AS BUILT SURVEYS OF ROAD SIDE FEATURES FOR GIS, VISUALIZATION, AND VIRTUAL REALITY

K.Jeyapalan[1], D.Bhagawati[2]
[1]Professor of Civil Engineering
428 Town Engineering Hall
kjp@iastate.edu
[2]Graduate Research Assistant
GIS Support and Research Facility
218 Durham Hall
dwipen@iastate.edu
Iowa State University
Ames, IA 50011

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ABSTRACT

The paper describes Total Station, Differential Global Positioning System (DGPS), Videologging softphotogrammetric and virtual reality methods of collecting data on road side features of urban, city and rural roads for creating a Geographic Information System (GIS). Total station can be used in mapping at a scale of 1″= 25ft or less; DGPS at 1″= 50 ft or less and Video images with softphotogrammetry at 1″= 25 ft or less. Data collecting using Total Station and DGPS are time consuming in the field where as soft photogrammetry uses more office time. Virtual Reality can be used for 3D visualization, fly through, and 3D view of proposed modifications.

INTRODUCTION

Recent advances in GPS, Total Station and Soft photogrammetry enable surveyors and photogrammetrists to undertake “As Built Surveys” of road side features at a cost that is affordable within the maintenance budget of state, city and county agencies. Typically, a preliminary survey for road development and construction cost between $15,000 to $20,000 per mile. An “As Built” survey is attractive if the cost is less than $ 1,000/mile. A mapping accuracy 1″ = 100′ is sufficient in a rural area where as a mapping accuracy of 1″ = 50′ and I″ = 25′ may be required in urban and metropolitan areas, respectively. The most accurate method of doing an “As Built” survey is by Total Station, but it is more costly and time consuming than GPS, videologging and soft photogrammetry.

A Real Time Kinematic Differential Global Positioning system (DGPS) collects data for “As Built” survey cost effectively. However, due to obstruction of satellite visibility by buildings and trees, it is not feasible to do so in obstructed areas. Also attributes of features such as heights of trees, light posts, and traffic signal are not easily obtainable with GPS. The DGPS method may also be time consuming.

Videologging, using digital cameras, GPS, Inertial Navigation System (INS) and tilt sensors, are currently used for inventory and visual verification of roadside features. Soft photogrammetry has developed to an extent that it is now available, at an affordable cost, for a PC and Unix workstation. Videologging images and soft photogrammetry can be used to do “As Built” surveys wherever DGPS cannot be used and Total Station are cost prohibitive.

The objectives of this paper are to present the results of the “As Built” surveys done in Oregon and Washington by Olympia and Thurston county in cooperation with Iowa State University (ISU) and Mandli Corporation using Total Sation, DGPS and videologging.

The paper describes the procedure and gives results of:

- a GIS for roadside features in rural, urban and metropolitan area by Total Station and DGPS
- inventory survey by videologging
- an “As built” survey by Soft photogrammetry,
- virtual reality

Conclusion and recommendation follow.

GIS FOR ROADSIDE FEATURES IN RURAL, URBAN AND METROPOLITAN AREA BY TOTAL STATION AND DGPS

According to the survey done by an ISU research team [1], for counties, cities and state DOT the first 15 highest priority road side features are: Intersections , signs , pavement markings , signals , curbs , guard rail , number of lanes , rail road crossings , shoulders, side walk , road names, pavement distress, roadway geometric, bridges and Right of way. It is clear from these responses that a GIS showing all roadside features will be valuable information for their inventory, maintenance, transportation studies and improvement.

For this study one urban area, WA-1, a metropolitan area, and a rural area, OR-5, are chosen. The WA-1 , urban area, can be easily done with DGPS, as it is free of obstruction by trees, buildings, power lines etc. Trimble Pro-XL with TDCI Asset Surveyor and Trimble Pro-XR with TDCI asset surveyor, fig (1) are used. These are rover receivers with accuracy of about ± 1ft, and can be used for mapping features at 1″ = 50′ in an urban area. These units were used to locate point features such as light poles, fire hydrants, by way of a walking survey, and line features such as road lanes, bike path by using a truck mounted attachment. Data collected by the TDCI data collector were processed using the GPS base station data, which were collected by US Forestry Department, Portland, OR. The processed data were then used to create Autocad drawing files which were then used in Arc/Info to produce the GIS base map and attribute tables. See fig 2 and table 1.

