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Issue 24

Compass Points

June 1999

BCRA

Blunder-detection using internal angles

Fixing a cave to multiple GPS locations

Building a Laser rangefinder

COMPASS POINTS INFO

Compass Points is published quarterly in March, June, September and December. The Surveying Group is a Special Interest Group of the British Cave Research Association. Information sheets about the CSG are available. Please send an SAE or Post Office International Reply Coupon.

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 LaTeX, Wordperfect or Microsoft Word documents (up to version 7.0) are probably best. We are able to cope with most common word processor formats. We are able to accept disks from most machines, but please check first. We can accept most common graphics formats, but vector graphic formats are much preferred to bit-mapped formats for diagrams. Photographs should be prints, or well-scanned photos supplied in any common bitmap format. 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.

INTERNET PUBLICATION

Published issues are accessible on the Web at:
http://www.chaos.org.uk/survex/cp/index.htm
THE CSG Web pages are reached via http://www.caves.org.uk/csg/

CAVE SURVEYING MAILING LIST

The CSG now runs a mailing list for cave surveyors around the world. To join send a message containing the word 'subscribe' in the body text to cave-surveying-request@survex.com

Cover: Various Silva instruments, newly available through the CSG

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The journal of the BCRA Cave Surveying Group.

Editorial

Well, as promised last issue, we are more-or-less back on schedule. I've also had a pleasing influx of new material from some new contributors. I hope you find it of interest.

The CSG field meet was a great success with some good work done and some new faces attending. The instrument test range there is a really useful ong-term resource. As well as testing out individuals and standard instruments it could be used for calibrating new experimental devices. We've organised the next one a useful time in advance this time. See some of you there.

Admin

If any of you are sad enough to read the masthead you will notice that the CSG has some new email addresses. You can now contact members of the group at addresses that should remain constant though changes of the committee and their
csg-editor@survex.com
csg-secretary@survex.com
csg-webmaster@survex.com
csg-meets@survex.com

All pretty obvious, except the last one perhaps, which gets to whoever is the contact for the next field meet.

Forthcoming Events

Autumn CSG field meet

The next CSG field meet is to be held at the headquarters of the Red Rose Cave and Pothole Club, Bull Pot Farm, on the weekend of 2nd-3rd October 1999. Cost will be £3 per night, unless you are a member of RRCPC. This field meet is open to anyone with an interest in cave surveying, from beginner to expert alike. You are encouraged to bring your own surveying gear if you have it. The provisional programme is as follows:

Sat 2nd October

- Practical surveying, probably in Marble Steps. Surveyors of all standards welcome, absolute beginners included.
- Setting up a fixed point on Leck Fell using laser theodolite.

Sun 3rd October

- Processing/drawing up of data collected on Saturday from all sources.
- Discussion of drawing up methods in use today.
- Presentation of methods used for underwater surveying.
- Discussion and demonstration of latest software releases.

This is an evolving programme - updates will be on the web or in the next issue of CP - and please contact the organiser with any suggestions of things you would like to do, or need assistance with.

You do not have to formally 'book' a place on this meet, but it would be helpful if you could tell the meet organiser, Ray Duffy (contact details below) if you intend to turn up, your level of expertise and what equipment you intend to bring.

For more information contact Ray Duffy by email rduffy@kencomp.net or write to him at:

13 Thacking Lane,
Ingleton,
Carnforth,
LA6 3EQ.

BCRA Swaledale Regional Meeting

Ernie Shield is keen for a few CSG members to attend this event. If you read your CP before it's too late, then do consider going along - it should be interesting. The meet is on June 12th -13th. Hydrology, exploration, local trips, cave radio.

More info at http://www.bcra.org.uk/events.html#reg99

Or contact Ernie at: Village Farm, Great Thirkleby, THIRSK, North Yorks, YO7 2AT. Telephone 01845 501424

SNIPPETS

Arthur Butcher Award

Your favourite editor is now on the panel for this - Seems you just have to win it one year and you get conscripted the year after!

Don't forget to enter if you've done anything at all surveyful this year. It doesn't have to be a huge project. If you've done a decent quality survey or a particularly beautifully-drawn extension then we want to know about it.

Silva and Suunto instruments available through the CSG

Wookey

The CSG has now set up an account with Silva, so we can get their instruments as well as Suunto's. They are significantly cheaper, and at least as good.

It's heading towards expedition time again, so any clubs/groups that new instruments or their old ones fixing please get in touch in good time, otherwise you'll be like Oxford UCC last year - having three-quarters of your surveying sets still being repaired come time to leave the country.

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, and pay the extra few pounds.

If you are spending less than £100 on Suunto stuff or £150 on Silva stuff then there is a £5 delivery charge. Then add postage (from me to you) at either £2 for normal or £5 for registered (in the UK). Make cheques payable to 'Wookey'.

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

SILVA Instruments

ClinoMaster clinometers

CM 360 % LA (standard degrees/percent clino)	£48
CM 360 % PA (prismatic verson of above)	£56

Battery and tritium options available on request, but no prices given.

SightMaster compasses

SM 360 LA (degress/backbearing scales)	£37
SM 360 LAT (360LA + tritium light)	£46
SM 360 LA/LU (360LA + battery light)	£49
SM 360 LMG (plastic body+rubber cover version)	£21
SM 360 PA (prismatic version)	£41

The 360 LMG looks interesting. One of these has been ordered so expect a review soon. If it's robust enough it could be very popular.

Accessories

Rubber covers (gree/yellow/blue) (state whether for lensmatic or prismatic)	£3
Spare battery	£4
Lighting unit	£12

SurveyMaster (double-ended clino/compass)

SUM 360/360% LA	£84
SUM 360/360% PAT (prismatic+tritium)	£104

Type80 compasses

Blue (standard)	£32
Yellow (tritium)	£35
Orange (battery)	£43

Type 80s are plastic bodied prismatic devices 87x73x28mm, so bigger than the normal aluminium-bodied ones but the prism doesn't stick up in that 'ready to be knocked off' way. They float, which could be useful occasionally. Accuracy is nominally the same as the ali-bodied ones, although whether they are really as good remains to be seen. They have a slightly dubious-looking hole in the top which looks likely to fill up with crud - I don't yet know if this is significant.

