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Morphological Monitoring of a High Energy Beach System Using GPS and Total Station Techniques, Runkerry, Co. Antrim, Northern Ireland

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ABSTRACT

Methodological aspects of GPS (Global Positioning System) and Total Station (Electronic Distance Measurement) surveying techniques were examined as part of a beach monitoring programme which was used to assess morphological variation of a high-energy beach system at Runkerry, Co.Antrim, Northern Ireland. The accuracy of the instruments as well as data processing methods concerning data conversion in different plane coordinates systems is discussed. GPS with Real Time Kinematics (RTK) provides high-resolution control on topographical surveying within limits on the order of centimeter-level accuracy in the horizontal and 2 cm in vertical dimension. Total station (EDM) also demonstrated high accuracy during its use in the monitoring programme. The model of EDM used in this work had a 5 to 6 degrees offset angle for the orientation due to the inherent characteristics of the instrument. A threshold-narrowed point selecting treatment was used to form a beach profile point set for the profile plot and any further processing. This work demonstrates that a two-dimensional translation and rotation for horizontal dimension data conversion is preferable over linear regression method; while the linear regression method for the vertical dimension data is still acceptable. It is suggested therefore that when a conversion of beach surveying data from one plane coordinate system to another is required, then this combined approach should be adopted in the analysis.

ADDITIONALINDEXWORDS: *GPS, Total Station (EDM), Accuracy, Coast, Beach Profile, Conversion, Method.*

INTRODUCTION

Quantitative studies in coastal geomorphology may sometimes require collection of data series' with high temporal and spatial resolution particularly when examining beach change over a weekly basis. Contemporary sophisticated technology provides a means to realise high quality data collection. GPS (Global Positioning System) and Total station techniques have been deployed in geomorphological and morphodynamic studies by coastal researchers throughout the years (MORTON *et al*. 1993, O'REGAN, 1996, DAIL *et al*., 2000).

This paper describes certain surveying aspects that have materialised during an ongoing Ph.D. programme to establish a seasonal beach behaviour model (WRIGHT and SHORT, 1984; KOMAR, 1998) for a high-energy beach system at Runkerry, Co.Antrim, Northern Ireland. The surveying aspects described here represent a small section of the host of field techniques employed which include side scan sonar, sub-bottom profiling, current measurements, sediment sampling etc. In this paper, aspects of the methodology of GPS and EDM surveying in beach area are examined, including the accuracy of the instruments, data processing, and data conversion in different plane coordinates systems.

METHODOLOGY

The site where the study is carried out is at Runkerry beach, a 1.2 km long, northwest orientated embayment located on the coast of County Antrim, Northern Ireland (Fig.1). SHAW (1985) was one of the first to examine the morphology of Runkerry beach. Significant attributes of the site include its location in a relatively high-energy environment within a sediment supply limited and geologically boundary controlled system. The site represents an ideal location at which to study beach dynamics with a well-constrained energy input-response system controlled physically by local geology and wave climate.

Profile and beach-face surveying using GPS with Real Time Kinematic techniques and Total Station (EDM) have been conducted monthly for 17 months and intensively

