Managing Agricultural Emergency Resources through Information Mashups

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Abstract

Agriculture is under constant threat of natural disasters, exotic animal diseases, pests, and potential bioterrorism. In the case of agricultural emergency, one of the challenges is to provide accurate geo-reference data to assist emergency response. Different agencies in response to an emergency event have to collaborate and share information about the actions they are performing. Google Earth, a technological icon in recent IT development, provides a high degree of data integration with client data. The technology brings an exciting global integrated platform that allows users share geographical information and facilitate emergency management and response. A web-based system is developed to assist agricultural emergency management using Google Earth and information mashups. In this paper, we will describe the web system in aspects of: 1) dynamic mapping of disaster sites or areas, 2) dynamic mapping of agricultural emergency resources, and 3) producing livestock evacuation plan using Greedy Algorithm to optimize travel distance. Discussion is also made to obtain geographic coordinates using Google Web service. The results indicate that web mashup custom data with Google Earth is an effective means of data visualization tool for agricultural emergency resource management. By leveraging creative combinations of geographical display in Google Earth and information associated with a geographic site stored in the database, the platform provides an effective collaboration environment for multi-agency to coordinate emergency response activities.

Keywords: agriculture emergency, mashup, Google Earth, mapping, information technology

Introduction

Florida's $13 billion agricultural industry is often at risk for natural and man-made disasters. In addition, Florida has 14 major seaports and 131 public airports. In the past, Florida has been struck by many destructive hurricanes. Given the potential for devastating natural disasters (hurricane, fire, and flood), animal disease, exotic species invasion or bioterrorist attack, for an effective agricultural emergency response, it is critical to gather dynamic data of the affected area and available resources for emergency response. Examples of such information includes: 1) location of affected area and people, 2) emergency resources locations for effective deployment, and 3) locations of first responders for disaster response and recovery.

In an emergency planning situation, multiple agencies need to collaborate and share data and information to effectively respond to an event. However, effective information sharing for cross-agency cooperation is not available through a shared platform. Google Earth is one of the technological icons in recent information technology development, and has been used for Hurricane Katrina response (Yarbrough and Easson, 2005). In the case of Hurricane Katrina, Google provided satellite image coverage of the disaster area immediately after the hurricane. Scientists found that personalized disaster data provided through Google Earth proved useful to disaster responders (Nourbakhsh et al., 2006; Malykhina, 2007). The technology has proved to be an excellent, high level, easy-to-use, and a web-based visualization platform to illustrate spatial information.

In 2004, Florida State Agricultural Response Team (SART) was developed to meet the needs of animals and animal stakeholders during the relief period of a declared disaster (Xin, et al., 2005). SART is a multi agency coordination group consisting of governmental and private entities dedicated to all-hazard disaster preparedness, planning, response, and recovery for the animal and agriculture sectors in Florida. The team's mission is to develop and implement procedures and train participants to facilitate a safe, environmentally sound and efficient response to agricultural emergencies on the county, district, and state levels. Information technology is a vital component in achieving SART's mission, and serves to facilitate better preparation for and respond promptly to agricultural emergencies.

Under the banner of Web 2.0 technologies, web applications are moving toward portable, sophistication, and Rich Internet Applications (RIA). While RIA technologies, such as AJAX (Asynchronous JavaScript and XML), provide rich user interfaces to improve user experience and productivity. Among all the Web 2.0 technologies, web mashup, which combines data from more than one source into a single integrated web application, has played a unique role in web applications. Increasingly, users realize single website has limited information and business value. To address web data integration from different sources, web mashups are widely accepted because they are built from easily understandable components and APIs and provide sophisticated functionality. With the mashup technology, the distinction of data integration between internal and external businesses is disappearing. Thus, web is becoming a platform that websites provide their own APIs, which bring a phenomenon that information from different sources and presentation that allows for novel forms of reuse or mashup. In addition to the public available data on the Internet, web mashup could largely increase its value by adding specialized data. According to the Programmableweb (www.programmableweb.com), mapping is one of the top mashup applications. Content and functionality created from a third party, such as Google Earth, can be dynamically embedded in web pages in real-time via web mashup technology, which provides a low cost means for mapping agricultural data.

