

AC 2007-2042: ENHANCE INTERDISCIPLINARY COLLABORATION AND GRADUATE EDUCATION BY APPLYING GEOSPATIAL TECHNOLOGIES IN PRACTICAL APPLICATIONS

Jin Zhu, University of Northern Iowa

MD salim, University of Northern Iowa

Ali Kashef, University of Northern Iowa

Recayi "Reg" Pecen, University of Northern Iowa

Kenan Baltaci, University of Northern Iowa

Enhance Interdisciplinary Collaboration and Graduate Education by Applying Geospatial Technologies in Practical Applications

I. Introduction

Geospatial technologies have been used in various applications, such as homeland security, transportation incident analysis, GPS-enabled agriculture management, or water quality monitoring. In some universities, the geospatial technologies have been taught and used in different departments, including engineering technology, geography, construction, agriculture, environmental sciences, and construction planning^{1,2}. However, the faculty in our Industrial Technology Department was not exposed to the widely expanding GIS/GPS technologies.

The University of Northern Iowa 2006 Carver Graduate Education Summer Institute (sponsored by Roy J. Carver Charitable Trust) provided an opportunity to faculty members to be exposed to the geospatial technologies. The geospatial technology is used as a vehicle to enhance the interdisciplinary faculty collaboration, and graduate education and research. This Summer Institute also provided an opportunity to establish effective mechanisms for communicating advances and cooperation in geospatial technology and novel GIS applications in a wide range of research areas. The authors attended the 2006 Carver Summer Institute, and have integrated the geospatial technologies in graduate education and research.

The research project discussed in this paper is on the investigation of potential electric power generation capabilities and determination of appropriate windmill sites by using GIS, and spatial analysis technologies. With the increasing demand for energy in the world, and soaring fuel price, investors and industry are increasingly interested in alternative energy sources, particularly green power. Therefore, the information on the prospective wind turbine sites and the estimated average energy production from each location are of our interests. The State of Iowa will be used as a test bed. Three faculty members with different background (Electrical and Information Engineering Technology, Construction Management, and Technology Management respectively) are involved in the project. The issues from the aspects of construction, planning/safety, and engineering economy have been considered to determine the suitable locations for wind turbines. Graduate students have also been engaged in this project.

In an effort to enhance graduate studies in our Department, the geospatial technologies have also been included in several graduate courses. For example, Global Positioning System (GPS) and Geographic Information System (GIS) are introduced in two courses: Wireless Networks, and Industrial Technology Seminar. The responses from students are very positive and efforts are under way to introduce the geospatial technologies in construction planning, and technology education /management courses.

The overall objectives of this research project are as follows:

- Enhance faculty skills and knowledge in utilizing GIS, and geospatial technologies in graduate courses, and research projects (three faculty members with diverse background working on this project.)
- Improve the intellectual engagement of graduate students.
- Engage graduate students in utilizing the state-of-the-art geospatial technologies in their research, and class projects.
- Educate the community on the importance of green power generation

Geospatial Technology

Geospatial technology refers to technology used for visualization, measurement, and analysis of features or phenomena that occur on the earth³. It consists of spatial software such as ArcGIS and analytical methods with terrestrial or geographic datasets. In general, geospatial technology may be divided into four categories: Geographic Information systems (GIS), Global Positioning Systems (GPS), Remote Sensing (RS), and Geovisualization (Gvis).

Remote sensing refers to means of obtaining information about a distant object without having close examination or physical contact using satellite imagery or aerial photographs. Geovisualization studies how the combination of technologies such as image processing, computer graphics, animation, simulation, multimedia, and virtual reality can help present information in a new way so that patterns can be found, greater understanding can be developed, and problems can be solved.

