Using Geographic Information Systems to Improve Civil Air Patrol Search and Rescue Missions

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Abstract

The Civil Air Patrol (CAP) is a civilian auxiliary of the United States Air Force. With a membership of approximately 64,000 citizens, it maintains a large fleet of single-engine aircraft. A primary mission of the CAP is search and rescue. This study shows that GIS can be used in a variety of ways to enhance CAP search and rescue missions. Results demonstrate increased accuracy in coordinate location and reduced expenditure of time. These directly translate into improvements in efficient utilization of resources and safety of personnel.

Introduction

History of the Civil Air Patrol

Although its beginnings date from the 1930's, the Civil Air Patrol (CAP) was created as a civilian auxiliary force on December 1, 1941. In a few short days the CAP would find itself filling a role that the founders never could have foreseen. After the attack on Pearl Harbor the United States was at war. Off the East Coast of the United States German submarines patrolled the waters in an effort to destroy unsuspecting ships to bring to a halt the United States' shipment of arms and supplies to England. The CAP pilots would fly many miles out over the Atlantic occasionally armed with bombs on their small aircraft in an attempt to forestall the damage to United States shipping. In 1943, by order of the President, the CAP became an auxiliary force of the Army Air Corp.

It was not until 1948, one year after the United States Air Force became an independent branch of the military, that the CAP became the auxiliary to the United States Air Force when Congress passed Public Law 557 (Civil Air Patrol, 2003). Throughout the years that followed the CAP worked increasingly with civilian authorities in search and rescue, aerial photography, disaster relief, transporting medical materials, and counter drug missions.

Current CAP Functions

The Civil Air Patrol is a non-profit 501(c)(3) corporation, consisting of nearly 1,700 units with a total membership of approximately 64,000 (Civil Air Patrol, 2003). It maintains the largest fleet of single-engine aircraft in the world: 550 corporate-owned and more than 4,000 member-owned aircraft (Figure 1). The three primary missions of the CAP are emergency services, cadet programs, and aerospace education. Its educational mission includes sponsorship of conferences and production of classroom materials for

Figure 1. Civil Air Patrol performs search and rescue (SAR), disaster relief, and homeland security missions—with a volunteer force, all at a fraction of the cost of other agencies.

America's teachers at no cost. The cadet programs enroll nearly 27,000 members between the ages of 12 and 21, and help to provide college scholarships in several disciplines, in addition to aviation education. The emergency services mission provides disaster relief support to local, state and federal relief agencies. In addition, the CAP is called upon to provide damage assessment, communications support, medical transportation, and aerial reconnaissance for homeland security. Most significantly, the CAP conducts 85% of all inland search and rescue in the U.S., as tasked by the Air Force Rescue Coordination (Civil Air Patrol, 2003).

Search and Rescue Missions

After the tragedy of September 11, 2001 the CAP was called upon to participate in the work of homeland security. These recent events coupled with advances in technology such as global positioning systems (GPS), satellite imagery, and geographic information systems (GIS) allow and compel the CAP to expand its capabilities like never before.

As an auxiliary civilian force the CAP does not receive government funds like the conventional branches of the military. In effect the CAP gets only its aircraft from the United States Air Force and only major repairs on those aircraft are paid for by the Air Force. On occasion the Air Force will provide a portion of the money required to conduct training for search and rescue (SAR) missions. Typical aircraft repairs such as oil changes, instrument repairs/replacements, and annual inspections come from the pockets of the squadron members. If squadrons are fortunate enough to locate meeting space at a nearby airport, they are responsible for paying the rent and upkeep of the building. The CAP also receives donations from non-profit service organizations and foundation grants to help curtail costs.

This financial constraint requires the CAP to be very economical. When technological tools become available, purchase by CAP is not often fiscally possible. It is necessary for the technology to be justified in terms of cost and training time. In addition, the CAP often operates in remote areas void of internet capabilities and, at times, even electricity.

Rationale for Study

Patrol members have found that the use of GPS has aided the ground crews significantly in the field, and its advantages to aviation have been known for years. However, documentation concerning extent of technology being used in CAP search and rescue missions is minimal. Missions are still being planned, conducted and analyzed manually with paper maps, markers, and colored pins. Geographic information systems have the ability to consolidate multiple paper maps, convert them to digital datasets and layer them so that critical information can be located efficiently. Because geographic information is stored within the data layers, location information can be relayed to and from the mission base quickly. For instance, precise location data for airports and hospitals can be created and attributed so that injured persons can be transported to the nearest facility. Previously collected GPS data can complement the GIS for keeping watch of the ground and aircrew movements.