The objective of this study is to develop a web-based system for managing emergency resources and assisting decision making during an emergency event. The specific goal is to: 1) create dynamic maps of emergency resources for each county, 2) share information on emergency events and disaster areas to assist cross-agency emergency response activities, and 3) study the feasibility of using the technology to assist livestock evacuation.

System Design and Description

The system is a web-based three-tier application designed for Florida SART. Authorized users can sign in to the system to manage emergency resources and create emergency sites. They may also specify a condition to query the database and display geographic information in Google Earth. The system provides an easy-to-use platform so that authorized users in different agencies can share geophysical information and data associated with locations stored in the database on the Internet.

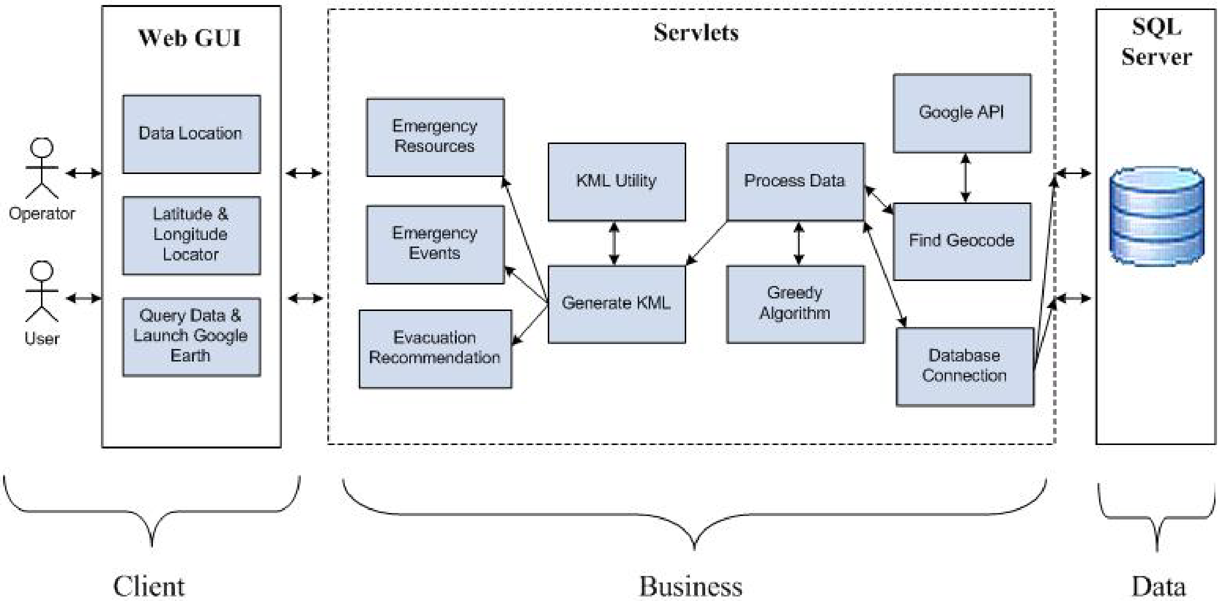

Figure 1. Structure of the system design.

Figure 1 shows the system structure of the 3-tier system, which includes client, business logic and data storage tiers. The client tier is a web presentation layer that provides an easy-to-use user interface. This web interface is designed to perform the following tasks: 1) managing the SART database, 2) finding latitude and longitude from an address or navigation of the Google Maps described in the following section, and 3) launching Google Earth to display user specified data in the database. A user may view geographic information inside Google Earth and click on each location on the map to retrieve data related with this site from the database server. With the combined data visualization, Google Earth illustrates geo-location, and a web browser simultaneously displays related data stored in the database; providing an excellent approach for data visualization of both spatial and relational data.

