HOW COMMON ARE BLUNDERS IN CAVE SURVEY DATA?

By Larry Fish

One of the most important problems facing cave surveyors is blunders. Blunders are fundamental errors in the surveying process and, unlike random errors, they can have drastic effects on the accuracy of a survey. For this reason, it would be very useful to know how common blunders are in cave survey data. Not only does this question have implication about the accuracy of our maps, but it also has implications for the design of cave survey software.

BACKGROUND: TYPES SURVEY ERRORS

There are three kinds of survey errors: random errors, systematic errors and blunders. Random errors are generally small errors that occur during the process of surveying. They result from the fact that it is impossible to get absolutely perfect measurements each time you read a compass, inclinometer or tape measure. They are predictable, their effects are generally small and they can be dealt with using standard statistical techniques.

Systematic errors occur when there is a constant, fixed error being applied to the data. For example, they could be caused by a bent compass needle, a stretched tape or a distortion of the earth's magnetic field. In some cases, they can be corrected by simply subtracting a constant from the data.

Blunders are fundamental errors in the surveying process. Blunders are usually caused by human error. They are mistakes in the processing of taking, reading, transcribing or recording survey data. Some typical blunders would be: reading the wrong end of the compass needle, transposing digits written in the survey book, or tying a survey into the wrong station. The thing that makes blunders so important is that they can produce very large and unpredictable errors.

TESTING CAVES FOR BLUNDERS

The COMPASS survey software has a feature that calculates the percentage of loops in a cave that are blundered. The feature is designed give you an overall sense of the quality of the surveys in a cave.

The process of finding blunders begins with an estimate of the typical errors that would be found in surveying instruments. The values are specified as standard deviations of the instruments. For example, the standard deviation for a typical survey compass might be 2 degrees.

The program then walks around each loop, projecting the expected errors through each shot and mathematically combining the result. This gives you a predicted error level for the whole loop if all the errors are random. Thus, any loop who's errors exceed the prediction are probably blundered. COMPASS lists the percentage of loops that exceed two standard deviations from the prediction. Because of the way the statistics work, any loop error greater than two standard deviations over the prediction has a 95.4% chance of being blundered.

Over the years, people have sent me a large number of survey files from caves around the world. I currently have more than 250 data sets from a wide variety of caves. To determine how common blunders are, I tested the survey data from a range of representative caves.

The following table illustrates the percentage of blundered loops in 16 caves from the U.S. and Mexico. I have lots of smaller caver, but I chose caves that had enough loops to give meaningful results. The chart represents the percentage of loops in each cave that has at least one blunder. For the test, I set the predicted instrument standard deviations at two degrees for compass and inclinometer and 0.1 foot (3 cm.) for the length measurement.

Cave Name	Number Loops	Percent. Blund.	Location	Length			
Alexander's	17	65%	?	2	miles	3.2	km.
Fixin'	7	57%	Colorado	1.5	miles	2.4	km.
Groaning	70	49%	Colorado	9.1	miles	14.6	km.
Lechuguilla	1142	32%	New Mexico	100.5	miles	160.6	km.
Cheve	36	30%	Mexico	16	miles	25.7	km.
Blue	46	28%	Eastern US	28	miles	45.0	km.
Wind	900	25%	South Dakota	71	miles	114.2	km.
St.Augustin	20	25%	Mexico	10	miles	16.0	km.
Kazamura	83	19%	Hawaii	38.5	miles	61.9	km.
Carlsbad	813	16%	New Mexico	22.1	miles	35.5	km.
Lilburn	238	14%	California	16.4	miles	26.3	km.
Fulford	14	14%	Colorado	1.0	miles	1.6	km.
Cave Of The Winds	17	13%	Colorado	2.0	miles	3.2	km.
Fairy	29	12%	Colorado	1.5	miles	2.4	km.
Spider	149	11%	New Mexico	3.5	miles	5.6	km.
Roppel	333	2%	Kentucky	69.1	miles	111.2	km.
Average	230	26%		24.7		39.7	

The data here represents a wide variety of caves, survey styles and surveying eras. For example, Groaning and Fixing are tight, crawly maze caves with difficult surveying conditions. Their entrances are at about 10,000 feet (3048 m.) of elevation and the year round temperature is 39 degrees (4 C.). It is not surprising that the blunder level is high in these caves. Lechuguilla is a less challenging cave, but the chaos of large expeditions and the rapid pace of discovery produced lots mis-tie errors. Finally, the Wind Cave data actually has surveys dating back to 1934.

