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REFEREED PAPER

Legibility of Orienteering Maps: Evolution and Influences

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Paper maps are generally planned for use under normal circumstances. One of the exceptions is orienteering maps, which are used in special circumstances, namely, at sport events such as running, when poor visibility and bad weather conditions may considerably reduce the legibility. When the drawing specifications of orienteering maps were created and when later new forms and disciplines of orienteering events were invented, the clear legibility of printed maps was one of the most important aspects. The International Orienteering Federation keeps the aim of preserving the characteristics of the different event and discipline formats by ensuring the legibility of the event maps.

Les cartes papiers sont généralement conçues pour un usage standard. Une exception existe pour les cartes d'orientation qui sont utilisées dans des conditions spéciales. En effet lors d'un événement sportif, une visibilité réduite ou de mauvaises conditions météorologiques peuvent réduire considérablement la lisibilité de la carte. Lorsque les spécifications des cartes d'orientation ont été produites, et lorsque plus tard de nouvelles formes d'activité d'orientation ont été inventées, la bonne lisibilité des cartes imprimées était un des critères essentiel lors des choix de conception. La fédération internationale d'Orientation garde l'objectif de conserver les caractéristiques des différents événements et de la discipline en assurant une lisibilité des cartes.

Keywords: orienteering map, map specification, legibility

INTRODUCTION

We communicate our knowledge of the world to other people by maps as we do by languages.

Legibility of paper maps is generally not a well-researched subject nowadays. Maps are special printed products, where the legibility is regularly limited due to the complexity of the map content: the text elements on the maps sometimes are not known for the users; there are different features mapped, and the users may focus on any of them; some of the features can be emphasized at the expense of other features. In short, the graphical representation of features is a result of the long-term experience of cartography, which was a well-researched topic in the last centuries.

Maps are generally used in good, possibly in perfect circumstances. Therefore, the mapmakers do not have to take into account this factor when they design their maps. Orienteering maps are used in special circumstances that are at orienteering events: in running, when weather conditions may affect the visibility, or even at night.

The objective of this article is to investigate how these special factors were taken into account when the map specifications of orienteering maps were created and updated or how they influenced the new forms and disciplines of orienteering events.

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MAP SPECIFICATIONS OF ORIENTEERING MAP SPECIFICATIONS

Orienteering as a sport started as a military navigation test/training in the second half of the nineteenth century (mostly in Norway and Sweden). 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.

By 1930, orienteering had become firmly established in Finland, Norway and Sweden with meetings and cooperation between these three countries already being a regular feature. The first independent national orienteering federations were formed around 1937–1938 in Norway and Sweden.

During the early period of orienteering, extracts of large-scale civil topographic or tourist, maps were commonly used. According to running speed and course length, the scale of maps was 1 : 20 000–1 : 40 000 (1 : 50 000–1 : 100 000 in the early years). In some countries, topographic maps were classified (Eastern Europe); in other areas, the largest available scale of topographic maps was only 1 : 50 000. Using tourist maps was a logical alternative, but in Eastern Europe, the accuracy of publicly available tourist maps was not suitable for these events. Therefore, these countries tried

to find more accurate tourist maps published before the communist era.

There was also a problem of copying. Offset printing (especially colour) was too expensive and technically very difficult even for keen organizers. To move one step further, the sport had to reach a higher level: increase the number of participants in the events, create international relations and form regional and continental organisations. The first orienteering map, especially drawn and based on specific fieldwork for an orienteering event, was created in Norway in 1941. The first colour orienteering map was published in Norway in 1950, but took additional 15–20 years, while colour maps were used on every orienteering map.

The International Orienteering Federation (IOF) was founded in 1961. The founding members were Bulgaria, Czechoslovakia, Denmark, East Germany, Finland, Hungary, Norway, Sweden, Switzerland and West Germany. The first European Orienteering Championships was organized in Norway in 1962 and the first World Championships was held in 1966.

For the first international discussions on orienteering maps, it was obvious to draw on the mapmaking experience of Scandinavians. At that time, the map specifications of different countries were based on their own topographic maps, which made the international events unfair by giving an advantage to local competitors. In 1965, the Map Committee of the IOF was formed. The members were cartographers and orienteers: Jan Martin Larsen (Norway), Osmo Niemelä (Finland), Christer Palm (Sweden), Torkil Laursen (Denmark) and Ernst Spiess (Switzerland). The most important and urgent work of the committee was to develop the specifications of World Championships maps:

- the maps had to be based on new fieldwork;
- the map had to show every detail of the terrain that could affect the route choice of the competitor;
- accuracy and legibility was most important: small and unimportant details had to be omitted;
- maps for international events had to use the same specification;
- suggested scales were 1 : 25 000 or 1 : 20 000, the contour interval was 5 m (10 or 2.5 m was also allowed) (Palm, 1972; Spiess, 1972).

