scientific journal of orienteering

Editorial

Orienteering maps and the science of cartography

Dear Readers,

This is a special issue of the journal focusing on orienteering maps.

Orienteering does not function well without good orienteering maps. Maps are cartographic products which require sufficient knowledge of mapmaking. When our sport started to be really globalized sport after the International Orienteering Federation was established in 1961, the first urgent issue was to create the international specification of orienteering maps. Every country had its own tradition of orienteering maps (regularly based on their state topographic maps).

Luckily, several professional cartographers contributed to the making of the first international map specification released in 1969. In fact this was the first time when scientific papers were published on orienteering maps: in the 1972 issue of the *International Yearbook of Cartography* three papers were published by the members of the IOF's Map Committee. Ernst Spiess and Christer Palm were professional cartographers, who developed the map specification by using their skills and experience of professional mapmaking. Few other scientific papers were published on orienteering maps at that time (the very first ones were written around 1970).

The International Yearbook of Cartography was an annual publication of the International Cartographic Association (ICA). This association shares some similarities with the IOF: they were founded near the same time (ICA: 1959, IOF: 1961), the number of member countries is almost the same (ICA: 78, IOF: 76 in the beginning of 2014). The ICA is the main international organization of cartographers, and has a large biannual conference on cartography, where hundreds of scientific papers are presented.

In the last few conferences there was a separate session on orienteering maps, which means that several (regularly 4-5) papers on orienteering maps were accepted by the conference organizers and presented.

This special volume of the Scientific Journal of Orienteering includes a selection of the most recent scientific papers on orienteering maps which were presented at the International Cartographic Conferences (most of these papers were revised and extended for this publication). Although these papers are available on-line on the ICA website (http://icaci.org/publications/), they are probably not really known by orienteers. This is the main aim of this special volume: to make these papers known by orienteers, especially for mapmakers of orienteering maps, who can utilize these papers in their work.

I would like to thank all authors for their contribution and the editor of the SciJoO for accepting our idea to come out with this special issue.

László Zentai (guest editor)

scientific journal of orienteering

Reducing Field Work with Automation in Orienteering Map Production

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Abstract

Automated production of orienteering maps seemed to be completely impossible due to extreme detainees and terrain adaptation of those maps. Use of dense LiDAR data point clouds, captured in non-vegetation season, that include also very small relief details and vegetation objects brought such ideas possible. The aim of described research was to evaluate the quality and usability of automatically or semi-automatically produced orienteering maps, without any field work. Positional accuracy, thematic correctness, legibility, use of map generalization's principles is discussed, based on two different methods; comparisons between existing orienteering maps (based on field work) and automated produced ones in the office and evaluation of runners' responses at the training course with a map, produced without any field work on the terrain, never before mapped with orienteering map.

Introduction

Orienteering maps are maps, specially designed for orienteering sports disciplines. Since the aim of these maps are to familiarize the competitor with the area where control points are positioned in the terrain and where he/she should find the optimal route, they have to be detailed, presenting all major terrain features that can serve as a place for putting control points and also those that influence on the correctness of the competitors decision about the fastest route to next control point. Therefore production of orienteering maps has taken a lot of field work since ever. The amount of field work in general depends on complexity of the terrain and quality and detainees of available source data, where use of LiDAR data as a source data brought a significant advantage in preparation of base map, a template for the field work.

But, nowadays we are faced with some computer programs that enable the use of LiDAR data as the only source for completely automated creation of orienteering maps. This way created maps naturally can't follow all the standards and requirements that have to be performed and such maps can't be used for orienteering competitions, but authors and some users of those applications propose such automatically produced maps for trainings. The goal in our research was to find out if this can be the case on different terrains and if additional visual interpretation of LiDAR data in office can significantly improve the quality and suitability of automatically created orienteering maps (O-maps).

Possibilities of deriving objects for orienteering maps

Traditionally national topographic database data is used as a source data for preparing template for orienteering maps creation. The main source for national topographic databases data are usually aerial photographs or satellite images, from where we can't recognise a lot of objects in forest covered areas, even if aerial survey is done in early spring. The final work, however, have to be done on the terrain. Due to extreme detainees of content of orienteering maps such creation is very expensive, time consuming and it requires a lot of terrain work, done by skilled map maker. Since terrain work requires a lot of subjective interpretation, O-maps can significantly differ according to the map maker, what might confuse orienteering runners.

Manual visual interpretation

The technology of aerial laser scanning (LiDAR) has importantly affected the principles of spatial acquisition of topographic and other physical data of the environment. The very important advantage of LiDAR capturing is its speed; it allows capturing large area in a short time with high density. The main results of airborne LiDAR survey are clouds of georeferenced points containing data of the reflection order and the intensity of the returned pulse. From point cloud two main surfaces can be generated, terrain model (DTM) from the last reflections and surface model (DSM) from the first reflections of

every laser beam. The airborne laser scanning data therefore seem to be a very useful source data for mapping different objects and phenomena, even vegetation density or terrain features in forest covered areas.
Recognition of objects, phenomena and edges from those data enable capturing different objects that has to be presented also on orienteering maps. Some methods for edge detection and building extraction mostly in urban environment, or for determine forest type, density or three-heights in forestry have already been very successfully performed and also mapped objects, like small water objects, relief features, paths and tracks etc. such automated methods haven't been efficiently performed yet, although some tests between orienteering map makers and also in topographic mapping field were done (Gartner at al, 2009). For those features manual visual recognition of objects on different LiDAR points
' derived images (eg. hillshading, slope map, vegetation height map) is probably still the most efficient method. Such images can be prepared either directly from point cloud, either from pre-generated DTM and DSM in different nowadays software. The orienteering map makers can use shareware las-tools programs, while OCAD11 ™ as the most popular software for orienteering map production also offers some procedures to create different derived images, as presented on figure 1.
Some additional images can be used as well, like slope image, surface shading etc. Besides, some specific shapes can be recognised also from contour lines, derived from DTM. Combining and composing all visually recognised and captured objects and phenomenon can result in quite complete orienteering map.

Automated O-map creation

Manual visual recognition is indeed much faster than detailed terrain recognition on field work, but is still needs a lot of detailed interpretation. Therefore automated recognition of different objects in one software solution might significantly shorten the required time for O-map creation. At the moment there are at least two software solutions that enable creation of "whole" map, both are shareware. The first one

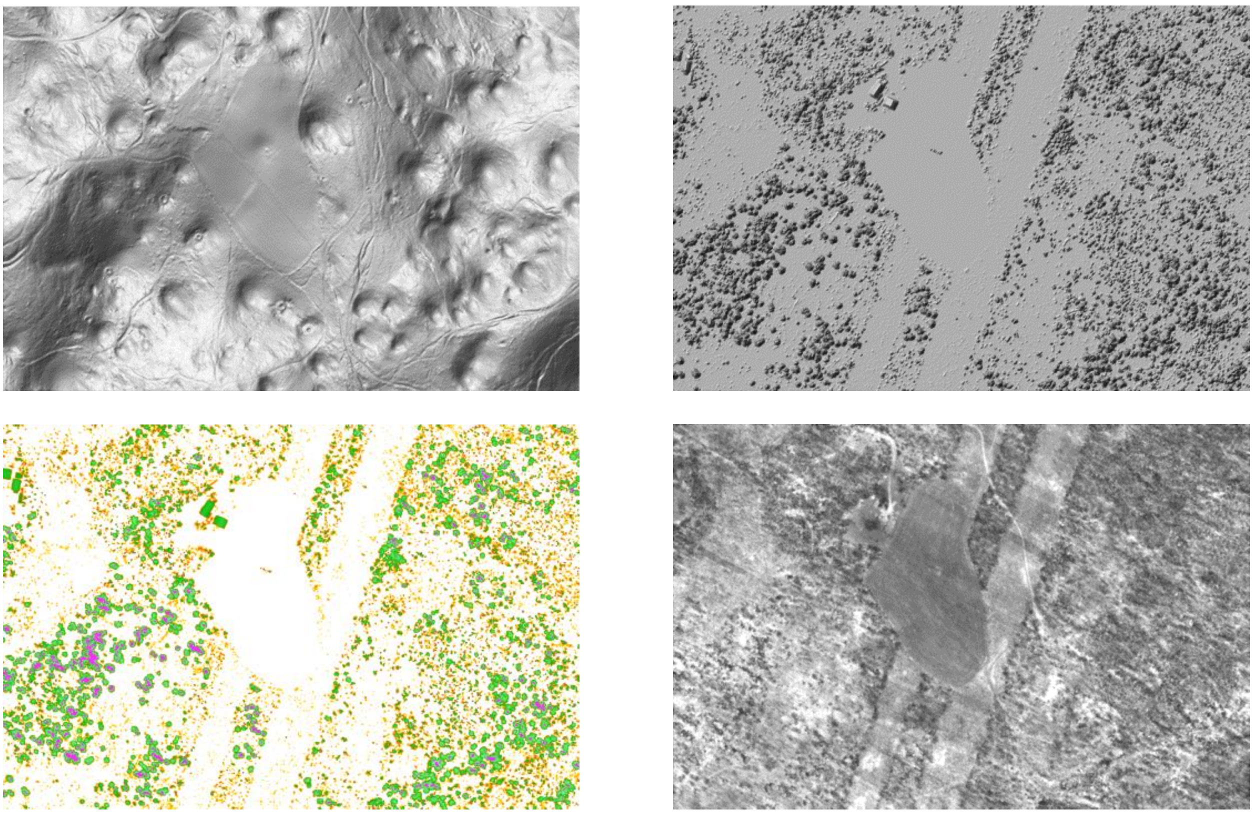


Figure 1. Images, that can help mapmaker for visual interpretation: ground relief shading, trees canopies, vegetation height and intensity image (created with OCAD11 ™)

is O-Laser ©, produced by Swedish Jarker Borman, while the other, Karttapullautin ©, was programed by Finish Jarkko Ryyppo. Both programs can create O-map consisted of contours, cliffs and vegetation. Since there are no big difference in final results we decided to use Ryyppo's Karttapullautin © for further tests.

Results

Our research on suitability of O-maps, produced without any field work, based on two different methods. In the first one, using Karttapullautin we automatically created inserts of the O-maps on different type of terrains, where O-maps made from different source data exists.

Comparison to existing maps

Few examples were made for areas where orienteering maps already exists to compare the content. Figure 2 shows the map of Domžale town, partly urban area with mixed individual houses and blocks of flats, river and partly steep recreational forest on the other side of it. The contour interval on automated created map is 2.5 m and is half of that on the corresponding O-map, this enables easier comparing of form lines and relief objects. Main template source for existing O-map were national topographic databases and orthophoto images, most of content is however captured in field work. It is evident that contour lines are both positional and vertical correct, criteria for cliffs is rather to low; only the largest presented cliffs corresponds to real ones, while the smaller one indicates other specific relief features. River is clearly recognised, while urban area with all buildings not at all.

Figure 3 shows the continental forest area of

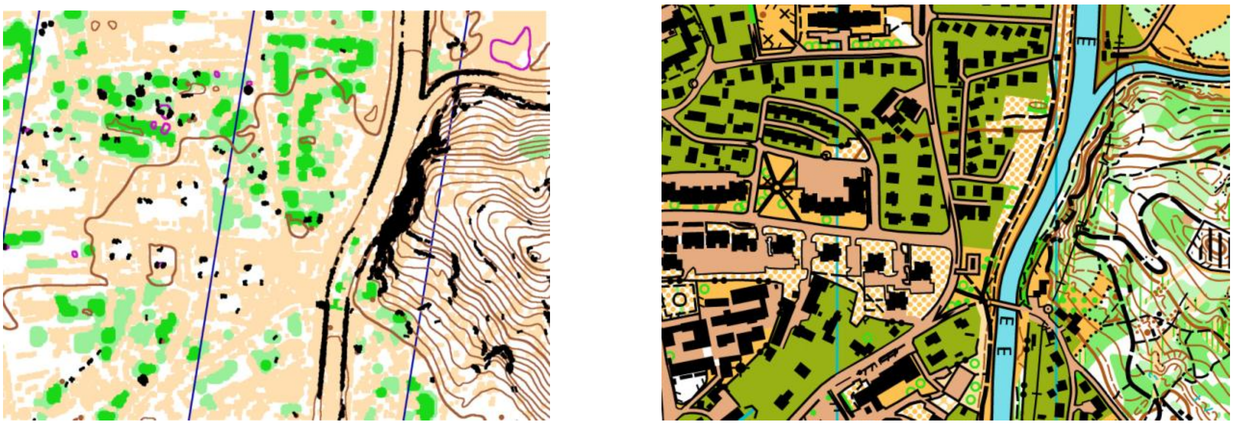


Figure 2. Automatically created O-map and corresponding O-map of urban area of Domžale

Figure 3. Automatically created O-map and corresponding O-map of continental forest area Kolovec near Radomlje

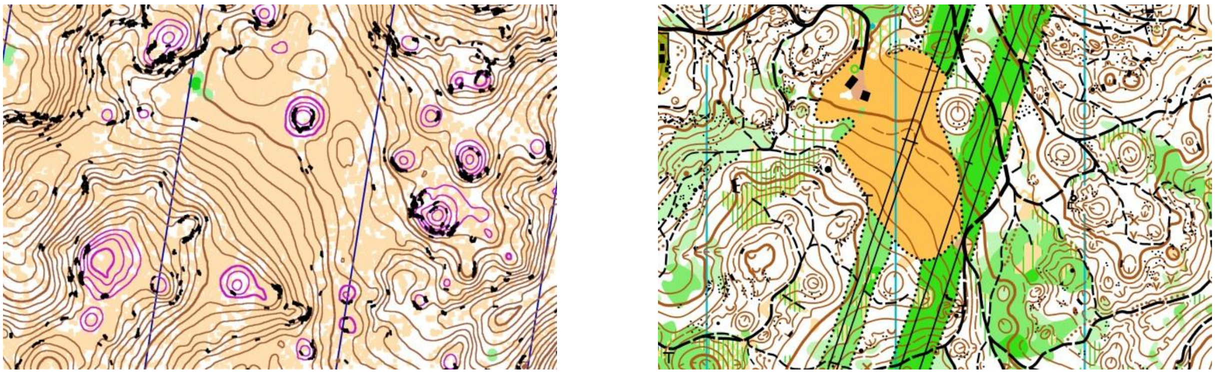


Figure 4. Automatically created O-map and corresponding O-map of karstic forest area Krumperk near Domžale

Kolovec near Radomlje, for which the original map is rather old (1991) and made using very poor template, out-of-date analogue topographic map with manual geo-referencing after the field work. But we can see that except cliffs, that present some deeper gullies and ditches, the maps fits very well, also positional accuracy looks perfect. Smaller relief objects are not recognised, while vegetation after more than 20 years couldn't be really compared.

A huge part of Slovenian territory is karstic and such terrains are very detailed and challenging both for map makers and for runners. Figure 4 shows the karstic forest area Krumperk near Domžale, with low density of trees, where the original map was made few years ago, using much better source data as the previous case Kolovec, more similar to map Domžale. Depressions are adequate, other larger relief features as well, with already mentioned underestimated criteria for cliffs. Vegetation is almost useless, areas with dense low vegetation was recognised as open area, what definitely isn't correct.

