Running Head: GIS FOR SEARCH OPERATIONS

A Geographic Information System for Managing Search for Lost Persons

C. Donald Heth and Edward H. Cornell

DRAFT
5 May 2005

Chapter to appear in G. Allen (Ed.), Applied spatial cognition: From research to cognitive technology. Mahwah, NJ: Lawrence Erlbaum Associates.

Acknowledgement. We gratefully acknowledge research support from the Search and Rescue Secretariat and the Natural Sciences and Engineering Research Council of Canada.

Authors' Address. C. Donald Heth and Edward H. Cornell, Department of Psychology, Biological Sciences Building, University of Alberta, Edmonton, AB, Canada T6G 2E1. Phone: (780) 492-4721. Fax: (780) 492-1768. Email: dheth@ualberta.ca ecornell@ualberta.ca

A Geographic Information System for Managing Search for Lost Persons

Psychologists have often derived insight from the limitations and mistakes of human information processing. Outside the psychological laboratory, however, perceptual illusions, retrieval failures, and other kinds of cognitive distortion are rarely cause for public reaction. When we forget to pick up a quart of milk because of proactive interference from previous trips to the grocery store, the consequences are usually confined to the personal. In contrast, mistakes in spatial orientation can often trigger massive public responses, as when a child wanders away from a family campsite.

Hundreds of lost person incidents occur annually in North America, and they often involve vulnerable children or cognitively impaired elderly citizens (Cornell & Hill, 2004). Communities have charged police, wardens, rangers and military organizations with the responsibility of responding to reports of lost persons. They in turn have developed search and rescue operations and trained teams to specialize in recovering the victim. In some jurisdictions, there may scores of incidents in a year; in others, this potential may be unused for months until an emergency response is required. Regardless, we can think of no other domain of human cognition where there is such a large public infrastructure of resources and personnel devoted to rescuing the individual from the consequences of a mistake in a typical undertaking.

Given that the state of being truly lost involves emotional and cognitive breakdowns, search managers have long called for psychological knowledge about lost person behavior (Cornell & Hill, 2005; Heth & Cornell, 1997; Hill, 1997). Here, we consider the problem of finding the lost person from a different angle: the spatial thinking of the search teams themselves. Both they, and the person they look for face the same issue: localization. But whereas the lost person must usually rely on a small set of cognitive tools (such as memory of the path taken), search teams can deploy maps, imagery, and protocols in their task. Much of their use of these tools is heuristic and guided by the pragmatic demands of working within a public agency. As might be imagined, technology is rapidly changing the way they work. It is an area wherein the applied cognitive psychology of spatial cognition can provide meaningful contributions.

In this chapter, we describe spatial thinking that search managers portray while problem solving during these extraordinary situations. Their attention to spatial aspects of their task was substantiated during videotaped training exercises and by observations while we were permitted in incident command posts. Our collaborative goal for these observations was to develop a decision support tool, computer software that prompted due diligence to procedures and allowed visualization of the geographic space. The software program we developed integrates the procedures used by experienced search managers with digital layered maps (geographic information systems, or GIS) and databases on lost person behavior. The software is designed to be used on lap top computers that police use in the field. The software is currently in its third beta version, and has been released by the Search and Rescue Secretariat of Canada for field testing in 12 police jurisdictions across Canada (Heth & Cornell, 2004).

Problem Overview

By the time that search and rescue agencies become involved, the problem of searching for the lost person typically involves a vast environment and several threatening possibilities. The fiscal, logistical, and legal implications of a response to this problem are significant. How they are addressed will vary depending on the jurisdiction involved, but, typically, authority for the actions of searchers is vested in a single individual—the search manager—who takes command of the incident. Unlike most paramilitary operations, there is a surprising amount of consensual decision making. Experienced search and rescue command teams believe that no one person can authoritatively state the best course of action. Like the naval navigation teams described by Hutchins (1996), there are fixed responsibilities and social hierarchies when operations are executed, but in contrast to an authoritarian and decisive control, experienced search managers seek consultation and develop their hypotheses and plans modestly with one to four others. During these discussions, the search and rescue planning team makes the search tractable by parsing the environment and developing scenarios of what likely happened to the lost person. Thereafter, search management consists largely of iterative task assignments in which individuals or teams are dispatched to check these possibilities. The methodology is Bayesian: the planning team will revise its priorities on the basis of field reports from the search teams, along with clues, eyewitness reports, and similar evidence uncovered during search activities. Although the formal calculus of probability theory may or may not be used in this process, planning teams recognize the probabilistic nature of the judgments that guide their priorities and treat a search of a particular area much like an experimental sample.