The most widely and commonly used ones are GIS and GPS systems. According to the definition from ESRI⁴, one of the leading companies in geographic information system modeling and mapping software and technology, GIS is a system of software, hardware and data, and people to help manipulate, analyze and display information that is linked to a certain location. GIS has been applied to various areas to help people process the information in a more understandable way. For example, the Missouri Historic Vegetation Project used ArcInfo GIS to reconstruct the pre-anglo settlement vegetation of Missouri⁵. Arizona Department of Health Services uses geoinformatics systems to track occurrences

of plague across time, monitor plague cycles and determine extent or severity of outbreaks⁶. GPS is a system of geosynchronous, satellites used for determining positions on the earth. Various GPS equipped devices are available for both military and civil applications, such as GPS navigation systems providing automatic driving direction to users.

In order to investigate on the potential electricity generation capabilities and determination of appropriate sites for wind mills, GIS and spatial analysis tools are used.

Wind Turbine for Green Power

The wind power is one of the strongest candidates to meet the energy demand to a considerable extent. Wind energy could supply about 20% of the nation's electric power, according to Battelle Pacific Northwest Laboratory, a federal research lab. There are many benefits of wind power⁷. Wind power produces no emissions and is not depleted. It may also help local economic development, energy price stability, and reduced reliance on imported fuels.

In April 2005, Iowa Governor Tom Vilsack issued Executive Order Number 41, directing state agencies to obtain at least 10% of their electricity from renewable-energy sources by 2010. Investigation on the potential electricity generation capabilities and determination of appropriate sites for wind mills are the main goals of this project. GIS, and spatial analysis will play a very significant role in achieving the project goals. The State of Iowa is used as the research test bed.

We first determined the critical factors on the selection of wind power generation sites. These factors include both physical features of the land, such as surface roughness, elevation, wind speed, and other environmental and human factors. By accessing existing GIS data in the public domain and/or collecting data using GPS unit, the required data are obtained, and processed. We can generate maps that provide information not only on current wind turbine sites and power generating capacity, but also on the prospective wind turbine sites in Iowa, and the estimated average energy production from each location.

Project Schedules and Outcomes

The project is expected to be completed by May 2007, and the necessary steps to complete the project and the target date are listed in Table 1. Currently we are in the process of collecting and processing GIS/GPS data. The progress is smooth and keeps pace with the schedule and we expect to present the final results in the conference. The expected outcomes are follows:

- Identification of the critical parameters for locating wind turbine sites.
- Generate maps for Blackhawk County of Iowa providing information on the potential sites for wind turbines.
- An approximate estimation of green power generation from each site.
- Investigation on the distribution of generated power
- Fostering the creativity and critical thinking skills of graduate students

In addition, we are also considering supporting web-based implementation so that interactive maps can provide information to the community and educate the community on the potential sites for windmill, and the importance of green power generation. .

Table 1. Time Table of the Project

Steps required to complete the Project	Target Date
Select interested graduate students to work on the project	October 2006
Learning geospatial analysis tools	November 2006
Investigate the geographical and physical features that have impact on wind turbine site selections	December 2006
Study and analyze available data from existing sources	January 2007
Collect additional necessary data	January 2007
Determine the model to estimate wind power production	March 2007
Analyze and generate maps	April 2007
Prepare Final Report	May 2007

Critical Factors on Wind Turbine Site Selection

The factors on the selection of wind power generation sites have been identified from three aspects: power generation, environmental factors, and community. The primary purpose of building windmills is to produce renewable energy in a cost-effective way without jeopardizing existing community services. The wind power generation depends primarily on wind resource at the location.

The minimum wind speed needed to produce electricity economically is decreasing as the technology develops. Current value is around 5-7 km/hour, depending on the type and brand of wind turbine used. The wind energy generating capacity in a wind stream is proportional to the cube of its speed, which means that doubling the wind speed increases the available energy by a factor of eight.

The instant wind speed is not enough to decide whether the candidate place is suitable for wind turbine. Instead annual wind distribution is more important to determine if the location is windy enough to generate energy economically. Therefore, one of the GIS data

sets we need is the monthly or annual wind data. The wind data can be obtained from Iowa environmental Mesonet⁸.

