BIOGRAPHICAL INFORMATION

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Specific Responsibilities

Roxanne Cox-Drake is currently an Industry Solutions Manager at ESRI, supporting the Electric & Gas Utility market and responsible for customers feedback and satisfaction, developing business partnerships, influencing product development and supporting the regional and international sales people with marketing strategies and materials for electric & gas utilities.

Past Experience

Previously, as Senior Technology Manager at Southern California Edison (SCE), Roxanne's responsibilities included integration of business processes and systems for Distribution and Transmission, technology to support Distribution Automation, maintenance management and related systems for nuclear generation and other corporate systems and services, such as human resources and benefits systems, Technology Operations Center and helpdesk, desktop support services and the corporate assessment for comprehensive outsourcing of IT services.

Other developed expertise includes organizational assessment and design and large team facilitation for business process improvement and work group integration. While these transferable skills were developed working on process improvement and cross-departmental initiatives at SCE they are regularly utilized by ESRI and the ESRI Electric & Gas User Group community.

Educational Information

Roxanne graduated with a Bachelor of Science in Business Administration, with a major in Information Systems from California Polytechnic University, Pomona, California. She also completed the Executive Management Program at University of California, Riverside.

Professional Memberships

Roxanne is a member of the Geospatial Information technology Association (GITA) and serves as Co-Chair for the Education Committee.

THE VALUE OF TIME

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ABSTRACT

Utility geographic information system (GIS) technology addresses facility location expressed in two dimensions, which are typically x and y coordinates. Few might even address a third dimension, elevation or z-coordinate, either as an attribute in a two-dimensional GIS or through visualization using an extension to the basic capabilities of the GIS. There is another dimension worth considering, however. That fourth dimension is time. When the capability to maintain historical changes of features or attributes over time is added to a standard geospatial system, the result is a temporal GIS.

This paper will explore an understanding of temporal GIS as well as considerations for implementation.

RESEARCH ON TEMPORAL GIS

Why investigate temporal GIS?

As utility GIS managers look to leverage their investment in data and systems associated with GIS, many focus on expanding the accessibility of their systems to nontraditional GIS users via the Intranet/Internet and out into the field. These new deployment strategies typically use the same data and systems with new devices or user interfaces. But what happens when you seek different types of answers from your GIS, such as:

1) Display the benefits of the “just in time” transformer maintenance program implemented in 1990.
2) Are there significant connections between vegetation management and the power outage of August 2003?
3) What are the implications to our distribution and transmission infrastructure if 50 percent of suburban households adopt distributed generation by 2015?

A subtle difference in data requirements and visualization of results is required to answer these questions. The dimension of time is now necessary. To the novice, this distinction only invokes a shrug. To the specialist, the addition of this fourth dimension of time changes one’s implementation approach. Today, most GIS implementations focus on the “current state” of energy networks or land base.

Those GIS teams developing their strategies to support future requirements will want to understand the possibilities and implications of adding this new dimension to their suite of offerings.

Building on examples from other industries with mature temporal GIS applications, such as transportation, local government, and the military, what follows is an entry-level overview of temporal GIS, its unique challenges, and its potential benefits for utilities. The desired outcome is that the possibilities encourage utility GIS practitioners to continue to explore and push developments leading to utility benefits from this new dimension of temporal GIS.

As an initial stimulant, the following applications are know to apply the time dimension: automatic vehicle tracking, fleet management, urban planning, emergency response, vehicle security and roadside assistance, intelligent transportation systems (traffic signals, rail monitoring, road condition sensors, traffic flow sensors), wildlife monitoring, E911, storm tracking, air quality control, crime analysis, petroleum trading, threat detection, and satellite tracking.

What is temporal GIS?

