Investigating Geospatial Holograms for Special Weapons and Tactics Teams

Sven Fuhrmann
(corresponding author)
Nevada J. Smith
Department of Geography
Texas State University
fuhrmann@txstate.edu
smith.nevada@gmail.com

Mark Holzbach
Zebra Imaging
Austin, TX
mholzbach@zebraimaging.com

Terry Nichols
San Marcos Police Dept.
TNichols@sanmarcostx.gov

Special Weapons and Tactics (SWAT) teams rely heavily on collecting and applying geospatial intelligence. Traditional two-dimensional mapping products might limit or hinder successful operations by not showing important three-dimensional information of the terrain and its natural and/or human-built objects. Geospatial holograms are able to display these three dimensional spatial features to users without requiring special eyewear or using complex viewing technologies. A point light source is all that is required to make the imagery visible. Before introducing geospatial holograms into the SWAT domain, where lives are at potential risk, a series of usefulness, acceptance, and usability tests need to be performed. One of the key geospatial hologram design requirements identified for SWAT incidents was support for effective route planning and wayfinding. This paper will report about a first pilot study that investigated and compared wayfinding performance of SWAT teams using both traditional 2D imagery and geospatial holograms. Our initial research indicates that geospatial holograms could enhance SWAT operations, especially in multi-story environments. In the pilot study geospatial holograms were positively reviewed by SWAT team members and were described as a technology that should be further explored.

Keywords: Geovisualization, Geospatial Holograms, Special Weapons and Tactics, Spatial Cognition, Usability

INTRODUCTION

Current domestic and international terrorism threats increase the demand for developing usable and useful tactical geovisualization tools for implementation with Special Weapons and Tactics (SWAT) teams. SWAT teams are responsible for handling high-risk tactical situations, e.g. hostage situations or barricaded suspects. Their primary operational goal is the successful resolution of these situations without injury or loss of life to citizens, suspects, or law enforcement officers (Cappel 1979). Depending on the incident, tactical decisions in SWAT situations mostly rely on experience, education, and geospatial intelligence gathered through observations, the use of aerial photography, and analog or digital maps. The goal of tactical decision making in SWAT situations is to combine analytical and sometimes intuitive solutions, arrive at an appropriate decision, and successfully accomplish a mission (Heal 2006; Bailey 2006; Jones 1996). Digital mapping services, such as Mapquest, Google Maps, Google Earth, and Microsoft Virtual Earth, increasingly serve as analytical tools in planning and managing SWAT incidents. The usage of Web-mapping

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tools within the SWAT domain indicates that first responders and decision makers consider these Web-mapping services highly valuable for many aspects of incident management. These Web-mapping services offer many improvements over traditional paper maps: (1) the datasets are detailed and almost up to date (depending on the service subscription), (2) the technology allows combining topographic information with aerial photography on the fly, (3) the basic mapping service is free, and (4) the graphical user interfaces are relatively easy to use. Recently, with the release of Google Earth and Microsoft Virtual Earth, Web-mapping has become also three-dimensional, i.e. it allows perspective terrain visualization including buildings and other landmarks. These are important features for SWAT incident planning and response, but it must be noted that the current three-dimensional Web mapping technologies in combination with a standard computer monitor offer only a flat two-dimensional view of the three-dimensional models and not a fully realistic three-dimensional visualization.

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Two and three-dimensional Web-mapping techniques could become a standard for managing many crisis situations. However, one must realize that Web-mapping services also provide numerous shortcomings and potential pitfalls. Web-mapping technologies might work fine during certain crisis situations, such as train derailments, large forest fires, warrant services, etc., but might face serious shortcomings if their base technologies such as electric power and/or computer networks fail. Small screen displays of laptops and/or desktops do not fully support the collaboration between law enforcement officers and/or decision makers. User interfaces of Web mapping applications are language-dependent and/or literacy-dependent and could hinder the communication in a hostage situation, such as between released hostages and law enforcement officers. Especially in high-stress and high-anxiety situations (high school shootings or hostage incidents, for example), first responders, decision makers, and other entities involved need technologies at their disposal that allow them to generate intelligent tactics and support the creation of a common operational picture. These shortcomings of today's Web-mapping services guided the exploration and development of geospatial holograms for tactical geovisualization in SWAT operations.

GEOVISUALIZATION REQUIREMENTS DURING SWAT OPERATIONS

". . . key requirements for geospatial hologram design are that it supports tactical planning, collaboration, and response at a moment's notice and helps build an instant common operational picture."