These digital techniques aid in faster and more accurate target location. A day-long search, if not successful, can be examined in the GIS to plan the next day's search patterns and placement of forces to maximize coverage. If night activity is necessary, the GIS supports data that can assist in the search and in the safety of personnel, such as topographic maps and digital elevation models. The GIS can be customized to fulfill the specific needs of the CAP. Customization can assist in reducing the training time and increasing the speed of mission planning and execution. The products of this pilot study might also be used as a training tool for those who might be called upon to plan and conduct a SAR mission.

Objective

The main goal of this project was to increase the efficiency and accuracy of the CAP SAR mission neither exceeding acceptable costs nor discouraging them with complicated technology. As previously stated, altering existing techniques had to be justified in terms training time and financial constraints. Also, given the fact that CAP is a volunteer effort of citizens from various professions, uncertainties about the complexity of the technology had to undergo careful consideration.

Data Development

Reference Data

The first step consisted of examining the information needed to plan a SAR mission. It was essential to understand the use of Federal Aviation Administration (FAA) sectional aeronautical charts. These show detailed airport locations, navigational aids, radio frequencies, maximum elevation figures (trees, towers, antennas), and airspace information for large areas of the United States. The sectional aeronautical charts have a scale of 1:500,000 (Federal Aviation Administration, 2004). Sectional charts consist of United States Geological Survey (USGS) 15 minute quadrangles called the National SAR grid. There are 37 sectional chart areas which make up the conterminous U.S. at the present time.

Pilots are trained to plan flights according to sectional charts. However, when SAR missions are called for, National SAR grid maps become part of the reference data. The CAP delineates a standard grid system based on 15 minute USGS quads. Figure 2 shows a portion of the Chicago sectional chart with a CAP grid superimposed.

