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Panel Discussion: The Future of DTM*

The production of large-scale DTM, formatting the DTM for the user, and the accuracy of the DTM were of major concern.

INTRODUCTION

E. M. Mikhail: As a general background, it is useful to concisely summarize the areas covered by the symposium. A broad definition of DTM is a representation of terrain characteristics either in a discrete form, i.e., in points, be they uniform or otherwise, or in functional form. It need not be limited to elevations, as it can refer to other characteristics. So, associated with each point in the terrain you can have a multivalued vector, of which elevation is one element. The U.S. Geological Survey uses the term "DEM" or Digital Elevation Model, which would be a subset of DTM. There are two broad aspects or phases of DTM: data collection, and data processing and applications. With regard to collection, we consider equipment and collection procedures. Equipment includes those which scan graphics, and photogrammetric instruments extracting data from stereo-models. Data come out either in patch form or line form. The collection procedures relate to whether we take point by point, line by line, or patch by patch. So, in the collection procedure we consider both pattern and density, and of course when you talk about that you cannot divorce it from accuracy. With respect to accuracy, we need to know how well are the data derived, how well is the terrain represented, and, after the digital terrain model is constructed, what accuracy statement can you attach to it. Normally, the accuracy statement depends on the product and the use that you plan to make of that digital terrain model. With regard to processing, it may concern interpolation, filtering, etc. It has been suggested that, when using a smoothing function, the accuracy of the digital data can be related to that function.

Finally, the various uses of DTM include (1) production and maintenance of a cartographic data base; (2) graphic and image products; a good example would be a digital off-line ortho photo production system using DTM; (3) engineering and planning, such as for highways, railroads, powerlines, etc.; (4) classification; (5) simulation; and (6) meteorology and navigation.

This briefly summarizes the general coverage of the symposium. In this closing

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panel we would like to discuss the future of DTM. We, hopefully, know where we are and what problems we have. Looking ahead, we may pose pertinent questions: What is the emphasis going to be on? What kind of problems are we to address first? Should we continue to seek better means of automated matching of corresponding imagery? Is correlation along epipolor lines the best way? Are there other procedures that are better, in the sense of better approximating the human eye-brain combination? Can the correlation coefficient be supplemented by other measures such as the information content in the imagery to give a better image match? Are we doing the right thing to be collecting very dense DTM just because we do not know before hand the collection frequency of points? What about DTM for large scale? Finally, can we do something about technology transfer? There seems to be a significant gap between those organizations with large amounts of funds where considerable research and development on DTM is being carried out and the civilian user. It is important that the results of these efforts be transferred and in a timely manner to users. These general questions are posed not only to the panel members but also to all in the audience.

We have assembled six distinguished panel members; each will address an area in which he is both interested and active:

(1) U. V. Helava, Bendix, discussing: General Hardware Considerations in DTM
(2) J. R. Jancaitis, U.S. Army Engineer Topographic Laboratories, addressing: The Impact of Minicomputers on the Future of DTM
(3) F. Doyle, U.S. Geological Survey, who will talk on: Civilian Governmental Mapping Considerations of DTM
(4) R. J. Helmering, Defense Mapping Agency Aerospace Center, discussing: Military Mapping Considerations of DTM
(5) F. Ackermann, Stuttgart University, addressing: General Accuracy Considerations for DTM
(6) A. K. Turner, Environment Consultants, Inc., covering: Economics and Commercial Applications of DTM.

THE PANEL

U. V. Helava: I would like to take the liberty of adopting a little bit wider view, at least in the beginning; not only discussing instruments, because we are dealing with an extremely many-sided and varied problem. When considering these things, automatically you get ideas and opinions about different aspects of the DTM concept. One of the things that may turn out to be, indeed, controversial, although I think we are in agreement, is the definition. I do agree that there is a great attraction to a wider definition. You can easily imagine that all the exotic data bases where all possible data can be collected and organized according to their position on the Earth's surface would be included in the digital data base. Undoubtedly, such things will come into being and do exist to a large measure. Geographers are particularly involved in that area, talking about these large data bases that include all kinds of possible information including sociological, and what have you. To keep things somehow organized, I think it would be good for us, at this meeting, to perhaps remember the origin of the concept of digital terrain models as Doyle mentioned in his introduction. The origin of our concept was dealing simply with terrain elevations expressed against their position. I think it is perhaps a good idea to remember that that is DTM. When we add other information, particularly when we go very far in the direction of adding all kinds of additional data, then perhaps we should use different names and keep the bunch of them separated because, in many ways, they are.