Several names are given to the addition of the time dimension to GIS: temporal GIS, 4D GIS, time-integrative GIS. Some confusion occurs related to the term 4D GIS, as elevation (or the third dimension) is not required for time-related studies. As experts may have other in-depth differences for these terms, for simplicity sake, *temporal GIS* will be used throughout this paper. The following table assists in setting a context for the various dimensions of a GIS (Ott, 2001)

Dimension	Values	Type
2	*x* coordinate – longitude *y* coordinate – latitude	Spatial (area) Spatial (area)
3	*z* coordinate – elevation	Spatial (volumetric)
4	*t* value – temporal indicator	Temporal
5	*a* value – attribute data value	Content

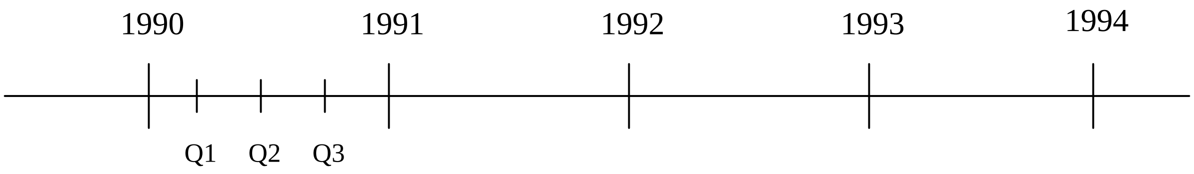
Invariably, research materials regarding temporal GIS start with an understanding of time. While on the surface this seemed straightforward, the distinctions of time ultimately drive the variations of data collected and maintained in the GIS to support temporal analysis.

Several metaphors for time have been established to assist in conceptualizing its characteristics.

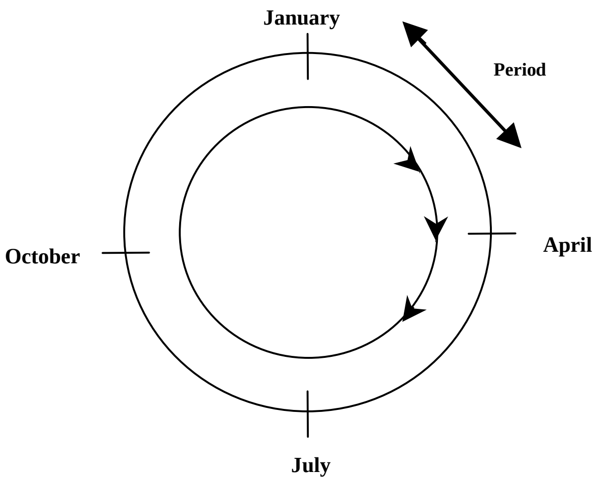
- Linear time is consecutive and can be continuous or in a container. Continuous time generally has intervals of similar or varying durations. Examples of specific intervals would be a day or a year. Variable intervals might be milestones in history or even a project. A container of time is for a specific period, such as a tax year, setting boundaries for a period of time.
- Cyclic time is recurring. It has no beginning or end. It represents things such as the seasons, bird migration, or customer billing cycles.
- Branching time allows the possibility for alternate futures or the postulation of the past. It can be seen in planning, history, and archaeology.

The following diagrams represent the various types of time described above (Ott, 2001).

