GIS Server Use at Gundersen Lutheran Medical Center

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Abstract

Gundersen Lutheran Medical Center in La Crosse, Wisconsin is a Level II trauma center with 325 beds and over 1.25 million inpatient and outpatient admissions each year. Gundersen Lutheran Medical Center has an outreach of over 25 clinics throughout Minnesota, Iowa, and the Wisconsin tri-state area. Gundersen Lutheran Medical Center has been attempting to integrate GIS Server technology into its outreach service since 2008. The end goal for Gunderson Lutheran Medical Center is to allow for graphically pleasing displays with easy to find data. It is hoped that this service can help individual departments throughout the hospital make decisions as to where new outreach sites should be located, as well as assess the amount of business current sites are bringing in for Gunderson Lutheran.

Introduction

Gundersen Lutheran Medical Center provides services to over a million people in the regional area. The use of Geographic Information Systems in Hospitals can take a variety of approaches including business analysis hazmat mapping, and outreach analysis. Gundersen has taken the outreach approach by using a Geographic Information System to interactively connect their proprietary appointment creation software with ArcGIS Server technology. This is being done to improve patient appointment booking times, accuracy, and to create a spatial reference for employees. It is also intended to create a marketing service line from which users can perform business analyses.

The history of the use of Geographic Information Science software at Gundersen Lutheran Medical Center dates back to the spring of 2008, when the hospital purchased GIS Server software and individual ArcGIS licenses for the Corporate Research Planning and Development department for the implied purpose of creating GIS web services.

The intended tasks were to create service lines for the hospital and to create a geographic linkage to the appointment server. The following three goals were decided upon by Gunderson Lutheran to guide their organizational projects:

- Interpret hospital patient data, create datasets, and perform analysis
- Create a model to automate the analysis

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- Add customized function to the ArcGIS Server output.
- Have modularity to extend to other projects

Goals

Interpreting hospital data was Gundersen's most immediate concern. In order to perform any sort of analysis between datasets, new geographic base layers were needed. These consist of all up to date spatially significant data as it relates to Gundersen's outreach in the area.

A model to automate the analysis was also deemed important because it would allow for more projects to be completed and to free up resources to work on additional projects since it would remove a number of steps in data creation through the new automation process.

Customizing ArcGIS Server functionality was necessary to allow individuals to export files from the GIS Server and give users the option of conducting their own analyses on the data.

Hospital resources were also finite. Therefore it necessitated the wise use of resources. According to Murad (2006), ArcGIS software can be used to define the demands of a hospital or medical center. GIS can then allow for the analysis to take place that will better allocate resources. Analysis of hospital resources can also take many forms ranging from the distribution of facilities, occurrence and outcomes of diseases to the variation in health treatment across a spatial area such as over Wisconsin, Minnesota and Iowa (Figure 1).

Methods

Data Source

The acquisition of data came from many sources. These included the medical departments in question, census data, and other private sources.

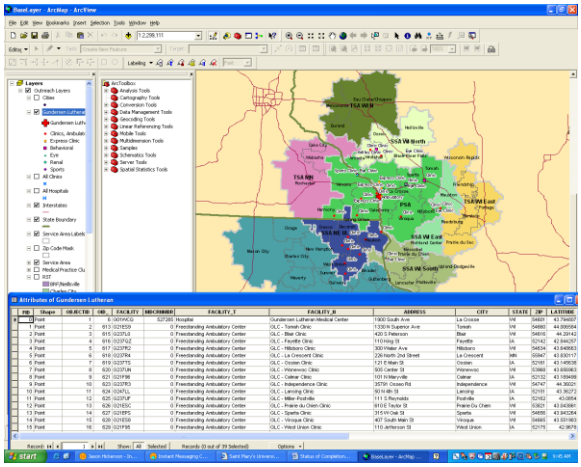

Figure 1. Gundersen's geographic base layer including the new service areas consisting of Clinics and medical practice clusters.

