

Therion – Digital Cave Maps

Therion – cartographie souterraine digitale

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Abstract

This article gives a high-level overview of the features of Therion, software package for processing cave maps and models. After a historical introduction explaining the reasons for its development, the basic philosophy of the system is given. Following sections shortly describe data creation; on-the-fly warping of data to get a map and 3D model; and other data(base) outputs.

Keywords: cave surveying, computer generated maps, cartography, cave visualization, GIS

Resume

Cet article presente une vue detaillee des fonctionnalites de Therion, logiciel de traitement des topographies deavites, ainsi que de modelisation tridimensionnelle. Apres une introduction historique donnant l'origine de son developpement, la philosophie soutenant le systeme est indiquee. Ensuite, nous detaillerons la saisie de donnees, la deformation dynamique des donnees pour une cartographie detaillee et une modelisation 3D et les autres possibilites de sortie de donnees.

Mots-cles : topographie souterraine, cartographie assistee par ordinateur, cartographie, visualisation de grotte, SIG

1. Introduction

For a long time it has been a nightmare for cave surveyors to draw a map of large and complicated cave system. The nature of underground surveying does not allow us to achieve accuracy comparable with high-precision geodetic measurements. This implies that we never get the final map of any cave unless it is just a few dozens of metres long and contains no loops. When a new passage is discovered, which connects between known parts of a cave, the new loop does not usually fit perfectly into the old map. We need to do some error distribution (slight changes in the positions of stations) in order to fit the new loop into the whole network of loops. If we changed only the new loops, they could be distorted substantially, and the old ones would not be improved.

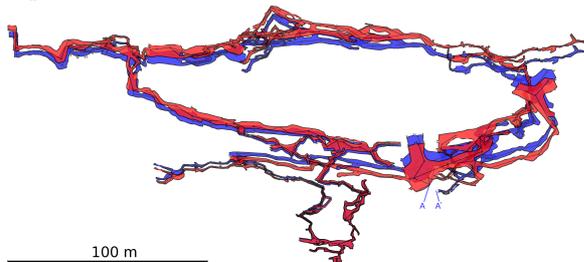


Fig. 1: Relative position of passages before (blue) and after (red) loop closure between stations A and A'

Such sequential loop closure used to be common in the time of hand-drawn maps, when surveys were plotted using ruler and protractor. Computers brought a great improvement more than 30 years ago: the error may be distributed over the whole loop network at once; information from each loop may improve (or distort) all other loops. This approach ensures the best error distribution and the least distortion in the centreline network. After the addition of new surveys all the loops are recalculated and we get better estimates of survey station positions than ever before.

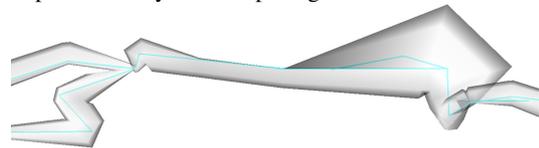
This is great so far. We get the best centreline estimate, so we may draw the most precise map. And here is the trap. If we finish the map and add a new loop later, the map will not fit the most recent centreline. The changes will be mod-

est, but visible. The only way to keep the map up-to-date is to redraw it. But for large caves it is too much work. Should it be done after each new loop closure? Once a year? Or should we do a step back and close the loops sequentially, distorting only new surveys?

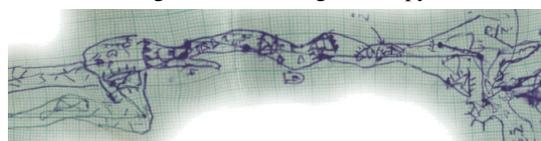
No, the correct question is: 'Can we get complete (hand-made-like), up-to-date maps directly from the computer?' The answer is: 'Yes.' There has been a long evolution in surveying programs; the outline of which is given below. Originally surveying programs helped with loop closure and centreline drawing; nowadays some of them are capable of producing the complete map.