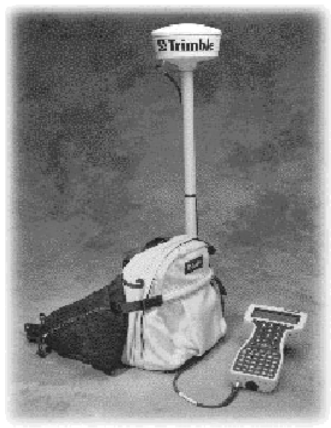

Fig 1. ProXL

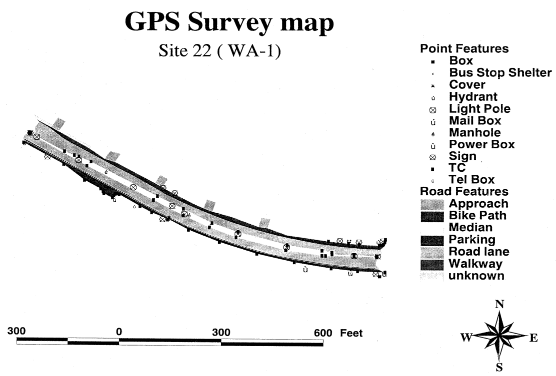

Fig 2. GPS Map

Point #	X-coord (ft)	Y-coord (ft)	Elevation above msl (ft)	Feature Type
1	1119185.352	107859.526	291.969	Hydrant
2	1119184.699	107862.360	291.541	TC
3	1119255.498	107815.008	292.369	Sign
14	1119450.474	107676.838	293.517	Hydrant
15	1119509.633	107654.287	294.412	Tel Box
20	1119610.049	107616.024	292.147	Manhole
21	1119612.090	107621.900	291.859	Cover
28	1120144.488	107448.503	295.483	Power Box
32	1120231.574	107436.708	286.983	Box
33	1120244.465	107447.518	293.290	Mail Box
39	1120156.456	107501.810	291.793	Light Pole
83	1120138.182	107551.333	295.957	Bus Stop Shelter

Table 1. Attribute

OR-5 is a rural road and DGPS with an accuracy of ± 1ft is suitable for mapping at a scale of 1″ = 100′. However because of tall trees and winding roads, fig (3), the DGPS cannot be used. A Total Sation traverse loop was used to determine the location of the features. Initially, the Total Station traverse was done on an arbitrary local coordinate system (10,000; 10,000). From the traverse stations, the locations of the features were collected by walking survey using the Total Station reflector rod and a data collector similar to the DGPS survey. In order to transform the local

Fig 3. Winding Road

Total Station coordinates to the WGS GPS coordinates, two calibration points on the total station traverse were established from GPS control station using two Trimble 4000 SSI GPS survey unit. As in WA-1, the GIS map using Arc/Info was produced from the Autocad drawing file drawn from the date collector data.

OR-3 is in the Metropolitan area. DGPS is not accurate enough for mapping at a scale of 1″= 25′ and further cannot be used because of the obstruction of signals by tall buildings (Fig 4). Therefore Total station methods were adopted. Further, because of the tall buildings calibration points using GPS were established outside the area which resulted in a long Total Station traverse. Fig. 5 shows the GIS map.

Fig 4. Tall Buildings

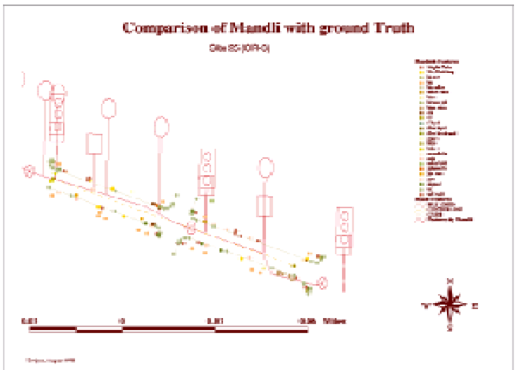

Fig 5. GIS Map

VIDEOLOGGING

With the advent of video and digital cameras videologging of roadside features have become part of the state wide transportation data collecting system.

By having a van equipped with a video camera whose triggering system is controlled by GPS receiver, it is possible to get a video image and also its location. Fig 6 shows the Mandli Cooperation Videologging system which was used in this study. The system was also equipped with Inertial Navigation System, which substitutes for GPS location whenever GPS loses lock due to signal obstruction. This ensures continuous position determination.

Fig 6. Videologging

In most inventory studies the location of features along the center line are sufficient. Therefore feature locations were interpolated from the average distance between photos. Figure 7 shows the comparisons of videologging with ground survey by DGPS and Fig 5 with Total Station.