From there, I tried to come back with some impressions of this symposium. Perhaps the one that struck me most is the enormous variety that already now exists. There are very many different uses and users for digital terrain models. Accordingly, also, there are very many kinds of implementations. I would agree that it would be very nice if you could somehow devise a system or a basis of a system that would be good for everybody and that all development work that goes into this system would be integrated into one system; everybody pulling in the same direction. That would lead, perhaps, to the fastest and most favorable development of the concepts and applications. However, I do not think that this will happen. There are just too many very specialized cases where the considerations on the resources of the user, both in hardware and in manpower and money, dictate special approaches and special solutions. So I would believe that we are going to see quite a number of different implementations of the digital terrain model concept, more or less "optimized," in quotation marks, please! The aim would be to optimize this digital terrain model implementation for particular purposes.

The other thought that came to my mind is that we can quite clearly separate two kinds of areas of application. I alluded to that already in my talk earlier by discussing small versus large scale applications, where I now mean small-scale map and large-scale map. Not necessarily meaning in relation to the map, but more precisely relating to the accuracy to which the digital terrain model has to be established. It seems to me that the government organizations in particular are mostly interested in relatively low-accuracy digital terrain models, those where you, in many cases, can overlook the influence of terrain coverage: houses, trees, and things of that sort. In this area the present automatic techniques and equipment can do a very good job, and there exist already systems' implementations, where marvelous results have been achieved, as you have detected from the papers in this Symposium. However, I am thinking of making an analogy with what happens in the general mapping field. In most of the commercial and civilian mappings, outside of the government circles, we have very large-scale mapping directed for engineering purposes and cadastral purposes and these kinds of things. I would guess that the expansion or increased application of digital terrain models in most of these areas is very heavily hampered now by the fact that you cannot do it with automatic means. You have to put a lot of manpower and a lot of human effort into the generation of digital terrain models, which reflects the current status of instrumentation in general. Whether you digitize maps by hand or produce new measurements by photogrammetry, in either case the amount of work that goes into the generation of the high-accuracy digital terrain model is extremely high. So, that was the second impression that I gathered from this meeting, although I had some thoughts in that area already before. The high-accuracy, large-scale area is the area that is of interest to the commercial user. Then there is a third one which did not necessarily come out of this meeting, but remains to be addressed, nevertheless, and that is that most people are poor. In consequence, very expensive and sophisticated equipment just are not attractive, and even if they are, they are just necessarily out of reach. Therefore, the instrument people, and I consider myself to be in that group, have to endeavor to perform this technology transfer that Mikhail mentioned in a manner that decreases the cost, and makes the technology available, at lower cost levels. What that means in practice is something that we instrument people, instrument designers and producers, will have to analyze carefully and then see what we can do.

J. R. Jancaitis: I am going to review very quickly the characteristics of minicomputers that are of importance to the DTM, and talk very briefly about what these characteristics mean to the user community and then what we expect in the foreseeable future. In general the minicomputers have sixteen bit word lengths; small compared to the larger machines. They have a severely reduced instruction set. Full floating point operation hardware is generally an option. Core memory is limited. The I/O (Input/Output) is controlled by the CPU (Central Processing Unit) as opposed to special processors. The operating systems have been built around controlled, or interactive, requirements. The minicomputer came about as a piece of digital equipment to control machinery; you can see that even now in the use of general purpose minicomputers to control exotic I/O devices. The cost is spiralling down incredibly, and it is a highly competitive market. There are now some low-cost parallel-pipe-line processors for minicomputers. It used to be that if you wanted to do things in parallel you paid four or five million dollars for an ILIAC or two million dollars for a STARAN. There are devices on the market now in the twenty- to fifty-thousand dollar range that come with standard minicomputers interfaces. The equipment is getting smaller and smaller and more and more rugged.

The implications of minicomputers for DTM may make you think that the shorter word length would mean lower precision. But that is not the case. Sixteen bits is generally all you need for elevation values, so we are safe. The higher-level language compilers are much less efficient, however, on the minicomputers because of the reduced instruction set, and this just means that, if you do something on a mini, it is going to take longer. The floating point operations cost relatively more because of system overhead. The floating point processors are options on minicomputers. They are add-ons and there is a system overhead associated with using them that you do not have on the large-scale machines. The code or application complexity is limited by the smaller core size, and heavily I/O-bound operations proceed as much as ten times slower. This is because the large-scale machines have, in essence, minicomputers that are doing all of the I/O control, and on the low-cost mini they just cannot afford that. Interactive applications, development, test, and use is much simpler and nicer on a mini. They were developed for real time applications, and well, they are tailored for it, much more so than the large-scale machines. You have much greater user control for special plots, inputted data, and data base interaction. Lower cost and availability of the DMA data is going to bring more and more applications into the realm of cost-effective solutions by DTM. Now, even computer-bound problems are going to be solved in real time on minis with special type applications on parallel processors.

