DIGITAL DATA COLLECTION AND ANALYSIS TECHNIQUES FOR FORESTRY APPLICATIONS

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Abstract

Forest management activities include locating and mapping management boundaries, transportation networks, streams, landscape topography, forest resources, and special management areas. Locating and mapping tasks associated with forest management have traditionally been performed using manual measurement techniques with varying degrees of precision, accuracy, and efficiency. This paper examines the use of digital measurement tools including laser rangefinders, global positioning systems (GPS), and total stations, in combination with geographic information systems (GIS), to digitally capture and map data associated with forestry activities. The benefits and limitations of these digital approaches over traditional data collection techniques are discussed.

INTRODUCTION

Traditional forest management techniques include locating and mapping significant forest resources including stand boundaries, transportation networks, streams, landscape topography, forest resources, special management areas, and other features. Forest resource measurement and mapping tasks have been typically performed through manual survey techniques with variable precision, accuracy, and efficiency (Kellogg et al., 1997). Inaccuracies in location and mapping activities often result in adding to forest management costs, and in some cases may lead to safety concerns. The tasks that are associated with forestry in the U.S. have become more demanding as the focus of forest management has shifted to accommodate multiple goals in addition to timber production. Management requirements within a multiple goal scenario place greater demands on forest managers in terms of the types and accuracy of forest data that must be collected to support management activities. One solution to meeting this challenge is to use technologies that can collect and analyze forest data more efficiently and accurately than through traditional means. Examples of technological tools include, but are not limited to, laser rangefinders, global position systems (GPS), total stations, and geographic information systems (GIS). These tools are designed to capture, manipulate, and analyze spatial data.

This paper briefly describes the use of a laser rangefinder, GPS, total station, and GIS to digitally capture and map data associated with forested resources. The laser rangefinder can capture locations of objects up to 200 meters away to within several centimeters of their actual locations. A GPS can provide coordinate locations of objects to within meters of their actual location but is often limited by canopy cover. Total stations can record the locations of objects to less than a centimeter of actual location. A GIS can analyze, measure, and map data collected from these instruments. Each of these precision...
measurement tools is within the budgets and operating capabilities of most organizations that manage forests and many organizations already own GPS and GIS equipment, although the actual use of these technologies varies between organizations. A strong need currently exists to identify and apply digital technologies that increase the effectiveness of forest management so that the multiple resources and values expected from forests can be better provided. The demonstration and comparison of the potential uses and benefits of precision digital tools over manual techniques will help forest management organizations identify opportunities to improve spatial data collection and analysis tasks.

HANDHELD DIGITAL RANGE FINDERS

Handheld digital range finders can calculate distances and, in some cases, vertical angles between an instrument operator and an object (Figure 1). Wing and Kellogg (2001) examined laser range finder use for collecting skyline corridors and harvest boundary measurements. In general, the range finder was found to be faster and more accurate than manual measurement techniques. Other studies have also examined laser range finder use in traversing stand boundaries (Liu, 1995) and estimating wood pile volumes (Turcotte, 1999) and have found the distance measuring capabilities to be beneficial but have raised questions as to the reliability of horizontal angle or directional measurements. Range finders vary in operation depending on the manufacturer; some depend on laser pulses while others utilize sound waves. In both cases, however, it is the length of time that it takes for a laser pulse or sound wave to travel between an instrument and target that determines a distance. Laser-based range finders may offer the option to utilize reflective or non-reflective targets, but users will typically find that distance measurements will occur with greater accuracy and reliability with a reflective target. Sound-based range finders offer an advantage over laser-based range finders in that a line of sight is not required between an instrument and target, and operators are not hindered by overly-bright or dark field conditions. A shortcoming to sound-based range finders is that they may be limited to distances of 50 meters or less, as sound waves diminish over space.

Vertical angle capability is important for many forestry applications including elevation profile measurements and in the calculation of heights, including trees and equipment. Most digital range finders provide vertical angle measurement capability and in some cases will allow an operator to calculate slope distances, which is a function of vertical angle measurements. In addition, vertical heights can be automatically calculated, given the availability of a solid target. This may be a challenge when attempting to measure a tree’s
height, as the upper portions of trees do not always provide suitable targeting areas. If directional information is needed in addition to distance measurements, the Impulse range finder has an optional compass module that can calculate and store direction information in conjunction with distance measurements.

