Geographical Positioning Using Laser Optical Instrument for Near-Shore Underwater Archaeological Explorations

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Abstract

Underwater archaeological explorations, which are being carried out both in shallow as well as in deep waters, need accurate positioning system for locating any artifacts and to plot on suitable scales. Even though surveying has a well establish procedure, but being underwater, it has it's own difficulty. Several conventional methods and instruments are available for obtaining underwater positions in shallow water areas. The main objective of this paper is to introducing a new technique of measuring angles and distances using laser optical instrument from the shore to obtain accurate underwater positions. The prescribed method can be applied effectively for all shallow water archaeological surveys. Under calm sea condition this method can be applied up to a water depth of 10 meters and with a coverage limit of about 5 to 6 kms from the shore, under calm sea conditions.

Introduction

Underwater archaeological explorations, which are being carried out in shallow as well deep waters, need accurate positioning system for locating the artifacts and to plot them on suitable scales. Ever since archaeological investigations started, the maritime archaeologists and surveyors have been using several gadgets and techniques for re-creating the layout plan of the site, which must be a true representation of the actual site. Even though surveying as such has well establish procedures, but being underwater, it is difficult adding an extra level of complication. Integration of DGPS (Differential Global Positioning System) and acoustic positioning can be more accurate and desirable for deep water archaeological explorations, but when it comes to near shore surveys, it is not economical due to huge initial cost of the acoustic transponders and loss of time for calibration. One of the limitations of the acoustic systems is that calibration of the instrument has to be frequently repeated (Pathak, et al., 1990).

Several conventional methods and instruments are available for obtaining positions of the artifact discovered on the seabed. But under poor visibility conditions, the diver archaeologists find severe hardship in using underwater compass and tapes for measuring angles and distances between corners of artifact. The present method almost eliminates the usage of underwater compass and tape measurements, especially wherever distance between the corners of any artifact is quite a large and the measurements are reduced to a bare minimum like noting down small minute features of the artifacts.

Paper deals with a method of obtaining geographical positions for underwater artifacts using Laser optical instrument, operated from the shore, especially for near-shore archaeological surveys. A programme namely " Conversion of Laser Track field data for obtaining final Geographical / UTM co-ordinates" written in a user-friendly GWBASIC language is developed for processing the collected field data. This programme enables the marine archaeologists to process their field measurements much easier than the manual method of plotting the corners of the artifacts, which were often on plain rectangular co-ordinates. As the final maps are prepared in geographical grid, they can be directly superimposed on hydrographic charts of the same scale. This gives a quick idea about the location and the topographical features of the survey area for further studies. The prescribed method using Trimble DGPS (for fixing ground control locations on the shore) and Laser Trak optical instrument (placed over ground control locations) with a multiprism (placed over carefully identified corners of the underwater artifacts) is found to be more accurate, faster, and reliable. This method can be effectively used only for shallow water near shore underwater archaeo-

Glimpses of Marine Archaeology in India,
Edited by A. S. Gaur & K. H. Vora,
Published by *Society for Marine Archaeology,* 2006

logical surveys. This paper highlights the technical aspects involved, method of survey with instruments used, and the listing of the indigenous software developed by the author to process the field data.

Methodology and Instruments used

As a first step, calibration of all the survey instruments has to be carried out before commencing the survey, to eliminate all types of error, if any, from the instrument. Subsequently, ground control stations (from where Laser Trak will be operated) should be installed at proper locations along the shore in transit with the underwater exploration site. If the submerged artifact is spread over a large area on the seabed, then more ground control stations may be required to be established. The geographical locations of all ground control stations A, B, C etc. can be very precisely obtained using Trimble DGPS in static mode, which forms the main base line co-ordinates, for underwater surveys. Finally, the field data can be collected systematically using Laser Trak (placed over selected ground control station) and a multi-prism (placed over carefully identified corners of the artifact). The standard survey procedures prescribed in the Laser Trak operation manual (Make III model) were used to carry out the positioning.