Wind turbines work best on flat terrain. In general, the more roughness of the surface, the more the wind will be slowed down. Steep hills or cliffs can create turbulence and should be avoided. In addition, wind speed increases as the elevation increases. For example, raising the height of the wind turbine from 10 feet to 50 feet will result in twice as much available wind power.

The distance to power lines also has impact on the selection of the wind turbine sites. Electricity generated by wind turbines must be fed into the electrical grid. Transmission losses is proportional to the distance and building new transmission lines can be very costly, so sites near existing power lines may reduce this expense.

Some other environmental and community factors may also need to be taken into account^{9,10}. For example, the wind turbine sites should avoid wildlife habitat and nature preserves. The feasibility of construction foundations of the turbines, and road construction to reach the site with heavy trucks should also be considered. The wind turbine sites may also affect the airport and aerial farming operations. The related data and maps may be obtained from Iowa Department of Natural Resources and Iowa Department of Transportation. The environmental maps including elevation map and wildlife maps in Iowa are obtained from Iowa Department of Natural Resources¹¹.

GIS Data Analysis

The software we used is ArcGIS from ESRI⁴. The original maps and digital model are loaded into ArcGIS and we use Spatial Analysis to process the values and display the suitable locations for wind turbine sites on the map. We are still in the process of manipulating the original maps and raw data. The converting process has high requirement on the computation capability of computers. We may need to adjust the criteria along with the progress of the project. The wind data used are from two observing networks AWOS¹² and SchoolNet¹³. AWOS is managed by Iowa Department of Transportation and the wind speed data is collected in one minute interval. SchoolNet includes weather stations located at schools throughout the state. The weather data is saved every minute and the wind speed data are 1 minute average value.

The actual observing sites we used for the wind data are shown in figure 1. Since the wind speed data is available for every minute, a considerable amount of time has been spent to process the raw data. Partial results are presented in the paper and more results will be available during presentation in the conference .