Snow (1996) explains that the most efficient tactical plan in SWAT operations must be kept simple and flexible so that it can be updated and changed at any minute. Thus, key requirements for geospatial hologram design are that it supports tactical planning, collaboration, and response at a moment's notice and helps build an instant common operational picture. Before a SWAT team responds to an incident with or without force, it collects geospatial intelligence. Geospatial intelligence (GEOINT) is a fairly new field and is broadly defined by the National Geospatial-Intelligence Agency as "the exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features and geographically referenced activities on the Earth. GEOINT consists of imagery, imagery intelligence, and geospatial information" (National Geospatial-Intelligence Agency 2008: 3). SWAT teams rely heavily on geospatial intelligence, less on remotely sensed data, because of the operational extent, but during their terrain analysis SWAT teams evaluate which features or locations (ranging from large buildings, towers, and hills to much smaller elements such as ditches, ventilation systems, and windows) will provide the suspect and the law enforcement officers with tactical advantages and disadvantages (O'Sullivan 1991; Heal 2006).

In the SWAT context, terrain analysis does not have the classical GIScience meaning of using remote sensing and elevation information to determine the morphology of a landscape or the influence of topography on environmental processes. Terrain analysis is the collection, analysis, evaluation, and interpretation of geographic information on the natural and man-made elements of the operation area to predict the effect of the terrain on SWAT operations. SWAT terrain analysis often includes an "eyes-on" assessment (Kolman 1982; Bolz, Dudonis, and Schulz 2002) to determine the line of sight and the potential fields of fire, i.e. the potential areas that can be covered with a weapon from one position (Mijares, McCarthy, and Perkins 2000). Once the potential fields of fire are determined, SWAT members usually try to determine cover, concealment, obstacles, and barriers (Grindle et al. 2004). The SWAT team usually tries to determine which obstacles and barriers might work in favor of law enforcement operations, since these objects might also block potential escape routes for the suspects (Bolz, Dudonis, and Schulz 2002). Barriers might not always have negative properties in SWAT operations, e.g. barriers such as a storm drain might hinder direct crossing, but could function as cover. The last step in the terrain analysis determines the routes of approach and escape. This task is often accomplished by the use of air photos and helicopter observations (Office of the Inspector General 2006; Heal 2006). The approach routes must provide concealment and/or cover and contain no barriers and fewer obstacles, while the potential escape routes should be covered by the field of fire. Thus, another key requirement for geospatial hologram design for SWAT incidents is to support effective route planning, spatial learning, and wayfinding.

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Tactical mapping, the use of maps or other forms of spatial representations for defining action plans and mission strategies, during fast-paced SWAT incidents is usually done (given the dynamic nature of the events) on car hoods, police car doors, paper scraps (e.g., napkins), and whiteboards, and more recently with Geographic Information Systems (GIS) and online mapping tools (Greene 2002; Sorensen 1998; Leipnik and Albert 2002; Wang 2005). However, these tactical geovisualizations cannot fully represent the three-dimensionality of the surrounding environment (which, as in most SWAT incidents, is within urban boundaries). Heal (2006) lists as one critical factor for urban operations the three-dimensionality of the urban landscape, i.e. multistory houses, towers, bridges, and drainage ditches, which often provide disadvantages for SWAT operations, i.e. close shooting ranges, potential ambushes, communication breakdowns, and the presence of civilians in close by residences. Thus, tactical mapping is required at several scales. Small scale representations of incident sites usually require aerial still photographs and videos taken by a helicopter. The main goals for the small scale terrain mapping are to a) document the built environment, b) set the inner and outer perimeters of the incident site, and c) determine tactical advantages and disadvantages (Snow 1996; Jones 2001). Geospatial intelligence is also collected at larger scale: Floor plans and sketches are obtained of the incident site and the adjacent buildings. Residents and/or employees are questioned for information about the building structure, hallways, doors, and windows. Typical large-scale information also includes details such as door structures, door swing directions, the location of light switches, and the type of lighting (Jones 2001). Thus, another key requirement for geospatial hologram design for SWAT incidents is to support multi-scale representation for tactical planning, wayfinding, and decision making.

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HOLOGRAMS

The Greek-based term *hologram,* meaning "whole or complete writing," describes very well that holograms contain full optical information, allowing the three-dimensional storage and representation of objects and scenes (Kasper and Feller 2001; Hariharan 2002). Holograms were first conceived of in the late 1940s by Dennis Gabor and have ever since been an object of and for scientific research and public interest (Heckman 1986). Over the last several decades holograms have been often associated with visualizing three-dimensional objects for entertainment and eye-catching purposes in amusement parks, commercial product presentations, and art/conference exhibitions and as anti-counterfeit additions to credentials such as credit cards, software license documents, and convention badges (Figure 1).

