computer-mediated simulation drill, a role-playing RSR tool use drill, and a role-playing physical evacuation drill. Each of the five activities involved KCHC staff (the latter three with a subset of the KCHC membership) and allowed the scenario to evolve to better support future planning and training for hospital evacuations. By participating in the scenario development process, the PARVAC team gained the trust of the KCHC that led to KCHC participant willingness to participate in both an RSR and RSV tool assessment process. The resultant RSR and RSV tools were then brought to a new emergency evacuation team in Hartford County, Connecticut to make a second assessment using role-players who had not gone through the scenario development process. Two metrics were chosen to assess the usefulness of the RSR and RSV tools. The team assessed situation awareness quality for the RSR tool and insights generated quality for the RSV tool.

BACKGROUND

The RSR and RSV developers have collaborated via an iterative design and development process that invites software developers to participate as they see fit according to an open source development model. Decisions to include code in the base software packages are made by committee. Some developers work only with the RSR code base and some only with the RSV code base. Others, especially those who communicate often with the KCHC, work with both of the tools as described in this section.

The RSR Tool

The RSR tool was built as a series of software components that could support role-playing games that took place within a simulated emergency response scenario. For the scenario designer, The RSR software affords the opportunity to design and implement a basic emergency response scenario without any necessary programming to extend the base RSR software. To seed a scenario's incidents and resources, the scenario designer uses the editor tool shown in Figure 2.

As the designer can place visual scenario details anywhere on a Java World Wind-based virtual globe that appears in the tool, the scenario can take place anywhere on the surface of Earth and incorporate spatial scales varying anywhere from a small urban neighborhood to

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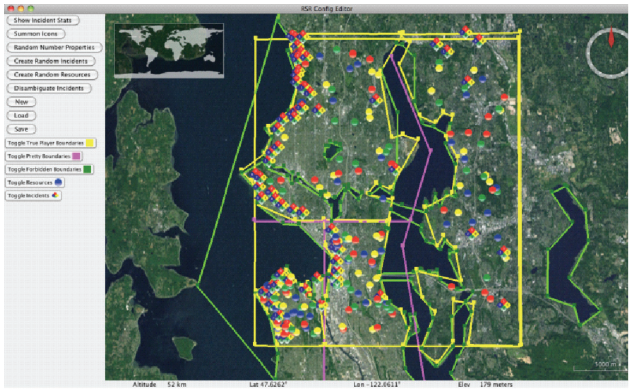
Figure 2. The RSR scenario editor



a full global reach. 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 places the emergency response resources geospatially that a simulation role-player can use to meet incident demand, individually by hand or as in bulk by using one of many menu-driven statistical distributions built into the software. For more specific scenarios, a developer can extend the software before providing it to the emergency response team first responder. A community of developers builds the base RSR tool, including the scenario editor that we describe in (Campbell & Schroder, 2009), and makes it available for download and exploration.

After the designer lays out the basic scenario, the RSR configuration file provides an opportunity to substitute a software-based agent into the simulation for each role identified for game play in the scenario. Those roles that aren't assigned a software-based agent are expected to be played by a live participant who participates in an active role-play simulation session over the Web by taking over the available simulation interaction controls at any time during the session. To gage the progress of scenario development and tool reliability, 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 the game players will. To be able to test often, beta-testing play sessions are announced via e-mail and are open for anyone to play and require only a Java runtime and broadband Internet connection.

During each session, the RSR software logs all key game session variables necessary to replay an emergency response simulation session. As a result, The RSR development team, beta-testing play team, or emergency response planning and training teams can review game play in any session that has been run if provided the session's log file for loading into the RSR tool. Playing the role-play simulation allows first-responders the opportunity to improve their situation awareness of a potential real-world scenario – especially in the area of distributed team activity. Replaying a wide variety of simulated emergency response scenario sessions 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 (Klein, 1998).