There's tons more irrelevant stuff in the catalogue, but the above are all the sensible cave-surveying options.

One interesting item is the electronic compass:

Outback ES (2 deg accuracy, 200hr batt, backlight) £53

SUUNTO Instruments

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

rubber covers (included with PCB model) are 5.50 each (choice of Yellow or Black).

REPAIRS

	Bare std capsule	Standard replaced	Tritium replaced
PM-5 clino	£47	£57	£70
KB-14 compass	£42	£46	£59
CM360% clino	£27	£48	?
SM360 compass	£27	£48	?

Note that we can now use an ultrasonic bath to clean 'behind the lens', which may make an otherwise 'too old' instrument salvageable. We are working on being able to replace these lenses too.

Compass and Tape Issue 44

This is our sister publication in the US.

Call for papers at the 1999 NSS convention, Survey and Cartography section.

Survey and Cartography Section minutes - Largely unexciting minutes, although the SACS embarrasment of riches ($3882 and rising as they make money on every C&T issue) is of note. They have 211 members, and have set up a website this year. The cartography salon was successful in it new format, and the winners of this year's surveying contest had set a new record with a 0.14% error!

1998 Cartographic Salon, Sewanee, Tenessee - 80 maps were submitted, 40 in the open category. There were several new categories: Computer maps (hard-copy and monitor-viewed), Junior, First-time entry, Published maps, and Experimental. The overall winner was a 28-map series of Crystal Cave, California, by Joel Despain and Greg Stock.

Data Reduction/Plotting Program Questionaire - George Dasher presents a thorough list of questions to try and define what different pieces of software can do. A future article will be produced from the responses

A comparison of Simultaneous and Sequential Closure Adjustment Methods - by Robert Thrun. A very interesting examination of what happens if you give a slightly warped dataset to programs that do simultaneous and sequential loop closure. The examples used were CMAP (simultaneous) and Compass (sequential). This was intended to test the assertion made by Larry Fish (author of Compass) that 'sequential is better'. Bob found that CMAP made a significantly better job of reconstructing the test grid than did Compass. The real test is what happens with blunders? This is where sequential algorithms should be much better. In fact some strange effects occurred where the blunder affected the grid over a much larger area than would be expected in Compass, so CMAP was still ahead. He also illustrates the effects of simultaneous closure on an error at one end of a much less complex test dataset for comparison with the previous 'error in the middle of a large grid' test.

Rebuttal: Simultaneous versus Sequential Loop closure - by Larry Fish. Larry's answer to the previous article (pretty exciting stuff for a surveying journal this!). Larry makes several points to counter Bob's arguments - firstly that the random dataset is not really random. He may be right, but I don't think it invalidates the points made earlier. Secondly he points out that using standard deviation to measure the quality of the loop cloures is not valid, as when fixing an error perfectly the overall SD will often increase. He also argues that a blunder in the middle of a 20x20 grid (400 simple loops) is not really realistic, and masks the significant distortion effects on the few loops around the blunder that are affected by simultaneous closure. Fourthly he points out that the propogation of a blunder into nearby loops with Compass is due to a flaw in way Compass chooses its loops, not the algorithm in principle. With the software fixed it generally removes such blunders perfectly. Finally he points out that using some genuinely random datasets and running them through SMAPS and Compass, Compass consistently does a better job even of the random errors.

All good stuff, and I may republish some of this in more detail in CP, although in my opinion there are serious flaws in some of the arguments in both articles, so I'd like to verify some things before publication.

In the spotlight: Junior SACS members - A few examples of maps by kids. They were really pretty good - two of them were better than I've seen a lot of adults produce!

UIS symbols list Ratified

Philipp Haeuselmann

After a long and laborious work here we are: The official UIS Symbol list is in existence!

Intense pre-work, an interesting session at the UIS congress, followed by endless email exchanges, lead to the final vote from the national delegates.

The list in its present form had been approved and can be seen and downloaded at:

http://www.speleo.ch/cgi-bin/cave_symbol.pl

I hope you'll find this list useful. Let's go surveying!

Many greetings, Praezis

(Chairman, UISIC Working group Survey & Mapping)

LETTERS

The following was posted to the Cavers Digest Mailing list. It is reproduced here (with permission), to see if anyone else has any explanations.

Unusual Inclinometer Readings

Robert Mudry <mushroom@best.com>

A couple of months ago, myself and a friend were surveying a lava tube cave in Lava Beds National Monument, California, when we came upon an unusual problem.

As I was taking the inclinometer reading, I noticed I was having a hard time getting a handle on the reading. It was almost as if the reading was "floating" around. Now I expect that behaviour with the compass, due to magnetic anomalies in the lava, but the inclinometer (a relatively new Suunto) has no such sensitivity. I persisted and eventually got a reading I could live with. My partner then did a backsight, and to our horror, we were off by several degrees. Once again, I took my reading, and this time got an entirely different inclination, but still no closer to the backsight. We went back and forth on this for awhile, each of us thinking the other was an idiot, when finally we switched positions. Same problem. Eventually, my partner decided to try shooting from behind the station, instead of next to it. We got readings that matched, and chalked the whole thing up to random strangeness due to bad station selection.

A couple of stations later, I find myself down in a lower passage, maybe ten or fifteen feet away and a couple of feet down. She shoots towards me and gets -8 degrees. I shoot toward her and get +12. Hrrm. We try again, with the same results. I use her instrument and she uses mine. Same result. We switch places. Same result.

Now this is getting spooky. We know the instruments are good. We switched positions and still got the same readings, so we know we're good. The stations are perfectly positioned for easy shots, so we're not standing on our heads to get the readings. The compass readings were dead on, and there was no sign of a magnetic anomaly. Our inclinations were 4 degrees off, and that was that.