The first issue of the International Specification of Orienteering Maps (ISOM) was ratified in 1969. This issue was still not a 'specification' but rather a 'guideline' (practically it was one A4 size sheet), although it already contained quite concrete requirements. The most important declarations were the scales and the colours:

- black, brown and blue for topography;
- yellow for open ground; and
- grey or green/black for restricted runnability (vegetation).

One of the largest discussions of these early years was the colour of the forest sign. This area symbol was traditionally green on topographic maps in every country. It was a Norwegian suggestion (1965) to use white colour (the paper colour itself) for the forest (good runnability). These maps were called negative maps and this suggestion was accepted internationally in some years.

The ISOM 1975 was the first real specification. This version used various well-established specifications from the official topographic representations used in Scandinavia. In comparison with the first ISOM, the symbols were organized into the five logical groups still used today.

The ISOM 1975 was a compromise between the very different interests and requirements of the IOF member federations (at that time, the IOF had 23 member countries). In some countries (Scandinavia and Czechoslovakia), green colours were not used at all, or only two shades were used neglecting the rules.

The third issue of the ISOM (1982) was a further development of ISOM 1975 with the aim of consolidating the established and eliminating weaknesses.

The fourth issue of ISOM (1990) could build on the foundation of almost 20-year experience of map drawing for orienteering.

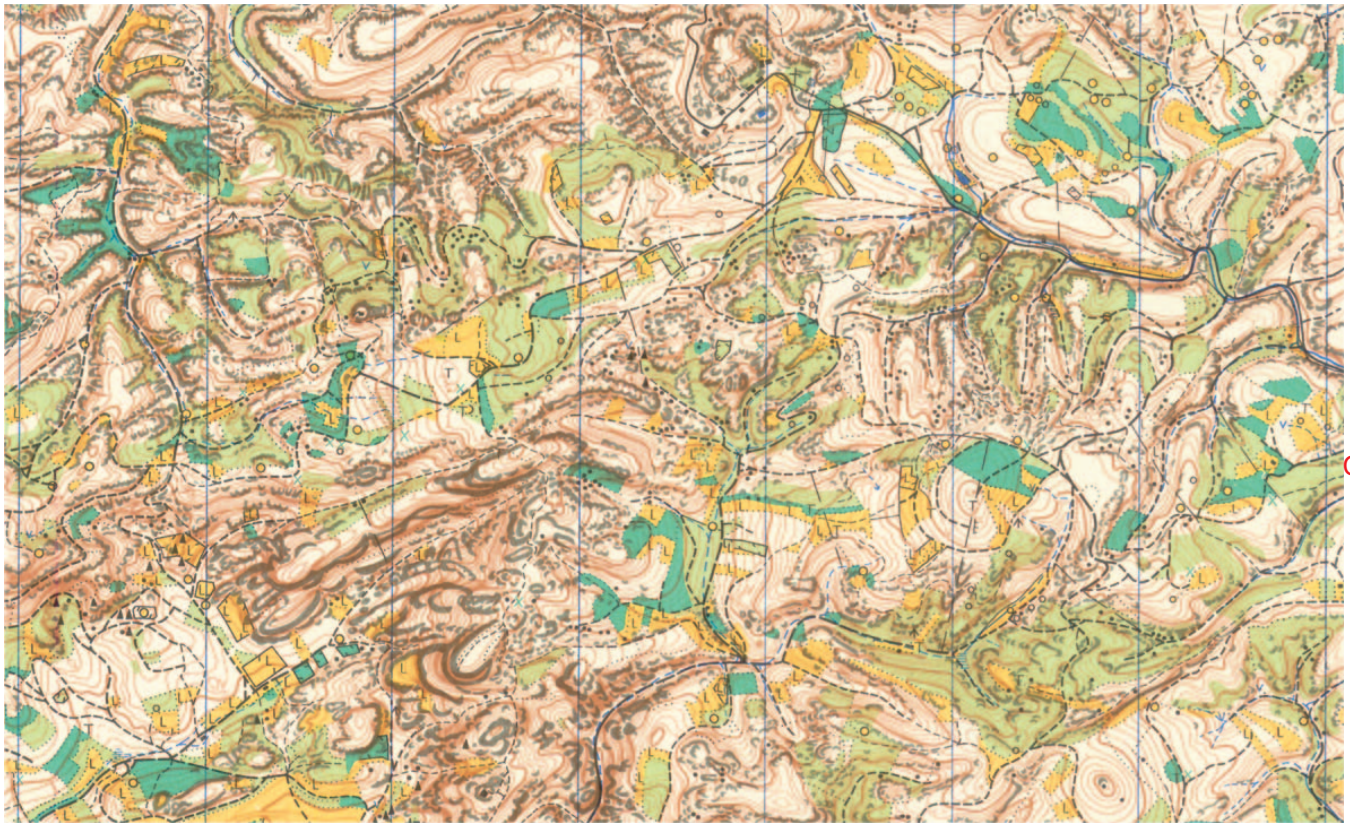
The last ISOM (ISOM 2000) was the first one which included all official disciplines (foot orienteering, ski-orienteering and mountain bike orienteering). It included a guideline for park orienteering, but 1 year later, the sprint orienteering also became a part of the official programme of the World Orienteering Championships (WOC): the Map Commission of the IOF decided to establish a special specification for sprint orienteering maps too (International Specification on Sprint Orienteering Maps – ISSOM).

