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GPS Application for the Digital Map Construction of Irrigation Canal Networks

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Abstract □ GPS(Global Positioning System) surveying is an effective method using satellite measurement system and can be applied to construction of digital map of irrigation canal networks. In this study, GPS surveying method for irrigation structures was developed. A selected main canal of an irrigation district were surveyed by GPS. The obtained surveying results were corrected by post-processed DGPS (Differential Global Positioning System) and imported to GIS for the digital map construction.

Keywords □ GPS surveying, irrigation facilities, DGPS, GIS

I. Introduction

Since large numbers of irrigation facilities were constructed before 1960's, deteriorated facilities need rehabilitation and repair works. Kim et al. (1997) investigated 1,824 reservoirs managed by Farmland Improvement Association (FIA) and found that about 88% of reservoirs were built more than 20 years ago. Overall irrigation systems which include irrigation canal and other structures were also built in same periods.

Development of computerized irrigation facilities management system, which identify prior irrigation structures that need rehabilitation and repair works, is required for efficient maintenance of aging irrigation structures. Construction of nation wide database of status of irrigation structures is fundamental for developing the management systems.

As an effort to develop irrigation facilities management system, IFIS (Irrigation Facility Inquiry System), which helps querying of irrigation structures managed by FIA were developed (Kim et al., 1997). Kim et al. (1998) also developed OMASIF which is unified management system for irrigation and drainage facilities. But those systems do not use Geographic Information System (GIS) which enable spatial data management and analysis. Application of GIS for the development of management system of irrigation facilities was attempted by Goh et al. (1998).

Construction of digital map of irrigation networks is essential for the development of irrigation facilities management using GIS. To construct digital map of irrigation facilities, design map of irrigation project can be used as a base map. Although there exists design map of a project, the map does not have control point for the coordinate system transformation and it is often difficult to integrate it with the national standard topographical map. Another problem of using design map as base map is that actual position of irrigation structures would be quite different from that of original design of irrigation project. Location of structures could be changed during construction and structures were built afterward might not be appeared on the design map of irrigation project. Therefore, surveying of current irrigation networks is required in many cases. But surveying irrigation facilities with conventional surveying method is challenging task due to extensive numbers of irrigation facilities, which limit construction of spatial data for the computerized irrigation facilities management system.

New surveying technology which reduces time and effort compared to conventional surveying method is preferred for surveying of irrigation facilities. Recently, GPS (Global Positioning System) satellite surveying method is widely accepted as new surveying method. In this study, GPS satellite surveying method was suggested for surveying of irrigation facilities. Appropriate indoor and outdoor procedures for GPS surveying were developed. Differential GPS surveying was conducted on the main irrigation canal of Bangsan reservoir and digital map of irrigation facilities was generated.

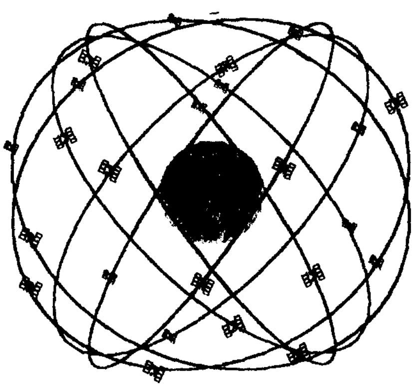
II. GPS and DGPS

1. GPS (Global Positioning System)

GPS is a technology, which uses a series of satellites called a constellation in a non-geosynchronus orbit around the planet. The satellites are constantly being updated with position information on every satellite in the constellation (Fig. 1). Therefore, each satellite has a record of all the other satellite locations. This data is stored in an almanac. Also, each satellite has an atomic clock with daily updates and encryption in a process called dithering. This information is being constantly transmitted from the satellites.

The satellite transmit at frequencies L1 = 1575.42 MHz and L2 = 1227.6 MHz modulated with two types of codes and navigation message. The two types of code are the C/A-code and P-code. Standard Positioning System (SPS) is based on the C/A-code, whereas Precise Positioning System (PPS) is provided by the P-code portion of the GPS signal. The current authorized level of SPS follows from an intentional degradation of full C/A-code capability. This measure is called selective availability (SA) and entail falsification of the satellite clock (SA-dither) and the broadcast satellite ephemeris (SA-epsilon), which is part of navigation message. Despite, selective availability, the C/A-code is fully accessible by civilians (Leick, 1995).

The GPS receivers pick up these signals. Using the information embedded in the signal, the GPS receiver selects the best four satellites that it will use for the trilateration calculation to derive the final solution. The simplified version of the trilateration calculation for each measurement requires the input of four variables: the x value, the y value, the z value, and time. In order to solve four unknowns or variables in mathematics, you need to have four equations; hence, you need to have four satellites.



