Olympics Road Race: Group 8 Report

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Introduction

Our approach to developing different players was to implement a number of strategies for coaching a cycling team and analyze their performance during our own testing runs. The testing runs and strategy analysis were used to tune our player or influence the decision to move to new strategies.

Background

This project focuses on implementing a player that coaches an Olympic cycling team over the course of a race. One interesting physical constraint in this problem is the ability for a rider to benefit, conserve energy, by riding in the slipstream of a rider ahead of him. A rider immediately behind another rider uses up to 30% less energy than the rider in front who is potentially taking the full force of the wind resistance.

For our group the two main challenges of this game are:

1. Completing the race
2. Coordinating the team's riders such that they can finish the race as fast as possible

Medals are awarded to the first (5 points), second (3 points) and third (1 point) place riders only.

One observation about the structure of this problem is that a race can be divided into three phases, an initial phase, an "in-flight"/steady state phase and a "last-leg"/final phase. As we will cover later, there are strategies we came up with which we think are suitable for each of these phases.

Game simulator parameters

There are seven (7) parameters exposed by the simulator:

currTime	– the elapsed time in the race
numTeams	– the number of teams participating in a race
D	– the total length of the race
L	– the number of lanes on the course
R	– the number of riders per team
E	– the initial energy of each rider
TeamStatus	– information about the riders on your own or opposing teams

Basic Building blocks

Calculating the optimal speed

Picking an arbitrarily low speed would possibly allow the team to finish races of varying length however there is no absolute guarantee of finishing using arbitrary speeds. A better proposition is to calculate the best speed based on a function of the energy of a rider and the distance remaining in the race. During class discussions we developed a general formula based on E, D and R to calculate the maximum rider speed. This calculation is based on the maximum speed an individual rider can go at, taking all of the wind resistance, and finish the race without dying.

Maximum rider speed = (Energy left / Distance Left)^(2/3) (Eq.1)

This formula was later extended to consider the benefit of the energy conserved by drafting. The extension calculates a multiplier for the energy left based on energy conservation of up to 30% and plugging that value in as the Energy Left parameter in (Eq.1).

Energy multiplier = ∑ i = 0 to R (0.3^i) where R is the number of riders on the team (Eq.2a)
Energy Left = Energy Left * Energy multiplier (Eq.2b)

Using this value for Energy Left calculates the maximum team speed assuming that the riders are all riding in a line where the lead rider takes all the wind resistance. A side-effect of this assumption is that at most (R – 1) riders will die allowing at least one rider to cross the finish line.

A simple strategy is to have riders from different teams ride in line in a group, and take turns leading the group. However, this can be an unstable strategy, because there is a short-term incentive for each rider to do less than their fair share in front. In an ideal scenario each rider backs off to allow other riders to lead, and eventually trailing riders can catch up keeping the group together. The potential for saving energy in hopes of gaining a medal at the end of the race is a long-term incentive for the group as a whole to cooperate. However, the zeal to medal may increase the distrust between teams and limit inter-group cooperation.

Rounding factors

We found when we calculated our speed according to the above calculations our player would die slightly before the lane. There was a discussion in class saying that you can add small negligible factor to either the distance or the energy to take care of that, however we felt there was not a solid basis for choosing these fudge factors. Also, we began to see inconsistencies in our runs with respect to whether we died or not as we changed race parameters keeping the fudge factors constant.

Target-lane selection

The target lane is the meeting point for all the players to move to before merging into a line. The selection of this lane impacts the total time taken for line formation and decrease the amount of benefit from drafting behind team players. Some possible ways to select a target lane include, random selection, static lane selection e.g. leftmost/rightmost/middle lane and adaptive lane selection e.g. the leftmost/rightmost/median lane of the R lanes assigned to our team's riders.

Random lane selection

Selecting a random lane is easy; however, there is no guarantee that the lane selected is not already occupied by a rider from some other team. If the lane is occupied then there is the potential for competition over this resource and/or the rider occupying the lane may interfere with/obstruct the line formation process.