In order to check the quality of video images and the accuracy of GPS locations of the video images a test range was established see fig 8. This test range represents a typical road section. It is a relatively flat section of road 100ft in length with pavement markings, street signs and reflectors that are used for identifying height from road surface, center line offset, location (x,y,z), color, shape and clarity. Fig 9 gives the design and GPS coordinates.

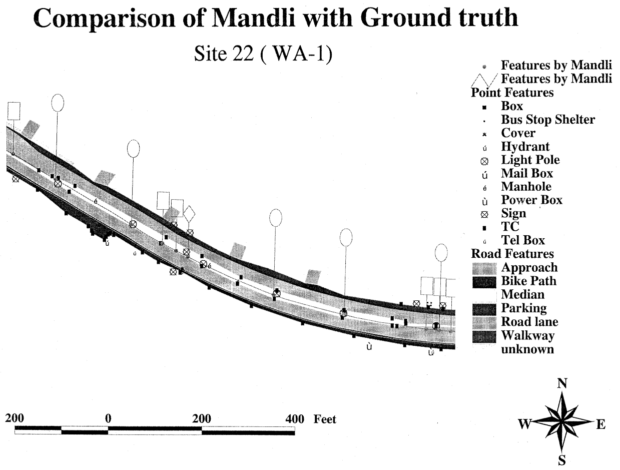

Fig 7. Comparison Map

Fig 8. Test Range

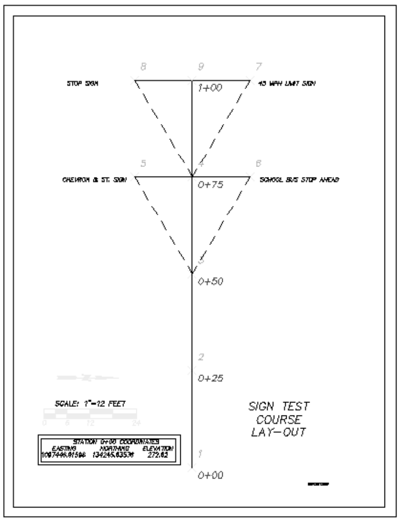

Fig 9. Design of Test Range

The test range was used to calibrate the Mandli's GPS and INS system. Initially the video logging vehicle was parked over the station 0+00 so that the GPS antenna was directly over it, thus initializing its system. The vehicle was then driven through the test range collecting video images and GPS coordinates. Table 2 gives the error in the Mandli's system and fig 10 shows a video image it obtained as it drove through the test range.

It can be concluded from the analysis of these tables and figures that by using the video logging system the positional accuracy of the roadside features along the center line of the road can be estimated to within a meter under different conditions. Mandli's images showed satisfactory clarity even at distances more than 100 ft. As the van moved through the test range, clarity remained good and all aspects of the road signs were readable.

Mandli Photo Number	Camera Position	Coordinate	Ground truth Coordinates	Mandli GPS Coordinates	Coordinate Differences
F_00001	0 ft	E	134246.477	134245.066	1.411
		N	1097446.281	1097448.877	-2.596
		Elev	274.921		
F_00005	25 ft	E	134247.433	134246.362	1.071
		N	1097420.908	1097423.342	-2.434
		Elev	273.325		
F_00008	50 ft	E	134249.171	134242.659	6.512
		N	1097395.938	1097402.786	-6.848
		Elev	271.766		

Table 2. Comparison of Ground Survey with Videologger

Fig 10. Image Clarity of Videologger

SOFT PHOTOGRAMMETRY

The videologging system gives the digital image and the X, Y, Z coordinates of the camera locations, using this information and soft photogrammetry it is possible to determine the location of any feature.

Because digital camera used in video logging is a non metric camera, therefore it must be calibrated frequently. The test range with road side features, (fig 10 and table 2), and their coordinates can be used to calibrate the digital camera. Video images of the test range from station 0+00, 0+25, and 0+50 were used in Calib [2], which is a simultaneous bundle adjustment software that uses collinearity condition (see fig 11 and the model equation).

