Separating runners in Orienteering

Overview and review of methods

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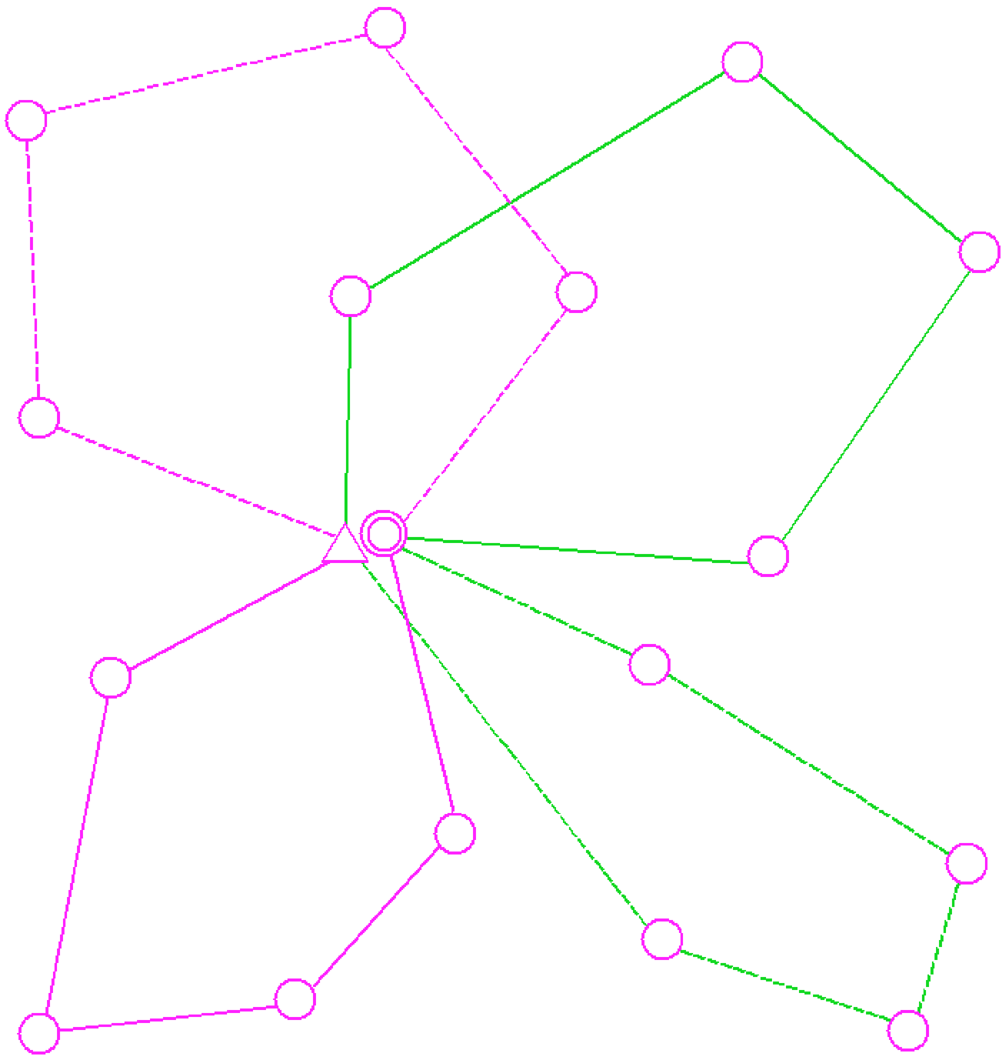


Content

1 Introduction

Co-working, and to some extent following is a major problem in orienteering, and has been for a long time. In many events, even at championships level, the results have been heavily influenced by runners not running completely independently. This report looks into different methods for separating runners to prevent or reduce following, co-working and collaboration during orienteering events. The terms will be defined in chapter 3.

The competition rules of IOF states that *In an individual start race, competitors shall navigate and run through the terrain independently.* However, as the IOF rules commission states in their October 2009 Newsletter "In practice, it is quite difficult to use this rule to disqualify anyone. When two good runners are running near each other, it is often the case that they both obtain some benefit. You can't expect one runner to take a poor route choice just to separate themselves from another runner. **In general, it is up to the organizer to minimise the opportunity for following by the use of an appropriate start interval and good course setting** (our emphasis).

Over the years many different ways of separating runners have been proposed, e.g. "butterflies", one-man-relay, micr-o, etc. However, there has been little formal evaluation of how effective the different proposals are, and how effective they are relatively to each other. This report addresses this problem by describing known spreading methods in orienteering, evaluating their effectiveness as a spreading method based on both theoretical evaluations and race analysis.

The main target for the report is to look at spreading techniques for world class runners – in particular to avoid that top class competitors are together for several legs, leading to one (or both) of the runners gaining an unfair advantage as a consequence of this.

We are grateful for the time many runners have taken to answer our questionnaire and the many long and well thought through comments they have made. This shows that the problem is also one that the runners are concerned about.

We appreciate the help from the reference group Mats Troeng (Sweden), Martin Lerjen (Switzerland) Graeme Ackland (Great Britain), Jarkko Ryppö (Finland),Kjell Blomseth (Norway) Emil Wingstedt (Foot-O Athletes Commission), Björn Persson (IOF) which have made many useful comments during the work.

2 Organization of the report

The motivation for using spreading methods in orienteering is discussed in section 3, followed by a discussion of requirements for a good spreading method in section 4. The theoretical framework to be applied in the analysis of the spreading methods is given in section 5. All spreading methods known to us that are thought to be relevant within the scope of this report, are analyzed in section 6. The different spreading methods are compared and discussed in section 8, and finally section 9 gives conclusions. Sections 10 and 11 give references and appendix, respectively.

3 Why use spreading methods

Orienteering is based on *independent* route choice and navigation. The aim is to find the best orienteer. This requires that the competitor solves the orienteering technical problems himself (or herself). It has been a problem over the year that the orienteer does not navigate independently. This has been a particular problem at the international top level. There are many runners of approximately the same ability. When they get together, they will, to a large extent, stay together for the rest of the course. Shorter start intervals and start lists based on qualification races has increased the problem.

We are facing three slightly different problems.

- **Collaboration** – two runners are actively working together. Has occurred, but is rare.
- **Co-working** - two runners of approximately the same ability navigate independently, but are running together. Both benefits from keeping the speed up, and also from the navigation. This

is probably the factor that mostly influences the results, but also to a large degree accepted by the runners. Many regard a good start position as something you have deserved through the qualification race.

- **Following** –one runner is navigating the other is the just following. Seems to be mostly a problem among the juniors where the technical abilities vary quite a lot.

Martin Lerjen[1] defined two different kinds of groups in orienteering. E-groups (equal groups) where the two runners have approximately the same strength, and H-groups (hierarchical groups) where one runner is clearly stronger than the other. Splitting E-groups will be equal correspond to prevent co-working, while splitting H-groups will correspond to prevent following.

The three problems mentioned above may be difficult to tell apart. However, there will be many of the same remedies to stop all three. For collaboration, co-working and following we need to separate the runners. Much of the thinking, and methods devised, has been based on following (or H-groups). It has been assumed that as soon as the runners are separated the weaker runner will loose time, and the problem is solved. In reality we are not trying to separate a "good" and a "poor" orienteer, we are trying to separate two runners of nearly the same ability (the E-groups).

4 Requirements for a good spreading method

The requirements for a good spreading method depend on event type, TV-coverage, etc. The following requirements must be weighted for different types of events and different types of runners:

1) **It should enforce independent navigation**. This is the main purpose of any method for separating runners and is required for all events.
   - Prevent following (one runner is navigating the other is more or less blindly following)
   - Prevent co-working (both runners are navigating, but their route choices and speed is helped by the company)
   - Prevent collaboration (two runners are actively sharing information and helping each other)

2) **It should be fair.** We want to find the best orienteer. The method we choose should not introduce differences that are large enough to influence the result. The method should not only be fair, but also be perceived as fair by runners coaches and spectators. This is also required for all events.

This means:
   - The same orienteering challenges
   - The same running time and length
   - The same information about map and terrain
   - The same tactical considerations
   - The same weather conditions
   - Minimal influence from the vegetation
   - Minimal influence from errors by other runners

3) **It should be easy to follow for spectators at the arena and via TV**. Making our sport more spectator-friendly has been one of the main reasons for the increased awareness of the problem. This goal should not be abandoned, when we try to enforce independent navigation. However, this requirement is most important for the major championships. Unfortunately this is also the events where the focus on the problem of runner being together is largest.
   - Not too large differences
   - Possible to compare intermediate times
   - The result more or less ready when the runner finishes (although mis-punching will still be a possibility)

4) **It should maintain the character of the different distances**. This is important for most events, although there has been and will be many deviations from the championship distances in local events.

[1] See http://www.arua.ch/index.php?face=insp&topic=214

- Still have long legs for the long distance
- Still have high speed for the sprint
- Still be technically challenging for the middle distance

5) **It should be simple for the organisers**. This certainly applies for most events but is less important for the major events where there is most focus on the problem.
   - Have a limited number of map exchanges
   - Have a limited number of controls
   - Not require any excessive programming
   - Result in minimal work after the race
   - It should not increase the chances of organisational errors

It is important to note that different spreading is required for different types of runners and events, e.g.

- Individual start versus Mass start versus Chasing start
- World Class compared to national Elite compared to national Juniors etc.
- Women versus men
- Spreading of equally good runners together as opposed to poorer runner running behind good runner

5 Theory

5.1 Definition of a grouping

In this study we have used split times, which after the advent of electronic timing, are available for many events. It should be remembered, though, that two runners being together on two controls in a row does not necessarily mean that they have been together between the controls. It is possible to take different route choices that are fairly similar in time, and will thus not separate the runners on the controls. Unfortunately, not enough route choices are available to check this. This will hopefully improve as tracking systems becomes more and more common. One illustrative example is the middle distance in the World Games on the 720 m long leg from 14-15 the left hand and right hand route choices were separated by up to 660 m. Still the fastest runners on the two route choices had exactly the same time, only the 7th fastest was more than 20 (21 to be exact) behind the best time.

As we will see later, there are many instances of runners being together at two or three controls, and then going separate ways. This is probably a faster runner catching up with and passing the slower runner. From the split times this will also appear as a grouping, which it strictly speaking is. However, this is not the “problem behavior” we need to limit.

An analysis has been made from several events (see appendix) for group building in orienteering to gain information about how the runners are grouped in the forest. The motivation was to get information about how many seconds a spreading method must spread two runners if it shall work. The question is: How much must two runners be separated not to get back together at the next control? This is an important prerequisite for looking at what we want to do with a spreading method. **Based on the analysis below, it is seen that in most cases, runners are either within 12 seconds, or evenly distributed. Thus, a spreading method should spread two runners at least 15-20 seconds to be effective.**

The plots show the times between runners passing any given control. If all runners were equally fast and made no mistakes, they should pass any given control one, two, three … start intervals after each other. If all runners were together they would pass through the control at the same time. In reality there will be a spread. What we see is that many runners are very close together (to the left hand side of the graphs) while others are more or less evenly spaced.

An example with start interval 2 minutes and no separating method is shown in figures 1-4. In the histogram plots in Figure 1, Figure 2, and Figure 3, we look at how runners are grouped in a course. In the histogram plot there is one point for each 4 seconds – that is

- The number of runners which are less than 4 seconds behind another runner at a control are in the first group of the histogram.
- The number of runners which are between 5 and 8 seconds behind another runner are in the second group in the histogram.
- The following groups are for 9-12 seconds, 13-16 seconds and so on.

In the qualification, the start list has been drawn, whereas in the finals start lists are set up in a way that the runners get better and better, increasing the chance for grouping. This can also be seen from the below figures. Between 5-15% of all control visits are with a runner within 12 seconds. For the finals, the number of runners being within 12 seconds increases significantly compared to the qualifications. Also, grouping seems to be more severe in the men's class compared to the women's class. Most control visits are in a "vacuum", i.e. not close to other runners.

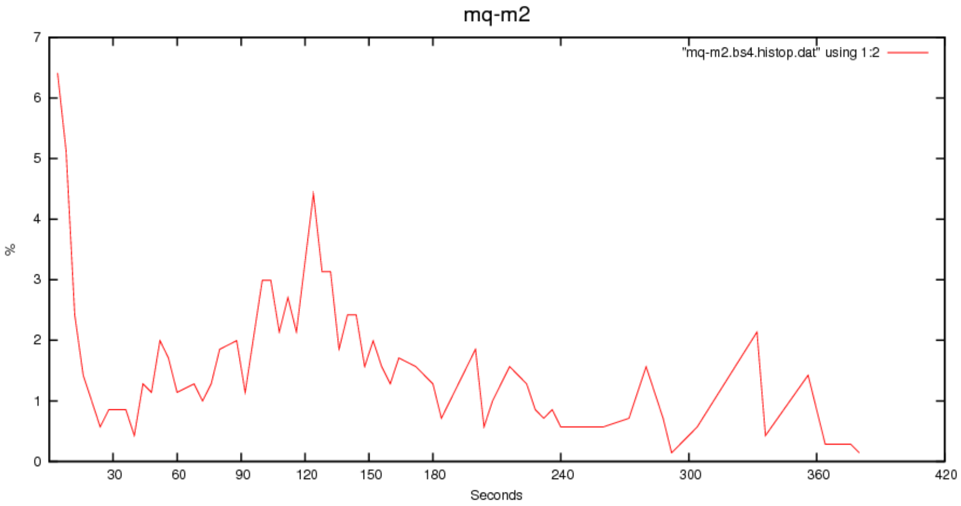
The hypotheses are:

Hypothesis 1: In an aggregated histogram, where we plot the number of runners within 5s, 10s, 15s etc, we should see a drop in the number of runners at each tic at about the time where visibility drops, or the distance feels too long for the runner.

Hypothesis 2: As the runners are of fairly equal abilities there should be an increase in the number of runners, around the tics for the starting interval. This is also clearly seen.

Grouping can be defined as two runners being within 18 seconds at 3 controls after each other. This is 1.5 times the 12 second gap where most runners are when they are together.

It seems clear that the large groups seen in some events (WOC 1993, 1997 and 2005) are an anomaly. In most cases there are relatively few and small and also seems to break up quite frequently.



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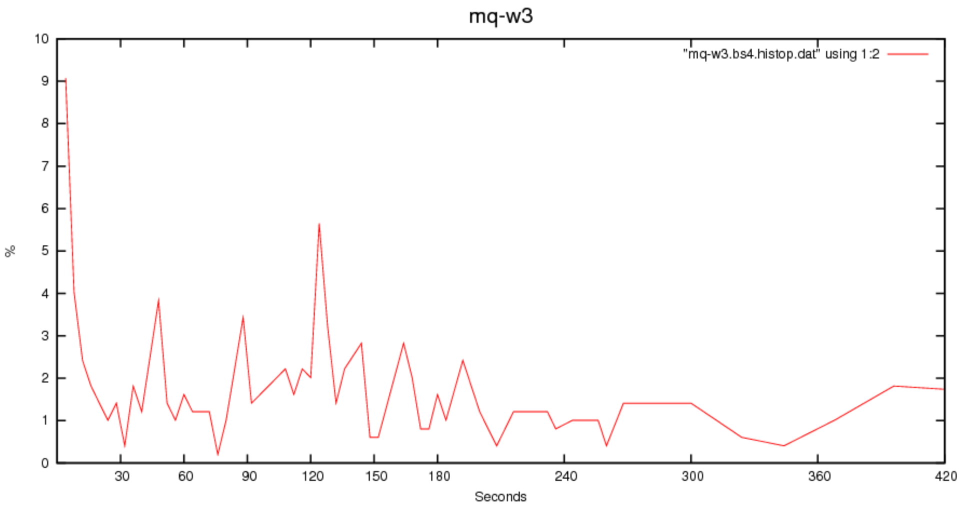

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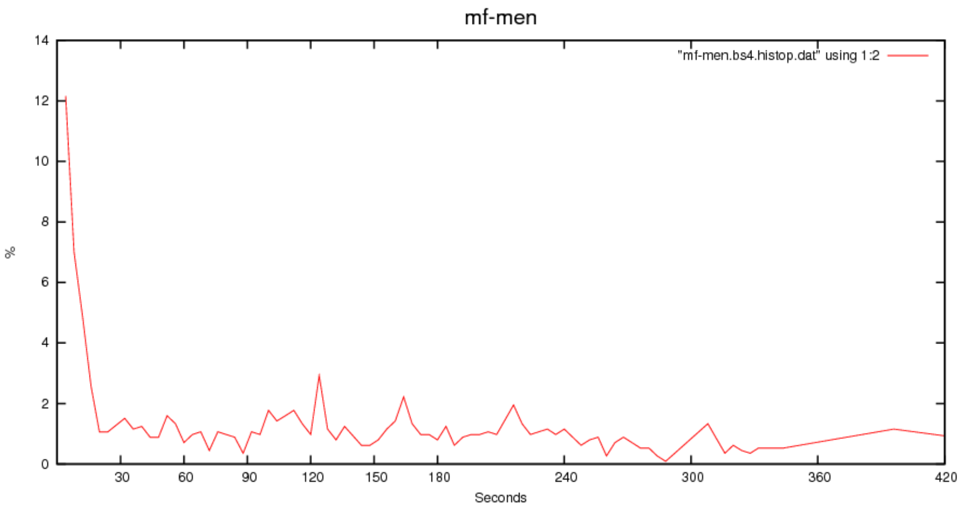

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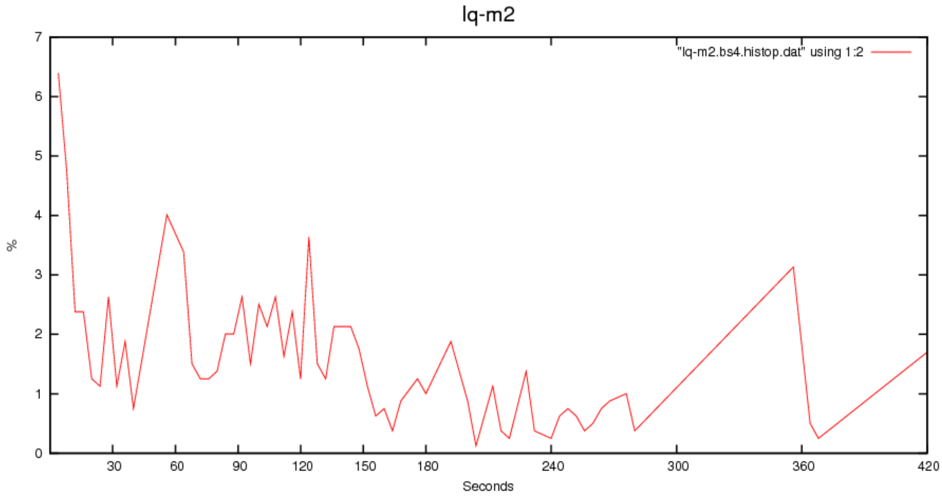
Figure 1. Histogram from (a) EOC 2008 Middle Qualification Men heat 2. (b) EOC 2008 Middle Qualification Men heat 3. (c) EOC Middle Final Men. The histograms show how runners are grouped in the course. Data are typical for international championships. For detailed explanation of the figures, see the text.