The evolution of programs for cave surveying:

1. Programs for loop closure, error distribution and centreline plotting. The centreline is then used as a background layer for the hand-drawn map. This does not solve the problem when a new loop is closed – after recalculating the centreline a new map has to be drawn by hand.
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2. Programs that plot a preliminary 2D map or 3D model based on additional information added to each survey shot or station, usually LRUD (left-right-up-down) data. The map is very rough and can not replace complete maps with finely detailed passage walls and interior.

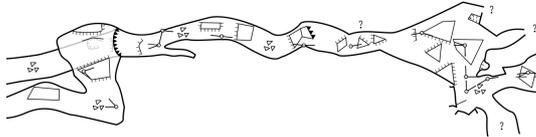


3. Programs that use scanned survey sketches (that are transformed, or 'warped' to fit the survey stations) to display the preliminary 2D map. This needs to be hand-traced to get a nice-looking final copy.



The problem with loop closure remains – the whole map needs to be redrawn by hand if new loops change the centreline significantly. Carto and WinKarst are of this type.

4. Programs that create complete maps. Maps which do not require any additional ink strokes. A few years ago only a dream. Now, reality. At least three programs aim to fill such a requirement: Therion, Walls and Tunnel.



This article describes main features of Therion.

2. Architecture of Therion

Therion is a complete package which processes survey data and generates maps or 3D models of caves. It runs on a wide variety of platforms: Linux, Windows and (partially) Mac OS X. It is completely free, released under the terms of GNU GPL, with source code available. It does not require any other commercial software to run.

Therion consists of several layers: it has its own language specification (described in The Therion Book), data editor (called XTherion), processing engine (called Therion) and model viewer (called Loch).

The basic design decision was to create (1) a universal language which would be able to describe almost all features present in the cave or in the karst area in general and (2) some kind of compiler which would translate this abstract representation to a visually pleasant map or 3D model. This approach is on the one hand really powerful, but on the other hand it is much less user friendly than most graphical WYSIWYG editors (the user has to learn a lot before using the program).

There is a strict separation between data and presentation. Data files contain an abstract description of the cave (position, type and other attributes of all cave / karst objects) without any information about how they should be displayed in the map. For this purpose there are definitions of map symbols and page layout in other specialized languages: MetaPost (generic vector graphics description language) and TeX (typesetting language). In the map processing stage the abstract data and appropriate presentation definitions are processed together to get a map visualization.

The language of Therion belongs to the family of *markup languages*, such as XML or more familiar HTML. For readers familiar with Web pages design and creation here is an illustrative analogy between HTML and Therion languages:

<i>Data creation tool</i>	any HTML editor (may be more or less WYSIWYG)	XTherion (less WYSIWYG)
<i>Data files</i>	HTML files	therion data files
<i>Layout definition</i>	CSS styles	MetaPost and TeX macros
<i>Visualization</i>	Web browser rendering engine	Therion
<i>Output</i>	Web page displayed in the browser	map & model displayed in appropriate viewers

The language defines just a few basic data objects: *centreline* for all data measured by compass, clino & tape, *scrap* for a simple section of 2D map, *map* for a collection

of scraps, *surface* for entering of topographical or aerial maps or digital terrain models. Scraps may contain *point*, *line* and *area* symbols. All objects are encapsulated in *survey* objects which make it possible to build complex hierarchical models of karst consisting of cave systems consisting of caves consisting of passages and chambers consisting of individual rocks, pits or water flows...

Although there are no more objects, the real power is in the attributes which can be assigned to each object. Attributes define more detailed information about the object, like *height* (predefined attribute) or *climbing_grade* (example of user-defined attribute) for the *chimney* line symbol.

The separation of data and presentation makes Therion fully customizable. For existing symbol types it is possible to define your own complex visual representation. If there is no symbol for a particular need, it can be defined by the user. For all symbols user-defined attributes can be created and later evaluated.

3. Creating the Data

There are basically two distinct kinds of data recorded in the cave: centreline measurements and survey sketches. They are entered into Therion in different ways.

Centreline data can be entered in the integrated editor in tabular form or – if there is existing centreline in Survex or Compass (PLT) format – simply imported. It is possible to combine both approaches. This should be familiar for anybody who used any cave-surveying software. The input language is based on the language of Survex.