Static lane selection

The main benefit of static lane selection is its ease of calculation. However, there are a number of drawbacks especially in multi-team races. There is nothing preventing other teams to select the same lane leading to resource competition. This resource competition also occurs in multi-instance races where there are 2 or more instances of the same team. In addition, there is nothing that guarantees that this selected lane is not initially occupied by a rider from another team who may interfere with/obstruct the line formation process.

Adaptive lane selection

Calculating the leftmost, rightmost or median lane occupied by the R riders of the team is as easy as lane calculation using random or static lane selection. The additionally benefit of this approach is that it is guaranteed that the lane selected is "controlled" by a rider from your own team who will not interfere/obstruct the line formation process.

It should be noted that the lane selection techniques outlined above do not take into consideration the obstacles that may prevent riders from moving over into the target lane. In our lane selection process the initial lanes are sorted and we initially chose the lowest numbered lane as the target lane. The lowest was chosen because in the event of a tie the lowest numbered lane is awarded the medal points by the simulator.

We found however that we lost a lot of time and some energy in creating our line by forcing our riders to transition all the way to the lowest numbered lane we occupied. We then decided to go with the median lane to minimize the number of lane changes needed by each rider to make it into the target lane.

Forming Lines

Based on the optimal team speed calculation above, forming the team's riders into a line is integral to realizing a result where pushing riders up to the maximum team speed does not cause all R riders to die from exhaustion. Furthermore, the speed of line formation can significantly impact the number of rounds it takes to finish the race. Selecting a target lane/meeting lane where the team's riders will go to merge, maneuvering into the target lane and into position can all impact the number of rounds needed to form a line.

Keeping the lines tight

Riders can maintain the maximum team speed and get at least one rider to cross the finish line if they keep within an acceptable distance of the rider ahead of them. For this project the acceptable distance is a bike length = 2.0 distance units (meters). Some attention must be paid to ensuring that the line is not broken up while the riders are "in-flight" i.e. riders have formed their line and have accelerated up to the maximum team speed.

Coordinating the line forming in-flight is trickier than forming the line at the beginning, especially when the field is crowded. Precious time and energy is lost while re-forming the line necessitating velocity recalculations which may result in the new maximum team speed being lower than the original value, increasing the number of rounds it takes to finish the race.

No more benefit

The purpose of creating a line is to receive the benefit from drafting behind players. If we have saved enough energy through the course of race that we can run the whole race at 25m/s, then we can not save any more energy by staying in the line. We thus decide to move out of the line and sprint the rest of the race. Similarly, if we initially calculate that we can run the entire race at 25 m/s we never bother to waste time forming a line.

Leeching/Drafting

As mentioned before, riders conserve energy by "leeching", where "leeching" is defined as riding in another riders' slipstream. There are three approaches to drafting.

Internal Leeching/Drafting

The R riders of a team form a line and perform an initial calculation such that the line moves at some velocity v with a distance of at most 2.0 meters between riders resulting in at most (R – 1) riders dying and at least one rider crossing the finish line. Internal leeching focuses not only on forming the initial line but on regulating the gaps in the line to keep them <= 2.0 meters.

Individual Rider Leeching

Each of the R riders on the team picks a unique rider of another team and tries to draft behind them for as long as possible.

Team Leeching

The R riders of a team form a line and pick a rider from another team to position themselves behind. This approach allows the leader of our team to live a bit longer since he is not absorbing all the wind resistance, and this can increase the possibility of receiving multiple medals.

Counter Strategies

Leech detection

Because of the benefits of leeching, one counter-strategy is to detect when players are leeching off of your team and determine whether to ignore, evade or disrupt them.

Blocking

Actively disrupting other players is a potential strategy which can be effective based on the "brittleness" of teams' strategies for forming lines, attempting to leech and evading other players.

