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Measurement errors in participatory GIS: role of individual workers

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The internet, with high resolution images from 'Google Earth', has facilitated detailed earth observations by common man/indigenous societies. This study analyses human errors in elementary steps of map preparation and compares different workers doing similar work. The objectives of the study are to determine variation in observations (point and length) made by an individual at different scales of working, and to determine user-dependent variations in mapping and measurement of the same task (multiple users). A common set of methodology was adopted by different students to accomplish a similar procedure. The role of scale (size of object) on observations was minimal to affect an individual's ability in determining the precise location of a point. Individual workers may contribute significant errors in the Geographical Information System (GIS) work, where multi-user task is assigned to complete a project. In participatory GIS, additional support by the leader/supervisor to the workers may produce better results with higher accuracy.

Keywords: Geographical Information System, map preparation, measurement error, multiple users.

REPRESENTATION by mapping an earth feature acts as a vital information tool for the development of human society. The internet has opened new horizons for the common man. Free services like 'Google Earth'[1], with high resolution images, has facilitated detailed earth observations and creation of maps for various purposes by different stakeholders to generate information which otherwise does not exist or is expensive to develop (e.g. detailed city map, small patches of vegetation in surrounding, land parcels, etc.). Certain limitation does exist (images are only of recent time, all the areas are not covered, information on time and season not available, etc.). High resolution images in Google Earth provide an opportunity to create maps on participatory Geographical Information System (GIS) by common people/indigenous societies/ citizens, which invites consequences of data integration and multiplication of errors during the process. The word 'error' includes not only 'mistakes' or 'faults', but also statistical concept of error[2], i.e. 'variation'. Similarly, in professional GIS it has been realized that geographical data are not of homogenous quality, and may have errors and uncertainty that need to be recognized and addressed accurately[3-5].

Visual methods of map interpretation include formation of various shapes (different boundaries) by interpreting maps. This process requires determining a point location to initiate line drawing and judgement to realize a boundary to be marked as a line. However, various image/map-related factors (which remain the same for all workers using that map) contribute in this judgement, which is also influenced by one's own ability to determine the location and control the precise movement of his/her hand. Thus we hypothesize that the scale of observation (distance from the object) may act as a source of error by affecting an individual's ability to determine the precise location of a point and also initiating the creation of a polygon or line during mapping. Hence different users may also act as sources of errors while contributing to the same work. The objectives of the present study are to determine the

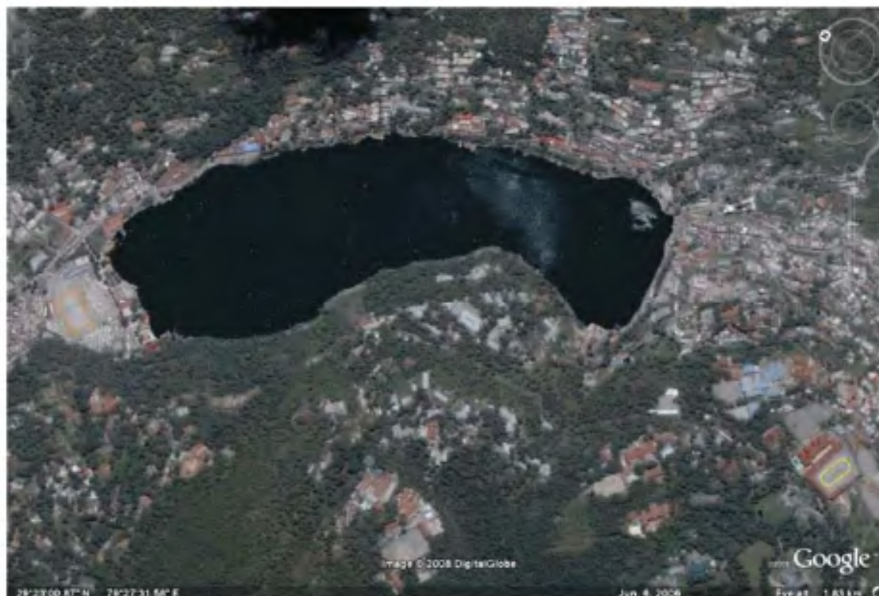*For correspondence. (e-mail: subrats@rediffmail.com)