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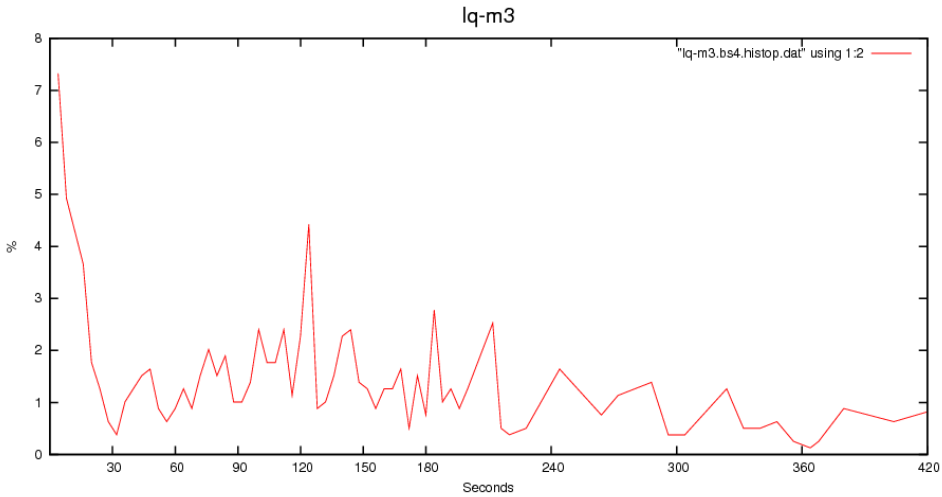

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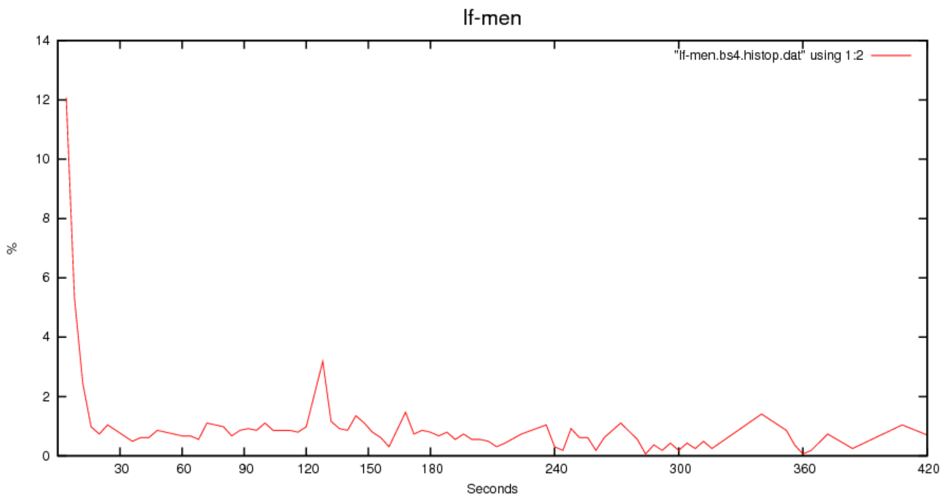

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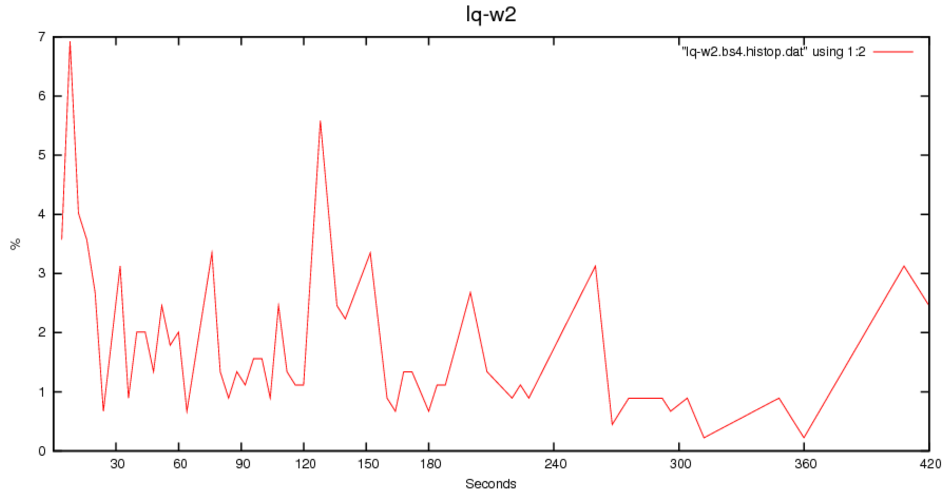
Figure 2. Histogram from (a) EOC 2008 Long Qualification Men heat 2. (b) EOC 2008 Long Qualification Men heat 3. (c) EOC Long Final Men. The histograms show how runners are grouped in the course. Data are typical for international championships. For detailed explanation of the figures, see the text.



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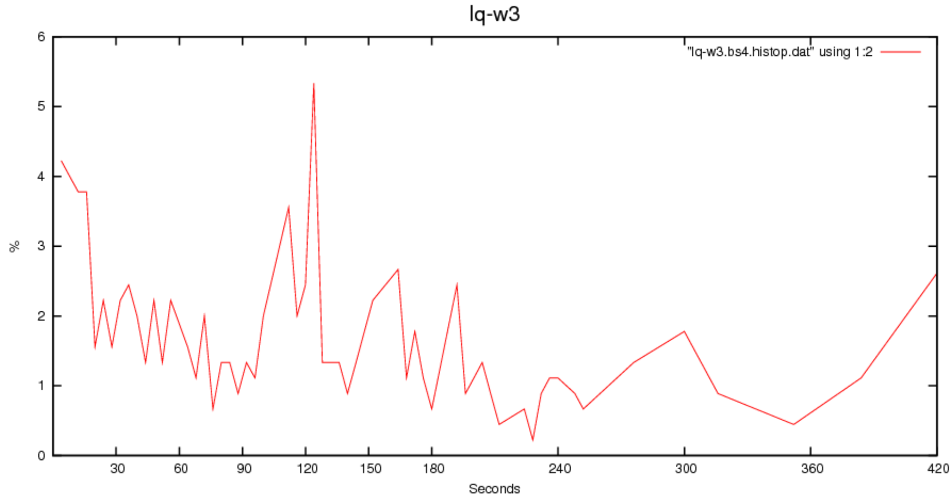

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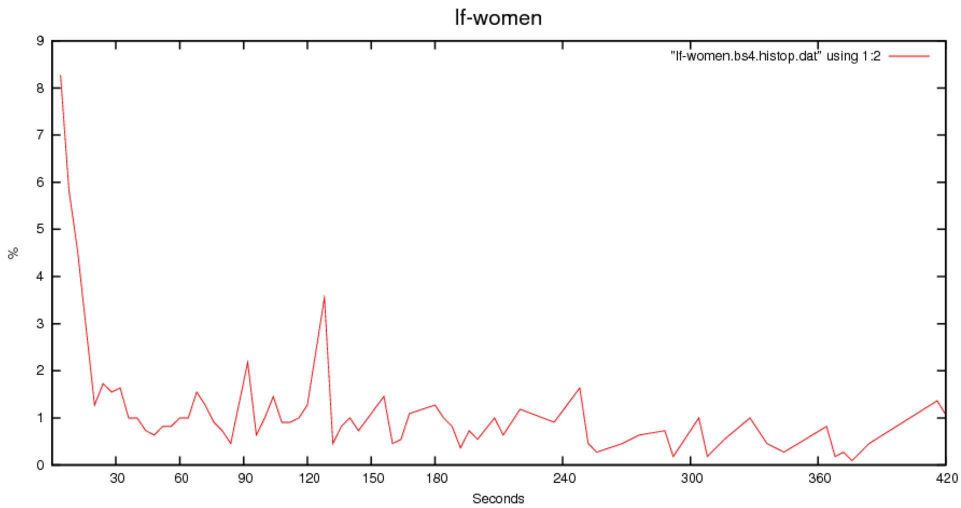

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Figure 3. Histogram from (a) EOC 2008 Long Qualification Women heat 2. (b) EOC 2008 Long Qualification Women heat 3. (c) EOC Long Final Women. The histograms show how runners are grouped in the course. Data are typical for international championships. For detailed explanation of the figures, see the text.

5.2 Definition of good spreading

To separate two runners, there should be at least X seconds between them at the end of a spreading method. Here X should be such that:

- X is larger than the interval which is given as a group in the previous section, i.e. larger than 18 seconds.
- In addition, there should be an extra separation distance to make sure the runners are not grouped again in a very short time

Based on this, 25-30 seconds seems to be an adequate definition of good spreading.

5.3 How fair is fair?

How far "down" should the result list be unaffected from co-operation, co-working and following?

There is of course no objective answer to this problem. The "correct" answer is the opinion of the competitors, officials, spectators and media. It is difficult to probe the opinion of the spectators and media, but judging from the media coverage and interest from spectators at races, it is the top runners that are of importance. We have sent a questionnaire to national team runners (via the national team coaches). The results are given below:

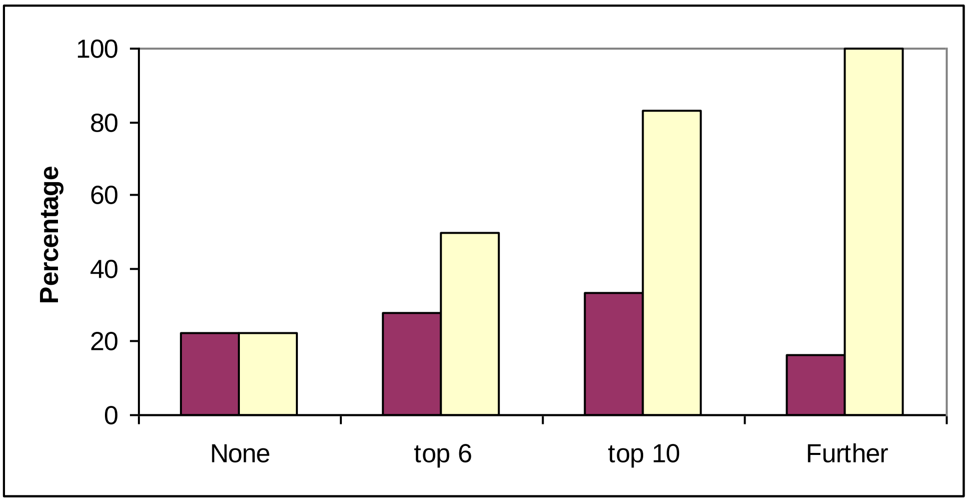

Figure 4.
The first column shows the percentage that has given each alternative, while the second shows the accumulated percentage. We see that with correct results within the top 6 around 50% of the runners will be satisfied – and with top 10, 83% of the runners will be satisfied.

The media mostly concentrates on the medals in their coverage – and partly on top 6. ,.Top 10 (or possibly also top 6) should also satisfy most of the sport financing bodies, and sponsors which reward top performance.

To cite just one runner: "in my opinion this is really part of the game - even on absolute top level. Therefore we run Qualification races, so that everybody gets the chance to start in a group of the best runners". More than 20% of the runners share this view and do not see any reason for a "correct" result list. This might seem strange, but the same was found in poll among Norwegian runners in an earlier preliminary study. Many runners regard a good start position in the finals as something you have earned by a good race in the qualification heats. (We do not think this is a position that we as organisers or officials can, or should, defend. And of course if we do this whole project is meaningless.)

5.4 Runners accept of the different methods

A separating method should be fair, but how fair is fair? To get some information about this we asked the runners about their opinion. The runners were also asked about how efficient they regarded the different methods. Both answers were given on a scale from 1 (lowest) to 7 (highest).

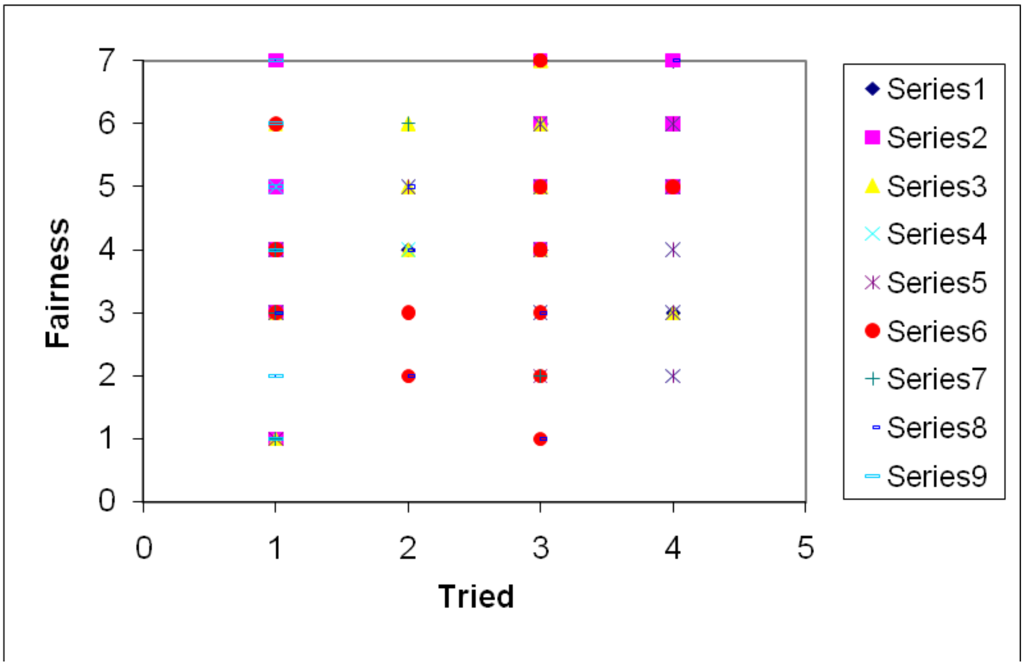

Figure 5. The accept of different methods *versus* how familiar the runners are with the method.

We might expect that runners are sceptical to any new ideas, after all these runners are among the world's best the way the sport is played today. In figure 5 we have checked whether there are any systematic effects of how many times the runners have tried the different methods. 1 = Never, 2 = Once, 3= 2-5 times, 4= More than 5 times. We haven't bothered to distinguish the different methods as there are no significant differences.

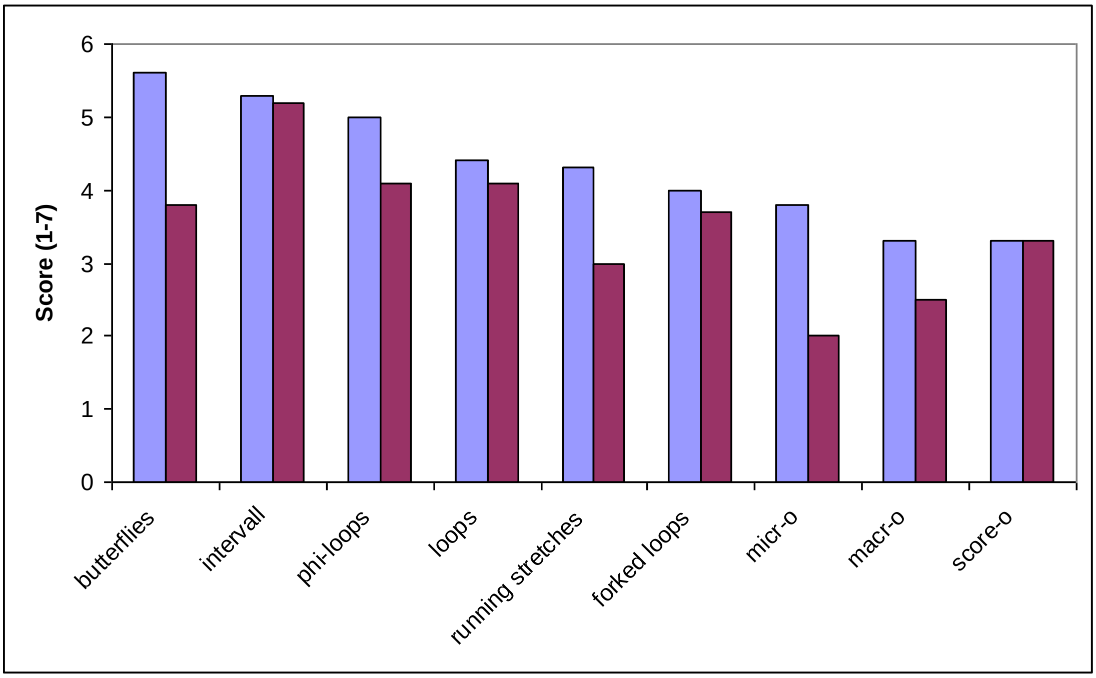

Figure 6. The perceived fairness (blue) and effectiveness (purple) of the different methods.