THE LEGIBILITY ISSUE OF ORIENTEERING MAPS IN GENERAL

An orienteering map can be considered to be a visual communication 'device'. Map-reading requires the competitor to attend to and extract information from the map during visual examination in running speed. The reader must then process these visual inputs into concepts and translate the latter into an image of the terrain. Most orienteering maps contain an enormous amount of information, far too much for any map reader to perceive and process rapidly.

The legibility issue of orienteering maps was part of the standardisation process of the sport. As the sport was practiced in more and more countries, the issue of standardisation became increasingly important. When the organisation of international championships started in the 1960s, the international federation had an ambition to establish not just a map specification, but also to standardize somehow the whole sport itself (competition courses and terrains). Although after some years, it became evident that the standardisation of terrains is not possible (and even using different types of terrains for events is one of the main attractiveness for the competitors), the early experts developed some methods to 'measure' the complexity of orienteering maps, which expresses the legibility too.

One of the ways in which orienteering maps differ from other topographical maps is in the amount of fine relief detail that is included. On most topographical maps, contour lines provide two main types of information. Firstly, quantitative information is provided about absolute heights of the area. Secondly, by visually integrating the contour lines, qualitative information can be obtained about the shape of the landscape. As far as orienteering maps are concerned, the



COLOUR FIGURE

Figure 1. Part of the World Orienteering Championships map, Czechoslovakia, 1972. Courtesy by the Czech Orienteering Federation

heights of contour lines are very rarely shown (because they have no relevance). Thus, the main purpose of contours on these maps is the indication of the shape and steepness of the terrain, simply to show all details which are easily identifiable by the competitor during the event.

However, the best strategy of map reading (especially in orienteering) is the selectivity; the competitors attend to certain types of information and ignore or rather only pay minimal attention to other kinds of information.

Based on the results of a test made by Barrel and Cooper with top orienteers around 1984, we could identify a rank order of difficulty of features with drainage the easiest, then man-made features (paths and special features), vegetation and contours the hardest. Although this was the most thorough test on orienteering maps, the later changes in the sport caused serious changes in the order.

CHRONOLOGICAL CHANGES

As mentioned previously, the first international specification was published in 1969, but the first real specification was the ISOM 1975. Table 1 is the summary of scales of orienteering maps of the World Championships.

It was so evident that the maps of the first international championships were based on the national topographic maps that the outlook of these maps was very different. However, the generalisation level of these maps was very similar. There were very few point, line and area symbols, so the legibility was not an issue at all. The scale 1 : 25 000 and the base map (the national topographic map) pushed the map-makers not to add too many details comparing to the orienteering maps. The only exception was the contour lines details, because:

- the first international championships were organized in the countries where orienteering was on the highest level; in this way, the use of special stereo-photogrammetry influenced the mapping and enriched the contour lines;
- other elements of orienteering maps were treated as frequently changing map elements, and due to the large costs of the printing, the map-makers and the organizers spent time and efforts only on the most permanent elements of the terrains, the relief.

Table 1. Summary of scales of orienteering maps of the World Championships

Year of publishing	Suggested scales	Remarks
1969	1 : 25 000, 1 : 20 000	First used on 1970 World Championships, where 1 : 25 000 scale was last time used
1975	1 : 20 000, 1 : 15 000	1 : 20 000 was last time used on WOC 1979; 1 : 15 000 scale was first time used on WOC 1976 (relay)
1982	1 : 15 000, 1 : 10 000	
1990	1 : 15 000, 1 : 10 000	WOC 1993: 1 : 10 000 scale was first used (short distance)
2000	1 : 15 000, 1 : 10 000	WOC 1997: 1 : 10 000 scale was first used in relay