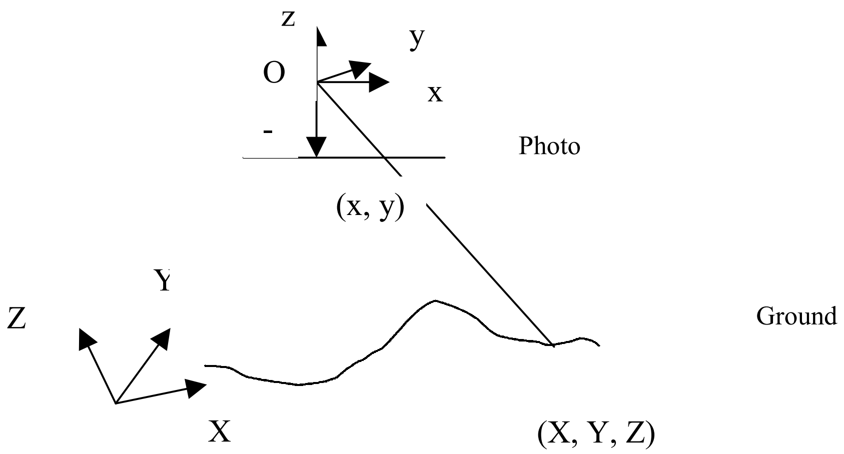

Fig 11. Collinearity

$$x - x_o + \delta_{xr} + \delta_{xd} = -f \frac{a_{11}(X - X_o) + a_{12}(Y - Y_o) + a_{13}(Z - Z_o)}{a_{31}(X - X_o) + a_{32}(Y - Y_o) + a_{33}(Z - Z_o)}$$

$$y - y_o + \delta_{yr} + \delta_{yd} = -f \frac{a_{21}(X - X_o) + a_{22}(Y - Y_o) + a_{23}(Z - Z_o)}{a_{31}(X - X_o) + a_{32}(Y - Y_o) + a_{33}(Z - Z_o)}$$

$x_o, y_o, f = \text{int}\, erior\ orientation\ elements\ photo\ system$

$X_o, Y_o, Z_o = camera\ location\ in\ X, Y, Z\ ground\ system$

$a_{11} \ldots a_{33} = parameters\ depending\ on\ rotation\ \kappa, \phi, \omega$

$\delta_{xr}, \delta_{yr} = radial\ distortion$

$\delta_{xd}, \delta_{yd} = decentering\ distortion \ldots\ldots\ldots\ldots\ldots\ldots equation\ (1)$

The Calib program simultaneously determines interior and exterior orientation elements as well as ground coordinates provided there are enough known parameters and/or observations to make the normal equation non-singular.

Table 3 shows the results of the calibration. It indicates that the best results are obtained from station 0+50 which is closer to the control points suggesting, that the geometric quality deteriorates as the camera moves away from the object. The table also shows that single photo can be used to calibrate the camera and multiple photos, in the direction of travel, can be used to calibrate as well as locate position of features.

Calibration of Mandli CCD Camera Using Test Range					
	Std Dev of Residuals At Control Points (ft)			**Calibrated Principal Distance**	**Standard Error of unit weight**
	X	**Y**	**Z**	**(pixel)**	
Photo 1	0.268	0.301	0.041	-765	5.09E-01
Photo 2	0.689	0.508	0.088	-878	2.33E+03
Photo 3	0.057	0.120	0.025	-868	4.61E+00
All Photo	0.438	0.315	1.531	-774	2.77E+04

Table 3. Results of Calibration

Table 3 also shows that (X,Y,Z) of feature locations using the multiple video imageries (non stereo) can be obtained to an accuracy less than ±0.5 ft; however the accuracy in Z is about ±1.5 ft. The error of ±0.5 ft in (X,Y) is acceptable for mapping at a scale of 1″=25′ or smaller. The error of ±1.5 in Z is acceptable for information about road side features but not for preliminary or location surveys, which may require ± 0.1 ft accuracy.

Table 3 also suggests that the strict photogrammetric model used in the Calib may not be acceptable for calibrating a digital imagery. However, by limiting the object distances from 25 to 50 ft from the camera and the camera locations from 0 to 15 ft, it may be possible to get accuracies better than ± 0.5 ft in all (X,Y,Z).

Fig 12 shows a video logging system of Transmap which is equipped with a pair of digital cameras unlike the Mandli's system which used only one camera. Four pairs of the Transmap's video imageries , 25 ft apart (See figure 13), and the soft plotter, which is a soft photogrammetric workstation by Autometrics Inc, were used to produce the GIS map showing the roadside features. First, the digital cameras were calibrated using the Calib software. Then, using the interior orientation elements, a triangulation was done using the soft plotter, followed by collecting line and point data, viewing one stereo pair at a time on the stereo plotter. See fig 14.

The Fig 13 shows that the location of features between stereo pairs are satisfactory. However, locations of features obtained beyond 50 ft from the camera are not acceptable for mapping at a scale of 1″ =25′ scale.

Fig 12. TransMap Van

Fig 13. TransMap Video Image

VIRTUAL REALITY

Virtual reality is the mode in which a user can view in 3 dimension, fly through the virtual model, modify in real time and view or measure its effect.