The discourse that accompanies these activities is predominantly visual and graphical. Maps serve as the basis of plans and as the means of recording actions. Accordingly map semiotics (Imhof, 1982; MacEachran,1995) play a critical role in search management. The search and rescue community employs their own conventions of map usage which not only iconify search decisions, but also assist with search calculations. For example, if a delimited area is traversed by a search team, that area on the map will be colored in on the map using a cross-hatched pattern. If the same area is searched again, a cross-hatching of a different orientation will be overlaid on the same area. The density of cross-hatching therefore serves as a visual cue of the extent to which that area has been searched.

The dynamic relation between maps and the spaces they represent is common to geographic information systems (Worboys, 1995). Our observations of search and rescue operations suggested that GIS provides search management with procedures that complement search operations. Among these are:

<u>Boolean overlays.</u> GIS allows the union, intersection, or other Boolean operation of different, usually metrical, subspaces of regions of interest. Similarly, search managers will often need to assess joint characteristics of mission areas.

It might, for example, be important to know whether a trail system overlaps with areas of heavy vegetation, so that the detectability of person off the trail can be accurately evaluated.

Buffering. GIS allows an analyst to expand the dimension of a given feature. The most common application is to extend a linear feature, such as a river, into an areal one, such as the watershed within 100 meters of the river's center. Search managers likewise will dispatch teams to cover areas based on linear or network landmarks. In one dramatic case, a park ranger in charge of a search for two hikers instructed his searchers to scan for footprints leading to the border of a popular trail, looking for those that might shortcut a circular route. His team found the hikers trapped in a ravine just before a blizzard enveloped the area.

Georeferenced data.. GIS is based on structured information that is tied to the geometry of the map. For example, a line on the map might be linked to a database record of a series of latitude and longitude coordinates specifying the geographic location of its course. The GIS database would tie this geographic information to its description as a gravel road, maintained by a timber company and usable only in winter. The power of GIS analysis is that these structures can be retrieved through specialized queries of the database and displayed as different overlays. In the same way, experienced search managers consider spatial features in multidimensional ways. Nondescript backwoods sheds might be "attractors," remembered for the many times that search victims were found in them.

Spatial analysis. GIS permits rapid analysis of the relations among georeferenced objects. For example, nearest neighbor analyses can partition a space into regions defined by their proximity to key features. Search managers will likewise partition a search area into zones dependent on spatial distance from attractors, hazards or other key environmental elements.

The fit of GIS features to the requirements of search operations guided our development of a geographic decision support system. Our observations suggested to us that the task of the search manager was dominated by the requirements to parse the environment adequately and to develop likely scenarios of what likely happened to the lost person.

Comprehending Large-Scale Space

We observed that the first step toward visualizing the problem space involves search planners standing side-by-side pointing and identifying environmental features in front of large paper maps. The chief resource for these orientations is a resident expert who can answer questions about symbols on the map, such as whether plot lines or trails are as depicted, whether certain roads might provide good access to areas, or whether narrow creeks are dry at this time of year. Following comprehension of local conditions, the planning team usually segments environmental spaces using built or natural geographical boundaries and discusses what might occur within them. In the sections that follow, this functional parsing is illustrated first by the ways that search planners consider how the lost person would behave in geographically distinct locations. The second kind of functional parsing is consideration of how spaces afford different kinds of search operations.

Local features and user goals.

Immediately after the report is received, the lost person becomes the subject of an investigation. One way to interpret possible routes and locations is to understand the trip plans or goals of the lost person for using the environment. An investigator asks family members and colleagues to provide details about the habits, experience, and equipment of the lost person. For example, a teen may be overdue from a hike when nights are becoming cold in the fall. His car is parked near two trail heads, with one leading into a popular network of creeks and waterfalls. The search planning team assumes the car is the point last seen and marks its location on the map with a standard icon.