It simply doesn't make sense to us. Has anyone seen this type of behaviour using Suuntos before? The thought of a gravitational anomaly is just downright silly, and a magnetic anomaly wouldn't affect the inclination.

Refraction of the air between the stations due to temperature differences, causing our readings to appear off? We were no more than ten or twelve feet apart--the air would have had to turn into soup in order to produce that much of an affect by refraction.

Water ingress in Silva instruments

Robert Smallshire <smallshi@globalnet.co.uk>

This letter, and the responses, were first published on the cave-surveying mailing list: cave-surveying-request@survex.com

Hello surveyors,

I'm having problems with water ingress in to my Silva Sightmaster compass (equivalent to the Suunto KB14). I've removed the capsule and sealed it top and bottom with silicone sealant and also sealed around the outside of the eyepiece tube where it is in contact with the case. Despite this water has still entered the space between the lens and the capsule where you sight through. I suspect it may have entered through a gap between the eyepiece lens and the inside of the tube. The amount of water is small, but its enough to cause troublesome misting of the optics.

What is the current thinking on how to *effectively* seal Suunto and Silva compasses of this type? We have been surveying 400 m of canal passage with some very-low airspace sections and so immersion of the instrument has been frequent and unavoidable.

Wookey replied:

Well, the bottom line is that it's difficult to do effectively. However you can do various things to improve matters.

The first thing is to ensure that your instrument in entirely dry inside before sealing it up, otherwise you just seal the water in. This is best done with a lab dessicator, or a drum of carbide, but careful use of the oven can also work (if you aren't careful you can boil off the oil in the capsule and get a bubble in it). Disassembling the instrument before drying will speed things up dramatically and reduce the risk of overcooking.

Several US respondents have had success with clear thermoplastic rubber (a.k.a. plasti-dip). This is designed for coating tool handles, and is like the stuff on a Petzl Stop handle. You cover the centre of the sighting window with tape then dip the instrument (several times for best effect). Then you cut away the little circle over the sighting lens and remove the masking tape/whatever you used to cover it. This gives a continuous cover over the instrument except for the middle of the sighting window - which should be entirely waterproof. Details of this process are in Compass and Tape issue 37 by Mike Yocum. I have never tried it - the above is all 2nd-hand info :-)

I have used both Araldite and silicone sealant. I have found the former to work better for longer, despite it being non-flexible. I just apply these round the capsule join and sometimes the lens and base joins for good measure. Both are a pain to remove for servicing. I think plasti-dip is better in this respect.

You suspect that the water is getting in round the sighting lens. In my experience (admittedly almost entirely with Suuntos, not Silvas) the instrument leaks round the capsule, not the lens. The capsule, despite having an O-ring, is only weather resistant, not waterproof. The lens, on the other hand, is very tightly fitted, and usually waterproof.

I don't know if the deeper Silva lens mount is more or less waterproof than the Suunto ones. I would expect it to be much the same.

Another approach is to make the instrument clearable on site, on the assumption that you'll never be able to keep the condensation out. For a long time this has means the 'flush ports' available on the 'cavers' version of the Suunto instruments, but these aren't much good for condensation, unless you take a small alcohol bottle with you to flush with. A recent Compass Points article (CP21) showed how to retro-fit a removable lens to the instrument which means all you need is a screwdriver to be able to wipe condensation off the back of the lens. This is fiddly, but a lot better than a wasted trip.

A final thing I have wondered about is putting a suitable material between the lens and the capsule so that there is no space for condensation to occur in. A liquid/gel of suitable refractive index would perhaps be best, as it would automatically conform to the right shape. Dean Osgood suggests that this might be possible, but difficult, as it is quite a wide gap. Suitable adhesives are expensive, and also very runny so some kind of former would need to be constructed to hold it in place whilst setting. The cheapest option would be windscreen stonechip repair kits, which might do the job.

Spring Field Meet Report

Wookey

The CSG gathered at SWCC on April 10th and 11th. Attending were Allan Richardson, Brian Clipstone, Iain Miller, Stuart France (SWCC), Anthony Day, Julia Bradshaw (DUSA), Will, Ben Cooper (MCG), Wookey, Olly Betts (CUCC), and Mark Stephens.

We carried out a good set of experiments, and played with a lot of kit. Everyone learnt something, and we even furthered speleological knowledge a little.

Radiolocation

First thing was a training session where Stuart France educated the assembled masses in the theory and practice of radiolocations and depth determinations. The plan was for everyone to get a chance to try a radiolocation (and see how similar our answers were). We would do locations at a couple of different depths, from accurately-surveyed underground stations. The surface locations thus determined would be surveyed to by theodolite and compass and tape, thus allowing us to determine the accuracy of these methods.

We split into underground and above-ground teams and headed up to OFDII. This is an ideal test site as we have suitable pre-surveyed fixed points, easy access, and a range of depths without having to do too much caving! There were the usual teething problems (both transmitters turned on at once giving a confusing echo effect until Stuart worked out what was going on).

I was impressed with how easy radiolocation is, although the strong wind did cause problems as it made it hard to hold the aerial vertical to get a consistent null.

Meanwhile the new surveyors (Will and Julia) learnt how to do it from Anthony (ooer missus), and also got to check their accuracy against the underground survey points. Mark took photos of everyone (fnarr!).

Once the locations were done Stuart and Wookey surveyed between the above and below-ground stations. Iain Miller and various assistants worked the very fancy theodolite provided by Dorset Land Surveying.

Saturday Evening

We processed all the data to find that nothing added up - the radiolocations were both 5m off horizontally and the heights didn't agree, and the compass and tape survey was also several metres out vertically - more than it ought to have been over 200m. Not very satisfactory. We also took a disto to bits for fun and compared new theodolite data for the compass course with the existing data.

Sunday

The novices drew up their efforts from yesterday, which were pretty good, with no major errors. The experts' first job was to find out why none of yesterday's numbers added up. Iain decided he had set off from the wrong baseline point so he did his survey again, and Wookey and Anthony re-did the compass and tape survey. We found that there was at least one serious blunder in the first survey and the new one was much better.