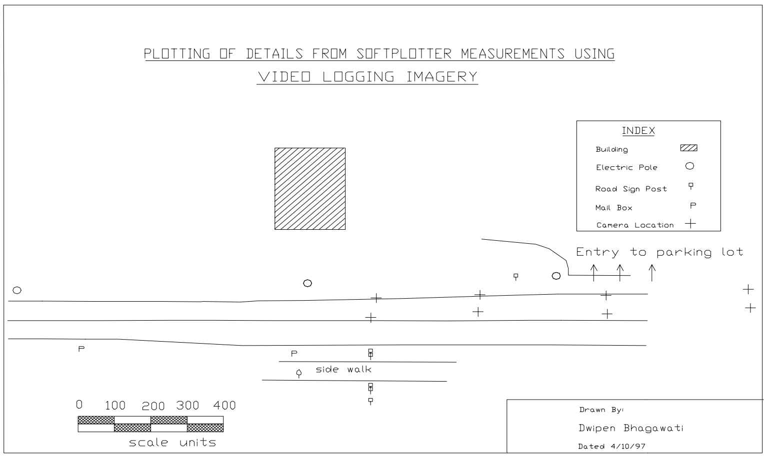

Fig 14. Soft Photogrammetric Map

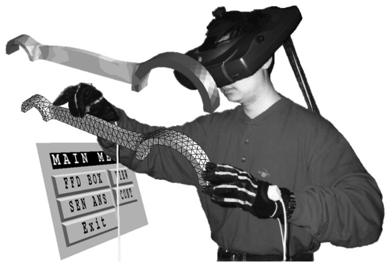

Fig 15. Multi Direction

In soft photogrammetry one view in 3D where the image is displayed, in front, on the computer screen similar to a mirror except it is a real image and not an inverted mirror image. In virtual reality one could view in all direction see fig 16 or in any one direction see fig 17. And by having the sense of touch the model can be instantaneously changed and viewed.

In order to accomplish the virtual reality the 3D view is diplayed in one to six directions using one to six computers, fig 17, and the displays are controlled by hand held control which in turn controls the computer display, see Fig 15. This is done by knowing the 3D coordinates of every pixel of the object as well as its texture. From the hand held control the camera location and orientaion, X_o, Y_o , Z_o, κ, φ, ω, for each camera are changed and the photo coordinates, p_x, p_y , for every pixel for both cameras are computed using equation(1) and displayed with its texture instantaneously see fig 15.

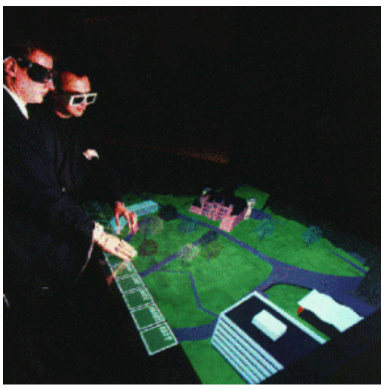

Fig 16. Unidirection

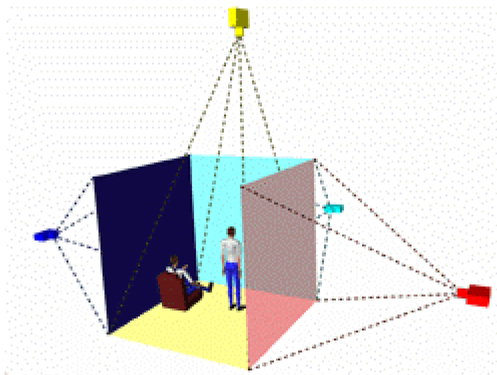

Fig 17. Virtual Display

Soft Photogrammetry can be used to determine the 3D coordinates of every pixel in the image of the object captured by metric camera, digital camera, video camera etc. In practise the geometry of the object can be visualized using the TIN (Triangular irregular network) of points whose 3D coordinates are determined by soft photogrammetry and the texture by remote sensing.

CONCLUSION

Total Station can be used to collect data for creating 2D GIS showing roadside features at a scale of 1″=25′ or larger and or smaller. DGPS can be used for maping at scale 1″ = 50′or smaller. Both systems are time consuming in the field. Soft Photogrammetry with digital videologging imagery can be used to map roadside features at 1″=25′ or smaller. It saves field data collection time; however, it requires calibration and stereo data collection time in the office.Virtual reality can be used to vizulize in 3D, fly through to simulate driving conditions and to visulize modifications prior to construction

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