The business tier handles business logic of the system, and includes four main functions: 1) finding geographic coordinates from an address using Google's Web service, 2) generating KML (Keyhole Markup Language, an XML-based language schema for expressing geographic annotation) file according to user specified conditions, 3) processing user data and database, and 4) computer algorithm to optimize animal evacuation path (see Fig.1). In order to display dynamic geographic data in Google Earth, it is essential to create a proper KML file, which is a file format used to display geographic data in Google Earth or Google Maps. The file is an XML-based format with custom data that can be fetched from a web server and overlaid on top of Google Earth. The Generate KML module creates a KML file based on user specified data. The KML Utility module includes predefined styles, colors, and drawing shapes. By default, opening a KML file will trigger Google Earth. The computer algorithm, Greedy Algorithm (Cormen et al., 1990), is used to optimize resources for livestock evacuation recommendations. This method will be described in subsequent sections. The third tier is a database layer, Microsoft SQL server, for data storage.

Geocoding

Geographic coordinates are required in order to display a location in Google Earth. One of the challenges for dynamic data mapping using Google Earth is to obtain latitude and longitude. Normally geographical coordinates can be obtained using a portable GPS device. However, such process requires a visit to the site; consequently it is costly and time consuming. Luckily, Web services, like Google, provide a means to acquire geographic coordinates by geocoding street addresses. In our project, we provide solutions to dynamically geocode based upon street addresses or user's input of latitude and longitude. In this application, users at different locations maintain a large number of street addresses, which are dynamically geo-coded using Google Web service (Google, 2008). However, if large numbers of addresses are geocoded on the fly through the Web service, the system performance could be affected.

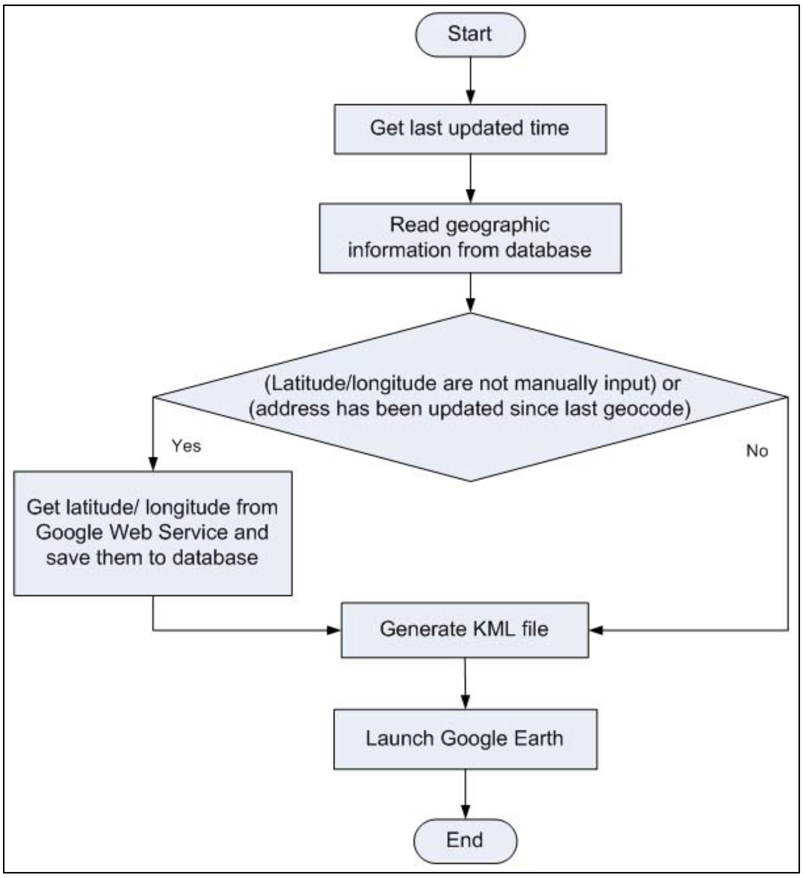

Figure 2. Dynamic geocoding of addresses through Google Web service.