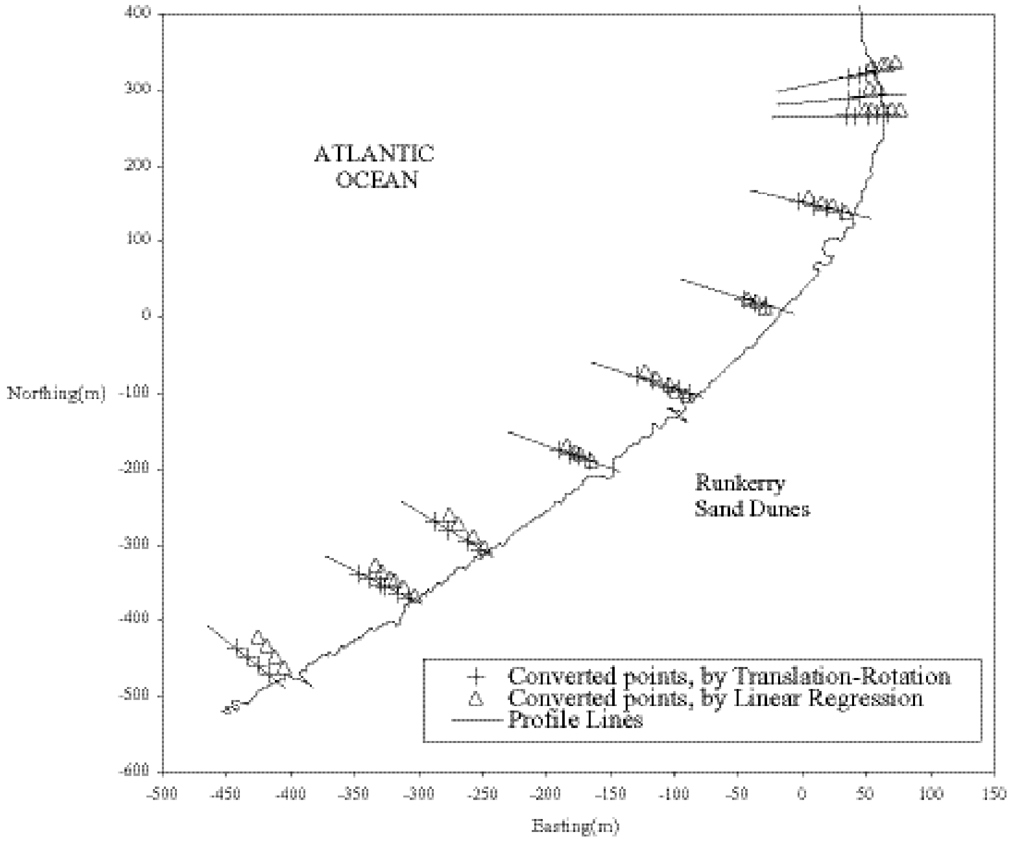

Figure 1. The location of the beach profiles, with the shoreline represented by the 'dune-toe' line. The comparison of converted points using the Translation-Rotation method and Linear Regression method is also shown. Profile points data were obtained on 10 Jan.2001. The coordinate system used is the local GPS coordinate system created for this project, with the Magnetic North represented with Y-axis and the perpendicular direction (East) as X-axis.

everyday for two durations lasting 2 weeks and 4 weeks respectively, for each of the 10 beach profiles. A total of 72 batches of the profile and topographical data have been obtained.

GPS and Total Station Overview

GPS is a satellite-based positioning system, developed by the U.S. Department of Defence. It provides continuous, worldwide, all-weather navigation primarily for military users. Its basic positioning principle is equivalent to triangulation with satellites as ranging sources (MORTON *et al*., 1993, HOFMANN-WELLENHOF *et al.*, 1997). The accuracy of the GPS surveying varies with the positioning techniques used. GPS navigation equipment makes use of the pseudo-ranges to calculate a GPS antenna's position to an accuracy of 30-100 meters (MORTON *et al*., 1993). The Standard Positioning Service provides a predicable accuracy of 100m (2rmd, 95%) in the horizontal plane and 156m (95%) in the vertical plane (KAPLAN, 1996). Using differential corrections with two GPS receivers employed, one at a known point, typically the corrected coordinates are accurate in the 1-5 meter range. Using Kinematic or phase differential processing techniques, the data from two GPS receivers is processed simultaneously to produce cm-level position accuracy. Using both the Real Time Kinetic technique (RTK) and radio-modem technology produces the exact coordinates of the points a rover receiver occupies (TrimMap User's Manual).

A total station or EDM (electronic distance measurement) is an electronic instrument for measuring points in 3-dimensional space. Using a sophisticated angle measuring component and laser beam emitting and mirror reflecting procedures, it determines the position of a target via its azimuth from a basic direction and the measured distance from the measuring point. Its accuracy can be in the range of X mm + Y ppm * Distance (X and Y less than 10) for the distance measurement and several seconds for the angle measurement.

GPS surveying is quite different from using total station in one key area of operation. Because the Kinematic survey technique joints the jobs of observing and occupying a point, the whole survey operation takes place at the roving unit. This means that there is no need for a person to be at the reference point. Both members of the field crew can occupy and observe traverse points (TrimMap User's Manual).

The GPS set used in the fieldwork of this project is a product of Trimble Navigation Limited. The receiver type is a 4400 series, with the function of RTK and OTF (On-The-Fly, a technique to provide initialization while the receiver is moving). To maintain initialization, the receiver must take a minimum of 4 satellites at all times throughout the survey. The typical precision of an initialised Kinematic survey is 1cm + 2ppm (1 standard deviation). The software for the GPS data processing is TrimMap Base 6.50.