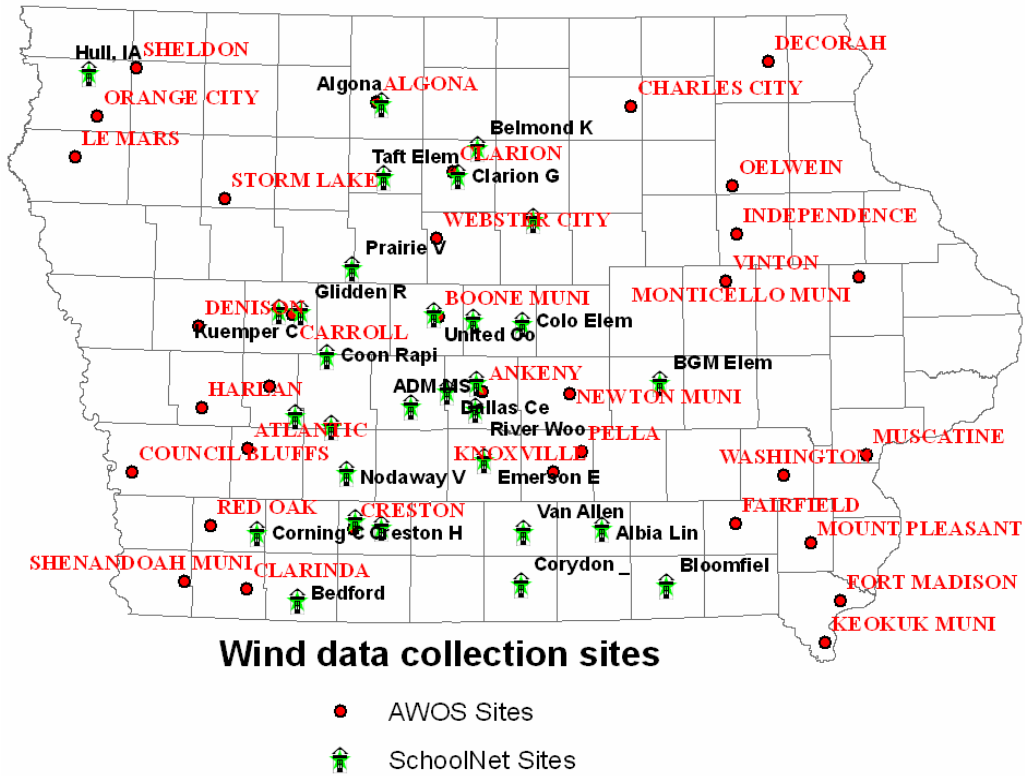


Figure 1 Observing sites used for wind speed data

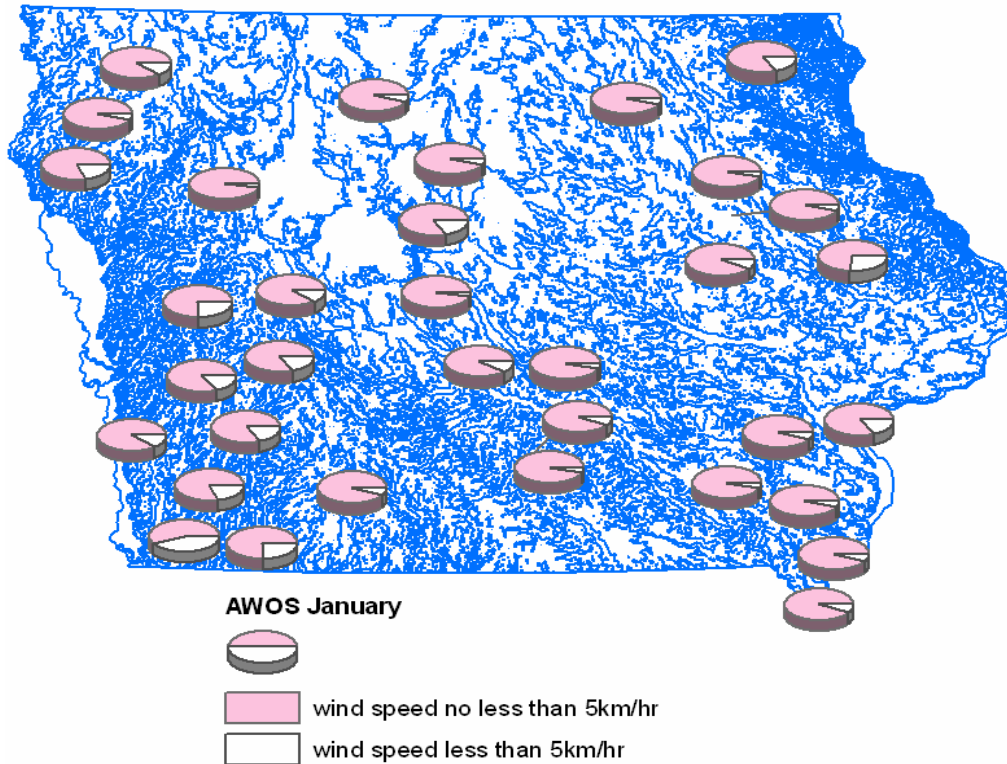


Figure 2. Percentage of time the required wind speed (at least 5 km/hr) available

Wind turbines are designed to produce electrical energy as economically as possible. Wind turbines are generally designed to yield maximum output at wind speeds around 15 m/s. (i.e. 30 knots or 33 mph). As discussed above, the wind speed has to exceed some cut in wind speed to produce electricity economically. Assuming the minimum wind speed needed to produce electricity is 5km/h, we can obtain the percentage of time that the wind turbines may work according to the history wind data. In figure 2, the percentage of time that wind turbines may work in January is shown for AWOS sites.