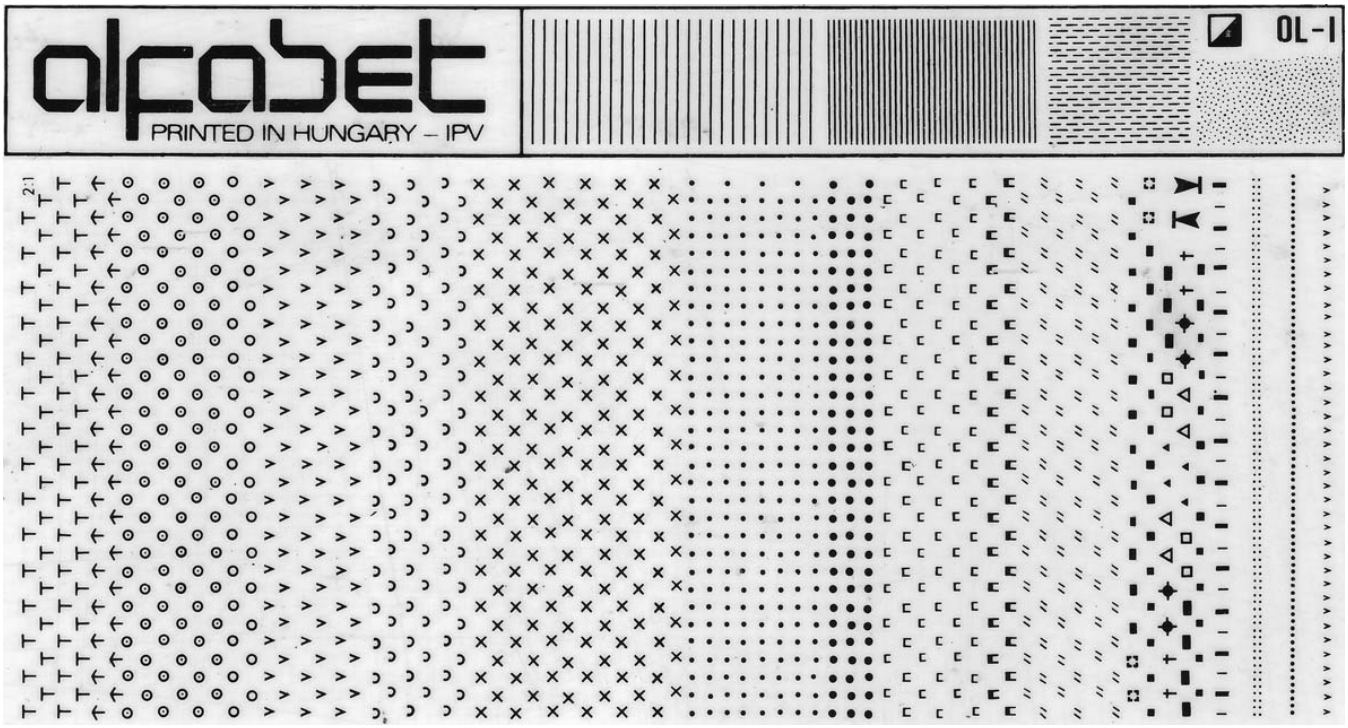


Figure 2. Dry transferrable map symbols for orienteering maps (produced around 1985). Courtesy by Tibor Erdélyi

The very first WOC where the legibility of maps was discussed was the WOC 1972 in Czechoslovakia. There were various factors that made this issue important:

- the terrain which was selected by the national organizers was a really extreme terrain (sandstone area), which type had never been used previously (a part of the terrain was similar on WOC 1970 in East Germany, but the generalisation level of that map was similar to the former WOC maps);
- the most detailed map element of this WOC was the rock features (sandstone cliffs and boulders). The grey colour was very unusual on orienteering maps and this was also the first time when different green colours were used to represent runnability. Compared to other map elements, the green features were over-detailed, and the small passages of long cliffs which affected the route choices were considerably difficult to see on the maps (the dark green colours also escalated this effect).

The larger scale (1 : 15 000), which is still the basic scale of orienteering maps since the second half of the 1970s, also influenced the map-makers to fill the 'empty areas' of maps. The easiest way was to add more point symbols, which was easily manageable in Nordic countries, where the terrain is full of features. In continental areas, due to the less number of point features on the terrain, the map-makers tried to add vegetation features which were difficult to identify on the terrain.

The WOC 1972 also had a relatively long-term effect to select extreme terrains for WOC. Every country which organized WOC tried to select its most difficult, most detailed terrains. This effect lasted until 1987. The WOC 1989 changed this attitude; Sweden was ready to select less typical Scandinavian terrain to organize fairer championships than previously.