Moving into the future of DTM, the users in industry are going to find more and more that the DMA data is the most cost-effective way to get going on using the DTM. It is already there and it costs about the price of copying on a mag-tape to get it. I might comment on Helava's remarks that DMA was the first into small-scale DTMS, and I can quite accurately predict they would also be the first into automatic equipment for large-scale DTMS, as for example, fine grids over very large areas. Money is the problem, or the answer there. The compression work is going to impact the future of DTM use on minicomputers by industry at large. You are going to have a lot lower memory requirements for very large expanses of data. Nobody has mentioned the global positioning system, which is being developed, which has surprised me up to this point. It is going to have a big impact on DTM and its users, people who are interested in elevation information, and its incorporation in various applications. I feel grossly inadequate in describing the global positioning system, and I will make some comments that I hope are not too terribly wrong, and suggest that most of you here find out more about this system. It is going to come in the mid-eighties and it is going to impact all of us. It is a network of satellites which will enable a person with a very small hand-held device to determine his position—latitude, longitude, and height above the reference datum—in real time, anywhere on the surface of the earth. DMA (Defense Mapping Agency) has been committed to this system, and I guess the first six satellites are up.

In the government sector, the future of DTM is going to be mainly in two areas. The first concerns incorporating DTM with other data types. Second is in the production of the high-accuracy, very large-scale data.

F. Doyle: It seems to me that in the last several days we have been hearing primarily from theoreticians. The Geological Survey does have the operational task of supplying digital data to a wide variety of users. That requires that we somehow or other transform a lot of these theoretical ideas into cost-effective operational techniques. We are producing a lot of digital data. We, ourselves, are one of the primary users of the digital data which we produce. We have heard a lot about the GPM (Gestalt Photo Mapper), and the GPM is, of course, the only operational system that we have at the moment for producing a digital cartographic data elevation model (DEM). We are using it with 1:80,000 scale photography to produce orthophotographs in areas of very rough terrain, and the GPM, as you know, has the possibility of collecting data in areas where there are extreme slopes up to sixty to sixty-five degrees, which are not adequately treated by most of the conventional orthophoto machines that are on the market, so we acquired the GPM, primarily for making orthophotographs. The digital terrain output from that has, of course, proved to be a very useful additional set of information. With the eighty thousand scale photography which we use for producing these orthophotographs, the GPM produces a grid network at about fifteen metres spacing on the ground. Our tests indicate that we get something like a five metre RMS accuracy in the spot heights which are determined during the procedure. Five-metre spot heights are, depending upon what kind of criterion you want to apply, appropriate for contouring at about fifteen-metre intervals. This is, perhaps, suitable for 1:100,000 scale maps, but not for larger scale maps, and that most of you know, that when we talk of a large scale map we mean 1:24,000. For those maps, we use contour intervals of five, ten, twenty, and forty feet. So we are not really addressing our major problem with the digital data that we are getting from the GPM. One of the features that was pointed out in Olsen's talk the other day, however, is that if you scan these same 1:80,000 scale photographs manually you get approximately the same kind of accuracy that we are getting from the GPM. We have not really tried GPM on the larger scale photographs that we would require for standard mapping.

One of the things which the GPM does is to attempt to match the elevation data along the lines between patches. It does that relatively well in terms of the statistical average along the line, but we do get differences in slope between the adjacent patches. When that happens, the GPM calls on the operator and the operator has to do his best to try to straighten that out. It is not possible, really, to do that in an on-line mode in a completely satisfactory way. So when we get the information out, we have to do some kind of adjustment between these adjacent patches. Filtering techniques are one of the approaches that we are seriously looking at in order to solve these problems.

One of the major problems that we have with the digital data is putting it in forms where it becomes available to a wide variety of users. Elassal mentioned that we are getting on the order of one to two hundred requests a month for the digital elevation files that we took over from DMA. We are not yet putting any of our GPM data on public distribution. So, we are not really as far along as we may appear to be when we get up here and give technical papers on the subject.

With regard to our standard large scale 1:24,000 maps, we are in the process of converting to metric map scales. We are going to produce them at 1:25,000. We have approximately 80 percent of the country currently covered with the 1:24,000 scale maps with contour intervals of five, ten, twenty, and forty feet, and these are simply not addressed by any of the automated techniques that we have been talking about. We normally use about 1:26,000 scale photography in the preparation of the 1:24,000 scale map. If we put that in the GPM we would get a 4-metre increment matrix of elevations on the ground. We think our primary requirement in terms of producing a digital data base at the 1:24,000 scale is to be able to extract that information from the existing contours which we have. I am sorry to say that the only feasible way of doing that right now is by manual line following.