Figure 5 shows larger area, insert of one of the first Slovenian O-maps showing the ancient glacier moraine area next to Bohinj Lake. Very detailed and complex terrain with none adequate base map was a great challenge for the mapmaker, who after few days of using out-of-dated basic topographic map with 10 m contour interval decided to make an O-map without using any template. In pre-GPS era he could use only compass and pacing for angular and distance measuring, therefore it is quite expectable, that positional accuracy of map

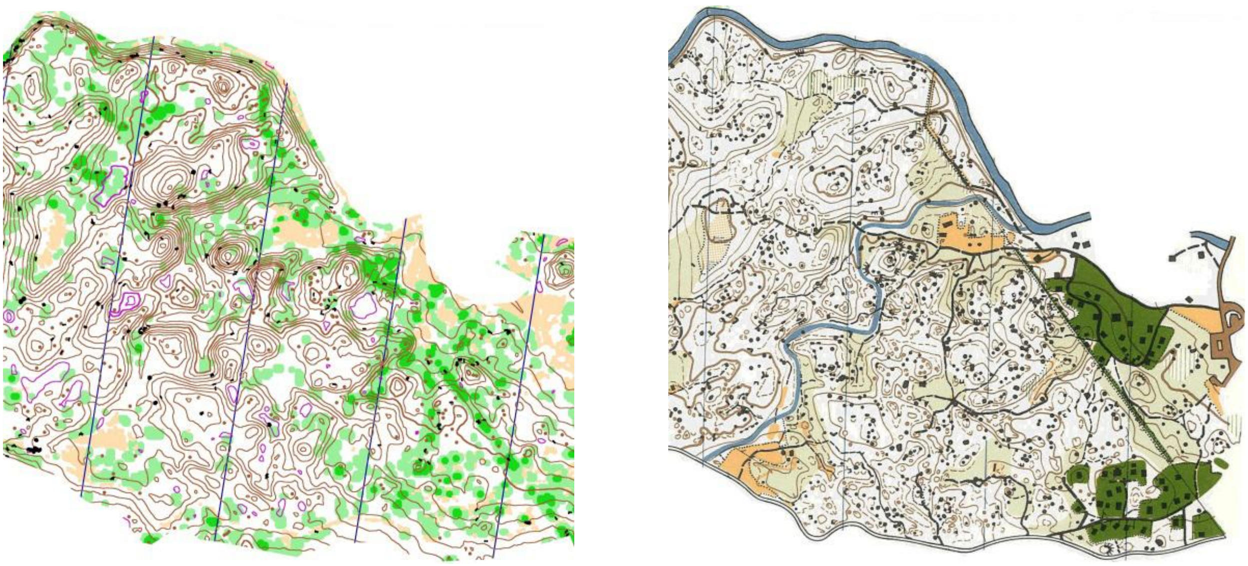


Figure 5. Automatically created O-map and corresponding O-map of moraine area next to Bohinj Lake, Ukanc

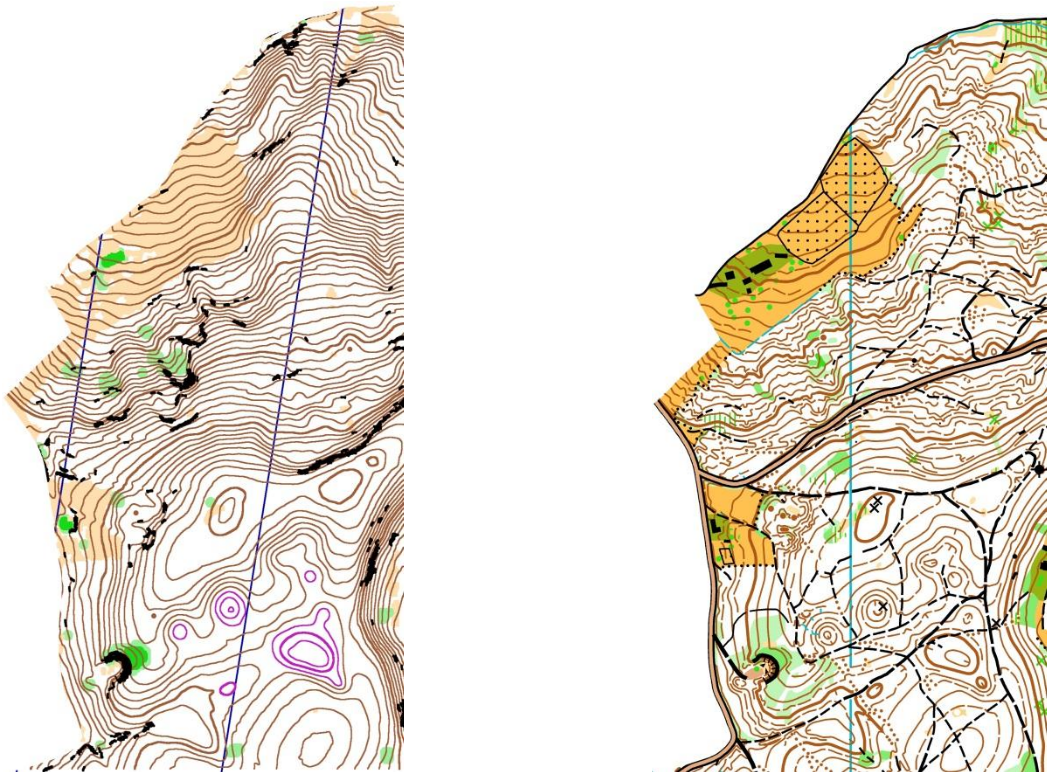


Figure 6. Automatically created O-map Hum and corresponding O-map, made from the same LiDAR data

features is worse that in previous examples. Heights of some hills and depths of depressions are not adequate, too, but general presentation of relief looks similar. On the old map we can see that there is a stream (usually dry) crossing the area form south-west to north-east, but on new map it couldn't be easy interpreted. Although the map is more than 20 years old we can still recognise open, semi open areas and even some dense vegetation areas, partly due to fact that the area lays in Triglav National Park, where interventions and activities in forest are limited. Finally, we can see that content fits very well, although the source data for the map were different. That fact encourages us that automatically produced maps are quite similar to originally made ones and therefore can be used at least for trainings.

As the last example we compared the automatically created map with the map made manually from the same LiDAR source data (figure 6) in the area of Hum, in north-east part of Slovenia.

The area is rather hilly, partly karstic on the south, partly continental and quite steep on the north. Contour lines are equal, maybe there were some additional contour displacements done during field work, while other conclusions can be similar like in other examples.

Training race on semi-automated created map

As the second part of our research we decided to prepare the real course on the map, created automatically, with as less manual work as possible. We were aware, that at such test runners could always be partly influenced with any existing map, based on the terrain check. Therefore it was obvious that the correct answers about suitability of map can be collected only on the entirely new terrain, where no O-map were ever available before. As the first one, we decided for the terrain near Prevoje. The selected terrain is mostly flat, what shouldn't be very common for LiDAR produced map, where we expect especially good presentation of terrain features. Different stages of maps were prepared. The very first one, created automatically form LiDAR point cloud using Karttapullautin ™ programme, consistas generalised contour lines, some relief point features (knolls, pits), vegetation (open area – presented in yellow and vegetation density – shown in green) and cliffs. The second version (figure 7 left) was upgraded with national topographic database data – buildings, roads outside the forest, water streams, lakes and, land use (mostly vegetation). The third version of map (figure 7 right) was completed with manual visual interpretation of features from DTM hill-shading image. Three different courses were prepared and Slovenian competitors were asked to make training course and evaluate the map they used. Within one week on spring 2013, 20 athletes, from youth and elite national team to seniors, from recreate runners to Slovenian top ones, tested and evaluated either automatically created map or the map, upgraded with manual visual interpretation of features. Few of the runners tried and evaluated both maps.

All participants were asked to answer short questionnaire and to give their opinion about the map they used, either automatically created either manually upgraded one. They were asked about the legibility, about colours, correctness and usability of presentation of deferent object types, about harmonization of overall objects' presentation, and finally, if such kind of map can be used for trainings or for competition. Every statement or answer was graded: 1 – very bad, 2 – acceptable, 3 – fair, good, 4 – very good, 5 – excellent, 0 – didn't notice, have no opinion. Results are presented in Tables 1 (for automatically created map) and 2 (for manually updated map).

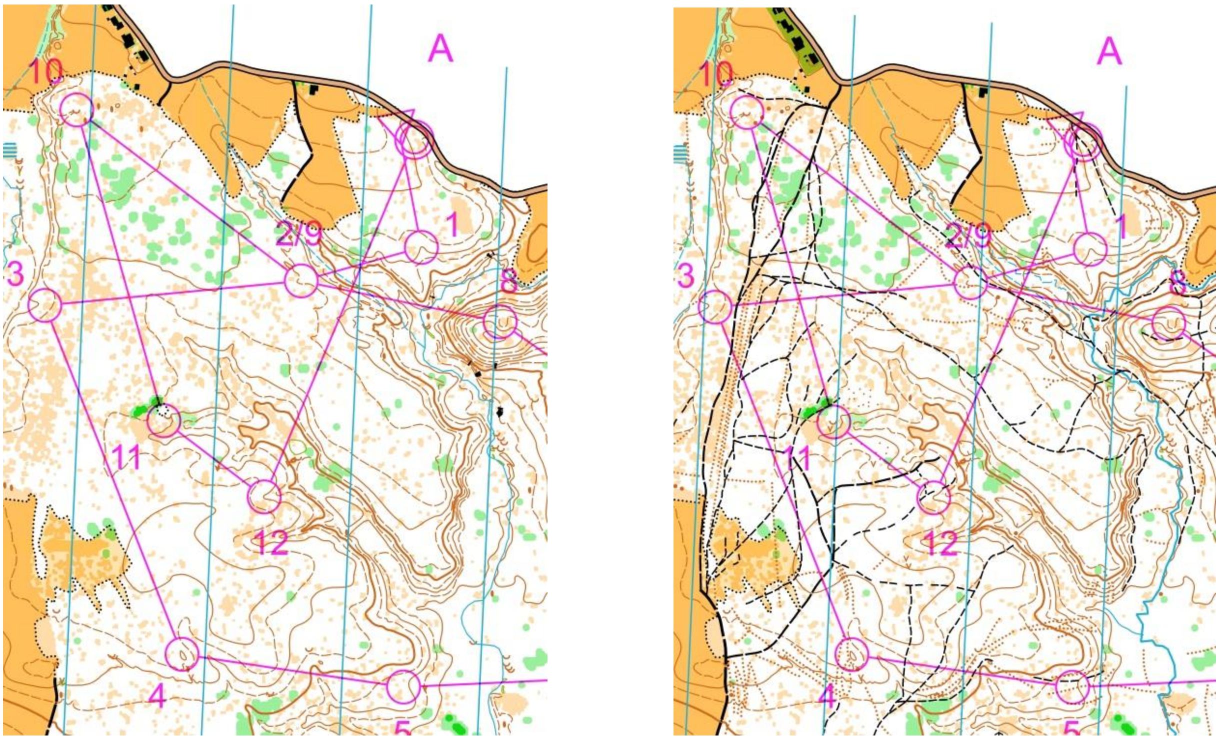


Figure 7. Maps "Prevoje", automatically created from LiDAR and national topographic database only (left); additional manual visual interpretation and capturing (right)

Automatically produced map

Criteria	mean	stdev
Readability of map:	3,9	0,8
Suitability of colours:	3,5	1
Correctness of contour lines:	4,6	0,5
Relief point objects (pits, depressions, knolls):	2	0,8
Presentation of vegetation - yellow:	2,9	0,6
Presentation of vegetation - green:	2,9	0,8
Presentation of water objects:	2,6	0,8
Harmonization of overall objects' presentation (generalization, mapping criteria):	3,7	0,6
Suitability for trainings:	4,3	1
Suitability for competitions:	1,4	0,7

8 answers

Table 1. results of research for automatically produced map Prevoje

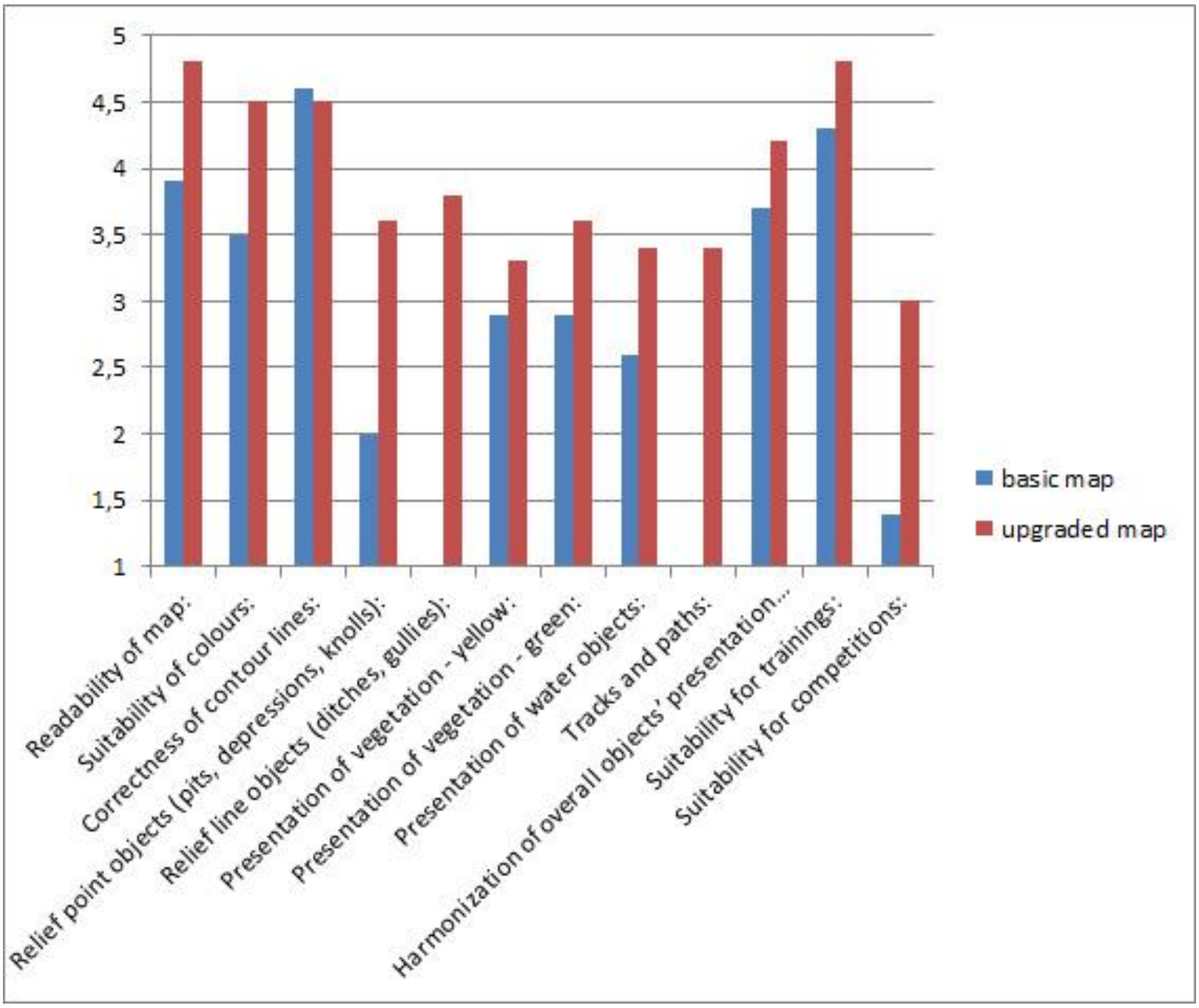
Upgraded map – semi-automatically produced

Criteria	mean	stdev
Readability of map:	4,8	0,4
Suitability of colours:	4,5	0,6
Correctness of contour lines:	4,5	0,6
Relief point objects (pits, depressions, knolls):	3,6	1,4
Relief line objects (ditches, gullies):	3,8	1
Presentation of vegetation - yellow:	3,3	1,1
Presentation of vegetation - green:	3,6	0,8
Presentation of water objects:	3,4	1,3
Tracks and paths:	3,4	0,7
Harmonization of overall objects' presentation (generalization, mapping criteria):	4,2	0,8
Suitability for trainings:	4,8	0,6
Suitability for competitions:	3	1,3

14 answers

Table 2.: results of research for manually upgraded map Prevoje

As we can see from the results in tables, the only really very well recognised content on automatically created map are contour lines, but even such map can be very useful for trainings, if it is based on relief recognition. But, with some manual upgrading in the office based on visual interpretation of LiDAR's data derived images the map become much better accepted, as presented in Graph 1. The main advantage is recognised at relief point objects, significant also at vegetation and water object, while they were no relief line objects or paths on automatically created map. It's obvious, that upgraded map gave much better overall impression for the runners, that's the only explanation why they better evaluated suitability of colours (they were the same on both maps) and even the readability of map (updated map contents more object and it would be logical to be worse readable).