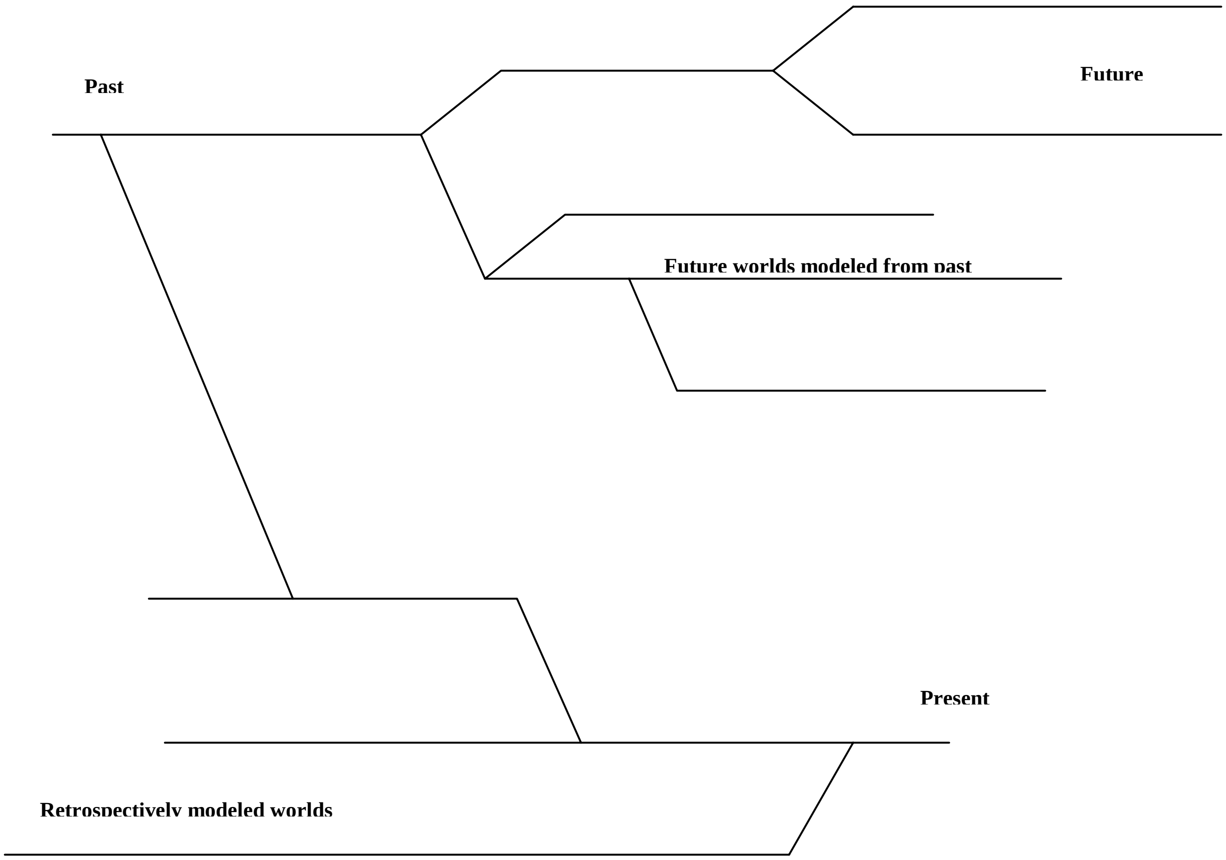
Linear Time



Cyclic Time



Branching Time



Given these concepts of time, temporal GIS is an attempt to store and analyze spatial objects and changes in their attributes through time. The purpose of temporal GIS is to reproduce temporal processes or sequences of events of the real world in a model in such a way as to make them accessible for spatial query, analysis, and visualization (Ott, 2001). Ultimately temporal GIS should capture information about change such as when and where it occurred and its effects over time including its transformation and movement in relationship to other objects.

The major features of temporal GIS are not different from a standard GIS but have some unique characteristics. The key components are data collection, analysis, and visualization.

Data

Starting with data, a temporal GIS wants to understand events and processes. The system expects *time* to be collected and maintained. Implementing time into an information system requires two views of an event: valid time and transaction or database time. Valid time is when an event occurs or when a fact is known to be true. Transaction or database time is when the information is placed into the information system. Capturing both views of time is a core feature of a temporal GIS and allows different access to the database (Ott, 2001) such as:

- ☐ Recover a certain state of the real world at a given date from the most current knowledge
- ☐ Recover a certain state of the real world at a given date from the knowledge available at some past time

The research summary provided by Thomas Ott and Frank Swiaczny in *Time-Integrative Geographic Information Systems* provides an overview of version and database management that helps point out differences and decisions that GIS managers will need to make in considering their temporal GIS data model and storage. They describe version management as another essential feature of a temporal GIS. Again, there are different ways of looking at version management. The method used affects your data model as well as data storage and processing techniques.

