University of Cape Town

STA5071Z: Simulation

CycleSim

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1 Introduction

CycleSim is a road cycling game used to emulate the role of a manager in a road cycling race. Various attributes of a rider are recorded such as energy, drafting coefficient, cooperation, power, position and number of fatigued riders. The results presented below are not meant to answer one specific question but instead are to be used as a method to select an appropriate strategy based on rider attributes at a specific time on some setting configuration. These results may be able to help inform the user on how to use the team and lead rider based on the configuration to strategically outmanoeuvre the adversaries.

This model was created on Netlogo and the results were obtained using the behaviour space tool available on Netlogo (Tisue and Wilensky, 1999). The results were analysed in R (R Core Team, 2023).

2 Sensitivity Analysis

Figure 1 is capable of depicting exactly how the configuration of parameters alters the final position of the lead rider.

While observing a Lead cooperation of 0 we see that a cyclist with average ability (average power), will place closer to pole position. A lead cooperation of 0 indicates that the cyclist is selfish, they do not take their turn leading the pack and very well may breakaway if they have sufficient speed. For the lowest power and at 0 cooperation, the cyclist tends to do better than a cyclist with greater power, although this difference is not very strong as the distribution indicates that they do place quite closely. This can be explained by how this cyclist will often not have enough speed to breakaway, so they will likely, sit-in and draft all the way to the finish. When they get to the finish they will have a sufficient amount of energy to outcycle those that have been breaking away. On the other end of the spectrum a cyclist with great power and 0 cooperation, places much further from pole. Here it's possible that the cyclist performs a breakaway most times they find themselves in the front, resulting in a greater loss of energy, they then continue to sit in the front as they attempt to draft, however, since they're close to the front they will attempt another breakaway very soon.

For a lead cooperation of 0.5, cyclists with average power and great power place much closer to pole position than cyclists with low power. This shows that if a rider has the power, they are able to easily use strategic breakaways and sit-ins to gain a better position and conserve energy. Whereas a cyclist with low power, even with strategy, struggles to place well.

Finally, for a cooperation of 1, strong cyclists dominate and tend to place very close to pole position. Although they are aiding their weaker counterparts, they do also conserve enough energy, enough to enable them to make a strong final breakaway.

Results in Figure 1 are actually relatively consistent with the findings by Hoenigman et al. (2011). Especially in the case of riders with more power, i.e. 7.5 and 8. What Hoenigman et al. (2011) found is riders with low power are better off not cooperating. Hoenigman et al. (2011) mentions that strong riders place much better if they cooperate. This paper also demonstrated how this is consistent with professional cycling behaviour.

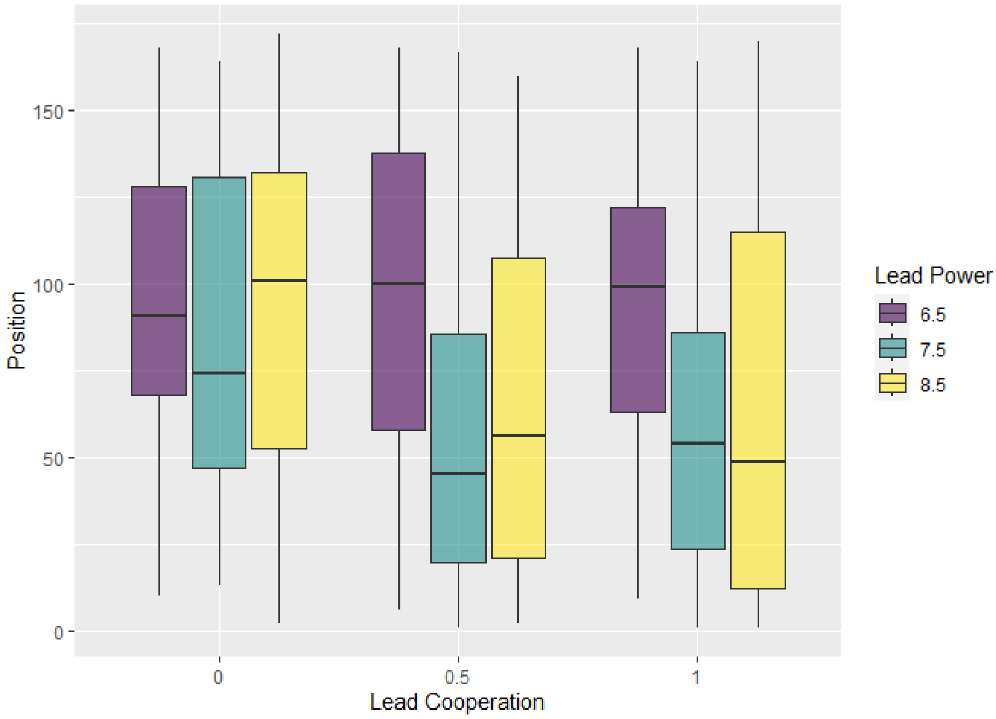

Figure 1: Sensitivity analysis looking at the lead cyclist's position in consideration to their cooperation and power

