A Web-based Survey on Digital Elevation Models

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Abstract
In many earth and environmental science applications, DEMs serve as inputs for detailed spatial analyses, such as the determination of the extent of hydrographic networks, and the classification of terrain for suitability assessments such applications, appreciating the spatial accuracy of the DEM and its variability as a function of location can be critical. Accuracy is very important for any application and user should aware the important of DEM errors and accuracy. Present study, a survey on DEMs investigates how much importance DEM users giving for quality assessment and error analysis. The information provided in this document is based on survey responses received since last 6 months. DEM users from various countries, organizations and industries participated in the survey via the World Wide Web (WWW).

Keywords
Digital Elevation Model(DEM), error, quality assessment, Web based survey

I. INTRODUCTION

The DEM is a computer representation of the earth's surface and provides a base data set from which topographic parameters can be digitally generated. The routing of water over a surface is closely tied to surface form (Wood, 1996) and hydrologic features are often extracted from DEM data. DEMs are used to perform cost analyses and viewshed analyses for resource management as well as business applications. Error modeling is a way of providing estimates of the consequences of the quality level in data, and so enables informed judgments by users as to the suitability of the spatial data for specific tasks. Error modeling has been applied to single data types, including raster-based elevation models (Fisher, 1991, 1992; Lee, et al., 1992; Hunter, et al., 1997) soil maps (Fisher, 1991; Goodchild, et al., 1992) and vector shore lines(Goodchild and Hunter,1997), and to multi-variable spatial models(Davis and Keller, 1997). The principal problem in error modeling, however, is making the model reflect a realistic statistical and spatial distribution of the error. The DEM is a model of the elevation surface, and like other models, the data are subject to error. Error is the departure of a measurement from its true value. Often, in geographic analyses that use spatial data we do not know or do not have access to the true value. Our lack of knowledge about the reliability of a measurement's representation of the true value is referred to as uncertainty. DEM errors are elusive and constitute uncertainty. This survey was designed to identify DEM users, and DEM uses, as well as to determine whether DEM users were aware of errors (uncertainty) in the DEM and whether they perceive it as an issue that affects their DEM related applications. The main objective of this survey was to determine: types of source DEM user used? DEM user? What are DEMs being used for? Is DEM error recognized? Is DEM error accounted for? How much effort would DEM users expend to evaluate DEM error?

II. METHODOLOGY

This survey questions were prepared to obtain information from the DEM user community. Many DEM vendors do not distribute information about their customer base, and generating survey participation through DEM vendors could bias the sample. Many readymade DEMs are available via the www, thus the www was deemed the most appropriate vehicle for targeting survey participants. Survey participants were targeted to collect emails from most popular conference proceedings and sent individual mails with survey website.

The website was designed using active server pages (ASP) and it was available for receiving feedbacks from DEM users at URL http://www.earthmetrica.in/demsurvey. Survey participants could answer the survey questions listed in Figure 1 and submitted responses to this author.

III. SURVEY ANALYSIS

Percentages were computed for each survey question and based on the number of responses received for that question. The data were further evaluated to investigate perceptions of DEM users who use certain types of DEMs such as readymade product or self-generated DEMs and those who use DEMs for specific purposes such as terrain modeling, topographic parameter calculation (such as slope, aspect), hydrologic modeling and map visualization.

IV. RESULTS

DEM users from 11 different countries responded to this survey. Participants residing in the India comprised 66% of the response pool. Other participants were from: Canada (4%), Ethiopia (2%), Fiji land (2%) The United Kingdom (2%),