The total station (EDM) used is supplied by Sokkia, typed SET4A. Its telescope resolving power is 3 seconds, with the horizontal and vertical accuracy of 5 seconds for the angle measurement. For the distance measurement the accuracy is +/- (5mm+3ppm*Distance).

Surveying control (planar and vertical)

To conduct GPS surveying on the beach, a GPS coordinate origin was established on the dune at the back (landwards) of the beach, to establish a local coordinate system. It was positioned at the top and center point of a concrete post and set out before for previous beach monitoring work. The location is at a central part of the working area to get proper surveying control of the beach range. When a survey is conducted, the GPS antenna plate is oriented to the Magnetic North by a compass with a sensitive magnetic needle. The three axes of this local system are, Magnetic North as Y, its planar perpendicular direction to the East as X, and the height in the vertical direction from the origin point as Z. Using the option "here" in the Data Collector of the GPS receiver 4400, the WGS84 geodesic coordinates for the origin point was taken, and then was input into the Data Collector as the reference point afterwards in each batch of surveying. The coordinates of some or all the profile posts (control points) were measured repeatedly with different batches of GPS surveying to examine the repeatability of the accuracy.

The output of the GPS surveying is the GPS vector from the origin point to the surveyed point. Because the purpose of a survey is to obtain repeated beach profile data in a time series, it is reasonable to use such an independent local GPS coordinate system to conduct the surveying.

For the purpose of monitoring local beach variation, 10 profiles were set out along Runkerry strand, with roughly equal distances between every two profiles. However, the intervals are smaller among the 3 profiles with rather active morphodynamic features in the north segment of the beach. To set a profile, two posts were positioned on the dune at the back of the beach to line up a profile transect. The distance between the two posts varied according to the local terrain of the site, from 5 to 20 meters.

Because of unavailability of the GPS equipment on occasions, a total station (EDM) was deployed for 4 batches of the survey to obtain continuous beach profile data points in the monthly time series. When the EDM was employed, a compass was used for the orientation of the instrument to the Magnetic North as a basic direction. The instrument was set at a spot on the upper part of the beach with underlying cobbles exposed to the air. Its field of view covered the entire surveying area of the beach. The measuring point is an arbitrary base for the surveying, so a coordinate conversion is required afterwards to convert the whole data into the local GPS coordinate system in order to make it possible for the data from different batches of survey jobs to be compared. For this reason, when an EDM survey was conducted, the positions of several profile posts as control points were measured for calculation of the converting parameters.

Profile surveying

When conducting a GPS survey for beach profiles, two ranging rods were installed at two profile posts on the dune respectively, in order to line up the profile for the surveyor. The GPS rover receiver was carried by the surveyor, with the GPS antenna on the top of the surveying pole. The surveyor then walked along the profile that was delineated by the two ranging rods, from the beach-water edge to the beach-vegetation edge, in order to get GPS positioning data for points along the profile. The interval of the points varied according to the slope and planeness of the beach, but normally came to one or more meters.

Alternatively, fixing the GPS receiver unit onto a quad motor bike also generates a profile. When the quad is driven on the beach, the topographical data are collected using the Data Collector's function of "continue", but this might be with lower accuracy than using the pole and surveying by walk. However, this does save on surveying time with a larger area of surveying zone being measured, particularly important in capturing information on the exposed subaerial beach before tidal inundation occurs.

Processing the controlling data and surveying data

To compare the profile data obtained in different batches of surveying, it is essential to put all the data into the same coordinate system. In this project it is converted to the GPS local coordinate system mentioned above. In the following discussion, this GPS local coordinate system is abbreviated as 'LOC-system' with any of the arbitrarily based coordinate system is referred to as 'T-system.'

In the LOC-system, the positions of the posts for the 10 profiles were measured many times as the profile surveys were conducted. The 20 posts acted both as references with which to line up each profile and as control points for the calculation for the coordinate conversion.

To convert the data from the T-system to LOC-system, both translation and rotation are needed. The compass of the EDM used is not so fine as the one with GPS instrument, when lining to the Magnetic North with the compass in the EDM, obviously there was some error, leading to a rotation of the T-system from the LOC-system.