In figure 6 we have indicated how fair the runners regard the method (blue) and how effective they regard the method (purple).

From this graph increased start interval is clearly the best method. This is even more obvious if we look at the product of the two answers (the sum would give a similar result).

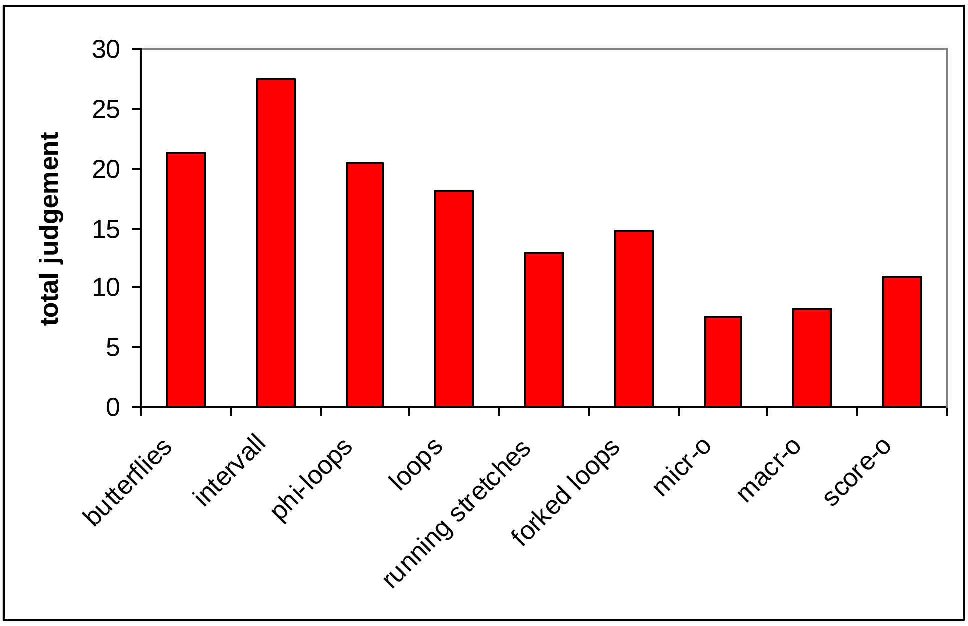

Figure 7. Fairness multiplied by effectiveness to give a total judgement of the different methods.

However, the runners also recognise the short-comings of this method, as this somewhat subjective selection of the comments show (see 6.1).

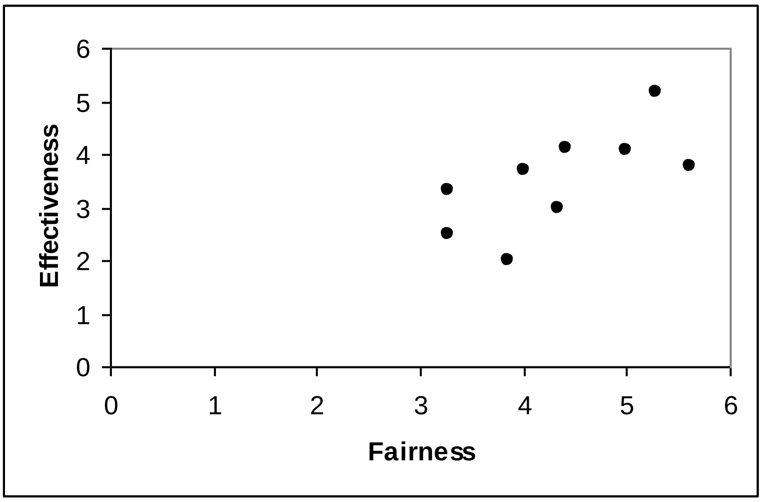

Figure 8. A correlation between how fair and how effective runners regard the methods to be.

It is interesting to note that there is a reasonable correlation between how fair and how effective the runners regard the different methods from the graph. (However, the correlation coefficient is low R^2 = 0.46.)

5.5 Boost factor

A good indication of the boost factor is needed for quantitative analysis. How much faster does a runner proceed in the forest when there are other runners nearby?

There are two different boost factors. One is the gain in 6-7% by being together due to higher running speed and reducing the amount of errors[2]. This is the boost factor that influences the results (Obviously .the influence on the results does not only depend on the boost, but also for how long this boost applies; e.g. for how long the runners are together.)
The other is the boost in running speed by being together. It is this smaller boost that is available when we want separate the runners. To get some indication of this we looked at the result for WOC 2005. The organisers have published data for the running speed of the runners on each leg relative to the average of the three best on that leg. Using the best half of these they obtain a cruising speed for each runner.

Pekka Inkeri has produced progressographs that show which runner has been together during the race. Combining these two we could find the relative speed of the runners on legs where they have been alone and on legs where they have been together with others. It is thus easy to find how much faster the runners are when they are together compared to when they are alone, e.g. the boost factor.

We have progressographs for the Men's and Women's Long Distance as well as the Women's Middle Distance. Thus these races were analysed further. We used the best half of the leg times when they are together and the best half of the leg times when they are separate to calculate the boost factor. Runners with just one or two times in each group were excluded from the analysis (typically these runner have made a large mistake in the beginning and been caught up on the first few controls). Using the best half of the results excludes legs where large mistakes are done, and gives a reasonable indication of the speed the runner can sustain over time. It might be argued that fewer mistakes are one of the main effects of runners being together and that all legs should be included to take this into account. But clearly for the top end of the result list (which are of most interest) the runners are so good, and mistakes so infrequent that relying on the mistakes to separate runners does not work.

For these calculations we are basically applying the method of Tomita. It can be argued that the split times we use are themselves influenced by co-working, and thus boosted. This will mean that the average of the three best is somewhat boosted and that the abilities at individual runners are thus

[2] G. Ackland The effect of pack formation at the 2005 world orienteering championships, Scientific Journal of Orienteering 17 (2005) 12

underestimated. However, as we are comparing individual runners with themselves to find the boost factor this should not influence the result. The hypothetical best time will be approximately 3% in all cases. (As the hypothetical error free time for the best runner always involves split from runners that has not done any mistake, it doesn't matter whether this is due to their own ability or help from others for our calculations. It is thus only the extra boost of the running speed that is of concern.)

Assuming that the runners make no mistake within the spreading method – an assumption which is mostly valid for top runners in an E-group - the spreading method should thus be able to separate runners with their normal running speed. For H-groups (ref. section 3 for definition), the chances of mistakes being made by the "weaker" runner within the spreading method is increased (even if this is usually also often a good orienteer, mistake frequency will often be higher), and thus the boost of less mistakes should to some degree be taken into account here . The same is the case for E-groups consisting of weaker runners, but these groups are not necessarily the main target for the spreading methods.

The table shows the per cent points boost factor found for WOC 2005.

	Men-long	Women-Long	Women-Middle
Average	2.6	0.85	2.5
Standard deviation	5.4	5.9	11.3
Median	2.7	0.80	-0.5

Table 1. The boost in speed by being together (the effect of less mistakes is not included in these numbers).

The results shows a nearly Gaussian (normal) distribution, but with a large deviation. For the Long races the average and median are close, confirming that we have a fairly Gaussian distribution. Quite a large part of the runners show negative boost factors, indicating that they loose time together with others.

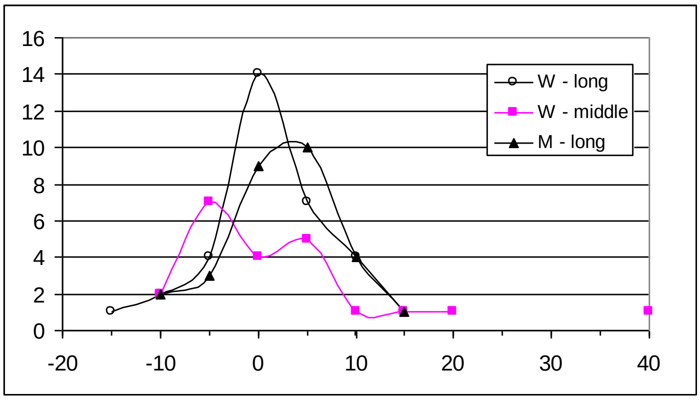

Figure 9. The distribution of boost factors.

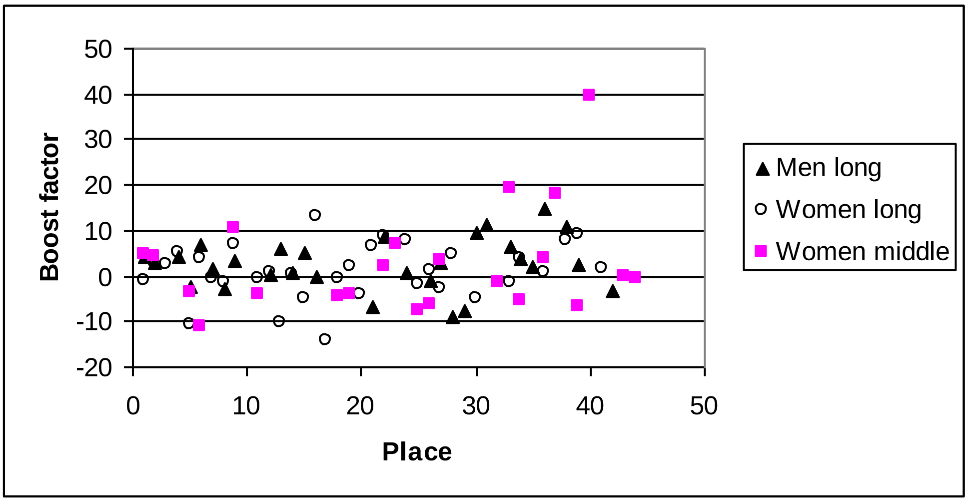

Figure 10. The boost factor as a function of result in the final.

It could be expected that weaker runners gain more when they can benefit from the help of others. When we plot the boost factor as a function of the result we see relatively flat lines. The best linear fit gives an increase of 0.05%/place for men, and 0.10%/place for women long distance. If only the 30 first runners are used for the analysis, we find -0.13%/place for men and 0.02%/place for women. In other words there is no systematic difference between the best and the second best. However, there is a confounding of the results as the qualification races ensures that the runners start among others of about the same ability.

For the Men's Long distance race we also calculated the boost factor with all legs included. This gave an average of 6.3% with a standard deviation of 11.3 and a median of 5.9%. These results are in very good agreement with Ackland which used a boost factor of 6% to mimic the results of that race. For runners catching up with each other the effect of mistakes is much larger and in this case probably all leg results are relevant. The same analysis for the men's middle distance final during WOC 2007 gave a slightly higher boost factor of 7.4% when all legs were included, and 4.8% for the best half. The women's middle final gave extremely large boost factors of 13.1% for all legs, and 11.3% for the best half of the legs.

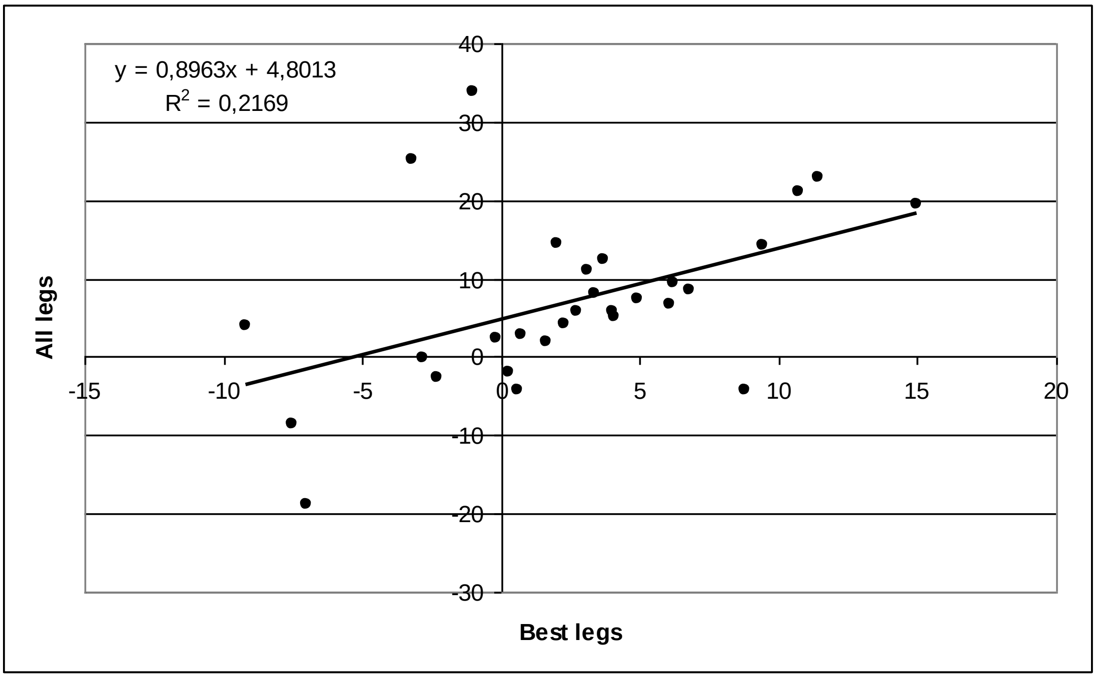

Figure 11. Comparison of the boost factor when the best half of the legs are used and when all legs are used. The effect of mistakes adds 4.8% to the boost factor.

5.6 How much do mistakes influence the results?

Several of the methods for separating , force the runners apart and then rely on one of them making a mistake so they will not be together after the separation. The question is whether runners at the top level makes enough mistakes for this strategy to work.

The results in orienteering depend on both running ability and navigation ability. Is it possible to separate the two in any way? It is possible to get a good indication of how well the runners perform relative to their own ability. This was done for WOC 2005, and an index shows the runners' time compared to their theoretical best time. This index ranges from 102-140 for the actual race. Subtracting 100 we get a figure for how many percent each runner is behind his or her optimum performance (on that day).

Finding how many percent each runner is behind the winner is trivial from the results list.

In the Figure below we have plotted the two percentages:

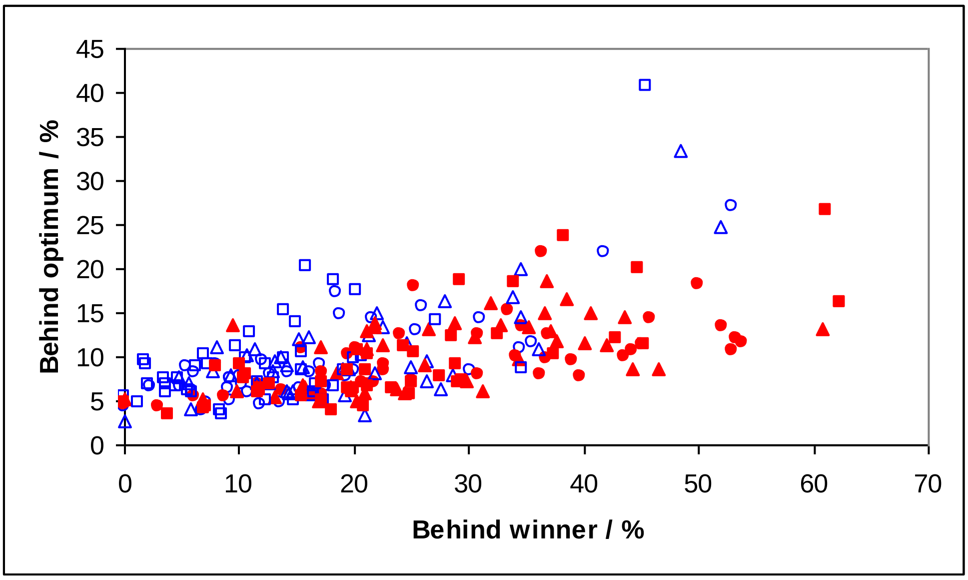

Figure 12. WOC 2005 results for each runner. Blue points for men and red for women. Circles long distance, triangles middle distance and squares sprint.

If all the data points had fallen on the x-axis everybody would have performed to their optimum and the result list would reflect pure differences in running speed. If all points were along the diagonal, all runners would have the same running ability and the result list would purely reflect the amount of mistakes. In reality of course the points fall between these two extremes. Some runners make few mistakes, but are not fast enough. They are found along the lower edge of the data set. Other runners are fast, but make too many mistakes and are found along the upper edge of the data points.