The field data consist of the following: I) The uncorrected raw range (D), ii) the horizontal angle (H) (between the ground control points A and B (base line) and the multi-prism placed over carefully identified underwater marks, subtended at the Laser Trak instrument station (A) and iii) the vertical angle (V) (of the underwater mark from the Laser Track station). This field data can be taken to the laboratory, for further processing and to prepare the final maps.

A programme "Conversion of Laser Trak filed data for obtaining final Geographical / UTM co-ordinates" which was individually generated, can be used for obtaining the final corrected geographical positions of the artifact. These final corrected underwater positions can be used for preparation of final charts in geographical as well as in UTM grid using HP Plotter.

Establishing Ground Control Stations

A Trimble make DGPS, Series 4000 receiver can be used for obtaining accurately the geographical co-ordinates (Horizontal control) of the ground control stations (base line stations "A", "B", "C", etc. This instrument performs the precise static surveying and therefore is quite ideal for establishing ground control stations. After setting up the instrument on the base station, it requires observations of at least four satellites for a period of about 60 minutes. There are two types of static surveys: single and dual frequency. Single-frequency static surveys are appropriate for surveys with base lines shorter than about 15 km, under good atmospheric conditions. They yield base lines, that are precise to better than ± 2 cm ± 2 ppm. Dual-frequency static surveys are required to ensure accurate results in geodetic control surveys, with base lines up to 30 km or more under good atmospheric conditions. They yield base lines, that are precise to better than ± 5 mm ± 1 ppm. The observation and simultaneous data logging time, recommended for these surveys is at least 45 minutes, during times when five or more satellites are available, or 60 minutes, during times when only four satellites are available (Ganesan, 2003a)

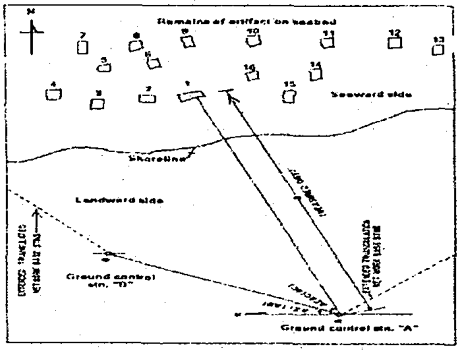

Figure 1. Figure shows the method of obtaining field data using Laser optical instrument (Laser Trake) from ground control station "A".

Collection of Position Data Using Laser Trak

The tripod mounted Laser Trak instrument, located at fixed ground control points, provides fast, accurate and logistically simple positioning of underwater artifact surveys. This instrument can also be used to obtain the position of archaeological survey vessel from a fixed ground control location. Other applications include hydrographic/ archaeological surveying of lakes, rivers and harbours and precise positioning of offshore structures and construction barges. Laser Trak is an electronic instrument which measures distance by timing the passage of a light pulse fired at a target and its return. The angles are measured with help of optical encoders and elevation by electrolytic liquid level sensors and / or optical encoders. Laser Trak has its own integral UHF data telemetry system and has facilities to interface a gyrocompass and computer system directly via cable (Ganesan, 2003b). For standard Class I surveys the range of coverage from the shore is 1500 meters with single prism reflector and 5000 meters with multi-prism reflector. For high power Class III A surveys, the range of coverage from the shore is 2500 meters with single prism reflector and 10,000 meters with multi-prism reflector. The accuracy of this instrument on measured ranges is ± 20 cm for standard Class I surveys and ± 10 cm for high power Class III A surveys.

Limitations

The practical limitations involved in this method are: (i) The condition of the sea should be very calm. It is preferred to carry out the whole operation only at selected good weather conditions. (ii) Minimum two diver archaeologists are required for holding the multi-prism over the corners of any object of interest and one diver archaeologist for providing communication link from the site to the shore through radio communication system. (iii) Vertical rod of sufficient length should be tied to the multi-prism, so that the multi-prism can be sighted well above the water surface, while seeing through Laser Trak, from the shore. (iv) The ground control stations should be established at reasonably high altitudes along the shore, to get a better coverage of the survey area.

