

Issue 16



COMPASS POINTS

June 1997

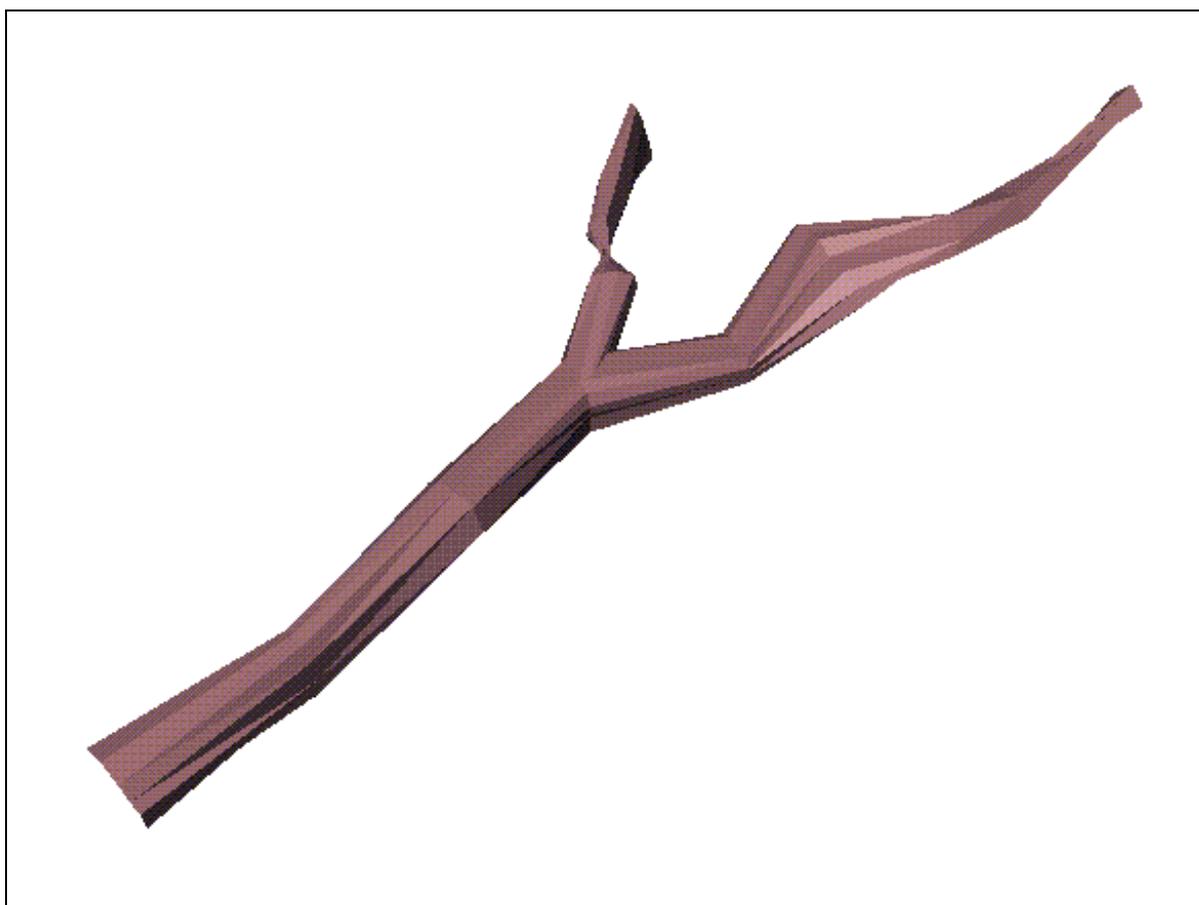


Figure 1 Rendered VRML output from Tunnel

Underwater surveying VRML for cave visualisation

Garmin GPS12XL review

Generating Tick Marks with AutoCAD

COMPASS POINTS INFO

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NOTES FOR CONTRIBUTORS

Articles can be on paper, but the preferred format is ASCII text files with paragraph breaks. If articles are particularly technical (i.e. contain lots of sums) then *Microsoft Word* documents (up to version 7.0) are probably best. We should be able to cope with most common PC word processor formats. We are able to accept disks from other machines, but please check first. We can accept most common graphics formats, but vector graphic formats are much preferred to bit-mapped formats. Photographs should be prints, at actual size, and non-returnable (so we can cut them). Alternatively, well scanned photos (e.g. from a PhotoCD) supplied as .BMP or .PCX files are OK. It is the responsibility of contributing authors to clear copyright and acknowledgement matters for any material previously published elsewhere.

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The group aims, by means of a regular Journal, other publications and meetings, to disseminate information about, and develop new techniques for, cave surveying.

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COMPASS POINTS LOGO
courtesy of Doug Dotson, Speleotechnologies.

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Editorial

Reading the results of a survey of CREG & CSG members I was struck by one of the comments. It said something like 'Compass Points was full of stuff I've already read on the net - is this typical?'. This is a fair criticism and I feel that I should answer it, and make the CSG's editorial position clear. We feel that most readers of this journal do not have Internet access, although obviously the number who do is increasing all the time. Thus the Editor will reprint news items or discussions that he thinks will be of general interest to keep the non-netted informed. Obviously this can annoy those who are netted and have already read such items, so a balance must be struck. In general all major articles have not been published elsewhere previously, but letters,

discussions, and snippets may well have been. From next issue we will start to use a 'net' icon to show previously-published information. I hope this is a sensible compromise for the time being - please write if you have a significant opinion on the subject.

July Field Meet (not in March or June!)

Well, some of you will have noticed that I muddled the waters even more last issue by getting the date of the Field Meet wrong in this 'contents' section, but right in the display Ad. I can only apologise, and make clear that the meet is the weekend 12th -13th July.

Numbers are looking good with plenty of beginners coming to learn to survey (including a few of the Cave Radio Group). There is also a good smattering of rigging volunteers for Leck Fell to make life easier for the surveyors. Imperial College CC are hoping to bring along a helmet-mounted laser surveyor to play with if they can extract it from the manufacturers in time. It should be an jolly weekend.

See you there!

Suunto instruments from Viking

Wookey

As you know the CSG has an account with Viking Optical, the people who distribute Suunto instruments in the UK. This is a non-profit exercise to enable surveyors and expeditions to buy or refurbish instruments at cost price. This year's prices for instruments are:

Prices all inc. VAT, ex. postage:

	Standard	Drain holes	Tritium	Light
PM-5/360 clino	£ 86 (PC)	£ 96 (PC)	£ 101 (PCT)	£ 107 (PCB)
KB-14/360 compass	£ 68	£ 77	£ 88 (RT)	£ 94 (B)

The letters in brackets are the suffix letters to indicate the type required. Note that there is no special suffix for the drain-hole-equipped models, so if you want those you need to say so. All the above have the compass marking in 360 degrees (no back-bearings), and clinos in percent and degrees. There are other options available - ask me for details.

Rubber covers (included with PCB model) are 5.50 each (choice of yellow or black).