Graph 1. Comparison of results of automated and semi-automated produced map

Such upgraded, semi-automatically created map were evaluated as almost perfect for trainings, some of responders even evaluated it as suitable for competitions.
We continued our research almost a year later, when we semi-automatically created the map Podbrezje. Terrain is much different like in Prevoje, only the very eastern part is relatively flat, while all the other is very hilly, with deep and steep valleys and gullies, shown on Figure 8. Same additional manual upgrading of map content were done, but much less like at the map Prevoje. Results of the same questionnaire are presented in Table 3.
Although the terrain seems more suitable for creating map automatically from LiDAR data the runners evaluated the map Podbrezje worse comparing the map Prevoje (Graph 2). Partly the reason is less manual capturing, especially with paths and tracks, but there were also some other facts (a lot of falling frees on the terrain, less distinctive colours on paper prints), that might also influence in evaluation.

Conclusion

The LiDAR technology enables very detailed and speed capturing of large area and therefore can significantly improve and shorten the procedure of orienteering map creation.

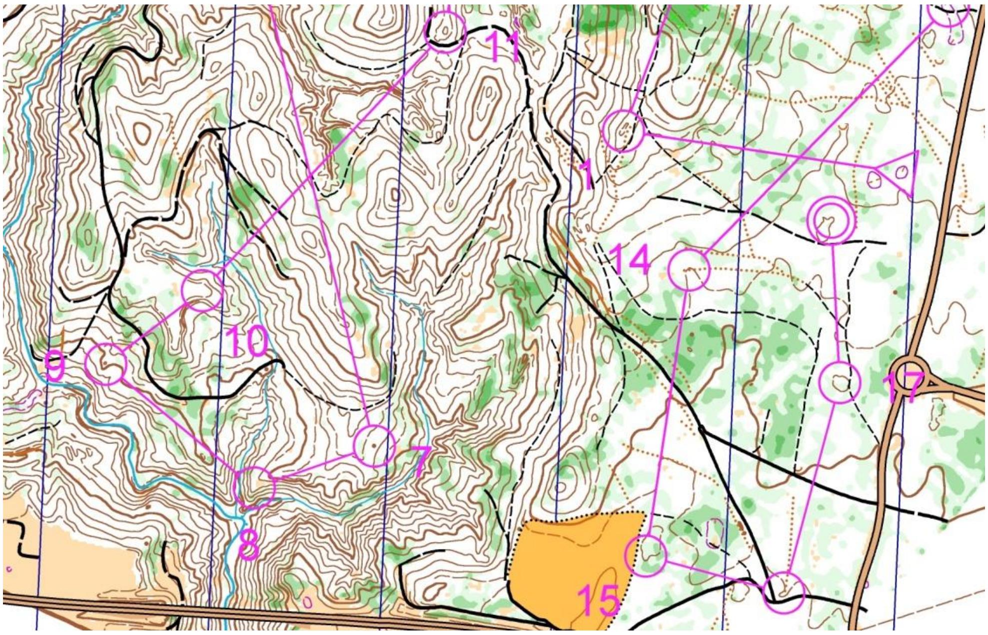


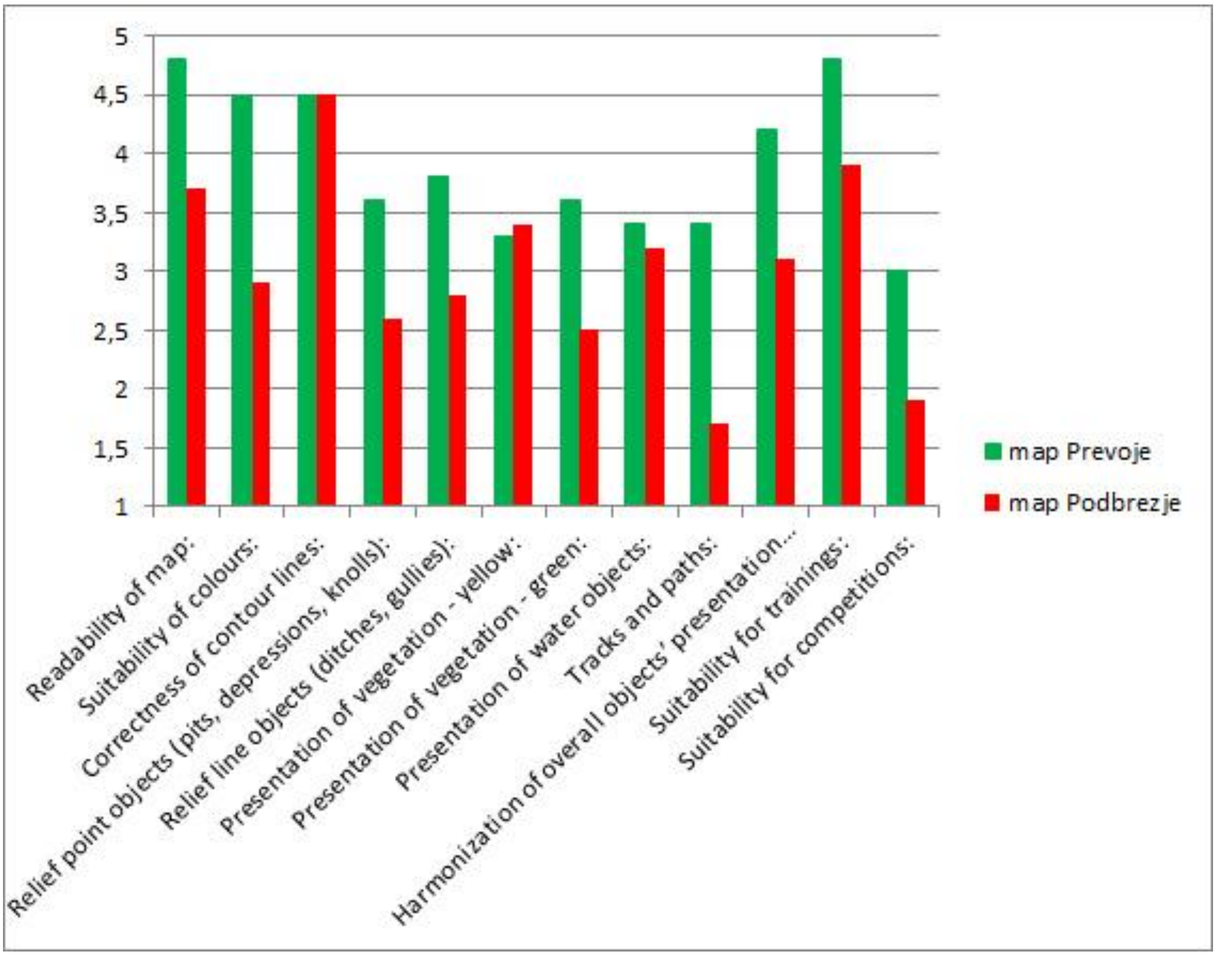
Figure 8. Map “Podbrezje”, semi-automatically created from LiDAR and national topographic database with additional manual visual interpretation and capturing

Criteria	mean	stdev
Readability of map:	3,7	0,9
Suitability of colours:	2,9	1,3
Correctness of contour lines:	4,5	0,8
Relief point objects (pits, depressions, knolls):	2,6	1,1
Relief line objects (ditches, gullies):	2,8	1,0
Presentation of vegetation - yellow:	3,4	1,6
Presentation of vegetation - green:	2,5	1,5
Presentation of water objects:	3,2	1,3
Tracks and paths:	1,7	0,7
Harmonization of overall objects’ presentation (generalization, mapping criteria):	3,1	0,9
Suitability for trainings:	3,9	1,2
Suitability for competitions:	1,9	1,1

19 answers

Table 3. results of research for semi-automatically created map Podbrezje

Completely automated production at the current state of interpretation algorithms is possible only for creation of maps for some specific trainings, like relief following, bearing trainings etc. With some additional manual interpretation in the office maps could be significantly improved and regularly used for some orienteering disciplines, like ski-orienteering or mountain bike orienteering (Petrovič, 2011), but also for foot orienteering trainings on different type of terrains. For regular competition in foot orienteering, creating maps would still require terrain identification, but with help of detailed LiDAR data created basemap amount of field work decreases. The future development of LiDAR technology, which could enable even more dense point clouds, and improvement of interpretation algorithms will further reduce the required amount of field work and consequently make the procedure of creating orienteering maps faster and less expensive.



Graph 2. Comparison of results of semi-automatically produced maps Prevoje and Podbrezje

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Laser Scanning and Orienteering Maps

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Abstract

Recently laser scanning has started to influence the process of making orienteering maps. Besides its use for generating precise contours, efforts are being made to extract additionally orienteering-relevant information out from laser scanning data. Finally, this leads to an already possible automatic derivation of orienteering maps. The aim of this article is to provide a review of relevant literature on this topic which have been published over the last five years. Of course the enumerated literature is not complete. A lot of examples and introductions to the practical use of laser scanning data can be found in the internet.

Literature Review

Laser scanning data which is suitable for supporting the process of making orienteering maps is provided with Airborne Laser Scanning (ALS). Emitted laser beams are reflected from the vegetation and ground. Echoes being received first usually have been reflected by the vegetation. This allows the derivation of a Digital Surface Model (DSM). The last echo is assigned to the ground and is used to derive the Digital Terrain Modell (DTM). It is suitable to produce contours. The difference between DSM and DTM shows the height of vegetation. An introduction to ALS can be found in (Zentai, 2009). Laser scanning is just a part of this publication. In addition the development of orienteering maps is summarised and other new technologies and their use are discussed. In the meantime laser scanning data is available in large-scale and has become much cheaper. In a few countries it is even free of charge (e.g. Finland[1], Denmark[2]).
The International Specification for Orienteering Maps (ISOM, 2000) defines features which should be included in an orienteering map. Which of these features can be derived from laser scanning data? (Gartner et al, 2009) are pointing out the potentials of extracting features from laser scanning data by comparing shaded ALS-based DTM and DSM with an existing orienteering map. Linear and point features such erosion gullies, paths, cliffs, knolls, depressions or boulders are detected in a shaded DTM and areal features, especially vegetation, in a shaded DSM. In the analysis of the results recognisability, geometric accuracy and the possibility of the classification of the terrain features are examined. The extraction of features with visual interpretation is possible and showing various success for linear, point and areal features. Nearly all linear features, big parts of point features and changes of vegetation can be detected. The classification of all found features has to happen in fieldwork.
Another comparison of laser scanning data and orienteering maps is found in (Petrovic, 2011). In three different Slovenian terrains, laser scanning data is compared with existing orienteering maps with nearly perfect congruence. Mainly based on laser scanning data and the idea of reducing fieldwork a new orienteering and a ski orienteering map were created. The time needed was reduced drastically.
Based on the aforementioned, the automatic derivation of orienteering maps is a logical step. The most impressive tool is Karttapullautin[3]. Karttapullautin is a program respectively a workflow which generates orienteering maps from laser scanning data. By now, it derives contours, form lines, knolls, depressions, cliffs, vegetation and water. It supports the input of vector datasets for adding data to the resulting map (e.g. roads, buildings). It has been developed from Jarkko Ryypöö and is steadily improved. Karttapullautin was awarded by Maps4Finland in 2012.
In (Petrovic, 2013) Karttapullautin is used for automatically deriving orienteering maps from laser scanning data. In different Slovenian terrain types the output is compared with an existing orienteering map. For an objective test a new area is mapped without fieldwork. One map is created only with Karttapullautin and data

[1] https://tiedostopalvelu.maanmittauslaitos.fi/tp/kartta?lang=en (access 19.1.14)
[2] http://download.kortforsyningen.dk/ (access 19.1.14)
[3] http://routegadget.net/karttapullautin/ (access 19.1.14)

from the national database and another one with additional visual interpretation of the shaded DTM. Orienteering athletes have tested the two maps and the results of a questionnaire are shown. They were asked about the quality of the map and their suitability for trainings and competitions. The results which are achieved with Karttapullautin are impressive: The map enriched with data from the national database seems absolutely sufficient for training and the map with additional visual interpretation even suits for competitions.

Typically a contour line connects points of same altitude. In (Born, 2013) the needed adaption for contours in orienteering maps in terms of better legibility and understanding of the terrain are pointed out. The aim of the thesis was to develop a Matlab[4] algorithm which creates optimised contours for orienteering. This includes the generation of form lines, knolls and small depressions. In a test area the output is compared with an existing orienteering map. Additionally, the output of different existing tools to create contours is compared. It is proved that OCAD[5], QGIS[6] and OL Laser[7] deliver the same contours. Contrary to Karttapullautin, they do not make an adaption of contours for orienteering such as (better) smoothing. The self-written Matlab algorithm delivers an output, which is not as good as manually-optimised contours but should be useful for orienteering mappers.

The benefit of laser scanning data for the mapping process and fieldwork is tested in (Guldimann, 2012). Three different ways of mapping are compared. Several test areas are mapped with different equipment. The basic setup consists of an aerial image, topographic basemap and contours with an equidistance of 1m from a DTM. The second setup additionally includes a vegetation map made with OCAD 11 derived from ALS data. The third setup extends the second setup with a laser rangefinder and a tablet PC. As a comparative value the hours of work were measured and compared. The vegetation map is proved to be a useful additive for mapping. The height of vegetation is shown color-coded and especially changes from deciduous forest to coniferous forest can be recognised well. The usefulness changes from area to area and depends on the terrain type. First of all, it is important that the ALS is up-to-date. Furthermore, an ALS is made for deriving a DTM normally. The quality of the side product DSM depends on the particular data. The date of flight influences the number of points reflected from the vegetation and in consequence the quality of the DSM. Nevertheless, the additional base map makes mapping easier and increase the correctness of the resulting map.

In (Olivant et al 2012) the practical application of various digital spatial data sources (particularly laser scanning data) in the UK is pointed out. A few examples in terms of revising existing orienteering maps especially with the aid of laser scanning data and in comparison with other data are shown. The danger of adding too many form lines is mentioned. This phenomenon can be observed when looking at the maps of EOC 2008 as shown in (Map Evaluation 2008). Besides financial problems the various data provide good results.

