

Geospatial field applications within United States

Department of Agriculture, Veterinary Services

Priscilla L. FitzMaurice, Jerome E. Freier & Kenneth D. Geter

Summary

Epidemiologists, veterinary medical officers and animal health technicians within Veterinary Services (VS) are actively utilising global positioning system (GPS) technology to obtain positional data on livestock and poultry operations throughout the United States. Geospatial data, if acquired for monitoring and surveillance purposes, are stored within the VS Generic Database (GDB). If the information is collected in response to an animal disease outbreak, the data are entered into the Emergency Management Response System (EMRS). The Spatial Epidemiology group within the Centers for Epidemiology and Animal Health (CEAH) has established minimum data accuracy standards for geodata acquisition. To ensure that field-collected geographic coordinates meet these minimum standards, field personnel are trained in proper data collection procedures. Positional accuracy is validated with digital atlases, aerial photographs, Web-based parcel maps, or address geocoding. Several geospatial methods and technologies are under investigation for future use within VS. These include the direct transfer of coordinates from GPS receivers to computers, GPS-enabled digital cameras, tablet PCs, and GPS receivers preloaded with custom ArcGIS™ maps – all with the objective of reducing transcription and data entry errors and improving the ease of data collection in the field.

Keywords

Accuracy, Animal disease, Coordinates, Emergencies, Geographic information system, Global positioning system, Standards, Surveillance.

Applicazioni nel campo geospaziale nell'ambito del Dipartimento dell'Agricoltura degli Stati Uniti d'America – Servizi Veterinari

Riassunto

Epidemiologi, funzionari medici veterinari e tecnici di sanità animale all'interno dei Servizi Veterinari (SV) utilizzano attivamente la tecnologia GPS (sistema globale di posizionamento) per ottenere i dati posizionali sul bestiame e sulle operazioni nelle aziende avicole negli Stati Uniti. I dati geospaziali, se acquisiti a fini di monitoraggio e sorveglianza, vengono memorizzati all'interno del Database Generico dei SV (GDB). Se vengono raccolte informazioni nel caso in cui le informazioni vengano raccolte nel caso di un focolaio di una malattia, i dati vengono inseriti all'interno del Sistema di Risposta e Gestione delle Emergenze (EMRS). Il gruppo di Epidemiologi Spaziali insieme al Centro per l'Epidemiologia e la Sanità Animale (CEAH) ha fissato degli standard minimi di accuratezza per l'acquisizione dei dati spaziali. Per assicurarsi che le coordinate geografiche raccolte sul campo soddisfino questi standard minimi, il personale di campo riceve formazione sulle corrette procedure di raccolta dati.

United States Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services, Centers for Epidemiology and Animal Health, 2150 Centre Avenue, Building B, Fort Collins, Colorado 80526,
United States of America
priscilla.l.fitzmaurice@aphis.usda.gov

L'accuratezza posizionale viene validata con atlanti digitali, fotografie aeree, mappe parcellizzate basate sul Web, o indirizzi geocodificanti. Differenti metodiche e tecnologie geospaziali sono in corso di valutazione per un futuro utilizzo all'interno dei SV. Queste comprendono il trasferimento diretto delle coordinate dai ricevitori GPS ai computer, alle fotocamere digitali GPS-compatibili, PC portatili, ed ai ricevitori GPS precaricati con mappe ArcGIS™ – tutte con l'obiettivo di ridurre gli errori nella trascrizione ed immissione dei dati e migliorare la raccolta dei dati sul campo.

Parole chiave

Accuratezza, Coordinate, Emergenze, Malattie Animali, Sistema globale di posizionamento, Sistema informativo geografico, Sorveglianza, Standard.

Introduction

Veterinary medical officers and animal health technicians within the United States Department of Agriculture, Veterinary Services (VS) acquire geospatial coordinates for livestock and poultry locations during routine inspections of animal operations or while investigating specific animal disease incidents. These data are ultimately used for monitoring and surveillance applications, risk assessments and to predict the spread of animal diseases using geospatial analysis. In addition, VS uses standardised data collection methods to ensure that minimum accuracy standards are met. New technologies are frequently investigated to improve and enhance the data collection process and to reduce transcription errors.

Although global positioning system (GPS) receivers are the most commonly used method for collecting geographic coordinates of animal facilities, digital atlases are periodically implemented when site visits are impractical. Alternatively, digital atlases may be used in VS to verify positional accuracies of field-collected GPS coordinates.

Adhering to standardised methods of geospatial data collection by VS is critical to ensure that premises with affected animals can be rapidly and accurately located during an animal disease emergency. VS field staff receives periodic training in the use of GPS

receivers and digital atlas software to confirm that all data collected and recorded are complete and accurate.