GPS Nominal Constellation, 24 Satellites in 6 Orbital Planes, 4 Satellites in each Plane, 20,200km Altitudes, 55 Degree Inclination

Fig. 1. GPS constellation

2. DGPS (Differential GPS)

However, as mentioned earlier, the time variable is encrypted. The encryption has the effect of time distortion, which in turn distorts the GPS locations by as much as 400 meters. There are military GPS units available to Federal agencies, which decode the time variable; however, the positional accuracy for these units is only around 15 meters. To get the 1~3 meter accuracy or sub-meter accuracy, differential correction is needed. Differential correction requires two sources of data. One source is the raw uncorrected GPS data captured by the GPS rover receiver (unit in the field), and the second source is the corrected GPS information from a base station .

A base station is a stationary GPS receiver where the position of the antenna has been surveyed to sub-centimeter accuracy. Since the base station already has an accurate location, the raw uncorrected data is corrected for any variances by simply subtracting the raw location by the known location of the base station. This process is completed on a second by second basis. The differentially corrected positions are then stored in flat files, broadcast via radio waves, or both.

Basically, the base station data offers a correction vector (i.e. distance and angle) which can then be applied to the raw data collected by the GPS rover either on a real-time or post-processed basis. Each raw measurement is then corrected using the correction vector, which is applicable to the exact time of the raw data was collected. After all the measurements have been corrected, the measurements are then averaged to supply a single solution: the location or point.

III. Irrigation networks and code assigning for GPS surveying

1. Irrigation networks

The irrigation networks are composed of several structures which deliver and distribute water from the water sources such as reservoirs, pumping stations to the field unit. The main components of irrigation networks are irrigation canals. They can be hierarchically classified into main canal, branch canal and farm ditch. Those canals can be also classified into the open channel or pipeline. The open channels, which are mainly used for irrigation networks, are classified into earth canal, lined canal and concrete flume. Furthermore, the lined canals are classified according to lining materials like concrete, shotcrete, concrete block, gravel and clay.

Other structures are required for head control, water delivery and distribution in the irrigation networks. For the head works, the head control structures such as drop, chute and control gate are used while culvert, siphon, tunnel and aqueduct bridge are used for overcoming topographical obstruction. To distribute water from canal into field, divisions are installed across canal.

2. Code assignment for GPS surveying

The results of GPS surveying is directly digitalized and captured, stored and processed in digitalized numeric forms. The digitalized surveying procedures need more advanced and detail techniques, but high quality results can be obtained. Furthermore, the significant merit of the GPS surveying is that the results of digital data can be directly imported into the CAD and GIS software.

Numeric code of irrigation facilities are required during and after GPS surveying to

Table 1. Attribute code of the irrigation canal and hydraulic structures

attribute	function	type	material	shape and other
Line	1. main canal 2. sub-main 3. lateral 4. other	1. lining 2. flume 3. pipeline 4. aqueduct bridge 5. other	1. earth 2. concrete 3. cast iron 4. steel plate 5. steel pipe 6. block 7. wood 8. stone 9. other	1. triangle 2. trapezoidal 3. circular 4. rectangular 5. horseshoe 6. other
Point	1. headwater control structure 2. division structure 3. other	1. starting point of structure 2. end point of structure 3. drop 4. tunnel 5. culvert 6. siphon 7. shute 8. division 9. other	1. concrete 2. cast iron 3. block 4. wood 5. stone 6. other	1. gate 2. weir 3. orifice 4. valve 5. other

identify attribute of surveying objects. The irrigation structures are classified into line features or point features to put into digital map, and the features are hierarchically categorized with functions, types, materials, and shape and other. Table 1 shows assigned 4-digit code used in this study to identify irrigation structures.

III. GPS surveying and data processing

1. GPS surveying and results correction by DPGS

Fig. 2 depicts the GPS surveying procedures. GPS surveying consists of planning and preparation, on-site surveying, and data processing after surveying. Well designed planning may reduce time and effort. At the planning stage, surveying route and scheme should be