To find the parameters of translation for a batch's survey, the coordinates of the origin of LOC-system measured in T-system in the same batch of survey are used for the calculation. While in some batch's of surveys with an arbitrary origin for a T-system, the origin point of LOC-system was not measured. If this is the case it is necessary to calculate the origin point of the LOC-system in the T-system (or the origin point of T-system in the LOC-system) to achieve the conversion parameters. To find the position, three control points (posts) are taken as a group, to calculate the translation parameters. Taking a group of control points Pi (i=1,2,3), the coordinates of these in the LOC-system and in the T-system are (Xi,Yi) and (Xi',Yi') respectively, the distances from the origin point O to Pi are Ri, where Ri is the square root of (Xi2+Yi2), (i=1,2,3), then three equations can be listed as:

$$(X-Xi')_2 + (Y-Yi')_2 = Ri_2 \quad (i=1,2,3) \qquad \textbf{(1)}$$

Theoretically, the solution for the above equations should be a single point, but practically, because measuring errors exist, three points rather than one can be yielded from the equations (usually they are rather close to each other). The treatment applied in this work is the average of these 3 points which is taken as the final result for the combination. Solved from each of the possible combinations of any three points, the result points will probably be different from each other because of the measuring errors. The average of these points is found and was set as a circle's center, and a threshold is selected as the radius for removing all the points outside the circle. The average value of coordinates of the points within this circle are calculated and taken as the final solution point (X_0,Y_0). For example, when in a survey batch the coordinate of 17 posts (control points) were measured in the T-system, the final solution point is calculated from a set of points yielded by every possible kind of combination of the 3 elements from 17, i.e. 560 groups of the 3-points.

As for the rotation parameter, assume Pi is one of the post numbered i (i=1,2 … 20), (Xi, Yi) are the coordinates of Pi in LOC-system and (Xi',Yi') are the coordinates of Pi in T-system, then the rotation angle of the T-system to the LOC-system, here referred to as θ, is:

$$\theta = \tan^{-1}(Yi/Xi) - \tan^{-1}((Yi'-Y_0)/(Xi'-X_0))$$

so the conversion formula is:

$$X_L = (X_T - X_0) * \cos\theta - (Y_T - Y_0) * \sin\theta$$
$$Y_L = (X_T - X_0) * \sin\theta + (Y_T - Y_0) * \cos\theta \qquad \textbf{(2)}$$

where (X_T,Y_T) are the coordinates of a point in the T-system and (X_L,Y_L) are the corresponding coordinates in the LOC-system, (X_0,Y_0) are the coordinates of the origin of the LOC-system in the T-system.

There is another method to find the relationship between the coordinates of the LOC-system and the T-system, namely the least square method of the linear regression. The measured coordinates of the control points in T-system can be taken to establish a linear regression relation against their corresponding positions in the LOC-system, that is, X, Y and Z coordinate, respectively.

To plot overlapped beach profile curves for all batches of surveying data of a profile, a Distance-Height graph is created using MS-Excel programme. A threshold of distance was given for selecting the points into the "profile points set" for a profile. A point from the survey with a distance to the profile line less than the threshold is counted into the set for the profile. Then the distance from the point to the seaward post of the profile (as the starting point of this profile) is calculated and this segment of line is projected to the profile line. The length of this is the value of the abscissa in the graph and the height value is plotted against the ordinate axis. The points of the set will not belong exactly to the defined profile line because it is near impossible to achieve this in field conditions. This is the reason for using the "threshold and point selecting on" method presented here.

RESULTS AND DISCUSSION

Accuracy of the GPS (RTK)

An initialised kinematic phase differential survey typically provides a precision of 1cm + 2ppm (1 standard deviation). This was verified using 70 batches of the GPS (RTK) survey data of this project. GPS vector records in the Data Collecting file contain the horizontal and vertical precision information, this makes it possible to pick out and examine each record in the data set for the accuracy. All of the records were examined, and those with lower qualities (prompted by the data processing software, TrimMap Base 6.5) were rejected from the data series for further treatment. Subsequently, it is found that among over 80000 points, the average values of the horizontal and vertical precision is 0.97 cm and 1.53 cm respectively (1 standard deviation). In the working site, these results fit quite well with the accuracy claimed by the manufacture. The extreme values were 5.6 cm and 6.6 cm (1 standard deviation) for the horizontal and vertical dimension respectively.