The raster scanning technique has a lot of problems, some of which have been alluded to already. With regard to the problem of different line weights, we think one of the probable approaches to that is to photomechanically manipulate the contour sheets to produce a uniform line weight for all of the lines. This will make the raster scanning operation quite a bit better. We still have a problem in tagging the contour lines. We look for some help from parallel or array processing to change the raster scan data into vector kind of information which we need for contour.

I mentioned that metrication is one of our problems. One of the things which we hope to be able to accomplish with the digital data extracted from the existing 1:24,000 maps is to change our foot contour intervals into metric contour intervals. This is going to impose in my opinion quite a number of problems with regard to the cartographic expression that we get in the contour data. I believe that adequate cartographic expression is going to require geomorphological points or break points as they have been referred to here. Either that or an extremely dense network of grid elevations which I do not think we can extract from our existing contours. Automating the collection of geomorphological points seems to me to be a problem. It is a fairly simple thing for a stereoplotter operator to select such points but trying to do that by any automated technique I think is a very serious problem.

Besides collecting topographic data in digital form, we are also collecting line data in digital form. I mentioned to you in my opening talk that we have as an objective to produce all the information which is on our existing 1:24,000 maps in digital form. So, we make a separation in our collection activity between digital elevation models which is what we have primarily been talking about here and digital line graphics which is the other type of planimetric information. These are the public land surveys, boundaries, transportation network, hydrology, and so on. Digital line graphics are much more amenable to data compression than digital elevation models. We heard from Page of NOS (National Ocean Survey) about techniques for eliminating extra points along digital line graphics. We do exactly the same kind of thing. We have had some discussion about attribute data. Such things as land use, soil types, vegetation, demographic and geographic information. Collins mentioned collecting those data or at least tagging those data along with the dense arrays such as those produced for the digital elevation models. I think there are two different approaches to handling these kinds of attribute data. One of them is assigning it to points in the dense array. This is what the geographers call the grid cell technique. Personally, it seems to me that these kinds of data change relatively slowly, and that they have fairly well defined boundaries, and, therefore, it is more efficient if you handle that information by polygons and eventually combine those polygons with the point information that defines digital elevation models. Operating with digital polygons creates a whole new set of problems which we think are most appropriately addressed by imposing what we call a topological structure on the data. Topological structures and polygon data open a whole new area of interest and I suggest that this is an appropriate subject for the next DTM Symposium.

R. J. Helmering: The things that I will address are (1) a quick review of production steps involved in DTM work, and (2) some of the error contributors which I am particularly interested in. The production steps that are involved in the metric production of DTM include the following. The first is the triangulation step. Although we are not addressing it at this symposium, I think it does contribute in some cases significantly to the future steps of DTM production. Therefore, it should be considered in any type of DTM production planning. The next function that is performed is collection of digital data from the model. This collection is done in a variety of ways both manually and automatically and there are certain considerations that have to be taken into account, based on the type of equipment that you have. Next is the editing and smoothing function and it has often been said that one person's data is another person's noise and I think that is probably true. You do have to consider what you are doing to the data as you modify it in any way from the normal or the way you get it from the instrument. The next step is what we call the interpolation or the data base format step. Most large data base producers I think have some type of fixed data base format that they use. From a photogrammetric point of view the collected and edited data is normally not in the format that is finally used for the data base storage and retrieval system. Finally, there is a very important step, one that is becoming an increasing problem for us, and that is post processing. When data bases or data base formats are established, generally you have a series of potential users in mind. But the first thing that you find out several years later is that a great number of users come forward that you had not anticipated in the beginning and then you are stuck with DTM data that has been designed for one thing and people are trying to use it for something else. So, some post processing steps are needed that range from such simple things as restructuring the matrix at a different interval, to producing a completely new product from a DTM.