Evasive maneuvers

Based on the calculation of optimal rider and team speeds and the fact that riders are considered as homogenous, it is usually detrimental to the team to try to outrun other riders if the team must accelerated up to speeds which are greater than the optimal speeds. A preferable approach is to proactively and/or reactively avoid/evade other players. An example of proactive avoidance is to monitor the lanes close to you – 2 or 3 lanes to the right and left of your team or directly in front or behind your team– and move to some other lane if someone else enters your "safety-zone". Although this is not always optimal because even when non-attackers are close by we move away, but there was no way to figure out who is attacker since the indices of the other teams were random. As an example, groups 4 and 9 implemented blocking players, had we been able to identify them by team index we could have been less paranoid about riders from other teams being close to us. Another reason for being paranoid about other players is to avoid players who try to block from the front and bring down our speed to 0.

Player Analysis

FastSoloStrategy

In this strategy riders calculate how fast they can go when they take all the wind resistance. No attempt is made to form a line. The goals of this strategy were to verify that our max rider speed calculations allowed all riders to finish and to get an idea of how long it takes riders to finish the race on their own.

For the standard course:

L	: 15
D	: 180000
R	: 4
E	: 5000000

The time taken was: 19629

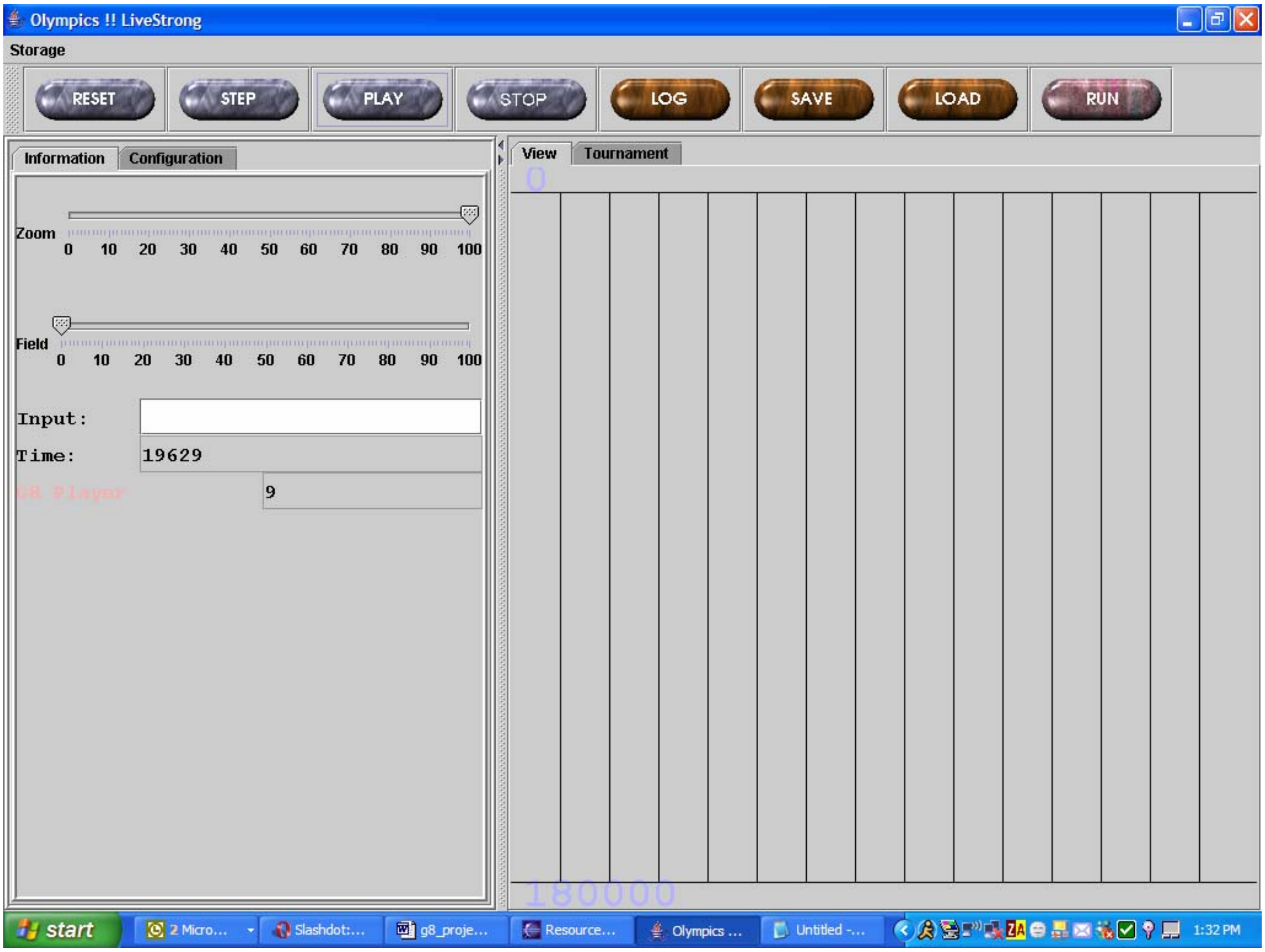

Figure 1 FastSoloStrategy Time trial - standard course