For separating the runners we are mostly interested in the runners that will be in the top of the list or entering the podium.
Below the first part of the data set is enlarged.

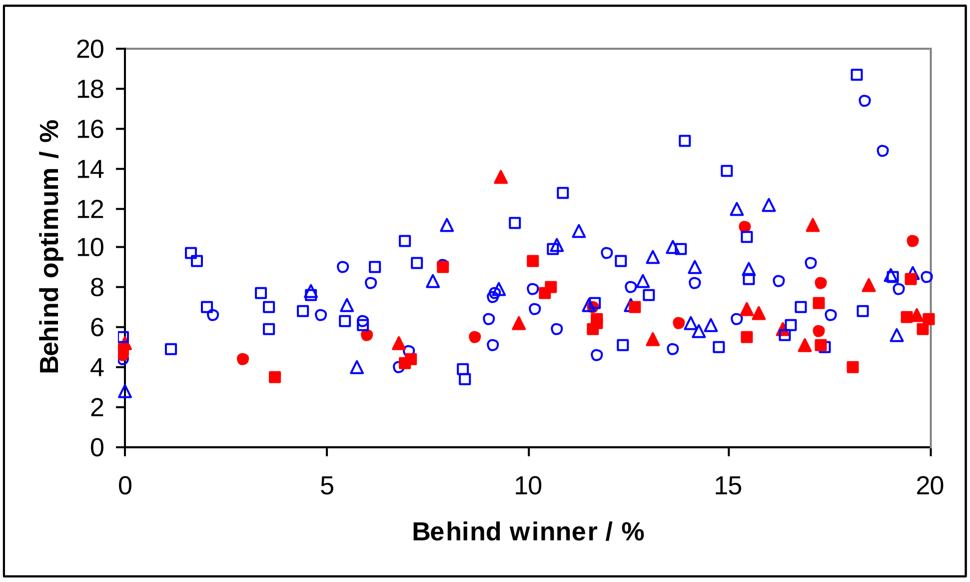

Figure 13. WOC 2005 results for the best runners. Blue points for men and red for women. Circles long distance, triangles middle distance and squares sprint.

An interesting observation can be made. For the first 10- 20% behind the winner the women usually makes much fewer mistakes than the men. This probably reflects the fact that there are fewer really good women than men. (which can be seen be much fewer red than blue points in the diagram). A mistake-free run will give you a good result and it pays of to run conservatively and safe.

For the men's results it is clear that several runners are further behind their optimum performance than behind the winner. In other words if they had avoided (most of) their mistakes they would have won. The men seem to use a more risky strategy and often it fails. With many more good runners a mistake-free, but slow run will still leave you well behind the winner and away from the podium.

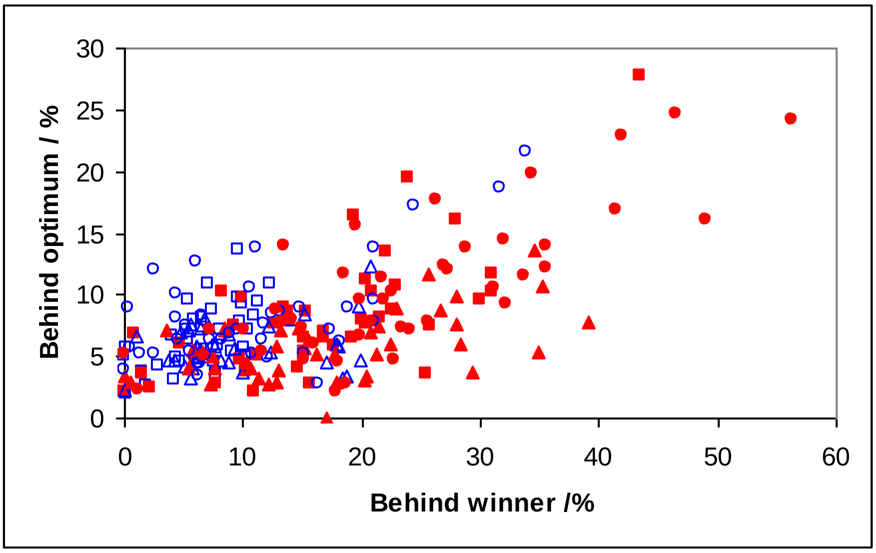

Figure 14. The same analysis for WOC 2006 in Denmark.

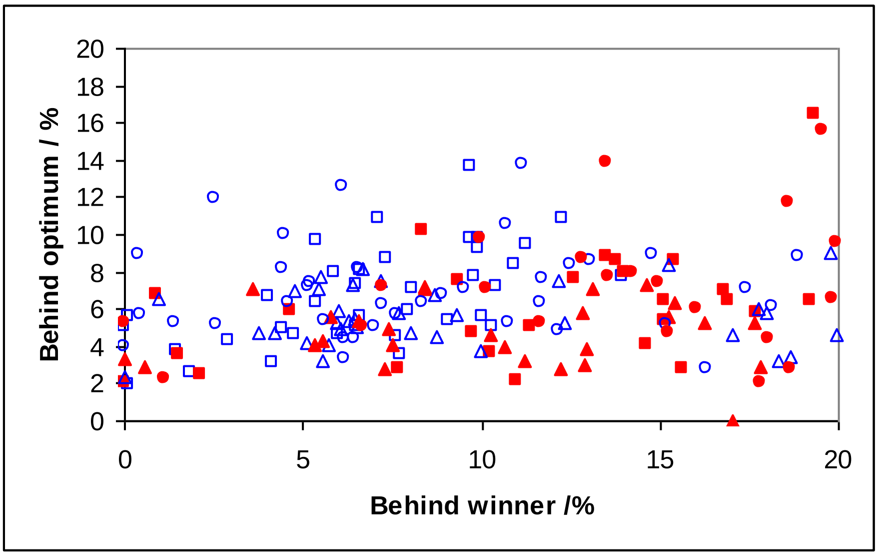

Figure 15. The best runners from WOC 2006.

The data here indicates that it should be more difficult to separate the women than the men. The women are less likely to make mistakes through a butterfly or any other kind of loop. On the other hand, the same factor makes them less likely to form groups.

Looking at the data from WOC 2005 it seems like the runners make a mistake of 20 seconds or more on average every fourth leg. This could mean that butterflies will work, but probably that they need to be longer than the two times three legs usually used. (More legs in the butterfly will increase the chances of mistakes.) We also looked at the WOC 2006, among the top 10 runners there were on the average a mistake of 20 seconds or more every seventh leg. An error of 30 seconds or more only occurred every seventeenth leg. In other words, mistakes large enough to separate top runners running in E-groups are too few for butterflies (or other loops) to work efficiently.

These data indicate that to be as effective as possible, the butterflies (or other localized spreading method) should be in terrain with difficult/technical orienteering where the risk of mistakes is higher to further increase the risk of mistake which the spreading system is based on. Also, the difference in orienteering speed (i.e. map reading, simplification) will be a factor which gets more important relative to running speed for terrain with difficult/technical orienteering. The difference in orienteering speed may vary more than the difference in running speed – especially for H-groups. On the other hand several short difficult legs after each other will also rise the probability of new groups forming.

5.7 Grouping of separation methods

When analysing different separation methods, it may be observed that there are many different variants, all may be divided into four different main groups.
1) Modification of the start interval (or composition of the start list).
2) Introduction of loops. Two general types of loops exist:

- Loops where the runner knows that the next control is common (generally all spreading methods where there is no map exchange).
- Other cases e.g. phi-loops with map exchange. (Phi-loops without map exchange are in the other category).

3) Choice of controls or route choices, e.g. score-o and micr-o or macr-o where not all runners have the same controls within each cluster.
4) Methods for which a piece of running is introduced. E.g. micr-o, macr-o or dead running.

The statistical and theoretical treatment of several seemingly different methods will thus be the same. Most clever new schemes for the placement of controls will also fall into one of the groups above and thus already be analysed.

5.8 Evaluation of the methods

In the evaluation of the spreading methods there are several graphs based on the split times that can be used.
1) Time difference between runners at the control. This was used to determine how long time interval between two runners we should have to regard them as separated or not. The cut of we use is 18/20 seconds (as discussed in 5.1)
2) The number of groups of different sizes with the chosen cut-off.
These graphs tell us how many groups there are and the size of each group. However, it does not tell us how long-lived each group is.
3) The number of runners in groups. This tell us how many runners are together with others, but again the information of how ling lived each group is, is lacking.
4) Progressograph. This tells us when the runners passed the controls. From this it is possible to tell which groups we have, and how long each group (or sub-group) exists. The graph also makes it very clear which runners that gain by being together with others. The scale often makes it difficult to tell whether runners are together or not.
5) Bunching graph. These make it very clear which runners that are together (based on some – more or less – arbitrary criteria). These graphs make it easy to see how long lived the groups are, and also how runners pass in and out of groups.

In our analysis of the different methods we have mostly used the bunching graphs, as they give most information. However, these types of graphs do not always reveal all information about what has happened in the forest as the following example from WOC 2007 shows (x and y denote two different groups):

	5	6	7	8	9	10	11	12	13	14	....	26	27	28	29	
AK						x										
MK				x												
AP	x				x	x	x	x	x	x						
NK	x			x		x										
RS					x	x	x	x	x	x						
LF							x	x	x	x		x	x	x	x	
OK												x	x	x	x	
LB	y				y			y	y	y						
MM	y				y			y	y	y						

Here we have chosen not to regard AK and MK as part of a group. They have been passed by another runner (MK at control 8) or group of runners (AK at control 10) but have never been part of a group in the sense we want to avoid in orienteering. Likewise AP seems to have passed and been passed by other runners without wanting (or being able to(?) join) the groups. If the runners are together at **two** consecutive controls we regard them as part of a group. Thus we regard AP and RS as a group from control 9 to 14. This group also consists of LF form 11 to 14. The group AP, RS, LF is split through the loops (control 15-25), while a new group LF and OK forms immediately after the loop.

LB and MM forms another case for which it is not possible to conclude about what has happened in the forest.~~,~~These are two runners that form a group, break up again, and then reform. This could be one runner trying to follow, but not being quite fast enough (thus only catching up when the faster make small mistakes), or it could be to runners with no intent of running together, but being very evenly matched. In the former case the loops have had the desired effect, in the latter case they would have split anyway. We have regarded runners that have been together for the two controls preceding the loops as being a group and thus being split by the loop if they are split.

In several cases we have groups that are separated at control 26, but together again at 27. We have regarded these as split by the loops, but also noted this in the text (as it might be an overestimation f the effectiveness to regard these groups as split).

Thus, analysis of GPS tracks should be used to fully analyze the grouping. This type of data is now getting available for more and more races – and thus a full analysis of grouping based on GPS tracks should now be possible e.g. from the Nordic Championships in Finland 2009. Although GPS will still only tell that two runners were at the same place at the same time, and not whether they actually cooperated or consciously benefitted from each other.

6 Analysis of known spreading methods

6.1 When and how do groups form?

It seems to be a general feature that more and more groups form over the first few controls. Often the groups have already formed after 3-4 controls. Usually they have formed after 7-8 controls. After that the number of runners in the groups stays more or less constant. In a few cases there is a slight increase over the whole course. It seems like whatever pattern we have approximately 40% of the runners are together at the end of the course. The average for all cases where there are reasonably stable groups are 40.5% (+/-6%), if we exclude one extremely low value we get 41.4% (+/-4.5%) In other words when there is a gradual build up over the whole course it is because fewer runners get together early (several of these cases are sprint races, or middle distance races).

The groups mostly consist of two runners and they hardly increase in size over the course. This is consistent with a pair forming when the runner in front makes a mistake. In most World Championships these has thus probably been E-groups.The distance from the pair to the runner in front of them is then two start intervals. For a middle distance (and long distance at WOC) this would mean four minutes. With a boost factor of 6% (taking into account both increased running speed and less mistakes) four minutes with a running speed of 5 min/k would mean about 13 km of running to catch the runner in front. Thus it is very unlikely that a pair will catch the runner in front unless that runner makes a big mistake. Two events with few groups forming was WOC 2006 and WOC 2007, in both cases there was relatively simple orienteering. Thus the number of mistakes was probably low, and few groups would form.

The groups mostly consist of two runners (and as described above there are good reasons for only small groups forming). The trains sometimes seen (WOC 1997 and 2005 being most prominent), thus seems to be an anomaly due to poor course planning. Could the short start interval required at the WOCs be a contributing reason? WOC 1997 had technically difficult terrain, while WOC 2005 had technically difficult terrain at the beginning. Swedish Championships Middle 2007 (D21 final) gives an exceptionally large number of runners in groups (60% towards the end). Middle distance should be technically demanding, and Swedish terrain is demanding so this does seem to fit the pattern. This will be discussed more in chapter 7.

A discouraging feature of these graphs is the fact that it is impossible to identify where there has been any separating method (if there has been any). There is one exception. UK-WC long for women where there is a dip in both groups of more than two and number of runners in groups at control 18-22. A separating method should break up pairs of runner. We see from these graphs that even if they are apart for a while they rapidly get back together.

There are mostly pairs forming and very few larger trains of runners. This shows that the separation methods do not have to be very elaborate, as there are relatively few runners to separate. On the other hand they will probably be E-groups, which by nature are difficult to breakup. We also note that most groups that form break up again. Of the 32 groups that formed during the middle distance women's final during WOC 2007 only six existed at the finish. (This analysis used only 15 seconds as a sign of a group due to the low visibility. It is thus likely that some of the groups that broke up and reformed several times might have been together more of the way, and that the number of groups should be reduced by 5-6.) Of the 38 runners that were involved in a group somewhere in the race only 14 were in a group when they finished.

Difficult orienteering promotes mistakes, which promotes formation of pairs of runners (and also occasionally larger groups).

6.2 Increased start interval

6.2.1 Description of method

An increased start interval will reduce the possibility of two runners coming together. The IOF competition rules require 2 minutes for the WOC long distance, but 3 minutes for all other long distances. For the middle distance the start interval is 2 minutes. Increased start interval does not give any extra work for the course planner or organizer. The start will take longer time and the event will be less spectators friendly. The probability for issues regarding changes in weather and temperature will also increase with increased start interval.

One possible implementation of the method is to use the same approach as in cycling and cross country skiing, where the start interval is larger for the red group / favourites than for the rest of the start field (i.e. 3 minutes for the last 15 starters, 2 minutes for the rest of the start field). However, as the media will be most interested in the red group and the start interval is already too long for TV coverage this does not seem to be a viable solution.

6.2.2 Analysis of method

In the Table below we have listed the World Championships from 1993 to present, and given the time the second, third, sixth and tenth runner is behind the winner as a proportion of the start interval.

		Start				WOMEN				MEN
		intervall	2nd	3rd	6th	10th	2nd	3rd	6th	10th
1993	Short	*2*	0,26	0,27	0,81	1,28	0,22	0,43	0,53	0,59
	Classic	*3*	0,64	1,12	1,64	3,29	0,17	0,62	1,08	1,43
1995	Short	*2*	0,18	0,28	0,39	0,64	0,55	0,59	1,01	1,32
	Classic	*3*	0,94	0,94	1,32	1,79	0,58	1,10	1,18	1,64
1997	Short	*2*	0,12	0,35	0,64	1,10	0,10	0,18	0,61	1,13
	Classic	*2*	0,37	0,82	1,83	3,00	0,85	1,40	2,57	3,48
1999	Short	*2*	0,52	0,94	1,00	1,51	0,19	0,22	0,47	0,77
	Classic	*3*	0,18	0,20	0,61	1,50	0,97	1,00	1,85	2,23
2001	Sprint	*1*	0,10	0,12	0,42	0,82	0,18	0,23	0,40	0,60
	Short	*2*	0,11	0,14	0,50	0,77	0,18	0,28	0,70	0,90
	Classic	*2*	0,03	0,38	1,08	2,64	0,28	1,13	2,06	2,83
2003	Sprint	*1*	0,15	0,32	1,05	1,53	0,32	0,35	0,58	0,78
	Middle	*2*	0,14	0,43	2,01	2,53	1,31	1,50	1,78	2,10
	Classic	*2*	1,54	3,32	4,14	5,13	1,13	1,40	1,83	2,37
2004	Sprint	*1*	0,48	0,78	0,92	1,33	0,05	0,05	0,13	0,47
	Short	*2*	0,09	0,23	0,63	2,13	0,18	0,23	0,76	1,61
	Classic	*2*	0,51	0,72	0,93	2,28	0,27	0,79	1,93	3,15
2005	Sprint	*1*	0,53	0,98	1,43	1,65	0,17	0,23	0,50	0,67
	Middle	*2*	1,11	1,53	2,53	2,79	0,77	0,91	1,32	1,89
	Long	*2*	1,10	2,22	5,07	7,18	1,07	2,39	2,98	4,43
2006	Sprint	*1*	0,10	0,18	1,00	1,33	0,02	0,03	0,40	0,67

	Middle	*2*	0,18	1,13	1,72	2,29	0,07	0,09	0,47	0,93
	Long	*2*	0,22	1,43	2,31	3,17	0,58	0,83	2,03	2,33
2007	Sprint	*1*	0,33	0,67	0,90	1,37	0,02	0,32	0,43	0,70
	Middle	*2*	0,54	1,01	1,63	3,22	1,01	1,08	1,40	1,61
	Long	*2*	-----	0,76	2,00	4,59	1,82	2,07	2,68	3,59
2008	Sprint	*1*	0,16	0,32	0,52	1,00	0,05	0,61	0,84	1,04
	Middle	*2*	1,02	1,13	1,57	2,33	0,29	0,32	0,78	1,48
	Long	*2*	0,36	0,53	1,78	3,16	0,63	0,98	2,08	2,34

Table 2. How far behind the winner2nd, 3rd, 6th and 10 places are compared to the start interval for the last 15 years.