Materials and methods

GPS receivers are the preferred method when acquiring positional data for animal and poultry facilities by VS. The Garmin eTrex Legend GPS receiver (www.garmin.com) is presently the standard GPS receiver for field staff (1). This low-cost, recreational grade receiver has a simple, easy-to-use interface that is relatively intuitive to operate. Personnel from outside agencies, working in conjunction with VS in response to animal disease emergencies, can be easily trained to use this GPS receiver to acquire positional data. Furthermore, the eTrex Legend is capable of receiving positional corrections through the Wide Area Augmentation System (WAAS). As a result, significant improvements in positional accuracies to within three meters can be achieved 95% of the time. This threshold is more than sufficient for most animal agriculture applications.

Data collection standards

Locational data are acquired using specific data standards, thus overriding the need to convert the data when it is exported out of the Generic Database (GDB) and the Emergency Management Response System (EMRS) and displayed in a desktop mapping program for analysis. Standardised formats are especially important when responding to time-critical events, such as animal disease emergencies (2). The following GPS receiver settings have been established as VS standards for coordinate data collection: 1984 World Geodetic System (WGS 84) or 1983 North American Datum (NAD 83) map datum, decimal degrees format recorded to six decimal places, 3D fix or a minimum of four satellites, 25 foot accuracy or better, and 'feet' as units of distance.

Field personnel may collect several sets of coordinates for each premises. The primary location for acquisition of premises coordinates is at the 'front gate' (Fig. 1), which is defined as the intersection of the private entrance into the facility with the public right-

of-way. These coordinate pairs are useful for matching E-911 or geocoded addresses for verification of positional accuracy. A secondary set of coordinates is obtained where individual groups of animals associated with the premises are housed. A final set of coordinates may be gathered at habitats favourable to disease vectors, at areas containing specific plants or chemical sources implicated in toxin exposure, or at sites where domestic animals interact with wildlife vectors. This final set of coordinates is useful for targeted epidemiological studies.

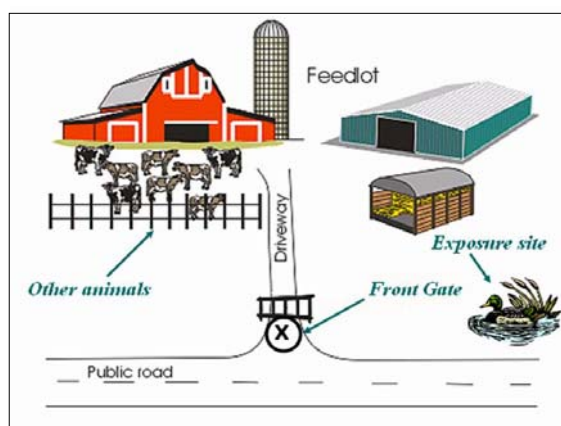


Figure 1
Standard locations for coordinate readings

For individual groups of animals, standardised sites for collecting coordinates have been established by VS to ensure identification of animals, either for routine animal health surveillance or in the event of an animal disease emergency. Locations for coordinate readings vary with species of animal and type of facility. Coordinates for a feedlot or cow/calf operation, for example, are obtained at the entrance to a corral or a pen, whereas coordinates at a dairy operation are acquired at the entrance to the milk parlour. For poultry or swine operations with multiple buildings, the feed mill provides an easily-recognisable location for coordinate observations. As in cattle feedlots or cow/calf operations, coordinates for sheep or horses are collected at the entrance to the pen or pasture. If there are multiple entrances to the pen, coordinates are obtained at the entrance closest to the front gate. For free-ranging animal populations, multiple coordinates are obtained, outlining

the perimeter of the estimated home range of the animals. The home range is defined by vegetation, terrain or other landscape factors which tend to naturally confine the movements of the animals. If the animals are on open range only during the day, additional coordinates are acquired at the entrance to the pens or corrals where they are held at night.

Collection and recording of geospatial coordinates

Many veterinary field personnel use digital atlases instead of GPS receivers to obtain geographic coordinates for routinely-inspected facilities, thus replacing onsite visits to each premises. VS uses DeLorme's *Street Atlas USA* (www.delorme.com), although many other digital atlases are available at low cost. In addition to locating premises by address, digital atlases can be used to verify the accuracy of GPS coordinates and to locate affected premises during an animal disease emergency.