SimpleStrategy/Late Random Strategy

These two strategies are our initial attempts at coordinating riders. Both strategies use the same methodology for organizing the team into a line. Riders initially calculate their individual optimal speed and the line moves at that speed. During the race riders recalculate their individual optimal solo speed and accelerate up to it. Near the end of the race the riders at the back of the line that have been benefiting from drafting can go a bit faster than the riders that were leading the line taking all the wind resistance. Therefore all our players move out of the line and sprint to the finish line as fast our energy will allow. The players also randomly move across lanes hoping to come in front of another player and slow them down.

The SimpleStrategy/LateRandomStrategy causes riders to break the line formation and select a random lane when there is <= 1000 meters left in the race, switching each of them to the FastSoloStrategy where they move at their individual optimal speed based on the energy they have left. With strategy we observed the number of rounds taken to finish the race decrease a bit (see Figure 2).

For the standard course:

L	: 15
D	: 180000
R	: 4
E	: 5000000

The time taken was: 19090

Line formation

The line is formed by selecting the target lane as the leftmost lane occupied by a rider on our team. Riders are positioned by sorting them based on the distance they have traveled in the race. Based on a riders position in sorted order we make each rider perform the following acceleration sequence:

1 acceleration
(R – position) waits (Acceleration = 0)
1 deceleration (Acceleration = -1)