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Holograms are instantiations of a class of technologies that utilize the physics of light diffraction to transform or manipulate light. Many of these technologies have the ability to create optical illusions of solid three-dimensional objects or scenes (Kasper and Feller 2001; Hariharan 2002). Photographs usually record the light waves (brightness and color) that are reflected from an object or a scene, while holograms record both a reference light wave (i.e. a laser beam) and the amplitude of reflected light waves from an object or scene. These two reference and object beams are creating an interference pattern which is recorded on the holograms. When correctly illuminated, holographic interference patterns are decoded by the human physiological system, and a realistic three-dimensional scene appears before the human eye (Kasper and Feller 2001; Hariharan 2002; Heckman 1986).

The technology applied in this research utilizes a digital version of holographic technology that is growing out of the Massachusetts Institute of Technology (MIT) Media Laboratory research. The technology is capable of accurately depicting digital three-dimensional structural and terrain information recorded on flat or flexible plastic panels of laminated photopolymer film with full-parallax (i.e., both vertical and horizontal parallax). Users can view these holograms without special glasses, goggles, or tethered eyewear. Only a single point light source, i.e. unobstructed sunlight, a standard LED flashlight, or a standard halogen light, is required to make the imagery visible. Compared to previous versions these holograms are lightweight and use very little space (Figure 2).

"The technology is capable of accurately depicting digital three-dimensional structural and terrain information . . ."

These "modern" holograms differ from traditional holograms. Previously, holograms required as input physical objects on the scale of the recording material and could not easily be tiled together to form larger displays. Nowadays, a number of commercially available three-dimensional digital scanning technologies, e.g. NextEngine's 3D scanner or ATOS by Capture 3D can be used to generate source input data for holograms. Most 3D scanners collect three-dimensional surface information through light, ultrasound, or x-ray and digitally reconstruct these objects as three-dimensional models. While the 3D scanner technology mostly works for smaller objects (although examples for larger objects include commercial airplanes), scanning urban spaces or natural landscapes with these devices is not feasible. For small-scale representations, e.g. urban terrain or a university campus, digital models have to be developed through three-dimensional modeling software, e.g. Google SketchUp, Autodesk Maya, or ArcView 3D Analyst. Nowadays, these digital three-dimensional models replace the old analog models, and the interference patterns are no longer physically recorded (through an actual laser beam), but created through a computational model in which a virtual camera provides the potential viewpoints and interference patterns. In theory, holograms can be created

Figure1. Hologram of the Texas State University campus.

from any digital three-dimensional geospatial model or scene. In the last decade, the production times for holograms have decreased from several days to several hours; thus the designer of these digital model-based holograms just needs to decide which geospatial objects and patterns to include in the final product.

"In the last decade, the production times for holograms have decreased from several days to several hours . . ."

In comparison to traditional analog maps or photos and dynamic two-dimensional electronic displays, the holograms have a low (1 mm) resolution on the surface, but offer a far higher information content because of their directional resolution. Two-dimensional media, such as photographs or maps, display the same information regardless of the viewing angle while holograms can display different spatial information according to the viewing angle of the user. Modern holograms can actually encode spa-

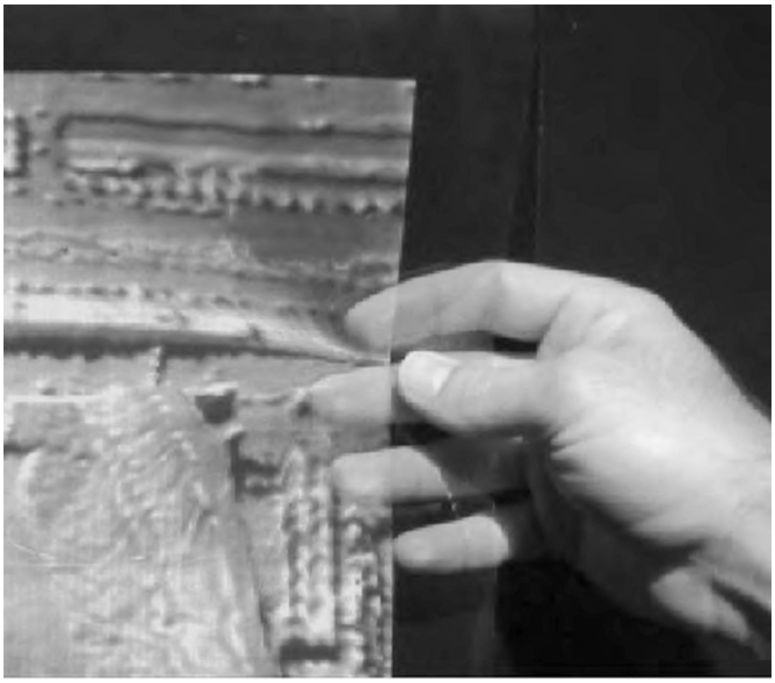

Figure 2. Digital holograms recorded on photopolymer film.