The majority of the caves were surveyed by cavers from the United States using U.S. style surveying techniques. It would be interesting to know if surveyors from other countries, using different techniques would get different results.

As you see from the chart, there are a surprisingly large number of blundered loops. In fact the average cave in the list has 60 blunders. In many ways this is not surprising given the difficult environment and the large number of measurements that make up a cave survey.

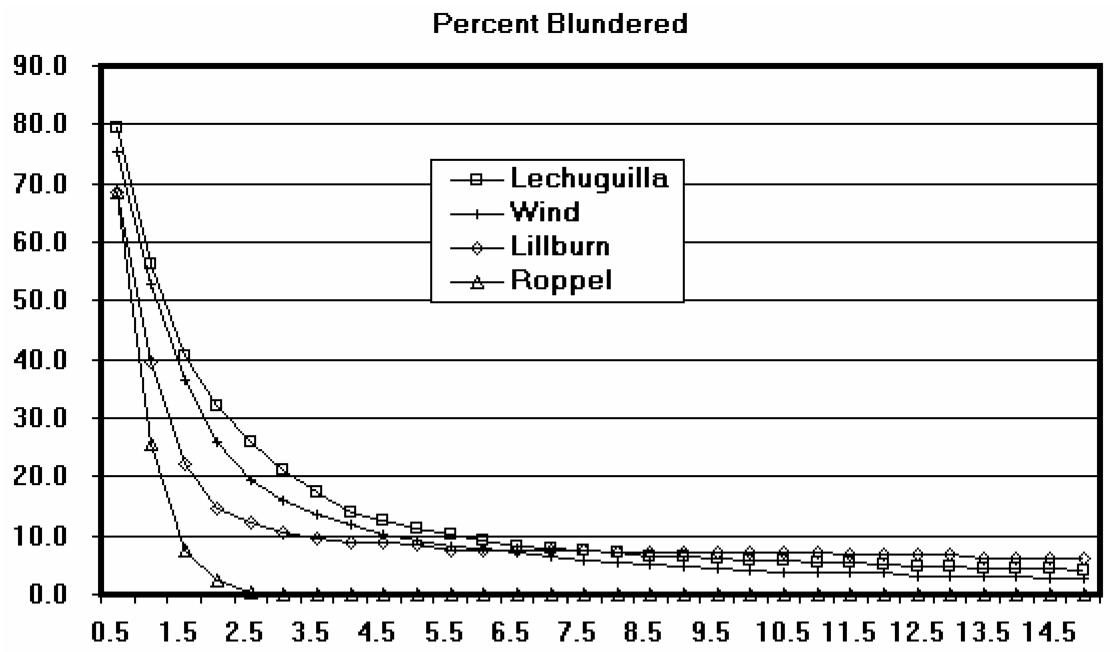
ESTIMATING INSTRUMENT ERRORS

While I was working on this project, Olly Betts suggested an experiment that might show us something about instrument errors. He suggested that we gradually increase the projected instrument errors and see what happened to the percentage of blunders. The result was very interesting.

I started with 0.5 degrees STD for compass and inclinometer and 0.25 foot for tape. I then tested the percentage of blunders and increased the values by 0.5 degrees and 0.025 foot for tape. I did this for four caves representing a range of survey quality. Here is a chart of the result:

Comp/Inc STD	Tape STD	Lech % Blnd.	Wind % Blnd.	Lilburn % Blnd.	Roppel % Blnd.
0.5	0.025 ft.	79.5	75.4	68.5	68.5
1.0	0.050 ft.	56.1	52.9	39.5	25.5
1.5	0.075 ft.	40.5	36.4	22.3	7.5
2.0	0.100 ft.	32.0	25.8	14.7	2.4
2.5	0.125 ft.	26.0	19.6	12.2	0.3
3.0	0.150 ft.	21.2	16.1	10.5	0.0
3.5	0.175 ft.	17.3	13.8	9.7	0.0
4.0	0.200 ft.	14.1	11.8	8.8	0.0
4.5	0.225 ft.	12.6	10.2	8.8	0.0
5.0	0.250 ft.	11.4	9.2	8.4	0.0
5.5	0.275 ft.	10.2	8.2	7.6	0.0
6.0	0.300 ft.	9.2	7.7	7.6	0.0
6.5	0.325 ft.	8.3	7.1	7.6	0.0
7.0	0.350 ft.	8.0	6.4	7.6	0.0
7.5	0.375 ft.	7.4	5.9	7.6	0.0
8.0	0.400 ft.	7.0	5.4	7.1	0.0
8.5	0.425 ft.	6.6	5.2	7.1	0.0
9.0	0.450 ft.	6.4	4.9	7.1	0.0
9.5	0.475 ft.	6.2	4.3	7.1	0.0
10.0	0.500 ft.	5.8	4.1	7.1	0.0
10.5	0.525 ft.	5.7	3.9	7.1	0.0
11.0	0.550 ft.	5.5	3.8	7.1	0.0
11.5	0.575 ft.	5.5	3.8	6.7	0.0
12.0	0.600 ft.	5.1	3.6	6.7	0.0
12.5	0.625 ft.	4.9	3.1	6.7	0.0
13.0	0.650 ft.	4.7	2.9	6.7	0.0
13.5	0.675 ft.	4.6	2.9	6.3	0.0
14.0	0.700 ft.	4.5	2.9	6.3	0.0
14.5	0.725 ft.	4.3	2.8	6.3	0.0
15.0	0.750 ft.	4.1	2.8	6.3	0.0

I have also included a graph of the results that is much easier to understand. As you can see, as the standard deviations for the instruments increase, the percentage of blundered loops drops rapidly and then flattens dramatically. The best cave flattens out at about 2.5 degrees of standard deviation and the lower quality caves around 7 degrees.



I think it is easy to understand what is happening here. As the standard deviations increase, large numbers of the better quality loops are eliminated from the group of blunders and so the percentage goes down rapidly. At some point, all we have left are loops with severe blunders that have not eliminated by the higher standard deviations. Clearly, the loops below the inflection point are blundered. You would never expect to have random errors of 10 or 15 degrees in a compass or inclinometer. Likewise, the loops at the very top of the curve must be blunder free.

Obviously, the sudden flattening of the curve represents the point at which we shift from unblundered loops (with high instrument standard deviations) to blundered loops. Thus, this point represents the maximum standard deviation for the instruments.

By looking at the graph and calculating the first and second derivatives, it is easy to estimate the point where each line goes flat. Here is list of my estimates:

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Lechuguilla - 7.5 Degrees   0.375 ft. 11.4 cm.
Wind        - 5.5 Degrees   0.275 ft.  8.2 cm.
Lillburn    - 5.0 Degrees   0.250 ft.  7.6 cm.
Roppel      - 3.0 Degrees   0.150 ft.  4.5 cm.
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The values may seem surprisingly large, but they are similar to other experimental values. For example, the March 1998 issue of Compass Points has an article describing the analysis of compass errors in an outdoor test-course. In spite of a relatively simple course and the use of experienced surveyors, some of the compass errors were in the range of 6 degrees.

Measuring instrument error this way has two advantages over the traditional survey course method of determining instrument errors. First, the values are based on the combined effects of thousands of measurements, with hundreds of different instruments, done by hundreds of surveyors, each using different survey techniques. Second, it enables us to look at the performance of instruments and surveyors in widely varying survey environments.

One disadvantage of this technique is that it gives you a composite error value that doesn't tell you anything about the individual instruments. It could be, for example, that the actual tape errors are much smaller and compass errors much larger than given here. Perhaps, a more complicated test would give separate values for the individual instruments.

CONCLUSION. In conclusion, it appears that blunders are a common problem in cave surveying, particularly for certain classes of caves. Also, examining real-world data is a very valuable technique for estimating the general quality of survey data and survey instruments. One advantage of the technique is that it tests the composite performance many different instruments and many different surveyors.