The next area concerns what I call the error contributors. One of the most difficult things is to put a numerical value for accuracy on a DTM. The error contributors include, first of all, the images themselves. Depending on the type of sensor used to acquire the images, scale, densities, etc., all those things go into certain capability to extract DTM information from those images. Secondly, is the collection device. Accuracy of the device also contributes to the total accuracy of the product. Photogrammetric algorithms, both for the data processing and triangulation and also for the extraction of the data in the collection device, will affect the accuracy. The topography that the imagery has been collected over will make a difference. Smooth terrain requires one collection interval different from that for rough terrain. Processing algorithms to get you into the data base format must be considered. The error, or in some cases the improvement, you might see based on smoothing and interpolation is pertinent. Finally, the post processing algorithms can significantly affect the accuracy of the original DTM data as you move it from the data base. The last thing, and one that is of particular interest to me, is the multi-use data base. For example, the difference between using the DTM to determine cut and fill operations and the cases where people may not even be interested in the fact that the DTM represents the terrain at all. For instance, for navigation purposes you can process terrain, and smooth it very much and, depending on the type of navigation system, they may be much happier with the smooth data than they would be with all the detail. So the definition of DTM I believe has to be against some standard. You have to say that the DTM is an expression of land form, and you have to always go back to that definition for an evaluation, no matter what you do to the data. If it is smoothed significantly for a particular use, one should be able to tell how much it has been degraded with respect to the original land form. Another thing of interest is the accuracy. You have accuracy in mind when you start the preparation of a multi-use DTM. In most cases this will result in what I like to call stratified data bases. In other words a great number of users are satisfied with very large area coverage, so that they can for example do route planning, general studies which include the information provided by DTM. On the other hand, there are users who need a DTM which has much more detail in it. But, in most cases these areas can be confined to not very large global coverage but restricted regional coverage, so we do not have production problems producing very large data bases over a very large area. The next thing concerns production requirements for a multi-use DTM. Another thing is the requirements of users. Every user seems to be developing his own use for a DTM. It is very difficult and for all practical purposes impossible for an organization like the DMA to provide a specific data base for every particular user that comes along. Therefore, we have to work with users and we have to attempt to help them to transform our data into data that is usable for their systems. And, finally, a very important thing is that a DTM is not an end itself; it has to interface with other data bases. It has to be manipulated with other data bases and, if it cannot, it is going to be useless. So, we have to consider not only the DTM in itself when we design a multi-use data base but we have to consider it in view of all the other information which can be extracted from the images.

F. Ackermann: I think Helmering was correct when he pointed out that before you observe data for DTM you must make a decision on the accuracy that you want and how you are going to get it. I think we should distinguish between two things when we talk about accuracy of DTMs. First, the accuracy of the grid of points. Of course we distinguish between observed points and derived points. Assessing the accuracy of observed points is nothing special; it is rather conventional and whether you do it by photogrammetric means or even with ground surveying, I think it is relatively easy to say how accurate the survey has been done. Then from the original data you usually derive a set of derived points, actually the DTM grid. This may include data compression, it may include filtering, and it includes interpolation. The accuracy of this step can be assessed with conventional means of propogation of errors. So, all this is nothing very special. In fact you can have very accurate points. For instance, what I showed yesterday, if you do a ground survey with Regalta, a large scale work, these points are accurate to about two centimetres. The real problem, however, is how well do these points represent the terrain? We could perhaps compile a range of accuracy which the points have. Even if this range is small, you still have the problem that the terrain profile is not very well represented by the points. So this is the real question, and now this refers, of course, to the spacing of the points. Where do you position them, and, of course, this is a function of the type of terrain you deal with. This problem is, in fact, very tricky, and I do not have a clear solution of how to proceed. We still have two basically different approaches. I refer to the paper of Schmutter: I think this is one extreme. You select few points, as few points as possible, to represent the terrain, and you position them as well as you can and as representative of the terrain as you can. With few points, each point carries a high qualification, as far as representation of the terrain is concerned. On the other end of the range, you have this more or less automatic dense system of observing DTMs. There, the individual point means nothing; it is the statistical entity and the bulk of the data which somehow represents terrain. So you have many points, a lot of redundancy, but each point is not very much qualified. Now, in between these two extremes there are numerous possibilities. I think what we really have to do is to find out rules or criteria to determine the fidelity with which DTM represents the terrain. Now, what I showed you yesterday, that was one approach to it, simply by experiment. You could also do it by theory, but only if you have a theoretical description of the terrain. I do not mean, necessarily, an analytical description, but it could be a statistical description. It could be covariance functions, it could be frequencies, and so on. As soon as you have that, then you could predict and you could assess what a certain DTM would give you. Now, this relates to absolute accuracy, but we still have the very tricky problem of how well a DTM represents the individual detailed features of the terrain, especially for cartographic application.

Another thing which we have not touched on here at all is that we may have blunders in the data. This could be registration mistakes or any failure of equipment. We do not really know what to do about them. If it is very obvious, then it is no problem as it can be eliminated. But if it is composed of many gross errors, then it is a difficult problem. Now, turning to what should be done in the future, I suggest designing a complete research program in order to determine how to assess the accuracy of the DTM in terms of how well does it represent the terrain. If I may make a remark not related to the panel: I am one of the few people here from Europe attending this symposium and I may express my views that I have been very much impressed by this symposium. It showed an extremely great variety of activities and of methods and of things which are going on here and this is always very stimulating for us. I thank you very much for having been able to attend a most interesting and most stimulating symposium.