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Figure 3. The RSV geospatial page

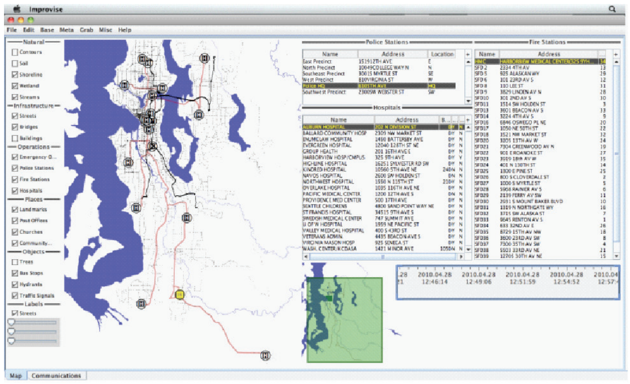
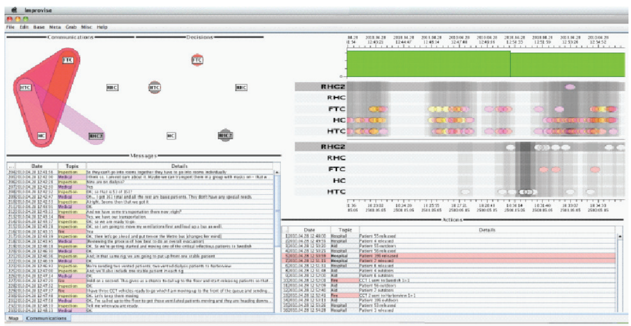


Figure 4. The RSV communications page



The RSV Tool

The RSV tool was built to enable interactive visual querying through a series of highly coordinated views. Data logged during an RSR tool use session can be loaded into the RSV to explore the data in a highly interactive, non-sequential manner. Transcribed verbal communications between role-playing game participants are also loaded to provide an analysis of geospatial game state in conjunction with participant response.

The underlying Improvise software platform (Weaver, 2004) upon which the RSV tool exists enables rapid control widget and views construction. In the RSV the views exist within an interface that provides two tabs to access the two pages of views seen in Figures 3 and 4. The RSV development team allocate widgets such that one visual page provides an emphasis on geospatial analysis of responders, resources, and incidents, while the other provides emphasis on simulation participant communications and actions. The two pages are coordinated such that both sheets update dynamically when the user interacts through the interface in order to refresh all views immediately independent of which page initiates changes.

The view in the upper-left of Figure 3 identifies the same geospatial extent used in the RSR simulation tool session, embedded within a view container in order to be able to communicate with all other RSV tool controls and views. The inset map view in the bottom center of Figure 3 allows an analyst to drill down on a map view of the community with visualization layers that show many commu-

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nity objects relevant to emergency response (fire hydrants, buildings, waterways, roads and highways, police stations, hospitals, etc.). The analyst can toggle the layers using the check-boxes that run down the left-hand margin of the page.

The inset view in Figure 3 lets the analyst consider the context of the scenario's geographical coverage. The analyst can drag the green rectangle to move to a different location or can drag its corners to grow 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 key response resources appear on page one. Upon selecting a named object, the 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 or she 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. Often-used and trained-upon driving emergency routes to hospitals are emphasized with a salmon colored road network of just those roads used whenever possible during a community crisis event.

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 details about the current incident load as incident requirements wax and wane. 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-provided panning, zooming, rubber banding, and brushing 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 resource allocation tasks, 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.

After a simulation session ends and their interpersonal verbal communications have been transcribed to text, the role-playing participants are invited to sit as a team and use the RSV tool to investigate their role-play in response to the scenario goals. Players can ask each other questions about why actions were made and discuss the ramifications of those actions. They can investigate recurrent themes to see how often a specific point-of-view leads to player actions. Over time, the assessment team developed a process whereby the players explicitly point out scenario specific insights that were made during game play and reach a consensus as to the value of that insight on a scale of 1 to 100. The scoring process enables a quantitative analysis across simulation role-playing sessions.

SHARED DATA MODEL

A shared data model helps coordinate RSR and RSV tool development as the same data model is incorporated within both tools. Working backwards from the types of queries they wanted to support, the PARVAC team generated the data model in Figure 5 that could support the RSV tool with three types of data: communications between first response coordinators, actions

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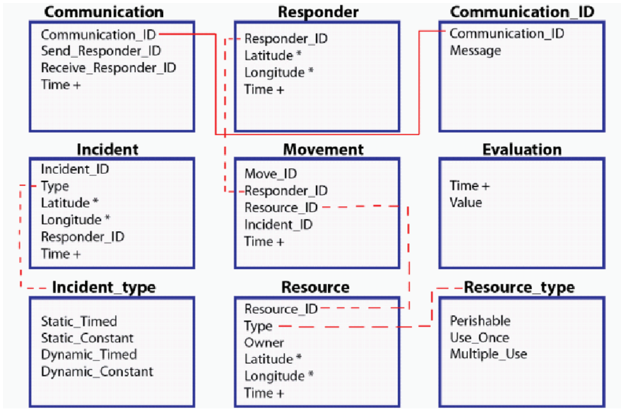
Figure 5. RSR and RSV shared data model



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 updating 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, the software development team revisits the shared data model and, if warranted, updates the data model to incorporate newly identified attributes. Then, the model drives software changes to both the RSR and RSV tools.