The investigator quickly determines that the teen does not fish, but enjoys wilderness photography. An inventory of camping equipment at home indicates the teen is not prepared for an overnight delay. The investigator asks the family informant to sort through recent packets of photos and describe typical photographic subjects. There are several panoramic views of alpine ranges. Probing, the investigator further ascertains that the teen has probably packed his wide angle lens. Given this information, the search planning team might consider a trail sweep from the trail head that leads upward to vantage points for views of mountains.

Establishing a frame of reference. We now turn to the implications we saw for the design of our decision support software. The shift from representing the environment on large paper maps to the computer display required special features to facilitate the initial orientation and interpretation of map features by the search planning team. Because most of the planning begins in reference to the point last seen of the lost person, we thought that the computer display of the GIS should open with that point at the center. However, search planners preferred that they first establish where they were in relation to the represented surround. To provide this egocentric framework, we designed the software to open the digital map centered on the district headquarters where reports of lost persons are received, usually the initial location for the lap top computer. A field operations guide provided a conventional symbol for the incident command post (Hill, 1997). We used this symbol as a you-are-here icon that would be placed on the map at the district headquarters or could be moved when a field trailer closer to the point last seen had been established. The icon could be clicked for repositioning, which brought up a window with fields for specifying a street address or exact geographic coordinates such as latitude and longitude.

When they knew their position relative to the problem space, the search planners began to isolate characteristics of local geography and highlight map features that represent routes to and areas of user interest. As in almost all applications of GIS mapping, users can temporarily click off layers of information so that other layers can be seen more clearly. In the case of the photographer, the search manager could remove map layers illustrating watersheds and vegetation, allowing an uncluttered exposure of sites where trails afford views of ranges. Map viewers can check for overlooks by using tools to move the display and zoom in on clusters of elevation lines.

Search planners wanted two methods of moving the map. Following the lead of commercial software, we designed a tool depicted as a hand icon that allows the map viewer to grab the map and slowly tug it in any direction. The search planners use this tool to follow a course or examine an area in detail. We also designed a map repositioning tool as a response to the search planner's impatience with the rate of movement of the hand tool. The icon for this second tool is a depiction of arrows converging on a point. Search managers can click this icon and place their cursor at any point on the map display. When the point is clicked, the map is centered there; short or long distances are instantly traversed. The search planners use this tool when they quickly want to situate events that are peripheral to their current focus, such as when a radio call indicates that evidence has been found at a site.

Representing lost person behavior. The search planning team can also add to the display, so that the prioritized trail is overlaid within concentric tinted circles from the trail head to the farthest distance that the teen might be found under the circumstances. The software automatically calculates this distance by access to a data base containing records of previous incidents involving adult hikers lost on alpine wilderness trails (Heth & Cornell, 1998).

The psychology and behavior of lost persons is numerically modeled in a search planning construct termed the probability of area. In this model, segments of the environment are identified with a likelihood estimate that the lost person will be found there. At the onset of a search, probability of area is determined by actuarial data, aggregated case histories of individuals who have been found in similar circumstances (Syrotuck, 1977). The aggregated data is represented by four concentric circles centered on the point last seen. The radius for the first circular area is the crow's flight distance traveled by 25% of the wilderness hikers who were found closest to the point last seen. A surrounding ring contains another 25% of the case histories; the radius for its outermost boundary represents the median crow's flight distance between the point last seen and point found of lost hikers. The size of the ringed areas that contain 25% of the found hikers increases greatly as distance increases from the point last seen. Hence, search managers know that their limited search resources can be effectively deployed to search the smallest area near the point last seen. This is known as prioritizing according to a probability density function (Wartes, 1983).

In the initial versions of our software, we attempted to portray the probability density function by using different saturations of colors for the rings surrounding the point last seen. It is common semiotic practice in thematic cartography to grade the density of occurrence by the darkness of its areal representation (Slocum, 1999). However, the area closest to the point last seen is where search planners focus a variety of operations and zoom in for detailed study. We noted in training workshops that they frequently removed and restored ringed probability zones; darker saturation blocked their view of other map layers. Our more recent version of the software represents the probability density of lost persons by colors of different salience (red closest to the point last seen) with equally low saturation (Kosslyn, 1994).