There is definitely a moral here - even very experienced surveyors are bloody useless and can't do a noddy 200m survey in luxurious conditions ☺

We then spent the rest of the day going round the compass course with 5 sets of instruments. This produced a good dataset, largely free of the problems of our first attempt back in CP16. The results of both the compass experiments and the radiolocation work will be in the next issue (this one is full!)

Fixing a Cave Survey to Multiple GPS Points

Ben Cooper

Abstract::An anlysis for fitting survey data to GPS locations using Least Squares

I would like to address the issue of fixing two or more GPS points to a survey. At the moment, Survex will “Fix” a survey station to a co-ordinate datum, and compute the co-ordinates of all other stations from the fixed station. If co-ordinate data exist for other stations, these too can be fixed, and Survex will bend the survey to fit the co-ordinate data. The problem arises if the co-ordinate data have been derived from a GPS, in which case the positions will frequently have errors that are significant compared to the error in the survey data. In that case, it is no longer appropriate to distribute all the error over the survey: it would be better to distribute it by partly bending the survey to fit, and by partly moving the GPS data.

This problem arose for me while on expedition in Madagascar [1]. It proved difficult to obtain a GPS location at the cave entrances, because the towering cliffs and thick jungle canopy shielded the satellites from the unit. Instead, we produced a surface survey linking the cave entrances together, and to a point away from the cliffs from where we were able to obtain a GPS fix. Later in the expedition, we found a second GPS fix, by climbing high in the cliffs.

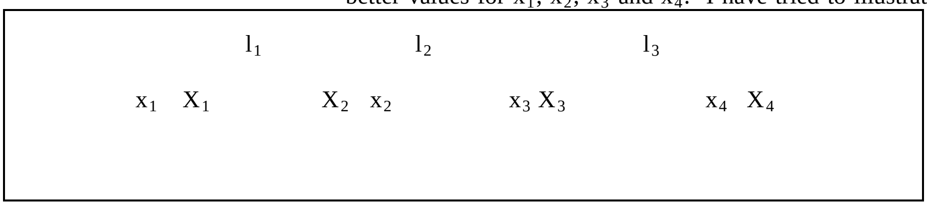
Everything about the jungle is exhausting. Even under the shelter of the trees, the temperature is over 30 degrees Centigrade, the ground is steep and the vegetation snares your every move. On the cliffs, you are quickly exposed to the blistering heat of the sun, under which the sand and rocks bake to as much as 50 degrees. In contrast, the caves are at a pleasant 22 degrees. In other words, there was very little incentive to go back and collect more readings at the same location, and we decided to settle for one reading at each of the two locations. I knew how to combine weighted averages of the same reading, and I intuitively guessed that it must be possible to use GPS readings at two different locations, and somehow combine the results to give a better overall position of our survey data. However, it was not obvious to me how this should be done.

The GPS unit was a Garmin GPS 12, which was used to average the GPS data for a period of about six-hours giving an accuracy of about +/- 5 metres [2]. The distance between the two GPS points was 213m. The survey data indicated that the horizontal distance between the two GPS points was 201m, with an error of about +/- 2 metres [1].

At first, I tried to calculate a weighted-average between the Survey leg and the vector between the two GPS points. However, the arithmetic is fairly tedious, and I could not see how to generalise if for three or more GPS points. I therefore went back to first principles, and derived a solution based on least-squares that can be applied to any number of data points. This solution also shows the way for how to use weighted averaging, but I still think that the arithmetic for the least-squares solution is simpler.

Least Squares Solution

For this example, I have assumed 4 GPS locations, connected by three survey legs. This should be sufficiently general to be extended for any number of GPS locations. Let’s say that GPS fixes are known for positions x_1, x_2, x_3 and x_4, with weighting factors w_1, w_2, w_3 and w_4. The GPS locations are connected by survey legs, l_1, l_2 and l_3, with weighting factors v_1, v_2 and v_3. Now, consider that we are trying to calculate new locations, X_1, X_2, X_3 and X_4, which represent better values for x_1, x_2, x_3 and x_4. I have tried to illustrate the relationship between the values in the following diagram,



where the left-hand end of each survey leg has been attached to the corresponding "best-fit" location, X_n. Note that the diagram is intended to only show the X-co-ordinate. Any offset in the Y-direction is to separate overlapping symbols.

Notes:

1. The weighting factors are the reciprocal of the square of the standard error for each value. The weighting factor is used in preference to the standard error, to simplify the arithmetic. The weighting factor is then substituted at the end.

2. I assume that the Easting and Northing co-ordinate data is independent, so that the data for each can be considered separately. To re-phrase that more formally, when the partial differential is calculated for X, all values in Y disappear, and vice-versa.

3. In reality, each leg l_n is actually made up of several measured legs. Survex (or similar) is used to pre-process the survey data to close loops and determine the relative x-y positions of each survey station. The survey is not yet fixed to any co-ordinate datum (i.e. an arbitrary survey station is selected as the zero co-ordinate). The survey distances between the GPS locations (l_n) can then be determined by subtraction.

4. The error for the survey can be estimated by the error contained in any closed loops, or by an explicit assessment of each measurement error, suitably aggregated. For my Madagascar data, there were no closed loops between the GPS locations, and an explicit assessment of the error was made using a spreadsheet [3].

The unknown values X_1, X_2, X_3 and X_4 are determined by a least-squares best fit from the residuals for each measured value, defined as follows:

For the GPS reading x_1:
Residual = $(X_1 - x_1)$;
for x_n: Residual = $(X_n - x_n)$

For the survey leg 1_1:
Residual = $(X_2 - (X_1 + 1_1))$
for l_n: Residual = $(X_{n+1} - (X_n + l_n))$

The residual for the GPS reading is obvious, but it took me some time to settle on the definition for the residual of the survey leg. The problem is that the survey leg is not fixed to any location, and I did not know how to fix it in order to compare it to the GPS data. Eventually I chose the following scheme: fix the survey l_1 to the best-fit location X_1, and then determined the residual from the far end of the survey at position $(X_1 + 1_1)$ to the best-fit location X_2. I think this is the best solution, because from the outset it ties the survey leg to the location to which it will finally be fixed, i.e. the newly calculated location X_1. Also, in the case that the error is zero, this scheme reduces to $X_2 = X_1 + 1_1$, which is correct.