Taking the averages for all the years (only from 2001 + 1997 for the classic distance as the start interval was higher prior to that) we find:

	WOMEN				MEN			
	2nd	3rd	6th	10th	2nd	3rd	6th	10th
Sprint	0,27	0,49	0,90	1,30	0,12	0,25	0,46	0,70
Middle	0,41	0,69	1,24	1,89	0,44	0,52	0,89	1,31
Long	0,59	1,30	2,26	3,67	0,75	1,30	2,04	2,81

Table 3. How far behind the winner2nd, 3rd, 6th and 10 places are compared to the start interval as an average.

Classic and long is regarded as the same distance as is short and middle.

As long as the time for the tenth position is less than one start interval longer than the winning time it is impossible to reach this position even by following the winner. In other words we see that for the sprint race there is no problem among the men, for the women the problem is also small. For the middle distance the task is much bigger and in two of the six last championships (after the event found is present form) it has been possible to gain a medal by following among the men, and three of the five among women.

In 7 out of the last 11 World Championships it has been possible to win a long/classic distance medal if you started 2 minutes before the winner and followed him to the finish. Increasing the start interval to 3 minutes would reduce the number of instances to 4. For the women there is a reduction from 4 to 2.

If the results should be “correct” for the ten first runners it should be impossible to get into top ten by following the eventual winner. In other words the time between the winner and tenth place should be more than one start interval (or we will have to use some form of separating method). This leads to the requirement of a start interval of 7-8 minutes if no separating method is applied (see section 6.1 for a comparison of start interval and results

Ackland has shown that when 13% of the runners are able to catch the runner in front the packs will grow in size. With qualification races the runners are sorted somewhat after running ability, and there will mostly be mistakes at a control to allow them to catch up.

As can be seen from the tables in 5.3 the start interval would have to be increased to 7-8 minutes to completely prevent co-working influencing the results among the top ten.

Increasing the start interval to 3 minutes for the last 15 starters while keeping 2 minutes start interval for the rest of the start field will increase the time from the first starter heads out to the forest until the last runner reaches the finish from approximately 190 minutes to approximately 205 minutes using stipulated times for the men’s class from WOC 2009 long distance – a total increase of 8% in the total time of the event. But the red group with most interest for live TV coverage will also have long start intervals.

6.2.3 Examples

Not applicable in major IOF events. Having different start intervals for the same course has to our knowledge never been tried.

6.2.4 Runners comments

Increased start intervals are fine as long as everything related to the orienteering competition stays the same during this time. For instance, the weather!

This is in my eyes the most fairely method - everybody runs exactly the same course in the same following of controls and cannot take profit of coming together with others like in a butterfly after one loop.

If one gets caught up, he should be definitely out of the decision of race. So it is not that matter of running together.

It's quite good to spread the runners but there is a big disadvantage that the overall starting time is very long. That can be unfair because of weather conditions and it is hardly attractive for spectators or media!

For a runner, it's often enjoyable. From an organiser's point of view, you don't always get the opportunity to use this system. In fact, it's mostly the smaller races (with less competitors), where you can use this system. In bigger competitions (maybe with TV), I think, this system cannot be used.

It makes the race very unattractive for the spectators to watch.

If the start interval is increased too much, it could lead to unfair situations (like different weather conditions)

This is absolutely the best method to separate runners, but hardly conceivable with spectacular races for spectators and medias. Exciting for me as runner-because only one person can affect my final result: me.

I also believe that increasing start interval is not a problem even if the competition in question is to be sent on TV. In most finals (WC and so) the best runners start at the end, either because of qualifications or some kind of seeding. Thus for the TV-companies it doesn't matter if the first runner starts at 9.00 or 10.00 when they know that the best ones are starting between 11 and 12.

It is good method for training but not for the competition. Competition would take to much time.

6.3 Long route choices / Optimized course characteristics

6.3.1 Description of method

The course characteristics – i.e. optimal leg length and characteristics in different parts of the course and type of terrain/orienteering in different parts of the course – contribute significantly to the properties a course has with respect to spreading. Some constraints are given by the terrain, but the coursesetter still has possibilities to influence strongly on the spreading properties of the course. Long route choice legs reduce the chances that runner come together. Runners have the possibility of passing each other without coming in contact. On the other hand, long route choice legs do not appear to separate runners that have come together. Often it is difficult for a runner to judge small differences between the route choices. The advantage of being together with other runner will often more than compensate for the 20 seconds that can be gained by a better route choice.

Short legs generally lead to increased probability for groups forming due to (1) more mistakes being made when approaching a controls and (2) due to orienteers generally reducing the speed when approaching a control – making it easier for a runner from behind to catch up by running on the other runners back.

6.3.2 Analysis of method

It is evident that more route choices will give better spreading. Thus for optimal spreading, there should be many different options (micro-route choices) on the long leg. This, however, also often depends on the terrain. The chances of two runners who decide independently taking the same route choice will be inversely proportional to the number of route choices. $P = 1/N$. Route choice legs typically involves choice between runnable fast tracks. For runners to catch up there must thus be a substantial difference in running speed. From calculations of the error-free time at WOC 2006, we see that there is 10% difference between the fastest and slowest among the top 25. If we assume a running speed of 3 min/km on good paths this gives a difference of 18 seconds pr. km. To close the start interval of 120 seconds the best runner will need more than six kilometers. Even if we take the difference between the slowest and fastest which were 30% the faster will still need 2 km to catch up (and in this case it is very doubtful whether the slower runner will be able to hang on).

If we assume that runners are alone when they are 12 seconds behind or in front of another (probably a low estimate) we see it takes 24 seconds to pass a runner. Micro-route choices that take less than 24 seconds will thus do little to separate the runners. With 3% difference in running speed and about 3 min/km for good tracks, this means that micro-route choices of less than 450 m does little to separate the runners.

Short technical legs increase the chance for mistakes, which generally increases the chances that groups form. However, in some parts of the course (i.e. within certain spreading methods like the wings of butterflies [cf. section 6.4] and phi-loops [cf. section 6.5]), this is a desired effect. to separate H-groups

Experience tells that there should not be too many consecutive short legs, particularly not in the beginning of the course. Long legs also mean fewer controls, which also mean fewer mistakes in the vicinity of the controls and a smaller chance of catching up.

6.3.3 Examples

Long legs are used in (almost) all Long Distance races, but they do not work as well as a spreading method in all competitions. For example, in WOC 2005 in Japan (see map in appendix), the long legs did not work well as a spreading method due to:

- The runners were already together in large packs before the long legs due to many mistakes on the short legs with difficult orienteering in the start of the course
- There were not many micro-route-choices – only a few major route choices. Thus, there was a larger chance runners would meet each other during the long leg.

In WOC 2006 in Denmark (see map in appendix), the long legs worked much better as a spreading method (or a method which made grouping less evident). This is possibly due to significantly more different micro-route choices on the leg, making it much less probable that two runners would see each other on a leg.

Consider the two following cases:

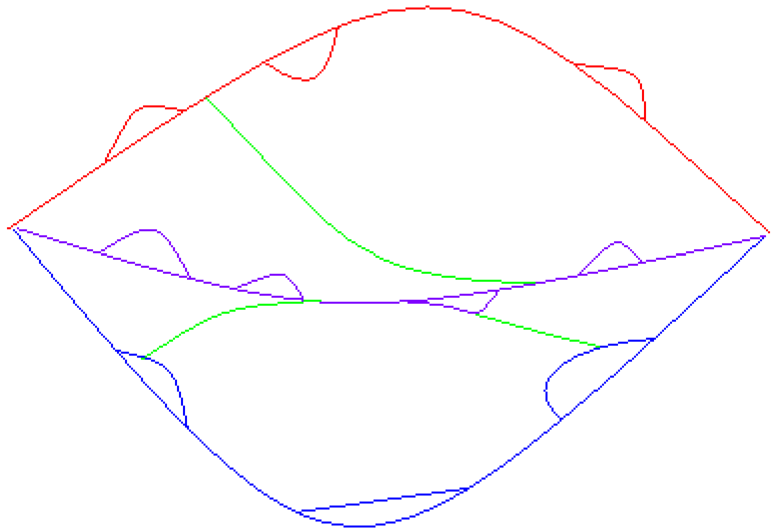

Figure 16.

1. When analyzing route choices, runners have chosen 3 different routes (red, violet and blue)
2. When analyzing route choices, runners have chosen 32 different routes (considering all minor differences for the three major choices)
3. When analyzing route choices, runners have chosen 7 route choices (red, violet and blue + combining them via the green)

Case 1 has few route choices so it is relatively likely that runners will choose the same.
Case 2 has seemingly many route choices, but the micro-route choices are so similar that they will not separate the runners. Taking a better micro-route choice will only give gain of a few seconds, and thus not separate them in the long run (on the other hand they have at least to some extent oriented independently during the leg, so some is gained). These micro-route choices have to be long enough to actually spread the runners. As we have seen, this means that there should be at least 20 seconds in running speed between the alternatives for them to have any effect. Adding too many nearly equal micro-route choices will make the decision more difficult and may actually promote following. The runner can decide for himself what is best, but relies on the judgment of a runner that is perceived as better.
In case 3 we have tried to strike the balance with enough route choices to separate the runners, but not so many options that the choice becomes impossible. The Swedish course planner hand book has argued that runners rarely take the more extreme route choices. If they are unsure they will take the route choice they expect the other runners to take. As long as you don’t take a poorer route choice than your competitors you will not loose time relative to them. Taking an extreme route choice involves the risk that you are making a choice that few others do and actually loose time.

6.3.4 Runners comments

This modification was not specifically mentioned in the questionnaire. But a few mentioned it under other comments.

The classic one: - Legs with route choices in the beginning of the course (both on macro and micro level). But include this kind of legs in the later parts of the course as a measure for spreading runners.

Few short legs (because of the advantage in following: it is more difficult to get away because of no route macro/micro route choices, plus the reduction in speed that the extra navigation that is necessary when attacking a control - more controls, more intense map-reading, decreased speed, easier to follow. The follower doesn't need to navigate the last meters if he sees a runner ahead, and he can skip to check code/control description.

6.4 Butterflies

6.4.1 Description of method

The philosophy has traditionally been that there is a good orienteer navigating and a poor orienteer following behind. Thus the problem has been regarded as solved as soon as those two runners have been separated. In modern elite orienteering the problem is more of co-working. There are two nearly equally good orienteers that both benefit from being together with each other. As they are of equal ability they will also have more or less the same time through short butterfly loops.

Butterflies usually consist of two short loops. The same control is used for the first and last control in the butterfly as well as once in the middle. The runners run the two loops in different order. The butterfly may be extended to three or four loops – and the length of the loops can also be varied.

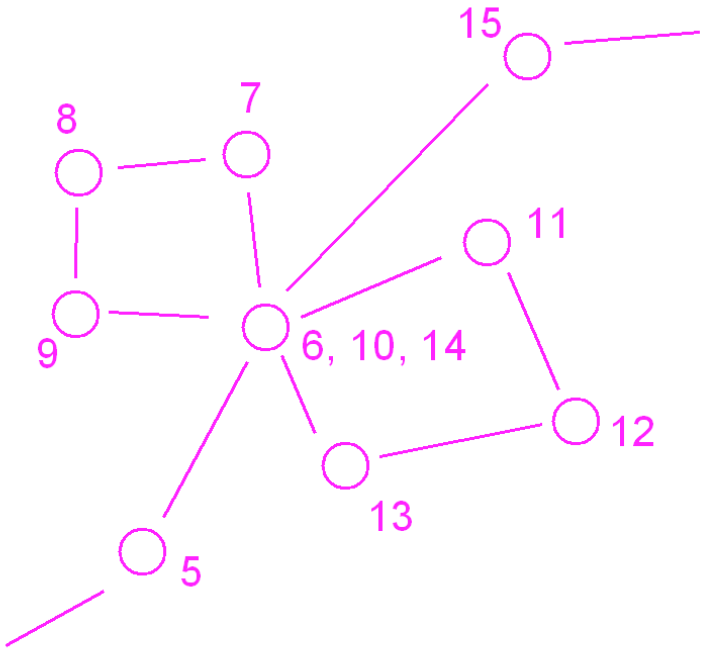

Figure 17.

6.4.2 Analysis of method

Butterflies, like other methods of separating runners, must be long enough to achieve the goal. In the same way as many short technical legs will cause groups of runners, short butterfly loops will also cause groups of runners. Butterfly loops will typically mean six to eight short legs in a row.

Too long butterfly loops might introduce other unfairness. The runners will meet the technical problems at different stages of the course. Long butterflies will also "steal" much of the total course length, and can be difficult to combine with good long distance course. There is little distance left for the long route choice lengths.

One problem with butterflies which decreases their value as a spreading method, is the sharp angles between the legs. Considering the example in figure 17, a runner approaching control 14 will see runners coming from control number 5 and possibly also from control number 9 before seeing the control – contributing to higher running speed. In some cases, runners from both wings have been approaching the common control from approximately the same direction (e.g. WOC 2004 long distance men, see map in separate part) or runners from the wings approach the common control from nearly the same direction as runners leave the butterflies (e.g. WOC 2006 long distance).

Experience indicates that the two wings of the butterfly should be of unequal length, so the runners will not meet halfway through (it does not directly help the runners to meet halfway through except that they might see the control due to another person being at the control. The reason for unequal length being advantageous must be because unequal length gives one longer wing which can give more varied orienteering – or the reason must be on a mental level?). Half a start interval difference should be the optimum. The aim of the butterfly is to separate runners and ensure independent navigation. As it takes some time for runners to get together the butterfly should not be too early in the race. On the other hand there should also be a reasonable part of the course after the butterfly, so the runners have to navigate independently towards the end of the course, too. For the classic course with individual start 45-50 minutes running before the butterfly and 25-30 minutes after seems to be a reasonable balance.

As discussed in section 5.5 above, short technical legs increase the chance for mistakes, which increases the chances that runners come together if they are used outside of butterflies. However, in a butterfly wing, short technical legs can aid in **separating runners in H-packs,** as the time spent in the butterflies will vary. They will however increase the chances that new packs form. Splitting of existing packs is however more important.

Completely generalised, the separating method is a part of the course where two (or possibly more) runners are forced to navigate independently. The idea is that the fastest runner should exit from the separating method first. The weakest runner should be sufficiently far behind so he can't catch up.

We consider two runners. The weakest runner gain x more than the strongest by running together. To separate them there should be at least 20 seconds between them at the end of the separating method. (20 second is the minimum from our analysis in 5.1.).

The time through the separating bit of the course is l_{sep}/v, where l_{sep} is the length of the separating method, and v the running speed.

$\Delta t = l_{sep}/v_1 - l_{sep}/v_2 = [(v_2-v_1)/(v_1v_2)]\ l_{sep} = [x/(1+x)]\ l_{sep}/v_1$. Where v_1 and v_2 are the running speeds of the two runners, $x = v_2/v_1-1$, e.g. how much more runner 2 will gain. Δt is the time difference through the loop.

The running speed varies much from terrain to terrain. But generally we will have for a long distance $v = L/90$ min, where L is the course length and 90 mins the winning time according to the rules.

We want $\Delta t > 20$ sec or 1/3 min.

1/3 min $= \Delta t > [x/(1+x)]\ l_{sep}/v_1 = [x/(1+x)]$ 90min l_{sep}/L, here we have inserted L/90 min for v1.

Assuming x = 0.03, e.g. runner 2 gains 3% more by being together than runner 1 does, we find

$l_{lsep}/L > 0.12$, in other words, for a separating method to be effective in separating the runners it should be at least one eight of the total course length. If we increase the wanted separation to 30 seconds, the loops should be one fifth of the course. (Interestingly if we consider this for the middle distance with winning times of 35 minutes the separating should be about one half of the course length.)

This analysis is valid for all separating systems where the runners navigate through the separation method at something close to their normal running speed, e.g. 6.3, 6.4. 6.7 and 6.10. Micr-o (6.8), macr-o (6.9) and dead running (6.11) all force the runners apart by some extra running.

We see from this that it will be very difficult to device a separation method for the middle distance races. On the other hand, for the middle distance races the winning times are so short that bunching of runners is less of a problem and rarely influences the top six places.

It has often been assumed that the weaker runner will make more mistakes during the butterfly, and that this will break up the group. The effect difference frequencies of mistakes have on the separation is calculated in 6.8.2 (Micr-o). Micr-o uses a fixed penalty of 20-30 seconds pr. mistake, and in real life the mistakes will vary in length. However, the around 20 seconds seems to be a reasonable average. Thus as shown in 6.8.2 the probability of the weaker runner coming out of the butterfly so far behind that he cannot catch-up is rather low (22%). There is also a fair probability that the weaker runner will actually finish the butterfly first (17%).