This sensitivity analysis, simply illustrates that for a winning strategy, if the user's cyclist is weak, tell them not to cooperate and to defect as much as possible. If a user's cyclist is strong, tell them to cooperate and defect as little as possible to maintain energy throughout the race.

3 Results

Table 1 illustrates a robust set of configurations selected from 81 different configurations that manage to explore the behaviour of the agents. These settings were each run 5 times to obtain a distribution of results. The average of this distribution was obtained for each group, resulting in a graph that seems to be a more stable representation of the change in attribute of the agents over time. Figure 2, Figure 3 and Figure 4 show this averaged longitudinal data for each configuration.

Table 1: Setting configuration for Figure 2, Figure 3 and Figure 4

Country List					
Setting #	Team Ability	Lead Power (W/kg)	Lead Coop	Lead Mass (kg)	Lead Energy (kJ)
9	Bad	6.5	0	63	720
11	Bad	6.5	1	63	720
15	Good	6.5	0	63	720
17	Good	6.5	1	63	720
63	Bad	8.5	0	63	720
65	Bad	8.5	1	63	720
69	Good	8.5	0	63	720
71	Good	8.5	1	63	720

3.1 Energy Considerations

Figure 2 illustrates energy expenditure over time. As mentioned above each of the settings were run 5 times and an average was taken for each setting in an attempt to obtain a more stable measure of expenditure over time.

For setting 9, we see that the lead cyclist maintains similar levels of energy as the rest of the group, same goes for the lead's team. As mentioned above, for a bad cyclist, it is in their best interest not to cooperate and that is exactly what the lead cyclist does here. This defecting nature results in a more maintained level of energy for a longer period of time. This result is consistent with what is expressed in the sensitivity analysis. The team being bad and generally uncooperative also demonstrates this behaviour in comparison to their adversaries. The same can be seen in setting 15, where the lead rider loses energy but is still able to recover over the rest of the race.

In settings 11 and 17, the lead cyclist still has low levels of power but decides to cooperate, which results in exhaustion very quickly. It is not advised to cooperate if you are a cyclist with low power.

Setting 63 and 69 are anomalies to the expected trend of the analysis. Cyclists have strong power, but they are also uncooperative. Where, previously, it was mentioned that cyclists that are strong benefit a lot more from cooperation than not. It is possible that Figure 3 may be able to explain why these anomalies arose.

The results of setting team ability interchange, which results in no concrete observation of how this plays into team energy expenditure. There are two cases where the team's energy expenditure is lower than that of the adversaries, and this is when the team's ability is set to good. The cooperation probability was selected randomly from a normal distribution with $\mu = 0.3$ and $\sigma = 0.3$, this would illustrate that more often than not, the cyclists will be uncooperative. However, not much can be said unless the actual cooperation probabilities are included.