Results and Conclusions

The prescribed method totally eliminates the conventional tools like underwater compass and measuring tapes, especially at places where distance between the corners of any artifact is more than 10 meters. This saves lot of time and possible human error due to poor visibility conditions, thereby improving the accuracy of the positions. The measured angles and distances can directly be fed into the developed software namely "*Conversion of Laser Trak field data for obtaining final Geographical / UTM co-ordinates*" to obtain the final geog. / UTM co-ordinates of underwater artifact and the final map can be prepared in any desirable scale. These final maps, being in geographical grid, can be super imposed on hydrographic charts of same area, for correlation and confirmation . As distances and bearings are available from the ground control stations (on shore) to each and every corner of the artifact, re-locating any artifact or underwater structure, after a period of time (even after one or two years) is quite easier and faster.

Acknowledgement

The author is very thankful to Dr. Satish Shetye, Director of National Institute of Oceanography, Goa for his kind permission to publish this Paper. Dr. A.S. Gaur, and Dr. Sila Tripati and Dr. A. Gujar are gratefully acknowledged for going through the manuscript and making valuable suggestions for improvement. The author is also thankful to Mr.M.C. Pathak for his valuable support in preparation of this paper.

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The listing of the software is given below:
(Test field data collected off Hazira coast was used as input))

```
10  DEFDBL A-H
20  DEFDBL J-Z
30  GH$="### ####.## ######.### #######.### ###.##
###.##"
40  PRINT "GEOGRAPHICAL CO-ORDINATES OF TEST
DATA"
50  PRINT
60  PRINT "FIX  H.DIST  EASTING(M)  NORTHING(M)
AZI(DEGS) AZAC(DEGS)"
70  PRINT "GIVE INPUT FILE NAME":INPUT INFILE$
80  REM THE ENCLOSED SAMPLE INPUT FILE FOR THIS
LAND SURVEY IS "TEST.INP".
```

```
90 OPEN INFILE$ FOR INPUT AS #1
100 OPEN "TEST.OUT" FOR OUTPUT AS #7
110 PRINT "UNDERWATER POSITIONING SURVEYS NEAR HAZIRA"
120 PRINT #7,"                    "
130 PRINT #7,"FINAL OUTPUT OF THE SURVEYS IN UTM VALUES"
140 PRINT #7,"                    "
150 PRINT #7,"FIX NO. H.DIST EASTING    NORTHING AZI  AZAC"
160 PRINT #7,"         (Mts.) (Mts.)    (Mts.)    (Degrees)"
170 PRINT #7,"------------------------------------------------------------"
180 PRINT #7,"                    "
190 FOR I=1 TO 69
200 INPUT #1,F,H,V,D
210 H=(H+.01)
220 EA= 253294.42# :: NA= 2334245.68#
230 EB= 253923.51# :: NB= 2333684.12#
240 P= 3.14159265358#
250 X= 4.848136811095337D-06
260 G= (H*3600)*X
270 J= (V*3600)*X
280 R= (D*COS(J))
290 IF EA > EB GOTO 320
300 ED= (EB-EA)
310 GOTO 330
320 ED= (EA-EB)
330 IF NA > NB GOTO 360
340 ND= (NB-NA)
350 GOTO 370
360 ND= (NA-NB)
370 LET N= (ED/ND)
380 A= ATN(N)
390 AZI= (180/P)*A
400 IF NB > NA AND EB > EA GOTO 450
410 IF NB < NA AND EB > EA GOTO 470
420 IF NB < NA AND EB < EA GOTO 490
430 IF NB > NA AND EB < EA GOTO 510
440 GOTO 520
450 AZI= (AZI+0)
460 GOTO 520
470 AZI= (180-AZI)
480 GOTO 520
490 AZI= (180+AZI)
500 GOTO 520
510 AZI= (360-AZI)
520 AZ= ((AZI+H)*3600)*X
530 AZAC= (180/P)*AZ
540 E3= R*SIN(AZ)
550 N3= R*COS(AZ)
560 IF AZAC < 0 THEN AZAC= (360+AZAC)
570 EC= (EA+E3)
580 NC= (NA+N3)
590 IF AZAC > 360 THEN AZAC= (AZAC-360)
600 PRINT USING GH$;F,R,EC,NC,AZI,AZAC
610 PRINT
620 PRINT #7,USING GH$;F,R,EC,NC,AZI,AZAC
630 NEXT I
640 PRINT "------------------------------------------------------------"
650 PRINT "END OF DATA.    "
660 END
```

DEFINITION OF SYMBOLS USED

In the above program,

"F" denotes the Identification number (identification number of every mark over underwater artifact, which may include shore line also).