For compasses you need to state where in the world you intend to use them so that they are properly balanced for the area. Fortunately most of the northern hemisphere is 'group 1', so you generally only have a problem if going to Africa, south America or somewhere else exotic

BCRA Cave Surveying Group, Compass Points 16, June 1997

If you already have instruments but they aren't working properly anymore (sticky, illegible, smashed) there is the option of repair, which is generally much better value than new instruments. The capsule containing the actual compass or clino is usually replaced, although in a really bad case the viewing lens can also be replaced. So far, only The Red Rose have managed to produce instruments which are so far gone that Viking have thrown up their hands in despair, pointing out that one of them was over 20 years old and definitely shagged! In this case part-exchange prices are offered.

Repairs (replaced capsule) cost:

	Standard	Tritium
PM-5 clino	£ 57	£ 70
KB-14 compass	£ 46	£ 59

If you are spending more than GBP100 then postage will be 4 quid. Otherwise 8 quid.

Cheques payable to 'Wookey'.

Note that this is offered as service to surveyors - I am not making money here, just work for myself. So there's no money-back guarantees, swapping bits if you got the wrong thing etc., and if things get lost in the post that's tough. If you are worried, ask me to send things registered.

If you aren't sure what you need then ask me first.

SNIPPETS

UIS Conference approaches

This is the last issue of compass points before the UIS conference in Switzerland. The CSG will be well-represented with at least 2 members there, and a couple of papers. We will also be holding up the British end at the UIS symbols meeting and the follow-on symposia for surveyors and survey software programmers.

If anyone wants their surveys displayed then see CP15 for details. Wookey or Andy Atkinson can transport surveys to the conference and hang them up.

Helmet mounted Total Surveyor

Mark Minton

I received an information package from the manufacturer, MDL Technologies of Houston, Texas, on the helmet-mounted total surveyor I saw advertised recently in "Professional Surveyor" magazine.

As I suspected it is one pricey item, going for a whopping \$8,500 including helmet but without any of the options like a portable computer or a night vision monocular (which might be pretty handy

for caving!). They do have a rental program at \$45-60 per day depending on length of time you want it.

I guess we won't be seeing many of these underground in the near future.

There doesn't appear to be a web page for this company, but they do have email: dlorimer@mdlh.com.

According to the spec sheet for this new system, it only weighs 4 lb. (2 kg) and appears to be about 6 inches long, 4 inches high, and an inch and a half thick (actual dimensions weren't given). It will operate at temperatures from 14 - 122 F (-10 - 50 C), and is water and dust resistant to IP66 [*waterproof, but not submersible - Ed.*]. It is accurate to 0.1 m at 50 m (200 m range without use of a target reflector), 0.25 deg inclination, and 0.5 deg compass. Measurement time is 0.5 second. Power is a 9-v battery; battery life not given. Overall this sounds like a pretty good system!

Press Roundup

Le Clinometre Electronique au Laser, Paul de BIE: Bulletin de l'UBS, 1995 issue 21, pp 15-17, in French.

This Belgian article describes how a Bosch electronic spirit level (the DNM6) was combined with a laser pen to produce a rather upmarket clinometer. Cost of the two devices 3730 +2000 Belgian Francs (plus tax), which comes to about £110.

Basically the ends of the spirit level were cut off, leaving the centre 17.5cm portion containing the sensor and electronics. Then the laser pen is sat in a handy channel on the top of the instrument, and held in place by a couple of cable clips. The LCD panel is protected by a piece of transparent plastic held on with tape. The device has a memory button, which you push as soon as the laser is on-station.

The advantages are that the clino can be comfortably read in front of your face, and survey stations can be anywhere within reach, as opposed to having to be possible to get your head up against to sight. Accuracy is +/-0.3 degrees, and the device will survive a drop of 10m.

The disadvantages are: it's big and heavy, the battery compartments aren't waterproof, the batteries (9V for the clino, 2 AAs for the laser pen) can go flat. Also you need to keep the clino approximately vertical otherwise the answers will not be accurate (you will get a 1 degree error if the instrument is tipped 35 degrees to one side), and the plus/minus indication is confusing as it is given by an up or down LCD arrow, which swaps at 45 degrees as well as 0! The laser is also class IIIa which means you need to be careful not to point it in peoples' eyes.

Loops done with the device had tiny vertical errors - a test loop of 98m has errors of X=13cm, Y=11cm, Z=0cm. It was also quicker. The device can also be used outside in the daylight, having a range of 50m or so.

Software Updates

A quiet quarter this time. The only update I know of is that Survex has had it's UNIX (X-windows) graphics portion (Xcaverot) brought

up to date, thanks to John Pybus, and the European compass web-pages have been updated.

Letters

Bryan M. Ellis.

Reactions to some recent items published in 'Compass Points' (and a couple that weren't)

Cave surveyors, like most specialists/enthusiasts get carried away with their subject and I, in my time, have been as guilty as the rest of them. The last few issues of 'Compass Points' have shown this particularly well. In fact, in the past cave surveyors have been likened to the apocryphal Jesuits discussing how many angels could balance on the point of a needle. In our case who, except for a few other surveyors, really cares? (Not about the needle point question but about the 'finer points' of cave surveying). Certainly neither the non-cave surveyor nor the survey user.

1. The draft UIS Cave Survey symbols. I have not changed by views on this since the meeting of the Mendip Cave Survey Colloquium in August 1963! The recommendation from that meeting was further refined in my book, 'Surveying Caves' and repeated in 'An Introduction to Cave Surveying'. Those who try to establish such sets of standards, from Arthur Butcher in 1950 to the current proposals, always seem to want to establish a symbol for every conceivable feature. Many of these (e.g. avens in the roof of a passage) are unnecessary if the surveyor produces both a plan and sections, as he should; a glance at a different view and they will become apparent. Others occur so infrequently that there is no need for a standardised symbol.

By all means have a standard list of symbols for those features that appear very frequently and on virtually every survey; but this will be quite a short list. Other features can be denoted by a description in words or, if they appear frequently enough, by symbols devised by the surveyor. (If it is thought necessary to devise a new symbol the surveyor should consult the earlier works...on cave surveying to see if they include a suitable symbol.) Those two sentences were published twenty years ago in 'Surveying Caves' (page 24), and I have seen no reason to change my mind since then. Remember, the detail included on a survey is for the benefit of the general caver; a specialist will not (or should not) trust scientific data put there by the surveyor - he will want to check it for himself. Finally, if a list of symbols is short there is a good chance that it will soon be learnt by heart and used but if it isn't, well...

2. BCRA Survey Grade Definitions. Here, in the same issue of 'Compass Points', we have a second example of surveyors letting themselves get carried away by detail that is of little (if any) value or interest to anyone but fellow surveyors, certainly not to the normal survey user. To be fair, Ken Grimes did make this point in his contribution.

What amazed me was all the discussion that went on about the basic question, "what was actually meant by the wording of the BCRA survey definitions?" Didn't it strike any of those concerned to consult the originator of the definitions, the person who put into words the views of the many British cave surveyors who were

consulted at that time. I can tell you that even if they did think about it they didn't carry it out. If they didn't know who it was but had consulted the earlier literature (I am continually amazed at the number who fail to do this) they would have found that it was first published in 'CRG Newsletter', No. 132, pp 15-17 (Jan 1973) and that it appeared above my name. The wording was changed slightly when first published by BCRA, which was in 'Surveying Caves'. Wouldn't it have been easier, quicker and probably better to have consulted the horse's mouth? Maybe I'm not yet on E-mail but there are still a number of us outside it (about 90% of the population I believe). I can easily be contacted by Royal Mail or telephone, the address and number are on the back of your BCRA membership card!