tial information for over one million different viewing angles. Although visualizing one million angles is not practical for a human viewer; this large data storage capacity is required for creating a display that can create and control such a powerful illusion. A one-foot-square map printed at 600 dots per inch with 16.7 million different colors (24-bit = 3 bytes) contains about 156 MB of information (7200 dots * 7200 dots = 51.8 million dots multiplied by 3 bytes) whereas a one-foot-square hologram printed at 25.4 holographic elements (hogels) per inch with the same number of colors contains about 365 GB of information (1 hogel containing 1280x1024 pixels with 24-bit colors results in 3.9 MB/hogel; one square feet of hogels (93025 hogels) results in approximately 365 GB). Since the information in the hologram can be controlled according to viewing direction, entirely different data sets (e.g., variable 3D models or multi-scaled scenes and objects) can be presented at different angles. Benton and Bove (2008) provide a further outlook of different holographic technologies and describe optical computing, metrology, microscopy, and non-destructive testing as important holographic application areas that go far beyond "traditional" display holography. The holy grail, however, in three-dimensional display technology is a dynamically updatable hologram, a challenge that might be solved in the coming years (Benton and Bove 2008).

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INVESTIGATING WAYFINDING PERFORMANCE AND ACCEPTANCE OF GEOSPATIAL HOLOGRAMS

Before introducing geospatial holograms into a domain where lives are at high risk, a series of usefulness, acceptance, and usability tests need to be performed. One of the key geospatial hologram design requirements for SWAT incidents was identified as supporting effective route planning and wayfinding. This paper will report about a first pilot study that assessed acceptance and compared wayfinding performance of SWAT team members with a traditional map and a geospatial hologram in a multistory maze.

The study was conducted at a three-story laser tag facility in Austin, Texas. Laser tag is a leisure action game in which participants wear a lightweight vest and carry a futuristic "phaser" to "tag" opponents with a visible laser light beam and score points. At the end of each game, participants receive a score, hit-to-shot ratio, rank, and winning team information. The laser tag facility used in this study was an indoor arena containing a three-dimensional maze consisting of towers, ramps, alleys, and bridges rising up to sixteen feet. Flexible light, sound effects, and fog settings allow for creating custom test environments. For this pilot study we set the lighting level to a low (dim) setting and did not utilize any sound effects, fogging, or tagging equipment.

In collaboration with a commander of the Hays County SWAT team, we designed a 2D tactical map and a geospatial hologram of the laser tag facility. Both geospatial representations were generated at the same scale and media extent. The 2D tactical map (Figure 3) was printed on paper and utilized a five-step grayscale classification and numeric data to indicate height information. Arrowheads indicated ramp slope and direction. The geospatial hologram (Figure 4) showed a three-dimensional representation of the maze. The monochromatic nature of the hologram did not encode color changes or arrowheads to indicate ramp slopes or direction. The walls of the towers and bridges in the hologram were semi-transparent. The paper map and the holographic image of the maze were placed on two different tables in the preparation room and lighted from above. No special user interfaces or additional visual aids were provided to the participants. Participants could freely turn (or walk around) the geospatial hologram and the paper map so that both representations could be studied from any angle.

Eight male SWAT team members from the Austin Police, Hays County, and Travis County SWAT teams participated in this pilot study during their active duty. All participants did not receive previous training in map reading or wayfinding and were novices to geospatial holograms. SWAT commanders gave our initial study a ninety-minute window in which we had access to these domain experts. This narrow time window required us to conduct the study with four observers and one study coordinator to ensure a smooth workflow. Before the arrival of the SWAT team members, we conducted several pilot runs with volunteers from the laser tag facility to filter out any potential on-site problems and to ensure that our observers knew the workflow. Since holograms often astonish first-time viewers, all SWAT team members were introduced to holograms and invited to review a non-study-related hologram to get accustomed to this visualization technology.

"All participants did not receive previous training in map reading or wayfinding and were novices to geospatial holograms."