The wind power can be calculated using the following equation¹⁴:

$$P = 0.5 * \rho v^3 \pi r^2$$

Where P is the power of the wind measured in W (Watt), ρ is the density of dry air measured in kg/m³ (kilogramms per cubic meter), v is the velocity of the wind measured in m/s (meters per second) and r is the radius of the rotor measured in meters. We should notice that the actual turbine power output is much less than the wind power. The wind power density and the actual turbine power output¹⁴ are demonstrated in figure 3. Here we assume the air density is 1.225 kg/m³, the average wind speed is 5m/s, the tower is 50 meters above the ground, and the surface roughness class is 1.5 (i.e. agricultural land with some houses and 8 meter tall sheltering hedgerows with a distance of approx. 1250 meters). Since the wind speed varies through the year, the distribution of the wind speed is needed to determine the wind power density. The Weibull shape is used to describe the variation of wind speeds and Weibull parameter of 2 is used. A typical 600kW wind turbine with 43-meter rotor diameter is adopted for demonstration. From figure 3, it can be seen that the turbine output power only equals about half of the wind power input.

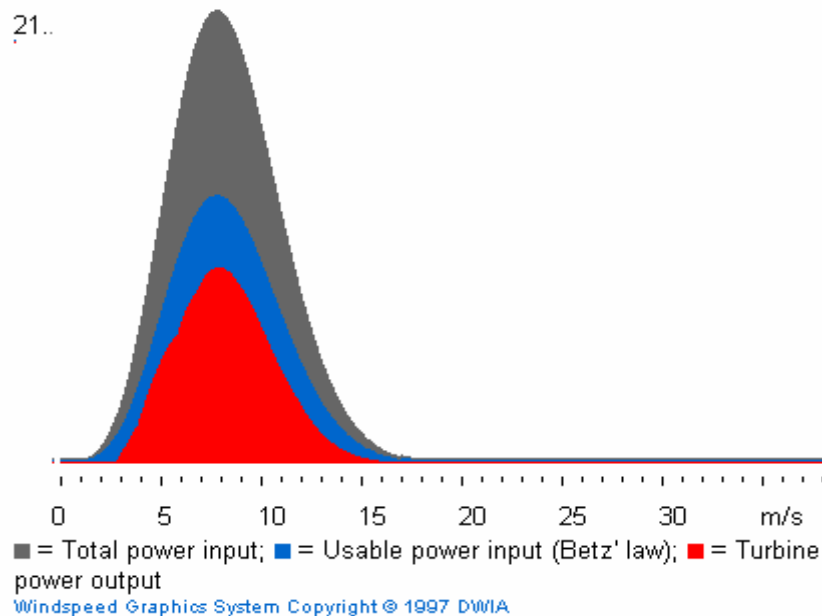


Figure 3 Power density function

The estimated energy output for a typical 600kW wind turbine at different sites is shown in figure 4. We analyzed the wind speed data from the AWOS observing network for 2002-2004 and determined the wind speed distribution for each sites. The results are obtained under the assumption that air density is 1.225 kg/m^2 and 600kW wind turbine is 50 meters above the ground.