Laser Scanning Data for the Production of Orienteering Maps

Airborne Laser Scanning (ALS) is a technology that has been used in the last years more and more to produce orienteering maps. At the beginning of using this technology, only contour lines have been derived, but the quality of these contour lines where not sufficient for the production of maps, due to the resolution of the laser scanning data. Only main morphological structures could be represented, small land forms where only represented where breaking lines where available (Ditz et al, 2005).

The use of ALS data with a higher resolution and full waveform information could increase the accuracy of the derived contour lines and the digital terrain models (Gartner et al, 2007) as shown in figures 1 and 2. Figure 1 demonstrates the impact of a higher point resolution, shown by the example of DTMs. Due to a point resolution of 4 points/m², the details at the right side of this illustration are much more accurate, than at the same part of the left side. Apart from the erosion gullies, roads down to footpaths can also be depicted from the DTM, as Attwenger et al (2006) describes comprehensively. Good examples are the footpath at the south-east side and the vehicle track crossing from the south up to the western part of this illustration.

Figure 2 shows the comparison of contour lines derived from different DTMs. The equidistance of the illustration on the left side is 1 m, the equidistance of the contour lines derived from

[4]Numeric computing software, http://www.mathworks.com/ (access 18.1.14)

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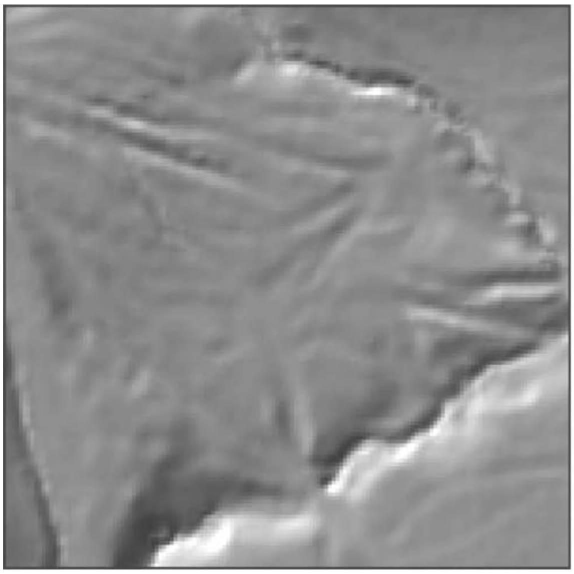


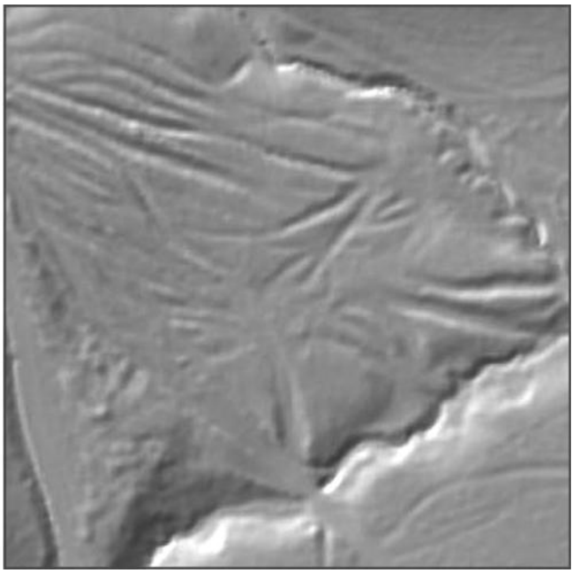
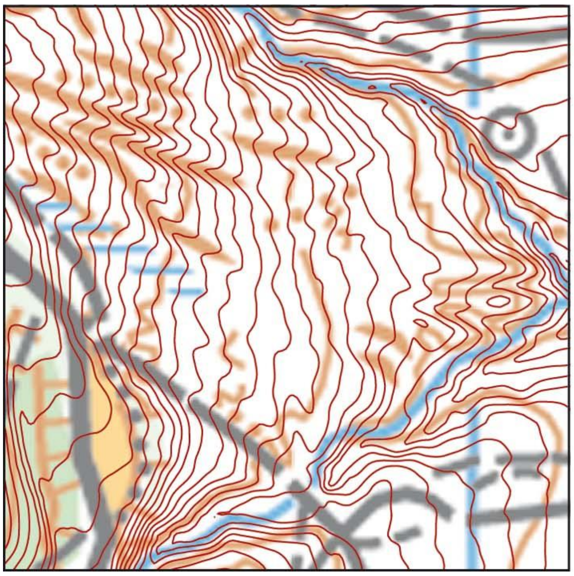


Figure 1: Comparison of digital terrain models with the resolution of 1 and 4 points/m²



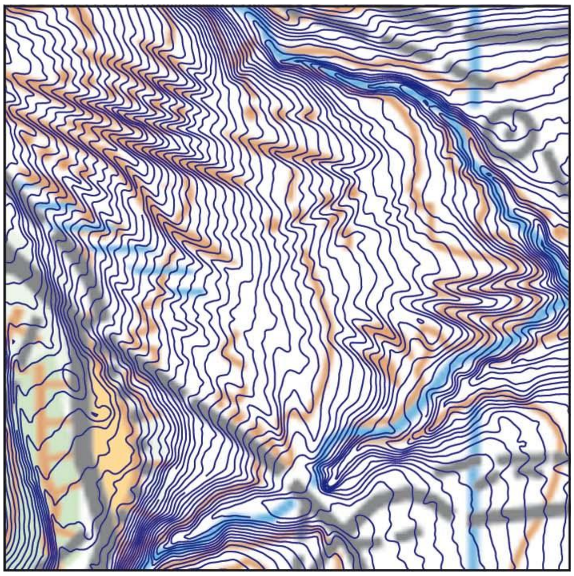


Figure 2: Contour lines derived from DTMs with different resolutions

the high resolution DTM on the right side is 0,5 m. It can be shown, that even small features like erosion gullies can be presented.

Rock faces can be detected easily as well in terms of the geometrical definition, as highlighted with blue markings in figure 3. A semantic classification as rock face remains insecure and therefore uncertain. In summary the geometry of linear features can be detected with sufficient reliability while a semantic classification of the feature type is hard to define. An additional validation is necessary, either by using additional data such as aerial images or by executing a topographic field work campaign.

Point features can be detected with different grades of quality (Gartner et al, 2009), using a high resolution DTM. Land forms like pits, holes or depressions can be depicted with a high geometric accuracy and probability, as shown in figure 3, marked with orange circles. The size of the feature is an important attribute to be used for the identification of the feature type. Features like small knolls and boulders, marked with red circles, can be depicted with a sufficient geometric accuracy but remain uncertain in their semantic plausibility, except those knolls that are large enough in size to be visualized with combination with the orienteering map. The filtered point cloud of the first pulse data could be applied to depict open land, as illustrated in figure 4 at the upper part with the green lines. The orange lines of figure 4 shows areas of rough open land that could not depicted from the DSM, but that are slightly represented with a different surface structure compared to the

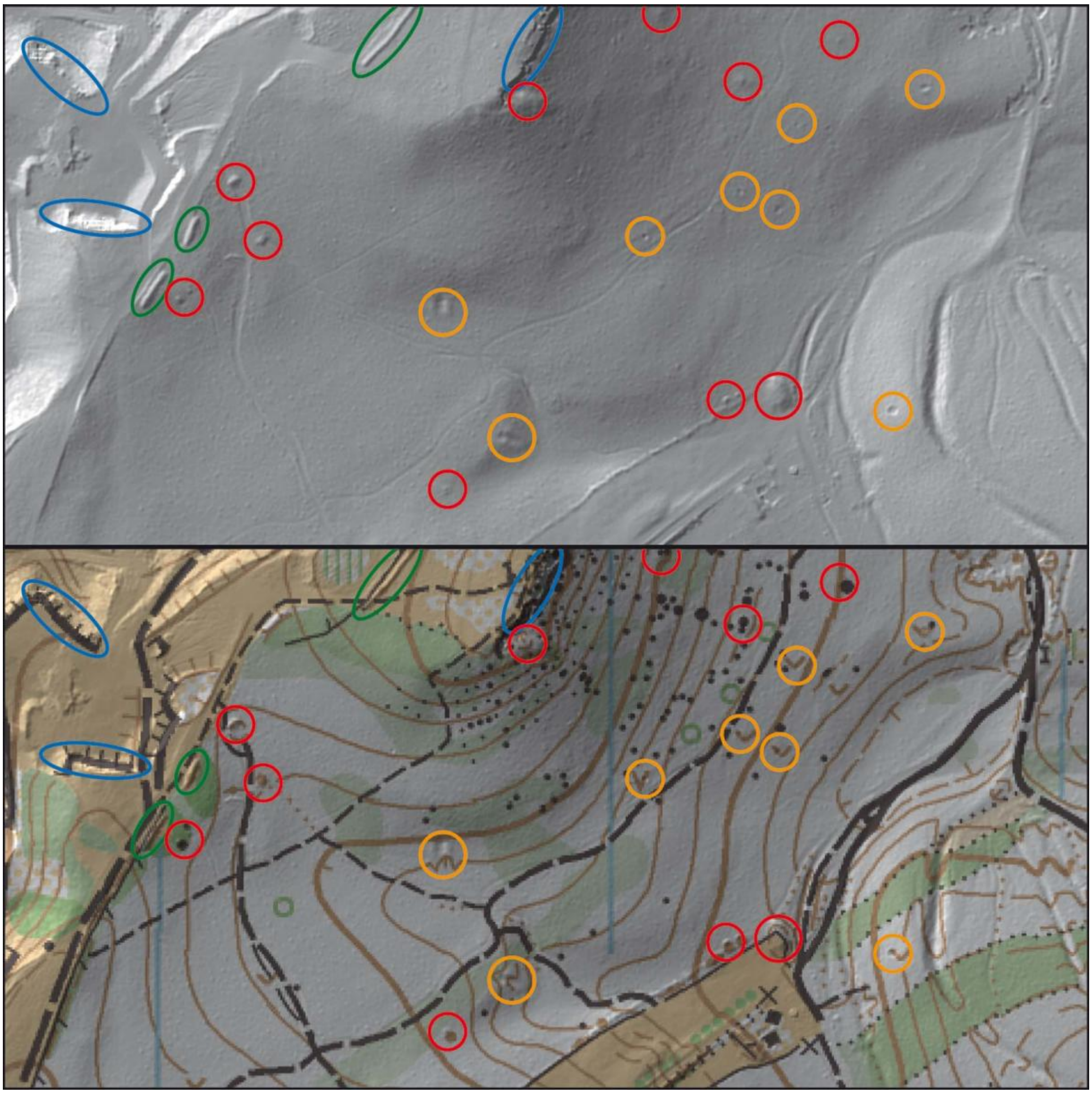


Figure 3: Point features like knolls, depressions, pits and boulders and further linear features like rock faces and earth walls

contour lines. The classification has to be done again at the field work.

For the detection of areal features, especially vegetation, a DSM has to be used. At the lower part of figure 4, the DSM is shown in ground structure of the surrounding forest. These areas can also be recognized in classified model of high vegetation, due to different structures. The model of high vegetation is shown at the lower parts of figure 4.

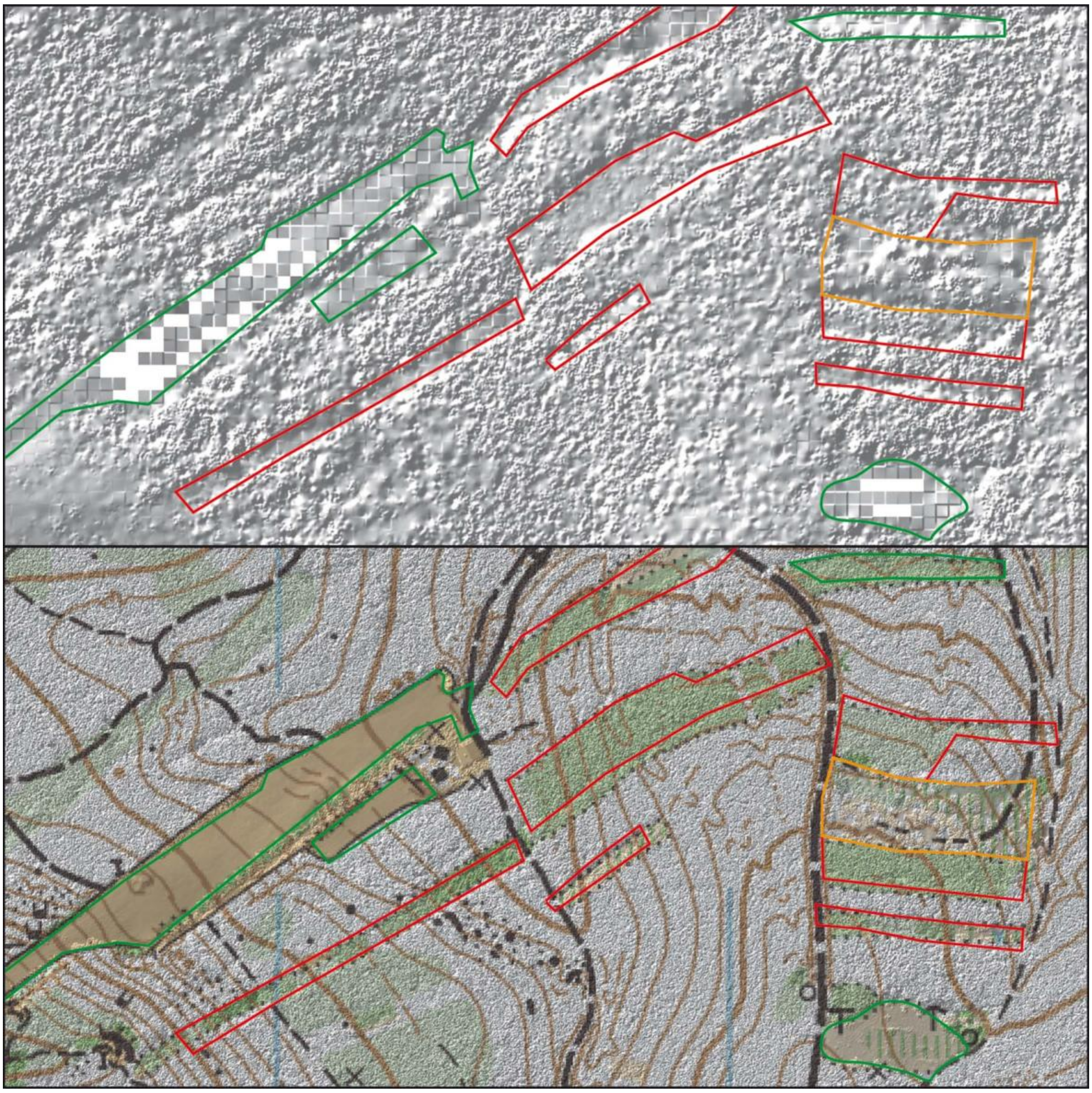


Figure 4: Detection of areas with different vegetation

Summary

With various examples in different terrain types it is proved that laser scanning data and orienteering maps match. The extraction of orienteering-relevant features with visual interpretation is definitely possible. But not each feature is recognisable and the classification has to be done in fieldwork.
Precise contours derived from laser scanning data make the mapping process easier and more efficient. The needed adaption of contours for a “good” orienteering map is only partly automatable and has to be done manually. Beside the use of precise contours, there are several possibilities to use laser scanning data in other ways. If careful used, basemaps (e.g. vegetation map) derived from laser scanning data improve the creation and revision of orienteering maps and simplify the mapping process. From a practical point of view, the aid of laser scanning data can definitely be recommended for mapping.
Moreover, the automatic derivation of orienteering maps and consequently the automatic extraction from orienteering-relevant features is possible. With additional vector data or visual interpretation the product is perfectly useable for trainings. But for orienteering maps suitable for fair competitions classical mapping and fieldwork is currently irreplaceable.