Repeatability of GPS (RTK) surveying accuracy

During some of the surveying, the control points (posts for profiles) were measured. The coordinate data of all the posts for two batches of surveys are listed in Table 1, from which some features of the accuracy and repeatability of GPS surveying in the local area are demonstrated.

The maximum deviation in absolute value is 0.103m, 0.072m, and 0.019m for X, Y and Z direction respectively. After correction (see the note for Tab.1), the figures should be in a smaller range. From the data listed, for the local survey practice, the GPS (RTK) technique provided an accuracy better than 10 cm in X-Y plane and 2cm in Z direction. For beach variation studies, this quality is quite good for monitoring the beach variation in long time period especially in Z (height) direction which is much concerned by researchers.

Theoretically, the GPS (RTK) technique provides a positioning accuracy better in X-Ydirection than in vertical direction. In the field at Runkerry beach, this quality has been shown in every single batch of surveys, commonly better than 1 cm in X-Y direction and 2 cm in vertical direction. In Tab.1, the relatively large quantity of the maximum horizontal deviation for the two batches of survey over a time interval of longer than a year could be due to several factors. Besides the explanation of the note for Tab.1, there may be other influences. The wooden posts might be subject to artificial movements by human interference at the site, although this is unlikely as the post is quite securely fixed into the ground. The antenna pole was fitted with a flat foot section rather than a tipped end to take a more accurate point position, maintaining horizontal position. Some deviation within the GPS satellites' system

Table 1. Coordinates of the profile-posts (control points) in the local GPS coordinate system, Runkerry Beach, by surveying conducted on the 7th April 2000 and 4th July 2001 (units in metres). Note that all data in the table are raw data from GPS data collector. In the batch of 7th April 2000, the pole of the antenna was put at the edge of the top of a post rather than at the top center of the post which was the practice for all survey batches subsequent, so the data for this batch needed to be corrected by about 4 -5cm maximum in the X-Y plane. The maximum deviation will be reduced after the correction, according to the record in the fieldwork. In the "post" column, the numbers represent the order of the profiles, "L" and "S" means landwards and seawards respectively.

	Batch A (07/04/2000)			Batch B (04/07/2001)						
Post	**X**	**Y**	**Z**	**X**	**Y**	**Z**	**Delta X**	**Delta Y**	**Delta Z**	**Deviation**
P01-L	81.228	333.252	-1.027	81.255	333.314	-1.012	-0.027	-0.0625	-0.015	0.068
P01-S	76.039	331.429	-1.45	76.142	331.434	-1.452	-0.103	-0.005	0.002	0.103
P02-L	89.99	296.739	-0.157	89.98	296.678	-0.165	0.01	0.061	0.008	0.062
P02-S	79.44	295.006	-1.581	79.525	294.996	-1.571	-0.085	0.01	-0.011	0.086
P03-L	86.039	268.767	-0.413	85.971	268.715	-0.418	0.068	0.052	0.005	0.086
P03-S	76.58	268.192	-2.765	76.662	268.183	-2.771	-0.082	0.009	0.006	0.082
P04-L	61.097	127.691	0.373	61.088	127.656	0.365	0.009	0.036	0.008	0.037
P04-S	53.044	130.813	-0.876	53.081	130.757	-0.874	-0.037	0.057	-0.002	0.068
P05-L	0	0	0	0	0	0	0	0	0	0
P05-S	-6.371	3.201	-0.555	-6.374	3.156	-0.56	0.003	0.045	0.005	0.045
P06-L	-64.199	-114.04	-0.763	-64.196	-114.112	-0.768	-0.004	0.072	0.005	0.072
P06-S	-77.432	-106.787	-2.189	-77.407	-106.794	-2.189	-0.025	0.007	0	0.026
P07-L	-131.248	-209.45	-0.315	-131.164	-209.433	-0.303	-0.084	-0.0175	-0.012	0.086
P07-S	-143.315	-202.382	-2.239	-143.274	-202.349	-2.229	-0.041	-0.033	-0.01	0.053
P08-L	-228.425	-327.274	-0.317	-228.426	-327.238	-0.325	0.001	-0.036	0.008	0.036
P08-S	-241.482	-314.623	-2.535	-241.441	-314.566	-2.538	-0.041	-0.057	0.003	0.07
P09-L	-282.212	-392.751	2.127	-282.195	-392.786	2.138	-0.017	0.035	-0.011	0.039
P09-S	-296.944	-379.948	-1.807	-296.991	-379.902	-1.825	0.047	-0.046	0.018	0.066
P10-L	-399.546	-493.172	-1.221	-399.611	-493.138	-1.24	0.065	-0.034	0.019	0.073
P10-S	-404.14	-487.244	-2.741	-404.095	-487.28	-2.748	-0.045	0.036	0.007	0.058