Taking into account the weightings, the sum of the squared-residuals for the configuration is therefore as follows:

$$\text{Sigma\_R}^2 = w_1.(X_1 - x_1)^2 + v_1.(X_2 - (X_1 + l_1))^2 + w_2.(X_2 - x_2)^2 + \ldots + w_4.(X_4 - x_4)^2$$

Now, we want to minimise this expression, by varying the values X_1, X_2, X_3 and X_4. The minimum is the point at which the differentials are zero. The four partial differential equations are:-

$$\frac{\delta}{\delta X_1} = w_1.(X_1 - x_1) - v_1.(X_2 - X_1 - l_1) = 0$$

$$\frac{\delta}{\delta X_2} = v_1.(X_2 - X_1 - l_1) + w_2.(X_2 - x_2) - v_2.(X_2 - X_1 - l_1) = 0$$

…

$$\frac{\delta}{\delta X_4} = v_3.(X_4 - X_3 - l_3) + w_4.(X_4 - x_4) = 0$$

There are four unknowns, and four equations, so with a bit of arithmetic, these can be solved. I have done this for the case of two GPS points, for which the differentials are as follows:

$$\frac{\delta}{\delta X_1} = w_1.(X_1 - x_1) - v_1.(X_2 - X_1 - l_1) = 0$$

$$\frac{\delta}{\delta X_2} = v_1.(X_2 - X_1 - l_1) + w_2.(X_2 - x_2) = 0$$

The equations are solved to give the following values:

$$X_1 = ((w_1w_2 + w_1w_3)x_1 - w_2w_3l_1 + w_2w_3x_2) / (w_1w_2 + w_1w_3 + w_2w_3)$$

$$X_2 = (w_1w_2x_1 + w_1w_2l_1 + (w_1w_3 + w_2w_3)x_2) / (w_1w_2 + w_1w_3 + w_2w_3)$$

These equations do not appear particularly intuitive, and even after manipulation and substitution of the actual errors for the weighting factors, I have been unable to improve on the presentation to a more intuitive form. To understand better what these equations signify, I found it helpful to consider the simple case that the weights are all equal. They reduce to the values:

$$X_1 = (2x_1 + x_2 - l_1) / 3$$

$$X_2 = (x_1 + l_1 + 2x_2) / 3$$

Imagine my real world data where the difference between x_1 and x_2 is 213m, but l_1 is only 201m. In other words, there is a discrepancy between the GPS and survey data of 12m. If each item has the same standard error (say 5m, but the absolute value is irrelevant), these equations will distribute the discrepancy of 12m in the following way: x_1 will be moved +4m, x_2 will be moved –4m, and l_1 will be stretched by 4m. This seems quite reasonable, and intuitive, once you know the answer!

Taking into account the actual weighting, where the GPS error is 5m and the survey error is 2m, the equations will distribute the discrepancy of 12m as follows: x_1 will be moved +5.5m, x_2 will be moved –5.5m, and l_1 will be stretched by 1m. This also seems quite reasonable and consistent with the stated errors.

References:

[1] Madagascar 98, Mendip Caving Group, in preparation.

[2] Assessment of the Figure of Merit of a GPS12, in preparation

[3] Assessment of Aggregated Survey Error, in preparation

A Do-It-Yourself Laser Rangefinder

Neville Michie

A description of a simple-to-build mechanical laser rangefinder which does essentially the same job as one of those fancy £400 devices for a great deal less money.

This instrument was constructed from junk box items, which of course could never be found again to build another The key item was Clinometer sight A.F.V Mk 1/3 F.V, 133074 which has a thimble calibrated in 2 minute intervals, set-able to one minute of arc.

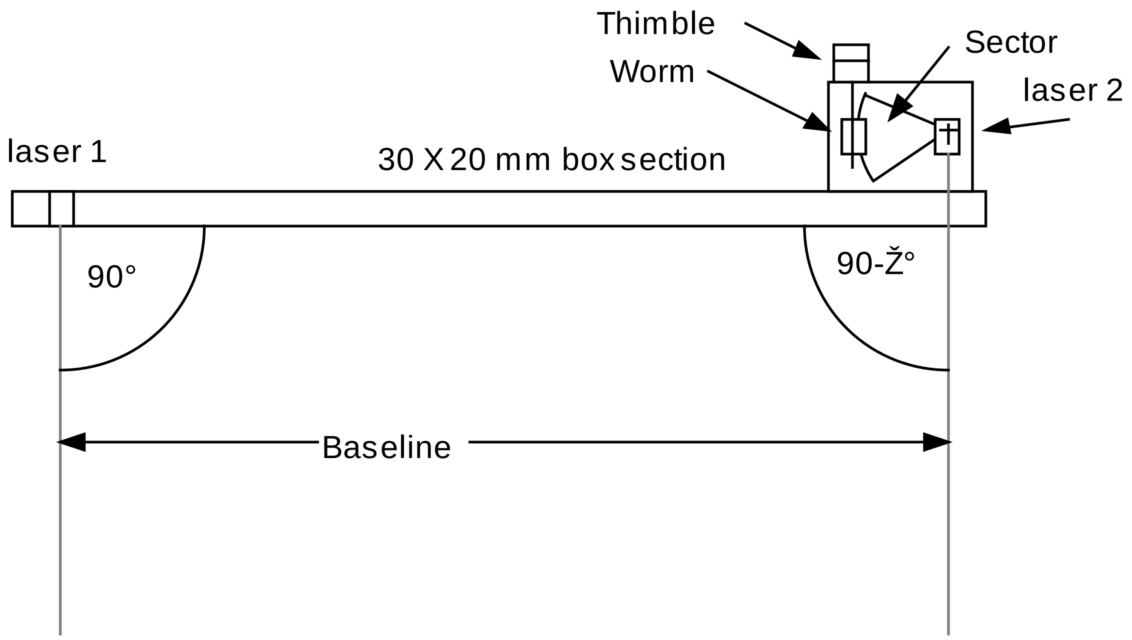


Figure 1 - Schematic of Laser Rangefinder

The principle of the instrument can be seen in figure 1. Two diode lasers from blackboard pointers (1mw) are set on a baseline with their beams near parallel. One is deflected through a small angle delta, so that the two spots coincide on the object whose distance is being measured. Trigonometry yields the distance from the baseline and the incremental angle. This instrument had a 500mm baseline, but half or double that would be no trouble, the accuracy increases with baseline distance.