6.4.3 Examples

Butterflies have been applied in many events – and have been the "standard" in the Orienteering Championships the last years. Some examples of competitions where butterflies have been applied:

- WOC 2001
- WOC 2003
- WOC 2004
- WOC 2006
- WOC 2009 (men only)

The length of the butterflies has varied significantly. For example, in WOC 2006 the butterflies where so short that you could hardly see the lines between the controls (see map example in appendix). This was due to the course planner not wanting to include butterflies, but being forces by the IOF/controller to include them.

6.4.4 Analysis of spreading effect in real-life examples

EOC 2008.
Women Long Final.
The butterfly was relatively early (control 6-10 of 25). Still 9 groups had formed (one additional pair of runners were together at the control before the butterfly). Six of the 9 (10) were together midway through the butterfly. Five groups were together after the complete butterfly, and of these two had acquired a new member. One (two) groups reformed after one additional control. One new group also formed immediately after the butterfly.

Of the five groups together after the butterfly, three split later. One (two) of the groups that formed at one additional control also split later in the course.
For the women the butterfly has no better effect than the rest of the course.

Men Long Final
There were seven groups before the butterfly. Six of them split during the butterfly. Two of the groups that split re-formed after one additional control. There were also four additional groups that formed. Nine groups formed after the butterfly, four of them split again. **For the men the butterfly has no better effect than the rest of the course.**

WOC 2004
Women Long final.
The butterfly was after approximately 60% of the course. There were nine pairs/groups into the butterfly. Six of those existed after the butterfly, but half of these split later in the course. Four new groups formed through the butterfly. Three groups formed and split again before the butterfly. As the butterfly makes up a rather short distance it seems slightly better than the rest of the course on a pr. kilometre basis. On the other hand on a pr. control (or maybe better pr. leg) basis it is less efficient than the rest of the course.

Men Long Final
There were seven pair/groups in to the butterfly, four of these split. On the other hand three new groups also formed. Of the six groups that left the butterfly five split later on the course.

Four groups formed and split again before the butterfly.
The butterfly does not seem to be any more efficient than the rest of the course.

WOC 2006.
Women Long Final
There were eight groups entering the butterfly, three of them split while five remained after the butterfly, and one new formed. Three groups formed and split before the butterfly.

Men Long Final
There were four groups entering the butterfly, three of them split while one remained after the butterfly, and one new formed. Four groups formed and split before the butterfly.

Relatively few groups formed, and the short butterflies had little effect.

Other events like WOC 2001, WOC 2003 and WOC 2006 also show approximately the same number of groups before and after the butterfly.

6.4.5 Runners comments

Two butterfly loops are ok if the terrain is especially technical (so that finding the centre control from different angles is different).

The best are not really spread, if they arrive at the same time into the butterfly. But weaker runners are usually dropped.

Butterflies and phi-loops are good friends with competitors and organisers alike. If you have smaller really technical areas in the terrain, the usage of these two systems makes it much more enjoyable for the competitors to run. You don't have that many crossings and it can look very natural also.
It is also fun for the runners to have a butterfly in a classical distance.

Two strong runners running together will meet each other again

Going three times to the same control is not any more so challenging.

Works well if long and technical (challenging) loops are used. But unfair for last starters, since there will be fewer runners in the forest (none) for the last loop.

Not so interesting as an orienteer to run several times to the same control.

There can be some groups of runners appearing during butterflies. I have seen several times that runners actually got together in the butterfly loops, instead of being separated.

Another drawback of butterflies is that they "destroy" a classical course, especially in the women’s' class, by splitting up the whole course and not allowing for real long legs (this is a smaller problem in the men’s class, as they have longer courses).

Easy for runners to understand the concept (requires little information in the bulletin)

The running speed is dramatically reduced and then the runners bunch together, not least visually in the forest. Once you can see a runner it is easy to catch up. In a butterfly it is “control picking” and it is difficult to gain or keep your back free in a situation with control picking.

It seldom leads to more spreading. It is usually too late in the race, or used only once. The loops are often too short to spread, too similar in length, and can lead to more following as one can run one loop with runners starting 1-2 numbers ahead or behind. (especially if the loops takes 3-5 minutes...)

Reducing quality of the course; fewer long/half-long legs, less interesting and challenging legs.

6.5 Phi-loops

6.5.1 Description of method

The loops are named after the Greek letter phi (ϕ) because they look somewhat like this letter. There are two controls that are visited twice. At the first the runners are sent different ways through the phi-loop. At the second they are sent out in the common last part of the course.

This method for separating the runners may involve one or two map exchanges in which case there is an additional “element of surprise” in the method (used at WOC 2007 long distance) – but may also be used without map exchange. For the case with map exchange(s), it requires more work for the organizers. As for butterflies it steals much of the total course length, and might make it more difficult to plan long, good route choice legs.

The runners does not approach any control more than twice. The Ultuna-method is a variation of this with one (or more) controls along the diagonal as well.

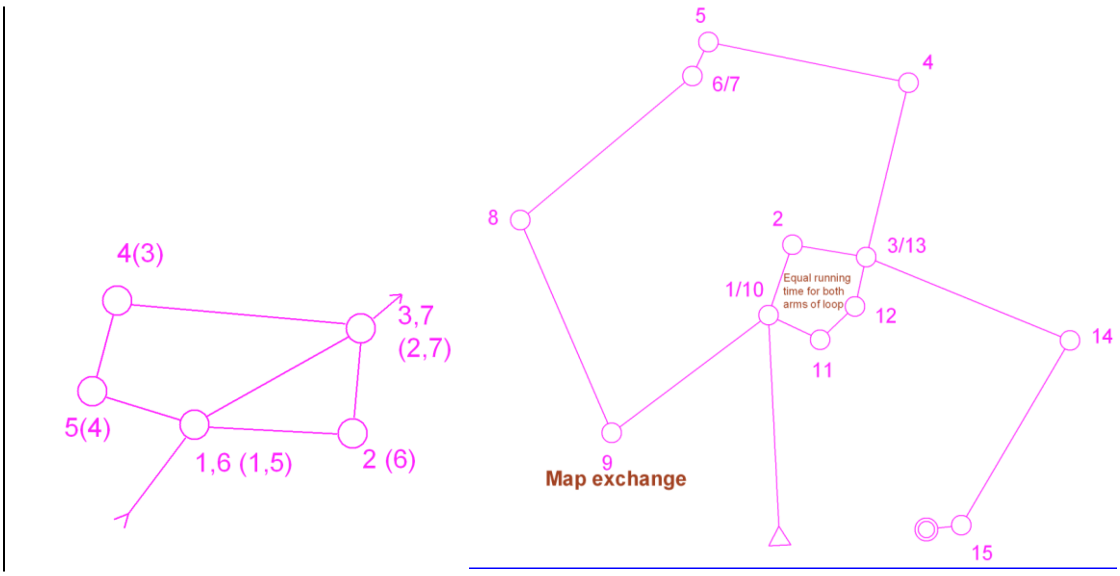

Figure 18. Two different variants of the phi-loop. To the left the normal phi-loop. To the right a special variant of the Ultuna-method were the diagonal is outside of the phi-loop. Map exchange could be on any control between control 3 and control 9, but would usually be on control 9 to keep the element of surprise as long as possible.

6.5.2 Analysis of method

The same considerations as for butterflies apply to the length of the phi-loop relative to the total length.

A special feature of the phi-loop method is the "element of surprise" which may be introduced by the fact that the runners can (in theory, but the course layout may tell something) never know if his/her next control is the same as another runner until after the map exchange. If more than one phi-loop is used in the course (i.e. a short second phi-loop towards the end of the course around the passing of a spectator control) and a course layout as shown to the right in Figure 18 is applied for the first part of the course, the "element of surprise" is extended to large parts of the course

This element of surprise may be introduced either by a normal phi-loop as shown to the left in figure 18 – or as a special variant of the Ultuna-method were the diagonal is outside of the phi-loop as shown to the left in figure 18. For the latter case, the "element of surprise" is extended to much larger parts of the course. The disadvantage is (1) potential unfairness due to some runners get the legs marked 1-3 early in the course – others late in the course and (2) you cannot compare split-times until after the phi-loops as runners have run different controls. Making running time for 1-3 and 10-13 as equal as possible – and also technical challenges and terrain as equal as possible, would address both these disadvantages.

On the other hand, if the running time for 1-3 and 10-13 differs by e.g. one fourth of the start interval (30 seconds for a 2 minute start interval), the probability for groups to form between control 3 and 10 would increase as effective start interval would be alternating between 1.30 and 2.30 – but the effectiveness of the spreading for 10-13 would increase significantly as there would be a time difference of 30 seconds built in to this part of the course. For a 3 minute start interval, this time difference between the legs of the phi-loop could be increased to 1 minute. The disadvantage here would be that you cannot compare split-times until after control 13. You could, however, in theory use extensive test-running to pre-calculate a time to be subtracted/added to the official splits published.

One advantage of phi loops compared to butterflies is that with phi-loops you reduce sharp angles – and thus it is more difficult to see other runners when approaching a control.

6.5.3 Examples

- WC-2005 race, UK (see map example in Appendix)
- WOC 2008 Long distance (see map example in Appendix)
- WOC 2009 Long distance women (no map example present)
- NOC 2009 Middle distance (no map example present)
- Norwegian night Champs Indre Østfold. 1999 mass start (no map example present)

6.5.4 Analysis of spreading effect in real-life examples

WC 2005 UK

Women

10 groups formed and split again before the phi-loop. Five additional groups formed and were together into the phi-loop. Two of those continued after the phi-loop. Of the three that split one reformed after three controls. One new group also formed through the phi-loop. Two groups formed after the phi-loop and one of them split again. The phi-loop was no more effective than the rest of the course.

Men

Six groups formed and split again before the phi-loop. Eight additional groups formed and were together into the phi-loop. Four of those continued after the phi-loop. Of the four that split two reformed after two controls. One new group also formed through the phi-loop. 11 groups formed after the phi-loop and seven of them split again. The phi-loop was no more effective than the rest of the course.

JWOC 2008

An interesting analysis has been performed where the runners have been split into two groups regarded as of “equal level” (e.g. E-groups) of “different level” (e.g. H-groups) dependent on their time before the phi-loop. If runners at equal level have the same loop they split up in 60% of the cases, if they have different loops they split up in 70% of the cases. In other words for runners at the same level the loop does hardly matter. For most senior championships there are qualification heats and runners coming together should thus be of nearly equal level. (Interestingly runners at the same level in the JWOC analysis will probably also include some groups were both are weak and should benefit from being together.)

If runners at different level have the same loop they split up in 35% of the cases, if they have different loops they split up in 71% of the cases. As we have pointed out most spreading methods are designed to split a weak and a good orienteer still we see that this fail in 1/3 to ¼ of the cases.

Our analysis show that 11 groups form and split again before the phi-loop. There are 10 groups that enter the phi-loop and five of those are split (one reforms again one control later), there are also two new groups that form. After the phi-loop another 12 groups form and four of these split before the finish.

6.5.5 Runners comments

Butterflies and phi-loops are good friends with competitors and organisers alike. If you have smaller really technical areas in the terrain, the usage of these two systems makes it much more enjoyable for the competitors to run. You don't have that many crossings and it can look very natural also.

Same as Butterflies but without three times the same control

Same consideration as for butterfly, but much better as spreading. This might be more difficult/more work for organizers/course setter, but on the other hand less obvious for the runners.

Better than ordinary butterflies, but mostly because the loops use to be longer.

6.6 Loops

6.6.1 Description of method

The simplest way of separating the runners is to let them run two or three loops, before a possible joint last loop. If the loops are in different part of the terrain the runners will easily discover who they are together with. If two loops are intervened it is more difficult to discover who you are together with. If three loops are intervened it is difficult to discover who you are together with, on the other hand the same terrain will be used thrice. This will not only be boring for the runners, it might also cause sporting unfairness. Two route choices might be fairly equal in the first loop, but it might on a later loop be an advantage to have chosen one of them that can be reused.

Loops limit how long route choice legs it is possible to plan. With more than three loops it is difficult to plan a good long distance course.

The effect of loops is to increase the time interval between runners. This effect disappears it the field of runners is too large. Runners with A as the first loop will then come together with runners with A as their second loop. Runners in both ends of the starting field will thus have less help from others than runners in the middle of the field.

Loops are much used for mass starts.

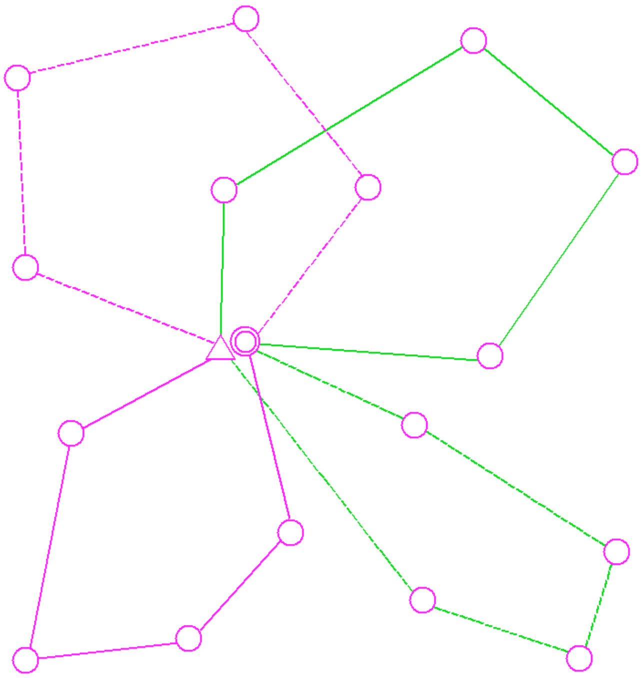

Figure 19.

6.6.2 Analysis of method

Simple loops and intervened loops can be treated as the same. We have N loops. These can be run in N! different ways. With N=3 we have six possibilities with N=4 we have 24 possibilities. However, in mass start event 1/N of the runners will have been together at any moment.

6.6.3 Examples

This spreading method has for example been used in:

- Norwegian Championships Ultralong 2008 (two loops. No map example)

6.6.4 Analysis of spreading effect in real-life examples

There were few groups formed during the Norwegian Ultralong distance championships.

6.6.5 Runners comments

The only problem with loops is that even though all runners do the same ones, one combination of the loops, say BAC, might be better than the other combinations. For instance, perhaps loop C is especially hilly and hence some people might prefer to have it at the end of the course, when their legs are warmed up, rather than right at the beginning. Or perhaps loop A is especially technical and again, it might be advantageous to start with one of the other loops to get a feel for the terrain before having to go into the really technical areas. Thus, the only completely fair way to set up a course is to have runners do all of the controls in the same order. But if the differences between the loops in terms of climb, technical difficulty, and distance is not too great, then it should not matter too much to elite orienteers which loops they do first.

It's really boring for a competitor. It means less long legs, probably easier areas near the finish, which makes a huge compromise for the course. Also a lot of extra running. You also need a good finish area.

Makes the race exciting but following is part of the game here.

For individual start, it is hard for runners, coaches and media to understand fully the situation during the races if some loops are shorter.

Loop can be easier without tiredness, or with knowledge of the area.

Because you can't go that far to the terrain it can reduce the quality of the competition. If there is under vegetation in one of the loops it could be better to have it late.

Not fair because it depends on who you come together with. Bad runners will easily get away with it. It only spread runners who have different loops!

Takes up a lot of space, giving fewer opportunities for good, difficult and interesting long/half-long legs

Often the same part of terrain is used.

Usually a lot of pure running through arena (marked route)

6.7 Forked loops and intervened loops

6.7.1 Description of method

The loops go through the same part of the terrain and have some common controls.

Forked loops make it more difficult to know which runners have the same controls, and that will also change several times during the race. On the other hand this variation incurs all the problems of intervened loops. This type of separating system is nearly always used for relays. Off course in this case each participant runs only one loop, and there is no problem of revisiting the same terrain.

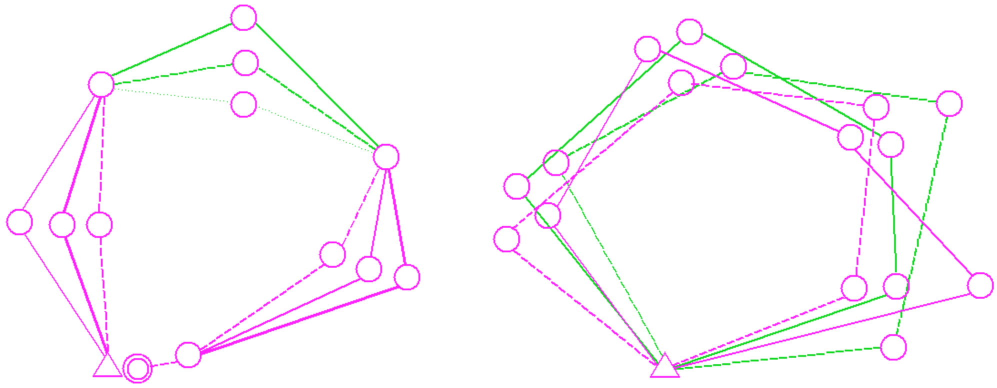

Figure 20. Forked loops to the left, intervened loops to the right. Intervened løøps can be regarded as and extremely simple version of the forked loops, where the different courses only are together at the start triangle.

6.7.2 Analysis of method

Every time the course split may be treated as a separate loop N is the number of courses. n is the number of times the courses split. There will then be $N!^n$ possibilities. Both N is typically 2-4,and n is typically2-4 for forked loops and 1 for intervened loops . We see that we rapidly get a large number of possibilities. However, in mass start event 1/N of the runners will have been together at any moment.