may occur (KAPLAN, 1996, HOFMANN-WELLENHOF, *et al*., 1997) over particular surveying periods and may therefore, also represent a source of the error. The coordinates of the posts used for the final calculation of profile positions are average values of many batches of surveying so they might vary slightly from those in Table 1.

The performance of the high resolution GPS (RTK) technique results in measurement of even small quantities of the beach level change and therefore enables calculation of sediment volume variation with high accuracy accordingly.

Accuracy of the Total Station (EDM)

To examine the accuracy of the total station (EDM) surveying, the distances from the origin to each post measured by GPS and EDM are calculated respectively and the result are put together for comparison. Table 2 shows the results.

Table 2. Distance of posts to the origin post, measured by GPS and EDM in LOC-system and T-system respectively. (EDM data obtained 10th Jan 2001, GPS data averaged from many batches of the posts' measurement).

Post	Distance to origin by GPS (unit:metres)	Distance to origin by EDM (unit:metres)	Delta
P02-S	305.524	305.45	-0.074
P03-L	282.167	282.15	-0.017
P03-S	278.931	278.873	-0.058
P04-L	141.536	141.546	0.01
P04-S	141.136	141.147	0.011
P05-L	0	0	0
P05-S	7.143	7.138	-0.005
P06-L	130.889	130.952	0.063
P06-S	131.93	131.95	0.02
P07-L	247.161	247.254	0.093
P07-S	247.95	248.046	0.096
P08-L	399.09	399.233	0.143
P08-S	396.599	396.698	0.099
P09-L	483.655	483.765	0.11
P09-S	482.223	482.267	0.044
P10-L	634.7	634.81	0.11
P10-S	632.99	633.095	0.105

The mean of the absolute value of the deviations is 0.062m and the maximum one is 0.143m. Presuming the GPS (RTK) surveying gives a frame of reference for the positions of the posts, and taking account of the GPS's accuracy demonstrated in Tab.1, the EDM surveying result is with an accuracy of the order of magnitude not lower than GPS's. Therefore, the EDM instrument itself also generates high accuracy surveying output.

Threshold and Projection of points to the profile-line

A measured point with the distance to a profile line less than a threshold is included into a set of "profile-points" for the corresponding profile, then the segment of the line connects this point and the starting point of the profile and this is projected to the profile-line. The projection is taken as the abscissa value for this point in a beach profile plot. The benefits of this procedure includes making full use of all the points collected during fieldwork and provides a data set with a strict mathematical basis for further treatment such as the mathematical description of the profiles and the calculation of the volumes of the beach along the profile.

The lower limit for a profile survey is the waters' edge. The level of the water varies with tide, so in a batch of surveys, it is hard to measure the waters' edge for every profile by walking and using the pole. Using a quad will make up for this restriction, obtaining points along the edge of the water as far as possible during low tide. Therefore, the threshold and selecting algorithm also collects the point(s) measured by a quad, however, this is generally lower than the lowest point measured by the pole and walking survey. By doing so, the profile is, if any quad surveyed points are included in the "profile-points" set, stretched further seawards and results in more data point(s) for the profile or volume calculation.

In the data processing, a threshold of 1m was given (down to 0.5m is still reasonable and practicable). With this threshold all the points obtained by a profile survey, as well as some points from the quad survey, were collected into a profile-point set for each profile. Meanwhile, the threshold should not be too large, particularly in the situation where the profile line crosses a wing of a sloped terrain like a cusp. In such cases, any point far from the line will have a rather different height than its "projection" point in the line.

Conversion of the coordinate system

To convert the coordinate data obtained from the surveys with an arbitrary base, a least square method was used and 3 linear regression equations were yielded for each survey batch's data, for the relation of X, Y and Z of the two coordinate systems respectively. The conversion parameters were also calculated for the translation-rotation method, and finally this method was used to conduct the final conversion operation.

