DIGITAL MODEL AND GPS BASED PATH REPRESENTATION AND OPTIMIZATION

Linyuan XIA
National Laboratory for Information Engineering in Survey, Mapping and Remote Sensing,
Wuhan University, 129#Luoyu Rd., 430079 Wuhan, China
Tel: 86-27-87881292, fax:86-27-87863229, e-mail: lnyxia@hp1.wtusm.edu.cn, lxyxia@hp1.wtusm.edu.cn

Jingnan LIU
President office, Wuhan University, 129#Luoyu Rd., 430079 Wuhan, China
Tel: 86-27-87884841, fax: 86-27-87863229, e-mail: jnliu@wtusm.edu.cn

ABSTRACT
A multi-purpose path representation and optimization system is introduced in this paper. Path analysis can be performed in two ways: (1) design and comparation on digital elevation map (DEM) for initial planning; (2) path evaluation and optimization with GPS navigation aiding for practical assessment. Digital model can be generated as DEM by Open Graphical Library with standard ARC/INFO data format or with other data format transferred. When implemented with practical GPS navigation data, environmental influence such as multipath interference can be given and point data quality plus reliability can be denoted on the map. Moreover, if a path is selected by mouse on the map, possible navigation accuracy by GPS is also indicated for path planning reference. The system can be used for fire farming, vehicle highway profiling, aircraft forestation and field investigation.

1. INTRODUCTION
With the rapid development of geoinformatics and spatial technologies, revolutionary innovations for geography and its related subjects have occurred. Geoinformatics based application such as resource management, environment conservation, traffic control and management, surveying and mapping is becoming more and more popular and important, and is gaining daily progresses. One of these development trends is the integration of spatial technologies (RS, GIS and GPS). In the integration application, GIS is the base for comprehensive application and analysis. Deren LI has developed 3S integration system of ITS (Deren LI, 2000). GPS combined with other sensors is employed as road network generation (Deren LI, 1999). David Tyler used GPS as data collecting sensor to form DTM for an agricultural GIS (David Tyler, 1992). American Institute of Navigation (ION) designed a AIRPLAN system to carry out flight planning with the global DTM base. In these application, DTM or DEM data source can be from RS, digital input or satellite image and it may be global or regional coverage according to the application purpose of the geomatics system. The digital model (DTM or DEM) is an important component in the database of GIS and forms a basis of terrain data and topographic analysis.

In this paper, a DEM is employed as a means of an area terrain representation to depict the earth's relief. GPS receiver is equipped into a dynamic object (vehicle or low flight plane) to collect data and achieve navigation. The positioning data is post-processed (differentiated if necessary) to get position point. Flight path or traveling path is then denoted on the DEM. Open GL approach is used to form moving terrain along the path to show the dynamic geographic environment. As an option, the terrain induced multipath influence on navigation and satellite distribution on the sky is indicated on the dynamic terrain map. Zooming local comparation and optimization can be carried out in the software system.

2. SYSTEM CONFIGURATION AND DATA REPARATION
In this analysis system, spatial modeling of the regional terrain is described by DEM. Source data is archived in format of standard ARC/INFO. To achieve the display of DEM and the related analysis, the source data is extracted and decoded firstly, and then data points are synthesized by the principle of efficiency and accuracy, efficiency is mainly the computation speed and accuracy is the display equality and modeling fitness (source data equality is not discussed here). In this process, a proper number of important points are selected and filtered to form some intermediate layer files for later display and analysis. This can reduce the burden of too dense points and large data quantity. The general chart is as follow.
Figure 2. Source Data Processing

Figure 3. Sketch DEM

Figure 4. Path Indication On DEM Map

3. PATH GENERATION AND REPRESENTATION

To facilitate flexible analysis, Path to be displayed on DEM can be generated in two ways:

1. Virtual path selection by mouse on DEM displayed. In this case, the chosen path can be stored as a file and can be recalled for later analysis.

2. Path generation from navigated files.

In case(2), the path is an actual traveled or flight path. The point position accuracy on path depends on GPS positioning mode. If single point positioning mode is used, the spatial accuracy is ±10m(with 90%); if navigation is in DGPS mode, the point accuracy will be ±1-2m to ±5m.

After positioning, point coordinates must be transformed from navigation system(WGS-84) to DEM based coordinate system.

The general transform principle can be expressed by following Wolf-Bursa model:

$$
\begin{bmatrix}
X' \\
Y' \\
Z_{DEM}'
\end{bmatrix} = \begin{bmatrix}
\alpha X \\
\alpha Y \\
\alpha Z
+ (\alpha + k) \begin{bmatrix}
R_x \\
R_y \\
R_z
\end{bmatrix}
\end{bmatrix}
$$

where

- $R$ is rotation matrix.
- $\alpha$, $\beta$, $\gamma$ are rotation angles.
- $\alpha X$, $\alpha Y$, $\alpha Z$ are origin displacement between the two coordinate systems.
- $k$ is scale difference for two systems.

These transform parameters are determined from a number of known coordinate points in both systems. When rotation and scale can be ignored, transform becomes a simple displacing by origin offset of two coordinate systems.

Another coordinate modification is projection from 3D to 2D plane. Mercator projection or Gauss(Gauss-Kruger) projection is the frequently used model to achieve this. When the projection is performed before, coordinate transform is carried out on a specified plane. This will be a 2D coordinate transform. Above Wolf-Bursa model is reduced into a 2D model.

Path generated from transformed point data is indicated on DEM map with a red color curve.
Besides, the altitude of path can be adjusted to observe the terrain effect at different heights. This is important when the inter-visibility conduct is needed in case of communication device layout, or foresting by airplane, or fine farming investigation. In some complicated situation, when the satellite line-of-sight is cut off and the number of navigation satellites are reduced, GPS navigation will become a problem and this will be dangerous for flight. It is quite essential to indicate this information for related parts of path on DEM.

Under this circumstance, the terrain induced environmental influence on GPS positioning is also studied and is indicated on a right windowed column for user reference. The window also includes navigation accuracy by GPS. The satellite cut off by terrain is denoted with a red color line. Zooming is provided to show regional parts of the path in complicated terrain situation. 3 levels of zooming is supported by the system.

5. GPS NAVIGATION PREDICTION

In some situation, it is useful to know the availability of GPS ahead of a specified time span at an appointed place. In this software system, the terrain induced visibility of GPS is taken into consideration. GPS satellite predicted positions in the sky are calculated from almanacs files. The position plus terrain factors determine the predicted GPS visibility and possible positioning accuracy (DOP values).

6. CONCLUSION AND FUTURE PLAN

The software system is an integrated analysis tool for path planning and investigation by GPS navigation.

REFERENCES:
[1] Li Deren, Zhong Sidong, Guo Bingxuan, Road Network Generation by Mean of 3S and multi-sense. 3rd International workshop on urban 3d multimedia mapping, Section D. Monitor road transportation and application, 2000, pp23-30
[2] Li Deren, Chen Xiaoming, Guo Bingxuan, Zhong Sidong, Road network generation by mean of GPS/GIS Integration, International workshop on Geographic Information systems for transport (GIS/T) and Intelligent Transport System (ITS), 1999
[3] David Tyler, Integration of a GPS DTM into an Agricultural GIS, University of Maine, ION-GPS1992

BIOGRAFY
Lingyuan xia: Associate Prof., Graduated from Wuhan Technical University of Surveying and Mapping in 1986(Geodesy). Research field: GPS and related application.