In the field trials it was found sensible to check the zero angle when the instrument was unpacked. The heads up operation was a revelation of what could be done with lasers in cave surveying, you look at the target and adjust the two points onto the target of choice. No sighting! No lenses fogging up! The reading can then be made at leisure, perhaps passing the instrument back to someone who is less precariously located to read and book.

To make the calculation completely crystal obscure, here is a program in QuickBasic to reduce readings.

```
CLS
REM Program DIST2.BAS              1998-04-23
REM for triangulation from 0.5 metre base line
PRINT "                Program DIST2.BAS"
PRINT "Converts angles to ranges for 0.50 metre baseline"
10 INPUT "enter maximum angle"; A
INPUT "enter minimum angle"; B
REM INPUT "Enter error on wall, mm. "; E
AI = INT(A)
AF = A - AI
IF AF > .59999 THEN
PRINT "Enter Angles in Degrees and Minutes"
GOTO 10
END IF
A = AI + AF / .6
REM PRINT AI, AF, A
PI = 3.141593
A = PI * A / 180
```

```
X = .5

IF A = 0 THEN A = .0000001#
D = X / TAN(A)
Y = ATN(X)
REM *******
BI = INT(B)
BF = B - BI
IF BF > .59999 THEN
PRINT "Enter Angles in Degrees and Minutes"
GOTO 10
END IF
B = BI + BF / .6
REM PRINT BI, BF, B
PI = 3.141593
B = PI * B / 180
X = .5

IF B = 0 THEN B = .0000001#
BD = X / TAN(B)
BY = ATN(X)

PRINT "Minimum Distance is ";
PRINT USING "####.##"; D;
PRINT " metres"
PRINT "Maximum Distance is ";
PRINT USING "####.##"; BD;
PRINT " metres"

REM EE = E / 500
REM PRINT "error is "; EE * 100; " %"
REM PRINT ""
GOTO 10
```

This program may have some twiddly bits that you would omit, like a section to establish field resolution by making two measurements, approaching from above and below the angle.

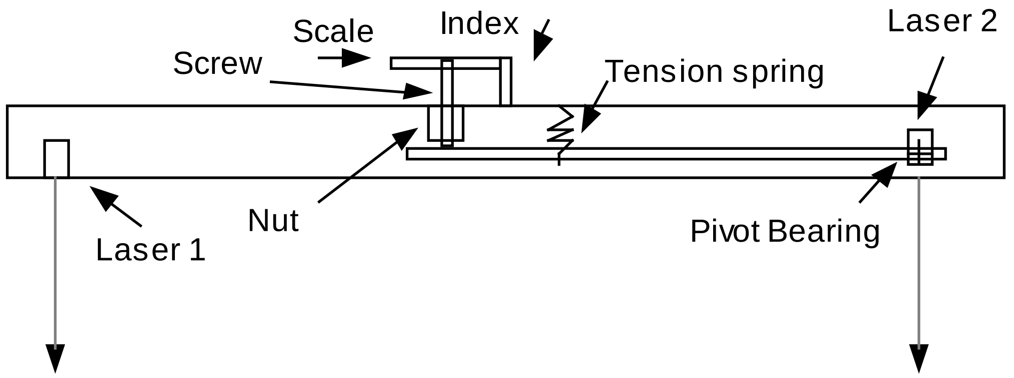


Figure 3 - A version with a different alignment mechanism.

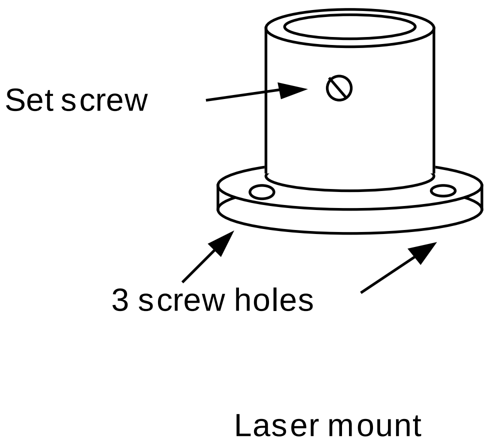


Figure 2 - Laser mount detail

Figure 2 shows a version that is more friendly to a home constructor, however the details are best worked out when you have found your materials.

Figure 3 Is the mount for the laser. The lasers were in a cylindrical brass mount and looked as if they could be mounted with great mechanical stability. After mounting, the laser direction can be trimmed by placing thin shims under one or more of the three mounting screws. It was found to be very advantageous to miss-align the lasers slightly, so that when the beam is held horizontal, one spot moves over the other, but at a very small distance, this enables you to identify the spots and also prevents a dazzling phenomenon when the two spots merge and small separations can not be seen. Anyway you would probably not be able to align them exactly without a lot of trouble.

The best way to adjust the instrument is to mark two lines on a piece of paper close to the instrument at the spacing of the beams, then take the paper to some distance and set the zero angle to give spots of the same separation. Figure 4 is a version that has linear output, and could be made to read directly in metres. It has a limit to the range because being linear some distance will be off scale, and if you make the maximum distance too big it will be insensitive. To change scales, only the roller needs to be changed. It works by generating a similar triangle to the triangle that is being measured with the beams, the roller, with an offset added, is the side that is similar to the baseline distance.