After viewing the representation of actuarial data of wandering, the search planning team further elaborates the scenario based on the photographer's unique preferences and equipment. After selecting from the tool bar, planners can use tools to bracket the upward trail. A careful tracing allows a measurement of its irregular course that is accurate to the nearest meter. This allows more ideographic estimates of distance traveled, in consideration of the reduction of rate inferred from the displayed elevation gain and opportunities to stop for photography that the teen would encounter.

Summary. After orienting to environmental features, the search management team limits the extent of the geographic space and parses it by measurement and projection of likely user interactions. The environment is deconstructed and visualized by adding or subtracting layers of information to the map display. Features that are pertinent to the behavior of the lost person are studied at various scales and rates. Areas and linear features are highlighted and punctate sites are marked.

Tailoring search operations.

Tasking. Search management involves development of search operations at several likely locations of the lost person and coordination of several operations in addition to search. For example, in the case of a child lost in a city, there are multiple routes affording ease of travel. The search manager quickly initiates a containment operation, rapidly deploying teams along familiar and well-traveled sidewalks until the teams reach a bridge or intersection that serves as a transition to a distinct area. Members of the team are left at that point to watch for and intercept the child. The search manager initiates the containment operation by filling out a tasking command form that specifies the parameters of the task, the team characteristics and leader, street address or geographic coordinates for the pertinent location, and communication channels. On our software, tasking forms are available from a pull down menu and when the search manager completes a form, the program automatically uses the address text field to place an icon representing the assigned team on the site on the map. The search manager can review details of the tasking by clicking on the icon at its location on the map, which brings up the original tasking command form.

Case histories of search operations indicate that problems can arise in deploying personnel. Sometimes a location specified by the planning team is misinterpreted in the field. For example, there may be a site along a river that runs through town where children often play on the bank. In our application of GIS mapping, the search manager drags an icon representing a search resource, such as a watercraft team, from the toolbar to the location as depicted on the map, the river bank. Once positioned, a window appears that specifies the location in units such as latitude-longitude or nearest street address. The window establishes a link between this location and details of the tasking. The search manager fills out what is expected of the watercraft team, sets a reminder for when the assignment should be completed and information allowing field communication with the team captain. The captain is instructed to call from the field after confirming their location using a hand-held global positioning system (GPS). After other operations have been attended to elsewhere, the search manager can return to click the watercraft icon to review the assignment window.

The location and time of the assignment is also automatically entered into an ongoing data base. It appears as a line in a tabular log that allows the search manager to review the status of all completed, pending, and overdue tasks.

Hence, the circumstances of search operations called for software that allowed two methods for recording activities on the map. When an address or geographic coordinates for a tasking are known, the menu bar can be used to fill out standardized forms and allow automatic placement of icons from address fields. When an address or geographic coordinates are initially unknown, an icon representing the tasked team can be dragged and dropped on an estimated location. When we observed search management teams multitasking and planning based on available information, we decided to make both methods available for recording all operations, events and records of evidence and eyewitness reports.

Visualizing lists. In addition to discrete locations, investigators requested that our software display configurations of categories of sites. They were aware that activities often occur in patterns and that people prefer least effort travel corridors. For example, in one urban search, investigators compiled a list of street addresses of friends visited by the lost child on previous bicycle trips. After the addresses were entered and the list categorically labeled as friend's houses, the program executed a plotting procedure that places identical map pins for each entry. The configuration on the map indicated an area of density of social activities and a sequence for canvassing homes.