K. Turner: I was asked to address you on behalf of the commercial interests and that gets down to problems of cost and productivity. As a commercial operator one has to consider buying some equipment; how much it is going to cost and how he is going to amortize that equipment over how many jobs, etc. Next, we need to establish some standards and some commitment to stick to those standards. We need not get too overly technical on the standards, but we do need some that will meet the needs. I worked in Toronto back around 1970 and at that time we put in a Gerber drafting system. The Gerber had, I believe, a four-by-five drafting table. The logical suggestion made was that we produce our plans in sheets of four by five. "Not adequate," came back the reply from the design people. "We like our plans in rolls twenty-two feet long." We said, "Why?" We found out the reason for this rationale, which went back to the dark ages, was that somewhere along the line the design system had a table in their board room which was twenty-two feet long! So that was the reason for that standard! What the guy did in the field trailer with the twenty-two foot long plan, well you know what he did: He cut it up into shorter lengths! But, still the requirement was there. The point that I am trying to make is that we do need some kind of an idea of which direction we are going.

As far as equipment is concerned, I would like to suggest that further consideration be given to the minicomputers. They are extremely powerful. I have, personally, been looking at some that are a little larger. Even the larger ones of those things are very economical to buy; they are extremely reliable. If possible, I would like to use standard equipment like the TV newspeople do. You know, they carry it on their shoulder and they drop it in the mud and they do all kinds of things with it and it still works. If we can go with the large volume equipment which is cheap, then I think we may have something. I have taken a look at some of these hobby kit computers, which are very, very cheap. Some of them you can hook onto a color TV and you can get color displays. I am throwing out an idea that some of this low-cost equipment may be extremely useful, and practically everybody has a color TV set.

As far as the data is concerned, I will point out the problems that we face with the Landsat tapes. We get a phone call from somebody who wants me to do some work somewhere using Landsat data which is quite inexpensive, but he needs the answer late this week. Well, it takes you ninety days to get the tape from Sioux Falls, so there is no way you can do the job with Landsat. You are going to do it by other means. Now I realize the problem; it is a huge factory up there, and the data comes up to your earlobes every five minutes, and there are all kinds of problems. We are facing the same set of problems, I think, with the task of Soil Conservation Service digitizing soil maps and the Geological Survey digitizing land use information. Frankly, the idea of having polygonal data which I am going to work with to get a useable product is difficult. I recognize its advantage but we need a standard way in order to be able to overlay them efficiently, and in a timely sort of way. Maybe that would solve the problem. Can we have it by state? By county? Or by quadrangle or something? Sioux Falls is going to have some standard Landsat to improve image products. If you like that image or that area, you can get it fast and much cheaper. If you need a specific thing that does not fit the standard, then you have to wait. The point being that if you can use the standard product to get a rough answer, maybe that is the way to go, and maybe we should concentrate on the standards for those.

I am more concerned about the problems of the small scale, large areas studies which are affected by environmental legislation. Many of these are being done manually at fantastic cost. That is why we do not have any coal leasing program until 1983, and that is why we will have various other problems in terms of energy resources. We do not even know where it is, we do not know what would happen if we took it out anyway. So there is a series of problems here which could be solved if we had some of the information in the DTM. This meeting has helped me in giving me some ideas of people that I did not have before and I would like to see it continued.