The primary data sources with respect to the individual service lines were the individual departments. From each of the individual departments, the following data was collected and analyzed:

- Hospital Visits by Number
- Clinic Visits by Number
- Locations
- Outreach facilities
- Outreach Personnel
- Monetary Data

Hospital Visits

Hospital visit data was collected from each individual department. This consisted of all inpatient and outpatient procedures performed by the specified department at Gundersen Lutheran Medical Center. This data arrived in the form of Excel spreadsheet files which

were then converted into .dbf database files and imported into ArcMap.

Clinic Visits

Clinic Visits are similar to hospital visits in that they comprise the same data but from Gundersen's outreach locations. These also were collected from the individual department in question and consisted of all inpatient and outpatient procedures performed by the specified department in the tri-state area. This data also came in the form of Excel files which were converted into .dbf files, and imported into ArcMap.

Locations

Locations data consisted of what outreach an individual department has at a facility and at which facilities they do outreach. This data also came in the form of Excel files which were converted into .dbf files, and imported into ArcMap.

Outreach Facilities

Outreach facilities are Gundersen and sometimes non Gundersen facilities where a department may do procedures. This may differ for each service line. This data existed in the form of an Excel file which was converted into .dbf files and imported into ArcMap for qualitative analysis including select by location, and spatial statistics.

Outreach Personnel

Outreach personnel are the individual practitioners of the department who perform the outreach and at what clinic they do the outreach at. This data was created as an attribute table within ArcMap from data retrieved by the medical departments in question.

Monetary Data

Monetary data consisted of Excel files showing economic data from each outreach location for any given quarter during the past eight quarters. This consisted of cost per procedure, and cost per visit. This data was retrieved through departmental contacts.

Secondary Data

Secondary data was accessed through the Thompson-Reuters Corporation. This data was used in order to provide for general information about medical trends including population and projected hospital visits in the area.

Data Creation

Once the datasets were obtained and created, they were combined and analyzed to remove the top 10% of the most common visits. This was done to limit data file size and to ensure that changes in small procedures did not skew the data. The results were then converted into .dbf files to facilitate their use within ArcMap. The files were then given spatial reference using their x, y coordinates and the projected coordinate system of:

NAD_1983_HARN_Wisconsin_TM.

BaseLayer Layer

The BaseLayer layer was created to provide for uniformity as it related to the spatial background of the area. The BaseLayer was constructed from the

following individual layers including custom medical practice clusters, and has been used as the BaseLayer for nearly all new service line projects (Figure 1):

- Gundersen Lutheran Clinics layer
- Cities
- All regional clinics
- Road lines
- State lines
- Medical practice clusters
- Service Areas
- Medical practice clusters mask
- State layers

Gundersen Lutheran Clinics Layer

The Gundersen Lutheran Clinics layer consisted of all geographic locations of hospital and clinics that are a part of Gundersen's network. This layer's purpose is to show Gundersen Lutheran's outreach throughout the tri-state region. The individual geographic coordinates for the sites were obtained through Google Maps and were loaded into an attribute table which was then projected to give spatial references for the locations. As a final step, hospitals and clinics were split in order to show graphically the different locations between the two.

Cities

The cities layer for the Base Layer service was obtained through an ArcSDE Oracle database. The cities layer was constructed to give geographic reference to where nearby locations were in comparison to the clinics and hospitals. Given the magnitudes of cities listed, a select by attribute function was employed and only cities meeting a certain size were selected (for example, POP2008 > 2500). The selected cities were then exported to a new layer.

All Regional Clinics

The regional clinics layer was obtained through an ArcSDE Oracle database. The regional clinics listed were then culled by a "select by location function" and only regional clinics within a 150 mile radius of Gundersen's main campus in La Crosse, Wisconsin were selected. The regional clinics displayed were exported to a new layer.

Road Lines

The Road lines layer was obtained through an ArcSDE Oracle database at Gundersen. The large numbers of roads listed were handled by instituting zoom in zoom out function where the cities could only be seen between certain map scales.

State Lines

The State lines layer was obtained through Gundersen's ArcSDE Oracle database. The purpose of the state lines was to show better definition as to where the borders of the states..