In Figure 5, attributes with asterisks can be used to analyze data geospatially (Responder. Latitude, Responder. Longitude, Incident.Latitude, Incident.Longitude, Resource.Latitude, Resource.Longitude). Attributes identified with plus signs enable temporal analysis (Communication.Time, Responder.Time, Incident.Time, Move.Time, Resource.Time, Evaluation.Time). Incident types are connected with a lookup table that can grow to manage scenarios of increasing complexity. Other attributes connected with dashed lines have a primary key – foreign key relationship associated with geospatial relationships. Attributes connected with a solid line are related via temporal relationships that lack concrete geospatial location.

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, an analyst 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 made its way from its base at the hospital to the downed power line incident location, affecting the incident and the resource entities.

To test out the data model's effectiveness, representative entities and relationships were chosen from multiple pilot scenario first response efforts to visualize in the RSV tool. Scenario specific response resources such as police, fire, and medical units were tracked geospatially through the responder entity over time. Vehicles carrying medical supplies or medical patients were tracked as resource entities and supply levels for resources are tracked by separate resource entity tuples for

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each location. The data model turned out to be sufficient for the development team and pilot subjects for all pilot scenario purposes.

In the case of a community-wide 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. The data model provides an analyst the necessary data to 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.

HOSPITAL EVACUATION SCENARIO

After presenting results from various pilot efforts at ISCRAM 2010 (Campbell & Weaver, 2010), the RSR tool development team teamed up with a University of Washington emergency response coordinator to recruit the King County Hospital Coalition (KCHC) in Seattle and Bellevue, Washington, USA to help build a game play scenario for a county-wide emergency hospital evacuation event that had been proposed as future work at the ISCRAM 2010 conference in Seattle. The scenario became the main scenario used for a full year to plan and train responders for the scenario and is described fully in Campbell (2010). The evacuation of patients in a single hospital that housed 200 to 250 patients to the other 20 hospitals participating in a community of mutual aid agreement became the focus of multiple tabletop session and live emergency response drills during 2010. The RSR tool development team attended the activities and participated in the activity preparation, activity performance, and post-activity discussions to iterate upon the RSR scenario that selected KCHC participants would play within the simulation tool. Tool developers observed the scenario to be well developed for inclusion in the RSR tool as a planning aid that could also help train emergency responders who participated in role-playing sessions.

Throughout the year of focus on hospital evacuation scenarios, the RSR and RSV tools were enhanced for any interested KCHC member's use. As the scenario evolved to identify a specific hospital to be evacuated, The RSR tool developers included an interactive hospital patient floor plan view as seen in Figure 6. Through mouse-based interaction with the floor plan view, role players could select patients, interrogate their current state, prepare each patient for evacuation, and suggest a route to take during physical transport. Upon releasing a patient, the view presented an animation of simulated movement of the patient for all role-players to consider and possibly incorporate into their situation awareness.

Two RSR-based game play sessions took place on April 26 and 28, 2010 with selected KCHC participants who had been studying their roles for more than six months and RSV tool use took place the following week in order to evaluate play performance by the team. The play session implementation team was surprised to see the level to which combined RSR and RSV tool emergency response users continued to point out improvements to the scenario roles and scenario event task orchestration. To improve scenario task coordination, the role-playing participants created a task list of eleven additional software changes the RSR tool development team was asked to make in order for the RSR to become more useful to planning and training participants who role-played the scenario. As a result, a final evaluation of tools could not be made effectively without additional refinement.