In order to integrate different surveying data and styles, Therion directly supports various geodetic coordinate systems and conversion between them. For compass measurements there is a facility for automatic computation of magnetic declination.

For map drawing there is a special map editor. The cave map is split into simple sections – scraps (usually corresponding to survey sketches, which serve as a background for digitisation). Each scrap contains survey stations, which are used during the output map generation to align the scrap with the centreline (the scrap is ‘warped’ on the fly, the original data is never changed). Besides the stations, there are three kinds of symbols which allow anything in the cave to be described: points (station, stalactite, label...), lines (wall, pit, rock border...) and areas (water, sand...). The symbols are not drawn exactly: only the position and attributes are specified (e.g. you do not draw a pit as a line with small ticks on one side, but just draw a line and specify as its attribute that this line should be displayed as a pit). All symbols are only rendered later during the map generation, just after the scraps are warped; see below. This allows easy switching among different map symbol sets (e.g. UIS and your local symbol set, if you define it) and adapting all map symbols to a particular output scale.

If scrap data is available as already digitized drawings in other programs, then it is possible to import SVG and DXF drawings.

If there is no time to properly draw a scrap in XTherion, it is possible to just calibrate the survey sketches and display them correctly warped on the centreline for a quickly generated preview map.

There is also a third kind of data, which is usually not measured by cavers, but obtained from external sources: digital terrain models and raster surface maps (aerial, topographical, geological). Therion combines all the available data to get a map or 3D cave model.

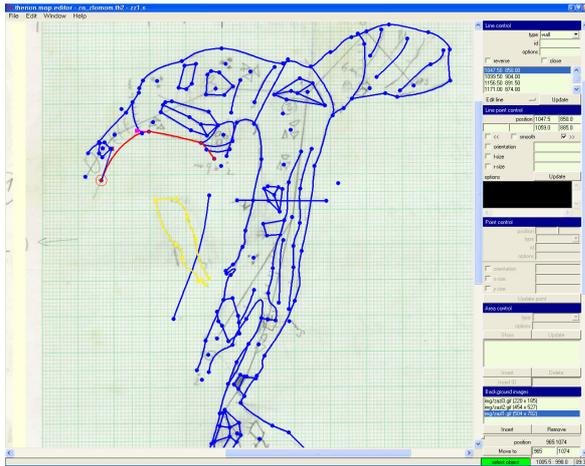


Fig. 2: XTherion – map editor

4. Data Processing

The missing link from abstract data to final maps and models is the Therion processing engine. When run, it reads the centreline, closes loops and distributes errors (using Survox and its least squares optimization).

Then it reads scraps, warps them to fit the centreline and joins them smoothly, and reads the definition of the symbol set which should be used and renders the map.

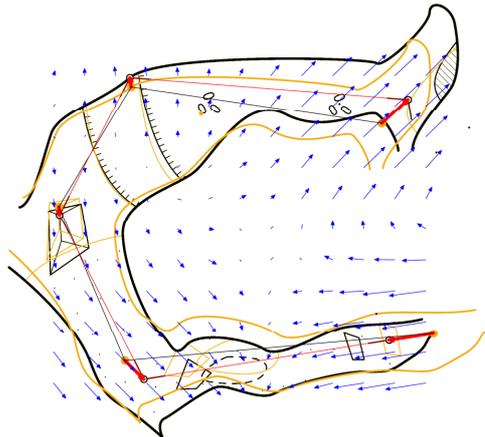


Fig. 3: The passage before (brown) and after (black) warping. The blue arrows visualize the transformation

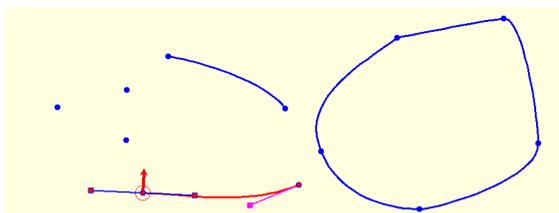


Fig. 4: Abstract point, line and area symbols in map editor. Selected object displayed red, attributes are not shown

