Measurement Technologies

Did you ever wondered how Global Circulation Models (GCM) are developed or about how biodiversity is measured – and sustainability concepts derived? Have you ever wondered how transportation corridors are designed with respect to nearby homes, taking noise into consideration? Perhaps you are interested to know just how wind speeds are calculated and how they are integrated into GIS, often referred to as wind mapping. How do we come to measure forest carbon, water quality and model plant growth or ascertain soil quality and snow depths? All of these phenomenon exist in space and time.

By Jeff Thurston, Contributing Editor

Most users think of GIS, GPS, LIDAR and photogrammetry when their minds turn to GI. There are other technologies that interface these technologies, which are being used to capture attribute information for spatial locations. Data logging and sensor technologies are providing unique information through space and time. Noise level, scent, light levels, density of materials, depth, shade and temperature of materials among many more are measured using sensors and instrumentation. This coupling of technologies extends the possibilities of GPS positioning and the analytical, modeling and visualization capabilities of GIS. It is through their application that GIS attribute tables can be populated quickly, enabling classification for a broad range of values. These instruments and technologies lead to new answers and questions due to the fact that they not only operate periodically but continuously. They can be found in oceans, in the colds of the north, in jungles and in cities. They are being applied in agriculture, forestry, environmental studies, archaeology, hydrology, location based servicing, industry, mining, construction, transportation and emergency services.

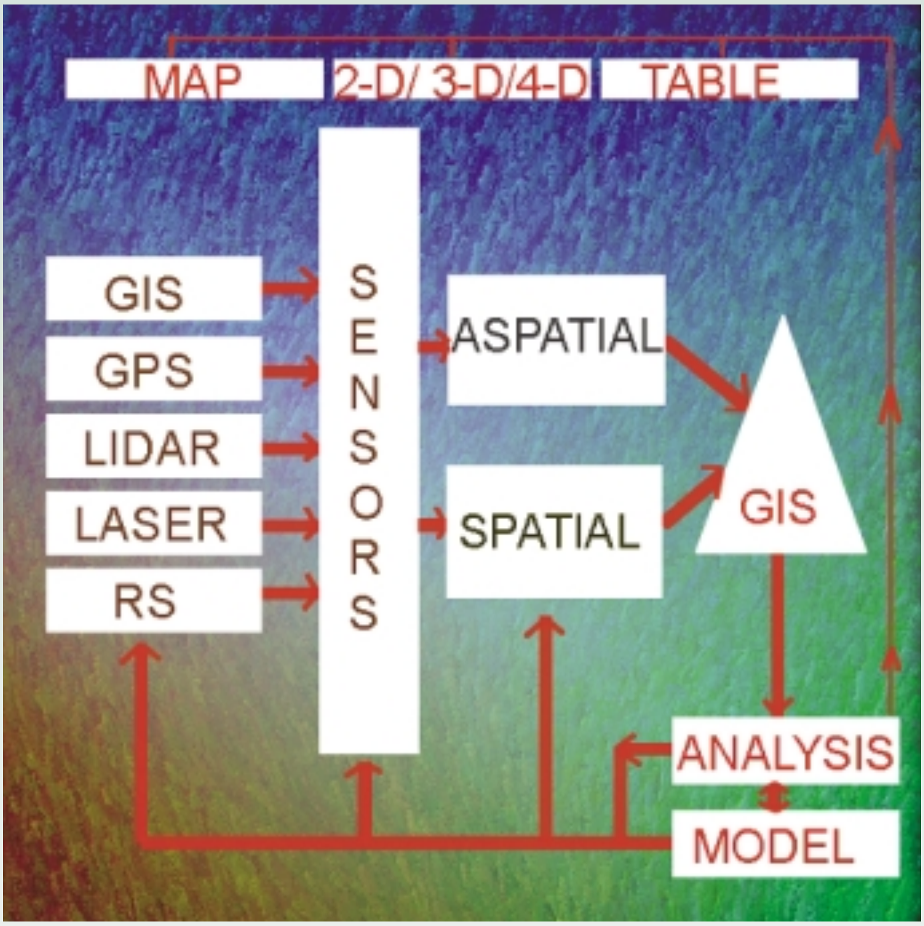

Figure 1: Integration of Sensor Technologies into GI.