The RSR tool team's negotiated time frame for working with the KCHC emergency response medical logistics team ended before they had incorporated all the RSR tool software changes suggested by KCHC scenario developers. The RSV tool development and assessment teams had met the objective of developing a workable process to obtain insight generation metrics after a scenario play session. To continue

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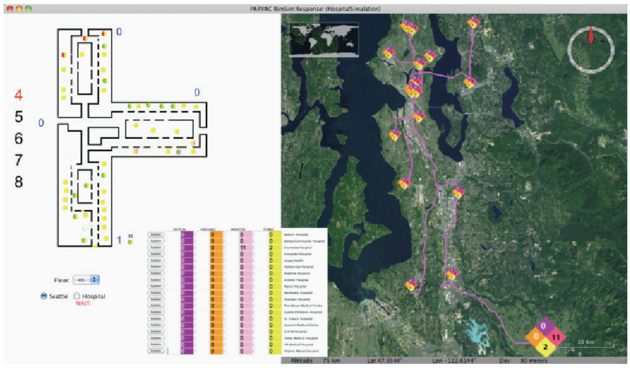
Figure 6. RSR during hospital evacuation scenario



scenario development within the RSR tool, the development team turned their attention to a new team of role-players who had not had the experience of participating in the scenario development, but who would likely have to perform the roles contained in the simulator should an evacuation event occur at their hospital. None of the participants in the second role-playing team had experience with the geography of King County, Washington as they were based in Hartford County, Connecticut (2500 miles to the east).

The assessment team felt the additional requirement of learning new geography would provide interesting results when running two more RSR-based game play sessions with the Hartford County logistics staff. The assessment team hoped the second team's inclusion in RSR and RSV tool use trials would provide a focused perspective on using both tools together for training purposes. The second subject pool was not key emergency response personnel who would be difficult to schedule meeting times with outside of the normal activities of their jobs. The assessment team scheduled the tool use sessions that took place on June 8 and 10, 2010. Similar to the relationship developed between the PARVAC and KCHC, the relationship with the Hartford County team has built mutual trust that can continue to motivate all participants as developers iterate design further on the RSR and RSV tools.

TOOL ASSESSMENT

Situation Awareness

In the June trials, game role-players played the simulated hospital evacuation using the RSR tool while the assessment team recorded their efforts. To gauge situation awareness, the assessment included freeze-probe questionnaires that were asked at ten random points in time during the game session. The five questions asked are listed in the first column of Table 1. The questionnaire took between two and five minutes to administer at each freeze point during role-play.

The KCHC helped the assessment team identify five questions that would suggest situation awareness quality. The questions included: 1) How many patients are in a significant state of discomfort currently? 2) Where are these patients located? 3) How many patients are currently in transit between the evacuating and receiving hospital? 4) How much more time will it require to fully evacuate the existing hospital given ideal circumstances? 5) How much more time will it require to fully deliver all evacuating patients to their receiving hospital given ideal circumstances?

The assessment team calculated a metric of situation awareness quality by comparing the hospital evacuation team role-players' answers to the questions compared to the state

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Table 1. Session 1 v. Session 2, Mean (Std.Dev), Diff, t-test

Question	Session 1 n=30	Session 2 n=30	Difference n=30	t-test data
1	2.933 (3.423)	0.333 (0.606)	2.600 (2.817)	t_{29}=4.347 p=0.0002
2	8.133 (8.253)	4.267 (4.362)	3.867 (3.891)	t_{29}=2.610 p=0.0142
3	2.467 (3.350)	0.533 (1.042)	1.933 (2.308)	t_{29}=3.537 p=0.0014
4	2.533 (1.655)	1.133 (1.042)	1.400 (0.614)	t_{29}=5.558 p<0.0001
5	19.667 (12.888)	15.9 (6.583)	3.767 (6.305)	t_{29}=2.055 p=0.049

of the scenario as contained in the simulation. The metrics were calculated for each of the two role-playing sessions, comparing situation awareness with use of the RSR tool interface to situation awareness attained previously without use of the RSR tool interface. Three players answered the five questions ten times each for each session, providing a sample-size of 30 questions to compare between sessions.

Session 1 did not use the RSR tool interface but provided role-players the opportunity to verbally inquire about the state of the simulation and make their own visualizations using pen and paper. The second column in Table 1 shows the mean and standard deviation of how far off the subject's answer to a question was from the state of that variable in the simulation for session 1. Subjects then spent the next two days getting familiar with the RSR tool interface before a second simulation session took place.