Now for some comments from the person who did compile those definitions. Bob Thrun was absolutely right when he wrote, **THEY MEAN WHAT THEY SAY**. The angles in the horizontal and vertical planes are to be **ACCURATE** (bold capital letters were used in 'Surveying Caves' specifically to emphasise this point) to within one degree; it's the mathematicians who have introduced concepts of standard deviations, etc. Nothing about hoping that they fall within that quoted range, or that the average is within it - they are to be that close to the real value and that means ensuring that magnetic variations, compass calibration and so on are all taken into account. Yes, it's a tough standard to achieve and too many surveyors don't go more than a little way towards even trying to achieve it, and then still claim the grade. This, I believe, is particularly true of 'expedition surveyors' - I find it difficult to believe that in the time available they can manage to survey the distances they do at the grade they claim, at least by my understanding of the grades. The original definitions were based primarily on practical rather than mathematical considerations though they were compared with actual results to see what had been obtained in practice. It will be seen that the philosophy of the Australian Speleological Federation, as quoted, is very different from that of the BCRA system; I wonder whether they realise that or not.

I am prepared to be shown (but if the proof is mathematical I probably won't understand it!) that it may not be practical to achieve the BCRA definition; what I have done is explain the original thinking. I believe that if you forget the maths and at least do the best possible towards achieving what the definition (not forgetting the accompanying notes) actually says then that is what was meant.

When it says that the angles are accurate to plus or minus one degree why does someone assume that this "simply meant that you read the compass to the nearest degree"? It doesn't say that at all and to encompass (apologies for the pun) this type of reading it would, at a guess, only require a definition something like "accurate to plus or minus five degrees" to compensate for magnetic variations, if nothing else. If he had read the table "and the notes that must always accompany it" he would have seen that the difference between accuracy and precision was appreciated by the author and was even explained. This was done because it was significant - not simply to show how clever he is.

However, I do agree with the statement that follows, namely "most cavers are NOT concerned about the details of statistical accuracy...". I'm also intrigued to know what the Australians mean

by a calibrated compass? Hopefully not just that one must use a liquid filled prismatic. This would be very far from what is required by the BCRA scheme because instrument calibration is an important subject of its own.

Well done that man who ended up by saying, "...the BCRA grades mean exactly what they say." But then he has read at least some of the earlier works on the subject as he knows about the important paper by Denis Warburton that started all these discussions on probable accuracy and was published way back in 1963! How many of the others have ever read it I wonder.

As already said, I am prepared to be convinced that "the BCRA accuracy estimates are overly optimistic" but in my day we didn't know any better. What is the true picture? Please tell the rest of us so that it can be sorted out.

3. The Ogof Draenen Survey. This goes back even further to 'Compass Points' No 12 and has much in common (in one sense) with my previous topic. It was extremely gratifying to read how the Chelsea Speleo Society surveyors coped with the organisation of their task in surveying Ogof Draenen; gratifying because it was obvious that, unlike virtually all other cave surveyors, they have taken the BCRA survey grades and applied them in both the letter and the spirit - just as 'An Introduction to Cave Surveying' tells you. If only the theoreticians referred to in the previous section had remembered back those two issues to the article by John Stevens (a practical surveyor) they would have had help with the answers to their questions - but I suppose they weren't to know that this was the case. It was this taking of the full spirit of the grade definitions for the Draenen survey that was a major factor in them receiving the Arthur Butcher Cave Surveying Award in 1996 - that I do know. Congratulations to them all.

4. The Distribution of Cave Surveying Errors. I have touched on this subject in two of the above topics. Can one of those mathematicians assure me of the following. Given that the magnetic compass is a relatively inaccurate method of determining direction in the horizontal plane, not only due to systematic and random errors, etc. but also to the relatively rapid (at times) variations in direction of the magnetic field itself, does any mathematical method of distributing errors along a survey traverse really guarantee that the amended figures are significantly closer to the TRUE figures than any other method? Surely, they are still only estimates as to what may be the true answer.

Secondly, do they (the mathematicians) take into account points such as variation of magnetic declination, variations between instruments and the like? These are not mistakes (or blunders as the Americans like to call them) but are still likely to be more significant than random errors, hence the emphasis placed on proper instrument calibration. Again, it's all described in 'An Introduction to Cave Surveying'.

Thirdly, are the differences significant in themselves when one considers the very low accuracy of cave surveys as a whole (even assuming that all surveyors took every effort to be as accurate as possible) and the small scale at which most surveys are published?

No matter what the mathematicians may prove, examination of practical results shows that one can expect a probable error of between 0.5% and 2% depending on the traverse length so unless the traverse is very short surely what has been discussed is of little practical value to the survey user.

If the answers to any of my questions is "No", then surely the only benefit of all the discussions that have taken place has been the satisfaction of those taking part!

(Some time ago I tried apportioning a closure error around a traverse by a number of simple criteria, e.g. proportional to the leg length, equal on each leg, and so on. The variation between them was almost indistinguishable, even when the survey was drawn at a large scale. Perhaps it comes down to accumulative errors.)

Who's going to put me, and all the others like me, right on these points?

5. 'An Introduction to Cave Surveying'. I couldn't help wondering whether those who have been discussing the survey grades have even read this booklet which describes them in some detail. It is still in print, is the only British publication on the subject and costs a mere £2.50 (plus 30 pence UK, 50 pence overseas, postage). I am sure you can guess where to write, if not it is again a case of looking on the back of your BCRA membership card.

But this does lead me on to my final point. There are less than 200 copies of the booklet remaining in stock which raises the question of a new printing as it has a good steady sale both in the United Kingdom and overseas. Does anyone feel like writing a new edition? (But if you do think about it, it is important to remember its title, especially the words 'Introduction to', and also its length which cannot be increased.) I am not at this stage interested in a learned treatise of some advanced aspect of cave surveying - that is another matter.

Unless someone thinks they can improve the complete text (probably not much of a challenge) I shall revise it myself and would be grateful to receive comments on what ought to be changed or added. But again, remember those two words in the title, 'Introduction to'.

On a related topic, has anyone contemplated writing a comprehensive manual on cave surveying? If they did, one problem would be getting it published because the potential sales would be so (relatively) small and these days BCRA does not have the capital available to provide much help. A more practical answer might be to publish a series of booklets on various aspects/topics of surveying, perhaps following the 'Introduction'. Do we have any members interested in practical surveying? (It doesn't seem like it at present but then I fully appreciate that the editor can only publish what is submitted to him.) OK, calm down. Titles dealing with theory and post-survey techniques could also be included. Either way, comments and ideas would be welcomed either in 'Compass Points' or in the form of a letter direct to me.

