NCHRP
National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

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These **Digests** are issued in the interest of providing an early awareness of the research results emanating from projects in the NCHRP. By making these results known as they are developed, it is hoped that the potential users of the research findings will be encouraged toward their early implementation in operating practices. Persons wanting to pursue the project subject matter in greater depth may do so through contact with the Cooperative Research Programs Staff, Transportation Research Board, 2101 Constitution Ave., N.W., Washington, D.C. 20418.

Area of Interest: 21 facilities design (highway transportation)

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NCHRP Supports Advances in Differential GPS Satellite Surveying

An NCHRP digest on the status of NCHRP Project 20-23, "Kinematic Differential GPS Satellite Surveying" prepared by Lloyd R. Crowther, Consultant.

This research has resulted in a technique by which highway engineers and surveyors may rapidly obtain precise positions necessary to maintain geodetic control. The technique uses measurements of the Global Positioning System (GPS), commercially available GPS receivers, and personal computers for data processing. Users of this technique need to occupy each point to be surveyed for only one or two minutes, thus providing an efficient means to quickly and precisely survey a large number of points. Horizontal accuracies of one centimeter and vertical accuracies of three centimeters have been demonstrated. The software has been written to run on most available personal computers (see minimum specifications listed below) and can be operated with no special skills required.

Although the Navigation Satellite Timing and Ranging (NAVSTAR) system, also known as the Global Positioning System (GPS), is a satellite system being developed by the Department of Defense under Air Force management, some civilian applications are allowed. Presently, 15 satellites providing positioning information are in orbit. An 18-satellite constellation providing 24-hour coverage is expected to be fully operational in late 1993. This constellation will provide very precise three-dimensional information on a continuous basis.

The GPS has made possible a revolution in the art of navigation, positioning, and surveying. In September 1988, NCHRP contracted for research by GPS Services, Inc., and the National Geodetic Survey Division of Charting and Geodetic Services of the National Ocean Service, National Oceanic and Atmospheric Administration to improve the civilian applications in land surveying.

Equipment presently on the market provides point positioning using a single receiver/antenna. Measurements are made in real-time with accuracies ranging from an estimated 10 to 30 meters. Point positioning can be accomplished in a static mode where the antenna occupies a single spot, or a kinematic mode, where a mobile antenna is continuously positioned. Point positioning data can be used by DOTs with a geographic information system (GIS) for such activities as highway inventories, accident locations, and maintenance operations. Because systems that provided levels of accuracy acceptable for some of these activities already existed or were expected soon, no research was proposed in this area at the time this NCHRP research was initiated. However, opportunities did exist in the area of precise relative (also called differential) positioning using GPS with two receivers/antennas, one normally stationary on a known point and the other mobile.

Use of the available satellite constellation had shown that differential positioning measurements with accuracies of a few parts per million were possible in 30 minutes or less of data acquisition. Preliminary work involving the use of GPS for rapid differential positioning of ground-based survey points has indicated the feasibility of greatly reducing the time required to accomplish the equivalent of geodetic traversing. This process uses the differential GPS measurement mode where the time needed for static data collecting from the mobile antenna over each point as the antenna moves from mark to mark is measured in seconds instead of minutes or hours. The benefits of such a process are marked when considering the amount of geodetic traverses being conducted by the state DOTs.

The NCHRP-funded research originally concentrated on the use of differential GPS techniques to determine the kinematic position of a moving antenna -- continuous, uninterrupted contact with satellites and a reference antenna/receiver being required. Initial conditions must be established, and this can be done in several ways, by: (1) occupying a monument with a previously determined position, (2) performing an antenna swap maneuver, or (3) occupying the initial positions for a sufficient time (approximately 15 to 30 minutes) to permit a "bias-fixed" solution. These techniques determine changes in the position of the mobile antenna from changes in the observed carrier phase, i.e., they measure the three-dimensional distance variations from a base point (reference antenna/receiver) using changes in the continuous reception of the transmissions from several satellites at the same time. Under these circumstances, the continuity of the satellite phases is critical; no cycle slips or other non-geometric changes in phase may be permitted that might be falsely interpreted as movement of the antenna. It is clear that while the kinematic differential GPS techniques offer great potential for a wide variety of applications, there are some severe operational constraints related to the maintenance of phase continuity that may limit the practical applications of those techniques.

A recently developed ambiguity function technique, more accurately described as a rapid static technique rather than a kinematic GPS because the moving antenna is not in continuous contact with the satellites when it is moving from monument to monument, was subsequently investigated by the researchers. The principal benefits of this technique are the speed and accuracy with which it may be used with an immunity to cycle slips or other discontinuities in the phase data that commonly occur. The technique requires measurements from only a single epoch (instant in time) but, in practice, monument occupations of one to two minutes would be expected.

A computer program employing this ambiguity function technique was developed, as part of NCHRP Project 20-23, and was used to process data collected during a special field test held for this project and data available to the researchers from other field tests. The researchers demonstrated that the results indicate horizontal precision and accuracies of one centimeter or less and vertical precision and accuracies of 1 to 3 centimeters. They also state that data processing requires no data editing, is easy to use, and can be operated without any specialized knowledge of kinematic GPS techniques. The means to include a correction for the effects of the ionosphere have been demonstrated, which will enable this technique to be applied over longer distances in future versions of the software.

This program of Rapid-Static Solutions has been added to OMNI, a complete GPS data processing program structured to allow easy manipulation of all functions required for GPS solutions. OMNI is not intended as a "hands-off" program. Rather, it is intended to provide the user with the means to efficiently examine the quality of his/her data and his/her processing at each step while documenting these intermediate results with a series of plots and output files. OMNI will process static, kinematic, and rapid-static data and will accept data from a variety of GPS receivers.

The OMNI programs are contained on five 1.2 Mbyte floppy disks. To execute all of these programs successfully you will need:

1. a 386 based personal computer with
2. 640 kbytes of RAM on the motherboard and
3. at least 4 Mbyte of available RAM,
4. a math co-processor and
5. M/S DOS 3.3 or higher.

OMNI is by no means a finished set of programs. Besides the bugs that occasionally need to be fixed, there are also some major enhancements being planned for future versions. In order to keep the OMNI users as up to date as possible and to minimize the burden at NOAA, the OMNI software is available through the computer network INTERNET. Users are advised to scan this directory periodically to check for new program updates.

INTERNET is an Information Database run by the National Science Foundation in Washington, D.C. It caters to academic institutions, but is available to others. Some state governments are already connected to INTERNET, as are all major universities, either directly or indirectly through gateways of other networks. Details on joining INTERNET can be obtained by contacting your nearest University and asking for the name of the local Midlevel Network representative. Additional information on using INTERNET is available by calling NSFNET Network Service Center (NNSC) at 617-873-3400.

State DOTs interested in evaluating these techniques can also obtain a subset for the Rapid-Static GPS Processing Subprogram and the documentation by contacting the Principal Investigator, Dr. Gerald L. Mader, National Geodetic Survey, CGS, NOS, NOAA, Rockville, MD 20852. He can be contacted by phone at 301-443-2520. This subset consists of two floppy disks and requires the same computer capabilities as the whole program as listed above.

NCHRP Project 20-23 is essentially completed; however, the finalized research reports are still pending. Once received, they will be made available through the TRB distribution system. Nevertheless, periodic contact with the National Geodetic Survey or the OMNI file in INTERNET is recommended for the latest, up-to-date information.