Session 2 required the role-players to use the RSR tool interface to track the state of the simulation without the help of any verbal inquiries to the assessment team. The third column in Table 1 shows the mean and standard deviation of how far off the subject's answer to a question was from the state of that variable in the simulation for session 2. The simulation engine remained the same in both sessions and managed the state of key simulation variables in response to role-player and simulated player actions. The roles of the players were kept identical, as was the beginning state of the simulation they encountered at the start of the role-playing session.

When comparing the level of distributed situation awareness accuracy between the game play session with and without the RSR tool interface, a paired-t statistic comparing situation awareness accuracy showed significant improvement when using the RSR tool interface compared to the session without. For question one, the mean number of improvement (M=2.6, SD=3.28, N=30) was significantly greater than zero, t(29)=4.347, two-tail p = .0002, providing evidence that the situation awareness of discomforted patients was higher with the RSR tool interface.

The t(29) statistic for question two showed a mean number (M=3.867, SD=8.114, N=30) that was significantly greater than zero, t(29)=2.610, two-tail p = .0142, providing evidence that the situation awareness of discomforted patient location was higher with the RSR tool interface than without.

The t(29) statistic for question three showed a mean number (M=1.933, SD =2.99, N= 30) that was significantly greater than zero, t(29)=3.537, two-tail p = .0014, providing evidence that the situation awareness of in-transit patients was higher with the RSR tool interface than without.

The t(29) statistic for question four showed a mean number (M=1.400, SD =1.380, N= 30) that was significantly greater than zero, t(29)=5.558, two-tail p < .0001, providing

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evidence that the situation awareness of the time to complete the scenario was higher with the RSR tool interface than without.

The t(29) statistic for question five showed a mean number (M=3.767, SD =10.040, N= 30) that was significantly greater than zero, t(29)=2.055, two-tail p = .0049, providing evidence that the situation awareness of discomfort patient location higher with the RSR tool interface.

To summarize Table 1, all five questions showed significant improvement with 95% confidence when using the RSR tool interface compared to when not as developed for the June 2010 use sessions.

Insight Generation

In the June trials, evaluators asked the role-playing team in training to verbalize the insights they had gained in regards to meeting the objectives of the hospital evacuation scenario. Evaluators recorded all verbal statements and game interface actions and transcribed them into a format appropriate for visualizing the data in the RSV tool. Players could then use the RSV tool to review their game play outside of the time pressure the simulated game-playing environment suggested. With the RSV tool, the role-play team identified all insights they had experienced throughout the game play session.

The definition of insight continues to be challenged more by researchers than the definition of situation awareness. Insight has varying definitions that appear to be honing in on two different definitions pursued by two distinct research groups — computer scientists and cognitive scientists (Chang & Ziamkiewicz, 2009). Computer scientists investigate insight as a contribution to knowledge building whereby each insight contributes to a relationally semantic knowledge base that enables problem solving and reasoning heuristics. In this regard, each insight is a describable incremental piece that adds value to the whole knowledge base — insight as a noun. Cognitive scientists investigate insight as a neurological function of the brain's left hemisphere where a new perspective on a problem is gained through a burst of brain activity — insight as a verb. Evaluators asked role-playing participants for a listing of all insights irrespective of whether they met the requirements of either or both definitions.

Along with help from the evaluators' notes taken during game play, the role-players listed all the insights they had that helped them make progress toward hospital evacuation objectives. The game role-players provided a time stamp and score on a scale from 1 to 100 as to the significance of each insight to overall scenario objectives attainment. Players discussed the scores at length if necessary to reach a consensus on the value to their overall shared performance. Evaluators watched the process and asked questions they believed could help the process become more accurate without suggesting new insights not identified by the game role-players themselves.

Evaluators noted how players interacted with the RSV in order to remember what had been said and the time the remarks had been spoken. Players asked a facilitator to scroll the chronological messages widget on the RSV Communications page to remind them of exact words spoken and cross-referenced the chronological glyph representation to review their thoughts during long periods of quiet on all communication channels. Patients also reviewed the timings of patient evacuations to gain a sense of how well they were grouped for transport to other hospitals. Although evaluators watched both the Communications and Decisions graphs change dynamically as other widgets were scrolled, the subject team did not discuss them at all to help them confirm their insights.