Segmenting. As other operations and information are sited, the GIS and drawing tools are used for search planning. Areas on the map are delineated for coverage by search resources. The areas are usually drawn as irregular polygons with edges delineated by constructed and geographical features such as roads, fences, river banks, and cliffs. Often a travel corridor, trail or road will be segmented so that the width of its narrow polygon includes 30 meters on both sides of the trail and any spurs leading to bordering features. In addition to physical features of the segmented area, the search planners consider the effective procedures of the resources available for initial searches. For example, a trail segment may be assigned to a cross country ski team, with instructions to be on the look out for particular tracks or evidence of off-trail excursions, such as tracks across the snow that borders the trail. A ravine may be segmented for a sweep by a canine team because the rift is protected from wind and facilitates fresh scent tracking. In suburban areas, segments may be defined by blocks along curved streets and closes; households are assigned to be canvassed and garages and out buildings to be inspected by foot teams on a plot-by-plot basis.

Segmentation makes the total area of the search operations more tractable but still requires consideration of extent. Search planners had difficulties estimating the size of sub areas so that tasking could be reasonable for search teams of different capacities. In response to this problem, we adapted a computational algorithm (O'Rourke, 1998) that calculates square meters of irregular polygons drawn within the GIS database. The area of a segment of any shape appears beneath the map window when its polygon is closed. The segment is then automatically assigned an identification number and search managers have the option to add their own label. This identity allows planners to link tasking and the history of operations to areas that may not have an established name. The area number pops up in a small window whenever a search planner selects an edge of its polygon.

Urban searches required a different method to represent the size of segments for tasking. The unit of search is the homes and buildings on a plot on a cadastral map of city blocks. In our application, after drawing a polygon surrounding a cluster of blocks, the search manager can click the edge of the polygon. This brings up a menu of options, including the option to list the addresses within the polygon. In effect, the segmentation of the spatial display of the GIS delimits a text data base. A list appears in a window with the number of addresses in the segment at the top. An especially useful feature is that addresses in the list can be ordered as to their distance from a reference point, such as the point last seen. There is also the option to print a map of the segment at a scale that the search manager has chosen for display. After printing, the search manager staples the address listing and mini map to the tasking orders for a team to canvass the homes.

<u>Estimating critical separation.</u> One important method of searching for clues in rural and wilderness areas involves sweeping; searchers are lined up to progress in a parallel manner along the same bearing. From classical search operations theory, each searcher is considered a detector with a similar <u>probability of detection</u> as the neighboring searcher (Benkoski, Monticino & Weisinger, 1991). At issue is the separation between these human detectors.

Placed too close, such as shoulder to shoulder, there is overlap between the areas being inspected by neighboring searchers and more personnel and time are required to sweep a segment. Placed too far apart, there are gaps between neighboring searchers where areas are too distant to be adequately inspected. Critical separation occurs when searchers are spaced so that the probability of detection is maximized given the visibility of the target in the environmental context. There are field methods to estimate critical separation (Perkins, 1989) but search planners need to calculate approximately the number of personnel that should be deployed to a segment before it is visited. To address this need, our GIS application allows display of specialized vector maps, such as from forestry and mining industries, that show the pattern and density of vegetation. In addition, urban search planners often had access to aerial photography that portrayed the recent landscape; our program was modified to display these raster representations as well.

Visualizing search operations.

The representation of the probability of detection requires a symbol of density. Following search of a segment, the probability of detection is estimated by the search team leader and reported to the search manager. It is expressed as a percentage. The search team leader relies on previous experience of his or her team in training exercises to estimate this percentage. For example, a training exercise may have been conducted in a field environment similar to that of the lost person incident. In the training exercise, a fixed number of targets are placed in random and likely positions in the field. The training exercise may specify the targets for an evidence search or a search for a person. In an evidence search, targets may be items such as a footprint matching the shoe of the lost person, a gum wrapper, a back pack, or a fire pit. If 50 of such items are placed in a square km area and 22 are found, the probability of detection for evidence is 44%. Similar empirical methods are used when life size dummies wearing scented clothes are placed in the environment. Or, an adolescent or adult may volunteer to be the target for a training exercise and may be moving, staying put, or hiding, as sometimes occurs when children are frightened (Hill, 1999; Syrotuck, 1977). When there is a unitary target, the probability of detection may be estimated for the whole team after separate combinations of personnel have searched the area.