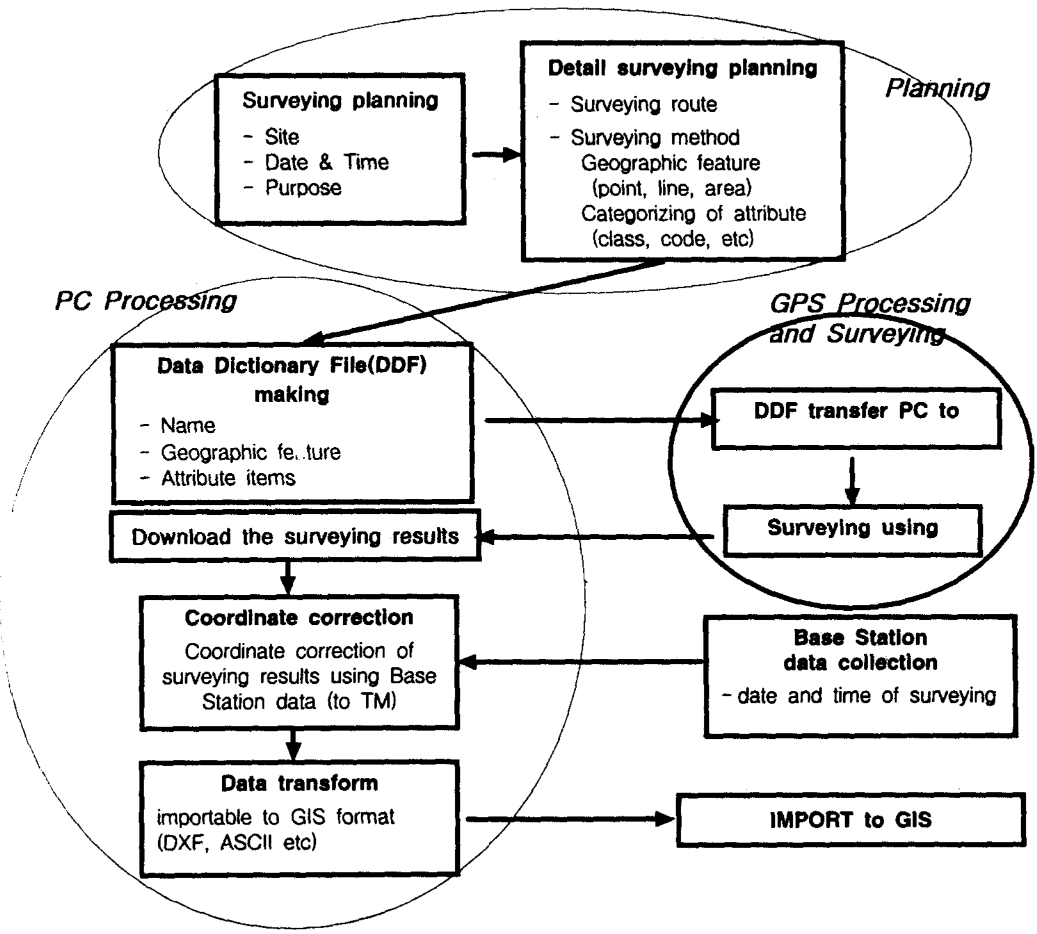


Fig. 2. GPS surveying procedures.

determined, first. Code assignment to categorize attribute of surveying object should be prepared before on-site surveying, either.

The GPS surveying and data processing need various devices and softwares. The devices are 2 GPS receivers for differential GPS surveying (DGPS). Projection software is required for transforming position value. of latitude and longitude to Transverse Mercator (TM) projection. Another software is also required for position calibration using difference from base station. Trimble GPS receiver was used for this study.

In this study, main irrigation canal of Bangsan reservoir located in Yesan county of Choongnam Province was selected for GPS surveying. General descriptions of the reservoir and the canal are shown in the Table 2. Fig. 3 shows surveying scenes of irrigation structures using GPS. GPS surveying results are shown in the Fig 4. The surveying results were corrected by post-processing DGPS. In Fig. 4(b), the post-processed surveying data showed better canal alignment. Nevertheless, in the middle of Fig. 4(b), some errors were still not correctly calibrated by DGPS scheme. The errors were seemed to be caused due to obstruction of signal by tall trees in surveyed site from GPS satellites. GPS surveying is known to be suitable in winter season to avoid signal noise by vegetation during summer

Table 2. Properties of Bangsan reservoir and irrigation canal

watershed area (ha)	irrigated area (ha)	dam			irrigation canal (m)	
		effective storage (1000 m^3)	length (m)	height (m)	main	branch
690	331	194.10	336	19	4,649	10,758

(Source: Inventory of irrigation facilities of Yedang Farmland Improvement Association, 1996)