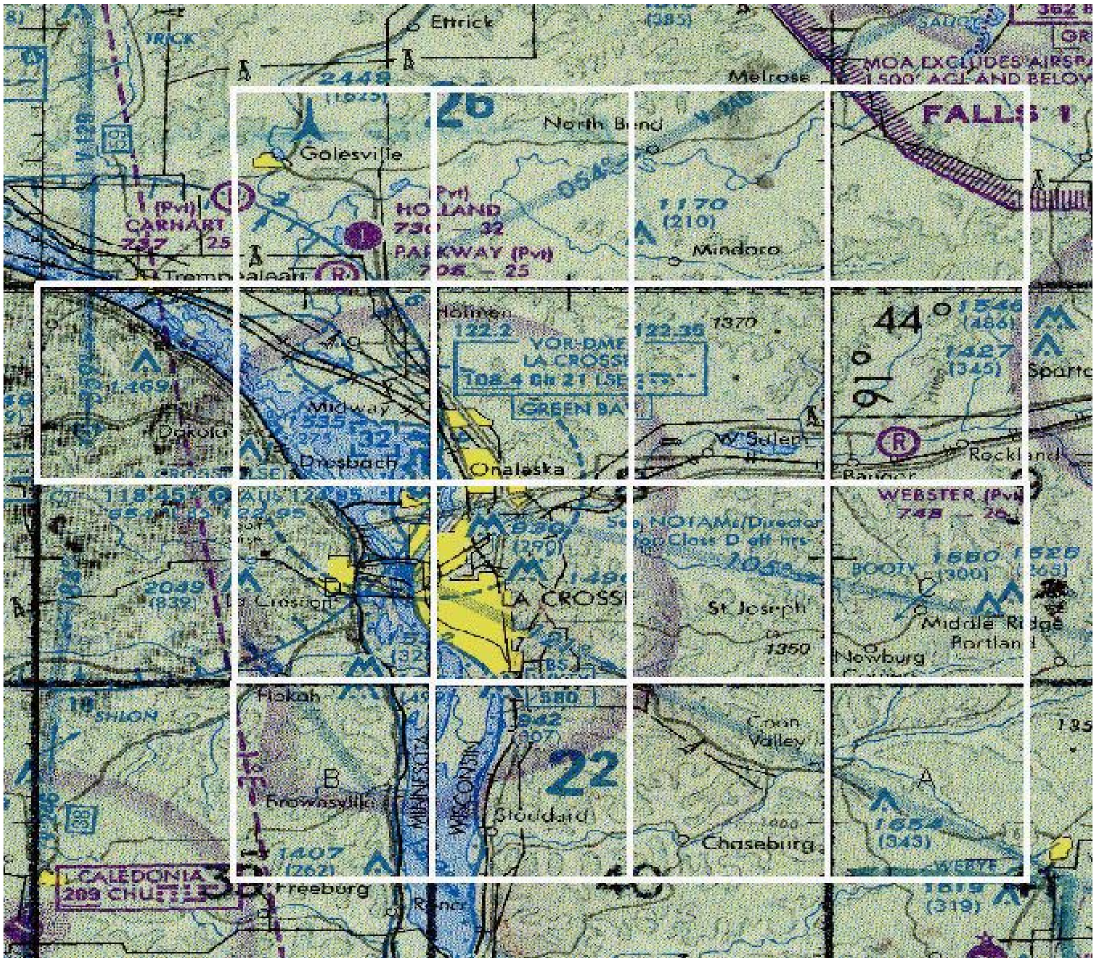

Figure 2. A portion of the FAA Chicago Sectional Chart, with the National SAR grid lines for the La Crosse County, Wisconsin, area superimposed.

Search Patterns

CAP defines three standard search patterns during SAR operations: creeping line, parallel track, and expanding box. A creeping line search is dependent upon reports of fairly reliable start-to-finish locations (Figure 3). Parallel track is used when only a general location is known (Figure 4). For instance, there might be a report of a missing aircraft that could have strayed off course or a missing person on foot. The expanding box would be more applicable in a situation where there has been a report from the air of a possible crash site (Figure 5).

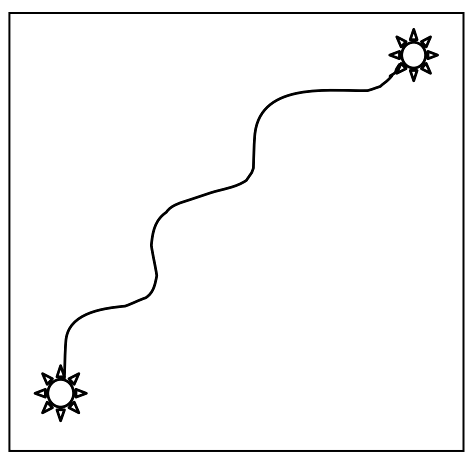

Figure 3. Creeping Line Search Pattern

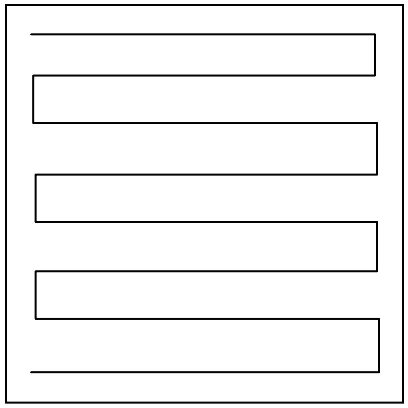

Figure 4. Parallel Track Search Pattern

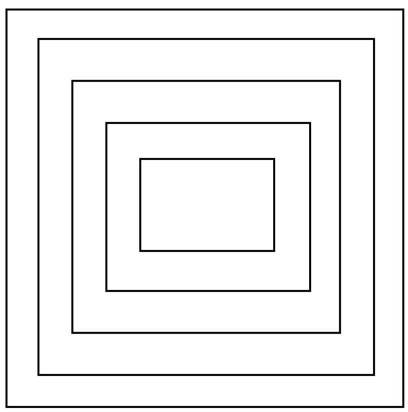

Figure 5. Expanding Box Search Pattern

Methods

Digital Conversion of Reference Data

First, an aeronautical sectional chart was scanned on a flatbed scanner and stored in a TIFF format. The study area was defined by working with the local CAP squadron, headquartered in La Crosse, Wisconsin. The Chicago sectional chart encompassing the southern portion of the State of Wisconsin, in addition to small portions of Illinois, Iowa, and Minnesota, was used. USGS digital elevation models (DEMs) and digital raster graphics (DRGs) were obtained. Since CAP is accustomed to coordinate information in the decimal degrees, these datasets were re-projected using ENVI© image processing software.

The scanned charts required georeferencing in order to be utilized as GIS layers. As previously noted, the CAP creates flight plans according to a sectional chart. An ArcView® Avenue™ programming script was revised whereby the precise latitude and longitude coordinates can be entered to generate spatially accurate polygons (Razavi and Warwick, 1997). These were stored as ArcView shapefiles.

Producing a digital version of the National SAR grid provided a base layer for georeferencing the raster format aeronautical chart. The x,y coordinates of the National SAR grid were used to establish links to the corresponding point locations on the sectional charts. During SAR missions, the CAP further delineates search patterns by subdividing into quarter grids. A script was obtained to automate this function. These quarter grids are labeled as A, B, C, D corresponding with NW, NE, SW, SE. See Figure 6 for an example.