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Indoor Maps for Orienteering Sport Events

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Abstract

The paper gives an introduction to existing maps used for orienteering in indoor environments. It discusses techniques that are distinctive for indoor maps in general and for indoor maps of multiple floors in particular. This is a challenge both for the map maker and the orienteers. When designing the maps it is helpful to use knowledge about human wayfinding inside buildings as a basis, particularly when it comes to the representation of several floors. The cartography on normal orienteering maps are based on international standards developed by the International Orienteering Federation. There are no standards for indoor maps so far. However, the design of indoor maps should build on the same philosophy as for outdoor maps. The paper also gives a brief discussion on suitable locations for indoor orienteering events.

Introduction

Today there is a trend that many sports are moving into indoor environments. An important reason for this is to avoid unstable and unequal weather conditions for the athletes. However, better facilities and a better experience for the spectators also play a role. Since ice hockey moved indoor many years ago several other sports have followed. Speed skating is for example today mainly an indoor sport, and several indoor football arenas are used in national leagues, at least in northern countries. Athletics is in many cases considered as an indoor sport during the winter, indoor ski slopes are built and we have even seen examples where Biathlon is arranged partly on indoor stadiums.

Orienteering is maybe considered as one of the most typical outdoor sports that exist. Orienteering maps over large wilderness areas have usually formed the basis for orienteering competitions. However, some years ago the sprint distance was introduced in orienteering. This moved orienteering out from the woods and into the cities. Since maps over built up areas include quite different details, compared to conventional orienteering maps, a new standard for sprint maps were established (International Specification for Sprint Orienteering maps (ISSOM), 2005).

While other sports usually depend on some kind of built sport facility, orienteering is based on one crucial facility; the map. Consequently, facilities for orienteering can be established in many different areas, as long as a map can be made and the area is accessible for sport activities. One more “exotic” branch within orienteering is when the event is moved indoor! It is no reason to move orienteering indoor to make equal weather conditions, and it is no reason to believe that indoor orienteering will be attractive to a large group of spectators. However, the sport is based on a constant development of maps over new areas, and orienteering in indoor environments may be a new and interesting expansion of the sport. So far it is most likely that indoor orienteering will be arranged as training events, especial during the winter season. However, when making better maps for a location well suited for this purpose we may soon see more serious competitions.

Indoor orienteering opens for new possibilities and new challenges both when it comes to the competition and to the making of the map. For example will indoor orienteering in a multi-storey building extend the sport into 3 dimensions, and the navigation in 3 dimensions based on 2 dimensional maps might be quite a challenge.

Indoor orienteering is not a new invention. There are sporadic examples on indoor orienteering competitions arranged in different locations. Zentai (2009) shows an example on indoor micro orienteering where a gym is the arena and different equipment forms the obstacles in the track. In this example the map scale is set to 1:100. A similar example is shown at Web:Lasnamäe (2007) where an indoor athletic stadium is the arena and the map scale is 1:500. An even more exotic orienteering map can be found Web: Plaza de Toros (2013). This is a 1:250 map for a micro-sprint at Plaza de Toros de Villena – an arena for bullfighting (Figure 1). The challenges in the track are made by a labyrinth of artificial obstacles placed on the arena.

Figure 1. Indoor micro-sprint at Plaza de Toros de Villena. Map made by José Samper.

All these examples are categorized as micro-orienteering and are on the most extreme edge of indoor orienteering. The arenas are very limited, arranged obstacles are used and everything is located on one plane (more or less). Another, and maybe even more challenging kind of indoor orienteering is when an ordinary building is used as arena, especially when this "arena" consists of several floors. In Web:osprint (2008) the arena consists of five different floors in a 1:500 map over the building. Accessible areas have a white colour and the different floors have about the same horizontal delimitation. This is also the case in Web: World_of_O (2012), which is a 4 floor "arena" represented in a 1:700 map. However, when it comes to Web:Kuusalu_Keskool (2011) the different floors have an uneven location in the horizontal plane and it is difficult to know for example where the second floor is located (Figure 2).

Wayfinding in indoor environments

Indoor orienteering as a sport event is a quite rare type of arrangement. However, the study of how people behave and find their way inside a building has been the topic for several researchers.

Indoor wayfinding is, like the orientation in outdoor environment, depending on individual skills (Montello and Pick, 1993). One possible explanation for this is that individuals focus on different information about the environment when they engage in wayfinding (Lawton, 1996). Researchers on environmental knowledge have pointed out different kinds of spatial knowledge that are used when humans are navigating (Russel and Ward, 1982; Lawton, 1996). These can be distinguished as landmarks, knowledge about routes between landmarks and survey knowledge about the routes and landmarks (metric relational information organized in a common frame of reference) (Montello and Pick, 1993).

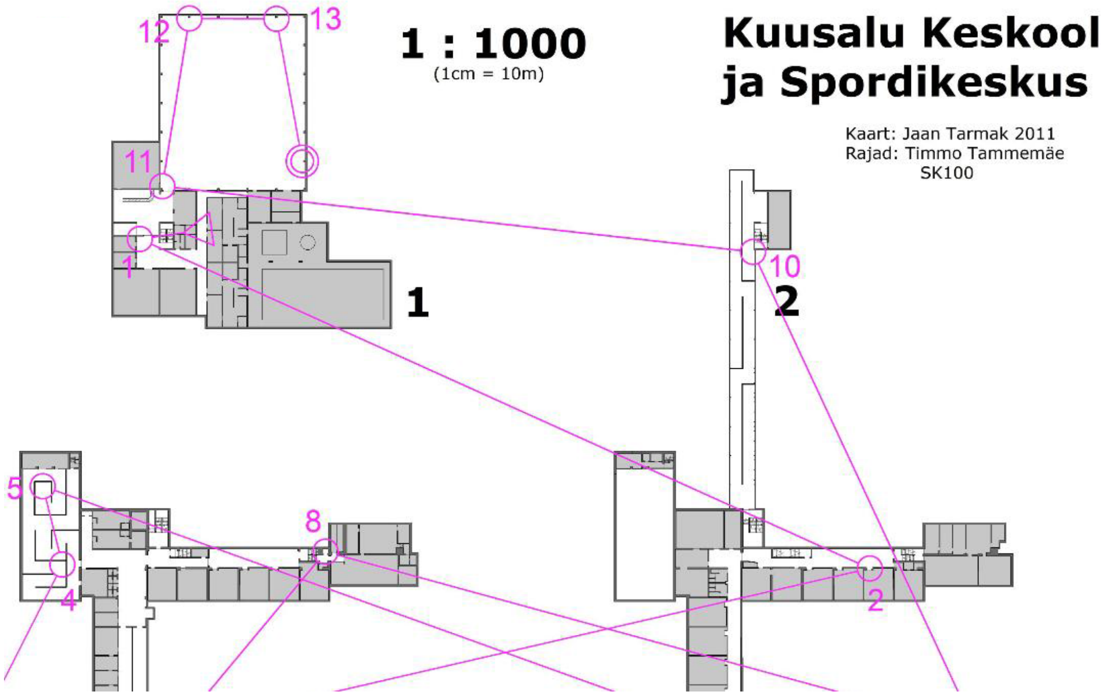

Figure 2. Different horizontal references. Map made by Jaan Tarmak.

Based on these theories has Lawton (1994), for wayfinding in outdoor environment, identified two strategies: the route strategy (route instructions as turn left, go ahead etc.) and the orientation strategy (makes use of references as compass direction, location of the sun etc.). Clearly the suns position will be of less importance in indoor environments. However, there might be parts of a building that may play the role as global reference points (stairways, common areas etc.). Lawton (1994) also suggests that individuals are switching between strategies depending on available information, and that shifting from a route strategy to an orientation strategy is most likely when the environment becomes familiar. Regarding the sport of orienteering it is likely that a rapid adaption of the orientation strategy is a key-factor for success in a competition.

According to Gärling and Mäntyla (1983) will decreasing the individual's sight inside the building reduce the effect of familiarity. This negative effect tends however to be counteracted by introducing a map. Even if the orienteer will use the map for familiarization, the total orientation in the building depends on several factors. Salient locations in the environment are the first "key-factor" in this process (Siegel and White, 1975). This is coincident with several authors who call attention to visible landmarks in indoor wayfinding (Puikkonen et al., 2009; Radoczky, 2007; Ciavarella and Paternó, 2004; Lawton, 1996).

Radoczky (2007) points out that change in direction happens more frequently inside a building, and consequently it is more likely to lose orientation. One suggested solution is a higher density of landmarks for indoor environments. Radoczky (2007) indicates that indoor landmarks may be elevators, escalators, stairs, doors, plants, info-boards etc., and to use universally understandable pictograms for landmarks that act as vertical connection lines between stories in 2D maps.

Puikkonen et al. (2009) point out several factors that should be considered when designing maps for indoor navigation: vertical navigation, orientation and relative position, navigation by visible landmarks and consistence between UI design and the real world. In addition to heavy pruning of details and simplification of the graphical layout, Puikkonen et al. (2009) recommend that the design of an indoor map should be in consistence with the materials, colours and shapes of the individual building. This in contrast to outdoor maps where colours associated with different natural phenomena are more equal. For indoor orienteering maps a long-term objective will be to make a standardized design. It is important for the

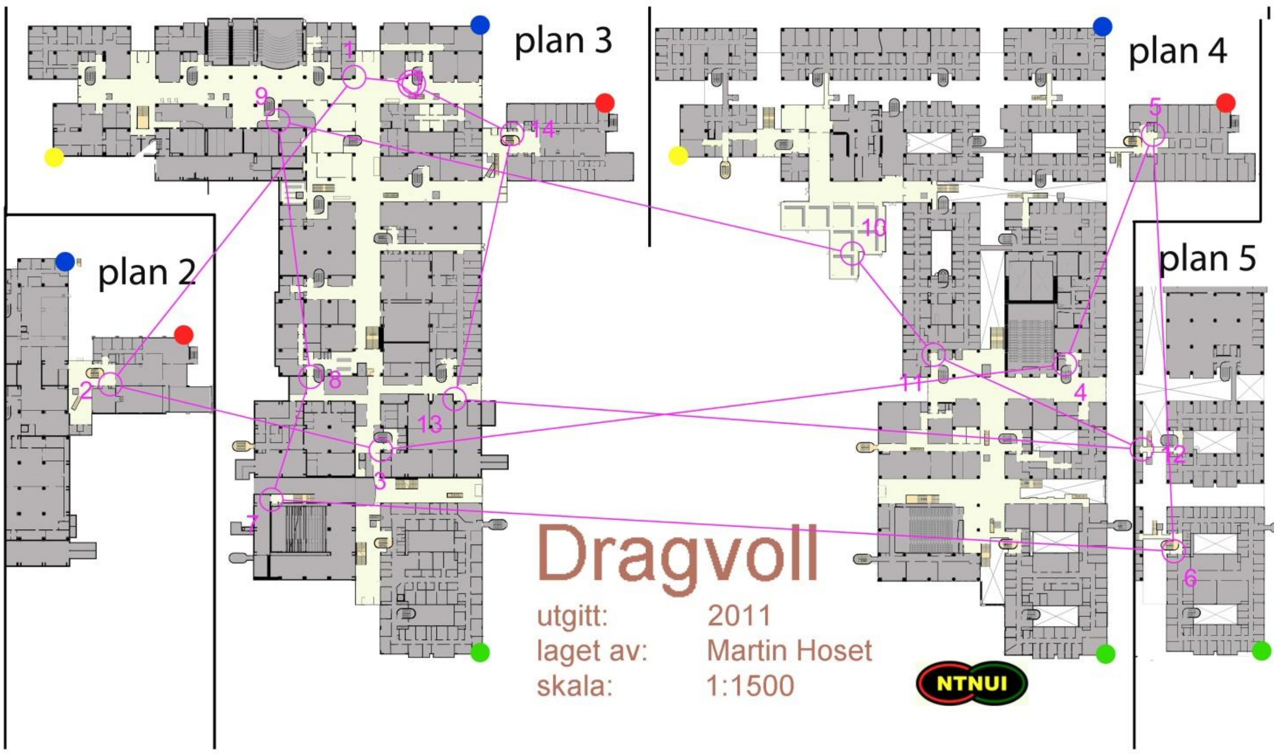

Figure 3. Map over NTNU Dragvoll. Map made by Martin Hoset.

orienteer to be familiar with the maps and their symbols rather than keep the colours etc. consistent with the indoor environment. However, when making standards for indoor maps it will be appropriate to use colours and symbols based on a general comprehension of the indoor environment.

The third dimension

The handling and presentation of several floors is maybe the most challenging problem for indoor navigation. Usually maps of the different floors are drawn side by side. In that case it is important to indicate how the horizontal positions of the different floors are related to each other. It can, as indicated in Figure 2, be very difficult to understand the connection between different floors as long as there are few similarities between the outlines of the floors. Figure 3 shows an example from one of the campuses at the Norwegian University of Science and Technology (NTNU) where horizontal reference points are included in the map to indicate the vertical connection.

The coloured circles in the corners of the floor maps are used as horizontal reference. Circles of colours have identical horizontal coordinates. In very short time it is necessary to find the corresponding stairs on two different levels, and with these references it is a challenge to do a rapid “mental movement” between different floors. The fact that the reference circles are virtual and not physical landmarks may hamper the apprehension of the situation. Web:osprint_1 (2013) solves this by using the same colour for the same stairs on different floors (Figure 4). The stairs will then act as horizontal reference points and link the floors together visually as well as in “the real world”. Emphasizing the stairs as links between the floors could in fact have been even stronger than in Figure 4, where the coloured stairs symbols are rather weak.

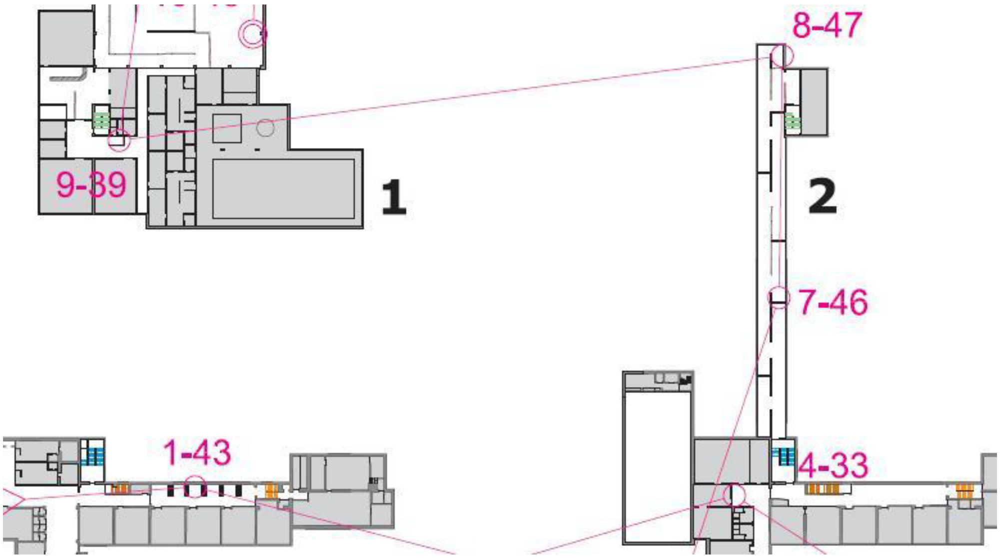

Figure 4. Coloured stairs used as horizontal reference. Map made by Jaan Tarmak.