During an actual search mission, search planners seek to achieve high probabilities of detection for prioritized segments. This almost always requires more than one search operation. For example, a helicopter spotter may report a 15% probability of detection over an urban area, a canine team searching a segment within that same area may report a 20% probability of detection, and a civilian search team using sweep and canvassing methods may go in last and report a 50% probability of detection. The representation of these activities on the map requires unique icons and stippling of the segment.

Search planners helped us decide how icons should be plotted when a search resource is tasked. One suggestion was to index the assignment by placing the appropriate icon at the site where the searchers would rendezvous. For example, an icon of a dog could be placed at a trailhead where the kennel truck would be parked. We rejected this suggestion when our observations of operations showed that planners often took time to disambiguate the initial map placement of a search resource and the area that was assigned to be searched. They did not have this problem when the various search resources were represented by icons in the center of drawn segments.

We can use the example of multiple searches to illustrate our current method for visualizing search operations. The icon for the helicopter would be placed in the center of its broad area for search and the spotter's report of a 15% overall probability of detection would be represented by filling this area with stippled diagonal lines. By convention, the diagonal lines would be oriented leaning rightward, indicating first search coverage (Hill, 1997). The second and third searches are particular to a smaller segment embedded within the helicopter's broad area, with second search coverage indicated by a field of leftward leaning diagonal lines and third search coverage by vertical lines, both only appearing within the smaller segment. The lines are lightly saturated, but each overlay makes the smaller segment appear more dense. The icons indicating the tasking of the dog team and civilian search team would be overlapping in the center of the smaller segment. The most recent search operation, the icon for the civilian sweep, is on top. The icons representing the different search resources have tabs protruding at different positions, so for example, even though the icon for the dog team is buried by the icon for the civilian search team, its brown tab is visible at 4 o'clock and can be clicked to open the history of that tasking and reported probability of detection.

Representing the net effect of all of the searches, the cumulative probability of detection for the smaller segment (66 %; LaValla & Stoffel,1987) can be reviewed by selecting the edge of its now darkened polygon. Clicking the edge brings up its menu; one menu option allows the planner to access the complete history of searches. Other options allow the planner to remove and restore the stippling to see geographical features within the segment more clearly.

Search managers wanted exact representations of search team activity. While we were developing our software, some of the more technically informed search managers began requesting that search team leaders record their paths of movement on portable global positioning systems. Some GPS units permitted downloading of episodes of movement to digital maps. Search managers asked if we could incorporate this feature to our GIS display of search activities. The request led to a common problem engendered by technology spurts. Commercially available global positioning systems use different data and filing schemes and military and police organizations have not agreed on standards for proprietary systems and software. We addressed the search managers' request by using the downloading protocol of the most commercially popular GPS unit.

Summary. Search operations require that activities be linked to environmental features. Planning involves the visualization of critical sites, configurations and areas of segmentation. As in earlier phases of assessing the problem space, search planners frequently use the tools for adding and subtracting layers of information from the display. Spatial elements are also transformed to measurements and lists. Tasking involves keeping a history of events at particular sites and across areas. The graphical representation of assignments and outcomes allows a visual check on operations and the emerging pattern of evidence.

Working with Maps

Our observations during the development of the software suggest a few principles of spatial representation and problem solving using maps. Students of cartography and cognitive psychology will find that this listing highlights some familiar research issues.

1. There is a problem of the match between spatial representation and environmental reality. Before addressing the problem of search, our search planners took time to question the meaning of certain map features. We found that previously learned conventions immediately solved the problem of translation. For example, a blue line was taken for a watercourse even when the particular river was green. However, principles of semiotics only provided loose guidelines for establishing new associations between symbols and events. For example, during training sessions we had to explain to map readers that there was an analogy between the saturation of a hue and the probability that the lost person was in the area that was filled with the hue. Our eventual use of a red fill (wavelength of hue) to indicate a high probability was the result of user suggestions rather than semiotic analysis.

2. People choose to estimate their own location as a process of adopting a spatial frame of reference. Again, convention helped. When search planners were indoors using paper maps, they first rotated the maps to be oriented with

cardinal directions, then discerned whether configurations of features matched their environmental knowledge, then localized where they were (cf. Pick, 1995). We were able to ease these processes by having the map open with north on top and the location of the user in the center.