In some survey batches, the local GPS origin was measured in the arbitrarily based coordinate system, but in some other batches it was not measured so it was a requirement to calculate the coordinates of that point. To test the algorithm, calculations to find the coordinate of the origin of the T-system in the LOC-system were also conducted for each batch of those data. Table 3 shows the 3 post combinations for the survey batch of 8th February 2001, that yielded solution points that were picked out and rejected from being counted into the point set to get the final average solution. In that particular survey batch, 10 posts were measured as control points. It is apparent that most of those combinations are so called "bad combinations" in a surveying sense, with two points very close and the third one far away, which tends to lead large errors when taken as a positioning base for calculations. In the calculation for the final result, the threshold was adjusted to find a solution with better fitness for the data.

Table 3. Post combinations yielding a point that was rejected from the final origin point calculation, and the corresponding distance to the average solution point. Data from the survey of 8th February 2001.

Post combination	Distance (m)
1. P08-L / P08-S / P09-S	1.992
2. P01-S / P08-L / P08-S	1.466
3. P01-L / P08-L / P08-S	1.476
4. P07-S / P08-L / P08-S	1.438
5. P03-L / P08-L / P08-S	1.447
6. P08-L / P08-S / P10-S	1.409
7. P05-L / P08-L / P08-S	1.308
8. P06-S / P07-S / P08-L	1.163

For other batches of survey data, the combinations of posts for rejected points were similar to those in the Table 3, with the majority of them consisting of two posts from the same profile, representing bad combinations. The calculated translation and rotation parameters are listed in Table 4. The parameters are average values for the final output of the calculation. The data in Table 4 shows that the total station (EDM) has offset angles of 5 to 6 degrees in the fieldwork conducted for this project (the last row were from a GPS survey with an arbitrarily based origin). The EDM surveys were carried out by the same operator in the same site under similar conditions, so the data were obtained using observations with the uniform precision. Therefore, it could be estimated that for such sort of instrument, when oriented to the basic direction via the compass attached in it, the offset angle caused by the poor accuracy of the compass for orientation operation is in an order of magnitude of 5 to 6 degrees. This estimation would be beneficial to the estimation of error in any survey data yielded by the same type of the instrument. On the other hand, the offset contains the component of deviation of two coordinate systems on the surface of an ellipsoid.

The accuracy of the conversion is also demonstrated in Table 4. The maximum of the deviation between the calculated and the measured point is about 0.04m. The quantity of the deviation is indicative of the efficiency of the algorithm for the conversion calculation, while also reflecting the measuring errors of both GPS and total station (EDM) surveying. Meanwhile, it can be seen from the offset angles that the GPS instrument has a better orientation compass set than the total station (EDM).

Comparison of the conversion methods

Fig.1 shows the profile lines and the effects of conversion from the arbitrarily based coordinate into the GPS local coordinate system, for the same batch of data of Runkerry beach. Tab 5 gives a comparison of the posts' coordinates converted by linear regression and the translation-rotation method.

Table 4. GPS local coordinate LOC-system: the origin points in and the rotation angles to the arbitrarily based coordinate system T-system (units: Coordinate in metres; Degree: DD-MM-SS).

Survey Batch	Rotation Angle	X (calculated)	Y (calculated)	X (measured)	Y (measured)	Delta X	Delta Y	Distance
10.01.2001	-6-26-19.84	-99.3168	-340.6491	-99.318	-340.612	0.001	-0.037	0.037
11.01.2001	-5-55-27.76	120.8908	112.7745					
08.02.2001	-5-37-02.39	-92.0849	-341.7485	-92.049	-341.728	-0.036	-0.02	0.041
09.02.2001	-5-35-13.55	- 92.0324	-341.7383	-92.019	-341.758	-0.013	0.02	0.024
10.05.2001	-0-00-12.82	-75.8406	-362.8393	-75.814	-362.806	-0.027	-0.033	0.043

Table 5. Comparison of the two conversion methods by converting control point data of Runkerry beach obtained on 10th Jan 2001. The last column relates to the discussion of the height conversion.