Relation-level versioning allows the application of a rollback concept. A new snapshot of everything is taken with each change. This method increases data storage requirements as it creates duplicate information that has not changed.

Tuple-level versioning suggests that only changes should be stored. As a result, what things looked like in a specific slice of time has to be derived from the data stored. This method increases the processing time required to conduct analysis.

Attribute versioning separates attributes from objects. While relationships are maintained between objects and their attributes, only the attribute table is modified as changes occur. This approach requires a more complex data model but minimizes duplication of data and processing time for analysis.

Ott and Swiaczny extend beyond the version of an object to an entire database. They characterize databases as static, static rollover, historical, and temporal. A *static database* stores only information that is currently valid. Old data would be written over and no longer available for use. There is also a *static rollback database* approach where old data is stored every time new data is added. This method generates redundant data, and if data changes are small or frequent this may have an undesirable effect. A *historical* database represents a valid state of the data relative to a specific event. The *temporal database* provides for each object to contain valid and transaction time stamps.

In addition to the details of time stamps for temporal GIS, consideration of overall system architecture may be necessary to provide a means for gathering, importing, and archiving new data sources. New sources include remote sensing devices or outside data sources providing complementary information such as weather.

Analysis

Analysis of temporal GIS differs from spatial or thematic analysis. This brief description of methods of analysis used for temporal studies does not go below the surface of this complex issue for researchers. A general list of analysis methods includes location, attribute, time series, and process analysis (Ott, 2001). *Location analysis* provides functions to determine, change, evaluate, and analyze spatial properties of an object. *Attribute analysis* provides techniques to handle attributes associated with objects. *Time series analysis* outlines procedures permitting documentation and investigation of changes to spatial or thematic characteristics of an object at different points in time. *Process analysis* supports operations enabling the modeling of spatial changes of an object in the past, present, or future.

The availability of time stamp data provides a long list of questions that can be asked relating one object to another during analysis. Examples of possible questions include: What happened before or after? What is adjacent, overlapping, or following? What preceded, started, or finished? The ability to answer questions such as these leads to an understanding of processes such as evolution, succession, production, and transmission.

Visualization

Visualization of temporal GIS presents analysis results and enables further exploration - a means to facilitate visual thinking. Often the map itself is an interim product as learning and thinking are reiterative processes for users. The key is to call out patterns of change. Maps can represent qualitative, quantitative, composite, or ratio changes. Qualitative change answers the question: What has changed? Quantitative changes answer this question: By how much did it change? Composite changes show the process of change itself. Space-Time ratio provides descriptors used to express the relationship between space and time. Animation and modeled symbolization are often the techniques used to display the essence of time.

Given this overview of temporal GIS, no doubt many aspects are present in current GIS implementations. Today’s utility GIS systems are not ignoring time. Time is often captured as an attribute of an object stored and maintained in the GIS database. However, an understanding of the different types of time, how time can be stored and maintained, and analysis and visualization techniques may better position an organization to answer difficult questions such as those posed at the start of this paper.

IMPLEMENTING A TEMPORAL GIS

After reviewing the research, there may be an overwhelming sense of challenge to implement a temporal GIS. Ultimately it comes down to the selection process of what to leave in and what to take out. The tendency will be to record all spatial and temporal events of significance. But this has to be balanced against creating a situation in which one is mired in irrelevant detail. The best tool to address this problem is good project management principles. Understand what you need to ask and what data will be required, and balance the trade-offs between data storage and processing.

What is the practical application of temporal GIS today?

Fortunately, a variety of barriers to the practical application of temporal GIS have been overcome. The following collection of enabling technologies provides a foundation of capabilities needed for temporal GIS (ESRI, 1999).

