Lane Difference Prediction Model

Feasibility study for quantification and
validation of the lane differences in rowing

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Challenge the future

Lane Difference Prediction Model
Feasibility study for quantification and validation of the lane differences for rowing
By

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Preface

Rowing and canoeing regattas are held outdoors on open water sports tracks. Boats race in fixed lanes which makes them depended on the varying local environmental conditions per lane. In contrary to most outdoors water sports like sailing, competitors are not permitted to change course to avoid unfavourable environmental conditions but are confined to their lanes. This problem is referred to as the problem of lane differences and is the subject of this study.

Rowing in unfair conditions damages the image of the rowing sport. It is unfair for athletes who put everything aside for winning a championship. But it can also harm the image of the sport in a comparable way to what doping did to cycling and match fixing did to football. As a consequence, the lane differences jeopardise the commercial interest of sponsors which are necessary for the funding of major rowing championships. For the sport of rowing it is therefore essential to assess, predict and act upon differences between lanes.

The Olympic Games of London showed the present threat of suspected lane differences. Many results were openly disputed by athletes and no clear defence could be given by the International Rowing Federation (FISA) to these allegations. With the Olympic Games of Rio de Janeiro coming up in 2016 it is important to take action.

Currently fairness is only assessed based on analysis of actual results which offers only a limited possibility to interfere when unfairness is expected. Moreover, it does not offer the possibility to foresee upcoming unfairness. The FISA has expressed its wish to develop a method to predict the lane differences before and during the rowing competitions so that the fairness committee can interfere sooner.

As an external advisor of the FISA I got the opportunity to analyse the problems from inside during the World Rowing Championship 2014 (WRC2014) at the Amsterdam Bosbaan. As a former match rower this further inspired me to write my master thesis on this topic. My goal is to contribute to a solid and well-funded discussion on how to solve the problem of lane differences by trying to prove feasibility of the desired prediction model.

Abstract

Problem Statement

Fairness in sport consists of many factors. Two categories appear in relation to these factors. In the first category, there are man-made rules and regulations which have an impact on fairness. Second category of factors is based on the other hand on external factors, namely the environmental conditions. Lane differences occur due to differences in wind, water flow and waves, in other words external factors which cannot be influenced nor mitigated by rules and regulations.

The environmental conditions also influence the rower in its stability and boat handling which can have a significant effects considering that rowers have a negative stability and use their oars and body weight to balance the boat in a way that is comparable to a cord walker. However in this study the scope is limited to the influence of the environmental conditions on the resistance of the rower only.

The problem of lane differences prevails itself in such a way that no study until now has been able to predict the magnitude of the lane difference to an extent that the conclusions were not subjected to assumptions that lead to debate. Although number of attempts were made to solve it by race result analysis, by modelling and by measuring, none have been satisfactory so far. According to the critics theoretical models lacked validation, measurements lacked refinement, calculations lacked accuracy and result analysis lacked significance.

This study will be the start of a larger project which should in the end lead to successfully being able to predict the expected lane difference. The role of this study in this perspective is to assess the feasibility of the construction of a lane difference prediction model before commencing a full scale construction and application.

The following research question (RQ) is therefore formed: <u>Can the Lane Differences on a Regatta Course be predicted based on a Validated Local Environmental Model?</u>

Approach

To answer the research question supportive sub questions (SQ) were formed based on a schematization of the research question (see Figure 1).

1. How can the theoretical model components of the Local Environmental Model best be acquired?
2. How can the Local Environmental Model best be validated with measurements?
3. How can the relationship between the Local Environmental Model and the Lane Difference Prediction Model best be established?
4. Can the Lane Difference Prediction Model be validated via a race result analysis?
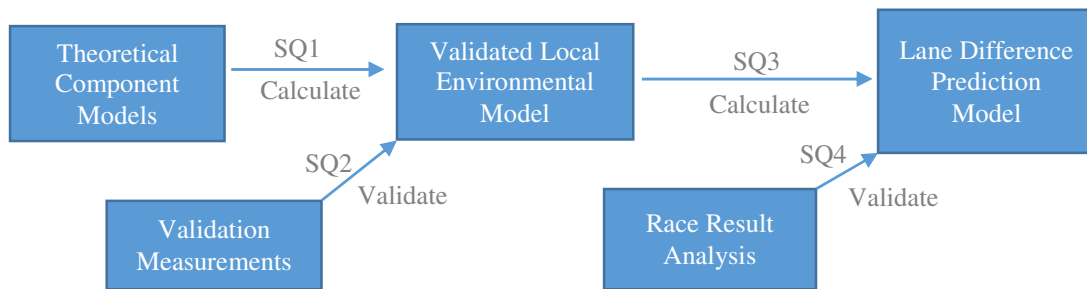
Figure 1: Schematic overview of the relations between the components of the research question and the sub questions

To be able to successfully answer the research question an approach of 'calculate and validate' was adopted for every step of the lane difference prediction process. An accuracy of 10% was arbitrarily choses as a limit for stating feasibility.