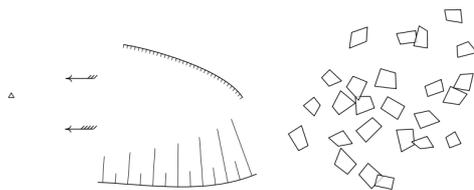


Fig. 5: Visualized symbols from previous picture

If the scraps are too distorted after the warping process, they may be processed in two steps: firstly scanned sketches are warped to fit the survey stations and only then digitized and again (slightly) warped on the centreline whenever it is changed in the future due to new loop closures. In the first step additional warping reference points (passage dimensions corresponding to LRUD data) besides the survey stations may be used to improve the results for non-proportionally drawn passages.

In the final step Therion traces all the passage walls from the map and creates a very detailed 3D model. All computations are hidden from the user, she only needs to draw scraps of the map as described above.

5. Map Output

Depending on the user's needs, skills and time available to enter data it is possible to generate different kinds of maps: just centreline, centreline with LRUD envelope, map built from warped scanned (bitmap) survey sketches or detailed vector map (or possibly a combination of all of them).

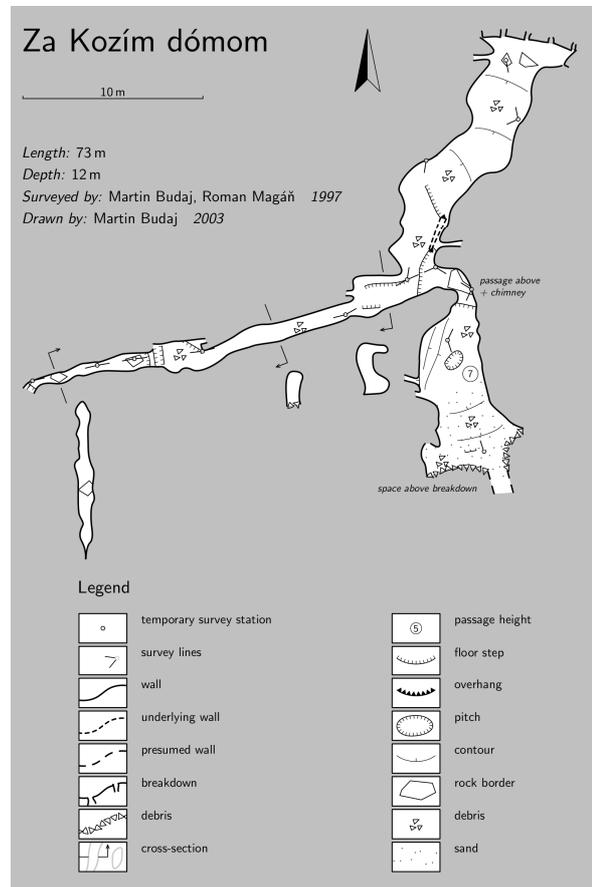


Fig. 6: Map with legend generated automatically

The output maps are very flexible – the map is not only up-to-date, reflecting all changes in centreline, but in addition you may change the scale, symbol set and format: either one-sheet map or multi-page atlas with cross references and hyperlinks.

Maps may contain the whole cave or only selected part(s).

When displaying complicated multilevel systems, you may choose between displaying levels as opaque or transparent, optionally coloured by depth; selected levels only; or

selected levels with the preview of some levels below (filled grey) and above (stroked as thin outline). Some levels may be shifted by a specified offset.

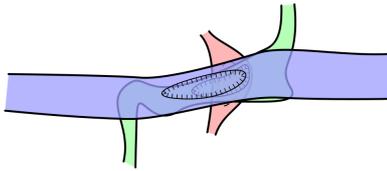


Fig. 7: Overlying passages displayed using transparency and different colours

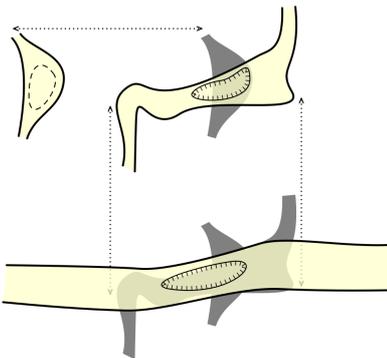


Fig. 8: The same passages displayed using map offsets

Therion can process three forms of map: plan with cross sections, elevation or extended elevation.