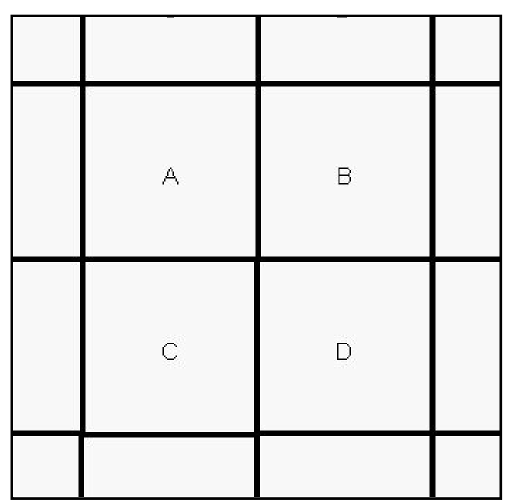

Figure 6. Quarter grids created by running an Arenue script.

Attribute Database

The power of a GIS is demonstrated through its capability for storing and linking nonspatial data (attributes) with spatial data. The need for efficient access to integrated information in search and rescue mission planning has been well documented (Payette, 1997, ESRI, 2000). To begin building a centralized database for CAP operations, an internet search for ancillary data was performed.

Location information for U.S. airports is available for download (Bureau of Transportation Statistics 2001) as an ArcView point file. The attribute table was edited to include up-to-date information from aeronautical charts. Use of the identity tool in ArcView gives mission base personnel immediate access, not only to coordinates, but also to radio frequencies, elevation, and runway parameters (Figure 7). Because the CAP utilizes both aircraft and ground search crews, TIGER® files for roads at the county level were downloaded in shapefile format (U.S. Census, 2000).

Previous aircraft crash sites were available from CAP as a list of x,y coordinates. An Avenue® script was used to create a point based on latitude and longitude. The following is an example of the programming code:

```
theView = av.GetActiveDoc
theDisplay = theView.GetDisplay
defaults = {"-108.8932","46.2116"}
labels = {"X(Longitude","Y(Latitude)"}
myPnt = MsgBox.multiInput("Set
   Coordinates","Make Point",labels,defaults)
x = myPnt.get(0).asnumber
y = myPnt.get(1).asnumber
mygp = point.make(x,y)
gp = GraphicShape.Make(mygp)
theView.getGraphics.Add(gp)
theView.invalidate
```

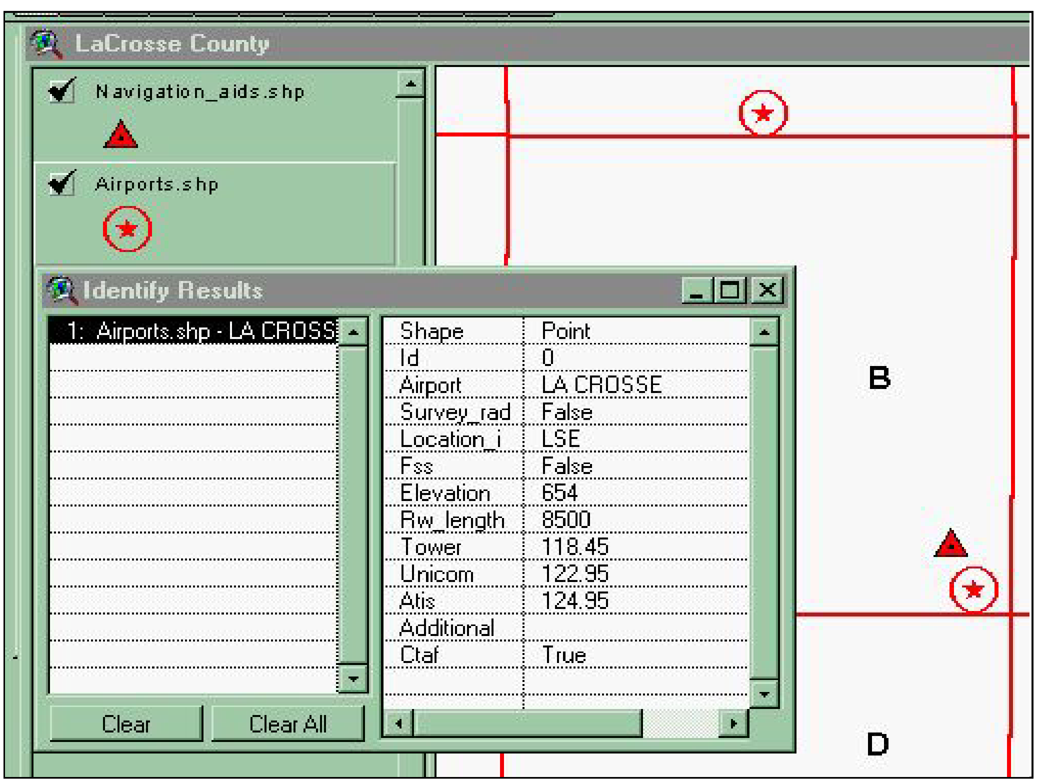

Figure 7. Graphical User Interface with Identify Results box displayed.