State Layers

The State layer was obtained through Gundersen's ArcSDE Oracle database. The purpose of the states were to show on the most basic scale where Gundersen Lutheran's clinics and competitors are located.

Medical Practice Clusters Layer

The Medical Practice Cluster is a group of Zip codes surrounding a clinic whether from Gundersen Lutheran or a competitor from where a clinic will draw most of its clients. The demarcation and basis for each MPC varies depending on a variety of factors. Including but not limited to the following criteria (Figure 2):

- Geographical Location
- Competition
- Population

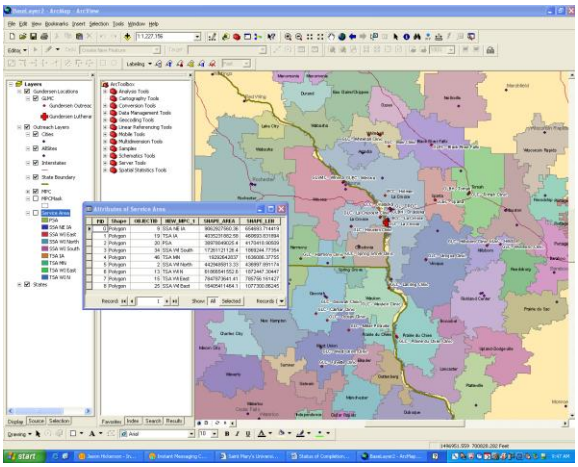

Figure 2. Gundersen's medical practice clusters consisting of individual hospital marketing areas.

Geographical Location

Geographically, an MPC can be limited by determinant factors such as a river or bluff lands. For example, Winona, Minnesota MPC's is limited on the east by the Mississippi River and on the northwest primarily bluff lands. Each one of these contributing factors can and does shape a possible Medical Practice Cluster.

Competition

Competition from competitors may shape individual MPC's especially in areas with limited Gundersen presence or the occurrence of powerful competitors such as in northern Iowa with local competitors, with the Mayo Clinic in Rochester, Minnesota and Eau Claire, Wisconsin where Marshfield clinic is headquartered.

Population

There are significant population centers towards Eau Claire, Wisconsin which will cause some MPC surrounding Eau Claire excluding Eau Claire itself, to be skewed more than other MPC's due to local population pressures. In addition, some MPCs' tend to be larger in Eastern Wisconsin or Northern Iowa due to low population in the surrounding areas.

Zip Codes

Zip codes are the basis for defining residential addresses in society. According to Hibbert, Liese, Larson, Porter, Puett, Standiford, Lui and Dabelea (2009), allocating cases to the smallest geographic unit available for all data points insures the database retains the maximum number of possible cases which allows for more detailed analysis. In the case of the MPC's using zip codes, this allows for a more localized analysis than by using counties and or states. The main drawback of assigning cases to a geographic unit is that a case may fall into an uninhabited or unavailable location (Hibbert et al., 2009).

New Service Area

The New Service Area is a Collection of MPC from which Gundersen Lutheran derides most of its primary marketing efforts. The demarcation and basis for each New Service Area depends

primarily on Gundersen Lutheran strength in the area. This allows for a more simplified marketing strategy than by using individual MPCs thus saving time and resources, which can be put into outreach efforts.

Service Line Web Service

The Service line is a combination of all selected layer files (previously discussed) into an operating ArcGISServer web service. Layers operating within a service line usually consisted of the following layers or group layers (Figure 3):

- BaseLayer Group Layer
- Medical Practice Clusters Layer
- ZipCode Layer
- Quarterly Data
- Thompson Reuters
- IS Layer

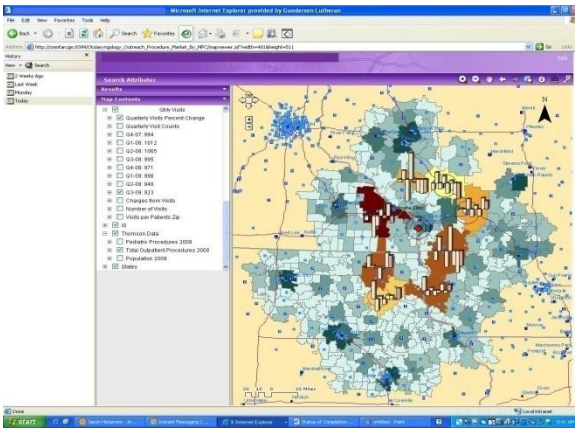

Figure 3. Service Line Alpha; confluence of all analysis and data.

