Development of a Geographic Information System for Risk-Informed Decision Making in Aerospace Medicine

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A geographic information system (GIS) is able to display information spatially by translating location data to a coordinate system. This system enhances the understanding of the distribution of events in both space and time. With spatial data, one can analyze the underlying information, discovering patterns and trends. GIS applications are valued among varying domains, including transportation, public safety, public health, and research.[6]

Tobler's First Law of Geometry states that everything is related to everything else, but near things are more related than distant things.[4] The concept of relatedness established from Tobler's First Law of Geometry supports the justification for a whole class of spatial statistics which can be performed at these various levels of scale. GIS specialists refer to this law as spatial dependence.[1] GIS coordinate systems support the examination of events at different scales: these levels can vary from that of a neighborhood to a national or global region.

An integrated database containing the details of the events of interest typically supports the GIS application. This database consists of both spatial data expressed as latitude and longitude as well as miscellaneous information concerning the event. The front end of a GIS application is typically a map, which relies on the underlying database. The resulting map conveys information visually to the end user concerning the spatial distribution of the events. Most GIS applications run on a high-end desktop or server, but in recent times, many of these packages have acquired the ability to interface via web pages. These web pages, encoded with GIS data, can distribute this information via a web browser. This enhances the rapid dissemination of spatial data concerning events seamlessly to senior managers and decision makers.

The Aeromedical Data Visualization Operational Reporting Safety System (ADVisORS2) is a GIS for aviation medical and accident research constructed at the Civil Aerospace Medical Institute (CAMI). The purpose of ADVisORS2 is to provide information concerning the distribution of fatal aviation accident findings to senior level managers and decision makers through GIS.

The ADVisORS2 application relies upon the Medical Analysis Tracking Registry (MANTRA) system maintained by the CAMI Autopsy Program Team. MANTRA is unique in that it is a nexus for varied sources of information on fatal aerospace accidents. These sources include the National Transportation Safety Board's (NTSB) aircraft accident database, Document Imaging Workflow System (DIWS), Airmen Registry, Bioaeronautical Sciences Research Laboratory toxicology database, and the autopsy reports submitted from medicolegal death investigations. The latitude and longitude of the accident data hosted within MANTRA is imported into ADVisORS2 and coupled with its associated reports from the NTSB and toxicology database to perform spatial analysis. The FAA's Flight Standards Service, New Technology Development Branch (AFS-150), provides technical support and training for ADVisORS2.

One type of analysis that ADVisORS2 offers is the hot spot analysis. This type of analysis enhances aviation safety by offering an immediate view of statistically significant clusters where high rates of aviation accidents have occurred. Visualizing the location via a map offers investigators and regulators an understanding of issues such as terrain or airspace that could be a cause of concern. A second type of spatial analysis that GIS offers is the nearest neighbor analysis. This statistic gives a ratio

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measurement of the difference between what is observed and what is expected. A nearest neighbor analysis can determine if a pattern is randomly distributed, clustered, or uniform. Another spatial statistic used within GIS is the deviational ellipse. First explained by Lefever in 1926, this descriptive statistic is a measurement of the standard deviation (SD) of a point in terms of location by latitude and longitude.[2] The deviational ellipse surrounds a given number of points based on the calculated standard distribution. Therefore, a 1 SD would encompass approximately 68% of the points around the calculated mean center.

These analytics support the risk-based decision making criteria in the National Aviation Research Plan (NARP).[3] The FAA Office of Aerospace Medicine is employing GIS applications to integrate risk-informed decision making within aviation medicine in response to the NARP. ADVisORS2 supports this effort by promoting the examination of medical trends and geostatistics concerning medical findings. Exploring the accident and medical events associated with GIS promotes a better understanding of the distribution of medical factors regarding specific aviation events. Spatial analysis allows aerospace medical researchers to determine the distribution of events and make statistical inferences based upon those findings.[4]