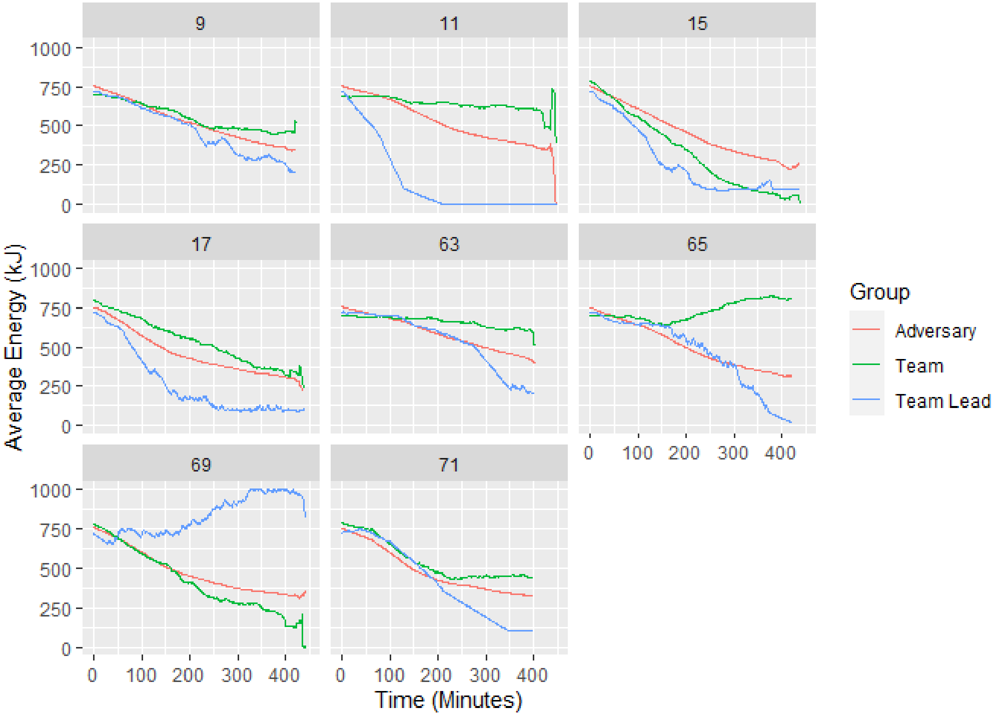

Figure 2: Energy expenditure over time in the race

Overall, the results found up till now seem to correlate with the findings of the sensitivity analysis.

3.2 Drafting Coefficient

Figure 3 illustrates cyclists drafting coefficient over time. As mentioned above each of the settings were run 5 times and an average was taken for each setting in an attempt to obtain a more stable measure of draft over time.

It was previously shown that not cooperating is an advisable strategy for cyclists who have poor power. In setting 9 of Figure 3 the reason for this is shown. When the cyclist refuses to take their turn leading the peloton, they find themselves drafting in someone else's slipstream. It is shown that the draft coefficient is rarely 1 until much closer to the end of the race, which indicates that the cyclist either refused to take their turn or actually never found their way to the front, which would explain the maintained energy for a long period as shown in Figure 2.

Settings 11 and 17 show that the cyclist is rarely drafting. This could either be a result of

In 11 and 17 we see that the cyclist barely drafts. In both cases the cyclists is cooperative. In 11 the lead cyclist has poor performance and as shown in Figure 2 they lose energy very quickly and almost never recover it. This may be due to their inability to maintain leading a pack with their weaker power, they may on the other hand have found themselves in no mans-land, where they are not close enough to the next rider to actually draft. On the other hand, although, in 17 the cyclist loses a lot of energy quickly, probably due to leading, they manage to gain it back as they are seen drafting later on in the race.

The anomaly that is setting 63 is clearly explained in Figure 3. It can be seen that this cyclist is drafting for most of the race, more than in any of the simulations explored. I would assume that this cyclist is good but that they started at the back of the peloton, so throughout the race, they are able to drift. This could explain how their non-cooperative nature actually benefited while they had strong power.