The method should be good at preventing following, but there will be plenty of runners to co-work with.

6.7.3 Examples

- Blodslitet (no map example)
- WC 2007 Sweden (no map example)

6.7.4 Analysis of spreading effect in real-life examples

Blodslitet uses three forked loops and then a long common loop toward the end. The experience from Blodslitet over the years is that there are normally fairly large groups during the last loop. Even if the runners have not seen each other earlier in the race the best often bunch up during the last loop. However, the weaker runners seem to be sorted away during the loops.

The world cup race in Sweden also seems to have worked well among the top runners according to the comments from runners in the various orienteering magazines. However, also here there were some groups during the last loop.

6.7.5 Runners comments

This is a good way to ensure that runners are always looking at their own maps rather than blindly following another to a wrong control, but it is clearly unfair! Although the controls might appear to be of the same difficulty level, this does not always hold in reality. So, all runners should have the same controls!

It gets boring in individual races because of turning cycles in same part of the terrain. Maybe best for relay or mass-start races.

Very good for relays but not for individual races.

It's really boring. You get to some of the controls 2-3 times, from the same direction. Once again it is a compromise with the courses.

Works quite well if there are lot of forking, but once more, but legs have to be quite the same (difficulty, lengths). If not, with a longer loop at the beginning, you'll get runners in front of you and we'll be more effective for the rest of the course.

Become really boring at the end.

Same as for loops, but better for spreading. (less obvious, more alternatives). But different lengths can also give more possibilities for running together (for example if one runner loose 1 minute on his first control one the first loop, and have the shortest forking, he can meet the leaders on the common control and possibly follow them on the next forking).

6.8 Partially forked loops

6.8.1 Description of method

This system was first introduced for the long distance during WOC 2007. Mostly there are two separate loops, but for a short stretch the two loops are forked together. A map exchange is required after the forking. The two forked branching are of unequal length, thus two runners going through the forked part will be separated by running a different distance. Unlike butterflies and phi-loops they will not have run the same distance when leaving the forking.

6.8.2 Analysis of method

Every time the course split may be treated as a separate loop N is the number of courses. n is the number of times the courses split. There will then be $N!^n$ possibilities. Both N and n are typically 2-4. We see that we rapidly get a large number of possibilities. However, in mass start event 1/N of the runners will have been together at any moment.

The method should be good at preventing following, but there will be plenty of runners to co-work with.

6.8.3 Examples

- WOC 2007 (see map example in appendix)

6.8.4 Analysis of spreading effect in real-life examples

WOC 2007
Women.
There were seven groups at the last control before the two loops. Five of these split, while two new groups formed. Two groups formed and split before the forking system. No additional groups formed on the last joint part of the course.

Men
There were five groups at the last control before the two loops. Four of these split, while one new group formed. Six groups formed and split before the forking system. One additional group formed on the last joint part of the course.

There seems to be little effect of the forking system. However, it is difficult to judge how well the method worked as there were very few groups entering the partially forked loops together, and the method has only been used once.

6.8.5 Runners comments

This modification was not specifically mentioned in the questionnaire.
From the spectator point of view this made the competition difficult to follow.

6.9 Micr-O

6.9.1 Description of method

Micr-o was developed to show orienteering on television. To high-light the navigation there are several false controls close to the correct one. To ensure that orienteering is still a running sport and that small navigational errors are not punished to harshly penalty loops instead of disqualification is used to punish runners that punch a wrong control in each group.

There are two ways of using the micr-o for creating separation. Either all the runners have the same correct controls, or the runners have different correct controls in each group of controls.

Experience is scarce, but it seems like the micr-o in itself separates little. It is the penalty loops that create the separation.

6.9.2 Analysis of method

The idea is to use micr-o controls to separate the runners. The strongest orienteer does fewest mistakes through the micr-o part of the course and ends up with fewest penalty loops. Thus the strongest runner gets away. The same analysis can be used for any separation method that relies on the runners to make errors to separate them (e.g. butterflies (6.3) or phi-loops (6.4). However, the calculations are easier for micr-o and macr-o where there is a fixed size of the mistake.

Let us consider a micr-o course with six controls. The strongest runner is one that finds 90% of all micr-o controls without mistake. The weakest is one that finds 80% of all micro controls with out mistakes.

The strongest runner will have fewest penalty loops 52% of the time. The weakest runner will have fewest 17% of the time, while they will have the same number of penalty loops 30% of the time.

	A strongest	B weakest			
	p=0.9	p=0.8			
6 controls					
p	0.9	0.8			
correct	0.1	0.2	equal	B best	A best
6	0.531441	0.262144	0.139314	0.12282993	0.39212693
5	0.354294	0.393216	0.139314	0.044930826	0.122103884
4	0.098415	0.24576	0.024186	0.003895296	0.009731275
3	0.01458	0.08192	0.001194	0.000104038	0.000247277
2	0.001215	0.01536	1.87E-05	8.448E-07	0.000001944
1	5.4E-05	0.001536	8.29E-08	1.536E-09	3.456E-09
0	1E-06	6.4E-05	6.4E-11		
			0.304028	**0.171760937**	**0.524211311**

Table 4. The chances of separating two runners of slightly different abilities through a micr-o-section.

It seems clear that micr-o orienteering is not terribly efficient at separating runners according to their ability. We have also looked at the “opposite” effect. How large is the chance that to runners of exactly the same ability will get exactly the same number of penalty loops? The results are shown graphically below.

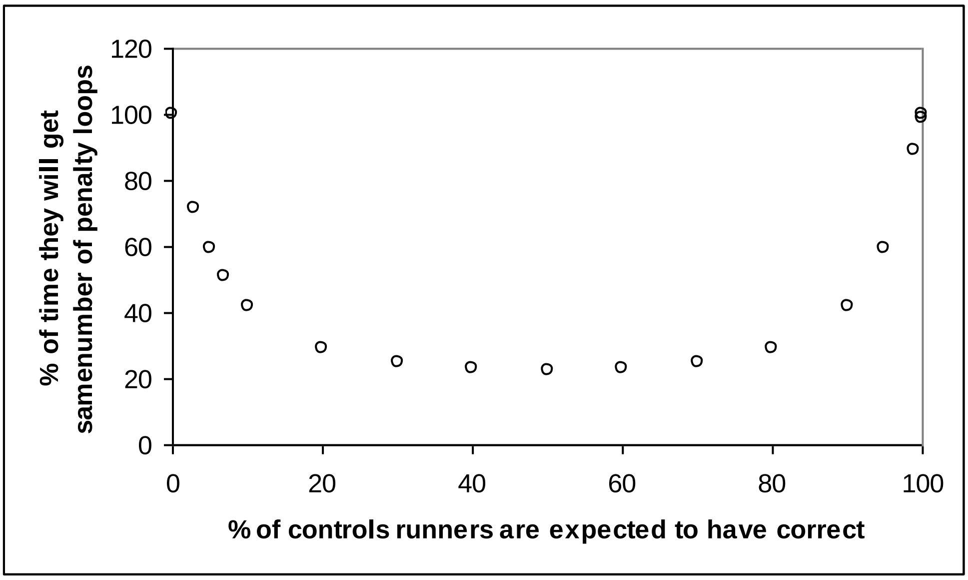

Figure 21. The effectiveness of micr-o as a function of the abilities of the runners.

We see that except for very good runners (who don't get any penalty loops, and will not be separated) or very poor runners (who get the maximum number of penalty loops and will not be separated), micr-o will most of the time give different number of penalty loops to runners of the same ability. Is this a fair way of separating the runners, or is it introduction of luck?

When the length of the penalty loop for micr-o was determined it was important to keep orienteering as a running sport. If the penalty loop was too long the runners would slow down too much to assure that they avoided the penalty. The penalty loop is thus relatively short, and close to a small normal mistake in orienteering.

Here we discuss ways to separate runners. The most effective will be that the weaker runner gets enough penalty loops to loose the runner in front but not enough to be caught by the runner behind.

The average error (and thus number of penalty loops) for a runner that gets 90% of the controls correct is 0.6 (with a most probable error of 0). For a runner that gets 80% of the controls perfect the average error is 1.2 (with a most probable error of 1). To separate the best runners it is thus fair to assume they receive one penalty loop. The penalty loop should thus be half the start interval for optimum separation. It could be an advantage to reduce it to 30 seconds. The punishment is still not large enough to loose the running aspect of our sport. It will also be possible to fit in two (or three) penalty loops before the next runner is likely to arrive.

Can a fair forking be created by the use of micr-o or macr-o (ref. section 6.10 for definition of macr-o)?

It has been suggested to use micr-o or macr-o as a forking system for individual competitions. Different runners will then have different controls in the cluster as their correct control. Is it possible to make these controls so equal that they will be fair (or more importantly perceived as fair)?

The system has been tested once during Norwegian Spring 2007 (macr-o).

We look at those data to check whether they are skewed.
The number of mistakes on a macr-o control will depend on several factors. How difficult is terrain, how correct is the map, how good are the runners and how many false controls are there?

We start by the null-hypothesis, that all the controls in the cluster are equally difficult. This will give us the overall probability of missing in this cluster, and correct for the factors above.

If there are more misses on one of the controls than on another we then need to calculate whether this difference in larger than we would expect by chance.

If we call p_m the chance of a mistake we will have $1-p_m$ as the chance of a correct control. If a total of N runners has this control as their correct control and a smaller number n of them making a mistake we will have

$(p_m)^n(1-p_m)^{(N-n)} \cdot N!/[n!(N-n)!]$ as the chance of a n mistakes among N runners.

For the control with most mistakes we want to calculate P_m which is the probability that the N runners will make n or more mistakes. In other word the probability that a group of N runners will do at least as bad as we see.

In a similar way will define P_c as the probability of a group of N' runners making n' or less mistakes on the control with least mistakes. (Notice that N and N' might be different as there is no need to assign the same correct control to an equal number of runners.)

Multiplying P_m with P_c we obtain the overall probability for (P) for a distribution of errors at least as skewed as the one we observe. The following are the data for the Norwegian Spring 2007.

Control	p_m	N	n	N'	n'	P_m	P_c	P
A	0.26	48	13	44	11	0.487	0.519	0.253
B	0.15	23	4	69	10	0.460	0.552	0.254
C	0.04	23	2	45	1	0.234	0.458	0.107
D	0.16	92	15	only one correct				
E	0.14	45	12	0	23	0.018	0.031	0.0006
F	0.15	24	7	68	7	0.057	0.181	0.010

Table 5. Checking for the fairness of the micr-o groups. Controls in groups E and F are unfair as the probability of such a skewed result is small.

We see that there is more than 25% chance that a result at least as skewed as the one observed will occur by chance at controls A and B. In other words we have no reason to believe they are unfair. There is about 10% chance for the result seen for control C, but the total number of mistakes is also very low.

Control E and F are clearly unfair. There is 1% or less chance for a result as skewed as this.

For the Norwegian middle distance championships 2006 micr-o was used, but with all runners in one class having the same correct control. However, W21 and M21 had different controls in most of the clusters.

For the two clusters where the two classes had the same controls the women had 79% correct on one and 70% on the other. In the men's class the numbers where the same but the men missed most on the control the women found easiest.

We thus conclude that the difference between the abilities of men and women (at least for this field) is 0 +/- 9%. This is in reasonable agreement that finds about the same number of mistakes among men and women.

We now look at the clusters where the men and women had different correct controls.

We calculate the difference in correct between men and women. The null-hypothesis is that the controls are equally difficult. We can thus check whether the observed result is more skewed than expected from chance.

Control	Women	Men	Diff.	80%	90%	95%
1	41	88	47	yes	yes	yes
2	79	70	-9	no	no	no
3	52	68	16	no	no	no
4	64	54	-10	no	no	no

5	70	79	9	no	no	no
6	97	73	24	yes	no	n9

Table 6. Checking for the fairness of the micr-o groups. Controls in clusterss 1 and possibly 6 are unfair as the probability of such a skewed result is small.

We see that there is more than 95% likelihood that the first cluster had controls with different difficulties. For control 6 there is a higher than 80% likelihood that the two controls within the cluster had different difficulties.

6.9.3 Examples

- NOM 2005 (see map example in appendix)
- Norwegian Champs 2006

6.9.4 Analysis of spreading effect in real-life examples

In most cases there is little effect of the micr-o itself. This is also as expected as this requires fine navigation which usually tends to slow the runners down, and make the formation of groups easier. In most cases there is some separation through the penalty loops. But in the examples used so far, these have been fairly short (~20 sec.) and thus not long enough to effectively separate the runners.

6.9.5 Runners comments

Micr-o is fine for sprint or ultra sprint events, but when doing classic or middle length courses, it seems very out of place. Also, I do not think that it would spread runners by more than a few seconds because if two runners are running together and come into the control circle, once one punches a control, it will put pressure on the other one to choose so that they can continue running together.

In my point of view, this is not really what orienteering should show on television. It is more like a gambling game.

Micro-O should never be used again. It disrupts the concentration of the runner, and therefor the runner does not get the same good (happy experience as when running a normal course

Orienteering must not be shown as a "walking-sports" in TV!
As you have the same course for everyone, it doesn't do any spreading at all. If it's not he same course for everyone, it can get really unfair.

It's pure fun

I find micr-o very unfair because the times I've tried it there were very unfair controls (such that controls placed into a shallow depression near each other where one had to guess exactly where the depression's flattest point is, etc.), and the whole micr-o part was transformed into bing-o.

Too many risky features but makes orienteering very enjoyable to watch...

Luck pays a high role here.

6.10 Macr-O

6.10.1 Description of method

In macr-o the micr-o concept is further developed to separate runners.

In this variation there is no change of map scale. Otherwise it is similar to micr-o

6.10.2 Analysis of method

The same theoretical considerations as for Micr-o apply.

6.10.3 Examples

- Norwegian Spring 2007
- Norwegian Champs relay 2007 (combined with normal forked loops).

6.10.4 Analysis of spreading effect in real-life examples

For Norwegian Spring 2007 it was mostly the penalty loops that separated the runners. More than one third of the runners came through without penalty loops, while another third had one penalty loop. The penalty loops were probably too short to give good separation. Some runners separated at the macr-o controls as they used a little extra time to avoid the penalty loops.

6.10.5 Runners comments

I've never tried, but my opinion is principally the same as for micro O. We find controls and have to work very precise for this. Then it's bad to have several wrong controls standing out in the forest.

I think, macr-o is generally OK, except that you most often expect the spreading of the runners after their control cards are checked...

Same as for micro, except that one can't just punch the same controls as the other, and no problem with the conversion between maps/scales. BUT still requires extremely precise and exact mapping which is impossible in 1:15000.

Not acceptable that runners don't run the same course (different controls/legs are always more difficult/easier or faster/slower than other).

6.11 Score O

6.11.1 Description of method

In the course there is a group of control which the runner can visit in any order. Sometimes all the controls have to be visited, sometimes only a fixed number of them. The effect is much the same as for long route choice legs. It prevents the runners from getting together, but it will probably not separate much when runners are together.

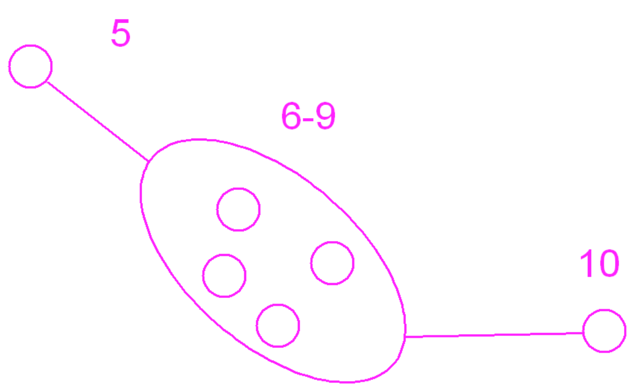

Figure 22.

6.11.2 Analysis of method

If there are N controls to be visited in any order there are N! (N faculty) theoretical possibilities.

If the runners are to visit n out of N controls there are N!/[n!(N-n)!] possible selection of controls to be visited. The n controls may be visited in n! possible ways. This leaves a total of N!/(N-n)! possibilities. Thus point of gives a seemingly large number of possible ways to visit the controls. With 4 controls there are already 24 different combinations. With 4 out of 6 controls there are 360 possible ways.

Mathematically the problem of finding the shortest distance through a number of fixed points is known as the travelling salesman problem. This is a problem that is extremely hard for computers to solve. In orienteering it is not only the distances that must be taken into account, but also runnability and climb, thus the problem becomes even harder. On the other hand humans are much better than computer in solving these kinds of problems. With 4-6 controls which are typically used there will in practise only be two or three sensible solutions to the problem.

The extreme variation of this forking method is score-orienteering. Even with 30-40 controls and 30-60 minutes running times there are only a few basic solutions to the problem.

6.11.3 Examples

This form has not been used in any major championships.

6.11.4 Analysis of spreading effect in real-life examples

This separation method has not been used in any high level competition, and can therefore not tell how efficient it has been.

6.11.5 Runners comments

If there are two elites running together and it is clear what the best order is to visit the controls in a given group, then they will both see it and run together anyway. If the best order is not clear, so that there are two or more good ways to visit the controls, then it is still advantageous for the two runners to choose one way and run together rather than to split up, so again they are together.

I have it only tried in a training. it is a good way to spread the runners but it is not fair. And fairness is the highest point in sports.