Figure 2 is a flow chart that illustrates the process used to dynamically geocode an address using the Google Web service. To improve system performance, we will incrementally geocode street addresses as the database is updated. Initially, an off-line conversion process is conducted to geocode all addresses in the database, and generated coordinates are saved into database. Although the initial conversion could take a long time, the process can be done during a system maintenance window. After the initial process, there is no need to perform geocoding unless an address is new or updated since last conversion. As Fig. 2 shown, this process skips repeated conversion process and speeds up system performance tremendously. Although Google Web service provides a simple solution to generate coordinators based on street addresses, in some cases, accuracy of the coordinates is largely dependent on accuracy of the address. Also, the service, sometimes, may not be available if the address is new. Luckily, Google Web service returns not only latitude and longitude but accuracy of a coordinate ranging from 0 to 8, with 8 as the highest accuracy. The application can determine if one location has acceptable accuracy. For those locations with lower accuracy, the system allows users to manually enter accurate latitude and longitude such as obtained by a GPS device. Obviously, those locations with manually entered coordinates do not need to go through the geo processing.

Clearly geographic coordinates can be obtained through a GPS device or a geo Web service as we described. However, in many cases, one location may not have a street address. In an emergency event, it is also not practical to visit the site and collect its coordinates. To address this issue, a web interface was developed to assist users finding geographic coordinates through either an address or by navigating the icon on the map (see Fig. 3). A user may enter an address and then click on the "Generate Geocode" button. If geocode Web service can provide coordinates for this address, latitude and longitude of this address are displayed, and the location is also placed on the right map. Alternately, one may find latitude and longitude of a location by dragging the navigating icon on the map to the desired location. This process requires setting the map viewer in a proper zoom level in order to visually identify the location. Latitude and longitude of the identified location are displayed on the left screen as users navigate the icon. The web interface provides a quick and convenient solution to specify a geographic location. Although the solution might not provide accurate geographic coordinates required by some applications, accuracy at street level is sufficient for this application.

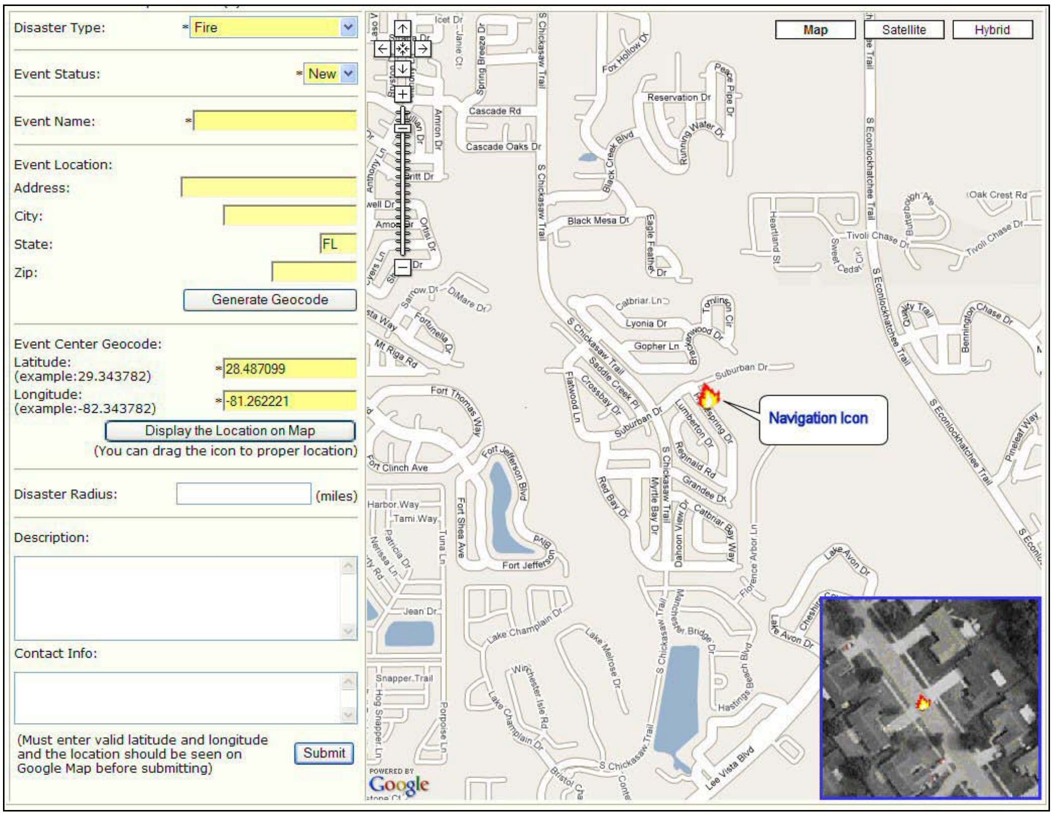

Figure 3. Web user interface for a disaster site entry and find latitude/longitude based on a street address or map navigation.