Role players challenged themselves to remember what they were thinking about when there were long absences between spoken words as if they were justifying the long gaps in interpersonal communication. The observers found that process to be one of the most important in team-building and in generating insights that could lead to a better distributed situation awareness in future game sessions. Participants

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suggested that the gaps in the presentations of scrollable timelines jumped out at them first and foremost before they considered the detailed distribution of glyphs overlaid upon the views associated with the timelines.

One of the more interesting results to the RSR development team came about when comparing insight generation scores between a paper-based interface that did not use the RSR tool interface (but did use the back-end simulation to run the scenario) and the RSR tool game interface. Evaluators found that the total insight generation score increased from 1,889 to 2,487.

Evaluators found it interesting that the RSR tool interface use trial generated 49 insights that were scored at less than ten points by the players versus only 17 insights scored less than ten during the paper-based trial. As a result, it appeared to the RSR development team that perhaps the computer-based interface lets players consider the evacuation at a higher level of resolution than their usual paper-based interface. Evaluators also found that five higher scored insights were generated significantly earlier in the RSR tool interface trial and three key scored insights were made by different role-players in the RSR tool interface trial.

Because both game play periods were exactly two hours in duration, a normalized insights metric on a per minutes played basis can be calculated by dividing the insight scored values by 120 minutes. The insights generation metric appeared to be highly dependent on the range of activities that took place before the game was played by role-players. The paper-only trial identified the physical cognitive aids (all consisting of words and symbols written on pieces of paper) players would have chosen to use in the absence of an available computer-based interface. Further details about the objectives, cognitive aids, and outcomes of role-playing trials are available in Campbell (2010).

DISCUSSION AND CONCLUSION

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 who judge first responder performance 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. And, we observed, there is a wide difference in opinion regarding where 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 by reviewing a role-play scenario session 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 recording scenario-appropriate behavior during RSR tool use. 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.

A development team built the RSV tool to support a metric of insight generation – the

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more insights generated from interacting with the RSV, the better. Although insight may appear to be just one valuable metric, raising its priority is consistent with recent goals of the visual analytics research community in general. Overall, the RSV tool should allow anyone to get a deeper sense of how an emergency response effort performed just by interacting with simple widgets that accumulate additional value when use is coordinated in groups.

The RSV developers observed that RSV users who were familiar with the RSR tool could not agree on a single scoring algorithm as being sufficient for building an optimal perspective on an emergency response effort to many scenarios. 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. A discussion of metric relevancy can be facilitated through prolonged RSV consideration as well.

Participants in the RSR and RSV tool development teams have remarked how many insights they have gained by participating in both the software development process and scenario development process. No one on either development team had much exposure to the roles involved with hospital emergency response logistics teams so both teams developed many insights about the nature of emergency response just by working with experienced individuals who have the responsibility of the community to be prepared for responding to crisis scenarios. The RSR tool team developers gained insights into potential RSR interface components that were successfully deployed in the RSV tool. The RSV tool development team gained insights into potential RSV interface components that were already implemented in the RSR tool. As a result, the two teams have been discussing a closer-knit development coordination process moving forward. Both teams agree they could continue to fine-tune the RSR and RSV tools through simulating other mid-size hospital evacuation scenarios being run with hospitals and regional fire departments elsewhere in the world. Other scenarios could help verify the usefulness of the approach of maintaining a core software base from which new scenarios could be encoded.

FUTURE WORK

In order to scale up to larger and more complex scenarios, 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 components will need to keep pace with new enhancements and the interactive RSV visualization tool will need to be enhanced to include coordinated views for new attributes added to support better scenario realism.

As the information visualization community works to transform the art of information presentation views into a better-founded science, highly relevant research publications suggest new widgets, views, and interaction techniques to be considered in both real-time simulation game interfaces and sense-making tool interfaces. Many potential countywide emergency response scenarios can benefit from detailed geospatial and temporal analysis. As the skill level rises in visual literacy of complex interfaces, the RSR and RSV teams can work to incorporate and assess emergent suggestions from the literature. Already, the RSV team is considering a more detailed presentation of geospatially moving assets in the mapping display views of the RSV.