Obviously, the quality of the instruments will depend on the quality of the engineering used, the calibration screw and its nut being very important. In version 2, a ball bearing sunk into the centre of the end of the screw can improve the precision of moving the bar, and an ideal nut would be tapped into a brass block with a split on one side and a screw to tighten the nut to optimum fit on the screw. Similarly the pivot bearing needs to be firm. A micrometer barrel could be used for the screw and nut, but although very precise, they are hard to read under cave conditions.

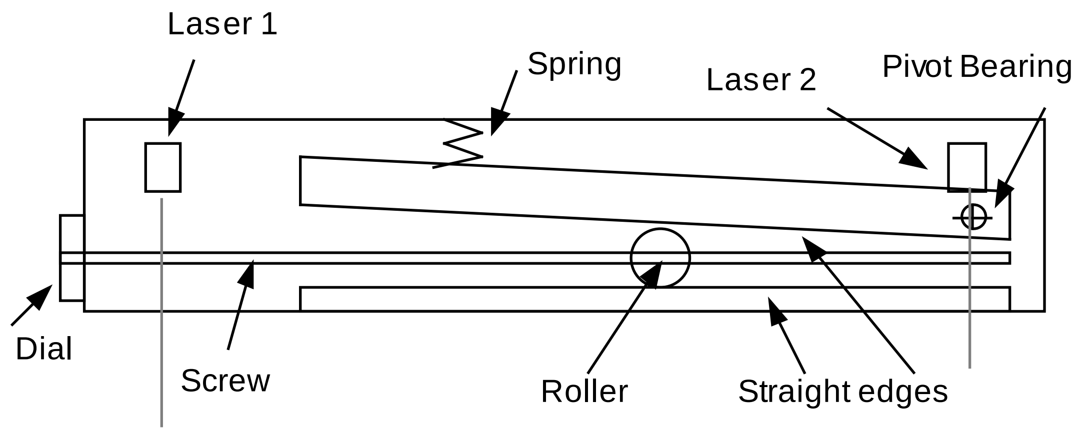


Figure 4 - Another design which gives a linear readout

Blunder detection using Internal Angles

John Halleck

Someone recently forwarded to me the URL for the text of "Compass Points #9, September 1995", which contains a discussion about blunders between Larry Fish, Olly Betts, and Wookey.

In this discussion Larry Fish mentions a remark I've made,and then Olly Betts makes a number of strange assumptions to come to a view which he then debunks claiming it is mine.

I'm sorry nobody forwarded this to me at the time, and nobody asked me at the time. But, since Olly's missconceptions are still common among cave surveyers, I'd like to debunk Olly's debunk of what was claimed to be my view.

My view, for the record:

In a survey with foreshots and backshots, the foresights and backsights can be used to provide MUCH more information than just forsights. The two together can be used to compute internal angles of loops, and can aid blunder detection and magnetic anomoly processing.

In surveys such as Lava tube surveys, where magnetic north can be vary 30 or 40 degrees between stations, only a survey with fore and backsights (or turned angles) can tell what really happened.

Here is an example of (contrived) data, with foresights and backsights, showing how the internal angles can be computed, and how they can distinguish between blunders and magnetic anomolies.

An example.

There seem to have been notable misconceptions in the cave survey community about what is meant by "computing turned angles" from a survey with foresights and backsights.

Hopefully this example will clarify what is meant.

Assumptions

There are [initially unknown] magnetic anomalies at every single point. (Not uncommon for a lava tube.)

The survey is laid out as in fig 1 (two equilateral triangles):

Survey Data

Contrived survey Data:

Shot#:	From	To	Dist	Inc	Foresight	Backsight	(Discrepancy)
1	A	B	10	0	214	42	(8 degrees)
2	B	C	10	0	162	336	(-6 degrees)
3	C	D	10	0	36	209	(-7 degrees)
4	D	A	10	0	327	154	(7 degrees)
5	D	B	10	0	267	102	(15 degrees)

Note that because there are severe magnetic anomalies at all points the foresights and backsights are going to be dramatically different. This is not wrong... they differ because Magnetic North at the various stations is different.

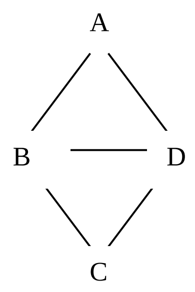


Fig 1 - The example survey

Rearrangement

In order to do the processing we have to rearrange the data from a shot specific viewpoint (as recorded) to a station specific viewpoint.

One advantage of this is that it groups shots with the same magnetic deviation. All sightings taken from exactly the same point should share exactly the same magnetic north, regardless of what direction that Magnetic North may be at that point.

Another advantage is that we can now compute "turned" angles to use in further processing.

Since we are only concerned with computing internal angles in this example, I'll drop the distance and inclination information.

From	To	Bearing	Is
A	B	214	(Foresight of shot from A to B)
A	D	154	(Backsight of shot from D to A)
B	A	42	(Backsight of shot from A to B)
B	C	162	(Foresight of shot from B to C)
B	D	102	(Backsight of shot from D to B)
C	B	336	(Backsight of shot from B to C)
C	D	36	(Foresight of shot from C to D)
D	A	327	(Foresight of shot from D to A)
D	B	267	(Foresight of shot from D to B)
D	C	209	(Backsight of shot from D to C)

The pattern here is listing foresight if the shot was *from* this point, the backsight if the shot was *to* this point. We are basically collecting all the measurements made at each specific point, and making a record of them with that specific point.

Note that we have to be careful here about the order of shots, angles, and labels. The angle BAD is **not** the same as the angle DAB, as one is the negative of the other. The label BAD, for example, refers to the angle between B and D as measured from A (214-154) and DAB is (154-214).

Now the internal angles in the loops can be computed as: (the label BAD, for example, refers to the angle between B and D as measured from A)

Computation

(Taking differences modulo 360, just means that if we get a negative angle, we replace it with the corresponding positive angle.)