Greedy Algorithm to Minimize Cost of Animal Evacuation

Randomized Greedy Algorithm (Cormen et al., 1990) is a classic and widely used optimization approach. The algorithm can be mathematically expressed in the equations (1) and (2) below. In this study, this algorithm is utilized to minimize travel distance to evacuate livestock in disaster area to animal shelters in the safe area. Given a set of *m* farms and *n* shelters, each farm needs C_{fi} times of evacuation and each shelter can accept C_{sj} times of evacuation up to its maximum capacity. Let us assume $X_{fi \to sj}$ represents the cost of evacuating route from farm *i* to shelter *j*, then.

$$C_{fi} = \sum_{j=1}^{n} C_{fi \to sj} \quad (1)$$

$$C_{sj} >= \sum_{i=1}^{m} C_{fi \to sj} \quad (2)$$

Thus, we want to minimize the cost or travel distance of overall evacuation, which is

$$\text{Minimum} \left\{ \sum_{i=1}^{m} \sum_{j=1}^{n} C_{fi \to sj} * X_{fi \to sj} \right\} \quad (3)$$

The Algorithm makes best choice at each step in order to find global optimum when solving meta heuristic problems. In this study, the software program greedily evacuates livestock in a farm to its nearest available shelter, farm by farm. The Algorithm first picks a farm from a random sequence, and then compares the number of livestock left in the farm with the remaining capacity of its most preferable shelter. If the number of livestock in the farm is greater than the shelter capacity, the shelter is filled first, and the Algorithm tries to evacuate the rest of the livestock to other shelters. On the other hand, if the number of livestock in the farm is less than or equal to the shelter capacity, simply evacuates the livestock to the shelter and continues with next farm. The program builds up a *Cost Table*, rows representing farms and columns representing shelters, to store cost estimated by the Euclidian distance from each farm to each shelter. According to the *Cost Table*, shelters for each farm are sorted in order of cost. Thus, a "preferable shelter array" is created for each farm. In order to achieve a relatively low total cost, the Algorithm runs in random sequence a linear number of times. If selected shelters do not have enough capacity for the evacuation, the program will accommodate to maximum capacity of the selected shelters and will recommend that users expand the radius of the evacuation area to include additional shelters. After completion of the cost analysis for all selected farms, the system creates an evacuation plan, which indicates farm name, shelter name, and number of livestock that need to be evacuated from farms to shelters.

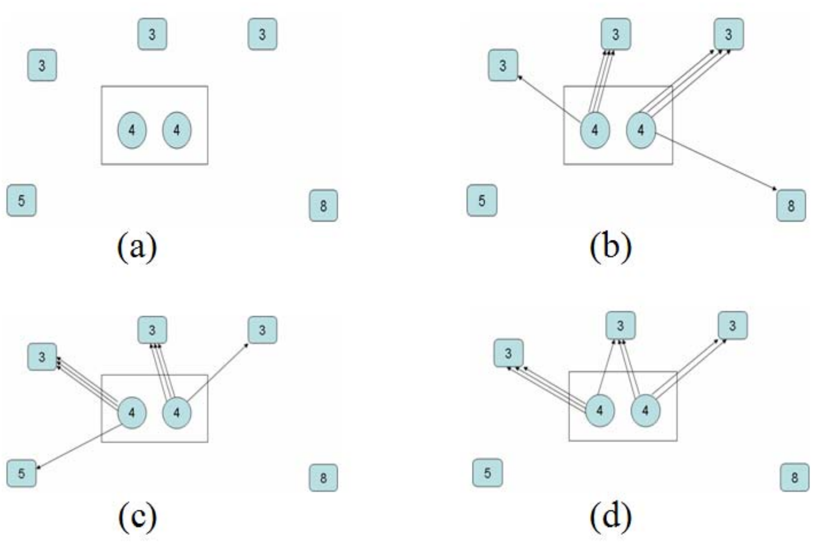

Figure 4. Possible evacuation plans provided by Greedy Algorithm.