A recent study on selective serotonin reuptake inhibitors (SSRIs) offers an example of the use of the deviational ellipse. This study plotted the fatal aviation accidents from 2009–2014 and categorized them as to whether there was a toxicological finding indicating the presence of an SSRI.[5] **Fig. 1** displays the first standard deviation ellipse of the spatial distribution of these fatal accidents. The center of the ellipse is indicated with a small cross. This figure shows the distribution of fatal aviation accidents in which an SSRI was discovered had a smaller SD than those in which no SSRI was found. The centers were also located in different parts of the nation, demonstrating further differences in the distribution of these events. Other aviation medicine related studies using ADVisORS2 included the examination of antihistamines under varying flight conditions and cardiovascular disease among U.S. civilian pilots [Gildea K, Hileman C, Rogers P, Guillermo S, Paskoff L. Antihistamines and fatal aircraft accidents in instrument meteorological conditions (IMC); unpublished study]. Future aviation studies amenable to GIS include examining issues such as airmen age, distribution of accidents by time, season, type of operation, and geographic location.

Fig. 2 depicts the level of detail that a GIS is able to deliver to senior decision makers. This figure displays the basic

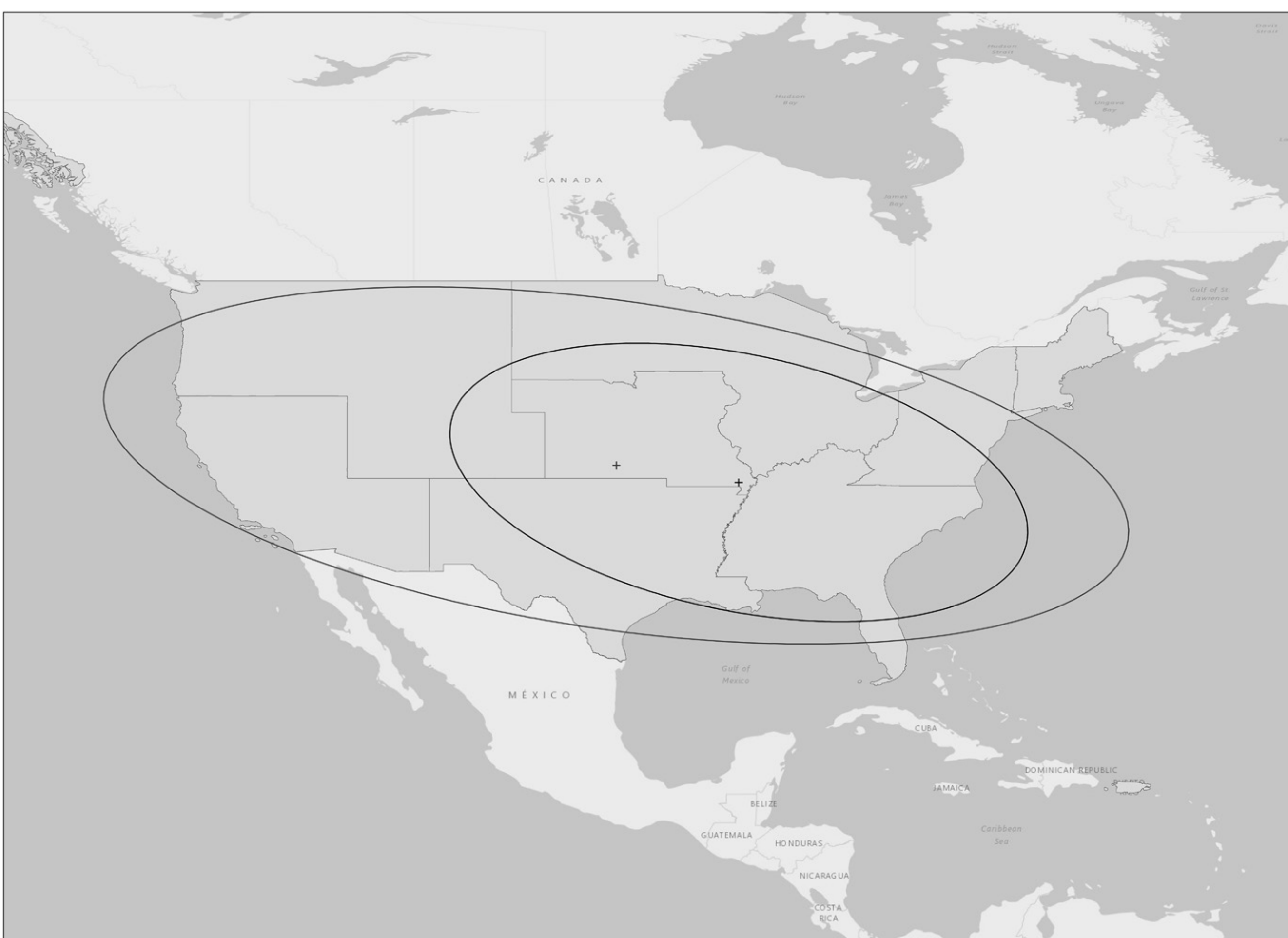

Fig. 1. Distribution of fatally injured airmen who tested positive for SSRI (smaller ellipse) along with the distribution of airmen who tested negative (larger ellipse).