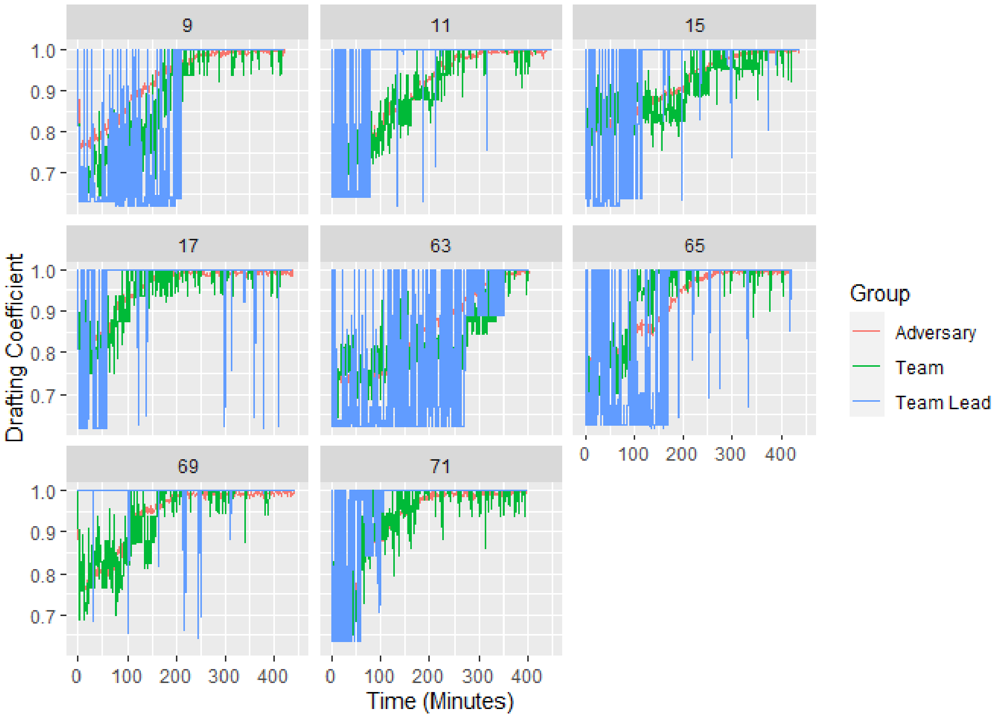

Figure 3: Drafting coefficient at each tick in the race, was the cyclist taking advantage of a slipstream?

3.3 Rider Fatigue

Figure 4, does not show as much detail as the previous two figures. Here we observe when cyclists start to fatigue in the race. In most races, it seems that regular fatigue started around the 100-minute mark and extreme fatigue occurred at the 200 minute mark of the race.

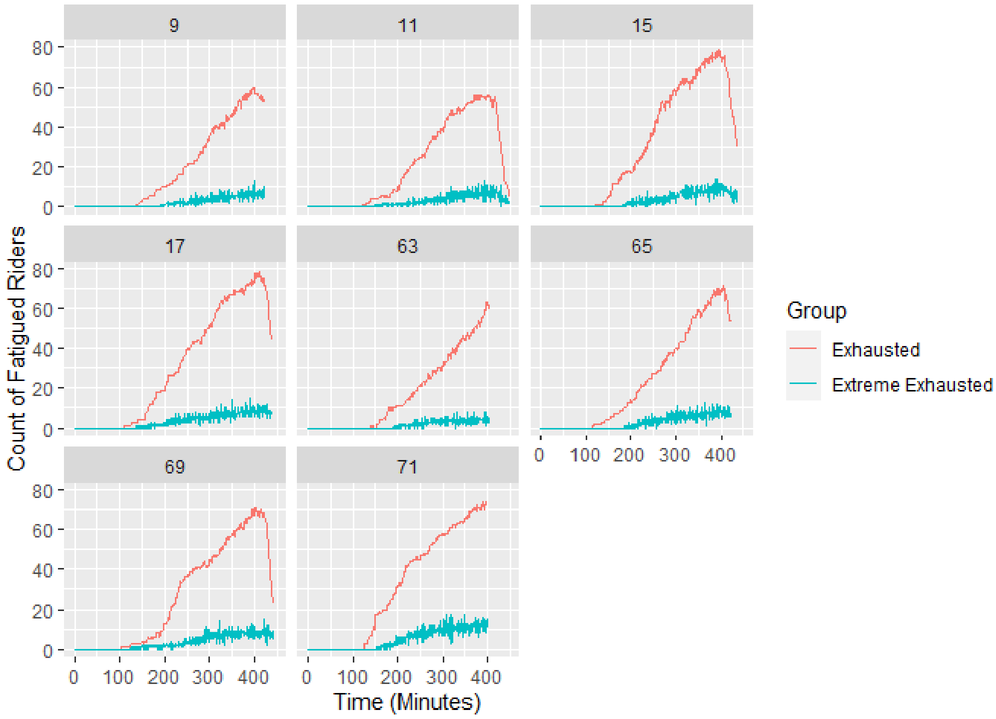

Figure 4: Count of fatigued cyclists over time

4 Discussion

The relevant information above is very important in forming adequate strategies in order to get a better final position for our lead cyclist,

1. Low power Vs Great power
   - If a cyclist has low power, it is advised that they not be cooperative. They will expend less energy by drifting and not become exhausted until much later.
   - If a cyclist has high power, it is advised that they cooperate. However, it may also be in their best interest to use strategic plays to defect or not depending on their situation. Cooperation ensures that they maintain sufficient energy to make a break at the end.

In the simulation, the user acts as a manager and issues commands to the team and the lead rider to get them into a more advantageous position. The user can make: the lead attack alone, the team block the peloton, the team attack, or make any member of the team bridge a gap. There are a number of strategies that I could think to implement based on the optimal settings described above.