By the way, those were not hypothetical questions that I raised. So that they could be incorporated in any rewrite of 'An Introduction to Cave Surveying', I would genuinely like to know the answers, if the experts can agree, to the questions:-

a) are the requirements for a BCRA grade 5 survey as stated impractical (or impossible)?

b) do any of the various methods of distributing a traverse error make a significant improvement to the ACCURACY of the finished survey and, if so, is it worth the effort? Which is the quickest to use, which is the best?

Having hopefully made a few people think, I can now crawl back into my hole, not to survey it but to go back to sleep.

Reply from the Editor: Bryan makes a very good point about people not often enough referring back to original documents, although in fact I know that most of those discussion the BCRA grades had read both Surveying Caves, and An Introduction to Cave Surveying. Nevertheless the article would have been much enhanced by a contribution 'from the horse's mouth' at the time of publication, and I will endeavour not to fall into that trap again.

Whilst I understand what Bryan is saying about the Grade definition meaning 'exactly what it says - i.e. readings must be accurate to 1 degree', I think the problem is that you can't meaningfully make such a simple statement in the real world, and hence the discussion. Most of the readings are going to be more accurate than this, and some are going to be less accurate. In order to properly define what is happening we need to know how many readings are in each group. This is the nature or both statistics and the real world, and definitions should allow for this. Analysis of existing data sets is useful in this context to answer both this question, and Bryan's about what is actually attainable. I too, would like to see further elucidation from those with a proper understanding of statistics, as well as relevant analyses of existing survey data.

GPS12XL Review

The development of GPS units continues apace. They are rapidly getting cheaper and better. Wookey takes a look at the latest offering from Garmin.

Wookey

Finally the temptation became too much for me and in April I coughed up the necessary and bought a GPS, in preparation for a recce trip to Greece. I picked the GPS12XL as, like all Garmin units it is well-supported by free software, and I knew I liked its forerunner the GPS45. [reviewed in CP11 pp7-9]. I bought it in the US just after it came out and paid £223. They are now available here for £205, from Lowe Electronics <http://www.lowe.co.uk/> (they are also radio specialists), and for \$250 in the US.

12-channel receiver

The main difference between the GPS12XL and the GPS45 is the new 'Phase-trac' 12-channel receiver. This is much faster and somewhat more accurate than the 5-channel multiplexing receiver in the GPS45. This means that doing a 'warm start' (where you haven't moved more than 100 miles and more than an hour hasn't elapsed with the unit switched off) it takes less than 15 seconds to acquire

and get a fix, a cold start 45 seconds, and an autolocate 5 minutes. This is more than twice as fast as the GPS45 and it really does make a difference as you can just turn it on for a few seconds every half hour to keep track of where you are. The other advantage of the more sensitive receiver is that even without the little quad helix aerial of the GPS45 it is much better at getting and keeping a lock in marginal conditions - that means inside the car, around tall cliffs or buildings, or under tree cover. It will generally work on the passenger seat, as opposed to needing to sit on the dash, and I even got a fix with it sat on the arm of the sofa, about a meter from a medium-sized window! There is an MCX (small co-ax) connector for an external aerial should you need it, although it would only be necessary if you wanted to put the unit somewhere very out of the way (inside a building or boat).

Firmware changes

The other noticeable difference is a selection of improvements in the firmware. Some of these are also available in the intermediate GPS45XL and GPS38 models. There are lots of small changes to improve the interface and use such as a different track-screen with a compass rose rather than a road/horizon which is easier to understand, especially for walking/driving as opposed to sailing. It can now do averaging automatically, saving you from doing post-processing on the data, (as described in CP15); whilst doing this it displays a continuous estimate of the error so far. You also get a general error estimate, which makes it very obvious when SA has been turned off, as your errors drop from a typical 40m to 5m (this happened a few weeks ago, curiously coinciding with the search for a missing A10 bomber in the US! There is also 'EZ-init' which pops up a menu by country if it can't get a lock quickly, in case you have moved it to the other side of the world. You just tell it that you are in 'UK-Scotland', for example, and it will acquire much faster than if it has to search the whole globe to work out where it is.

The logging facility can be set to log with an 'automatic' interval, so it just records points where there is a significant change in speed or direction. This provides an accurate log of your route with the minimum number of points. The waypoint log has been expanded to 500 points, and track log to 1024 points, you can also put long comments in instead of keeping the time and date of the point if you like. Another useful feature is 'trackback' which converts your current track log data to a set of waypoints as a route, so that you can easily reverse it. Finally the annoying 99-knot software speed-limit has been removed so you can at last use it in your plane! I did manage to hold it by the window for a bit on the return flight from Greece and found out that we were doing 752kmh at 12,050m (470mph at 39,100ft).

All these small improvements amount to a significant improvement in the software. It is still being developed as the first models (including mine) have v2.00 which has a minor bug entering waypoints using the UK grid (the display goes a bit peculiar around the digits you are entering). Fortunately the unit has a flash ROM so it is easy to take to a dealer/Garmin UK for an upgrade. They will fix this particular problem for free if you are using it in the UK. The newest units have v2.02 firmware.

Power and interface

The only thing which is not as good as the GPS45 is the power consumption which is about 20% higher due to the better receiver, so you only get about 10-12 hours from a set of alkalines, and 5-6 from nicads. Building an external cable for use in the car or from your caving light is very worthwhile. You can buy the special connector as 'shareware' from Purple Computing. The alternative is paying Garmin £20 for a cable with a suitable connector on the end. The purple computing connectors are fine, but are sold in a fairly radical manner. You pledge to pay whatever amount you think fit and ask your local 'pfranc' (Purple franchisee) to send you the connector. Then you send the money back - most odd, but it works and is cheap. Angus Pinkerton (of hang-gliding fame) is the UK pfranc.

So what's it like in use? Well the improved sensitivity and acquisition speed over the GPS45 is the thing you really notice. I used it in the pouring rain in a wooded canyon in Greece, which gave no problems, and even in the bottom of the 500m deep, sheer-sided Vikos gorge I could get a fix about half the time. It also works very well inside the car, although the cloth roof of a Seat Marbella was not a very difficult test!

A GPS is one of those things that you think you have no use for until you get one. Suddenly there are loads of occasions when you could really do with knowing where you are, which way you are going, and how fast. It stopped us getting completely lost on a rally, and was useful for navigating from the airport to the ferry on Corfu, as well as important things like marking the positions of caves.

Other units

There are a number of other units on market with similar performance but different features. Lowrance make the Eagle Accunav which has received excellent reviews and is a bit cheaper. The only problem is the lack of software support for it, although that may change. Garmin have also just released the GPS II+ which looks a bit like a block of wide Toblerone and has the handy ability to be used either on a surface on its side, or upright in the hand, like all the previous units. The display switches from landscape to portrait at the push of a button! Otherwise it is much like the GPS12XL, although apparently missing the important (for cavers) averaging function.