Figure 1. Snapshot of Nainital town from Google™ Earth showing two polygons created for study. Rectangular orange line is hockey field and semi-circular yellow line is racing track.
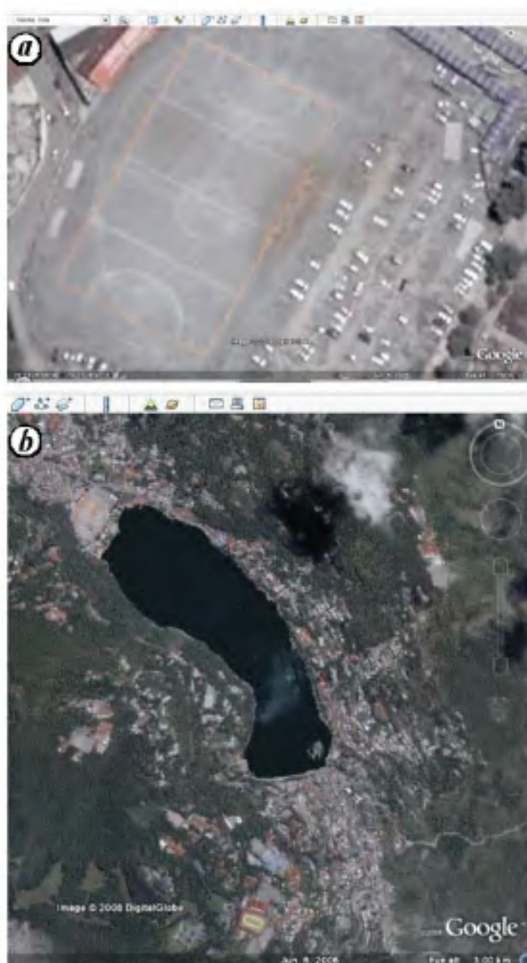

Figure 2. Size of object for measurement at two different scales (as represented by viewing distance of hockey field). *a*, 150 m and *b*, 3000 m.

variation in observations (point and length) made by an individual at different scales of working, and to determine user-dependent variations in mapping and measurement of the same task (multiple users). This study further explores the degree of error between different working scales on (i) X and Y-axis deviations for determining a point location on the map and (ii) measurement of length, and also similarity/dissimilarity between the observations of different workers.

All the variables which may affect the recording procedure of observations (visibility and resolution of a screen, and computer mouse movement) were made constant using a single computer system (with internet connection) for use by different students. Google Earth software[6] was installed on this computer. The effect of terrain was removed from the Google viewer. Google Earth image of Nainital Town (Figure 1) was used to create polygons of two distinctively visible, man-made boundaries on the flat earth surface, viz. hockey playground and racing track in a school (Figure 1) which were easily identifiable on the image with known shapes. Polygons on these shapes (rectangular and semi-circular) were created by an independent user (author), who had not participated in this exercise. Measurement procedure for each polygon was standardized using 'properties' option for polygon, keeping tilt as 0.00 to remove viewing-angle distortion. Scale of observation (distance from object) was changed using 'range' option in the properties of polygon (e.g. 150, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1500, 2000, 2500 and 3000 m, Figure 2). The same procedure was independently followed by each student to record observations.

Table 1. Standard deviation (in second and decimal fraction of a second) in determining a point location by a student at different scales of observation. N and E denote latitudinal and longitudinal directions of a point (1, 2, 3, 4)

Student	Marked points								Unmarked points			
	N1	N2	N3	N4	E1	E2	E3	E4	N1	N2	E1	E2
S	0.02	0.01	0.02	0.01	0.02	0.03	0.02	0.03	0.02	0.09	0.02	0.03
K	0.33	0.32	0.35	0.35	0.04	0.05	0.06	0.05	0.34	0.32	0.02	0.04
M	0.02	0.03	0.06	0.06	0.05	0.05	0.08	0.05	1.82	0.39	2.94	0.23
N	0.03	0.02	0.05	0.02	0.05	0.02	0.04	0.04	0.02	0.04	0.08	0.08
An	0.02	0.07	0.02	0.04	0.07	0.06	0.03	0.04	0.03	0.04	0.03	0.09
A	0.02	0.04	0.04	0.02	0.04	0.03	0.03	0.04	0.09	0.05	0.07	0.05

Table 2. Difference in determining the same point location by various workers

Student	Marked points				Unmarked points			
	N		E		N		E	
	Avg.	SD	Avg.	SD	Avg.	SD	Avg.	SD
S	0.02	0.01	0.03	0.01	0.06	0.05	0.03	0.01
K	0.34	0.02	0.05	0.01	0.33	0.01	0.03	0.01
M	0.04	0.02	0.06	0.02	1.11	1.01	1.59	1.92
N	0.03	0.01	0.04	0.01	0.03	0.01	0.08	0.00
An	0.04	0.02	0.05	0.02	0.04	0.01	0.06	0.04
A	0.03	0.01	0.04	0.01	0.07	0.03	0.06	0.01

Values in second decimal. Avg, Average; SD, Standard deviation.