Range finder prices vary from several hundred to several thousand US Dollars depending on features, accuracy, and reliability. Potential purchasers should carefully assess their measurement needs and very specifically, the level of accuracy required for measurements. There are usually reasons for price differences between instruments and potential purchasers should not base decisions on price alone. Wing et al. (in press) examined several commercially available digital range finders through a series of forestry measurement trials and found that most performed within the accuracy ratings claimed by manufacturers, although significant differences existed in instrument capabilities and reliability.

**GPS**

GPS hardware continues to become more affordable and conveniently packaged but still faces challenges to effective use in forested settings. Elements than can affect GPS use in a forested setting include canopy closure (Stjernberg, 1997; Karsky et al., 2000), GPS receiver quality (Darche, 1998), landscape topography (Liu and Brantigan, 1996), and environmental conditions (Forgues, 2001).

There are three broad grades of GPS hardware available: survey, mapping, and recreation grade. Survey grade GPS will typically cost users in excess of $25,000 but can provide measurement accuracies within one cm of true position when used properly. Unfortunately, these GPS require satellite signal quality that is often unachievable under forest canopy, or only available for brief periods. Survey grade GPS is therefore presently of very limited use in forestry applications although this may change in future years as satellites that are capable of transmitting more powerful electromagnetic signals are launched.

Mapping grade GPS cost approximately $2,000-12,000 and are capable of accuracies within several meters of true position. Within a forestry context, these systems are also limited by interference of satellite signals resulting from canopy cover (Karsky et al., 2000). Users can identify the best periods for data collection through mission planning software. Mission planning software can enable users to identify periods when satellite availability is high and measures of optimum satellite reception (e.g. Position Dilution of Precision- PDOP) indicate the best times for field data collection. Mission planning software for GPS can be accessed free of charge on the WWW but may sometimes prove unreliable. Potential users may want to purchase mission planning software from a reputable GPS manufacturer to maximize mission planning effectiveness. Regardless, the influence of forest canopy can only be estimated and it may be that even under ideal data collection periods, as identified by mission planning, that sufficient satellite coverage is not available to consistently collect location data.

A typical mapping grade GPS will include an antenna, receiver, and data collector that work in tandem to collect, process, and store location data (Figure 2a). This instrument setup results in several pieces of equipment, accompanied by communication cabling, that can present physical challenges in efficiently collecting forest data. Recently, some manufacturers have created mapping-grade GPS that are contained within a single handheld unit but measurement accuracy in these units is typically less than other GPS that feature multiple components packaged separately. Data collectors for GPS have traditionally been
a significant cost ($1000-5000) but some GPS users have turned to using hand-held PDAs (Personal Data Assistants) that offer more affordable and versatile alternative to traditional data collectors. A PDA costs about $500, typically features a color display, and can run handheld-based mapping software while allowing users the flexibility to store other digital files, such as digital orthophotograph and topographic map images, that can enhance the data collection process. Users can view their position, and the location of features from which they have gathered location information, in reference to other digital files and thus gain confidence in their field data collection process. Digital images may also enhance field data collection safety by identifying proximity to potentially hazardous locations, such as ongoing forest operations or steep topography, and reduce the probability of becoming lost. Some PDAs can accommodate Bluetooth wireless communication technology. This technology removes the need for physical cabling between hardware devices, reduces the amount of equipment that must be taken to the field and allows GPS data collection personnel to operate more freely. A GPS has recently become available, the SXBlue GPS, that can operate with Bluetooth technology. In addition, the SXBlue reportedly can gather location information under a forested canopy for up to 45 minutes once a solid GPS signal has been attained.

Recreation grade GPS are usually handheld units (Figure 2b) that are contained within a single device; the GPS antenna, receiver, and data collector are all integrated into one unit. Prices range from approximately $100-500 for a recreation grade GPS. With the disabling of Selective Availability, manufacturer estimates of accuracy typically claim that recreation grade GPS positions should fall within 15-20 meters of actual location. A recent development in terms of potential satellite availability and signal quality is the Wide Area Augmentation System (WAAS). WAAS is currently available only for GPS operations in North America and presently features two operational WAAS satellites although more are expected in the future. Designed to aid to airborne navigation, WAAS signals are only intermittently available to on-the-ground GPS users due to obstructions between GPS receivers and satellite positions. At present, recreation grade GPS manufacturers in the U.S. claim that WAAS signals will increase the accuracy of recreation GPS units to within three meters of actual location. While there exists a future potential for GPS that utilize WAAS technology to consistently attain these accuracies, it is premature for users to expect such performance at present due to the limited number of available satellites.