How to Create Evenly Spaced Tick Marks in AutoCAD 12

Reno Lippold

I'll attempt describe how to make "tick marks" along a line, a group of line segments (a "polyline"), or a curve (curved polyline, arc, or circle), using the AutoCAD version 12 "Divide" command. I believe the technical surveyor's term for tick marks in the United States is "hatchers". I'm talking about a series of short line segments, normally drawn perpendicular to another line or curve. I've seen them used to signify pits or sunken areas on US Geological Survey (USGS) and other maps. On caving maps, they are used commonly to show pits or sinkholes (tick marks on the inside of a circle or region), domes or chimneys (tick marks on the outside), or a sudden drop (tick marks along the edge, pointing in the direction of the drop). The technique presented here can be used to place any type of

drawn object along a line or curve at periodic intervals. Other CAD software packages may have something similar to the AutoCAD "Divide" command.

Lets me use a hypothetical example to illustrate the procedure. Let's say you want to draw a symbol for a pit which is roughly round with a diameter of about 20 meters. You must visualise and decide how long (scaled on the drawing) you want your tick marks and how you want them spaced along the pit edge. For this pit and map, you decide you want to use 1 meter tick marks and space them about 5 meters apart.

Now that you have decided the size and spacing, you must create your tick marks and store them as "blocks" in your drawing database for future use.

1. Draw a line segment 1 meter in length vertically on the screen (in the Y direction).
2. Turn it into a block by using the "block" command.
 - 2.1 Using my method, you will need to store a different line segment for inside and outside tick marks, and you may want to later create and store other tick marks of different length; so give the block you are creating now a name like tick-1m-inside
 - 2.2 For an insertion point, pick the top endpoint of the line segment.
 - 2.3 Select the line segment when it asks you to select objects.
3. Now repeat the procedure, only select the bottom end point of the 1 meter line segment, and call this block tick-1m-outside

Now you are ready to create your tick marked pit symbol.

1. First create the outline (or edge) of the pit. Draw it in a clockwise manner. Use a "polyline" to draw this edge so that the entire edge is one entity. (If you draw the edge counter clockwise, you will get outside tick marks when you use the inside named tick mark block.)
2. If you want to smooth the closed polyline you just created, do so now using the polyline edit command -- "pedit" and the subcomands "fit" or "spline".
3. Now you need to determine how many tick marks you want to apply to the inside of your pit edge.
 - 3.1 You need to know the length or perimeter of the object to which you want to apply tick marks. This can be had several ways. For a closed figure like our pit edge, the "Area" command, with the "Entity" subcommand, works well, giving the area and the perimeter distance.
 - 3.2 Lets say the perimeter of our pit edge is 61.3 meters. If you want tick marks about every 5 meters, then take 61.3 and divide by 5 and round the result.

$$61.3 / 5 = 12.26$$

So we will need 12 or 13 tick marks to get an approximate 5 meter spacing. You decide to use 12.

OK, now that you have the number of tick marks determined, it is time to insert them. I will illustrate the procedure here more exactly by showing the AutoCAD command line prompts and your inputs. Your typed inputs are in all CAPITALS.

- Command: DIVIDE {enter}
- Select the object to divide: (select the pit perimeter -- the polyline)
- <Number of segments>/Block: BLOCK {enter}
- Block name to insert: TICK-1M-INSIDE {enter}
- Align blocks with object? <Y> {enter}
- Number of segments: 12 {enter}

You should have your tick marks now, all perpendicular to, and on the inside of, the pit edge. Sometimes AutoCAD inserts one less than the number of tick marks you entered above. If it does this, it leaves a gap at the point where you started (and ended) the polyline. In this case, you will need to add one tick mark here manually. (If you break the code and find out why it does this sometimes, let me know.) You may have to change a couple of tick marks if your pit edge has some sharp corners in it. (This technique works best if you have obtuse angles or large radius curves.) If you want the tick marks on the outside of the pit edge (or on the opposite side of a line), you can use the block TICK- 1M-OUTSIDE instead.

This may seem like a lengthy procedure, but you only need to create your tick mark blocks once for the drawing, and if you store them, along with all of your symbols, in a caving map "prototype" drawing, they can be used for future maps as well. Additionally, the actual measurement of the perimeter and calculation of the number of tick marks is optional; you may do just as well by trial and error. That's why there is an "undo" command.

You'll have to decide if this technique is worth the bother. But I sure like the even tick mark spacing, consistent length, and perfect perpendicular orientation you get this way.

There are also a number of other books in the cave studies series, which you may find of interest, all at the same price:

- Caves and Karst of the Yorkshire Dales,
- Caves and Karst of the Peak District,
- An Introduction to Cave Photography,
- An Introduction to British Limestone Karst Environments,
- A Dictionary of Karst and Caves.

Introduction to Cave Surveying -

Cave Studies Series No.2

A handbook for the beginner and *aide memoire* for the experienced; by Bryan Ellis (1988) ISBN 0 900265 04 3, A5 format

As pointed out by Bryan in his letter in this issue - this is an invaluable little book. If you are a surveyor and haven't got a copy then you really ought to get one.

Price, including UK postage is £2.80 , outside the UK the price is £3.00.

To Order: Cash with order, payment in Stirling to BCRA, include your name and address and the book title. Send this to:

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B.C.R.A Cave Surveying Group

Field Meeting

on 11th, 12th and 13th July 1997

at Red Rose Cave & Pothole Club

Bull Pot Farm, Casterton Fell

It is intended at this field meeting to try and fix the locations of entrances connected to the Three Counties System on Leck Fell or in the Kingsdale valley using theodolites, plotting these surveys using Survox on return to the farm in the evening and discussing any abnormalities with the current maps and guide books. There will also be the chance to do some underground surveying or rigging in Lost Johns and Notts Pot, and a workshop to show both beginners and experienced members the best way to eliminate errors in surveying which only really come to light when you have multiple entrances and many small and large loop closures.

The accommodation will be at Bull Pot Farm on Casterton Fell in North Yorkshire. This is the club hut of the Red Rose Cave & Pothole Club and is ideally situated for exploring the Three Counties System, (the nearest entrance is virtually in their back garden). It is Standard hostel accommodation with alpine style bunks and a self catering kitchen although there are many excellent pubs providing food in the area. The club has a well stocked beer cellar and the late night revelries are second to none!! Cost is £2.50 per person per night, i.e. £5 for the weekend.

Novice surveyors are particularly welcome on this meet, with a surveying workshop giving the basic techniques, and some practice and useful tips from the more experienced members. There will also be the opportunity to try out the available range of surveying software, and see some ideas currently under development, and finally a discussion on methods of marking survey stations underground.

For Further Information please contact:

Pete Grant, GreenFoot Barn, Greenfoot, Bentham, Lancaster, LA2 7EQ Tel: 015242 62269

You can also book via the CSG's web pages <http://sat.dundee.ac.uk/~arb/CSG.html>

Surveying Underwater Caves

John Cordingley

"Mastery of diving technique will enable a caver not only to reach new territory above the water table, but also will enable him to study the submerged intermediate regions. Thus ... his field has been extended to include the underwater complement to all the activities of the above water caver and speleologist. He will in time ... survey, photograph and sketch them underwater, he will study the geological and morphological structures and relationships, the physical phenomena, the fauna and the flora, in the new environment."