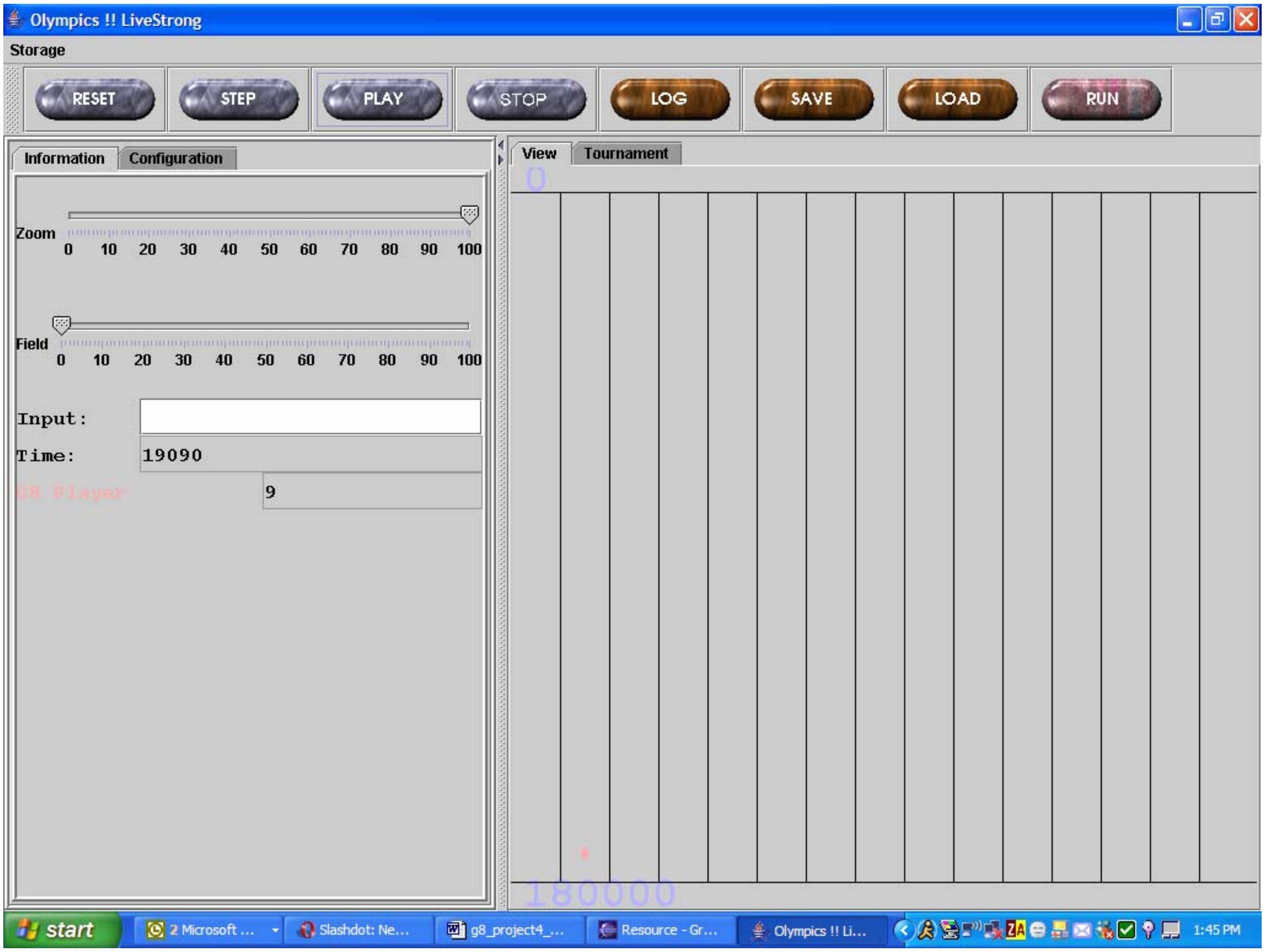

Figure 2 SimpleStrategy/LateRandomStrategy time trials

Critique

Even though this approach does succeed in getting the players to line up, we noticed a number of possible ways to improve team performance:

1. Adjust the calculations of optimal speed such that they consider the benefit of drafting
2. Determine whether our line was formed tight enough such that moving the line at the maximum team speed would not cause more than (R - 1) riders to die.

After making the speed calculation adjustment, we noticed that our riders were not consistently finishing the race, this we attributed to the gaps in our line being > 2.0 meters which meant that more than one rider at a time was taking the full force of the wind even though the intent of forming a line was to have only the rider leading the line taking the full force of the wind. We also noticed that although all our players will cross the finish line, if there are at least two players doing the original line up strategy where only one player crosses the line then our player will only get one or no medals defeating the purpose of trying to get multiple players across. We next set about working on other ways to form the line.

FastTeamStrategy

This strategy focuses on improving the line formation process and coordinating the riders to move at the maximum team speed, where this team speed is calculated taking into consideration the benefit of drafting and only one player crossing the finish line.

Line formation

To form lines we used a combination of initial acceleration staggering and monitoring of the gaps that formed between riders as the line continued to form.