In Figure 5 (Web:osprint_2, 2013) the circles around the stairs also act as horizontal references. However, here it is first of all the recognizable pattern of the circles that act as reference since the colours differ on the two floors. The green and red colours on the circles indicate if the stairs can be entered from the actual floor.

Some of the orienteering community in Estonia seems to be particularly active within indoor orienteering. They have experimented with different methods for visualizing one- or two ways connection between floors. This can be studied in Web:osprint (2009) (V-letters used as arrows), Web:osprint_1 (2010) (ISSOM passage symbols), Web:osprint_2 (2010) (arrowheads), Web:osprint_3 (2010) (Colour codes: blue –up (towards the sky), green – down (towards the grass)), Web:osprint (2011) (arrows) and Web:osprint_1 (2013) (Prohibited entrance marked with a red X). Since these constrains are made by the course setters it will be a part of the course rather than elements in the map itself.

In a normal orienteering course the connections between control points are drawn as lines. This method is also commonly used in "multi-floor" orienteering maps as for example in Figure 2 and Figure 3. However, for an orienteer this makes a visual mismatch. When he/she sees a long connection line between control points he/she expects a long distance. This is not necessarily the case when moving between floors.

Another, more innovative way of handling navigation on several floors is presented in Nossum (2011). This uses a new approach were the areas for moving around is visualized in a map inspired by the network-oriented map used by underground railways (Figure 6)

A consequence of this is stronger vertical links between the floors and less horizontal shifts between the representations of different floors. This last quality may help the orienteer in his/her judgement of distances. On the other hand, this kind of schematic map is quite different from a normal orienteering map where equality between the physical environment and the map is more conspicuous.

In Nossum et al. (2012) different floors are given unique colours codes. This might help in a

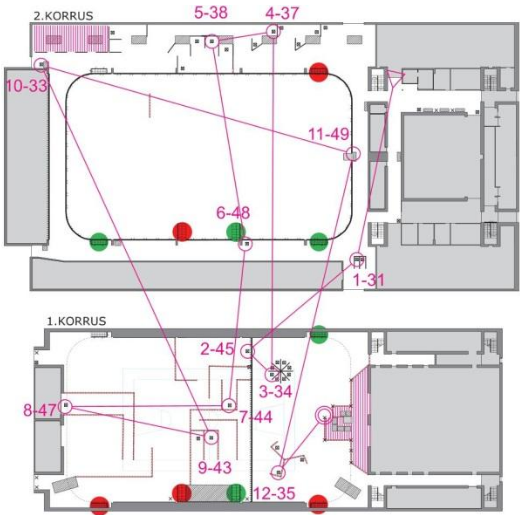

Figure 5. Pattern of coloured circles as vertical horizontal reference. Map made by Jaan Tarmak.

generalized representation where several floors are projected into the same horizontal projection. However, this concept can be

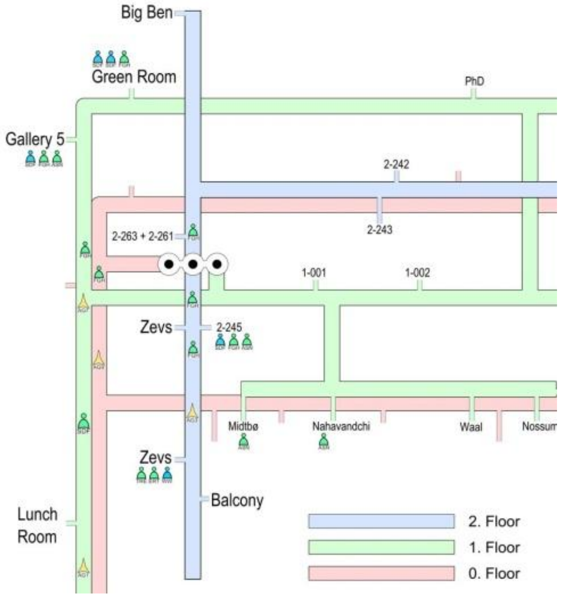

Figure 6. Indoor map inspired by subway-maps (Nossum, 2011). Reproduced with the permission from the Cartography and Geographic Information Society.

categorized as thematic maps and is based on too much generalization when it comes to navigational purposes.

The visualization of several floors in one map brings about several challenges for the map maker. However, the 3D extension of orienteering also introduces new and challenging possibilities for an orienteering course. When navigating between the controls, orienteers often have to select between two or more possible routes in the horizontal plane. In a multi-floor orienteering course it is even possible to choose between routs on different levels. Figure 3 gives an example on the “vertical challenge”. When moving between the 4^{th} and 5^{th} control it is necessary to select a route via another floor even if those two controls are located on the same floor. The same situation will arise when moving from the 7^{th} to the 8^{th} control. In these kinds of situations it is crucial to have good horizontal references in order to show the vertical connections between the floors.

Cartography

A significant challenge in orienteering is the use of different terrain and landscape types, both on national level and, in particular, between different countries. However, even if the areas for competition may have quite different characteristics, it is desirable to keep the setting for the competitions as equal as possible. To meet these objectives the International Orienteering Federation has agreed on several standards for orienteering maps. The most significant in this connection are *International Specification for Orienteering Maps* (ISOM) and *International Specification for Sprint Orienteering Maps* (ISSOM). These specifications use colours to distinguish between different areas. As a general rule accessible areas are represented by light colours while darker areas indicate less or no access. As an example is 4 different shades of green used to show the orienteer how easy it is to run through different kinds of vegetation. Areas with no admittance are also usually represented by dark colours.

In addition to be more detailed, the ISSOM defines slightly different colours in urban areas than ISOM. A lighter brown colour is used for streets and a dark grey value is used for buildings instead of using black as in ISOM. More roads are also represented as area objects in ISSOM, and not collapsed to black line objects as in ISOM.

When it comes to maps over indoor environments no specifications exist. For indoor maps in general there are fewer conventions on how a map shall appear. Outdoor we have natural phenomena where some colours are more appropriate than others, either based on natural appearance or by well-established conventions. Water is for example normally blue and vegetation is green. Few indoor areas are of a nature that invokes a natural colour representation. However, most indoor maps indicate public areas with a lighter colour than less accessible areas. This is in accordance with the results we will get if we apply the philosophy used in ISSOM for indoor environments. Since a building is represented by a grey colour in ISSOM it is natural to let some of the building remain grey when moving indoor. Most of the recorded examples use grey for rooms that are inaccessible, outlined by black or darker grey. This may also open for interesting variations in the map itself since the accessibility to certain rooms/areas can be turned on or off.

In Figure 3 it looks like there are 2 colours for areas that are open for the orienteers; white and light yellow. However, in this case only the yellow colour represents accessible areas. The white areas are actually outside the building modules in this building complex where several modules are put together under the same roof. A better outline of the building complex and a darker colour tone for the open "non-existing" areas between the building modules might have improved the readability of the map for an orienteer.

Yellow usually indicates open areas in an orienteering map (ISOM and ISSOM). The map in Figure 3 makes use of this. The open area in the map over Plaza de Toros de Villena (Figure 1) is also coloured in two nuances of yellow. However, to avoid that the course information drowns in the background it is important to avoid too high saturation value or too dark shadings.

Symbolization of the vertical connections in a multi-floor arena is a distinct cartographic challenge. As mentioned earlier it is important to emphasize the vertical connections between the floors. One solution may be to make more distinct symbols for stairs in a building, and make a separation between stairs with different horizontal positions. Figure 4 uses colours for the horizontal separation. Giving unique numbers to the same stairs at different floors is another possible solution. Figure 7 shows a three-floor map where accessible areas are white while the accessible stairs are given light yellow colour shading. In most cases it will be natural to include elevators as inaccessible!

All orienteering maps are a generalized picture of the real situation. Scale is of course an important factor when different generalization parameters are set. Sprint orienteering maps are based on larger map scale than a standard orienteering map (typical: 1:5000 vs. 1:10000). The scale for indoor maps is by nature even larger. A typical indoor map has a scale in the range 1:500 – 1:1000. For larger building complexes it might even be 1:1500, and for micro-indoor orienteering the range are from 1:100 to 1:500. Large scales open for maps showing quite small details. It is however important to avoid details that are superfluous for the orienteer. Details inside inaccessible areas in the building need to be strongly de-emphasized, or even totally removed.

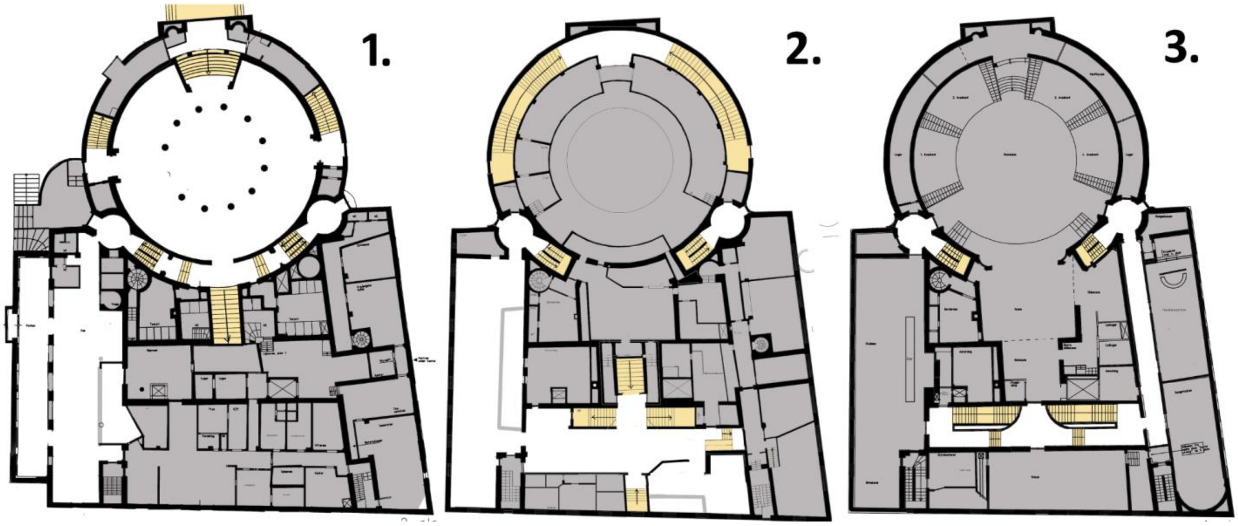

Figure 7. Indoor map of Studentersamfundet in Trondheim. Map made by Martin Hoset.

Figure 8 shows some maps Jaan Tarmak has made over Tallinna Spordihall. The three maps are dated (from top) 2007, 2009 and 2012 and show development in the generalization. From 2007 to 2009 the saturated background colours disappear together with all the marking on the floor. In addition are the tennis and basket areas marked as inaccessible, and most of the details disappear in those. In 2012 the individual seats on the tribune are replaced by a more general symbol and indications of different rooms are removed from the inaccessible area beside the running track (grey area). All these simplifications are made to reduce the amount of insignificant information for the participants.

Figure 8 and Figure 1 also illustrates how details in the “terrain” may be organized for events in large open indoor areas (sport halls, gyms, bullfighting arenas etc.). Different objects and obstacles are placed in the arena and a corresponding version of the map is updated.

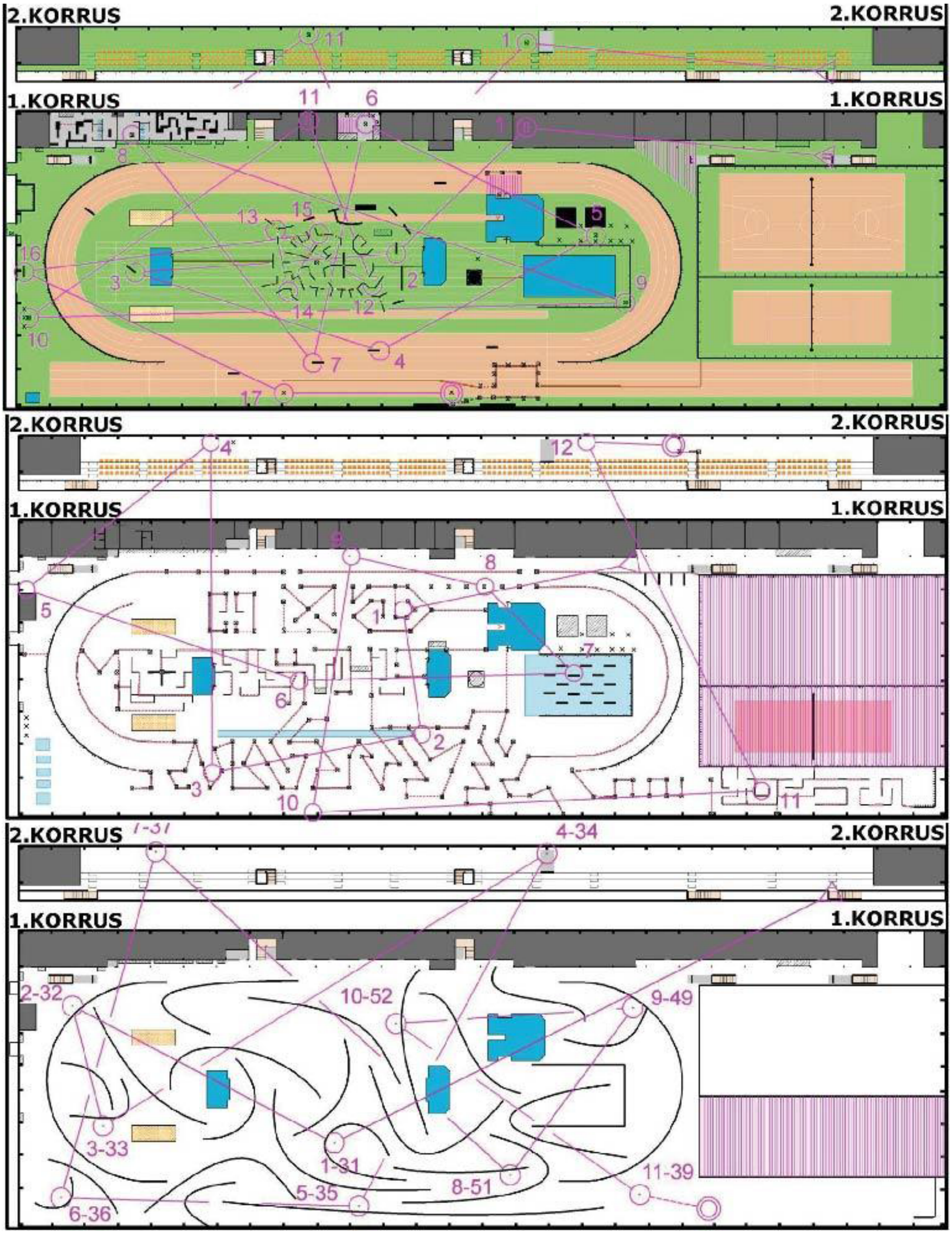

Figure 8. Three maps of Tallinna Spordihall showing various grades of generalization. Maps made by Jaan Tarmak.

All the examples in this paper are special made maps or maps based on existing floor plans for the constructions. The maps are edited and prepared for orienteering events by Cad-programs and the like. Today many modern buildings are handled in Building Information Models (BIM). Many governmental organizations demand that models of their buildings are handled in a BIM (Walton and Worboys, 1989). A BIM contains detailed information about the constructions, and may be a suitable basis for automatic generation of floor plans, which in the next step may be processed into an orienteering map. A future standard for indoor orienteering map will help making this process more automatized.