Two regatta courses were used for this feasibility study. The field study and problem analysis was conducted on the Amsterdam Bosbaan during the WRC2014 and the Rotterdam WAB served as an example location for the validation measurement set-up design.

An extensive analysis of related work formed the basis for answering SQ 1, 2 and 3. The magnitudes of the environmental conditions found in answering SQ 1 formed the start for the advised design of a validation measurement set-up under SQ 2 in combination with an assessment of possible measurement methods.

A Lane Difference Prediction Model (LDPM) was constructed based on results of SQ 3 which was used to assess the feasibility of accurate lane difference calculation and to analyse the potential sensitivity of its input variables.

No historical data is available on the combination of the weather conditions and lane differences. To be able to answer SQ 4 and to assess the feasibility of statistical race result analysis as validation for the calculated lane differences a simulation model was developed that can simulate rowing races under several fairness circumstances.

Conclusions

For both calculation and both validation steps, methods have been found which are likely to lead to sufficiently accurate results. Currently the accuracy of the individual calculation and validation steps is often above the chosen accuracy of 10%. Therefore a decisive feasibility for this approach cannot be established yet.

No extensive measurements nor extensive real race result analysis have been done within this study. Based on comparison between the outcomes of basic calculations and validation measurements it can be expected that accuracy will be improved in the future.

Inadequacy of a statistical approach for full scale assessment of the lane differences was concluded based on the simulations. Therefore it can be stated that currently predicting the lane differences based on a validated local environmental model is the only approach

available. It is advised to continue with this method even though full proof of accuracy was not established within this study.

Lastly, based on a basic analysis of the natural spread in race result in ratio to the expected lane differences predicted by the LDPM, it can be concluded that the lane differences are likely to be relevant to such an extent that they may actually determine the outcome of a race rather than only to influence them. It should therefore be concluded that predicting the lane difference based on validated local environmental models is not only the sole available option but it is also essential for the sports of rowing that it is put into practice.

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7 Conclusion and Recommendations

In order to reach a conclusion, the parts of the sub conclusions which contribute into answering the research question, will first be summarized within this chapter.

Sub questions

Sub question 1: How can the theoretical model components of the Local Environmental Model best be acquired? Over all it can be concluded that based on modelling alone, the accuracy of the outcomes would be insufficient. Validation measuring or sometimes even full scale measurements will be required for all component models.

- For wind: a full scale measurement campaign is advised over modelling alternatives when possible. The first main reason is the essence of correct wind velocities as a source for water flow and waves. Secondly, measuring the wind on a full scale is technically relatively basic and can be done with minor addition to the standard available equipment.

- For the water flow: a combination of CFD computations, mainly for flow pattern prediction and surface flow measurement for validation are expected to generate the best results. The main reason for this approach is the chance of occurrence of complex unexpected flow patters that migh be missed by measureing at a limited amount of points wereas the results of CFD computations alone give a to wide spread of results to achieve sufficient accuracy.

- For the waves: it can be concluded that use of universal empirical relations can give sufficiently accurate predictions as a concequence of the relatively simple geometry and sufficient water depth of the regatta courses. Which universal empirical relations is best to be applied can only be determined based on validation measurements on the regatta course.

Sub question 2: How can the Local Environmental Model best be validated with measurements?

Based on an assessment of the magnitude of the environmental conditions predicted by the models and an assessment of available measuring equipment it can be concluded that a feasible measurement set-up can be designed that should be able to measure the

expected environmental conditions. Extra attention should be given to the correct positioning in x, y and z direction to ensure correct values.

Sub question 3: <u>How can the relationship between the Local Environmental Model and the Lane Difference Prediction Model best be established?</u>

Based on the rowing balance a computer model is constructed to calculate the lane differences from the environmental conditions. The physical relations can be concluded as well-known thus the accuracy of this model is likely to be depended on the accuracy of its input variables. The variables can be split in two categories: environmental variables and crew chosen variables.