After being accustomed to the three-dimensional representation potentials of holograms, participants received a numeric ID badge and had to wait in the waiting area without access to holograms or the maze. Two targets, one red and one yellow chair, were placed in separate locations of the maze. The dim lighting of the maze made it possible to conceal the targets in locations not directly visible to the participants. Target one (the red chair) was placed in a location which required a moderate amount of navigation, while target two (the yellow chair) required navigation through several levels of the maze. Each subject participated in a total of four randomly given tasks: 1) a paper map-based search for target one, 2) a hologram-based wayfinding to target one, 3) a paper map-based navigation to target two, and 4) a hologram-based search for target two. The observers working in the preparation room would randomly assign one of these tasks to an incoming participant. The participant would be exposed

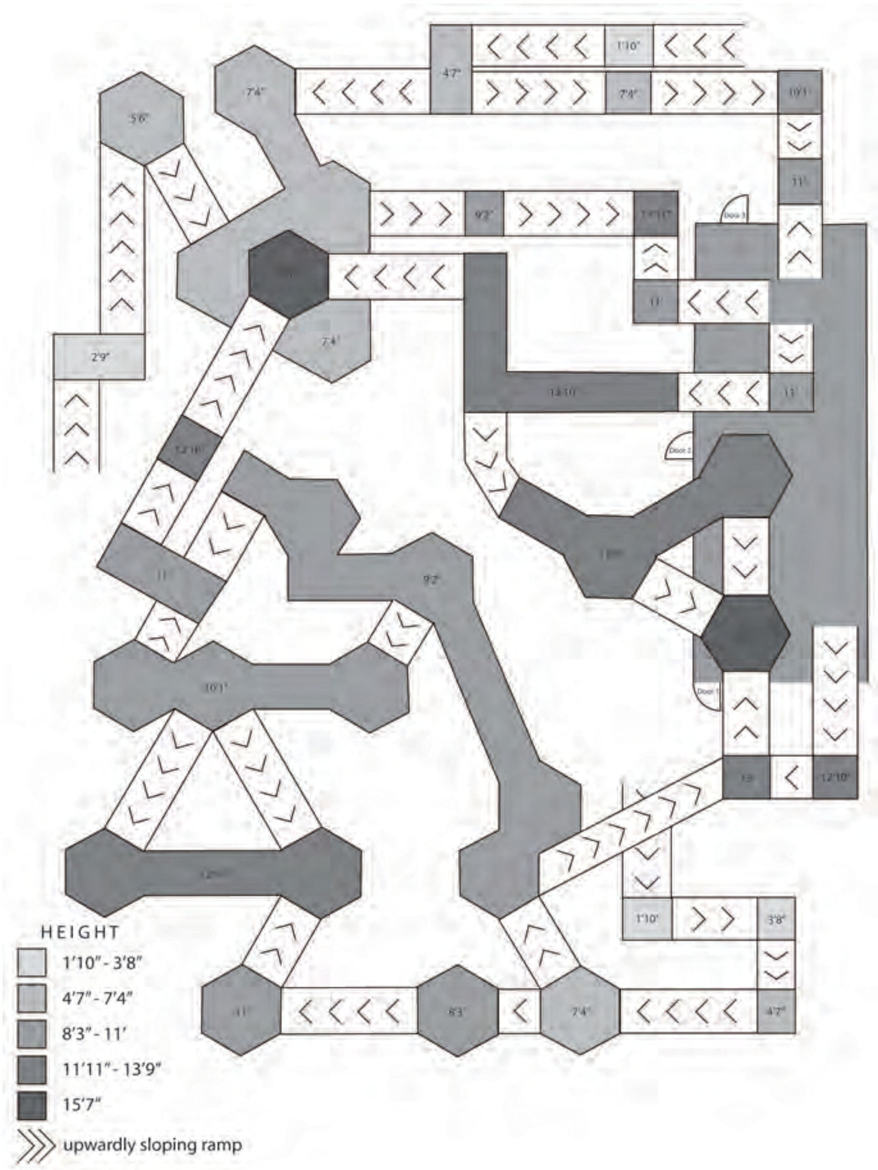

Figure 3. Two-dimensional map of the laser tag facility.

"The participant would be exposed to either the two-dimensional paper map or the geospatial hologram of the laser tag facility, asked to plan a route between the entry point of the maze and target one or two, and would let the observers know when he was finished with route planning."

to either the two-dimensional paper map or the geospatial hologram of the laser tag facility, asked to plan a route between the entry point of the maze and target one or two, and would let the observers know when he was finished with route planning. Participants were not asked to record the planned route, nor were they allowed to carry the spatial representations or any other recordings into the maze. As soon as the subject indicated that he finished route planning, he was guided to the entry point of the maze.