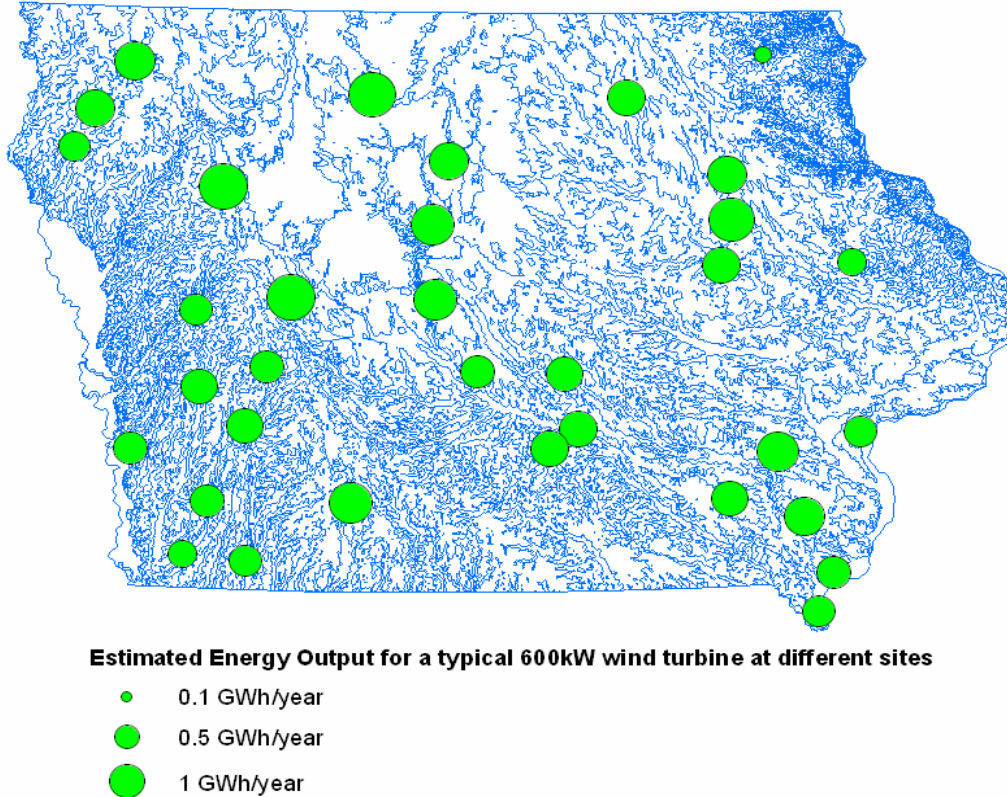


Figure 4. Estimated energy output at different sites

Assessment and Conclusions

Integrating the GIS/GPS in the graduate education in the Dept. Industrial Technology is very successful. It gives the faculty members and students the opportunities to use GPS units and the GIS software. Students are also interested to use geospatial technology in their research areas, such as in construction management, technology education and wireless sensor networks. One of the students in his laboratory project report stated that “It demonstrated practical application of the satellite communications we have been studying. It exposed us to global positioning systems (GPS) and ArcGIS, along with, demonstrations on how to import our GPS data onto a satellite image. The GPS and ArcGIS are excellent tools that I would like to use again. I thought this was a great way to get us out of the class room and use a modern device in a practical application.”

By working on the research project, Wind Turbine for Green Power – Critical Factors for Site Location, the skills and knowledge of faculty in utilizing GIS, and geospatial technologies in graduate courses, and research projects is enhanced. Upon completion of the project, we would be able to generate maps of current wind turbine sites, wind generating capacity, and maps on the prospective wind turbine sites in Iowa, and also the estimated average energy production from each location. We expect the project to be completed as scheduled and present the final results in the conference.

References:

1. F. W. Derby, and W. Ofosu, Geographic information system as a complement to the information sciences and technology program at Penn State University, Proceeding of ASEE annual conference, 2000.
2. R. Walters, Z. Gao, Strategy to incorporate GIS and GPS applications into construction education, Proceeding of ASEE annual conference, 2006.
3. http://en.wikipedia.org/wiki/Geospatial_technology
4. <http://www.esri.com>
5. http://www.grc.missouri.edu/projects_frame.html
6. <http://azdhs.gov/phs/oids/vector/>
7. A. Reeves, F. Beck, Wind Energy for Electric Power-a REPP issue Brief, Renewable energy Policy Project, available on www.repp.org, 2003.
8. Iowa Environmental Mesonet, <http://mesonet.agron.iastate.edu/index.phtml>
9. Impacts of Wind Energy Development to Wildlife, Rare Plant Species and Natural Communities on State Lands,” February 2004, available at http://www.vermontwindpolicy.org/workingpapers/wildlife_impact.pdf
10. Wind Power : Siting in Communities, Renewable Energy Research Laboratory, University of Massachusetts at Amherst, May 2004, available at http://www.reliance.org/4_Siting.pdf
11. Iowa NRGIS library, <http://www.igsb.uiowa.edu/nrgislibx>
12. AWOS data are available at <http://mesonet.agron.iastate.edu/request/awos/1min.php>.
13. School Net data are available at <http://mesonet.agron.iastate.edu/request/awos/1min.php>
14. Guided Tour on Wind Energy, by Danish Wind Industry Association, available at <http://www.windpower.org/en/tour/>