In multiplayer games we initially sit still for two rounds. Next we sort the players based on the distance they have covered in the race. Since all riders have been sitting still they all have the same position but sorting them is only to apply some logical ordering. After sorting the riders their accelerations are staggered once using an increment calculated on their position in sorted order and Maximum Acceleration possible e.g. for R = 4 and Maximum acceleration of 1.0, one rider accelerates 0.25 and the other riders accelerate 0.5, 0.75 and 1.0.
After the acceleration staggering, riders are sorted again on the distance they have covered, the furthest rider is now the leader and his lane is the target lane. While the riders are not lined up we keep track of the inter-rider gaps that occur and riders move closer to the target lane when a gap between them and the rider ahead of them position-wise becomes >= 2.0 meters. When all riders reach the target lane, the minimum and maximum gaps in the line are calculated, to tighten up the line the leader is made to decelerate slightly causing the riders following him to bump into him and in turn slow down. Once the line is tight, riders accelerate up to the maximum team speed.

For the standard course:

L	: 15
D	: 180000
R	: 4
E	: 5000000

The time taken was: 15564

It should be noted that based on our runs Group1Player1's best time-trial result was 15563 and Group5K's best time-trial result was 15565. Few other groups were able to break 15600. Based on these observations we concluded that in addition to forming the line, the methodology used to form the line is extremely important. For our own player we saw a dramatic decrease in our time-trial results.