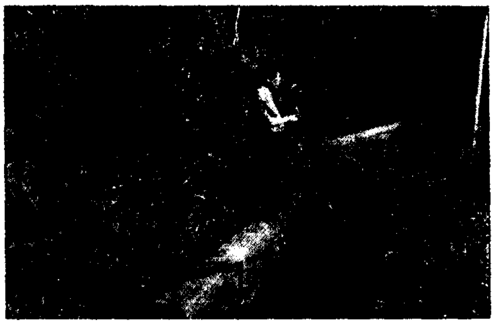
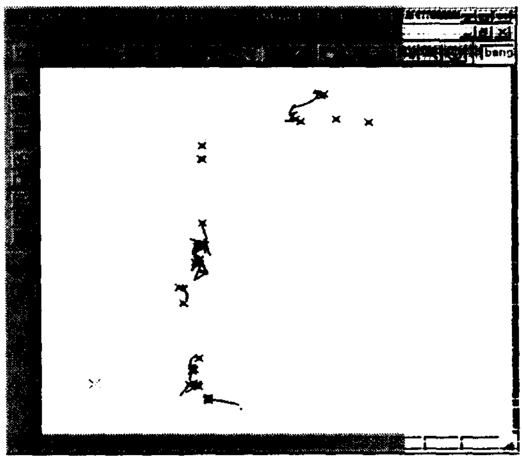
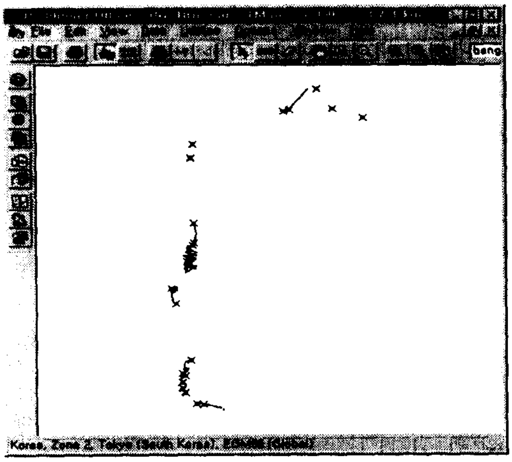


Fig. 3. Surveying with GPS



(a) Pre-correction



(b) Post-correction

Fig. 4. GPS surveying results

season.

2. Imbedding surveying results into GIS

To develop digital map of irrigation networks, design map of irrigation project was scanned to be used as base map. Scanned map of farm consolidation design map was vectorized and transformed to TM coordinate system using Arc/Info GIS. Latitudinal and longitudinal coordinate of control points captured by GPS was used for rectification with coordinate of national base topographic map. Topological relationships were generated and attributes were put into database. Irrigation canal was treated as line features and other structures were treated as point features. The attribute data of structures on the branch canals and farm ditches obtained from the registry of canal structures were put into Arc/Info GIS, too. Finally, results of surveyed irrigation structures along main irrigation canal by GPS were put into GIS map (Fig. 5). Location of irrigation structures was checked by comparing the results of GPS surveying with that appeared on the design map.

(a) Pre-editing

(b) Post-editing

Fig. 5. Imported and edited surveying results into Arc/Info GIS

3. Error analysis of DGPS surveying results

The Fig. 6. shows the error of GPS surveying results. Fig. 6(a) shows sequential error distribution and Fig. 6(b) is showing frequency of error. The error means distance difference between the canal alignment and the DGPS results which are shown in Fig. 5(a). The canal alignment as shown in Fig. 5(b) was obtained by several reference points and edited by comparing original design map and drawings checked at on-site surveying.

The error analysis as shown in Fig. 6(b) revealed that about 50% of GPS captured points were within error range of 1 meter. The largest error was 32m. It seems that not only correction by DGPS but also careful surveying of principal point or bench marking are required to enhance accuracy of GPS surveying for the irrigation structures

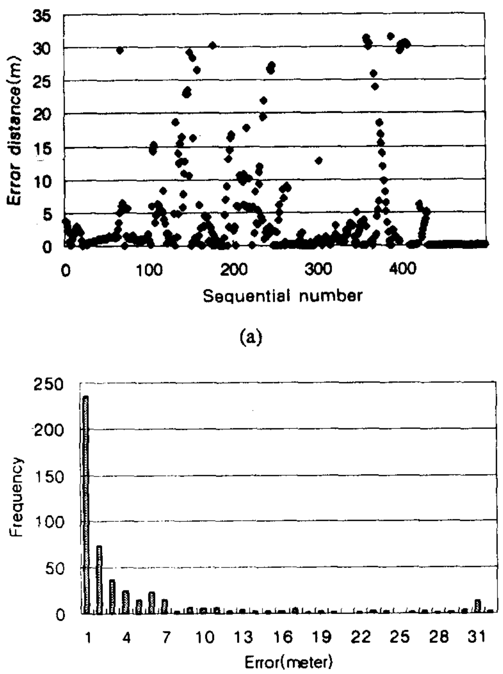


Fig. 6. Error analysis of DGPS surveying results

IV. Summary

GPS surveying is an effective method using satellite measurement system and can be applicable to construction of digital map of irrigation canal networks. GPS(Global Positioning System) surveying method was applied to construct digital map of irrigation facilities. The results are summarized as follows:

1. Appropriate procedures for GPS surveying of irrigation facilities were suggested. Coding system of irrigation structures for an effective GPS surveying was also developed.
2. GPS surveying was conducted on the main irrigation canal of Bangsan reservoir in the Yesan county, and surveying results were corrected by DGPS.
3. GPS surveying results were transferred to Arc/info GIS and digital map of irrigation networks was generated by the GIS.
4. Error analysis showed that about 50% of GPS captured points were within error range of 1m.

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