- Increased availability of fixed and mobile wireless communication networks makes data from sensors and collection devices available in near real time.
- The reduced size and increased capability of remote sensing devices allow collection of more types of information and an increased frequency of readings.
- The proliferation of global position system (GPS) devices provides time, position, and velocity data, answering questions such as: Where am I? Where are you? and Where is it?
- Computer processing and data storage technology improvements support the growth in data and processing capabilities addressing the cost/performance concerns of a temporal GIS.
- Government data initiatives and Web technology aided significant growth in data sources available for GIS system use. Data needed for complex analysis is often not owned by a single organization.
- The increased availability of data renews the importance of metadata standards and procedures. Quality metadata increases the confidence users have in the information and analysis they conduct. Metadata promotes the reuse and understanding of data over a longer period of time.
- Mature GIS installations reflect the advanced skills and understanding organizations have for spatial data and increase the likelihood of adopting temporal GIS practices.

Leveraging these complementary technologies, GIS tools available on the market today, are capable of tracking changes over time with a user interface for presentation and exploration. One tracking example is near real-time tracking of changes in location. Objects, such as line trucks, can be tracked based on speed, direction, and position. This can be used to demonstrate the route taken across private property when responding to complaints of access routes used to reach transmission line rights-of-way.

Other changes that can be tracked include attributes that change over time or changes in patterns. Attributes can be associated with several types of objects. A discrete object only exists in one position at one point in time, such as lightning strikes or automobile accidents. A stationary object does not move, but attribute values change over time such as sensors for traffic or power station monitoring (ESRI, 1998).

Time-related analysis is valuable for planning and responding to emergency situations. Simulating a variety of scenarios helps public safety agencies prepare for emergency response. Tracking changes over time of river flow monitoring, location of personnel and equipment, capacity of medical facilities, and weather attributes such as wind speed and temperature help anticipate problems and improve coordination of resources. Playback capabilities provide a means of learning from actual experiences, which in turn feeds back into the planning and prevention programs.

A final tip in helping to summarize the implementation issues of a temporal GIS comes in the form of a few short questions recommended to address the planning of a history archive but apply elsewhere as well (ESRI, 2003).

- ☐ Do I need full database history?
- ☐ How often will I need to make queries against the historical database?
- ☐ Do I need continuous/transaction level history or are snapshots sufficient?

While the list of applications of temporal GIS for utilities is relatively short at this time, utilities are encouraged to acquire tools and experiment with some simple examples of tracking objects or events. Consider time-related presentation when communicating with management or outside agencies. Take those tough questions asked by utility managers and executives and outline the data and analysis requirements that would be needed. Review the solutions being used by other industries for application to utilities. Weather information is a great source of possibilities. Replaying outage occurrences and restoration may aid in improving an organization’s response in an emergency situation. Experimentation adds to the pool of research conducted to drive improvements in time-related GIS thinking and the availability of temporal GIS tools.

SUMMARY

The future presents an unlimited set of possible solutions for better decision making through the addition of time. Vendors will continue to improve off-the-shelf tools, organizations will extend their data models to include types of time stamps, and analysts will extend their thinking to include more considerations for time.

The speed and depth with which analysis is conducted will drive faster decisions. Imagine studies of energy use patterns in conjunction with land use, population density, socioeconomic demographics, weather, and power generation patterns over longer periods of time. Results could improve long-range load forecasting, modify maintenance and construction activities based on modeling of infrastructure deterioration, or facilitate wholesale energy trading across the country.

Researchers are still working out the many complex principles and methods of temporal GIS. Ultimately, tools will be made available that hide the theories and differences, allowing non-GIS specialists to leverage temporal GIS. The human brain is well suited to process visual patterns. By playing information over time, temporal GIS enables users to extend the capacity of their capabilities, giving them access to more information in a form that is more easily synthesized. The desired results, as with many technological advancements, are improved understanding and better decisions. As the progress of research continues, consider new ways of thinking about GIS, shifting from strictly spatial to temporal, not just providing the means to analyze events but change itself.

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