Indoor arenas

All possible arenas for indoor orienteering are built for other use. The closest constructions in this connection are sport stadium, gyms etc. These can be allocated for orienteering events as well as for other sport arrangements, as long as there is a map present. One drawback by using stadiums is the lack of the 3rd dimension. The available area will also be quite limited and usually artificial obstacles have to be introduced to make the challenge interesting.

Other possible “arenas” for indoor orienteering may be university buildings, shopping centres and other large official buildings. Independent from where the indoor arrangement is arranged it is important to avoid conflicts with the normal users of the facilities. A fast moving orienteer inside a building may lead to dangerous situations if the “arena” is crowded with unsuspecting people.

A common feature for all “candidate arenas” is consequently that there has to be low activity at certain times when it comes to the primary use of the building(s). University buildings are for example less crowded in the evening or between the semesters, and the use of other official buildings is only possible outside the normal office hours. A crucial factor is that the management of the actual buildings is positive to this kind of arrangement, and that frequent arrangements in the same buildings are avoided. An “insider” with interests for orienteering in the management is an advantage!

Orienteering depends on adequate light condition since the participants need to read the map and comprehend the environment. Headlamps are used when it is getting dark in conventional orienteering events. When moving inside the buildings one expects that indoor lighting will solve this problem. However, in practice the lighting condition may change depending on where you are inside a building, in particular when the activities are arranged outside the timeframe for normal activities in the building.

Conclusions

Indoor orienteering opens for new and interesting aspects within the sport, and may be a valuable contribution as a new training scenario for orienteers. Increasing activity in the field will also open for more advanced competitions. The activity will of course be hampered by the lack of available “arenas”. However, the access to buildings that in principle is designated for sport activities might be a good option. Other large building complex with a public purpose might be another.

The map is of course a crucial component in this connection. Today there are no international standard for indoor orienteering maps. Standards for how the map should be designed may help in further development of these activities. When making these standards one should keep in mind important factors for how humans navigate in indoor environments. Literature show that landmarks are important, and that those landmarks can be associated with the vertical connection in a multi-story” arena”. The vertical transition between different floors is also a key component in an indoor orienteering map. Consequently a future standard should keep a particular focus on how to represent this on the map.

Theoretically, symbolization and the colours in an indoor map should be in accordance with the appearance of the environment it represents. However, when it comes to orienteering maps it is important that the presentation of the map is recognizable independent of which building it represents. When making the standards for indoor environments it is also essential to use a cartography that is familiar for an orienteer who is used to see more conventional orienteering maps for outdoor environments.

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scientific journal of orienteering

Cartography and Orienteering: the Implementation of New Cartographic Techniques in Making Orienteering Maps

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Abstract

Orienteering maps are very special maps, because not only they are using the same specification all over the World, but also the users themselves create these maps regularly. This paper summarizes the implementation of the most important cartographic techniques of the last decades including the application of the information technology. It is interesting and instructing how flexible and innovative are the creators of orienteering maps in the implementation and adaptation of these techniques in order to improve their map production method.

Short history of orienteering

Johann Christoph Friedrich GutsMuths was a teacher and educator in Germany in the second part of the 18th century and in the beginning of the 19th century. He was especially known for his role in the development of physical education, so he is known to be the Great Grandfather of Gymnastics. In his famous book (Turnbuch für die Söhne des Vaterlandes, 1817, Frankfurt), he set great store by the open-air exercises including such activities as map reading and distance estimation.
The Swedish Military Academy already specified in 1840 that cadets should be familiar with the knowledge of distance and height measurements and they should be able to make map sketches on the terrain.
Orienteering as a sport started as a military navigation test/training at the end of the nineteenth century mostly in Norway and Sweden (the navigation as an open-air physical exercise became part of the military training curriculum around 1880); and Finland as well, where ski orienteering events were organised earlier than foot orienteering events. The word "orienteering" was used to mean crossing unknown territory with the aid of a map and compass for the first time in 1886. The first civil orienteering competition was held in Norway in 1897 (Zentai 2011). Some other countries (Denmark, Estonia, Finland, Hungary, Switzerland) organized their first orienteering events between the two world wars.
In the early 1930s, the sport received a technical boost with the invention of new types of compass, more precise and faster to use at terrain navigation.
Due to the slow development of the sports at that time, the first independent national orienteering federations were formed only around 1937–38 in Norway and Sweden (Berglia 1987).

Early maps

The early period of orienteering maps was the age of using existing large scale state topographic maps. In the Scandinavian countries, these large scale maps were not classified in the beginning on the 20th century. In other countries, however, there were no suitable maps available for public use. The running speed of competitors and the available large scale state topographic maps (1:20,000–1:40,000 and 1:50,000–1:100,000 in the early years) partly effected also the length of the courses.
The development of the sport was very slow after the first civil event; the main change was that Sweden took over the leading role of the sport from Norway. Concerning the maps of the orienteering events, the organizers had no other opportunity than using various official maps: state topographic maps, ski maps, tourist maps. At this level of the development of the sport, there was no demand for special maps partly because the mapmaking was a very complicated and expensive process at that time and partly because the number of competitors was too small to cover the costs of producing such maps. The only change was the re-drawing of the existing topographic map in a larger scale, but without changing the content. However, sometimes all existing maps were so outdated for orienteering events that major revisions or updating would have been requested, but without experts and affordable methods this request could not be fulfilled.

The first orienteering map that was especially drawn and field-worked for orienteering was made in 1941 in Norway. The main reason of this special map was the inaccessibility of maps during the German occupation. During WW II, the sales of maps were stopped in most Scandinavian countries, but after negotiations, reprints of maps for sanctioned orienteering events were allowed.

New cartographic techniques in producing orienteering maps

The most challenging element of the large scale topographic maps at time was the representation of the relief. Although the experiences of the modern wars, especially WW I, proved that contour lines are the best method for this, but to transform all existing hachured maps to a modern contour line representation was a very expensive and time consuming process. As the precision requirements of the state users increased, this required more time on field-working using the traditional methods (plane table, theodolite). The only solution to speed up the mapmaking process was to invent better and more efficient measuring methods.
Aerial photographs have totally changed topographic mapping, although it took some ten years when traditional field-surveying methods were totally over-shadowed by the aerial technologies, especially because the technical change on the national mapping authorities required not only investment, but political decision as well.
One of the main advantage of the aerial photography was to decrease the update cycle time of topographic surveys. New surveys, updates can be completed in a much shorter time as most of the changes can be identified on the aerial photographs and the required field-working time was less and less.

Stereophotogrammetry

The invention of photography and the aviation have made a new method, photogrammetry for acquiring contour lines more quickly. The term of photogrammetry was first used in published work in 1867, when photography itself was still in its infancy, but already in 1833, it had been realized that three-dimensional perception was due to a parallax effect resulting from comparing the views of an object under two different angles, hence our own three-dimensional perception. Over the last hundred years, the principal application of photogrammetry has been the compilation of maps from aerial photographs.
Topographic mapping using photogrammetry was introduced at the end of the 19th century. The first terrestrial cameras made stereo-photogrammetry possible in mountainous terrain before the airplane offered itself as a useful camera platform in the beginning of the 20th century. This terrestrial method made easier the mapping of mountainous areas (especially the representation of the relief), but this method was not suitable for the efficient mapping of large (country-wide) areas.
In 1948, Norway made the first orienteering map where the contour lines were created from a special photogrammetric plot (Figure 1.). On the very detailed Scandinavian terrains this method was used continuously, but due to the high costs of the stereophotogrammetry the spread of this method in orienteering maps was relatively slow in the beginnings. This method also allowed much more accurate relief representation on orienteering maps, which also let the event organizers use relief details as potential control point sites. To have more details, more features to represent on the orienteering map, it also caused to increase the scale in order to keep the legibility of the map.
Using larger scale also meant that the production of orienteering maps started to be independent from the state topographic maps. In the Scandinavian countries, the largest scale of the state topographic maps was just increased to 1:25,000 at that time, but the scales of orienteering maps started to increase rapidly. The first *International Specification of Orienteering Maps (ISOM)* was published in 1969, where the scale was set to 1:20,000 and 1:25,000, but in 1975 the suggested scale was enlarged to 1:15,000.
In few countries (Hungary, Czechoslovakia, Slovenia) where the largest scale of the state topographic maps was 1:10,000 (or larger) these maps were good enough even for base maps of the 1:15,000 scale orienteering maps. Orienteers were very skilled to survey all features on the terrain, but surveying contour lines would be very time consuming and would require special experience and skills. However in countries where orienteers had no access to state topographic maps or any other reliable topographic maps mappers of orienteering maps created contour lines using only by compass and other very simple methods (practically they had no other chance for producing and using orienteering maps).

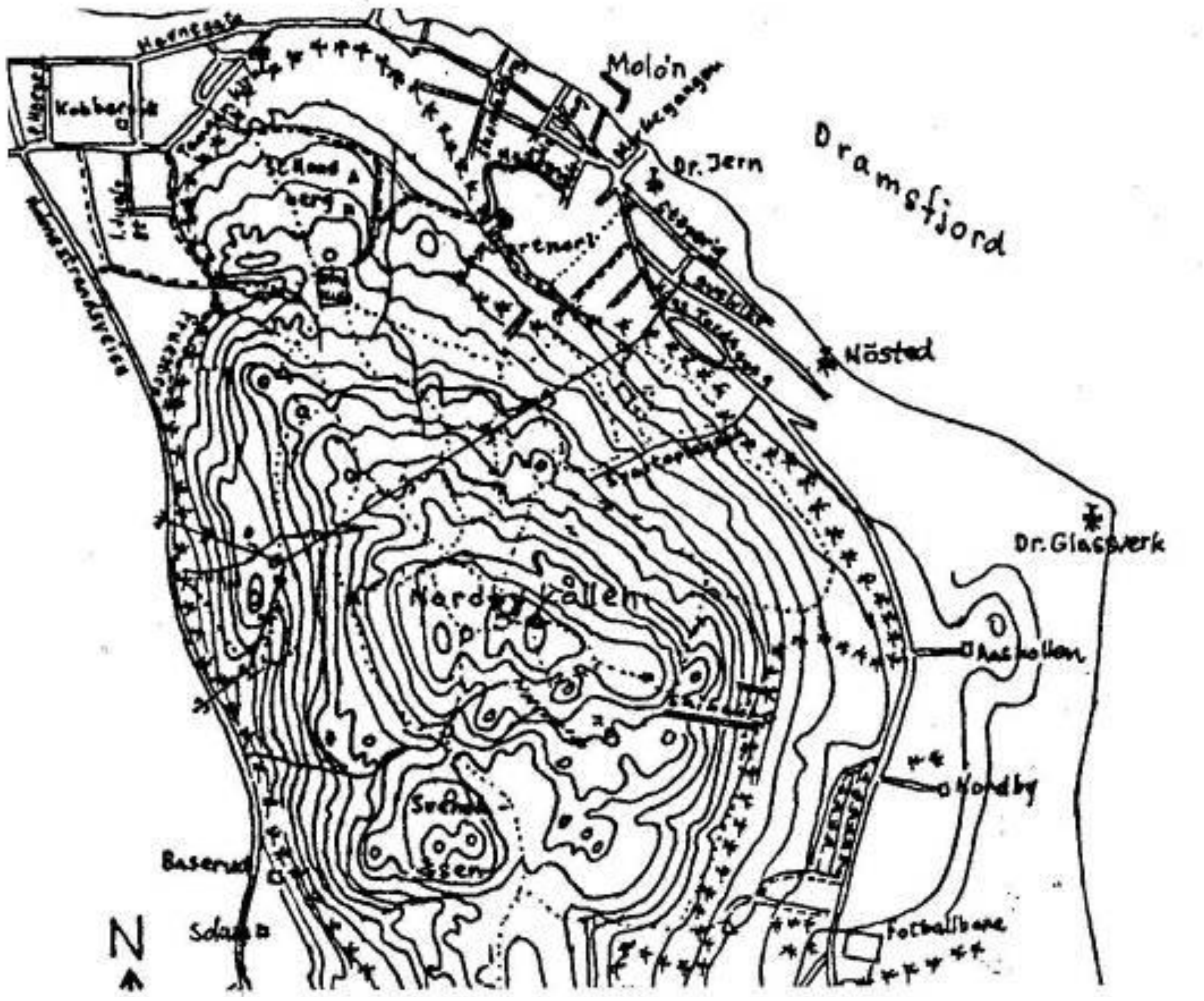

Figure 1. The first orienteering map made by using stereophotogrammetry (Norbykollen, Norway, 1948.)

From the early fifties, major Scandinavian (especially Norwegian) clubs and individuals experimented with mapping. A large number of maps were made of varying standard. Many of the people involved were professional mapmakers. Some keen orienteers became familiar with stereophotogrammetry getting experience in stereo plotting from major mapping companies and higher education institutes. The first orienteering base maps prepared by private orienteering firms were produced in 1954-55.
The revolution continued in the 1960s with the creation of the first orienteering map with a 5 meter contour interval, where the contours were incredibly detailed. Orienteers had to accommodate their navigational skills to these special orienteering maps, but it was just the right time as the International Orienteering Federation was founded in 1961 and the first European Orienteering Championships was organized in 1962. The maps contained so much information that a completely new orienteering technique was needed. The map was so detailed and accurate that the compass was not the most essential tool anymore; the competitors mostly just read the map. This is the reason that legibility was always a very important issue for orienteering maps.

Colour offset printing

Although we had suitable methods to make precise maps for orienteering, there was another crucial problem to be solved. Colours are essential parts of topographic maps, but the colour printing methods were complicate and expensive. Even the state topographic maps started to be printed in colour only from the beginning of the 20th century, when colour offset printed methods were invented.
The very first colour offset orienteering map was produced in 1950 for an international event. For several years, colour maps were used only at the largest events, where the number of participants let the organizers finance this

method. The scale of this first map was 1:20,000, with four colours; forests in light green, man-made features in black, water features in blue and contour lines in brown. The base map was Oslo city maps in the scale 1:5,000, with 5-metre contours. The map was much more detailed than anything used in Scandinavia up to that time (Figure 2.).

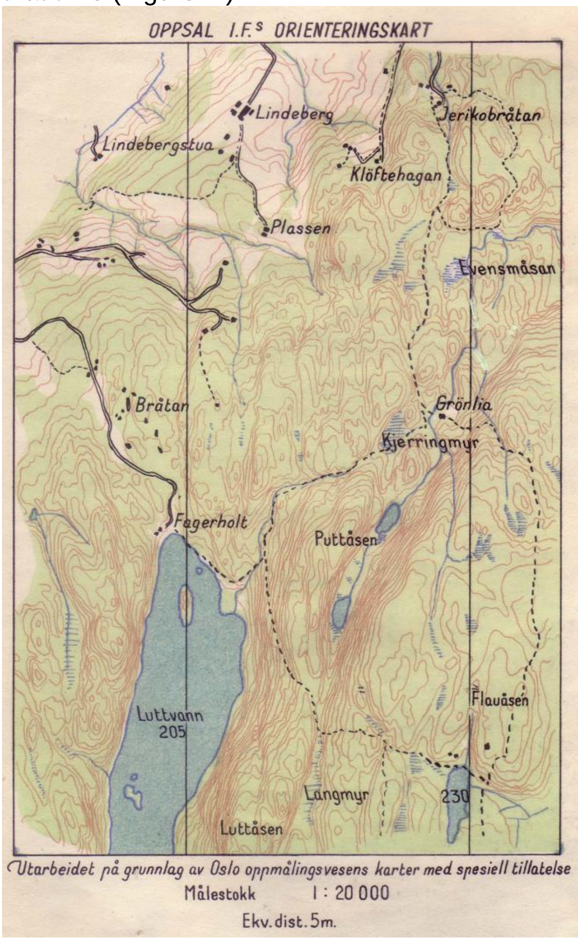

Figure 2. The first colour offset printed orienteering map (Norway, 1950)

The colour printing also helped the fairness of the sport: since then, the better legibility helped that all the events became based on fine navigation with precise maps. Namely, the control points could be found by the ability to navigate, not by luck or searching.
In the Eastern bloc countries where offset printing was strictly state controlled several other methods were used (or at least tested) to substitute the colour offset printing and avoid strict central control (Figure 3.).