I don't really think this is a spreading method. It can spread the runners, but if I want to follow someone, I won't go to other controls...

This method doesn't change anything. If a runner wants to follow another one during the point-o section, they will stay together.

It is a bit off from the concept that every runner runs the same controls, same order (or attack point/direction)

Interesting but I do not think it should be a part of an elite race.

Controls need to be spread the way that there are more ways to visit them and it is not obvious which way to run.

Runners don't run the same course, not even the same areas, legs or direction

6.12 Dead running

6.12.1 Description of method

It has been suggested to include two running stretches of where the runners at the first get zero, one or two “penalty loops” at the first one. At the second the runners get two, one or zero “loops”. Total all runners have two loops. The loop should be approximately 30 seconds long.

Thus runners that are together are forced apart. Those that run 0 loops the first time run 2 loops the second time (thus all runners run 2 loops, e.g. 40 seconds dead running during the course). The system can separate three runners as described and can easily be extended to a higher number of runners.

The advantage of this system is that it will always separate the runners. It will separate 3 runners also (and can of course easily be extended to more runners if required).

Difference in length between two parts should be as close as possible to half of the start interval between runners.

There are alternative ways to do this delay with controls and fences. See attached images. Either a penalty loop like micr-o or the simple 2 controls on road - method. You can draw controls to map and use regular control descriptions without so big rule change.

The bad thing is you need to have video camera - Emit backup paper doesn’t work if you punch several times on same control.

Issues to be considered: How do you avoid, that the faster runner has the longer loop and catches up the slower in a short while and that it will take until the second running stretch to definitely separate them? What is with the map reading during the stretches, will it be allowed? Note that the spectators will not know the actual standings before all runners have run all loops.

6.12.2 Analysis of method

The idea is to separate runners. The most effective will be that one runner gets enough penalty to loose the runner in front but not enough to be caught by the runner behind. If only one loop is given the problem is simple. The loop should be half the start interval.

If three runners are to be separated (by 0, 1 and 2 loops) the length of the loop should be 1/3 of the start interval. (Generally with n runners, 1/n of the start interval). For a middle distance race 1/3 of the start interval amounts to 40 seconds. It will be difficult to separate more than three runners. For long distance with 3 minutes start interval n=4 gives 45 seconds.

6.12.3 Examples

This method has not been tested yet.

6.12.4 Runners comments

I have not tried this, but it seems rather unfair to me. It gives a big advantage to orienteers that are also very good runners.

Sounds like an interesting idea.

Unfair with 3 controls (nobody do the same).

No more useful than butterfly with only 2 controls.

If the difference is short, it is easy to have a group again.
Seems like an interesting way of spreading runners
Difficult for organizers. There can be mistakes.

It is too athletic.

Have no experience, but there is no reason why this is not fair and does not spread! Best way.

Gives possibilities for runners to catch up with those ahead or behind. If two runners have get spread (for example through different skills/level and good course setting), the runners can catch up after the first penalties.

7 What went wrong?

In some World class events there has been large groups forming. WOC 1993, 1997 and 2005, WC Switzerland 1996 and Sweden 2002 comes to mind. Is it possible to find a common theme?

We have found that groups mostly form when a (weaker) runner makes a mistake (near the control) and is overtaken by a stronger runner. We would thus expect any system that mixes weaker runners (which are more likely to make mistakes) with stronger runners (that make less mistakes) to prevent bunching. The World Cup races in Switzerland and Sweden were mass-start races so here the weaker and stronger runners obviously were mixed.

WOC 1993 (USA) was without qualification races. This implies that every nation had the right to one runner in each start group. This also means that there were a few weaker orienteers started in the last start group as also the weaker nations could put one of their runners in this group. Maybe more important for the formation of large groups it also meant that the stronger nations had one of their runners in an early start group with many weaker runners. It has also been examples of races with qualification heats where one of the pre-race favourites makes a relatively large mistake in the qualification, and then acts as a broom sweeping through the field in the final. The women's middle distance in WOC 2007 is one recent example. In the races mentioned above we would expect many of the groups to be H-groups.

WOC 1997 (Norway) took place in extremely detailed and difficult terrain, with rather rough ground. The start interval was reduced to 2 minutes for the first time. There were qualification races over similar terrain, using the same map. It is difficult to measure the difficulty by objective means, but the qualification races seem simpler than the finals. For this championship there were also only two qualification heats with 30 from each heat to the final. The course for the final had many controls (24 for the men) and many short legs.

WOC 2005 had the qualification race in a relatively simple terrain, while the organisers (like all other organisers) spared the most demanding terrain for the final. A simpler orienteering for the qualification race meant that some weaker runners could obtain a good start position in the finals. The final map contained many short legs in the beginning of the course.

In WOC 2001 (Finland) and 2004 (Sweden) the finals took part in detailed terrains, but without many groups forming. Here the qualification races were in equally difficult terrain, thus the weaker runners were already sorted out. In WOC 2006 (Denmark) and WOC 2007 (Ukraine) both the qualifications and (long) finals were in fairly simple terrain. Again there were few groups forming.

It should also been noted that NOC (Nordic Open Orienteering Championships) which uses a fairly strict ranking system for the start list have had no problem with large groups forming.

8 Discussion and comparison

8.1 Comparison of spreading methods

Table 7 below gives an overview of the separating methods discussed in section 6 above, including a brief listing of advantages and disadvantages of each method – and which race type the separating method is applicable to.

Method	Advantage	Disadvantage	Race type
Increased start interval	• Minimal change.	• Not spectator and TV-friendly.	Individual race

	• Reduces the chances of runners coming together.	• Does not separate runners that are together.	
Long route choice legs	• Reduces the chances of runners coming together. • Easy to plan. • Easy to follow for spectators and TV	• Does not separate runners that are together.	Individual race and mass start. Relays.
Butterflies	• Simple to implement. • Half the runners in each in a mass start. • Does not require a map exchange.	• Often seems to bunch runners together, rather than separating them • Requires much of the total distance. • Only separates two runners. • Individual start gives more runners in each loop in the middle of the field. • Easy for the runners to work out.	Individual and mass start.
Phi-loops	• Seems to separate well. • Half the runners in each in a mass start. • Runners do not know when they split.	• Requires two map exchanges. • Requires much of the total distance. • Only separates two runners. • Individual start gives more runners in each loop in the middle of the field. • Too short loops have the opposite effect.	Individual
Simple loops	• Easy to implement. • Half (or one third) of the runners in each in a mass start.	• Requires map exchange. • Makes it difficult to plan good long legs. • Individual start gives more runners in each loop in the middle of the field. • Easy for the runners to work out.	Mass starts.
Intervenedloops	• Relatively easy to implement. • Difficult for the runners to work out. • Half (or one third) of the runners in each in a mass start.	• Requires map exchange. • Makes it difficult to plan good long legs. • Uses the same terrain several times. • Short last loop seems to be an advantage	Mass starts and relays.
Forked loops	• Relatively easy to implement. • Impossible for the runners to work out. • Half (or one third) of the runners in each in a mass start.	• Requires map exchange. • Makes it difficult to plan good long legs. • Uses the same terrain several times. • Short last loop seems to be an advantage	Relays and mass starts.
Partially forked loops	• Relatively easy to implement.	• Requires map exchange. • Uses the same terrain several times. • Difficult to follow for TV and spectators.	Individual start
Micr-o	• TV friendly. • Easy to combine with long distance and middle distance.	• Requires map exchange. • Much work for organizers. • Requires extra mapping. • Does not separate runners.	
Forked Micr-o	• TV friendly. • Easy to combine with long distance and middle distance.	• Requires map exchange. • Requires extra mapping. • Different technical problems for individual races. • Much work for organizers.	
Macr-o	• Less work than micr-o. • No extra mapping. • Easy to combine with any distance. • Penalty loops might separate runners.	• Much work for organizers. • Lack of software solutions. • Does not separate runners.	
Forked Macr-o	• Less work than micr-o. • No extra mapping. • Easy to combine with any distance. • Penalty loops might separate runners	• Different technical problems for individual races • Much work for organizers. • Lack of software solutions.	
Score O	• Relatively easy to implement.	• Different technical problems? • Lack of software solutions. • Does not split runners that are together. • May be difficult to follow for TV and spectators	Individual and mass start
Score O (selection of controls)	• Relatively easy to implement. • Prevents runners from getting together.	• Different technical problems? • Lack of software solutions. • Does not split runners that are together. • May be difficult to follow for TV and spectators May be difficult to follow for TV and spectators	Individual and mass start
Dead running.	• Relatively easy to implement. • Forces runners that are together apart.	• More work for the organizer. • Different time to read the map. • Difficult to follow for TV and spectators	Individual

Table 7. A summary of the separating methods.

8.2 Discussion

Based on the analysis of the different spreading methods in the preceeding sections, it is clear that the different separating methods have their own strengths and weakness. It is not possible to include a complete discussion of the ideal spreading method for any given orienteering event, as the best spreading method should generally be chosen depending on the terrain, distance run, composition of the starting field, and the media interest and coverage. By outlining the strengths and weaknesses of each method, this work should help in that selection in the general case.

8.2.1 Constraints for the discussion

Instead of considering the general case,we should look at different types of events separately . Also, the following discussion concentrates on the long distance, as this is (1) the discipline for which the problem is most severe (ref. discussion about start intervals in section 6.1) and (2) the discipline for which a spreading method has been most often applied in the major championships.

Due to these constraints, the suggested measures below are more in line with the characteristics of the long distance than the middle/sprint distance. Thus, the below discussion is not valid for a middle distance race, and should not be adapted uncritically, as the overall layout of the course and the form of the spreading method suggested below is not directly compatible with the middle distance format.

Most of the problems with TV and spectator friendliness can probably be removed by careful placing of the separating method relative to where TV and spectators are situated, but this still has to be taking into account when choosing a separating method. The separating methods that create problems for TV and spectators will also cause problems for coaches, but again careful placing of the coaching zone can remove the problem.

8.2.2 Fairness

The minimum requirement of the spreading method should be to produce a correct result list for the medals – as this minimum requirement is important for more than 80% of the runners (ref. section 5.3) – and with a large degree of certainty also for the sponsors, media and sport financing bodies seen from a fairness perspective. A *target* for the spreading method should be to produce a correct result list for the top 10, as set forth in section 5.3.

Some of the spreading methods discussed in this report introduce a new aspect of unfairness. This unfairness must be weighed against the unfairness seen when the medals go to the "wrong" runners due to grouping. For example, runners getting part of the technical challenges at different times in the course might be less unfair than the advantage a runner can gain by being in a H-group for significant parts of the course..

8.2.3 Organisatorical measures: Start interval and Start order

In seven out of the last ten World Championships it has been possible to gain a medal if you started 2 minutes ahead of the winner and followed him (or her) to the finish (ref. section 6.1). Increasing the start interval to 3 minutes would reduce the number of instances to four. With a start interval of 2 minutes and a single instance of a spreading method splitting the field in two, there is actually no spreading method at all for runners starting 4 minutes apart. This was exemplified in WOC 2009 long distance in the men's category, where the runners winning gold and bronze were together before the butterflies, throughout the butterflies and after the butterflies.

Due to the obvious effectiveness of increasing the start interval to reduce grouping, the method should not simply be dismissed without considering its implications in depth. For example, the approach used in other sports – defining a larger start interval for the best part of the start field (ref section 6.1) – is one option that should be considered. This must not necessarily be a big disadvantage from a TV point of view based on how the production is planned (e.g. this could be compatible with a production concept where the first part of the transmission is recorded, and only the last part of the race is broadcasted as a live production).

The start order in the final does also have impact on the grouping (ref. section 7 for examples and discussion). Simpler orienteering for the long qualification race than for the long final may lead to "weaker" orienteers with a good qualification race obtaining a good start position in the finals. This is typically not a good situation (ref section 7). Thus, the qualification race should ideally not be significantly easier technically than the final.

8.2.4 Separating techniques

The state-of-the-art methods to avoid grouping during the last years are butterflies (cf. section 6.4) and the last years also phi-loops (cf. section 6.5). In addition course planners have had some focus on optimizing course characteristics (cf. section 6.3). The other separating methods discussed in section 6 do currently not seem to be able to replace butterflies / phi-loops for the WOC long distance, and therefore the discussion in the current section is focused on implementing the state-of-the-art spreading method in an optimal way rather than discussing the alternatives.

As discussed in sections 6.4, 6.5 and 7 above, there have been several non-ideal implementations of butterflies (and partly phi-loops) in previous world championships,

- Butterflies with sharp angles have let runners see other runners more easily and speed up – making them less worth as a spreading method. Some butterflies have even let runners aproaching the center control of the butterfly see runners leaving the butterfly. Phi-loops have less problems with sharp angles than butterflies.
- The butterflies have been too short. Short butterflies do not split packs – they only put constraints on the planning which again may lead to more packs due to less long legs and nothing gained by the butterflies.
- The butterflies/phi-loops have not always been implemented in the most tricky terrain. The weak runners in H-packs tend to increase the speed in the butterfly in order to be able to catch up with the better runners from the pack – the risk for them making mistakes if the orienteering is tricky in the spreading method is then increased. Also, low visibility in the area of the spreading method is an advantage..
- In some cases the butterflies/phi-loops have been followed by short legs instead of long legs – and in forest with good visibility. Continuing with a short leg after the butterfly increases the chance for regrouping of the same runners. One should ideally use a long leg straight after the spreading (butterfly or phi-loops), and if possibly there should be low visibility at the start of the long leg straight after the butterfly.
- In some cases the course has started with short technical controls – increasing the chances for grouping – followed by long legs. Long route choice legs are not good for splitting up groups which have already been formed – but rather are a tool to avoid groups to be formed. A course should start with long legs to avoid groups being formed early in the course.
- The terrain chosen for the long distance has not always been optimal with regard to avoiding groups to be formed. For optimal spreading, there should be different options on the long legs. This, however, also often depends on the terrain**.** This should be taken into account when choosing terrain for world orienteering championships and world cup races over the long distance.

Focus in the coming championships must be to avoid these "mistakes" of previous championships while developing the state-of-the-art of spreading methods further.

For the long term, the use of multiple loops as a spreading method might be an alternative way to proceed. Multiple loops potential for fair events even if packs are formed..Running together might not be that much of a problem if everybody spends approximately the same time in packs. So loop races where groups are forming and reforming – everyone runs sometimes alone sometimes together – can be regarded as fair. The disadvantage of this method that this family of methods introduces some changes in the characteristics of the long distance discipline (e.g. less long routechoice legs).

9 Conclusions

This report gives a thorough review of separating methods for orienteering, as well as methods for showing that runners are together.

Groups of runners mostly form when the runner in front makes a mistake, and is caught up. Most of the groups that form stay closely together, usually within 12-18 seconds of each other at many controls in a row. Groups are rather transient. They seem to form and split up again. We can divide groups into two different types: E-groups (two runners with approximate equal strength, typically defined as cooperation) and H-groups (one runner is clearly stronger than the other, typically defined as following).

The aim of the separation methods is to split up the groups. Separation of the H-groups is an easier task than E-groups and most methods devised so far have concentrated on thisFor the E-groups, the task is much harder, but methods exists as discussed in this report. However, these remedies might partly be difficult to pair with media interests and perceived fairness.

No separation method devised is really effective. It seems like the most efficient way of avoiding groups of runners is to have few, but long legs and keep the navigation simple. The long distance should have several long legs. This will prevent runners from coming together at the controls; it will thus reduce the number of groups forming. When qualification races are used they should be at least as difficult as the finals. Thus the weaker runners, that are more likely to make mistakes and be caught up, are sorted out before the finals. It is probably also these runners that will gain most by being in a group, and thus they might be less likely to split up again. InDifferent ways of separating have their own strengths and weakness. The best one should be chosen depending on the terrain, distance run, composition of the starting field, and the media interest and coverage. By outlining the strengths and weaknesses this work should help in that selection.

There is still room for experimentation with the phi-loop format (cf. discussion in section 6.5 above) – and thus different variants of the phi-loops should be explored in major competitions the coming years. Also, already when choosing the terrain for the long distance, issues regarding grouping should be one of the factors taken into account. Regarding the overall layout of the course, the course planner should try to follow the guidelines for course layout given in the discussion of this report.

Recommendations for different types of events

Local event and national events with little media interest:
The simplest remedy here is to increase the start interval. There is little extra work for the organizer. The number of runners is usually so small that the extra time used does not matter for the organizers

National championships and World Ranking Events with little media interest
Here the field will typically be relatively large, and too large to increase the start interval. Phi-loops, butterflies or partially forked loops can all be used. That intermediate times can not be compared directly is not major an issue for these events. The focus should be on finding the best orienteer.

International Championships without live TV coverage
Here the field will typically be relatively large, and too large to increase the start interval. It is important that the qualification races (if present) should be difficult enough to reduce the possibility of H-groups forming. If there is no qualification races a system with red group should be adopted.

Phi-loops, butterflies has little effect in separating E-groups, which are most likely to form in this case. The most efficient will be to increase the start interval. Loops or partially forked loops can be used, in addition. That intermediate times can not be compared directly is not a major issue for these events. The focus should be on finding the best orienteer.

National and International Championships with live TV coverage
These are obviously the most challenging. The overall competition should be relatively short with something happening “all the time”, thus the start interval can hardly be increased. To be easy to follow, intermediate times should be easy compare. Short phi-loops or butterflies could be positioned between camera positions. They would need to be fairly short.