BaseLayer Group Layer

The BaseLayer provided the service line with geographical reference and all the basic items for viewing including clinic locations, state maps, and other local infrastructure.

Medical Practice Clusters

The medical practice cluster provided specific reference to the outreach strength of Gundersen Lutheran Medical Center within a specified of 150 miles.

ZipCodes Layer

The ZipCodes Layer gave specific reference as to what zip codes were within a given region, and to which ones comprise a given medical practice cluster.

Quarterly Data

Quarterly data consisted of analyzed visit data for an outreach location over a selected period of quarters displayed as a bar graph indicating visit trends over an eight quarter period. Business data over the same period was also represented in a similar manner.

Thompson Reuters

The Thompson-Reuters layer provided for future prediction of patient numbers over a 150 mile radius and population data for those specific areas.

Information System Layer

The Information System layer was a layer consisting of what Information System facilities each outreach location has. These can range from heart monitoring to virtual medicine where practitioners can conduct distant visits with patients over video (Figure 4).

ArcGIS Server

All the layer files were combined into one ArcMap .MXD file. This was launched into ArcGISServer where a

new service was made and then deployed to the internal hospital network which was run by Apache Tomcat on a Microsoft Server database.

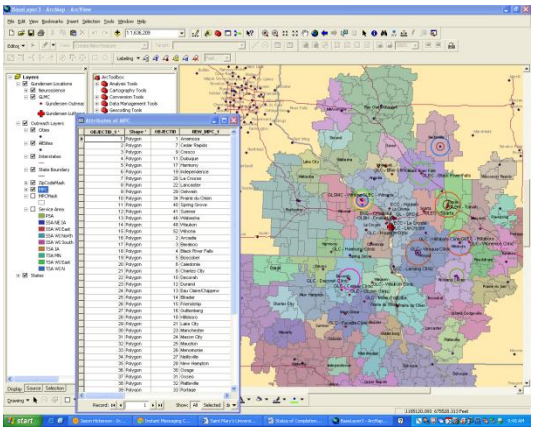

Figure 4. IS Layer of Gundersen technological services.

Appointment System Web Service

The appointments linkage project was a new project at Gundersen Lutheran Medical Center. The primary goals were to take the BaseLayer group layer and combine it with Gundersen Lutheran's internal appointment booking system, thus allowing for representatives to find the clinic closest for a client using a graphically interfaced system. When implemented, this system would consist of the following items:

- BaseLayer group layer
- Internal appointment service
- ArcGISServer web service

BaseLayer Group Layer

The BaseLayer for the appointment service was the standard BaseLayer. This group layer provided the new appointment service with all basic geographical and clinical information of the tri-state region as discussed earlier.
Internal Appointment Service

The internal appointment service was a proprietary homemade custom appointment making service that Gundersen Lutheran can use to schedule visits for clients at any of their hospitals or clinics.

ArcGIS Server Web Service

Using ArcGIS Server, the goal was to use ArcMap hyperlinks to connect the BaseLayer file to the appointment service allowing an individual to click on a specified city within an MPC and bring up the nearest clinic in vicinity to that location.

Travel Time Analysis

The advantage of linking the two services together was that time is the most important factor in medicine. The need to be close to facilities often affects outcomes. According to Haynes, Jones, Sauerzapf, and Zhao (2006), using ArcGISServer, one can find and locate the nearest facilities and facilities capable of handling the situation of the client. This can be done according to Jones (2009) by using a straight line Euclidean analysis, which simply is a straight line analysis from point a to b, or a road network analysis which use actual roads for analysis. The results according to Jones (2009) are similar with small differences between the Euclidean and Road Network analysis. A Euclidean method within ArcGISServer should cut down on patient travel times, and be more efficient then a Road Network analysis.