Loop (A, B, D)
ABD = 042-102 = -60
BDA = 267-327 = -60
DAB = 154-214 = -60 (Isn't contrived data wonderful?)
Total = -180 which is -1*180 + 0

The internal angles sum to a multiple of 180. This loop has no (angle) blunder.

Loop (D, B, C)
DBC = 102-162 = -60
BCD = 336-036 = +300
CDB = 209-267 = -58
Total = 182 which is 1*180 + 2

The internal angles sum to something other then a multiple of 180. This loop contains at least 2 degrees of angle problems. It could be a single blunder of two degrees, or it could have been a +8 degree blunder and a -6 degree mistake cancelling to be a two degree problem..

In this specific case, we know that CDB is blundered, but only because of the way this data was contrived. *however*, in general all we know is that there is a problem (or problems) somewhere in this loop.

Alternate Computation

Some folk prefer positive angles. For example they take -60 degrees as 300 degrees. This makes little difference, and one could have computed something like:

Loop (A, B, D)
ABD = Modulo(042-102, 360) = 300
BDA = Modulo(267-327, 360) = 300
DAB = Modulo(154-214, 360) = 300
Total = 900 Which is 5*180 + 0

Loop (D, B, C)
DBC = Modulo(102-162, 360) = +300
BCD = Modulo(336-036, 360) = +300
CDB = Modulo(209-267, 360) = +298
Total = 898 Which is 5*180 - 2.

Longer loops

An early reviewer of this complained that it wasn't obvious how to do a loop that wasn't a triangle. So... here is an example of the outside loop (A, B, C, D)

Loop (A, B, C, D)
ABC = 042-162 = -120
BCD = 336-036 = 300
CDA = 209-327 = -118
DAB = 154-214 = -60
Total = 2

Since the outer loop also contains the blundered angle, it should come as no surprise that it also miscloses by 2 degrees.

Note that each angle is just the next angle in the loop.

And for the 'positive angle' folk:

Loop (A, B, C, D)
ABC = Modulo(042-162, 360) = 240
BCD = Modulo(336-036, 360) = 300

CDA = Modulo(209-327, 360) = 242
DAB = Modulo(154-214, 360) = 300
Total = 1082 = 6*180 + 2

Direction of loops

It really doesn't matter which direction one goes around loops. As an example, the loop above in the other direction would be:

Loop (D, C, B, A)
DCB = 036-336 = -300
CBA = 162-042 = 120
BAD = 214-154 = 60
ADC = 327-209 = 118
Total = -2

Or alternately for the positive angle folk:

Loop (D, C, B, A)
DCB = Modulo (036-336, 360) = 60
CBA = Modulo (162-042, 360) = 120
BAD = Modulo (214-154, 360) = 60
ADC = Modulo (327-209, 360) = 118
Total = 178 = 180 - 2

Commentary

We now know that the first loop has no angle problems, and that the second loop does.

Since the first loop has no angle problems, the discrepancy between foresights and backsights in that loop must reflect real underlying differences between magnetic north between the stations.

Simple arithmetic can now show that the difference in magnetic north between A and B is 8 degrees (The discrepancy between fore and back sights in shot AB), between A and D is -7 (The negative of the discrepancy on shot from D to A) and of course between D and B it is consistently 15 (The discrepancy from shot BD). (The difference between magnetic Norths is the negative of the shot discrepancy if you are tracing the graph in a direction opposite the original shot.)

If one sets A as the reference, then it is easy to list the differences for the whole of the (unblundered) net. But magnetic north At C can only be estimated, since some shot to C contains a blunder.

A major obvious assumption being made with that technique is that all shots *from the same point* have the same offset from magnetic north. This is generally true unless the anomaly is being caused by something the caver is carrying.

Clearly, if you went around averaging fore and back sights no reasonable analysis is possible. For shot AB this would give you a recorded number of:

(azimuth_A + anomaly_A + azimuth_B + anomaly_B) / 2

which hopelessly intermingles the shots and any magnetic anomalies.

Without loops you have no redundant information to check against, so detecting blunders this way is not possible. HOWEVER, in surveys with few magnetic problems, there is sometimes some information to be gained. If one computes the (apparent) magnetic anomalies in a traverse, the assumed magnetic north will be stable but different on the two traverse pieces on each side of the blunder. In most limestone areas this may aid in locating the blunder. I really need to give another example to show this technique.

Software releases

Survex version 0.91 released

Olly Betts and Wookey

Development has been continuing apace and there have been 3 more releases since the last issue of CP. A list of the changes is given below, but in summary we think 0.91 is a stable release with a large number of improvements and better cross-platform support. The dataset has been given an overhaul too and should appear on the site very soon.

The survex website http://www.survex.com also now has an experimental US mirror at: http://members.xoom.com/survex/

Which we hope will speed up downloads for many people outside Europe. Tell us if it does/doesn't help.

Changes

- Cavern now stops after 50 errors to avoid swamping the user. DOS caverot now reverts to the mode picker if an invalid mode is chosen (it used to just quit unhelpfully)
- Output files now go in current directory rather than the same directory where the first .svx file is found. You can set a different directory using the "--output" command line option, which can point to a directory or a file. This lets you run cavern on data on a CD, and means that .3d files don't collect all over your dataset.
- There is a wrapper so that you can still use the old 'Survex' command line syntax instead of the new 'Cavern' syntax, if you need to.
- A pile of bugs fixed, including a memory allocation problem, missing plot text, caverot redrawing and zooming problems, and stations with 4 or more connections that were incorrectly included in the .3d file more than once.
- Xcaverot now centres and scales the data to a full screen on startup
- 3dtoDXF has had major improvements (thanks to Leandro Dybal Bertoni) and will now import into most, if not all, applications that accept DXF.
- DOS/Windows versions have DOS linefeeds on all text files, and .txt extensions. Unix/RISCOS versions have unix style ones.
- The HTML documentation now has a linked table of contents, and further updates have been made.
- The printer drivers info box has been improved, and the postscript files are much smaller as well as more correct.
- Various internal changes - e.g. messages files now use UniCode internally, new font format