This is not a perfect solution, however. North at the top may be confusing in circumstances when the computer user is facing a different direction (Levine, 1982). Moreover, roadways—even straight ones—are not always aligned with the cardinal directions and are not always orthogonal. We faced both of these problems when implementing our program for the York Regional area north of Toronto, Ontario. Major reference streets in this region are oriented about 20 degrees from true north and the intersecting parallels are not at right angles. Standard maps of this region accommodate this configuration by orienting the grid so that the parallels are horizontal. As a consequence, our north-south orientation confused users by showing them rotated parallelograms. Furthermore, the scrolling mechanism of moving in the cardinal directions made it difficult to follow any given right-of-way.

It is our impression that users can accommodate this problem when using large paper maps because the frame of reference (i.e., the paper boundaries) is more peripheral than the display boundary within a computer screen. We are exploring whether this problem can be solved by in the inclusion of a tool that allows the user to rotate the display while a compass rose remains fixed on north.

3. The place of interest should be near the center of the spatial representation.

Search planners tended to move the map so that they could see equal amounts of information surrounding a critical location. When their interest shifted to peripheral events, they wanted the option to center those locations immediately.

4. Areas are easier to comprehend if they are segmented. Search planners looked for areal discontinuities such as parks within the city to create segments and looked for linear continuities such as streets to draw borders between segments.

5. Spatial features are translated to numbers and categories to solve many problems. Search planners wanted to measure areas and lengths and needed to make lists of addresses in sub areas they had drawn.

6. People are able to shift the scale and pace of their spatial analyses quickly. Search planners wanted to click to zoom in and out and wanted the option to move slowly to examine features or jump to a different area on the map.

7. There is a phenomenological correlation between the scale of a map and the grain of map features. People expect more detail as they zoom in and may be looking for more general characteristics of areas and super ordinate labels as they zoom out.

Strangers in a Strange Land: Lessons Learned in the Journey from Research to Application

We began as experimental psychologists studying patterns of travel when children expand their activities from their home. In environmental psychology, this topic is known as the study of home range. After an invited presentation at a local search and rescue conference, a few search managers in the audience began using our observations to delimit areas for search for children reported missing in urban and suburban areas. A police search manager called one day to report that our tables of dispersion of wandering by children had lead to a successful search. The weather during the incident was severe and the search manager thought we should know that our data had likely saved the child's life. This notice was profoundly more gratifying than the letter from the editor that accepted the research for publication. We were hooked on applied research on spatial cognition, human way finding, and lost person behavior.

Over the next few years, we began to direct more of our research to the problem of search for missing persons. To understand the problem, we asked the local division of the Royal Canadian Mounted Police if they would sponsor our training as search managers. They did, and we sat in training workshops with grizzled veterans with guns on their hips and suspicions that academics would tell them what they were doing wrong. Like good cultural anthropologists, we remained quiet around the campfire respecting the customs and language of the host community. We consumed their foods and drinks when offered, so the police began to accept us and ask about the land of the ivory tower. When the police understood how our behavioral data could be used during search planning, they encouraged us to write a grant to develop a map display they could access from their lap top computers. The police suggested a federal granting agency they used when they needed search and rescue equipment such as radio repeaters or inflatable boats. After receiving our application, the granting agency had some questions. They needed us to clarify why we could not pay for research assistant salaries and subsequently submit an indent for reimbursement. They needed us to project quarterly outcomes for the project even though we explained that the course of development depended on outcomes from early phases. One agency director suggested that research must be a form of product development. The granting agency understood this concept and became excited about expanding their mandate to include funding for tools that did not yet exist. After approval, they asked if they could post our complete grant application to attract more researchers from the behavioral sciences. Once again, we were encouraged to commit more of our efforts to applied research.