If the measurement set-up as advised under SQ 2 can validate the models as advised under SQ 1, it is likely that the variation of the environmental variables can be obtained sufficiently accurate.

Based on a study of the crew chosen variables, it is concluded that the expected spread in these variables is small. A usable and representative average can be calculated for different boat types based on towing tank tests and wind tunnel tests. If any gain can be accomplished by the crew by positively influencing these crew related variables, it should be considered as a successful choice of the crew which contributes to their success rather than a variable for which should be corrected.

Sub question 4: <u>Can the Lane Difference Prediction Model be validated via a race result analysis?</u> Based on a simulation of a 100 rowing tournaments with a 1000 races each it can be concluded that statistical analysis is possible but not in its current form. Several measures can be taken to improve the accuracy so that application for validation of the LDPM might become possible. However up to 10.000 races would still be required to predict lane differences with a high certainty for the full range of wind conditions. Race result analysis is therefore not likely to be an alternative for the direct calculations of the LDPM.

Research question
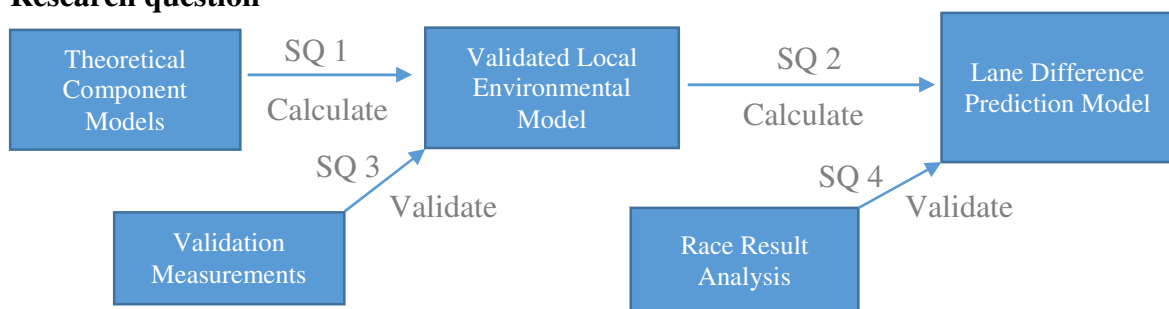
Based on the outcomes of the sub questions we answer the research question: <u>Can the Lane Differences on a Regatta Course be predicted based on a Validated Local Environmental Model?</u> For both calculation and both validation steps, methods have been found which are likely to lead to sufficiently accurate results. Currently the accuracy of the individual calculation and validation steps is often above the chosen accuracy of 10%. Therefore a decisive feasibility for this approach cannot be established yet.
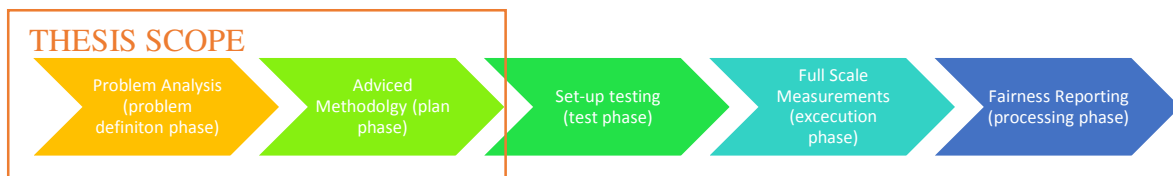
No extensive measurements nor extensive real race result analysis have been done within this study. Based on comparison between the outcomes of basic calculations and validation measurements it can be expected that accuracy will be improved in the future.

Considering that SQ 4 shows the inadequacy of the statistical approach to replace direct calculations via the LDPM it can be stated that currently predicting the lane differences based on a validated local environmental model is actually the only approach available.

Adding the sub conclusion of paragraph 5.4 that the lane differences are likely to be relevant to such an extent that they may actually determine the outcome of a race rather than only to influence them. It is advised to proceed the project with the evaluated approach even though complete feasibility cannot not be established yet.

Recommendations for further studies

THESIS SCOPE

Problem Analysis (problem definiton phase) → Adviced Methodolgy (plan phase) → Set-up testing (test phase) → Full Scale Measurements (excecution phase) → Fairness Reporting (processing phase)

The feasibility and the essence of the chosen approach have now been established, thus follow up work can commence to work towards the final goal of being able to predict the lane differences for the jury. Based on the work done within this study the following advices can be given for the steps to come.