E. M. Mikhail: This concludes the presentations; I open it now for remarks and/or questions from the audience.

THE AUDIENCE

R. E. Roger: I would like to make a few comments on what we have heard. Helava mentioned that most of the government people are only interested in low accuracy applications. I do not think he really meant it that way. There are several organizations that are interested in all the accuracy they can get out of whatever imagery is available. Because of that, I have to agree with what Ackermann and Helmering said about accuracy, that you have to think about it in the beginning. The first thing you do before you start a project is to figure out how accurate your end product will be. Because of that, one of the fundamental problems is trying to estimate that accuracy. Very often it is computationally much more expensive than getting the product itself. I would also say that the customers are getting smarter as they will want to know what the reliability of that product is, much more so in the future, especially when you see the rising incidence of legal cases. I really support the minicomputer concept that Jancaitis discussed but I would say that in many cases high accuracy, at least in some of the applications, requires more than 16 bits, and there are some good 32 bit minis on the market that we are using. I want to get a little controversial for a second. Everybody seems to be pushing large data bases that everybody can use, and I think maybe that is where we are right now. But in the future I envision such a large variety of potential applications for digital terrain data as well as time sensitive applications. Then, you may want to consider extracting quickly from the available sensor data the information you need to do your project. You do not need all the information on the imagery all at once, you only need a certain amount of it. So, with those comments let me just list six areas that I think we need to look forward to in the future. One is the automation of the data collection itself; you have heard a lot about how to interpolate and how to use the data bank. I think you need a lot more work in automation in collection of the data from the available sensor imagery. I believe there is a lot of work to be done in autocorrelation, to get that data out automatically. I am not talking about low accuracy requirements or low scale requirements that I think correlation has essentially solved; I am talking about very high accuracy requirements where you may be interested in a specific part of a city and you are trying to correlate imagery of that city. This is a real problem and there are a lot of applications for those kind of data. Also, change detection is another problem. If you have a digital data bank and another one a little later on, you can perform change detection if the data are accurate enough. Another area is using more than one stereopair to get that data bank built. How do you put four or five or six images together to get a better data bank or to get a more accurate one? Another area I found very little discussion on concerns product display. How are you going to show the customer this data bank? Nobody mentioned holography, at which I am little surprised. There was some mention of computer graphics, but there are a lot of ways to show the customer what you have for him, and there is a lot of work to be done there. The last area is statistical or quantitative measures of accuracy. There is a lot of work to be done in trying to figure out how to estimate the accuracy of the product.

S. Collins: Regarding a standard DTM, I recommend the dense grid because multivector analysis for terrain description attached to the DTM exists only in core; the other stuff comes in outline form or perhaps in pixel form. From the complete description of the terrain you can derive specific thematic information and throw outlines around it, and that is all done in core. We never have to carry that tremendous volume in detail.

Danko: I would like to present one concept that we have felt was valid in the data collection process, and ask the opinion of the panel, on this concept. It is our opinion that the profiling method is the best method for collection of data, over the contouring method and of course the point method, for large scale data collection. The reason for this is that in the profiling method the instrument paces the operator rather than the operator pacing the instrument. Of course each operator will scan at a certain speed, but all operators like to challenge themselves, so if they can set the speed of the profiling device to its maximum for them, they will do this. In the contouring mode the operator is moving the tracing table or the hand wheels and he is setting the speed, manual speed for data collection. Gentlemen, what is your opinion on that?

Mikhail: Since this is a hardware question, I refer to Helava.

Helava: I guess there is little doubt that the profiling method is a good way of collecting digital terrain data. My own feeling would be that there are many different ways to skin the cat. It depends on the circumstances as to what would be the most efficient technique. I may show my bias here also by saying that the most efficient method would be one in which the instrument goes by itself from point to point at rapid succession and the only thing that the operator has to do is point to the ground and push the button, and then it would move to the next point. It is not a continuous profile, but point by point measuring to get exactly the desirable point. But there are very many different ways of doing it and I think it depends on the practical experience.

R. Swann: When we consider large scale mapping and image correlation techniques, one thing we should bear in mind is the limitations due to large vertical discontinuity which a system cannot handle. Some of the work that we have been doing, I suspect a lot of other survey companies have been involved with, concerns large areas of the Earth where it is not a problem doing large scale mapping with image correlation systems, because there is not much ground cover. This land has a lot of oil underneath, it tends to be very flat on top, and it is not too difficult to deal with. In our estimation 30 percent of the conventional work that is being done right now can be done with present image correlation systems with all the accuracy that you would want. In referring to the small scale that Doyle mentioned, bear in mind what he said; that he was giving the worst work, the most difficult work on the GPM (Gestalt Photo Mapper). And when you start dealing with the most difficult work, the accuracy that he was talking about was dependent on that. We have found something which has not been divulged yet, that there is an easy way to get around one limitation in the system that should improve the accuracy by a fair amount, perhaps 30 percent or so. It is not expected to cost very much. Also, I take exception with Jancaitis' statement that he is going to be first with large scale digital terrain models, because we already have some large scale terrain models that we produced on the GPM. Finally, we do have some developments in terms of minicomputers and editing the digital terrain models which I think will allow a much wider use of our digital terrain models, that are by necessity arranged on a grid.

Mikhail: We should not perhaps be concerned with systems as they exist today, but should be talking about the underlying problems when you go to production of large scale DTM. For example, I should perhaps augment Roger's statement regarding correlation; perhaps we should be talking about matching of imagery from various records and that correlation is only one method. We should be looking at other things that would assist in matching images together, in addition to correlation, since correlation alone is not sufficient in many cases. There are organizations that are looking into such things as pattern recognition procedures, texture analysis, etc., to supplement correlation in determining matched imageries.