Analysis

Using Google Earth estimates comparing Euclidean measurement and road networks can be arrived at through the following steps:

- Taking the distance which was estimated by Google for arrival using roads and dividing it by the time.
- Multiply the result by 60 to get time.

For the example of Stockton, Minnesota to Winona, Minnesota this will result in a Euclidean travel time of 10.94 minutes versus 12.6 minutes by for road networks. A similar analysis was undertaken for Rochester, Minnesota and the results were similar (Table 1).

For a small scale sample, this confirms the hypothesis that the similarities between Euclidean and Road Network analysis are similar enough to be used interchangeably for most measurement purposes.

Table 1. Time-Distance Measurements.

Stockton to Winona	Euclidean	Road Network
Time "min"	10.94	12.6
Distance "miles"	7.9	9.1
Average MPH	43.3	43.3
Rochester to Winona	Euclidean	Road Network
Time "min"	49.42	55
Distance "miles"	42.5	47.2
Average MPH	51.49	51.49

Programming Functionality

ArcGIS is very customizable using the .Net, VBA, or Java framework. One can add significant functionality to an analysis and allow for a further in-depth examination of a question or problem. One goal of Gundersen Lutheran is to customize its GIS web services using Java or .Net with the end goal of bringing enhanced options for the end user.

Definition and Analysis

.Net is the Microsoft's development framework for programming. The primary integrated development environment associated with .Net is Visual Studio. Using Visual Studio, one can customize ArcGIS to suit one's goals. ArcGIS has Visual Basic for Applications imbedded into the software. This allows for basic programming to use ArcObjects.

Java is an open source language with the two most common integrated development environments being Eclipse and Netbeans. As with .Net, one can add or subtract functionality to make a service more in depth or streamlined.

Project

The primary project being attempted here was to be able to export an Excel file from the web service so that the user could conduct his or her own analysis geographical or business analysis. The following items were needed to complete this project:

- Netbeans/Eclipse
- Coding
- ArcGISServer

Netbeans/Eclipse

Netbeans and Eclipse are integrated development environments which can be used to add programmatic functions to software. Both Netbeans and Eclipse have ESRI plugins which allows for access to ESRI Java application development framework (ADF). The Netbeans integrated development

environment was chosen at Gundersen because of issues with running services within The Eclipse framework.

Coding

The coding needed for this project consisted of code similar to the following example:

```
oInitialize CoClass ***


Private Sub ExportDS(db As String, XmlFile
As String)

 Dim pWSF As IWorkspaceFactory
 Set pWSF = New AccessWorkspaceFactory

 '*** Open PGDB ***
 Dim pWS As IWorkspace
 Set pWS = pWSF.OpenFromFile(App.Path + db,
0)

 Dim pEnumDSN As IEnumDatasetName
 Set pEnumDSN =
pWS.DatasetNames(esriDTFeatureDataset)

 pEnumDSN.Reset

 Dim pEnumEdit As IEnumNameEdit
 Set pEnumEdit = New NamesEnumerator

 '*** QI for Dataset Name ***
 Dim pName As IName
 Set pName = pEnumDSN.Next

 pEnumEdit.Add pName
 Set pName = pEnumDSN.Next

 '*** Call GeoDBDataTransfer ***
 Dim pGDT As IGeoDBDataTransfer
 Set pGDT = New GeoDBDataTransfer

 Dim pEnumName As IEnumName
 Set pEnumName = pEnumEdit

 '*** Create Scratch Workspace Factory ***
 Dim pSWSF As IScratchWorkspaceFactory
 Set pSWSF = New ScratchWorkspaceFactory

 Dim pScratchWS As IWorkspace
 Set pScratchWS =
pSWSF.CreateNewScratchWorkspace

 Dim pDS As IDataset
 Set pDS = pScratchWS

 Set pName = pDS.FullName

 '*** Fill IEnumNameMapping ***
 Dim pEnumNM As IEnumNameMapping
 Dim bHasConflicts As Boolean
 bHasConflicts =
pGDT.GenerateNameMapping(pEnumName, pName,
pEnumNM)

 ' *** Create GdbExporter ***
 Dim pExporter As IGdbXmlExport
 Set pExporter = New GdbExporter

 ' *** Export Dataset in normalized format
and not compressed ***
 pExporter.ExportDatasets pEnumNM, XmlFile,
False, False, True

End Sub


'*** Create a commandbutton and copy/paste
following code. ***
Private Sub cmdExportDS_Click()

Me.MousePointer = vbHourglass

'*** Location of PGDB ***
Dim db As String
db = "\GN.mdb"

'*** Location of xml file ***
Dim XmlFile As String
XmlFile = App.Path + "\GN.xml"

ExportDS db, XmlFile

MsgBox "Exported Dataset to XML.",
vbInformation

End Sub
```