Additions to the current study
- Even though the FISA does not acknowledge the effect of the waves on the stability of the rower as part of the lane differences it is advised to further study the magnitude of this effect. This might be combined with further study into the non-linear effects of the wave resistance on the resistance as well. Quantification of this effect might be done via comparing the lane differenced calculated with the LDPM and the lane differences found via statistical RRA as stated in paragraph 5.3. The gap between these two approaches can be accounted for as the effect of instability.
- Considering that no validation of the calculated methods can be achieved via RRA it is advised to further study the accuracy of the coefficients used for the LDPM.
- If no successful validation measurements of the predicted water flow and wind can be achieved, further research should be conducted on alternative solutions. Currently the options which are not evaluated but still offer great potential are for example GPS based floaters for the water flow measurements and the application of CFD for wind.
- Lastly it is advised to do a more extensive analysis of a large amount of rowing tournaments to find out if the spreads for the heats, finals, amateurs and world records hold up. With this further study it should also be investigated if the assumption of the Gaussian distribution holds and if not, which distribution best fits the result analysis.

Fairness reporting and advice
- Build-up and die-out time for the water flow and the waves have not been found within this study. To be able to successfully advice on lane difference mitigation this knowledge will be required. It is advised to investigate the options to acquire this information directly from the measurements as part of the permanent measurement set-up.
- The velocity of the wind is expected to be strongly fluctuating due to the presence of wind gusts. Currently no information is present about to which extend this might contribute to the lane differences as well as to the balance of the rowers.
- The fairness limit of 0.25% as set by FISA should be re-evaluated based on the knowledge gained in this study. Furthermore a discussion should be started about at which wave heights rowing should be postponed.
- Like the studies in the past the focus has been put on a limited amount of situations namely head, tail, cross and 45° wind angles. For the final advising all wind angles should be assessed to be able to advice under all circumstances.

Alternative approaches
- In its current form RRA is not a feasible alternative for the LDPM. Several potential improvements to RRA have not been fully investigated yet. It is advised to do a separate full statistical study into the potential improvements to be able to have a faster convergence to a decisive conclusion. A few ideas to such a study could be as follows:
    - Finding a solution for filter the human factor out of the lane difference analysis. The velocity development over the length of the course could be a measure for the human factor and all races which show a large inconsistency in velocity at the end of the race could be filtered out of the data set.
    - Investigating the potential of lane grouping.
- Secondly full scale measurements on the boats resistance could be considered. A test comparable to the methods applied in the early days of towing test could be used which consists of pulling an actual rowing boat with crew through the regatta course. Alternatively, running tests with electrically propelled catamarans that have comparable dimensions and characteristics as rowing boats seems to be an option as well.

Mitigating lane differences
Lastly some advice can be given on how to best mitigate the lane differences based on knowledge gained in this study:
- Shallower courses will reduce the round flow and make throwing more fair. The expectation is that the magnitude of the $LD_\%$ could decrease with up to 40%.
- Correcting the travel time afterwards is the simplest approach to correct for the lane difference. It can however lead to confusion with the spectators when the crew crossing the finish line first is in the end not announced as winner.
- Delayed starting signal is a better alternative but only if a good prediction of the expected average travel time of the race is known in advance. The starting systems of regatta courses have individual lights which could be adopted for implication of this method. The disadvantage is that it will become very complex

to asses which crew caused a false start and the recall of all crews is unfair to the crew that had already started. Time Delay would give the slower crews a significant mental advantage since they can see their opponents, due to their backwards orientation, whereas the faster crew who started later cannot. On top of that the crews that start later are rowing in the wave wake of the earlier started crews. In the case of strong head wind from an oblique angle the crews that started later might be advantaged when they are in the wind shade of their earlier started opponents.

- An alternative solution to time delay is correcting the differences by shifting the start pontoons back or forwards. This is currently done to assure all boats of different lengths to be aligned on their bows. With $LD_\%$ expected in the magnitude of more than 1% this would mean shifting the pontoons more than 20 meters. Considering the length difference between a 1x and an 8+ is roughly 10 meters, the current starting pontoons are too short and significant adjustments would have to be made.

- Compensating the lane differences with added weights in the boats is proven feasible. To compensate 1% of lane differences the crew would have to take about 6 kilos of additional weight to compensate. However, if this additional weight is placed strategically, it will contribute to the stability of a crew which would make it easier for this crew to row in comparison to others. This effect can be seen as an additional unfairness.

- A combination of the solutions as mentioned above is also possible however it is not advised considering that all the disadvantages are also combined.