Sensors/Instrumentation and GI

The location of a coordinate is readily achieved using GPS, LIDAR, aerial photographs or basic compass and measuring tape. These locations are termed 'spatial information'. While location based servicing is focused primarily upon where something is, sensors and instrumentation are more focused upon not only where something is but also address 'how' it is being represented. That information is termed 'aspatial information'. GIS data tables are created using both spatial and aspatial information. The aspatial information describes a feature, offering an understanding about the features characteristic behavior. These attributes may then have values that are classified or segmented. Often values are subjective and interpreted – 'the red car is at a location and is making loud noises'. Sensor technologies open the door toward providing more information about those noises – are they loud, soft, sharp or intermittent? In the case of carbon balance and modeling, information about soils, vegetation and climate is useful. Amount of light relates to photosynthesis, as does moisture. Both light and moisture are therefore related to lower or higher rates of plant growth and subsequent sequestration of carbon. Since the sun comes up and goes down each day, it is not logical to assume that moisture conditions or the air temperature stay constant over time – they change. Sensors and instrumentation are

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and GI Expanding Position Toward Time

figure 2: Climate Instrumention and Sensors (image courtesy: D. Puurveen, Edmonton, Canada).

useful because they not only measure a moment in time but they can capture these differences over time. The ability to capture aspatial information with finer and finer resolutions in a continuous manner over time allows the GI user to study phenomenon more closely and model its nature more realistically. Some phenomenon have been monitored using these technologies, revealing information that previously was not possible including the movement of water beneath snow, fluxes in vertical winds and changing aerosol concentrations in the atmosphere.

The Element of Time

Our tendency to focus upon location (spatial) without applying technologies useful for investigating the time component in relation to features and phenomenon makes a big difference. Rainfall does not occur homogenously, but tends to be periodic and vary with the approach of a storm leading to higher intensities or events of very short duration then subsiding. Floods can occur if events have large intensities and last for longer periods of time. If soil is saturated, then it may be the case that rainfalls lasting for a long duration are not necessary to result in a flood. But information about the existing soil considerations and the amount and time of rainfall will lead us to determine if a decision should be made to issue flood warnings or not. Sensors and technology provide the means to collect the necessary information. Noise levels for neighborhoods vary throughout the course of the day. During peak traffic periods these levels are higher. Noise also travels at different speeds in differing air temperatures. Anyone who lives in a northern climate will know that the sound of a passing car is heard much like that of an airplane when the temperature is well below freezing - there is a delay and decay. Consequently, there exists a need to design routes with an understanding of the behavior of sound travel. Supervised classification of remotely sensed images involves relating landscape level information to the image information. Reflectance and scattering greatly impact remotely sensed images. A need exists to quantify the landscape for individual pixel areas on the remotely sensed image using sensor and measurement technologies. In this case light sensors can be used to measure those levels.

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In each of these cases measurement technologies are coupled to spatial technologies for the purposes of more accurately quantifying the nature of phenomenon (Fig.1). Since sensors and instrumentation information can be analyzed using GIS, it is logical to assume that at times more information may be needed based upon the results of the analysis. Therefore, there exists the possibility to integrate more information in both spatial and aspatial forms using those technologies. This new information can then be appended to existing GIS coverage's or layers, analyzed and ultimately output to map, data table or visualization dependent upon need.

About Measurement Technologies

Spatial data can consist of 2-D, 3-D or 4-D information. Sensor technologies are directly applied for 3-D and 4-D purposes – focusing on 4-D (x, y, z + time) primarily. In the case of meteorological instrumentation technologies will consist of a data logger and sensors. The sensors include soil temperature sensing, air temperature, wind speed and direction, relative humidity and solar radiation measurement devices. Many climate instruments are useful for a multitude of applications because they are common measurements for understanding many different types of environments (Fig. 2). In application the data logger is used to process the sensor inputs, scaling values and recording them. In some cases data loggers may be used to perform intermediate processing of recorded input (subtract one sensor value from another and record). The sensor values are recorded as well as time. Since sensors are flexible and can be moved they may be placed in inde-

Figure 3: Remote Sensor Installation (image courtesy: D. Puurveen, Edmonton, Canada).

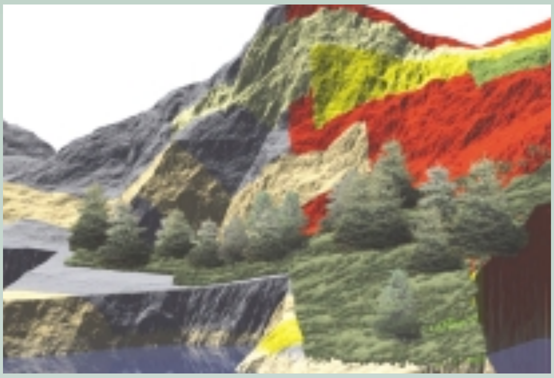

Figure 4: GIS Visualization and Sensor Data.

pendently or constructed in arrays – such as vertically for wind or soil temperatures. This is significance because they can be moved in (x, y, z) planes but they also may grouped from one location to another forming a network. Consequently, installations involving several hundred meters are possible. Additionally, several networks may exist. In this way local areas or large regions may be covered. Each region would have similar measurement sampling interval and output and all data could therefore be integrated together readily.