Even the maps of these years were mostly quite detailed, but still the 1 : 15 000 scale was the basic scale and using the larger scale, the 1 : 10 000 was an exception. Scale of 1 : 20 000 was less frequently used, but it was still in the mind of map-makers: they did not add small details to the map, so legibility was not an issue, because maps were well interpretable even in running speed.

The ISOM 1975 defined several minimum values of orienteering map symbols based on cartographic traditions (the importance of this chapter is shown by that the extent was one page in a 32-page booklet). The minimum line width was 0.1 mm in darker colours (black, blue and brown), 0.25 mm in green and 0.4 mm in yellow. The minimum area was 1 mm^2 for screens and 0.5 mm^2 for full colours.

These values were slightly adjusted in the following editions of ISOM and in the last edition, the permitted combinations of different area symbols (full colours, shades and different patterns) were also defined. The main reason of the creation of this table was to define illogical combinations (like cultivated area + uncrossable marsh) and avoid combinations which reduce the legibility considerably.

Orienteering became a better known sport at that time and due to the increased attention, the international federation made some changes in the programme of international orienteering events:

- a new form of event was developed (the short distance first time in the WOC programme in 1991) to give more opportunity for the competitors; this issue was supported by many countries which thought that this from may give more chance for non-Scandinavian competitors;
- the media attractiveness became an important factor and the classic distance event took too much time for television coverage.

The larger speed in short distance event also required a larger scale map (1 : 10 000). It had the same specification and the larger scale was just a simple enlargement. The organizers wanted to express the different characteristics of the new form, so to map smaller details was a logical step forward, although it was not encouraged by the specifications.

Since the end of the 1980s, computer drawing became possible. Previously only very experienced orienteers drew their maps themselves. This job required not only special skills, but also drawing pens and some special tools, like Letraset (dry transferrable lettering and map symbols). This technique was widespread for lettering and other elements before the advent of the computer techniques of word processing and desktop publishing. Although this was always a tedious job, the alternative, to draw the symbols by hand, was also tedious and required graphic artist skills. From the point of view of legibility of orienteering maps, the dry transferrable orienteering symbol set was an important step forward to ensure the standardized symbol sizes. Orienteering maps use simple geometric point symbols, which are symmetric; to create uniform regular shapes by hand drawing is really a difficult task, and even a small irregularity might decrease the legibility.

Computer drawing of orienteering maps should be based on personal computers to let the amateur mappers draw their maps individually, but the very first computer drawn maps were created on workstations. Some enthusiastic orienteers who were employed in a Scandinavian state company where they had access to early GIS software drew the first orienteering maps by computer. It is difficult to define which was the first orienteering map drawn by computer, but it was surely created at the end of the 1980s.

Owing to the special software and hardware requirement, there was no widespread influence of these computer-drawn maps. If we look at the first experiments to draw orienteering maps by personal computer, we should mention that Adobe Illustrator and Aldus Freehand were the first commercial softwares around 1988 which made this project possible. The Swiss OCAD software was also launched around 1989 and very soon this software became the dominant programme for drawing orienteering maps. The most important reason that made this software very popular in some months/years is that OCAD was very user-friendly and the hardware requirements were moderate. It was also important that the specification of orienteering maps was uniform all over the world, so the same product could be used in every country. As there is no text inside the orienteering maps, it was no problem that the very first versions of OCAD did not support text functions. Only later versions (starting from version 5, the first Windows version) supported simple text and labelling functions.

DIGITAL ERA

The digital era has not just created opportunities for computer drawing (which replaced the hand drawing and traditional cartographic techniques in some years all over the world), but also gave more chance for stereo photogrammetry. Digital elevation models and orthophotos provided more detailed base maps for orienteering maps.

The main problem of the very detailed base maps is that the details of the photogrammetric plots are not simplified by the map-makers, because the generalisation process requires cartographic knowledge. The other reason is that the map-making (including the base maps) is financed by clubs and federations and they insist on having more and more details on the final map.

It is forbidden to use GPS devices by the competitors during the events. The maps are not necessarily geo-referenced, although GPS technologies could be used in the updating process. Anyway there is a risk for using small mobile devices for helping the competitors, but to be prepared, it requires special skills and extra time.