(F.G.Balcombe, 1952)

Introduction

The purpose of this short article is not to teach readers of *Compass Points* how to perform a cave diving survey. However, a knowledge of how surveys are made in submerged sections of cave passage, including the limitations and advantages of the methods

employed, should help provide an understanding what cave divers have to offer. Having spent around 20 years surveying in many of our northern sumps I was recently asked to "write something" for this publication, so what follows is really Pete Grant's fault!

Basic Technique

The number one concern whilst hundreds of metres into a submerged cave is of course actually staying alive. Arriving back at the dive base with a coherent set of numbers is often very definitely a bonus! For this reason the C.D.G. developed a simple method of data collection several decades ago which is still in widespread use today. The technique is well described in references (1), (2) & (3) below. In summary, the diving line laid during exploration would normally have been tagged at regular intervals before being loaded onto the reel. On the return swim to base the diver records the compass bearing along the newly laid line between each belay point, together with an estimate of the distance (based on the tag intervals) and the depth (by depth gauge) at each belay point. The belay points are thus the survey stations. With this technique misclosures in the order of 5% should be fairly easy to achieve, with practice.

Errors

There are many factors inherent in using survey instruments underwater which can reduce accuracy. Reading a diving compass with 5 degree graduations, perhaps in poor visibility, when held roughly against a slack line is perhaps the main source of error (4). Added to this is the problem of localised disturbances of the earth's magnetic field due to the proximity of magnetic materials (e.g. steel cylinders, knives, regulator components etc.) or the fields which are created by powerful diving lights. Distance errors can also be significant; unless the tags happen to coincide with the belays the diver will have to estimate line lengths (often counting arm lengths as individual metres). To make things worse it is known that synthetic diving lines sometimes shrink by as much as 10% and some line might need to be used up in wrapping it round flakes when belaying. The depth errors will be much less significant as these are simply read directly from a gauge, although individual instruments commonly misread by up to 2%. In a shallow sump this error is therefore less significant than in a deep sump.

Advantages

Despite the comments above there are actually several reasons why certain aspects of an underwater survey might be more accurate than those made by dry cavers. For example levelling errors are not transferred to all subsequent stations as would be the case in a conventional survey using a clinometer. Many divers now take depth readings from submersible computers, which are accurate to within 10 cm. Indeed a diver's survey will always show (obviously) that one end of a sump is at the same level as the other - how many dry cave surveys can genuinely claim this? One is reminded of the occasion when the downstream sump in Yorkshire's Pippikin Pot ("known" from the cave survey to be at resurgence level) was passed only to find the water crashing down another pitch! Many dive computers can also download a dive profile onto a P.C. screen (eliminating errors made whilst reading or recording data underwater and also the 'exaggeration factor') and in a big passage they are accurate enough to swim from roof to floor and obtain the passage height by subtraction.

There are also methods which greatly improve the directional and distance accuracies (see below). Indeed, the common approach to the frequent problem of misclosures involving a section of sumped passage (to assume that the dry survey is right and distribute all the errors through the flooded part) demonstrates a tragic lack of understanding - and is really why this article is being written. It is also worth pointing out that the increasingly common use of nitrox or helium based breathing mixtures can be helpful in eliminating human errors caused by inert gas narcosis on deeper dives.

Special Underwater Surveying Methods

Where a need exists for a higher than normal level of accuracy then a slightly more time consuming technique has been devised. This has the disadvantage of requiring more equipment than that carried by any (safe) diver on a normal exploration. However the errors are significantly minimised and given that divers can now stay submerged in comfort for many hours (with the advent of big cylinders and drysuits etc.) it is the method of choice where producing a really good survey is the main aim of a diving project. One experiment using this method took place at Keld Head in Yorkshire a few years ago (5). A natural loop 115m long exists near the entrance and the misclosure achieved here was 1.92m (i.e. 1.7%) - see Figure 2. Directional errors were minimised by screwing a compass to an A4 sided dive slate. This gave the advantages of a longer straight edge to hold against the line and also exactly fitted a photocopier so that a permanent record of the original notes can be kept. The leg lengths were measured with a Fibron surveying tape fitted with a couple of clothes pegs. These were attached to the line at a station then the distance was measured to the subsequent station before the tape was yanked off and reeled in each time (thus avoiding having to swim backwards and forwards!).

Figure 2 - Results of a survey around the entrance loop of Keld Head

Electronic Methods

Apart from the widespread use of dive computers (the main reason for which is to allow safer decompression schedules) electronic sump surveying devices are really in their infancy. Submersible radio location units such as the 'Molefone' have proved invaluable on occasions to check or improve on conventional divers' surveys. One attempt was made in the 80's to produce an electronic sump survey device (as an undergraduate project) but which unfortunately only reached the prototype stage (6). The diver still had to count the tags on the line but the unit automatically recorded the station number, bearing, 'dip', depth, distance to walls, roof & floor and water temperature, each time the button was pressed. Another useful device is the 'sonic wand' (7). This contains a tiny echo sounder which was developed for producing three dimensional representations of large underwater voids. By taking several readings horizontally at regular intervals down a vertical shotline the deep flooded chambers of Pridhamsleigh Cavern have been electronically mapped, slice by slice. Cavers are also currently experimenting with a device which gives out a 360 degree "fan" of laser beams which can produce very accurate cross sections (8) and it is only a matter of time before this kind of technique is adapted for deployment underwater. The use of GPS in certain circumstances might be contemplated by cavers. A helmet mounted unit incorporating a head up display is already available (9) which might perhaps be made waterproof. Within the next few years reliance on a cheap diving compass and a tatty piece of old string with bits of insulation tape on may be a thing of the past!

Underwater Survey Symbols

This is one area where discussion is long overdue. The current debate aimed at standardising dry cave symbols under the U.I.S. banner must not ignore underwater passages. The traditional symbols for deep water and sumped passage ironically reflects most cavers attitude that whatever lies below is too horrible ever to contemplate trying to portray on a drawing! However, most of the features found above water exist in sumps, e.g. sediments (of assorted particle sizes), joints and bedding planes, large isolated boulders, and even speleothems! One symbol which isn't needed is that which indicates a draught, but direction of water flow and indeed layering of water masses are well worth including. There is a huge range of interesting information which divers can collect and which should be portrayed on the final drawing; clearly this would be obscured if we stick to the old fashioned "crossing out" symbol.

I sincerely hope that those who must make decisions about an agreed set of international symbols will bear the above thoughts in mind.

Summary

Cave divers have the ability to produce huge amounts of useful data and information about submerged sections of cave passages. To consider their efforts as second rate, compared with conventional cave surveys, is to misunderstand the value of what they can offer. The best approach is to work closely with the divers involved and understand the limitations and possible advantages of their methods as an aid to meaningful error distribution. Only by doing this can the best representation of a complete cave system be achieved.

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- (3) Balcombe, F.G. et al, 1990, "Underwater Cave Surveying", Cave Diving, The Cave Diving Group Manual, (Mendip Publishing), pp.191 - 196.
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Cave Visualisation using VRML

A number of people have been looking at the possibilities of using Virtual Reality Markup Language (VRML) as a basis for 3D cave visualisation. The current state of research and some relevant findings and techniques are detailed here.