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DIGITAL TOTAL STATIONS

A digital total station can calculate highly accurate and precise measurements of forested features to less than a cm from actual locations (Figure 3). Available measurements include distances and angles in both horizontal and vertical dimensions. For accurate and reliable measurements in a forested setting, the total station still has few equals. The total station operates very similarly to a handheld laser range finder in that a beam of light is emitted from the instrument, reflects off of a target, and is sensed by a receiving lens. Distances are computed as a function of the time that elapses during the light beam’s travel. Although digital total stations can also operate with reflector-less targets, measurements will typically be more reliable with a reflector, such as a prism. Digital total stations cost approximately $6,000-12,000 for manually operated instruments, and robotic versions are available for approximately $30,000. Robotic versions greatly speed total station measurements when only one operator is available.

Considerable care must be taken in the operation of a total station including instrument leveling, registration of instrument position to a known or assumed location, and proper recording of instrument and target heights. These procedures typically require an additional investment of time for total station users that is greater than that required by handheld laser range finders or GPS. In addition, whereas handheld range finders and GPS are somewhat forgiving and user-friendly in some use regards, proper total station use requires that operators be well-versed in instrument use and data collection, transfer, and processing procedures. Total stations also require that a line-of-sight exists between the instrument and target, and that great care be taken in instrument leveling and handling. Despite its limitations, a total station remains the most reliable instrument for gathering accurate and precise locational measurement data in forested settings.

GIS

GIS use has become a staple for many natural resource organizations and provides an avenue for organizing, viewing, analyzing, and mapping data collected by range finders, GPS, and total stations (Wing and Bettinnger, 2003). There are multiple GIS software manufacturers worldwide but the majority of GIS users use software by Environmental
Systems Research Institute (ESRI) or Intergraph Corporation. Both manufacturers produce a suite of GIS software products that allow organizations to select the software functionality they need for their specific GIS activities. In general, users can lesser-featured “desktop” or full-featured “workstation” software and can expect to pay between $1,000-15,000 depending on the version.

A GIS product that has recently begun to receive wide use for forestry data collection is ArcPad GIS software by ESRI. This software is designed to operate on a PDA and sells for about $500. Given the broad use of ESRI software by forestry organizations, ArcPad has become a preferred field-based GIS software that allows the seamless use of data structures on both PDA and workstation GIS platforms. ArcPad allows users to synchronize PDA operations with a GPS receiver and has user-intuitive tools for viewing available satellites and monitoring the potential strength of satellite signal reception. Users can configure GPS collection defaults so that only signals that meet minimum quality standards can be used to calculate positions. Users can immediately view their position, and GPS-collected data points, and background data layers, such as transportation networks and digital orthophotographs. Users can also attribute data points they collect, so that descriptive information can be added to the digital files during the field collection process.

CONCLUSION

Foresters have relied for many years on analog measurement tools including tapes, clinometers, string boxes, and compasses. Digital precision instrument use in forestry has tremendous potential advantages over manual methods of data collection including the speed at which measurements, particularly over long distances, can be taken. In addition, the accuracy and precision of measurements taken by digital instruments can be superior to those captured by manual tools. With digital data collection, databases can be created rapidly and can be transferred to a GIS for inspection, analysis, and mapping. This digital database creation process can reduce the opportunity for error as data no longer needs to be transcribed in a field notebook and then entered manually into a digital database.

Despite these potential advantages, there remain challenges to digital precision instrument use in forestry. Digital equipment often involves an expense that exceeds those of manual measurement tools, and includes instrument components that may be much less robust to use impacts and adverse weather conditions. Some users are also hesitant to adopt digital technology as it involves additional knowledge and skills beyond those required by manual instruments. Digital equipment often requires multiple components that must be linked by cabling and relies on one or more energy sources to operate. Should cables or energy sources fail, users may have to abandon data collection and return at a later date once the difficulties are solved. There is also an uncertainty with digital data collection that is unresolved until the data are downloaded and examined in an office setting. These uncertainties revolve around whether all data of interest have actually been saved to the database and whether the data can be successfully extracted.

Regardless of the current challenges to digital precision instrument use in forestry, technological advancements will continue to lead to new instruments that can benefit forestry. Advancements will result in digital instruments that are more accurate and reliable, easier to operate, and more flexible in the types of measurements that can be collected.
REFERENCES


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