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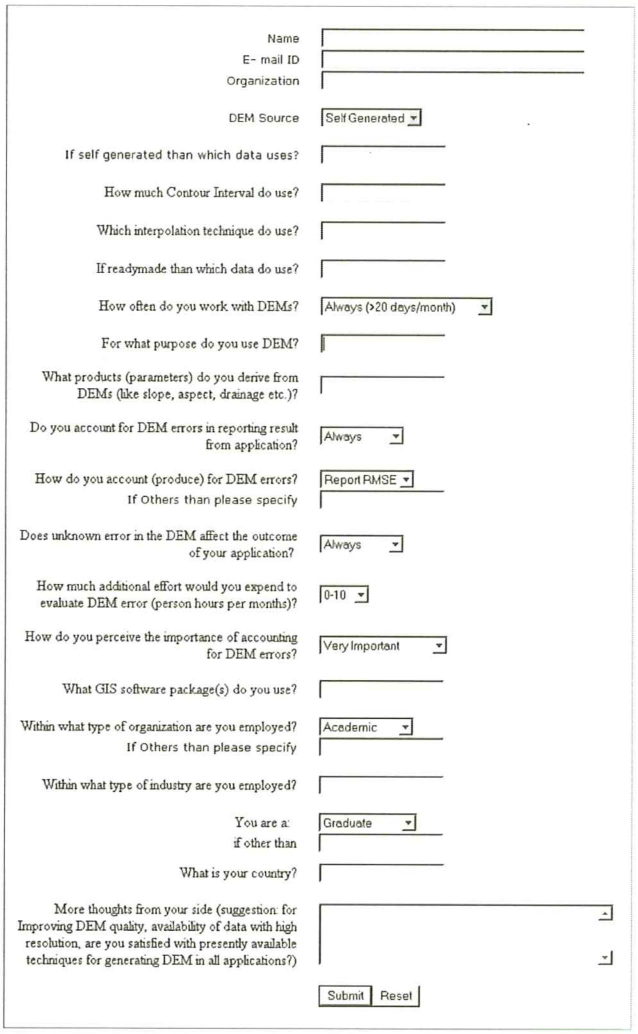
Name
E- mail ID
Organization
DEM Source: Self Generated
If self generated than which data uses?
How much Contour Interval do use?
Which interpolation technique do use?
If readymade than which data do use?
How often do you work with DEMs?: Always (>20 days/month)
For what purpose do you use DEM?
What products (parameters) do you derive from DEMs (like slope, aspect, drainage etc.)?
Do you account for DEM errors in reporting result from application?: Always
How do you account (produce) for DEM errors?: Report RMSE
If Others than please specify
Does unknown error in the DEM affect the outcome of your application?: Always
How much additional effort would you expend to evaluate DEM error (person hours per months)?: 0-10
How do you perceive the importance of accounting for DEM errors?: Very Important
What GIS software package(s) do you use?
Within what type of organization are you employed?: Academic
If Others than please specify
Within what type of industry are you employed?
You are a: Graduate
if other than
What is your country?
More thoughts from your side (suggestion for Improving DEM quality, availability of data with high resolution, are you satisfied with presently available techniques for generating DEM in all applications?)
Submit Reset

Figure 1. Survey questions (as appears in World Wide Web)

Germany (2%), Iran (6%), Iraq (4%), Turkey (2%), USA (2%) and Venezuela (2%).

Respondents were affiliated with the following types of organizations: academia (50%), research (8%), central government (18%), business (6%), non-profit (2%) and other (10%).

The industry most respondents were affiliated with was hydrology (32%). The remaining respondents identified the following fields: environment (2%), engineering (4%), forestry (4%), geology (2%), natural resource management (14%), planning (6%), conservation (9.3%), transportation (4%), terrain analysis (22%) and utilities (10%).

A. DEM type

The largest proportion of respondents use self-generated DEMs (76%) and readymade DEMs (24%). The readymade DEMs are USGS-DEM, ASTER (15m), SRTM, LiDAR, SAR and surveyed data (total station and GPS). DEMs in the self-generated categories were defined as follows.

- Generated from Survey of India 1:25000, 1:50000 map sheets.
- Arc/Info DEMs (variable resolution) generated from DLG data and tagged vector files, created DEM from vector polygon files of 1:250000 topographic maps.
- Digitized contour lines from 1:5000 topographic maps, additional automatic generated height points in valleys and ridges, linear interpolation with TIN, mean-filter for smoothing the TIN-edges.
- 1-km DEM generated from 1:250000 contour maps.
- DEM created using TOPOGRID in Arc/Info.
- Photogrammetric methods to update DEMs where significant earthwork has been performed.
- DEMs created from contour lines using various GIS packages
- Stereo images for generating DEM (ASTER, IRS).