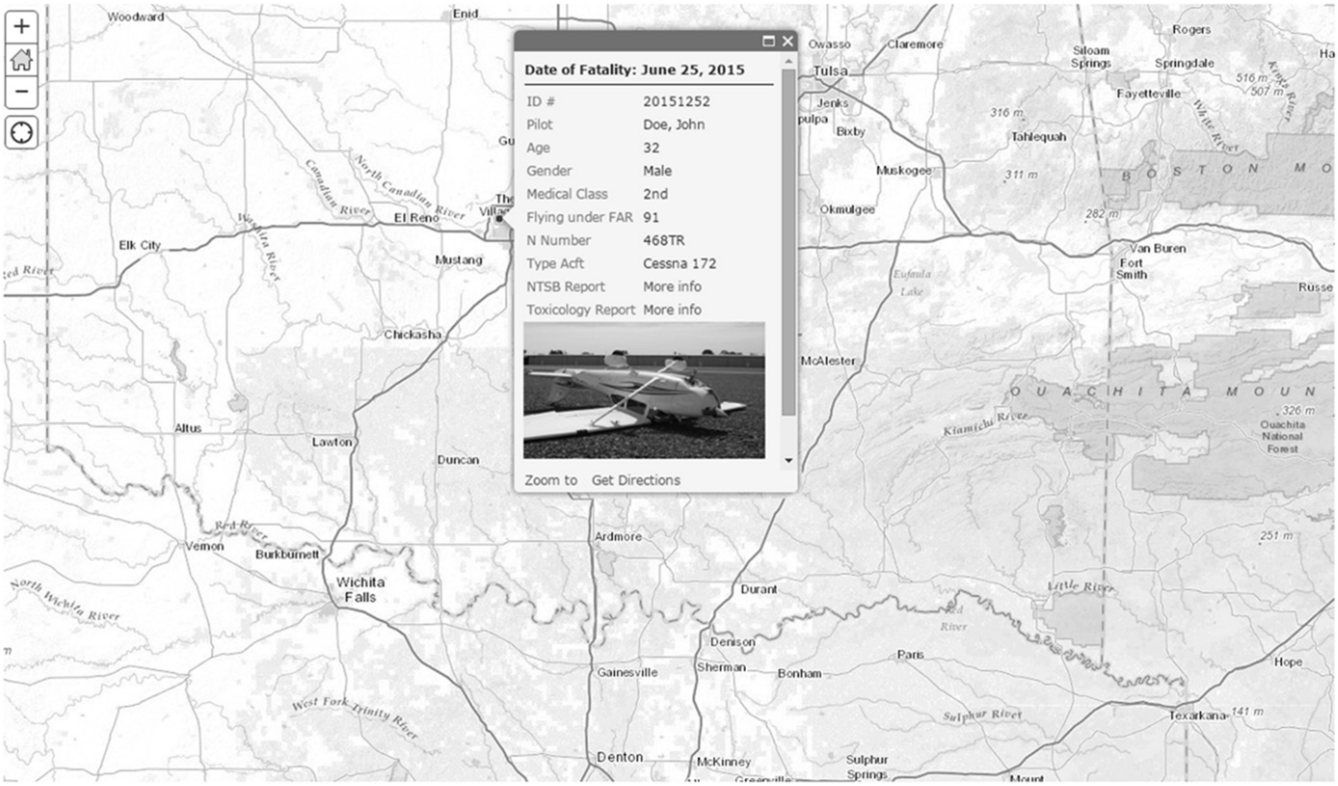

Fig. 2. A depiction of the level of detail available for each fatal accident.

demographics of the accident victim as well as the date, location, NTSB report, toxicology results, and picture of the accident wreckage.

GIS is invaluable in time trend analysis; adding the dimension of time allows the distribution of events to be observed from month to month. For example, a user can view accident trends both geographically and seasonally for agricultural industries that employ aviation companies operating under FAR Part 137 rules.

CAMI is exploring the integration of GIS with other efforts so as to enhance risk-assessment by decision makers.[7] For example, risk assessment in the medical certification of pilots is a more complex task than determining the shifting probabilities of component malfunction within hardware. The medical certification process begins when an applicant first visits one of the designated 4000 Aviation Medical Examiners located nationwide to obtain a first-, second-, or third-class medical certificate. Once the aviator's flight physical is complete, it is electronically transmitted to a central database located at CAMI in Oklahoma City. CAMI receives approximately 2000 electronic medical records a day for review.

It is expected that implementation of a GIS approach to a process as large as the national certification of airmen should reap the following benefits:

1. Allow the multifaceted process of medical certification to be seen as a coherent whole, highlighting areas that are the greatest risk contributors.
2. Identify risk-significant medical events spotlighting where improvements can be effective.
3. Cultivate a risk informed culture, thereby improving risk awareness, safety, and efficiency.
4. Quantify noteworthy performance measures.
5. Model and predict the effects of medical certification regulations and policies on the U.S. civil pilot population.