In some cases, livestock in one farm could be evacuated into multiple shelters due to limitation of shelter capacity or accuracy of the algorithm.

This greedy heuristic is a widely used algorithm because of its low time complexity ($O(n)$). One trade off of this method is its accuracy. As Fig. 4(a) shows, two farms have 4 livestock in each farm, and five shelters are available with capacity of 3, 5, and 8. The Greedy Algorithm may produce two evacuation plans as shown in Fig. 4, parts (b) and (c). Obviously, these two evacuation plans are not as efficient as the evacuation plan shown in Fig. 4(d). Although Greedy Algorithm doesn't guarantee to produce an optimum solution for all problems, it provides a reasonably fast solution, particularly if there is a large amount of data. To improve accuracy, a Brute Force (Cormen et al., 1990) method, which checks every possible solution to create optimization, is recommended. However, the algorithm leads to a nondeterministic polynomial time problem, which runs very slowly.

Results and Discussions

In an emergency event, successful response starts with a map. Knowing locations and status of emergency resources are important for emergency planning and response, in particular, if an event requires actions from multiple agencies. This work integrates geographic and relational data with Google Earth including dynamic mapping of disaster sites, dynamic mapping of emergency management resources, disaster zones, and livestock evacuation plan.

Dynamic Mapping of Disaster Sites and Disaster Zones

Figure 5. An illustration map of disaster sites and affected areas.

During an emergency event, it is essential to locate the disaster site or affected area for a quick response. Google Earth is an excellent tool to share such information with responders on the Internet. As Fig. 3 shows, the system's users may specify a disaster site, affected area, and detailed descriptions on the website. In addition, photos of the disaster site can be uploaded to the website and shared with other users. After a user updates the database, all users may query the database and view the update in Google Earth and a web browser side by side. Figure 5 illustrates disaster sites and affected areas as displayed in Google Earth. Each point represents a disaster site, and the circle represents a corresponding disaster area. In addition to a circle, it is possible to use different shapes to specify a disaster area. Different layers, like flood, fire, animal disease, rescue site, as well as location of emergency responders, can be displayed. Authorized users may login to the website and update information for each disaster site at any time to facilitate multi-agency collaboration during emergency events. Similar to the emergency resources described early, users may click on a site to view updated detail information and photos about the site on a webpage. Interaction of geographical information in Google Earth with the project website provides a rich user experience to visually access up-to-date information. A similar approach can be applied to other mapping applications.