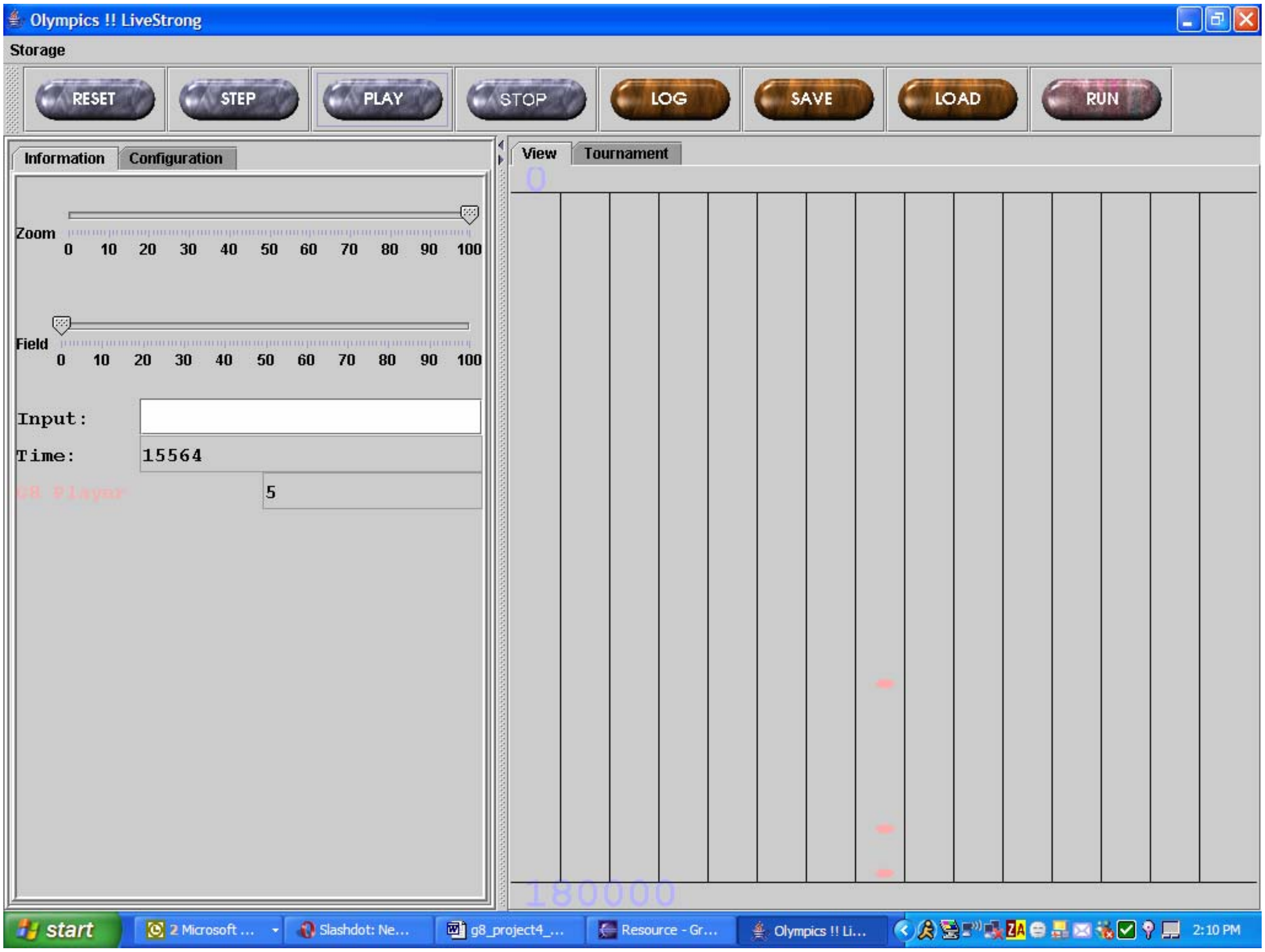

Figure 3 FastTeamStrategy time-trial using modified line formation

Critique

Despite these encouraging single player results, there were a number of deficiencies with the way we formed our line.

It only worked for R <= 4, for larger values of R e.g. R = 10 what we observed was 4 – 7 of the riders would eventually form a line, leaving the remaining 3 – 6 riders in another column and they both continued in parallel.

It was extremely brittle in multiplayer scenarios, if there was any interference, e.g. other players blocking our riders from transitioning to the target lane our line forming was most likely to fail. Initially sitting still at the starting line in multi-player games helped a bit as the other players accelerated away leaving this area relatively clear but other players were also using this technique to improve their own line forming.

Since we were expected to compete in multi-team races we set about working on a more robust line forming strategy that would have comparable performance.

InternalLeechStrategy – the FastTeamStrategy replacement

Line formation

From our own mini-tournament runs we noticed that Group1Player1 and Group5K had good performance and reasonably robust line formation strategies, with Group5K having the edge on Group1Player1 as we varied conditions. On examining Group5K we saw that their approach to forming lines was similar to our line formation approach used in SimpleStrategy/LateRandomStrategy mentioned above.
In these earlier strategies riders are positioned by sorting them based on the distance they have traveled in the race. Based on a riders position in sorted order we make each rider perform the following acceleration sequence:

1 acceleration
(R – position) waits (Acceleration = 0)
1 deceleration (Acceleration = -1)

Group5K uses:

1 acceleration
(R – position)*2 waits (Acceleration = 0)
1 deceleration (Acceleration = -1)

Which for them not only works consistently well, but also forms a line where the minimum and maximum gap between riders – calculated using our gap monitoring code – were around 2.4 and 3.1 respectively. It takes a larger number of rounds to form the line however, but the important property was its robustness. Because of these properties we revisited our initial line forming strategy and augmented it with gap monitoring such that once the riders are all in the same lane the minimum and maximum gaps are around 2.1 and 2.6. Our strategy continuously uses our gap monitoring and gap fix-up code to keep the lines tight during the race. To cater for riders falling behind either due to direct interference from other riders or issues with our complete line not being able to evade other riders we consider a rider “lost” when the gap between them and the rider ahead of them becomes >= 10 * 2.0 meters. Lost riders are cut from the column, the max speed of the column is recalculated based on the number of riders left in the column and the lost riders each moves at their individual optimal speed.