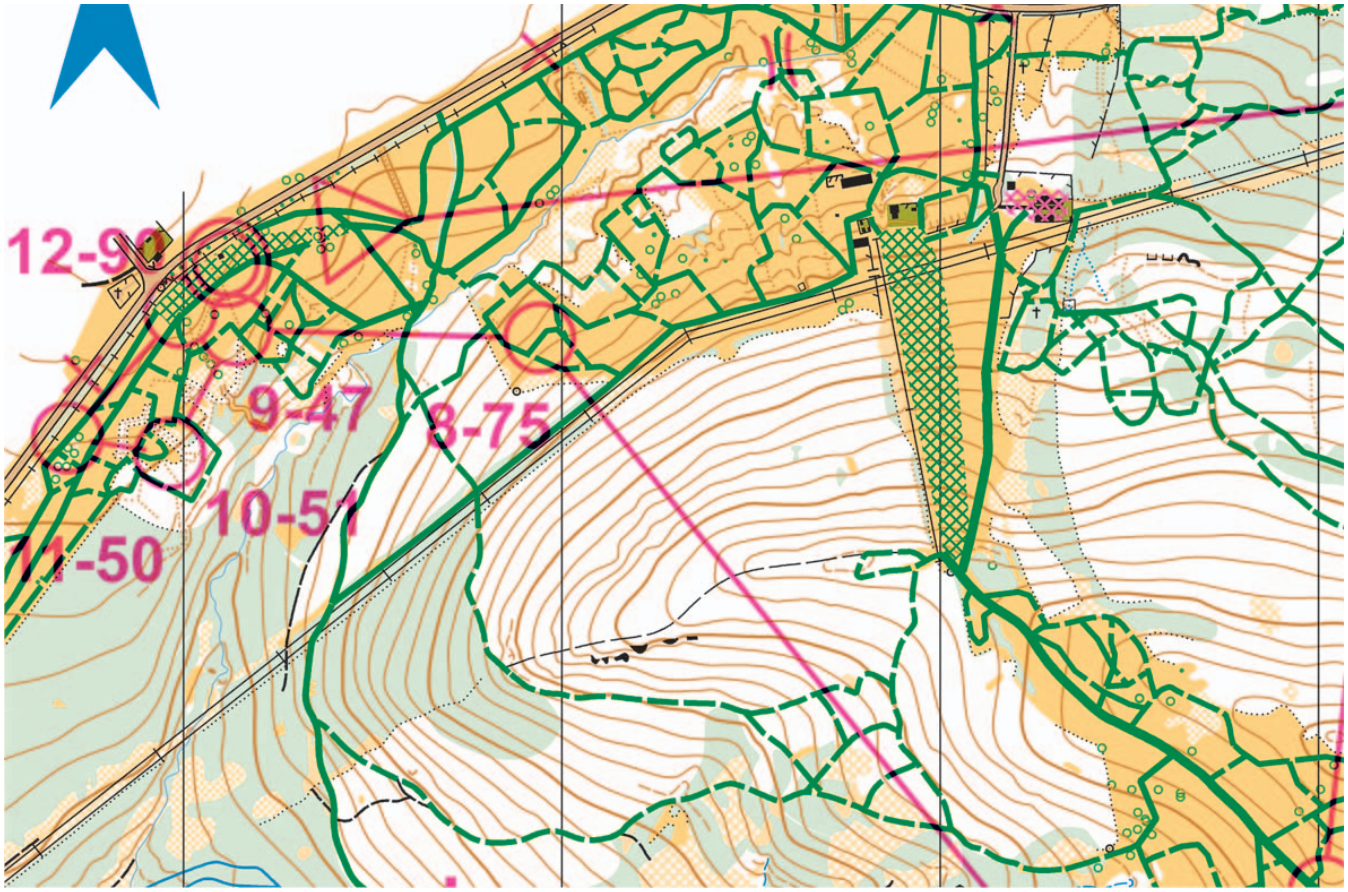
There is another factor that considerably affects the legibility of the orienteering maps in the digital era: it is the reproduction method. The only reproduction method of the modern orienteering maps was the spot colour offset printing (PMS colours: brown, black, green, yellow and blue). Nowadays, both the colour inkjet and the colour laser technology became more affordable and an increasing number of maps are reproduced using this technology. Although these computer technologies are usually not less expensive than spot colour offset printing, they are more flexible and even the map drawers can make all the copies themselves. However, the resolution of these printing technologies is not comparable to offset printing and the simulation of overprint effects which made the maps more 'natural' is quite poor. If we remember the minimum dimensions of area symbols, they are based on the offset printing technology and adopt the same values on inkjet or laser prints, which give a much less legible impression: the very small areas are invisible.

The newest technology, the air-borne laser scanning, gives much more detailed contour lines than any other methods previously. The first experience of the countries where laser scanning base maps were used is that the lack of generalisation of contour lines has made the navigation on orienteering maps totally different for the competitors. The competitors of these countries feel that maps with so many details are changing the characteristics of the sport: instead of running at high speed and selecting the most relevant information from the map. they should slow their speed to read all map details, although some of these small details are practically invisible on the terrain. The legibility of these maps is very limited: the competitors should use a magnifying glass to interpret most details of the map.