To realize an individual's ability to determine a 'point location' on the map, two approaches were adopted to record X and Y variations in the measurements of different users. In the first approach, students were asked to measure latitude (North, Y-axis) and longitude (East, X-axis) of four corners (identified points) of the demarcated polygon of the Hockey playground (hereafter hockey field, Figure 2 a). In the second approach, students were asked to measure two junction points of a distinct white line (not marked by author during observations) crossing the race track in the middle.

For marking distance on the map, students were asked to measure the length of (i) the line drawn by the author (polygon created), and (ii) two visible line objects in the image (but not drawn by the author) – centre line of the hockey field and a white line crossing the race track (same line which was used for measurement of points). Line measurements were done using tools of Google Earth – 'ruler' and 'line' option. For marked lines, each arm of the rectangular polygon was measured at the same time when four corner points were recorded for latitude and longitude, and semi-circular path of racing track was measured without providing a fixed point to initiate measurement. For length measurements of unmarked objects, students were asked to measure the length of the centre line of the hockey field, and the length of the line between junction points crossing the race track in the middle of the field. Students were also compared with each other for statistical similarity/dissimilarity for each observation. Various observations were subject to different statistical analysis (deviation from mean value, Student's t-test)[7] using the data analysis tool pack of Microsoft Office EXCEL spreadsheet.

Analysis of the recorded observations by various workers is presented here.

Variations in determining a point location (either marked or unmarked) by each student at different working scales are given in Table 1. Judgement by a person to realize and repeat a marked point location on the map remains individually the same at all working scales as reflected by the consistency in the quantum of an individual Student's error (deviation in X and Y directions) for different points, but varies considerably between students (Table 1).

Recorded observations for each marked point (corners of the hockey field) by each individual at different scales (150–3000 m) showed small variation (in decimals of each second, 1 second = 100 decimal points) by most of the students (Table 1). Deviation from observation point was more in the Y direction (0.01–0.35″) than in the X direction (0.02–0.08″).

Decision to locate a point which is not marked on the map showed mix of individual's capability between the students, but was not better than the case of taking measurements on marked points. Interestingly, during spotting of an unmarked location, the error contributed by left–right directional movement of the hand (determining factor for the X deviation of a point location) was much

Table 3. Probability of recording statistically similar values (*t*-test) by a pair of students for a point location

Pair of students	N				E			
	N1	N2	N3	N4	E1	E2	E3	E4
Marked points								
SM	Similar	Similar	Similar	0.05	<0.01	Similar	Similar	Similar
SK	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
SN	Similar	Similar	Similar	<0.05	<0.05	<0.01	0.05	<0.05
SAn	<0.01	Similar	Similar	<0.01	<0.01	<0.01	<0.01	<0.01
SA	Similar	Similar	0.01	Similar	0.01	<0.01	<0.01	<0.01
MK	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MN	Similar	Similar	Similar	Similar	Similar	Similar	Similar	<0.01
MAn	<0.05	Similar	Similar	Similar	Similar	<0.05	<0.01	<0.01
MA	Similar	Similar	Similar	<0.05	Similar	<0.01	<0.01	<0.01
KN	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
KAn	<0.01	<0.01	<0.01	<0.01	<0.01	Similar	<0.05	<0.05
KA	<0.01	<0.01	<0.01	<0.01	<0.01	Similar	<0.05	Similar
NAn	Similar	Similar	Similar	Similar	0.01	Similar	<0.01	Similar
NA	Similar	Similar	Similar	0.01	Similar	<0.01	<0.01	<0.01
AnA	<0.01	Similar	Similar	<0.01	<0.01	Similar	Similar	<0.05
Unmarked points								
SM	<0.01	Similar		Similar	0.01			
SK	<0.01	<0.01		<0.05	Similar			
SN	Similar	Similar		Similar	Similar			
SAn	0.05	Similar		Similar	Similar			
SA	Similar	Similar		<0.01	<0.05			
MK	<0.05	Similar		Similar	<0.01			
MN	0.01	Similar		Similar	<0.05			
MAn	0.01	<0.05		Similar	<0.05			
MA	<0.01	<0.05		Similar	<0.05			
KN	<0.01	Similar		Similar	<0.01			
KAn	<0.01	<0.01		Similar	Similar			
KA	<0.01	<0.01		<0.05	0.05			
NAn	Similar	<0.05		Similar	Similar			
NA	Similar	<0.05		Similar	Similar			
AnA	Similar	Similar		<0.05	Similar			

Similar, Statistically not different; Confidence level in differences.

higher for most of the students, than the up and down movement of the hand (*Y* deviation).