Jancaitis: I would like to make one comment about accuracy being important in the start. It is very fundamental to realize that R&D (Research and Development) pushes technology because that is its job. Since R&D pushes technology, feasibility studies often result in equipment that is rushed into production to do whatever it can because of the massive requirements that we have. A real good example is the UNAMACE (Universal Automatic Map Compilation Equipment), a production device designed to produce 1:250,000 scale orthophotographs. For the past 12 years its main job has been producing DTMS at 1:50,000 scale. Now, it makes orthophotographs that exceed all accuracy requirements for 1:250,000 scale and it has some trouble with 1:50,000 DTMS. But when it was built they had no idea that this is what it would be doing. So when we start shooting at things, we have to remember what the R&D is about. This is also what Helmering was referring to this morning.

Robinson: I am with the Defense Mapping Agency. Doyle in his opening address voiced some skepticism about the ease in the exchange of digital data, and standardization between various agencies, both here and internationally. It might be of some interest to this symposium to point out that DMA has in force at the present time, international agreements with four western European countries—Italy, United Kingdom, West Germany, and the Netherlands—where we are producing data for simulation purposes to a common specification. In fact, the people in Germany are going to produce a file at 1:50,000 scale by the end of 1980.

Mikhail: Since there are no more questions, let me ask a general question and see if someone in the audience would wish to answer. How would the accuracy of a produced digital terrain model be best expressed?

Faintish: One of the problems we have been looking at is just that accuracy of a matrix, and it has been my opinion that we can assign a quality factor to any matrix as far as the least significant bit in the data. You might have eight-bit or sixteen-bit data for your terrain, but if you know that there are non-random or systematic errors that are recognized, where they will affect the data in a particular bit, then you can express that matrix as being accurate to so many bits. That way, the user can either smooth out the data to the accuracy of the bits, or he can recognize the fact that there are insignificant bits in the data of which he should be aware. I think that would only be for the entire consistency of the data.

An attendee (name unknown): That still does not relate it at all to the terrain. We have done considerable work thinking about how to specify accuracies. We have sort of broken it down into three not entirely independent areas. One is a statement of RMS (Root Mean Square) error between terrain and generated model. A second statement of accuracy is some sort of morphological fidelity of the model (about which we have not the foggiest notion as how to specify). The third is some sort of a statement as to what the spectral characteristics of the instrumentation and the modelling techniques are that produced the given model. You can have a very dense regular grid which has been filtered, run through a low-pass filter, and you can have a very good RMS accuracy but after filtering, features below certain sizes may not appear in that model. And you can have false impressions of just what sort of terrain features you can pick up with that density of grid. As of yet I have not seen any kind of a statement, based on band-pass of instrumentation and modelling techniques.

R. E. Roger: Let me just make a comment on that, how you express the accuracy. I think that depends quite a bit on what you are going to use DTM for. We did a survey of all of our customers and found out that most of them do not know what accuracy is. We have been putting accuracy statements on all of our work for ten years. How do you express it? There are many ways of doing it; there needs to be a lot of research in that area, but how you express it will depend upon what you are going to use it for. Different people want it expressed in different ways so they can understand it.

Jancaitis: It is interesting, nobody mentioned the National Map Accuracy standards. The topographic map came about because it happened to be an incredibly useful product. You can fold it up and put it in your pocket. It is interesting if you look back and find out how the accuracy standard was derived for those maps. It was the best that people could do economically, cost-effectively. Ninety percent of the contours have to be plus or minus half a contour interval. I have a feeling that the accuracy standards that are derived for DTM will be incredibly linked to how well we can do it economically.

Ackermann: I may add a remark about this accuracy question. Of course, at the end the accuracy assessment must be simple, and I do believe as far as absolute accuracy is concerned, the difference between arbitrarily interpolated points and the actual terrain could be an accuracy indicator. The real question is, On which parameters does it depend? Of course, first the instrument, and this probably is a minor point. It really then depends on the type of terrain. I agree with what has just been said, that a regular spacing should have some reasonable relationship with the morphological features of the terrain. For planning, of course, one must turn it the other way around. You have a kind of terrain, you know certain features and properties, and have to decide how best to pick it up and represent it appropriately. I also think that for practical purposes, unless you go to extremes, the relationships are rather simple. But there is much more research to be done, particularly if you want to go into a much better assessment procedure. But what is not solved at all is this: relative accuracies, the morphological fidelities, the detailed features. There we do not have very much at hand for the time being.

Mikhail: With that, ladies and gentlemen, I enjoyed this panel very much; I hope you enjoyed it as well. We have as many questions, I believe, as answers, perhaps more. Then we look forward in the future to another symposium of this kind.

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