Another reason of increasing the number of details on the orienteering maps was due to the new formats:

- WOC 1991 – short distance;
- WOC 2001 – sprint distance;
- WOC 2003 – short distance changed to middle distance; the WOC programme (sprint, middle, long and relay) has not been changed since this time.

The sprint format required a new, separate specification, the ISSOM. The sprint events are regularly organized in urban environment (historical downtowns, parks) or in a mixture of different areas. The number of features is much higher in urban environment than in forest areas, but the minimum dimensions of mapped features are about the same: the running speed of competitors is regularly larger in sprint format, so they do not want to waste their time on looking



COLOUR FIGURE

Figure 3. Map of Ski Orienteering World Cup 2010, Romania, Csíkszereda

for features which are not prominent on the terrain at full running speed.

Table 2 below summarizes the number of map details counted on a 1 km^2 part of the long-distance final maps of the WOC (based on the OCAD map files). The big difference in the number of various parameters reflects the characteristics of terrains, but the file size lets us make better comparison. All the terrains are challenging, regularly full of complex features, but the characteristics are so much different that it is difficult to find parameters which are valid on all kinds of terrains. The legibility of the orienteering maps is also strongly affected by the complexity of contour lines, but it is nearly impossible to have a parameter on them. At the first look, the contour lines of the Japanese terrain look the steepest and most complicated, but due to the continental terrain, it is relatively easy to interpret for the competitors. The Scandinavian areas are not so steep, but due to the lack of regularities in the contour lines, the legibility is more difficult.

LEGIBILITY OF ORIENTEERING MAPS OF OTHER DISCIPLINES

Ski-orienteering and mountain bike orienteering (MTBO) are other disciplines which have their special map specification (but these specifications are based on ISOM). Owing to the larger speed of the competitors, the scales are smaller (1 : 15 000, 1 : 20 000 or even 1 : 25 000), but the main difference is that the specifications emphasize the most important elements: the road network. Any other elements which are not relevant, which are not visible at a higher speed or are hidden in the middle of the forest, are omitted. The track network is over-emphasized: the line widths are

Table 2. Summary of the numbers of map details counted on a 1 km^2 part of the long-distance final maps of the WOC (based on the OCAD map files)

Map	No. of objects	File size (bytes)	No. of point features
WOC 2009, Hungary	4739	759 296	192
WOC 2005, Japan	1478	539 780	56
WOC 2001, Finland	3226	718 624	590
WOC 1997, Norway	4769	937 392	1050

Map files are the courtesy of the Hungarian Orienteering Federation (Áron Less), the Japanese Orienteering Federation, the Finnish Orienteering Federation (Copyright: Orienteering clubs Koovee and Tampereen Pyrintö) and the Norwegian Orienteering Federation (Kristen Treekrem).