The table associated with this point file can be enhanced to store information as investigations proceed. Also, a point file was generated for navigational aids, with information derived from the sectional charts. Strictly speaking, navigational aids are VORs, very high frequency omnidirectional range. However, any recognizable landscape feature can be recorded as a navigational aid.

The ArcView interface was customized by associating scripts with buttons. With the click of a button, an input box prompts the user to enter x,y coordinates. An individual who is relatively unfamiliar with GIS can quickly be shown the use of this technique. During a mission, coordinates relayed by flight crews can be recorded and reviewed in mission briefings.

Results

In evaluating manual versus digital techniques in SAR missions, several issues were investigated.

- Time saving
- Increased accuracy
- Efficient utilization of resources
- Improved safety for personnel

Using the functionality of scripts, coordinate points can be entered into the GIS and displayed on a digital map. This is useful in locating a reported crash site or probable location of a lost person, so that the search area can be determined as precisely as possible. The SAR mission plan, and specifically the search pattern, is dependent upon the precision of this information. Traditionally, latitude and longitude have been plotted manually using hard-copy sectional charts and SAR grids. With minimal training, personnel can now enter x,y coordinates in a dialog box and view the point location graphically displayed. With the click of a finger, layers of information necessary for mission planning are available.

This capability is also valuable during the management phase of the mission. Aircrews can report GPS coordinates back to the mission base during fly-over, and the locational information can be relayed rapidly to the ground crews. These GPS coordinates can also be stored as waypoints by the air and ground crews, then they can be entered into the GIS for better assessment of the day's search. Information can be gained from the data to determine if there was sufficient coverage of the search area or establish new search areas for the next deployment. Timed tests to assess the difference between manual and digital location of points were performed. An average cumulative time saving of 30% was reported by qualified CAP members (Roldán, 2003).

Improved accuracy in locating the target increases the probability of saving lives. Statistics show that the number of hours during which accident victims or lost persons remain in adverse weather conditions and without medical attention is directly related to their probability of survival (Office of Aircraft Services, 1997). Improved locational capabilities help to identify hazards that might interrupt SAR efficiencies. For example, mission base personnel with GIS capabilities can relay information about specific ground features to SAR crews, such as, large forested areas, rivers or creeks, or swamp areas.

Digital techniques also show an improvement in efficient utilization of resources. As previously noted, search areas and search patterns can be better analyzed and assigned. This results in a reduction of flight time and ground vehicle time. In both instances, there are savings in fuel consumption and equipment wear.

All of the above translates to increased safety for the SAR personnel. Fatigue is a critical issue during missions. Air crews, ground crews, and mission base personnel will benefit from decreased time and energy expenditures. Better locational accuracy with detailed informative data allow for mission commanders to utilize their resources more effectively resulting in more lives saved, less money spent, and increased personnel safety.

Recommendations and Conclusion

While considering implementation of a GIS for CAP search and rescue missions, it is important to evaluate customized software which is currently available. SAR Viewpoint® is a commercial program created by Airways Technology. Advantages of this software included the integration of the national SAR grids and aeronautical information (airports, navigational aids, airways, airspace). However, there were significant limiting factors. The use of ancillary data was not as extensive as noted with ESRI ArcView. Perhaps most importantly, there is not the capability for customization as in a GIS. The purchaser of "stand alone software" has the limitation of data that the software manufacturer chooses to incorporate in the package, and the purchaser must pay for updates to the data. One can easily see that building and maintaining a centralized database is critical to SAR missions and overall emergency preparedness. This project emphasizes that it is important to consider the importance of keeping the database current. Sectional charts are deemed obsolete for aviation after six months. SAR Viewpoint includes a useful tool, called the Coordinate Calculator™. A similar function could be replicated using Visual Basic to provide an interface for calculating fuel consumption, crosswinds, air speed, etc.

GIS has the potential of becoming a familiar tool for personnel responding to emergencies. The framework of GIS layers and associated database tables makes data maintained by various agencies readily accessible. Up-to-date information can be brought to bear on a situation in real-time. This framework also centralizes and organizes data for analysis and visually displays critical information. By giving SAR mission personnel the tools for integrating data from many sources, GIS can transform the way SAR mission operations are planned and conducted in the future.

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