Wookey

If you follow computing hype you are likely to have heard of some or all of the following: VRML, Web Browsers, 3D video cards, DirectX, and Virtual Reality. All these new technologies are not just hype and actually have something to offer the cave surveyor.; they help to make complete 3D cave models a practical possibility.

First the Surveying background: We are all used to the now-standard centreline model that is produced by all modern cave-surveying software, but seeing this, especially on a viewer that lets you spin and zoom the cave quickly to get a better understanding of the relationship of passages, we all want more. We want to see the passages drawn in full, not just a line that passes somewhere inside them. This would make the larger passages and chambers more visually significant, sort out some problems of depth as things would be obviously 'behind' or 'in front', and give even better understanding of the relationships of passages and geology. Some existing survey packages go some way towards this goal by displaying a square or octagonal wireframe model, and a few even tackle some of the harder issues like the internal and hidden line removal of Toporobot, and the 'shaded polygon' display of Compass which gives an impression of 3D by filling in the wireframe with shaded polygons, lightest to the south, darkest to the north. This is all good stuff, appreciated by users, but is still largely nibbling round the edges of a full solution.

Now the Computing background: The demand for games that people can play on their computers, especially amongst home users, has produced a great deal of work on relevant technologies. A computer generated world you can move around in is called 'Virtual Reality'. Displaying such worlds and updating the display quickly enough to look realistic as the user moves about is very computationally expensive. Thus, to do this on cheap PCs and the like you need all the help you can get. The 3D video card is aimed at this - it provides hardware acceleration for commonly-used graphical elements of such worlds, and for the repeatedly-used maths of calculating angles and viewpoints and lighting sources, in relation to 3D objects. DirectX is a Microsoft-defined mechanism to allow the features of hardware-acceleration on video cards to be used by Windows software, without the software knowing in advance which features are available. There are also related software technologies which make it possible to keep track of which objects are in view, and which are obscured by others and so needn't be drawn, whilst drawing realistic surfaces and still leaving some CPU time leftover to actually run the game (or whatever).

Given the spread of the Web it was inevitable that people would want to use virtual reality over the Internet, so a way was needed to describe 'worlds' that could be accessed by different Web browsers on different computers to produce consistent models that the user could move about in. VRML was the format defined to allow this. It is actually a whole list of text and numbers which is downloaded just like other text over the net, and interpreted by the browser to show a world you can move about in. VRML browsers do a whole lot of very technical work for you like putting in surface textures, calculating lighting positions and thus which bits of the view are shaded etc., and hidden line/surface removal. All of this is stuff you want to leave to graphics experts if you possibly can.

Java doesn't have anything in particular to do with 3D, but is relevant to new cave surveying software. It is a programming language, like C, BASIC, Pascal etc., but it has the significant advantage of being designed in such a way that exactly the same software can be run on different sorts of computers. This is obviously appealing if you are writing a new piece of software so it is proving very popular. As you will see at least two of those working on 3D cave visualisation software has used it. It also has the significant advantage, along with VRML, and the Web browsers which can display it, of being free.

A number of people noticed the above connections and had the same idea - writing software to produce a view of a cave in VRML format, and thus using existing free software to view and move about the cave. All of Alan B Canon, Garry Petrie, Julian Todd, Mike McCombe and Jose Aguilera have done work in this area, and so far as I know they all had their original ideas independently.

Virtual Cave Project

The first example I saw was Alan Canon's work. His 'virtual cave project' was primarily considering the internal view rather than the external view, and used spheres at the stations connected by cylinders along the legs. He drew the textures 'inside out' to get them to appear on the inside of the cylinders, although this tended to confuse browsers, often making the walls appear transparent from the outside. Next I heard Mike McCombe was thinking about extending the concept of his Speleogen software to produce VRML output as well as DXF output. He wrote some experimental software in Java to test the concepts. He initially considered how to get both the internal and external views correct, and if you get inside the walls you can see the bright pink centreline bouncing along inside. He gives his own assessment of his findings below. Unfortunately I can't put an example in here as the VRML browser I have makes a bit of mess of his files and I get a horrible collection of black blobs and missing walls which doesn't really do the software justice! This illustrates a problem with this sort of development which is that the tools are generally fairly immature and bugs and problems crop up all over the place. Different browsers can interpret the same bit of VRML quite differently, for example, and the Java language has a significant number of bugs in it too.

Tunnel - Julian Todd

Meanwhile Julian Todd had some slightly different ideas. He recognised that the difficulty of the problem can be greatly reduced if you decide that you don't care what the internal view looks like, and just worry about getting the external view correct. This allows you to avoid the very difficult problem of calculating the intersections of two or more cylinders (or more complex shapes) at junctions. You just draw all the passages as far as the relevant station, and because they are opaque the shape seen outside is automatically correct, and you save a lot of computing. As he says: 'We know what the inside of caves looks like - we've been there, and the inside of some funny-coloured tubes isn't going to be a very realistic substitute' - what we want to do is get a convincing overview of the cave shape and structure, not wander along inside the passages. He also thought about how best to deal with the problem that decent 3D models require more information than is currently typically collected by surveyors. The centreline plus some LRUD data is not sufficient - you get very 'computery-looking' square passages, which users of Toporobot will be familiar with. Garry Petrie's VRML model of Marmot Cave (Figure 3) is an excellent example of the best sort of result you can get given this amount of data.



Figure 3 Marmot Cave VRML model

Julian's conclusion was that you needed proper cross-sections in the model, and the reason no-one put cross-section in at the moment was that there was no easy way to do so. Typing data into a text-editor is fine for centreline information, but entering co-ordinates for cross-section would obviously be extremely tedious, error-prone and difficult. The answer was to include the cross-section entry as part of the survey-data entry process, using a graphical method. He wrote an application (in Java) to test out this method. The application is called Tunnel, and I will explain some of the thinking behind it, and give you some idea of how it works and what its output looks like here.

The first thing to consider was the data structure necessary to support the addition of cross-section and passage information to the centreline. Each cross section is associated with a station, and has an X,Y,Z offset from that station and two angles of rotation, one in the vertical,

and one in the horizontal. This defines a general plane relative to the station. Each cross-section has an arbitrary number of points. It is joined to other cross-sections by 'tunnels' - i.e. sections of passage. This general format is sufficient to define just about any cave if enough cross-sections are entered. If none are available then LRUD can be used to give a square section of the appropriate size. Another idea was to keep the data format textual, so that it could be edited manually if required, although it would clearly generally be easier to use the graphical interface provided.

When you start Tunnel you are presented with the 'Trip Editor'. Into this you type the usual from, to, tape, compass, clino type information. Once you have done this you ask for the WireFrame view (*Figure 4*) which causes the entered data to be processed to get the centreline. In this wireframe view you can zoom, and rotate (using a 'finger on a globe' method - imagine a ball which spins in whichever direction you move the mouse), or select and edit stations, cross sections or tunnels. You double click on a cross section to edit it, and are placed in a dialog box where you get a circle with nodes top, bottom, left and right. You can drag these around, and add further points until the cross-section is sufficiently realistic. The cross section defaults to being the bisector of the legs before and after it, vertical, and centred on the station; you change these as required. You also mark the 4 primary nodes which mark the top, bottom, left and right, which will be connected by the tunnel to the next cross-section.