After determining the null effect of the working scale, an analysis was made to know the quality of work produced by different workers. Average deviations for marked and unmarked points of six locations are presented in Table 2. In the case of marked locations a minimal deviation from the mean value was observed in the *X* and *Y* directions (range 0.0–0.02″) measured by all the students, irrespective to the inbuilt error associated with each student. For measuring an unmarked location, large variations exist between students but more in the east-west direction (*X*-axis). Observations of different students were also compared to realize statistically similar/dissimilar values of a point during measurement of the same locations (Table 3). This analysis indicates that there is high chance (62% dissimilarity) of recording different values in both north and east direction by different students, while taking reading of the same point if marked on the map. However, this reduced to 48% while recording

an unmarked point. These observations suggest that an individual's handling capability may also vary by taking judgement at different points while interpreting a map, and trying to be more accurate may yield more errors (trying to match location of a marked point, the first case). Thus it can be concluded that individual workers may contribute significant errors in GIS work where multi-user task is assigned to complete a project, while working scale has minimal role.

Variations in length/distance measurement of marked features (four straight lines of the hockey field and semi-circular path of the race track) and unmarked features (two straight visible lines) measured by each student at different working scales are given in Table 4.

Similar to the result of marked points, repeat measurements taken by individual students at different scales of observations (reducing size of object from viewing distance of 150 to 3000 m) yielded not much variation in the length measurement, and in most of the cases remained less than 2.5 m. Between students variation in length

Table 4. Error in measurements by various workers in determining various shapes as described in Figure 1

| | Standard deviation in measurement of rectangular shape | | | | | | | |
| | Width (m) | | | | Length (m) | | | |
Student	A	B	Avg.	SD	C	D	Avg.	SD
S	0.32	0.83	0.58	0.36	0.79	0.72	0.76	0.05
K	1.27	1.05	1.16	0.16	1.15	1.44	1.30	0.21
M	1.56	1.30	1.43	0.18	2.56	1.63	2.10	0.66
N	0.84	0.94	0.89	0.07	1.05	2.00	1.53	0.67
An	2.48	1.06	1.77	1.00	2.12	1.76	1.94	0.25
A	1.95	1.25	1.60	0.49	2.50	1.11	1.81	0.98

| | Standard deviation in measurement of unmarked but visible lines | | | | Marked circumference |
	Line 1	Line 2	Avg.	SD	Track
S	0.46	0.45	0.46	0.01	0.57
K	0.89	0.86	0.88	0.02	1.19
M	1.40	1.96	1.68	0.40	3.81
N	1.31	2.14	1.73	0.59	7.74
An	1.14	0.54	0.84	0.42	1.91
A	1.52	0.55	1.04	0.69	3.08

measurements was from 0.3 to 2.56 m for marked lines (arms of the rectangular polygon), and from 0.45 to 2.14 m for unmarked lines. The same deviation in measurements of a marked line (at different working scales) contributed to errors ranging from 0.6 to 2.9% of the total length, while for the unmarked lines the same range of deviation resulted in higher error (0.8–6.9% of the total length). It is to be noted that the same values of deviation contributed to errors in different proportions, which was related to the size of the object under observation. The following example elaborates this. For student *S*, deviation values of two unmarked lines were 0.46 and 0.45 m for line 1 and line 2 respectively (Table 4). Error contribution by this student in measuring total length of these lines becomes ±0.8 and ±1.4% due to the difference in the total length of these objects (53 and 31 m respectively). Thus smaller sized objects were more sensitive to higher degree of error during digitization than larger ones used by the same person.

The degree of deviations (error) varied significantly while analysing the same feature by different students (Table 4), and difference between observations may vary up to nearly 13 times for the same object, as reflected by a comparison of the standard deviation between students. While taking an independent decision every individual appears quite different as apparent from a comparison of length measurements of the racing track (without any starting point), where deviation from the mean value for a few students differed widely between their measurements.

Facilities like Google Earth and other web-based GIS have opened new opportunities for developing maps by the common man and in a participatory manner by differ-

ent contributors. However, the working scale is important to realize the actual representation of various boundary lines, it has minimal effect on a worker's ability to be precise in determining a location on the map/image. In participatory GIS, if additional support/training is provided by a leader/supervisor, the workers may produce better results with more accuracy.

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