These benefits can be seen in both the long and short term with targeted safety efforts in the aviation safety community. ADVisORS2 will allow aviation safety professionals to study geographic regions that experience high mishap rates through the use of hotspot analysis, and better focus safety efforts in that given area. The application of GIS, including spatial statistics, is a novel approach to risk informed decision making in the realm of aerospace medicine and it is our intent to utilize GIS as a method to increase awareness of possible safety issues and better target efforts to reduce aviation accidents and incidents.

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REFERENCES

1. Getis A. Spatial dependence and heterogeneity and proximal databases. In: Fotheringham S, Rogerson P, editors. Spatial Analysis and GIS. Philadelphia (PA): Taylor and Francis Inc.; 2002.
2. Lefever D. Measuring geographic concentration by means of the standard deviational ellipse. Am J Sociol. 1926; 32(1):88–94.

3. National Aviation Research Plan. Oklahoma City (OK): Federal Aviation Administration; 2015. [Accessed on 18 July 2016.] Available from: http://www.faa.gov/about/office_org/headquarters_offices/ang/offices/tc/about/campus/faa_host/RDM/media/pdf/2015NARP.pdf.
4. O'Sullivan D, Unwin D. Geographic information analysis. Hoboken (NJ): John Wiley & Sons, Inc.; 2010.
5. Rogers P, Hileman C, Guillermo S, Cliburn K, Paskoff L, et al. Examination of selective serotonin reuptake inhibitors in the population of fatally injured pilots. Aerosp Med Hum Perform. 2016; In press.
6. Shekhar S, Evans M, Kang J, Mohan P. Identifying patterns in spatial information: a survey of methods. Data Mining and Knowledge Discovery. 2011; 1(3):193–214.
7. Zio E, Pedroni N. Overview of risk-informed decision-making processes. Toulouse (France): Foundation for an Industrial Safety Culture; 2012:10.