As the PARVAC office is located in Seattle and researchers have a history of collaborating with other institutions up and down the west coast of North America, the PARVAC researchers 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 event along the Gulf Coast of North America. Already, various workshops have been 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

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Northern California north to Vancouver Island (Pacific North West Economic Region, 2006). Earthquake visualization techniques improve in lockstep with ground motion and structural response data simulators (Meyer & Wischgoll, 2007). As a result, the RSR development team foresees a challenging opportunity to include natural phenomena visualizations in both the RSR and RSV tools to help with game play and evaluation.

The software development teams see some benefit to cross-pollinating the visual components between the RSR and RSV tools in order to provide a richer experience during game play. Perhaps there is potential to analyze past actions during role-play in a manner similar to post-simulation analyses performed today. In that case, RSV widget controls and views would need to be integrated into the RSR tool to enable such evaluations to take place by the first response team members or a specialized team member who trained on that specific skill within an emergency operations center. Real-time simulation controls could be added to the RSV tool in order to allow the emergency response team to replay a part of the simulation differently as part of a what-if analysis. Research processes of the nature presented in this paper will continue to be refined as a part of a large global community working on first responder emergency response scenario planning and training.

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REFERENCES

Adams, M. J., Tenney, Y. J., & Pew, R. W. (1995). Situation awareness and cognitive management of complex systems. *Human Factors*, *37*(1), 85–104. doi:10.1518/001872095779049462

Campbell, B. (2010). *Adapting simulation environments for emergency response planning and training.* Unpublished doctoral dissertation, University of Washington, Seattle, WA.

Campbell, B., Mete, O., Furness, T., Weghorst, S., & Zabinsky, Z. (2008, May 12-13). Emergency response planning and training through interactive simulation and visualization with decision support. In *Proceedings of the IEEE International Conference on Technologies for Homeland Security*, Waltham, MA (pp. 176-180).

Campbell, B., & Schroder, K. (2009). Training for emergency response with RimSim:Response! In *Proceedings of the Defense, Security, and Sensing Conference*, Orlando, FL.

Campbell, B., Schroder, K., & Weaver, C. (2010). RimSim visualization: An interactive tool for post-event sense making of a first response effort. In *Proceedings of the 7th International Conference on Information Systems for Crisis Response and Management*, Seattle, WA.

Chang, R., Ziamkiewicz, C., Green, T. M., & Ribarsky, W. (2009). Defining insight for visual analytics. *IEEE Computer Graphics and Applications*, *29*(2), 14–17. doi:10.1109/MCG.2009.22

Endsley, M. R. (2004). Situation awareness: Progress and directions . In Banbury, S., & Tremblay, S. (Eds.), *A cognitive approach to situation awareness: Theory, measurement and application* (pp. 317–341). Aldershot, UK: Ashgate Publishing.

Hutchins, E. (1996). *Cognition in the wild*. Cambridge, MA: MIT Press.

Klein, G. A. (1998). *Sources of power: How people make decisions*. Cambridge, MA: MIT Press.

MacEachren, A. M., Gahegan, M., Pike, W., Brewer, I., Cai, G., Lengerich, E., & Hardisty, F. (2004). Geovisualization for knowledge construction and decision support. *IEEE Computer Graphics and Applications*, *24*(1), 13–17. doi:10.1109/MCG.2004.1255801

Pacific North West Economic Region. (2006). *BLUE CASCADES III: Critical infrastructure interdependencies exercise: Managing extreme disasters*. Bellevue, WA: Pacific North West Economic Region.

Pea, R. D. (1993). Practices of distributed intelligence and designs for education. In Salomon, G. (Ed.), *Distributed cognition: Psychological and educational considerations*. Cambridge, UK: Cambridge University Press.

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Thomas, J. J., & Cook, K. A. (Eds.). (2005). *Illuminating the path: The research and development agenda for visual analytics*. Richland, WA: National Visualization and Analytics Center.

Weaver, C. (2004, October). Building highly-coordinated visualizations in improvise. In *Proceedings of the IEEE Symposium on Information Visualization*, Austin, TX (pp. 159-166).

Weaver, C., Fyfe, D., Robinson, A., Holdsworth, D., Peuquet, D. J., & MacEachren, A. M. (2007). Visual exploration and analysis of historic hotel visits. *Information Visualization*, *6*(1), 89–103.

Wischgoll, T., & Meyer, J. (2007). *Earthquake visualization using large-scale ground motion and structural response simulations*. Retrieved from http://imaging.eng.uci.edu/~jmeyer/ PAPERS/c-25.pdf

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