	By Translation and Rotation			**By linear Regression**			
Post	**Delta X**	**Delta Y**	**Point Deviation**	**Delta X**	**Delta Y**	**Point Deviation**	**Delta Z**
P02-S	0.076	-0.098	0.124	10.685	7.143	12.853	0.028
P03-L	0.085	-0.046	0.097	7.203	4.44	8.461	0.018
P03-S	0.089	-0.086	0.124	8.55	5.493	10.162	0.021
P04-L	0.064	-0.02	0.067	-2.639	-3.07	4.048	-0.008
P04-S	0.021	0.003	0.021	-1.176	-1.833	2.178	0.012
P05-L	0	0	0	-5.836	-5.19	7.81	0.04
P05-S	-0.002	-0.019	0.019	-4.583	-4.199	6.216	0.024
P06-L	-0.068	-0.034	0.076	-7.269	-5.971	9.407	0.015
P06-S	-0.065	0.024	0.069	-4.59	-3.76	5.933	-0.004
P07-L	-0.084	-0.057	0.102	-6.445	-5.007	8.161	0.007
P07-S	-0.197	0.023	0.198	-4.049	-2.909	4.986	-0.019
P08-L	-0.277	0.019	0.278	-3.401	-1.923	3.907	0.022
P08-S	-0.18	0.014	0.181	-0.17	0.58	0.604	-0.037
P09-L	-0.289	0.073	0.298	-1.679	-0.25	1.698	-0.064
P09-S	-0.246	0.137	0.282	1.796	2.563	3.13	-0.059
P10-L	-0.28	0.086	0.293	6.202	6.482	8.971	-0.002
P10-S	-0.215	0.043	0.219	7.498	7.421	10.549	-0.017

It is obvious that the translation-rotation method is much better than the linear regression method in conducting the conversion of the data from the arbitrarily based coordinate system to the GPS local coordinate system. In Fig.1, the points converted by the translation-rotation method are all fit very closely to the profile lines. Together with Table 5, there is an indication that a linear model doesn't fit well to describe the two dimensional coordinate rotation relationship among the data, and from the construction of the coordinate conversion formula, this holds true. For other batches of data, the comparisons yield a similar order of magnitude of deviations and the verdict on the methods is the same.

Height conversion

Though the linear model doesn't fit the two dimensional conversion in an X-Y plane, it has quite a good output for the height conversion. In Table 5, the last column shows the conversion results for the height data of the same batch of data in the table, using a linear regression equation. The maximum deviation is about 6 cm, this is acceptable until a better conversion procedure with higher precision is formulated in the future. In all the 72 batches of survey data, those obtained from an arbitrarily based coordinate point are in the minority, causing a rather limited influence on the total data set via the conversion error.

Ideally, a set of three-dimensional conversion models would need to be deployed in order to conduct the conversion. However, the three-dimensional conversion formula involves more parameters and an ill-conditioned system of equations might need to be produced. Owing to the error within the survey data, the solution will probably not be deterministic and the error will propagate within the calculation procedure and result in a considerably larger error in the final result. Attempts at finding a solution for this type of surveying has so far not achieved a better result than by using the two dimensional translation-rotation for X-Y plane plus linear regression for the height conversion.

CONCLUSIONS

The surveying practice in the local area of Runkerry beach demonstrated that the GPS (RTK) surveying technique provides high resolution control surveying and topographical surveying, which enables the detection of beach surface variation to the limits of 1 cm in horizontal and 2 cm in vertical dimension (average precision, 1 standard deviation). Total station (EDM) also demonstrated high accuracy in practice during the work. For the type of the EDM instrument used in this work, there exists a 5 to 6 degrees of offset angle for the orientation and this should be deduced and corrected when the data obtained are processed.

A whole set of methods has been established for the beach profile monitoring for both the fieldwork and the data post-processing. Therein, the projection treatment yields a profile in the strict mathematical sense and provides a way to make full use of the measured points on the beach face. It enables a sound base for further processing and analyzing of the profile characteristics and features, as well as for morphological and sedimentological studies. For the threshold narrowed selecting of points for a beach profile, the terrain and planeness of both sides of the profile line need to be considered for the threshold setting and adjusting.

The translation and rotation treatment has better output for the coordinate conversion in an X-Y plane than the linear regression treatment, but the linear regression method is suitable for the height conversion. This method is significant when two or more sets of data with different plane coordinate system need to be merged together into one coordinate system for further processing. Three-dimensional conversion should have better accuracy but because of the error induced in the actual surveying and the sensitivity of the formula to the error, no better output has been yielded by this means for the conversion of the collected data of this project. In coastal and beach research, the two-dimensional translation and rotation for X-Y data plus the linear regression method for the height data is suggested when a conversion is required.

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