When the program allowing map display of our data was completed, our grant allowed us to arrange a training workshop for three local search and rescue teams. The goal was to train the search managers to the extent that they would use the software during a simulated search. We encountered four reactions at this first workshop that we have re encountered as our decision support software has progressed through beta versions and subsequent workshops. Paraphrasing, the first reaction is a comment such as "Did I do this right?" This told us that the users tended to blame themselves rather than question our design of procedures. Nevertheless, we tried to avoid further training the user and instead noted where procedures needed change. The second reaction is a comment such as "Oh, this is great, but could you also make it do this?" The comment illustrates what experienced programmers call "feature creep". Feature creep indicates that the user likes what you have done to the extent that they want you to do more. The third reaction was usually not announced, but was revealed when we looked over the shoulders of users: They often used our software tools in effective ways that we had not anticipated. In other words, they quickly became comfortable enough with the system to discover what it could do beyond its intended function. Witnessing this creativity was fun, but the fourth reaction has been the most gratifying: "When can our team have this program?"

As a behaviorist might summarize, our journey from basic research to application has included intermittent encounters with powerful rewards. We also continue to learn from our wrong turns. Although the principles on the list below seem familiar in hindsight, we had to discover them in the context of our journey. Some of these principles seem redundant, but consider that the rewordings may help to recognize a future relevance.

1. Most research will reside in journals if the researcher does not explicitly develop it for users.

2. Many applications derived from research will reside on compact discs until users are trained to use them.

3. If a procedure is difficult to train, it needs to be re designed.

4. User's intuitions about what procedures should accomplish are less variable than user's intuitions about how procedures should be implemented. A good application allows for effective implementation in various ways.

5. The language and processing dictated by the software or operating environment must be subordinate to the terms and procedures of the user.

6. Users say they want technological solutions but mean that they want technology that they can use intuitively.

7. When estimating deadlines for roll-out, first determine how long it took to develop the previous version of the application, then add your best forecast of the time it will take to create the new features and integrate them into the system without bugs. Double this total and prepare for late nights as the deadline approaches.

References

Benkoski, S. J., Monticino, M. G. & Weisinger, J. R. (1991). A survey of the search theory literature. Naval Research Logistics, 38, 469-494.

Cornell, E. H. & Hill, K. A. (2005) The problem of lost children. In C. Spencer & M. Blades (Eds.), Children and their environments: Learning, using, and designing spaces (pp.) Cambridge, UK: Cambridge University Press.

Heth, C. D. & Cornell, E. H. (1998). Characteristics of travel by persons lost in Albertan wilderness areas. Journal of Environmental Psychology, 18, 223-235.

Heth, C. D. & Cornell, E. H. (2004). First response incident command (Version ß$_3$) [Computer software]. Edmonton, Alberta: Expert Spatial Systems.

Hill, K. A. (1997). Managing the lost person incident. Chantilly, VA: National Association for Search and Rescue.

Hill, K. A. (1999). Lost person behavior. Ottawa, Ontario: National Search and Rescue Secretariat.

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

Imhof, E. (1982). Cartographic relief presentation. Berlin: Walter de Gruyer.

Kosslyn, S. M. (1994). Elements of graph design. New York: Freeman.

LaValla, P. & Stoffel, R. (1987). Search is an emergency: A text for managing search operations (2^{nd} Ed.). Olympia, WA: Emergency Response Institute.

Levine, M. (1982). You-Are-Here maps: Psychological considerations. Environment and Behavior, 14, 221-237.

MacEachran, A. M. (1995). How maps work: Representation, visualization, and design. New York: Guilford Press.

O'Rourke, J. (1998). Computational geometry in C (2nd ed.). Cambridge, UK: Cambridge University Press.

Pick, H. L., Heinrichs, M. R., Montello, D. R., Smith, K., Sullivan, C. N. & Thompson, W. B. (1995),Topographic map reading. In J. Flach, P. Hancock, J. Caird & K. Vicente (Eds.), Local applications in the ecology of human-machine systems. Hillsdale, NJ: Erlbaum.

Slocum, T. A. (1999). Thematic cartography and visualization. Upper Saddle River, NJ: Prentice Hall.

Syrotuck, W. G. (1977). Analysis of lost person behavior: An aid to search planning. Westmoreland, NY: Arner

Wartes, J. (1983, September). Probability density: An aid to search planning. Conference papers (pp. 36-47), Meetings of the National Association of Search and Rescue, Dallas, TX.

Worboys, M. (1995). GIS, a computing perspective. London, UK: Taylor & Francis