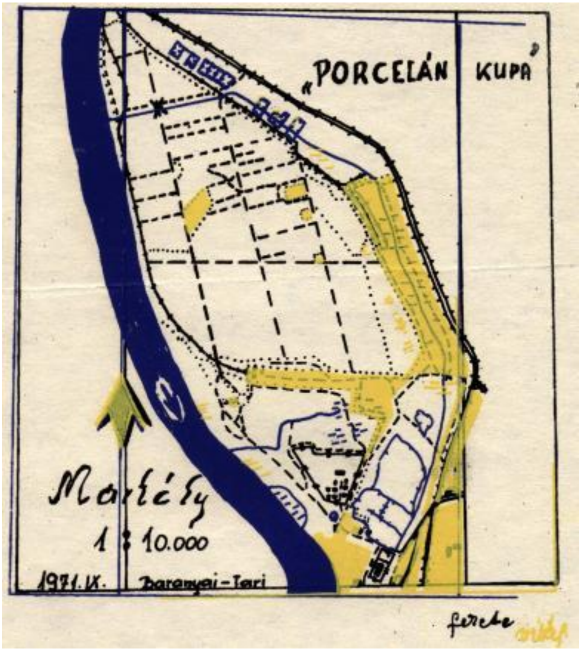

Figure 3. This Hungarian orienteering map was copied in a factory using porcelain dye (1971)

Modern map drawing tools and techniques

One of the most special characteristics of orienteering maps is that they are made by orienteers and not by professional cartographers (although there are some cartographers who are keen orienteers). As mentioned in the previous chapters, orienteering started to use the most modern base map creation methods (stereophotogrammetry) and printing techniques, which required not only professional experiences, but very expensive machines.
Other sections of the orienteering map production did not require expensive machines, but special experiences and tools were necessary. As orienteering maps started to become special maps, updating the base maps also meant that the maps had to be redrawn. Map drawing required special skills: dexterity, precision, material intensity, cleanness, but the perfect knowledge on orienteering was much more important. This caused several poorly drawn, ugly though relatively precise orienteering maps. After drawing some maps, a few orienteers showed affinity to this job and started to improve their drawing skills. The drawing quality of their maps became professional.
This drawing process was supported by certain tools as well: translucent plastic films, technical pens, drawing templates, stencils, dry transfer screens and letter transfers. These tools and materials were developed for technical drawings

and cartographic production, but orienteers were open to adopt them for drawing orienteering maps. In a later stage, some special products were developed for the orienteering mapping: drawing templates, dry transfer screen and symbol sets.
Most of the professional cartographic firms used scribing for map production. Scribing was used to produce lines for cartographic map compilations around 1960-1990. The lines produced by this technique are sharp and clear. This technology required investments too (light table, translucent coating film, scribing tools: tripod, stylus). Scribing produced a result superior to drafting, but was more time consuming and required professional experience. Only few orienteering maps were made with this method, especially by small professional cartographic firms (World Orienteering Championships maps, 1976, Great Britain).

Standardization

The **International Orienteering Federation (IOF)** was founded in 1961 with ten countries. In 1964, the association of Nordic countries had formed a map committee and they asked the IOF to discuss the maps of international events and to form the Map Committee of the IOF. The first internationally accepted principles were as follows:

- The maps have to be so accurate and detailed that they give the possibility for the organizers to make a fair event and let each competitor easily identify his/her position during the course.
- The main disadvantage of using outdated topographic maps without special orienteering fieldwork is the luck factor. If a competitor has found a path not shown on the map and has been able to use it during the event can reach the control point faster than the unlucky rivals who omitted that path. It was also important to reduce the potential advantage of local competitors.

In 1965, the IOF formed its Map Committee, but the progress was directed by the Scandinavian countries. All five members of the Map Committee were cartographers and orienteers (*Jan Martin Larsen*–Norway, *Osmo Niemelä*–Finland, *Christer Palm*–Sweden, *Torkil Laursen*–Denmark, *Ernst Spiess*–Switzerland).

The most important and urgent work of the committee was the specification of World Championship maps:

- The orienteering maps have to be new.
- The map has to show every important detail of the terrain which can affect the route choice of the competitor.
- The most relevant characteristic of an orienteering map is the accuracy and legibility: small and unimportant details have to be omitted.
- The maps of international events have to use the same specification.

The first issue of the ISOM was ratified in 1969. This issue was still not a real specification but rather a “guideline”, although it already contained quite concrete requirements (Spiess 1972). The most important specifications were the scales and the colours. Table 1 summarizes the ISOMs.

Year of publishing	Number of signs	Suggested scale
1969	52	1:25,000,
1975	100	1:20,000,
1982	98	1:15,000,
1990	105	1:15,000,
2000	104	1:15,000,

Table 1. Summary table of the International Specification of Orienteering Maps

The main reason of the standardization was the globalization of the sport. It was initiated by not only the top level events (World Orienteering Championships), but since the 1970s more and more multi day events were organized (especially in summer time) with thousands of competitors, where more and more foreign participant took part.
It is also interesting to mention another aspect of globalization that is not directly related to mapping. Multi day events lead to linguistic problems. Control descriptions previously were given in written form, mostly in German at international events, because this was the official language of the IOF (it was changed to English in 1985, when the IOF had several non-European members, where German was hardly spoken). These descriptions had to be translated into several languages, often with strange results, as the translator had little knowledge of the orienteering terminology in various languages.
In 1974, Swedish orienteers came up with a solution to this with the pictorial control

descriptions, where all possible control sites were given a symbol resembling the IOF map symbol, but with the restriction that it should be reproduced in black and white (to make it easier to copy/print). The idea was adopted very quickly by the IOF, and nowadays these symbolic control descriptions are used even at small local events, where no foreign participants are expected.

Desktop mapping (computer drawing)

The relatively small number of symbols in orienteering maps made it relatively easy to make formerly hand drawn orienteering maps by computer. The first vector based general graphic software for personal computers (Adobe Illustrator) and the first GIS software was released at the end of the 1980s, but professional companies, institutes (national mapping authorities) could use (and sometimes create and develop) such software even earlier.
It is not easy to find the first orienteering map which was made by computer. Keen orienteers, employees of the **Norwegian Mapping Authority** made the first digital orienteering map around 1980, which was made by automated scribing in a drawing machine based on digitized field work.
The **Swedish Orienteering Federation** started a project in 1989, which laid the foundation for the future production of orienteering maps with digital methods. Based on this preparation, the federation started the centralized and targeted work to turn the Swedish orienteering mapping base into digital format in 1991. Involved in this process were not only sports, but also authorities such as the *Swedish National Land Survey*, the *Communities Confederation* etc. It took about 5-7 years until the entire yearly production of orienteering maps was done with digital means as products of databases.
In **Finland**, in 1990 *Risto Laiho* made some A4 size maps with FINGIS (FINnish Geographic Information System) program, which was developed by the **National Board of Survey**. The application for orienteering maps was worked out by Risto Laiho. Although the development of FINGIS started in 1975, it was very difficult to use. FINGIS software was applied to terrain maps, geological maps, communal maps, forestry taxation, water resources management, cadastral and real estate surveys.
It was extremely difficult to draw all the symbols of the orienteering map specification in GIS software environment at that time, especially because these systems were not developed for professional output.
In **Denmark**, *Flemming Nørgaard* managed to draw the first digital Danish orienteering map, which was published in April 1989 (Figure 4.). He also made the map of the first IOF event which was organized to use digital orienteering map (World Cup event, 1990: Gjern Bakker). These maps were made with Adobe Illustrator 88 on Apple-McIntosh personal computers.
Text is not an important feature of orienteering maps. Text elements are supplementary, but they do not really increase the usability of the maps for the competitors. This fact made it relatively profitable (or at least manageable) to create orienteering map drawing software. *Hans Steinegger*, a Swiss orienteer/software engineer released the first version of his **OCAD** software in 1988-89. Nowadays, most of the orienteering maps all over the world are drawn with this software. At that time, the text handling features of the PC software were very limited partly due to the lack of standardisation and partly due to the very limited graphic skills of personal computers. Only Apple-McIntosh operation systems, Microsoft Windows 3.1 and later versions solved this problem at the beginning of the 1990s with using TrueType fonts.
OCAD became even more popular when scanners, colour inkjet and black and white laser printers became easily affordable and were substituted for the less comfortable input device, the digitizing tablet and the very low quality output device, the dot-matrix printers.

Vedstående kort er i alle detaljer fremstillet på en Apple Macintosh Plus computer i programmet Illustrator 88, der er et avanceret tegneprogram fra Adobe Systems Incorporated.

Rekognosceringsrentegningen i 1:7500 er scanned ind i maskinen og anvendt som underlag for den endelige rentegning, som er foretaget ved hjælp af en "mus" der kontrollerer tegneredskaberne på skærmen.

Udskriften af ovenstående kort er foretaget på en Linotype fotosætter i trykmålestokken 1:10.000 på 5 (en for hver farve) negative film, som er anvendt direkte for fremstillingen af trykpladerne.

Programmets brug af diskplads er yderst rimelig på grund af muligheden for anvendelse af bezircurves. (tangentkurver) Hele kortet incl. tekst og signaturforklaring fylder mindre end 250 Kb.

The attached map in all its details is produced on an Apple Macintosh Plus computer using Illustrator 88, which is an advanced drawing program from Adobe Systems.

In practice the finished copy of the field work is scanned into the machine and used as the basis (template) for the final drawing, which are done with the help of a "mouse", which controls the cursor on the screen.

The map print-out is done on a Linotype phototypesetter at the printing scale 1:10.000 on 5 sheets (one for each colour) of negative film, which are used directly to make the offset-plates.

The program's use of storage for the drawings is reasonable due to the use of bezier curves. The whole map, including text and legend occupy less than 250 K on the disc.

Flemming Nørgaard, april 1989

Figure 4. Risskov, Denmark. The first orienteering map made on Apple-McIntosh personal computer. Courtesy by Flemming Nørgaard.

GPS

One of the most interesting parts of the orienteering mapping which requires orienteering experience is the field-working. Even if we have very good base maps, the whole area should be thoroughly checked and all base map information should be transformed into the features of the orienteering map or partly dropped. Depending on the quality of the base map and the complexity of the terrain, the field-working should take about 30-50 hours/km^2.

Global Positioning System devices are more commonly used during ground survey in general. To enable the data to be used easily, maps need to be “georeferenced”. Orienteering maps are not regularly “georeferenced”, which means that only very few of these maps were fitted to known projections and/or datum of the national or international mapping systems. Theoretically, the orienteering maps used the same projection/datum as the original base maps, but as time went on and the old maps were updated, new areas were added with smaller and smaller distortions, and they were incorporated in the maps. Practically, if we try to use GPS measurements and fit them to the orienteering map, we have to “georeference” the orienteering map first. The “unreferenced” orienteering maps were suitable for the events, because the inaccuracies were distributed on the whole area of the map, and these failures practically did not affect the navigation of the competitors, who use only the orienteering map and simple compass on the terrain. Absolute positional accuracy is of little significance compared to relative accuracy and to the proper representation of the terrain shape and features. Coordinates are not indicated in orienteering maps and GPS does not have a role in classic orienteering (according to the competition rules, external help like GPS devices and other navigational aids during the events is prohibited for the competitors).

The “georeferencing” of existing maps is a time consuming process and requires some technical/cartographic knowledge. This explains why orienteers need experts to help the “georeferencing”. However, orienteering map projects normally do not allow financing such service.

What are the main advantages of using GPS?

- They are definitely more accurate than traditional orienteering “surveying techniques” (pace counting, bearing).
- Absolute positions are very helpful to improve mapping and can save minimum 25% of the survey time.
- Easy to discover the base map errors and uncertainties.
- Sharing mapping work with non-mappers: we can ask experienced orienteers to collaborate in measuring without any knowledge on GPS.

Professional orienteering mapmakers have a different approach to the GPS technology:

- A GPS device is used at an early stage of the ground survey to add more point and linear features; however, if we have a good base map, it is not very important whether we use GPS or not.
- A semi-professional GPS receiver is used in the initial stage of mapping. The mapmaker covers the terrain with the GPS receiver, recording anything that looks worthy, adding extra data: paths, walls, all kinds of point and line features. Differential corrections can be used as post processing, and the data can be imported into the drawing program. This enhanced map will be used as a base map for the normal orienteering ground survey.
- Real-time differential correction is used in the terrain with the orienteering map drawing software on a tablet PC. The main disadvantage of this hardware is not only the price, but also the lack of long time lightweight power supply (mappers regularly spend 8-10 hours on the terrain).

Mapmakers can use other instruments like laser range finders and clinometers on the terrain, but using these devices is not widespread and these devices have not affected the process of mapmaking dramatically. Using these devices may increase the accuracy of terrain measurements or may speed up the time of measurement. These devices must be small enough and easily usable on the terrain even in difficult weather and terrain conditions (Zentai 2007).

Laser scanning

One advantage of airborne laser scanning compared to classical stereophotography is that laser scanners are not dependent on the sun as a source of illumination (good aerial photos for orienteering maps can only be taken in certain weather and light conditions). If we use a precise digital terrain model, we can get more detailed relief information even in the case of dense vegetation. Because the technology can provide information not only about the illuminated top layers of the forest canopy, but signals from the surface can also be processed, users can extract valuable information for orienteering mapping: vegetation density/runability. Technology could be ideal for orienteering maps, but it is still not easily available in every country or sometimes it is too expensive for orienteering map projects.
Advantages of laser airborne scanning for orienteering maps:

- Saving of time in the terrain because of its availability without interruption and its preciseness.
- Time-consuming work to find suitable photogrammetric pictures is not any more necessary.
- Significant reduced costs compared to photogrammetric base maps (if the raw data are already available).
- Combination with other georeferenced products (e.g. orthophotos) is easy.

The main risk of using laser airborne scanning in orienteering mapping is that the detailed contour relief of raw data could easily lead to an overcrowded and poorly generalized map image. Unfortunately, in certain countries where this data is freely available its use has changed the characteristic of orienteering competitions considerably: the competitors become slower, because they continuously want to identify all relief features that they see on the map.

Conclusion

One of the most important lessons that we have learnt from the example of the orienteering map is how the user requirements can influence the mapmaking process. If the maps are special, sometimes the users themselves have to learn the cartographic techniques, because professional cartographers are not able to make such maps for them. Orienteers have been trained for this job in the last fifty years and they flexibly adapt new tools and technologies.

Orienteering maps remained the only classic topographic products: they are field-checked and they are still printed on paper as required by their users.

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