B. DEM uses

Nearly half of the survey respondents "always" work with DEMs >20 days per month (40%) while 22% of respondents "often" work with DEMs 5–20 days per month; 40% reported working with DEMs "sometimes" (1–5 days per month) while 4% reported "never" working with DEMs.

C. DEM parameters

Most DEM users who responded to the survey create maps of slope aspect, convexity and/or concavity (17.6%), followed by shaded relief (17.2%) and contour maps (15.2%). Other DEM products included: watershed boundary delineation (10.7%), drainage network delineation (8.6%), viewshed maps (8.0%), channel network definition (6.1%), model parameter generation (5.9%), ridge detection (4.8%), and cost analysis (2.3%). Less frequent applications mentioned (3.6%) were: "roadway design cut and fill estimates", "point elevations for groundwater analysis", "slope and aspect maps which are used with digital geologic maps to prepare earthquake-triggered landslide hazard maps for local government planning"; and "the Minnaert Model".

D. Perception of errors

Survey respondents perceptions of DEM error are:

(i) Accounting for errors

Nearly half of the DEM users who responded to the survey always (46%) or never (10%) account for error in the DEM. However, approximately one-quarter of DEM users (26%) sometimes account for error while 18% rarely account for error. Reporting of the RMSE was the most common method for reporting error (52%) followed by visualization (26%), error maps (6%). Other methods (16%) for evaluating errors in DEMs included:

- Compare elevation values from the DEMs against values in the original topographic maps, and reported the range of difference, average difference and standard deviation.

- Determined a minimum map resolution that is depicted on the final map product. Areas smaller than the minimum are essentially considered to be within the noise range and are removed.
- Visual spot checks and the software have a routine whereby elevation is given for the cross hairs as they move across the surface".
- View DEM with man-made features superimposed.

(ii) Effected by error

DEM users believe that the effects of error in their DEMs are somewhat important (14%) or important (22%). 76% of respondents perceive error as very important. Nearly half of respondents believe that they are sometimes affected by DEM errors (46%). 8% of DEM users believe that they are rarely affected by DEM error, 6% believe they are never affected, while 42% of the respondents perceive they are always affected by unknown error in their DEMs.

(iii) Time allotted to evaluate DEM error

DEM users would prefer to spend minimal time to evaluate DEM error. The original survey form lumped the minimum contribution into one range of 0–10 person hours per month. Of the survey participants who responded on this form 76% would spend 0–10 person hours per month. Of all the survey participants, 18% would expend 10–20 person hours per month, 6% would expend 20–30 person hours per month, 2% would spend 30–40 person hours per month and again 2% would expend greater than 40 hours per month to evaluate DEM errors.

E. Results–responses by DEM applications and type

The survey identified readymade and self-generated DEMs as the most commonly used DEM form. In addition, use of DEMs for terrain modeling, topographic parameter generation, map visualization and hydrologic modeling were identified as the more common uses of DEM data. Responses of users in these categories were evaluated to determine their perceptions of DEM errors.

Table 2 lists responses to the question: Do DEM users account for error? Table 3 lists responses to the question: How is Error accounted for? Table 4 list responses to the question: Are DEM users affected by error? Table 5 lists responses to the question: What is the DEM User's Perception of DEM Error? Those who make their own DEMs (self-generated DEM users)

Table 1. How much effort(person hours per month) for error evaluation

Effort to evaluate	0–10	10–20	20–30	30–40	>40
Hydrologic modeling	30.5%	33.3%	33.3%	100%	0%
Terrain modeling	33.3%	44.4%	66.6%	0.0%	100%
Topographic parameterss	36.1%	22.2%	0%	0%	0%
Readymade	75%	16.6%	8.3%	0%	0%
Self-generated	71%	18.4%	5.2%	2.6%	2.6%

Table 2. Do DEM users account for errors

Account for error	Always	Sometimes	Rarely	Never
Hydrologic modeling	47%	17.6%	23.5%	11.7%
Terrain modeling	25%	41.66%	16.6%	16.6%
Topographic parameterss	38%	23.8%	14.2%	23.3%
Readymade	41.6%	16.6%	25.9%	16.6%
Self-generated	47.3%	28.9%	15.7%	7.8%