For a weak cyclist who is not cooperating, it might be better to attack the peloton at the beginning of the race. This allows them to get into a good position and to spend the rest of the race recovering in the front. When they come to the final sprint, they may have just enough energy to win.

For a strong cyclist who is cooperating, it may be much better to attack when all the cyclists begin to get extremely exhausted. This would be a great moment to get ahead as they would have the energy to continue even after attacking.

If at some point our lead cyclist finds themself tired early on in the race, it would be advised to send the team to block the peloton so that the lead can have time to recover and to catch up to the front, even by just a little bit. That moment of recovery might just give the cyclist enough energy to make a final attack at the end.

References

Hoenigman, R., Bradley, E., and Lim, A. (2011). Cooperation in bike racing—when to work together and when to go it alone. *Complexity*, 17(2):39–44.

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Tisue, S. and Wilensky, U. (1999). Center for connected learning and computer-based modeling northwestern university, evanston, illinois. *NetLogo: A Simple Environment for Modeling Complexity, Citeseer.*

A Appendix

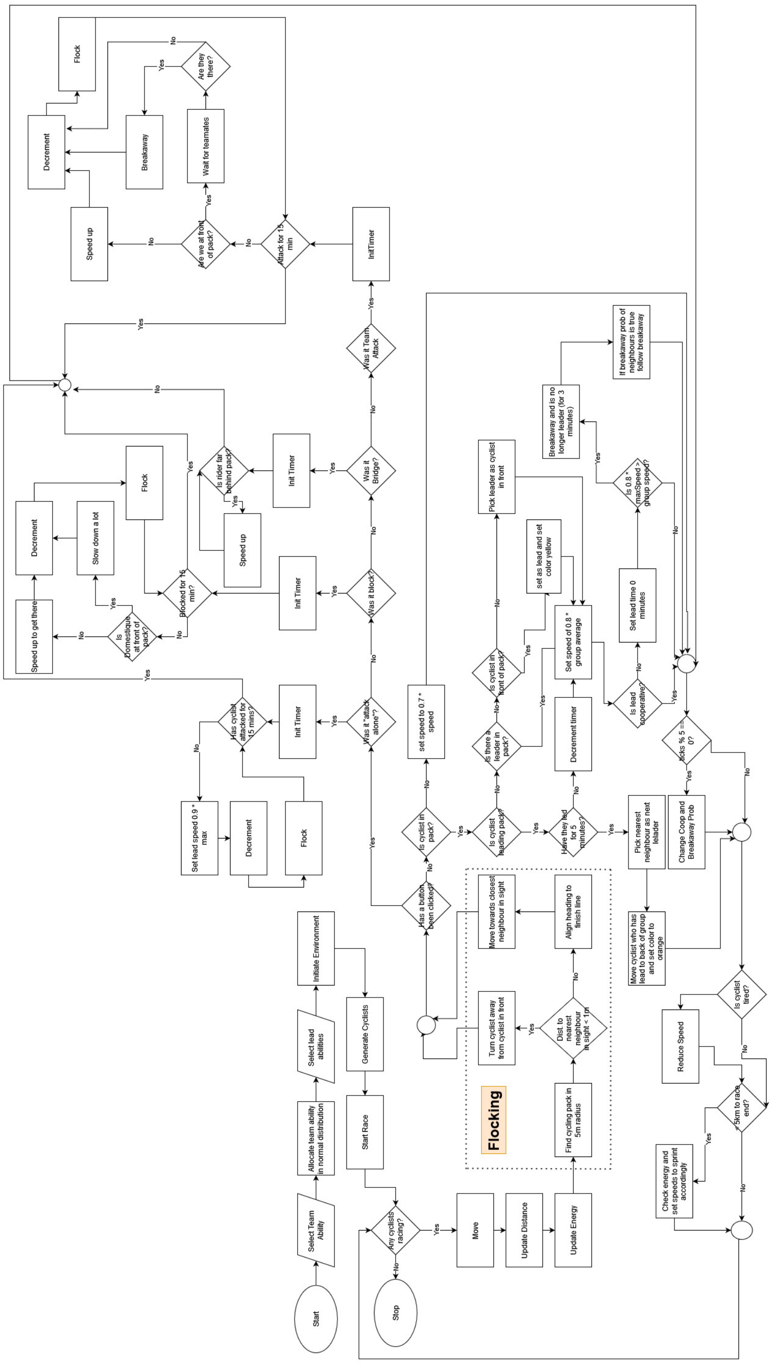

Figure 5: Flowchart of Cycling Process