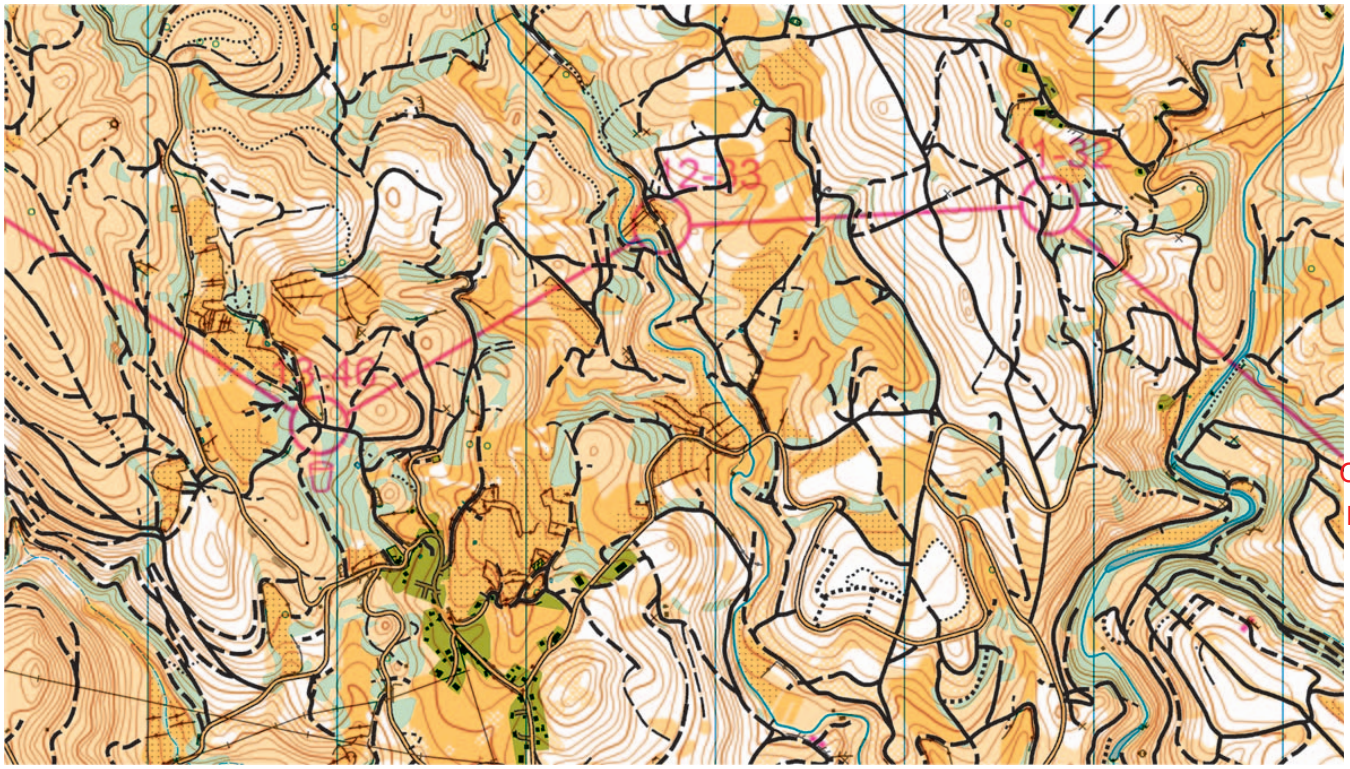


Figure 4. Map of Mountain Bike Orienteering World Championships 2010, Portugal, Montalegre

thicker and the quality difference is shown by continuous, dashed and dotted lines in both disciplines referring to the width (speed) of the path/road. As a result, the legibility of these maps is very good.

It is interesting that competitors of these disciplines do not insist on adding more and more details on the maps. The ski-orienteering has a longer tradition and due to the winter conditions, point symbols are nearly totally omitted on these maps. Snow covers everything; the only relevant information for the competitors is the classified track network and the relief (contour lines).

MTBO is a sport in which the competitor uses the map to navigate a track and path network in order to visit a number of control points. The competitor must always stay on the tracks and paths and (regularly) is not allowed to cycle freely in the terrain. Man-made features (except the track network) are shown in dark grey colour, but most of the point features are removed. The first World Championships in mountain bike orienteering was organized only in 2001, so the map specification is continuously improving based on the feedback of elite competitors and the relevant commissions of the IOF. The key point is the legibility, and MTBO competitors are very creative: they even test new colours (like red or purple) to emphasize the hierarchy of features. These new improvements of MTBO maps may affect the specification of traditional orienteering.

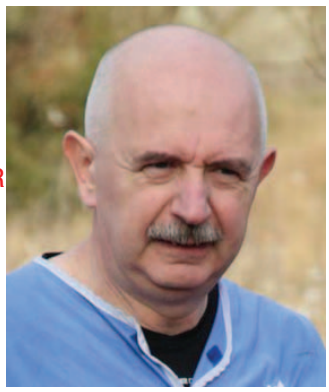
CONCLUSIONS

The legibility issue of orienteering maps is an interesting sample of how users' demands influence the map itself. Orienteering maps are probably the most sensitive maps for legibility. The first specification used the traditions of the cartography when the minimum dimensions were defined. As the sport developed, established new formats and disciplines of these traditions were adjusted to the changing needs: like the higher speed of competitors in ski-orienteering and in MTBO. The most important changes occurred in the last 10–15 years: digital printing methods and laser scanning considerably affect the orienteering maps, the methods of mapping, the reproduction techniques and overall the legibility. New technologies give more support for the mapping (mostly for the fieldwork) and the main result of this is that mappers tend to add more details on the maps and finally the legibility is decreasing. The IOF and its responsible commissions are continuously working on keeping the characteristics of the different formats and the legibility is the most important factor on that. Cartographic experiences help orienteering to emphasize the importance of the legibility of orienteering maps on keeping the essence and the most relevant characteristics of the sport.

The Map Commission of the IOF is working on the new specification of orienteering maps, which will be ready by around 2013. Probably, there will be no considerable changes, but the new specification is going to emphasize the generalisation to improve or at least keep the level of legibility. Now the mapmakers have access to new technologies and to have accurate base maps is easier than ever before, so the education of mappers (and also the training of competitors) should focus on generalisation issues. Mapmakers should understand that without the proper level of generalisation, the legibility of orienteering

maps will not be suitable for the organisation of fair events.

BIOGRAPHICAL NOTES



COLOUR FIGURE

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His main research interests include computer cartography, topographic maps, relief representation and orienteering maps. He has been practising the orienteering sport continuously since 1973.

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