Table 3. How is errors accounted for

How accounted for	RMSE	Visualize	Error maps	Others
Hydrologic modeling	42.3%	25%	33.3%	40%
Terrain modeling	34.6%	50%	16.6%	20%
Topographic parameters	23%	25%	49.9%	40%
Readymade	41.6%	41.6%	0%	16.6%
Self-generated	55.2%	21%	7.9%	15.7%

Table 4. Are DEM users affected by errors

Affected by errors	Always	Sometimes	Rarely	Never
Hydrologic modeling	38.8%	47.6%	25%	42.8%
Terrain modeling	22.2%	19%	50%	28.5%
Topographic parameters	38.8%	33.3%	25%	28%
Readymade	50%	46.6%	0%	8.6%
Self-generated	39.4%	44.7%	10.5%	5.2%

Table 5. What is the DEM user's perception of DEM error

Importance of error	Very important	Important	Somewhat important
Hydrologic modeling	38.4%	45.4%	20%
Terrain modeling	20.5%	27.2%	60%
Topographic parameterss	33.3%	27.2%	20%
Readymade	75.9%	16.2%	8.3%
Self-generated	65.7%	23.6%	10.5%

are most aware of DEM error and associated uncertainty. Respondents in this category report that they are affected by errors, that it is important and that they account for uncertainty in reporting results. Users of the Readymade DEM product generally do not perceive DEM error as an important issue. The majority of these respondents reported that they rarely or never account for error.

Those who use DEMs for map visualization reported they were not generally affected by DEM errors. This can be understood since errors in DEMs generally do not affect the use of a DEM for visualization purposes. The majority of survey respondents who use DEMs for terrain modeling, map visualization, hydrologic modeling and slope generation reported that they are "always" or "sometimes" affected by errors. Relatively large numbers of respondents do not account for errors but large numbers also perceive it as important or somewhat important.

V. CONCLUSIONS

DEMs are used in many parts of the world for various purposes. The major reported uses of DEMs are in terrain modeling, map visualization, and hydrologic modeling with the largest percentage of respondents' affiliated with water and natural resources management. Many DEM users are aware that there is error associated with use of DEMs and analyses derived from them. Some DEM users apply a variety of measures to account for the effect of DEM errors. These DEM users seem to perceive uncertainty as a non-issue. Results from DEM users who responded to this survey indicate that many DEM users deem errors in the DEMs they use to be somewhat important, however indicated an unwillingness to devote much time to evaluate the impact that this uncertainty might have on their applications. GIS programs that are developed to assist DEM users in evaluating error should take little time to implement if they are to be applied.

The products derived from DEM applications are likely widely used for the purposes of decision-making. DEM data are the underpinning of major environmental projects throughout the world. DEM data have wide applications in the military as well as civilian domains. Land use planning and water resource utilization are basic applications. The products derived from DEM data are critical for such planning and decision-making. These products are assumed to be valid and reliable representations of reality. Scientists who apply DEM models are expected to provide the most accurate data possible in presenting their findings to other professionals, public officials and other end users. The results of this survey indicate that there is much room for examination of the extent and accuracy of data in the application of DEMs.

This survey suggests that about half of the DEM users recognized that their work is affected by errors. About 25% of users reported lack of awareness as to whether DEM errors affected their work at all. On the other hand, half of the users recognized that error was very important and this same proportion of users reported that they account for uncertainty in their work. The methods used by the small group of respondents who do account for uncertainty are varied. There do not appear to be any consistent procedures that have been adopted by the community of DEM users. There are no consistent methodologies that are applied to DEM data to address problems of error, apart from the Root Mean Square Error (RMSE), an accuracy statistic provided for some DEM data. Decision rules about managing the error in the data are defined by individual DEM users. Nevertheless this survey suggests that DEM users appear to be trying out various methods to clarify, reduce, communicate and limit the effects of errors on DEM applications in their work. Indeed many DEM users indicated some willingness to commit limited time and resources to identifying and accommodating for errors in their work. Therefore tools that could be easily utilized might assist DEM users to more precisely specify the limits of accuracy of their DEM derived products and/or further refine their products. The need for educating users who are currently not aware of the problems of errors (uncertainty) in the DEM data is another conclusion from this survey.

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