Figure 4 Tunnel Trip Editor & WireFrame view

Once this is complete you can switch on the tunnel display and edit the connections if necessary. They default to being the same as the legs, but you can delete sections by clicking on them, and then drag a cross section to any other cross-section to put a tunnel between them (Figure 5 - the lighter-coloured cross-section has just been dragged to its neighbouring destination). Once this is done you can save the survey and export the finished product as VRML. An example of the result is Figure 1 on the front cover. The fact that this is version 0.1 explains the rather odd crossover in the top left-hand branch (visible to bottom right in Figure 5)!

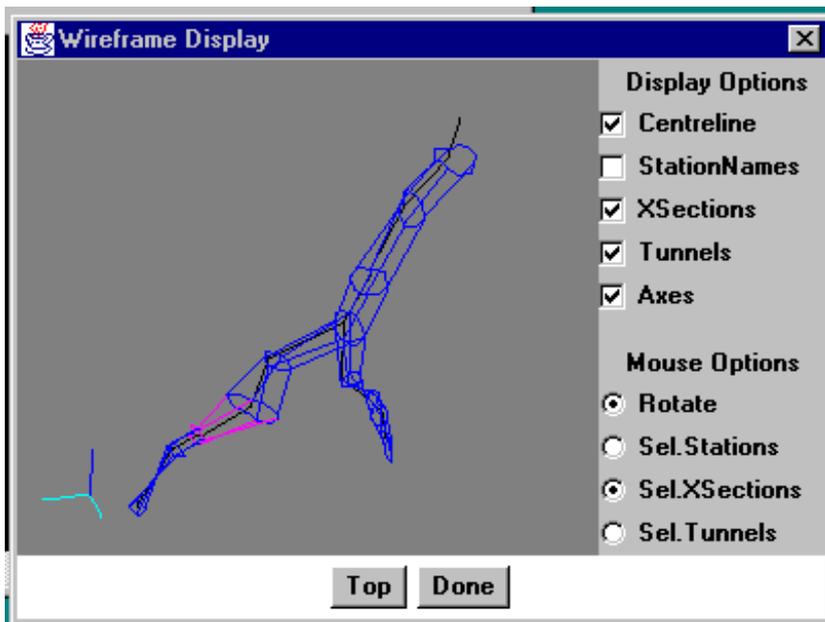


Figure 5 Dragging a cross-section to create a tunnel

Julian is now working on incorporating much of the Survex functionality to create a complete surveying application capable of importing existing Survex data so that we can see how it performs on larger datasets, and just how well it improves visualisation.

Mike McCombe

This is what Mike McCombe had to say about his efforts and findings:

Having realised that VRML had a lot of potential for modelling caves, I decided to write some software, just to explore the concepts and limitations. This takes the "3D" output from Survex and adds passage walls based on LRUD data to make rectangular "box-tube" passage which can be viewed from inside or outside. Surface terrain can also be added using a table of spot-heights. The output was a VRML "world" file which can be viewed using a standard VRML viewer: I found Netscape 3.0 the most successful.

Although the prototype seemed to work reasonably well, the project is currently 'on hold' for a range of reasons:-

1. I'm not sure who would want to use VR in caving and what for. If the aim is to create a good 'external-only' view of a cave to illustrate structure, the solution is probably very different to something designed to give inside views of the cave. In the latter case, technology has some way to go yet before views could be regarded as "realistic".
2. VRML is probably best regarded as a means of "publishing" 3-D objects over the Web. One can imagine that at some point in the future a cave survey might be "published" in this way and viewed on-line, as an adjunct to the inevitable paper print. My prototype seemed to show

that this is not feasible without a lot more work. For example, up to now, we have kept the whole cave in a single file and left it to the browser to discard data which is not in the field of view. For online viewing of anything complex it would be necessary to structure the model into a set of linked files so that the browser only downloads objects that are visible. Likewise, objects which are distant would only be loaded at low resolution. Tools to produce this sort of optimised multi-resolution model from survey data need quite a bit of thinking about. Even when the data is on the local machine, expecting the browser to digest the whole thing in one file has a disastrous impact on performance.

3. I wrote the software in Java because it was convenient and machine-independent. Because the software needs to write files, but this is prohibited within a browser for Internet security reasons, it would need to be re-compiled or re-written in another language before it would be useful to anyone other than another Java developer.

4. Current surveying practice does not record enough information to re-create the complete 3-D model. To cope with the full variety of cave structures such as pitches, junctions and loops within chambers, numerical measurements need to be supplemented by graphical input - typically surveyor's sketches. As yet, there does not seem to be a systematic way of ensuring that all of the essential data is collected or of assimilating it into a model. My feeling is that a VRML project would need to go hand in hand with another on surveying techniques and involve some seriously clever thinking.

Julian's approach is very interesting in that it brings the graphical input step forward in the process but until we have rugged hand-held computers which can be taken underground it seems we will have to rely on a pencil and paper stage. Coming up with a 3-D graphics editor that is suitable for drawing caves is a lot of work and will probably take several iterations to get right. It's important, for example, that the drawn passage shape is taken to be relative to the surveyed centreline. Otherwise, re-computing the centreline might mean that the whole cave has to be redrawn as the absolute station positions shift.

Overall, my conclusions have been that the true VR survey is still a few years off. Apart from better surveying techniques, we need faster processors in our computers, better viewers and something a little more sophisticated than current VRML.

Others' work

Garry Petrie has also been working on this idea. I don't have much detail at this stage having simply seen some of his results. The Marmot picture above is an example, and he has also produced a movie (5Mb in AVI format) of a large section of Lechuguilla Cave filled out in 3D and rotating, although I think this was done with DXF export and Autodesk animator rather than VRML. This simply shows that there are several ways to produce a useful 3D model.

Finally Jose Aguilera, a Spaniard, has recently produced some impressive surface models with caves in VRML which can be viewed at the URLs below. He used a graphics tablet to digitise the elevations from a map, and convert the results into a 3D mesh in DXF format. The cave data was also put into DXF format, then both these parts were combined using 3Dstudio which did the VRML conversion. This is an example of using existing tools to produce a model, as opposed to writing applications which contain cave-surveying-specific features.

It is also worth noting that Fred Wefer in the states has been producing full 3D models, including cave contents, for the last 10 years or so, as he works with high-power CAD workstations and has had the necessary technologies available for some time. So far as I know all this has been done with proprietary software and standards, which unfortunately precludes its use by the unwashed masses with typical desktop machines.

So as you can see this technology is likely to produce quite realistic models of caves, although exactly how much computing welly you will require to make use of it remains to be seen in the next year or so. Watch this space, and get ready for having to change your surveying style to make full use of this technology.

URLs for further reading

Alan B Canon:

<http://www.goodearth.com/virtcave.html>

Jose Aguilera:

<http://www2.uca.es/huesped/giex/r.wrl>

<http://www2.uca.es/huesped/giex/m.wrl>

Garry Petrie:

<http://www.europa.com/~gp/winkarst.html>