Information about the given wayfinding task was handed to one of the maze-based observers which would follow the participant in the maze and time each participant's wayfinding performance as he attempted to locate the target. Once the wayfinding task was completed, the executed task was marked on the badge and the participant was guided back to the waiting area. Testing was repeated using the different geovisualization media and targets until a participant had taken part in all four tasks. After finishing the wayfinding study, all participants were surveyed about their

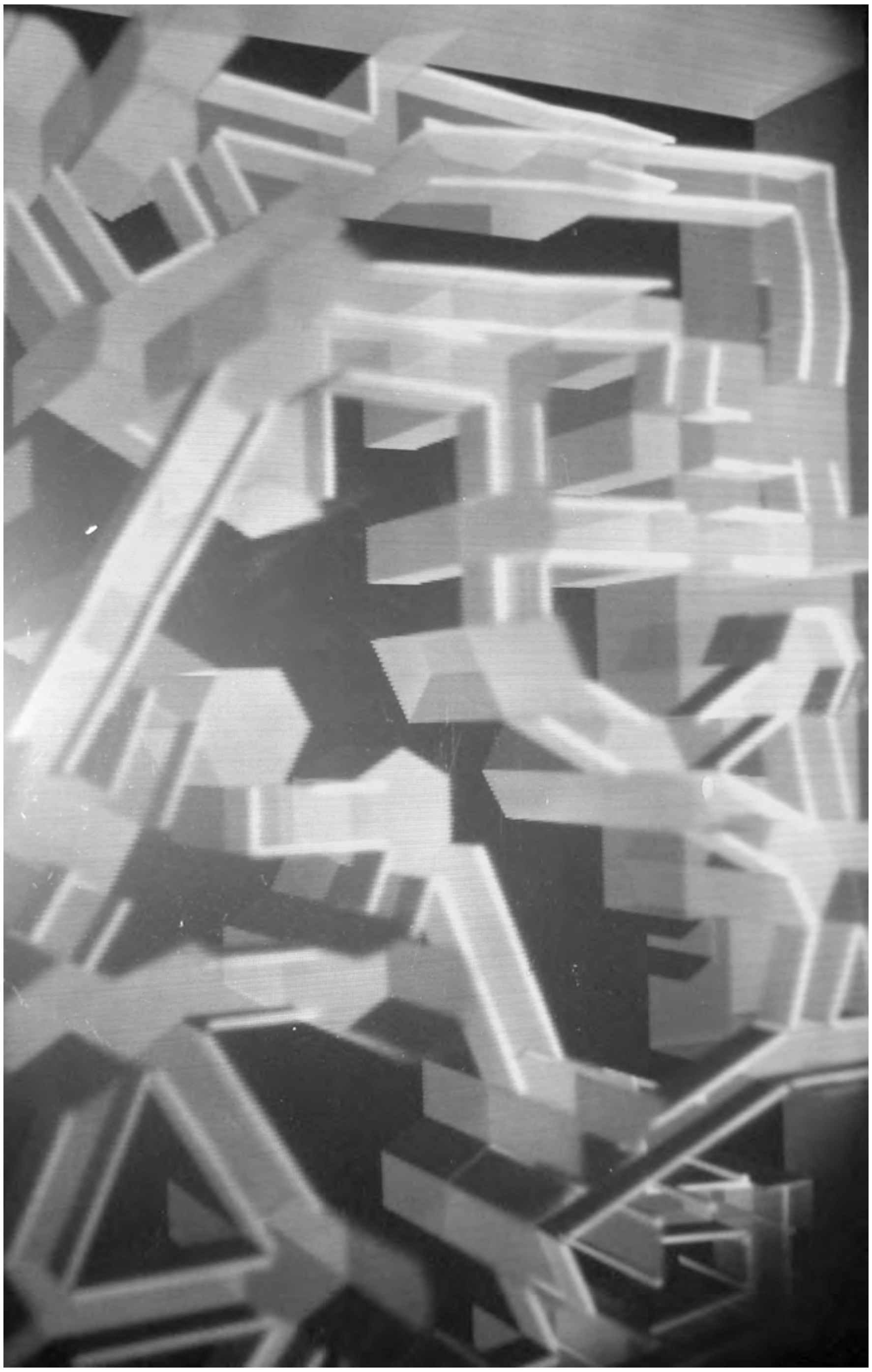

Figure 4. Geospatial hologram of the laser tag facility.

experiences with the hologram-paper map comparison activity and were thanked for their participation.

RESULTS

The search for target one yielded mean values of 38 seconds (SD = 18.4, paper map) and 29 ¼ seconds (SD = 3.8, hologram) while the mean search values for target two resulted in 65 ¾ seconds (SD = 74.6, paper map) and 30¼ seconds (SD = 11.1, hologram). The descriptive statistic results are displayed in Table 1. Overall, the mean times from the search tasks performed by the participants using geospatial holograms were approximately 23 percent faster for target one and 54 percent faster for target two. The relationships of the standard deviations and standard errors also suggest that the times of hologram-based wayfinding are less variable and more evenly distributed than the times of the paper map-based search.