This was done by adding the selected code to new class and adding linkages in the faces-config and map server files. This was then run and deployed onto the server.

ArcGIS Server

ArcGIS Server was the host from which the customized web service including the export to Excel function was housed. This was backed up by Apache Tomcat, an Oracle Database and a Microsoft server.

Results

Service Line Web Service

A geographic service line for Gundersen Lutheran Medical Center was created for the department in question. Though the analysis of the data confirmed Gundersen's postulation that there was a steady drop in procedures for the particular department, it was not confirmed however, whether this drop

was due to greater use of non-surgical techniques or the faltering economy of late 2008 and early 2009. The additional goal of creating an internet based service line using ArcGISServer was completed using all the data requested by the department, and received positive feedback. It resulted in the assignment of an additional service line with another department for construction.

Web-ADF/Programming

The ESRI Java Web-ADF development framework with a capable IDE such as Eclipse or Netbeans was needed in order to manipulate data to perform exacting analysis on the datasets.

There were also significant setbacks related to the application of the Java-ADF. There were issues with the Eclipse framework which necessitated the use of Netbeans, which in turn necessitated upgrades to the server.

Appointment Booking System

The Appointment Service ArcGISServer is a work in progress. There is basic functionality between the two services. An HTML linkage was created between the two resources, but additional steps are needed before full scale implementation of the service can be completed (Figure 5).

Additional Java based resources from Gundersen Lutheran Java development personnel may also be required in order to provide for a graphical interface for outside viewers to review the system.

Conclusion

The second departmental Service Line, Java functionality and Appointment booking web service are still a work in progress. The basic parts of each project are now in place.

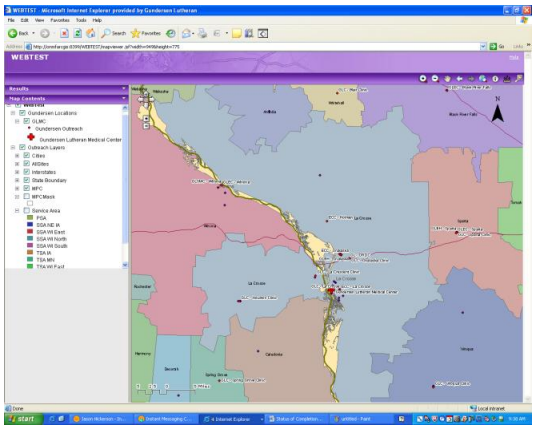

Figure 5. Appointment Server, a service between BaseLayer and the internal Appointment Service.

Murad (2006) and Schuurman (2008) conclude GIS can be used to develop a decision support system for a hospital which can help to determine service needs for a region; this can help health professionals make better decisions on care.

Appointment Service

The Appointment Service consisted of the following layers:

- Base Layer consisting of the MPC's needed for a Geographical overlay
- An Operational internal booking service created by Gundersen
- Linkage between the sites
- Support from all parties involved

Java

- Netbeans with Java ADF
- Updated Server

Service Line

- Base Layers created

- Analysis structure in place

Acknowledgements

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