Dynamic Mapping of Emergency Management Resources

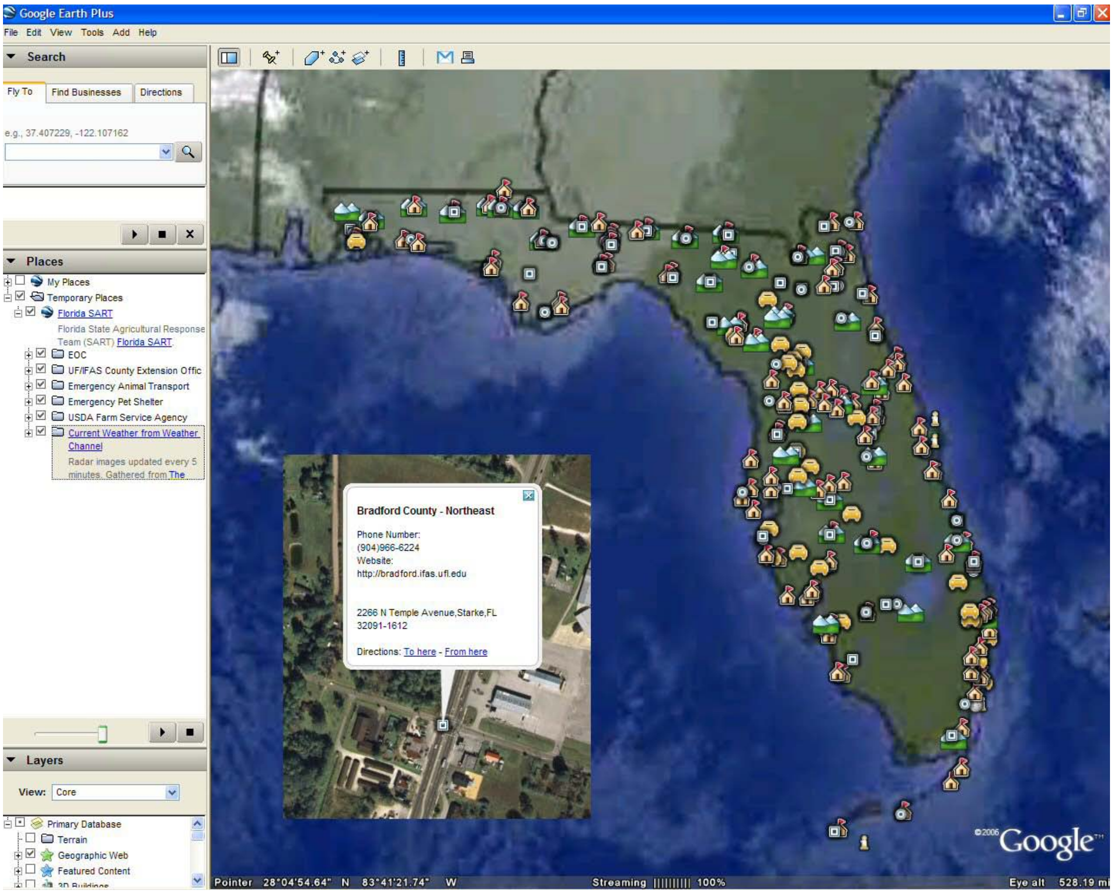

Figure 6. An illustration map of various emergency management resources overlaid with a current weather map.

Figure 6 shows various state wide emergency resources, which are displayed in different layers in Google Earth. As a feature of Google Earth, pop-up balloons can provide abstract information of a site and a hyperlink to view detailed information of the site (see Fig. 5). In other words, users can run Google Earth and a web browser side by side. If a user clicks on the hyperlink, it opens a browser to retrieve detailed information about the site from the database. Knowing weather conditions is important for responding to emergencies such as flood. To provide this valuable information, current weather maps, using a service provided by the Weather Channel, are overlaid with other resources. In this study, we have implemented the following layers in Google Earth: 1) emergency operation centers for 67 counties, 2) state-wide large animal shelters, 3) state-wide emergency animal transport services, 4) local pet shelters, 5) county extension offices, 6) USDA farm service agency, 7) USGS topographic map or user specified images, and 8) real-time weather map provided by Weather Channel. Additional layers could be included as the project evolves.

Livestock Evacuation Plan

It happens very often that when a major disaster happens, livestock are left behind causing a great loss. If data of affected farms and locations of livestock shelters are available in a database, it might be feasible to produce an evacuation recommendation. Our aim for this part of project is to provide a livestock evacuation plan to minimize the travel distance of the evacuation. As a feasibility study, a testing database with dummy data was created with the following information: 1) geographic locations of livestock shelters and their capacities, and 2) geographic location of farms and numbers of livestock in each farm. Similar to the approach of mapping a disaster site described in previous section, users may specify coordinates of a disaster center, radius of a disaster area, and an evacuation area (see Fig. 3). In Fig. 7, round icons inside the red circle represent affected farms. In other words, livestock in these farms need to be evacuated. The house icons between the red and green circle are available shelters in a user specified zone for evacuation. Figure 6 exhibits an example in which disaster and evacuation zones have the same center; however, evacuation area can be in any location specified by a user. Based upon the user specified disaster area and evacuation area, farms and shelters in the user specified areas are then determined by calculating Euclidean distance between every farm and shelter to its center. For instance, if the distance between a farm and the center of the affected area is less or equal than the radius of the affected area, this farm is affected. The program then finds numbers of livestock in each farm that need to be evacuated. Similarly, the program finds all shelters and their capacities inside the evacuation area. As all this information is gathered, a computer algorithm, Randomized Greedy Algorithm, is used to provide an evacuation plan to minimize overall cost or minimize the travel distance of an evacuation.