Although the sample size was relatively small for quantitative analysis (it is very difficult to recruit many SWAT domain experts), the paired

	N	Min. (seconds)	Max. (seconds)	Mean (seconds)	Std. Error	Std. Deviation
Hologram, Target 1	8	22	34	29.25	1.34	3.80
Map, Target 1	8	17	72	38	6.53	18.47
Hologram, Target 2	8	16	53	30.25	3.93	11.11
Map, Target 2	8	23	236	65.75	26.39	74.64

Table 1. Descriptive statistics of wayfinding performance.

t-test was conducted for both target searches at a 95 percent confidence interval and used to assess whether the mean time of the tasks completed using the different media were significantly different (Table 2). Overall, the time to complete the first task objective while using the geospatial hologram was not significantly different than when using the paper map ($p = 0.1486$). Subsequently, the time to complete the second task while using the geospatial hologram was also not significantly different than when using the paper map ($p = 0.1739$).

A box plot was created to represent the variability of task completion times for each task objective using the paper maps and geospatial hologram (Figure 5). Especially with smaller sample sizes, box plots are useful in identifying variability and trends when comparing data distributions. The data represented within each box displays the upper and lower quartile in the dataset. The median (black line) in each box indicates the distribution of task completion times relative to the mean. The evaluation of the box plots for both wayfinding tasks suggests that there is a larger amount of variability within the data collected during the paper map tests than the data collected during the geospatial hologram-based wayfinding tasks.

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QUALITATIVE ASSESSMENT

A second aspect of our pilot study was to assess the general acceptance of geospatial holograms and maps in the SWAT domain. Especially in domains where lives are at risk, a new technology is only successfully implemented if it is perceived by the domain experts as helpful and easy to use. After the wayfinding exercise in the maze, the SWAT officers were given a brief questionnaire. The questionnaire consisted of fourteen Likert-scale questions, focusing on spatial representation, remembering height

	Hologram, Task 1	Paper Map, Task 1
Mean	29.25	38
Variance	14.5	341.1428571
Observations	8	8
Pearson Correlation	0.875441414	
Df	7	
t Stat	-1.623086135	
P (T<=t) two-tail	0.148600368	
t Critical two-tail	2.364624251	

	Hologram, Task 2	Paper Map, Task 2
Mean	30.25	65.75
Variance	123.6428571	5572.214286
Observations	8	8
Pearson Correlation	0.780428185	
Df	7	
t Stat	-1.513675942	
P (T<=t) two-tail	0.173875457	
t Critical two-tail	2.364624251	

Table 2. Quantitative analysis of wayfinding performance.

information, recalling route information and general usability aspects, and five open-ended questions eliciting positive and negative aspects, suggestions for improvement, and additional remarks.

When asked if the geospatial hologram or the paper map was an accurate representation of the laser tag facility, seven of the eight participants responded that the geospatial hologram was an accurate representation and six responded that the paper map was an accurate representation. Seven participants stated that the hologram clearly displayed elevations and six participants stated that the paper map did not clearly represent height information. Seven SWAT members found that route planning was easy with the geospatial hologram and four members found that route planning was more difficult with the paper map. Seven participants claimed that they could easily locate the targets in the hologram and recall the route in the maze, and four found it more difficult to find the target and the correct route with the paper map. Height information from the hologram could be remembered by seven participants while six described that it was difficult to remember height information from the paper map. Overall, seven of the total of eight participants stated that holograms might be useful and effective tools in SWAT operations, and five members stated that paper maps are very useful and effective. Figure 6 summarizes the results as mean representation for each question in a radar plot.

When asked about positive and negative aspects of geospatial holograms, the majority of the participants described the holograms as good

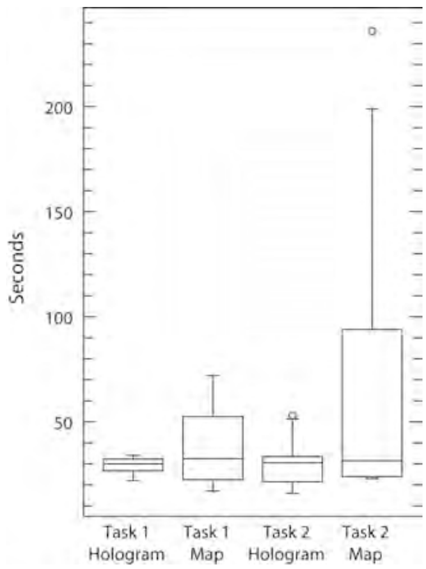

Figure 5. Box-and-Whisker plot of wayfinding performance for both geovisualizations.