Field personnel currently transcribe coordinates from GPS receivers to data entry forms by hand. At the field office or the incident command centre, the data are entered into one of the primary animal disease VS databases. The GDB is an Oracle® database system that captures monitoring and surveillance data for VS programme diseases, including brucellosis, scrapie, avian influenza and bovine tuberculosis. There are separate data fields for front-gate coordinates and for coordinates representing groups of animals associated with the premises. Records can be extracted for analysis in ArcGIS™ using a structured query language (SQL) statement or through an Oracle® database connection in ArcCatalog™. The EMRS is a Web-based task management system that captures data related to animal emergencies, including disease outbreaks and natural disasters. As in the GDB, data entry fields are available for entering front-gate coordinates. A direct connection to the EMRS database through ArcGIS™ can be established to display and analyse data.

Identification and correction of geospatial coordinate errors

Errors in GPS-collected coordinates may be caused by selecting an incorrect datum or coordinate system, poor acquisition of satellite signals, or by using an insufficient number of satellites for a GPS fix. Transcription errors, when copying coordinates from GPS receivers to survey forms and during database entry, are a common source of data inaccuracies. Several methods, described below, are employed by VS to ensure that geographic coordinates, acquired during routine surveillance and animal disease emergencies, are correct.

An accuracy checkpoint (ACP) (Fig. 2) is established by field staff to verify that their GPS receivers are collecting coordinates within acceptable accuracy limits. The object selected as an ACP must be easily accessible to home or office, relatively permanent, and have an unobstructed view of the sky for optimum signal acquisition. Several pair of coordinates are collected and averaged to determine the final ACP coordinates. Prior to collecting coordinates in the field, veterinarians and animal health technicians obtain new coordinates at the ACP and compare them to the established ACP coordinates. The new coordinates must match the ACP coordinates to at least three decimal places. If the coordinates deviate beyond this threshold, the settings within the GPS receiver may have been inadvertently altered and must be manually corrected. If the settings are correct, the receiver may be defective and will require repair or replacement. It is important to note that the GPS coordinates should correlate to three decimal places at the ACP. However, coordinates collected for premises and animal locations must be recorded to a minimum of six decimal places to ensure appropriate accuracy.

Digital atlases

Digital atlases may be used as a visual tool to assess the positional accuracy of GPS-collected coordinates. When coordinates are copied by hand onto data entry forms, frequent transcription errors may occur. To identify potential positional errors, GPS coordinates are

downloaded into a digital atlas, such as *Street Atlas USA*, and referenced to detailed street information. Any significant errors will become readily apparent. These can be corrected, if necessary, by choosing the digital atlas coordinates, or by making another visit to the premises. Coordinates obtained with a GPS receiver are typically more accurate than those extracted from a digital atlas. However, if the field veterinarian or technician is familiar with a facility's location from prior on-site visits, the digital atlas coordinates can be surprisingly accurate.

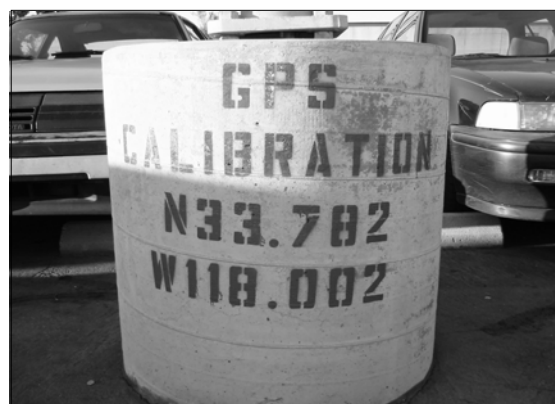


Figure 2
Example of an accuracy checkpoint

Additionally, digital atlases can be useful for locating premises with susceptible animals and creating simple maps for routing emergency and surveillance personnel during animal disease emergencies.

Address geocoding

Address geocoding is a process that assigns geographic coordinates to an address using a reference dataset. VS use Tele Atlas' dataset of highly-precise street networks for the United States (www.teleatlas.com), which is available to the United States Department of Agriculture, Animal and Plant Health Inspection Service (USDA, APHIS) through an enterprise licence agreement. In ArcGIS™, geocoded coordinates are compared with their respective GPS coordinates to identify errors between the two coordinate pairs.

Web-based cadastral map services

Web-based cadastral map services are often available through third-party vendors or

individual county assessor's offices. These Web-based services are useful for locating and viewing detailed parcel ownership and boundary data. Premises can be located either by address or geographic coordinates. Some map services provide high-resolution aerial photography as a base layer, overlaid with polygon layers depicting property boundaries. These map services often contain additional information related to house values, parcel sizes and other property information that may be useful in locating premises or designing spatial models in a desktop mapping program that predict areas with affected animals or poultry.

