Implementation of Cartographic and Digital Techniques in 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.

Keywords Orienteering maps · Topographic maps · Map drawing

1 Short History of Orienteering

Johann GutsMuths was a teacher and educator in Germany in the second part of the eighteenth century and in the beginning of the nineteenth 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). 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

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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 a new compass, more precise and faster to use.

Due to the slow development of the sports at that time, the first independent national orienteering federations were formed only around 1937–1938 in Norway and Sweden (Berglia et al. 1987).

1.1 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 twentieth 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 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, 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.

2 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 slow 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.

2.1 Stereophotogrammetry

Topographic mapping using photogrammetry was introduced at the end of the nineteenth century. The first terrestrial cameras made stereo-photogrammetry possible in mountainous terrain before the airplane offered itself as a useful camera platform at the end of the nineteenth 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 larger areas.

In 1948, Norway made the first orienteering map where the contour lines were created from a special photogrammetric plot. 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.

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 1954–1955.

The revolution continued in the 1960s with the creation of the first orienteering map with a 5 m 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 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.

2.2 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 expensive. Even the state topographic maps started to be printed in colour only from the beginning of the twentieth 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 m contours. The map was much more detailed than anything used in Scandinavia up to that time.

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.

2.3 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 papers, orienteering started to use the most modern base map creation methods (stereo-photogrammetry) 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.

2.4 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.
- 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.

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).[1]

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 released in 1969. This issue was still not a real specification but rather a "guideline", although it already contained quite concrete requirements (Spiess 1972) (Table 1).

[1] Ernst Spiess got the ICA Carl Mannerfelt Gold Medal in 2005; Christer Palm is an ICA Honorary Fellow (1997).

Table 1 Summary table of the international specification of orienteering maps

Year of publishing	Number of signs	Suggested scale
1969	52	1:25,000, 1:20,000
1975	100	1:20,000, 1:15,000
1982	98	1:15,000, 1:10,000
1990	105	1:15,000, 1:10,000
2000	104	1:15,000, 1:10,000

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, 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.

2.5 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 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, 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 (Fig. 1). 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 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 to create orienteering map drawing software. *Hans Steinegger*, a Swiss orienteer/software engineer released the first version of his *OCAD* software in 1988–1989. 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 due to the lack of standardisation. Only 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 and colour inkjet printers became easily affordable and were substituted for the less comfortable input device, the digitizing tablet.

One of the most difficult tasks was to make the traditional orienteering mappers used to computers, to be familiar with the personal computers. Keen Apple personal computer users had no chance to use OCAD (at least not in the first part of the 1990s, when OCAD ran under DOS environment). On Mac computers, Adobe Illustrator was used producing the first digital orienteering maps on personal computers. One of the most difficult challenges for the beginner computer users was to be familiar with the output section of the orienteering mapping (desktop publishing, imagesetting, Postscript).

The user friendly environment of the OCAD software makes map drawing relatively easy even for beginners who are not familiar with any type of computer software. The development of colour printing technologies and the price reduction of good quality colour laser and ink jet printers made the colour printing technology more affordable.

Fig. 1 Risskov, Denmark. The first orienteering map made on Apple-McIntosh personal computer. Courtesy by Flemming Nørgaard

The number of offset printed maps is continuously decreasing and the number of non-offset printed maps is increasing. The main factor of this change is not simply financial, but the opportunity to very late updates before the event. The mapmaker is also able to control the complete printing process. The continuous development of colour printing technologies will continue and the quality of digital printed maps can approximate the quality of spot colour offset printed maps.

2.6 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 h/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 (datum, projection etc.). 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. 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 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 during the events is prohibited for the competitors).

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

The main advantages of using GPS:

- They are definitely more accurate than traditional surveying techniques (pace counting, bearing).
- Absolute positions are very helpful to improve mapping and can save the survey time.
- Easy to discover the base map errors and uncertainties.
- Sharing mapping work with non-mappers.

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. This enhanced map can be used as a base map for the 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.

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 conditions (Zentai 2007).

2.7 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/runnability. 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.

3 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 the 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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