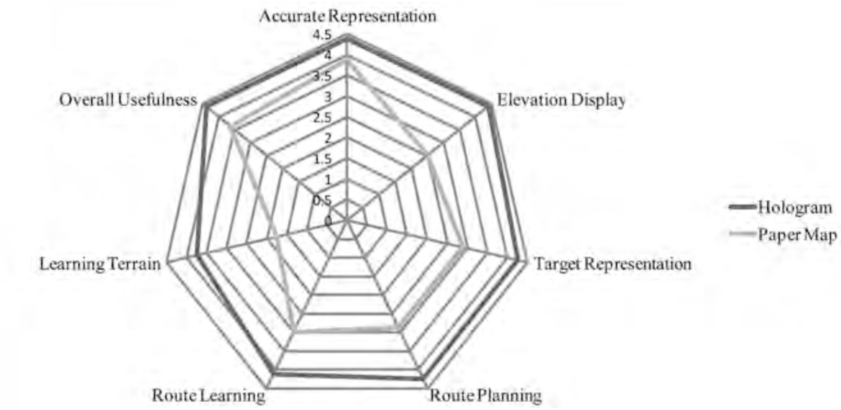

Figure 6. Radar plot of geospatial hologram and paper map assessment.

reference to plan routes, with obvious structure representation, three-dimensional object and elevation display, and an element of realism. Some participants worried about the cost of the technology, light settings, and the timeframe to produce a geospatial hologram for a specific incident. The paper map provided many participants with a sense of familiarity and was favorably viewed for being comparatively more portable and foldable. Participants described the longer time required to depict elevation and height information as a negative aspect of the paper map. Overall the geospatial hologram was described by the majority of participants as easy to read, because “it was like looking down at the maze” (participant 5) and it provided a realistic image of the environment showing “all sides of the location and routes” (participant 4). Most of the participants saw an immediate need and an intrinsic value in geospatial holograms, specifically with respect to its ease of use, and practical applications towards tactical planning, training, executing search warrants, rescue, and tactical response in hostage situations and other life-threatening incidents.

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CONCLUSION

Geospatial holograms hold the potential for more widespread research and application in cartography. Norman (1998) argues that in any domain each of five possible user categories–innovators, early adopters, pragmatists, conservatives, and skeptics–have specific preferences and goals that need to be considered when designing technology. Currently, geospatial holograms are evolving from the tools of innovators and early adopters to the broader audience of pragmatists and conservatives. This process brings up many open research and development questions that need to be addressed in cartographic research before introducing the technology into real-world situations. Besides the SWAT application domain, we can envision many holographic applications in cartography ranging from reference maps, urban landscape visualizations, and geomorphologic representations to special thematic maps.

Holographic technology has resisted incorporation with mainstream visualization technology for multiple reasons, including the high degree of difficulty and long length of time for production, high cost, and inconvenient restrictions on features such as size, color representation, and viewing angles. These limitations are now starting to vanish with the development of more advanced and effective holographic software and hardware. However, current holographic technology does not allow instant hologram generation or real time data processing, a major shortcoming compared to standard Web-mapping services. On the opposite side, geospatial holograms support three-dimensional object visualizations that cannot be provided through standard Web-mapping services or paper maps. This "true" three-dimensional representation ability could have a major impact on building a common operational picture by supporting geospatial intelligence gathering, tactical planning, operation, collaboration, and response.

Our initial research and collaboration in the SWAT domain indicates that geospatial holograms could hold great potential to support many aspects in high-stress law enforcement situations. The goal of our pilot study was to investigate if geospatial holograms might support effective route planning and wayfinding in SWAT situations and if this geovisualization technology might be seen by these domain experts as useful and effective technology. Although our quantitative analysis did not reveal significant differences between the use of holograms and paper maps for wayfinding tasks, our qualitative data analysis indicates positive responses towards the use of geospatial holograms during SWAT incidents.

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Obviously, the paper map and Web mapping technologies will not vanish from the SWAT domain, or as one participant puts it: "a paper map is better than nothing" (participant 6). Thus, it is our goal to investigate how to design and implement complementary geovisualization technologies for better and safer law enforcement. Snow (1996) notes that in SWAT operations the difference between success and failure is a matter of timing, often separated by seconds. If we can advance geovisualization, especially geospatial holographic technology, to provide our law enforcement personnel with extra time to operate effectively, efficiently, and successfully in crisis situations, this technology will quickly move from the early innovation stage to the hands of pragmatic and conservative users. Future user testing in a human-centered design approach will provide us with important indicators about the design and redesign of geospatial holograms for SWAT operations.

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