"H" denotes the Horizontal angle (between baseline co-ordinates A, B and the underwater mark) subtended at Laser Trak station "A".

1,8.48,0.12,706.85
2,8.63,0.10,693.25
3,9.03,0.06,677.10
4,9.65,0.10,662.75
5,9.61,0.08,651.90
6,9.80,0.09,641.60
7,9.18,0.05,618.90
8,10.11,0.10,610.55
9,10.49,0.10,597.40

"V" denotes the Vertical angle (subtended at the Laser Trak instrument station "A" between horizontal plane to underwater mark)

"D" denotes the raw range (from the Laser Track instrument to the underwater mark.

"R" denotes the corrected horizontal distance from instrument station to underwater mark.

"AZI" denotes the Azimuth AB (Inclination of the base line at point A, measured always Clockwise from true north. from 000 degree. to 360 degrees.)

"AZAC" denotes the Azimuth AC (Inclination of AC at point (Station)" A" towards "C"

(which is the underwater mark) from true north 000 degree. to 360 degrees. clockwise.

"EA" denotes the Easting co-ordinates of A (obtained using DGPS inst.)

"NA" denotes the Northing co-ordinates of A (obtained using DGPS inst.)

"EB" denotes the Easting co-ordinates of B (obtained using DGPS inst.)

"NB" denotes the Northing co-ordinates of B (obtained using DGPS inst.)

"EC" denotes the Easting co-ordinates of Point C (final corrected Easting co-ordinates of the underwater mark obtained through the above program)

"NC" denotes the Northing co-ordinates of Point C (final corrected Northing co-ordinates of of the underwater mark obtained through the above program)

INPUT DATA

The order of sequence follows as given below: (Identification number (Fix No.) of the underwater target, Horizontal angle from instrument station to the target, Vertical angle from the instrument station to the target and Slant distance from the instrument station to the target).

10,10.60,0.12,593.00

(Fixes from 11 to 64 are omitted for want of space)

65,326.14,0.11,222.00

66,326.31,0.11,231.30

67,331.60,0.09,255.75

68,336.86,0.10,286.75

69,340.81,0.11,314.55

FINAL OUTPUT

The final output file (after conversion using the above program) is given below :

(F,R,EC,NC,AZI,AZAC)

FINAL OUTPUT OF THE SURVEYS IN UTM VALUES

FIX NO.	H.DIST (Mts.)	EASTING (Mts.)	NORTHING (Mts.)	AZI (Degrees)	AZAC
1	706.85	253746.465	2333702.274	131.75	140.24
2	693.25	253736.371	2333711.570	131.75	140.39
3	677.10	253722.423	2333721.011	131.75	140.79
4	662.75	253707.771	2333727.628	131.75	141.41
5	651.90	253701.359	2333736.393	131.75	141.37
6	641.60	253693.265	2333743.114	131.75	141.56
7	618.90	253684.378	2333765.087	131.75	140.94
8	610.55	253671.370	2333765.390	131.75	141.87
9	597.40	253660.126	2333773.298	131.75	142.25
10	593.00	253656.532	2333776.082	131.75	142.36
(Fixes 11 to 64 omitted for want of space)					
65	222.00	253514.311	2334215.153	131.75	97.90
66	231.30	253523.427	2334213.194	131.75	98.07
67	255.75	253543.244	2334186.567	131.75	103.36
68	286.75	253566.154	2334154.106	131.75	108.62
69	314.55	253584.870	2334124.933	131.75	112.57

End of Data.