You may choose to hide some groups of symbols, so with one setting you can get a simple map containing only the passage outline and centreline; or you may instruct Therion to highlight all symbols denoting possible continuations in red... All variants are generated from one source simply by changing processing options. You draw the map once and get dozens of different customized maps as output.

In addition to print-ready maps (in PDF or SVG formats) you can export a map in various GIS formats (ESRI shapefile, DXF, KML), which contain the abstract objects with attributes assigned to them. As these maps can be exported georeferenced, they can be easily imported into another GIS project and processed further.

6. Cave Models

The map is reused once more while creating the 3D model. In addition to the tube-like models generated from LRUD data by almost all surveying programs, Therion uses precise passage outlines and information about passage height as specified in the 2D map to create much more realistic models without any additional work.

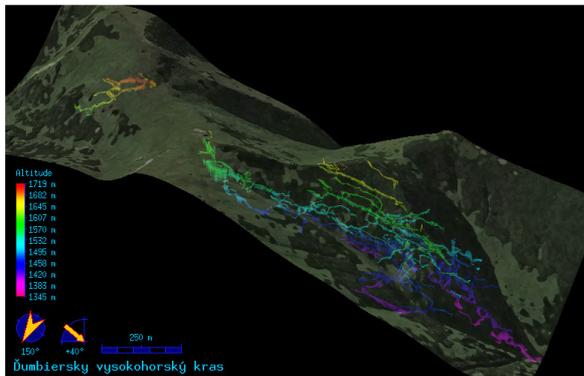


Fig. 9: Dead Bats Cave 3D model displayed in Loch

The model is combined with a digital terrain model and topographical map, if available.

For quick previews when no maps are drawn the model is generated from LRUD data.

The spectrum of available formats includes Therion, ESRI shapefile, DXF, VRML, 3DMF, Survex and Compass formats.

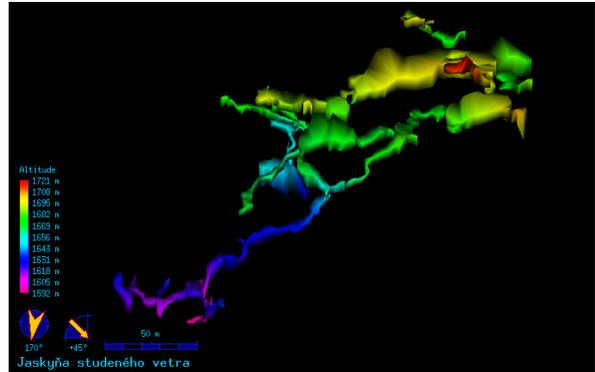


Fig. 10 More detailed 3D view

7. Database and Lists

Besides the maps and models there is another useful output. The centreline data can be exported to an SQL database, where queries like 'which passages were surveyed by X.Y. in April of 1973' could be given.

For exploration management in large cave systems there is a commented list of all (possible) continuations marked anywhere in the centreline or maps.

Projects covering larger karst areas may benefit from the structured list of all caves and their entrances.

8. Using Therion

Therion is especially suitable for large cave systems. Indeed, maps of some large cave systems over five continents (see <http://therion.speleo.sk/wiki/doku.php?id=proj>) have been generated by Therion and without Therion some of them would not have any usable map; only a lot of partial maps, sketches and notes which nobody would be able to put together.

It might seem that Therion is overkill for small, simple caves. Quite on the contrary; it brings the benefit of a uniform symbol set, and the ability to display a particular cave in any scale or all the caves in one scale, printed on the top of a topographical map.

9. Conclusion

Therion is quite a complex beast requiring some effort to tame it, but – all in all – it is well worth learning.

See the Web page of Therion (<http://therion.speleo.sk>) for examples, screenshots and documentation. Here you can download Therion and example files, read the Wiki pages and participate on mailing list.

10. Acknowledgements

Wookey helped us substantially to improve the language of this article. Thierry Gonon translated the abstract into French.