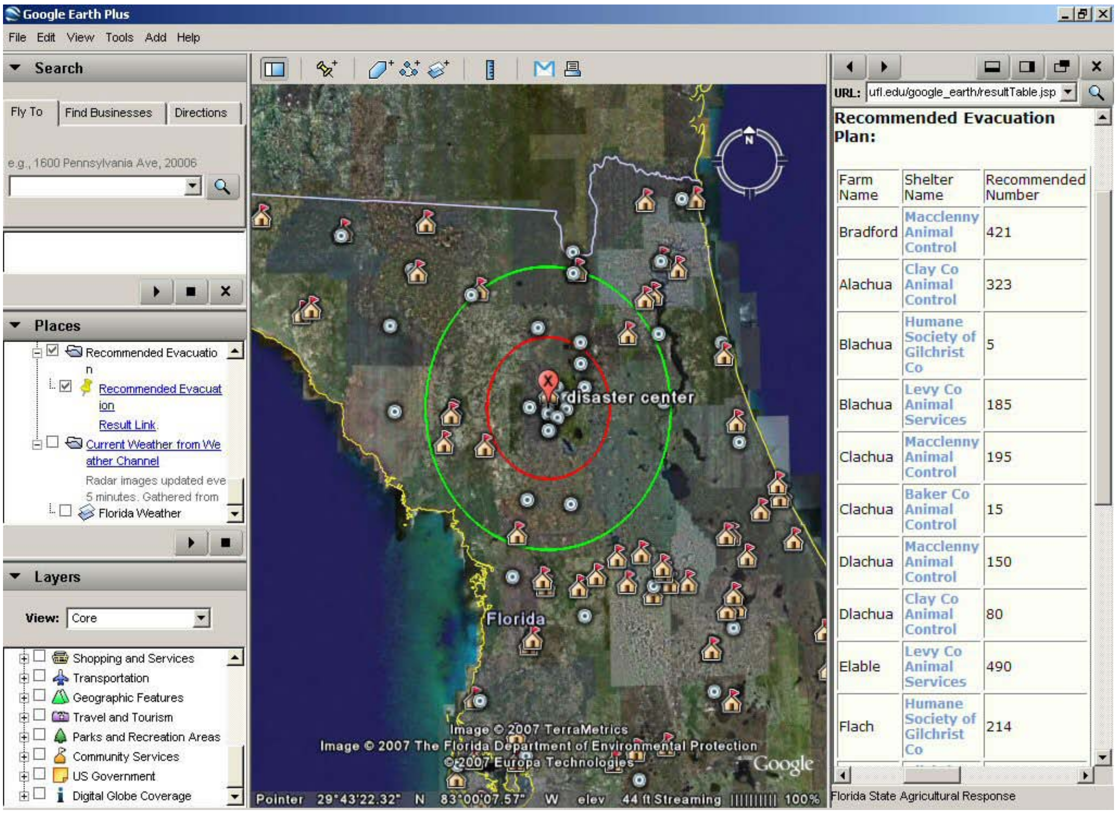

Figure 7. An illustration of user specified disaster area (inside the small circle) and evacuation area (area between large and small circles).
On the right displays recommended animals to specific shelters.

Conclusion

Web mashups has becoming a new phase of web evolution that uses the web as a platform for creating new kinks of content rich and user experience applications. Google Earth offers a user friendly mapping technology for representing geographic information. This technology brings an exciting map-based data visualization tool to users' fingertips. Web mashup technique makes it possible for average developers to seamlessly integrate data between Google Earth and custom content. The technique provides not only a low cost solution for geo-base data visualization, but it also allows dynamic data integration with different data sources. Preliminary results indicate that the approach described in this paper provides a cost effective means to mapping agricultural emergency resources and disaster areas. The technology provides a dynamic collaboration environment for multi-agency to coordinate emergency response activities.

This study is preliminary and further validity study on livestock evacuation plan is needed to determine its effectiveness. In addition, if the Google satellite image of a disaster area is updated immediately as it was after Hurricane Katrina, the approaches described in this paper could become effective tools for obtaining meaningful real-time data and make it universal accessible during an emergency event. It should also be noted that the approach described in this paper can be used in other different problem domains.

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