The Data

The data logger sample interval is the time period over which the data logger actively acquires a sample. It could be set to measure all sensors using one-second intervals or all sensors every day. Setting of the sample interval is dependent upon the amount of internal storage for remote locations, though storage is not an issue where direct dial-up to the location and interrogation of the data logger is possible (Fig. 3). More importantly however is to determine the nature of the phenomenon under study. Sampling rainfall total for the day may not provide answers about the small recurring events or their intensities. Sampling the density of materials as they dry over time would recognize these changes. Sampling the wind direction once every hour may not truly reflect the wind direction for the preceding fifty-nine minutes. Thus some idea about the nature of the feature and its values is useful prior to measuring the phenomenon. The time will be stamped to the data for the sample interval is chosen. This table may exist separately as an aspatial data table linked to the spatial information that was previously acquired using spatial technologies such as GPS, LIDAR, aerial photos, RS. Programming can be done in such a way that recording does not take place until certain events take place. For example, sample the rainfall every hour and totalize but if it starts to rain then sample every minute. In this way both hourly and intensity information is captured. Such programming allows for unique opportunities. Imagine a GPS equipped vehicle traveling in a city that is equipped with sensors. Travel times can be ascertained through GPS between waypoints, but engine performance coupled to travel time can be acquired with sensors. For every waypoint recorded, engine performance would be indicated – or, if the engine performs irregularly then it could trigger for a GPS waypoint to be recorded. Thus both GI technologies and sensors can operate interactively. A growing number of applications involving are being developed around sensor technology due to the fact that what and how events both in quantity and quality are as important as where they occur. Data tables for sensor information may be very large dependent upon the sample frequency and the numbers of sensors involved. Data may also be lost in harsh environments due to extreme conditions. Precision farming is an example of coupling GI and sensor technologies together. Other creative concepts are being developed for the application of sensors with GI.

New Potentials

The development of new applications involving sensor technologies, are prime candidates for visualization. This is due to the fact that these applications are inherently 4-D in nature and of high resolution. Thematic content for each sensor may be constructed and analyzed in a bivariate or multivariate manner. Since the data tables are large this also increases the likelihood of using data mining technologies to understand the relationships within the data. Forty sensors sampling every 5 minutes will yield 11,520 values per day or almost 3.5 million per month. Visualization of these values within immersive environments provides a means to examine the relationships of such large quantities of data. Alternatively, coupling of GIS to visualization is resulting in the ability to construct realistic vegetation on landscapes and other 3-D objects such as buildings, which also include representation of sensor data (Fig.4). In this example, photo-realistic realistic plants appear with soil carbon contents in a 3-D image. The viewer can quickly see the vegetation components along with the spatial distribution of soil carbon – simply by walking through the landscape. Plant density is adjusted slightly to allow the viewer to see the ground (color). These images are very effective for communication purposes since soil carbon and other indeterminate phenomenon without sharp boundaries is often difficult to represent. If these images were collected into a sequence then an animation could be developed.

Conclusion

Incorporating sensor and instrumentation technologies with location technologies such as GPS provides the GI professional with new opportunities to understand in greater detail, characteristics about features. These sensors are easily coupled to GPS in real-time or they may be located at positions previously determined. Data tables for the information are appended to existing data tables and form the nucleus for creating visualizations in 3-D and 4-D that utilize photo-realistic objects or for applications involving data mining techniques.

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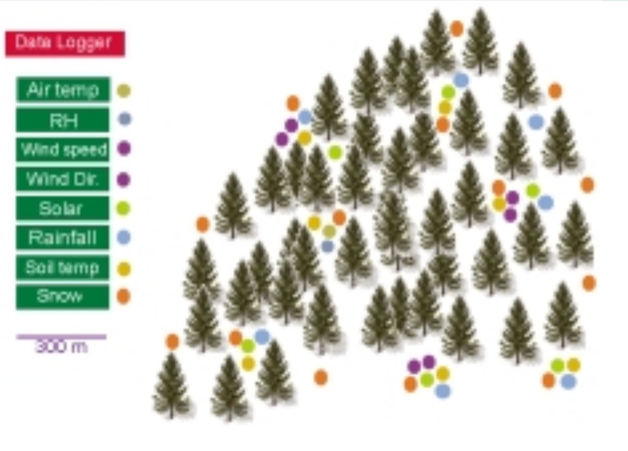

Figure 5: Data Logger Landscape Application.