High-resolution imagery

High-resolution imagery, such as digital orthophoto quarter quads (DOQQs), can be used to visually identify and verify the location of poultry houses or other large agricultural buildings that house animals. Coordinates, obtained from this type of georeferenced imagery within a GIS, can be an efficient means of locating animal operations in a disease emergency or for routine surveillance purposes.

Future geospatial field applications

Veterinary Services continue to improve their data collection methods by investigating and implementing new technologies that facilitate data collection in the field while striving to minimise data entry errors.

Several new methods for gathering and recording coordinate data are currently under review. Many of these technologies will reduce the incidence of transcription errors by directly transferring premises coordinates into ArcGIS™ for display and analysis.

Presently, VS field staff manually transcribes coordinates from GPS receivers to survey forms which increases the possibility of data errors. To address this problem, VS is promoting the use of DNRGarmin, a freeware program that is downloadable from the Minnesota Department of Natural Resources website (www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html). Coordinates can be transferred directly between GPS receivers and computers. This is

especially useful in animal disease emergencies where data collected in the field can be downloaded from GPS receivers to computers at the incident command centre and utilised in geospatial mapping and analysis. DNRGarmin can be used as a stand-alone program to create text files or shapefiles or can be used interactively from within ArcGIS™. Coordinates can also be uploaded from ArcGIS™ to Garmin GPS receivers, allowing field staff to identify premises using preloaded coordinate locations from ArcGIS™.

GPSMapEdit (www.geopainting.com/en/) is a shareware application that transfers custom vector maps developed in ArcGIS™ to a Garmin GPS receiver. Shapefiles of quarantine zones, buffer zones and farm locations can be created in ArcGIS™ and uploaded to GPS receivers for positional reference in the field. During an animal disease emergency, surveillance personnel can use these maps to accurately locate affected premises within a quarantine zone. This technology can also be used to enhance surveillance and monitoring efforts.

Field veterinarians and technicians who collect coordinates for premises and animal locations during routine disease surveillance may import these coordinates into mapping software for visualisation, verification and basic spatial analysis. Lacking established GIS staff at the field office level and with ArcGIS™ evolving into an increasingly complicated software package, it is more appropriate for VS field staff and epidemiologists to use mapping freeware or shareware than to invest their time in learning ArcGIS™. Many of these simple mapping applications are widely available online at little or no cost and provide a user-friendly alternative to ArcGIS™ for importing, viewing and validating the accuracy of GPS coordinates. In addition to data visualisation, many of these applications perform basic spatial statistics or spatial analysis, and can create relatively sophisticated maps.

GPS-enabled digital cameras combine a GPS receiver with a digital camera to capture geographic coordinates in real time and synchronise the digital photos with GPS coordinates. Geospatial Experts' GPS-Photo

Link software (www.geospatialexperts.com) uses an ArcGIS™ extension to integrate and view digital photos in ArcMap™. By using GPS-enabled digital cameras in the field, coordinate acquisition is simplified, with less likelihood of error. Coordinate locations with embedded hotlinks to the appropriate photo of the animals or the facility can then be displayed in ArcGIS™.

Another emerging technology for field applications is the wrist-mounted GPS receiver. This receiver resembles a large watch and is light and compact. Presently, these units have very basic GPS functionality and are incapable of uploading maps, changing datums or altering coordinate formats. However, with future modifications, these units may provide a convenient alternative to handheld GPS receivers. Proprietary software and a USB cable are required to transfer coordinates to a computer.

Tablet PCs provide a paperless system for data entry that may help reduce transcription errors. Data are entered into customised digital forms by pen or keyboard. Ruggedised versions, specifically designed to withstand the rigours of field use, are also a viable option. Many tablet PCs include an optional compact flash GPS card that automatically acquires coordinates in real time and populates appropriate coordinate fields in the

digital data form. These are fully-functional computers running on Microsoft® Windows operating system, and can easily accommodate ArcInfo™. Currently, there are severe limitations to the accuracy of the integrated GPS card, although the technology is gradually improving.

Results and discussion

USDA/APHIS VS is targeting methods to acquire accurate geospatial data, in accordance with VS standards. This is accomplished through the continual training of field staff in the proper use of GPS receivers and digital atlases, combined with a strong emphasis on data accuracy.

Future enhancements in positional data collection for VS may include transferring GPS coordinates directly into ArcGIS™ or entering data into digital forms using GPS-integrated tablet PCs while in the field, thus avoiding transcription errors. In addition, field application of user-friendly mapping software to display geospatial data for analysis and basic map making is being explored. GPS receivers, preloaded with detailed map data from ArcGIS™, and GPS-enabled digital cameras may eventually become standard equipment during disease emergencies or for ongoing surveillance activities.

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