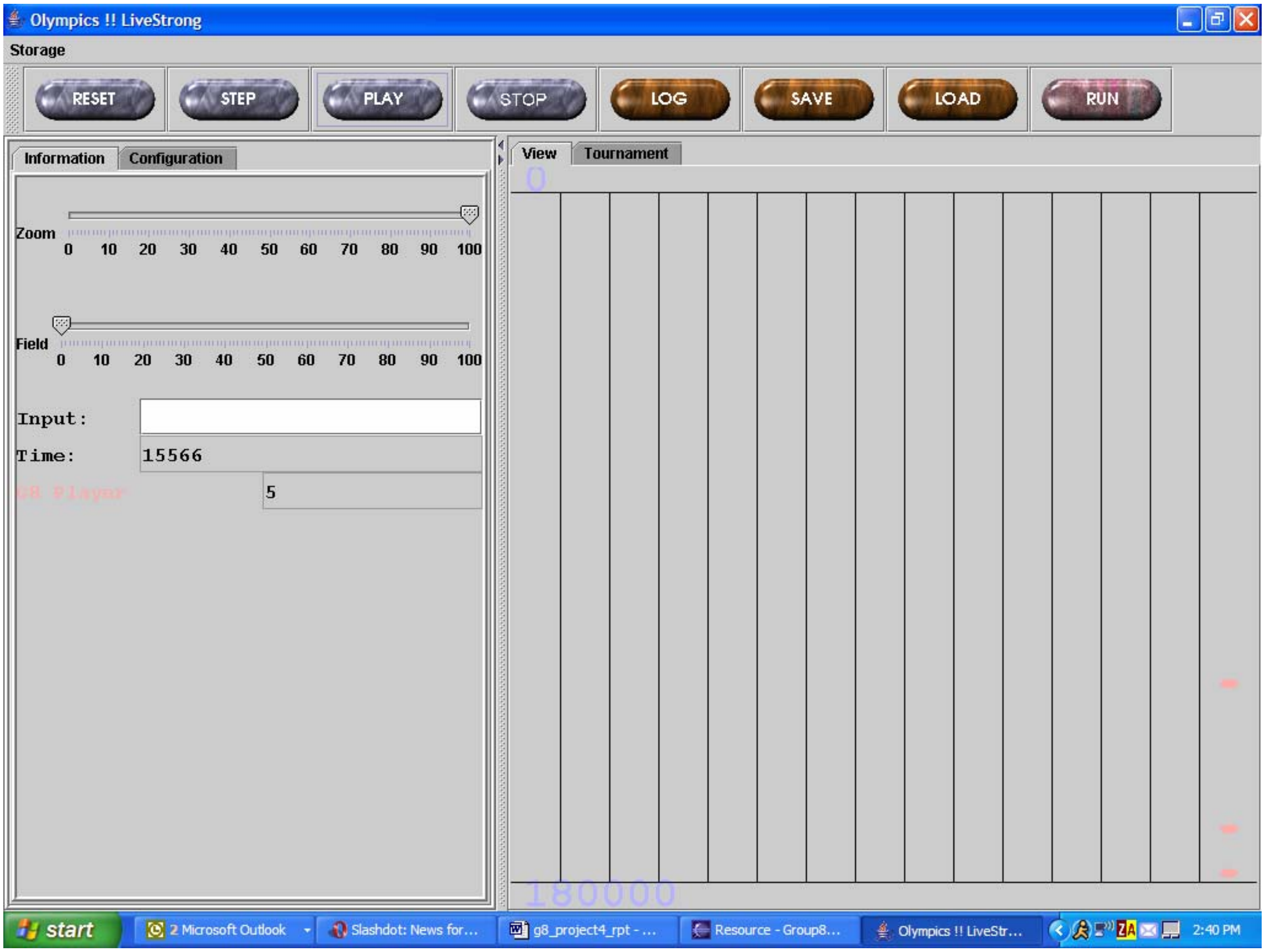

Figure 4 InternalLeech time-trials

Critique

This strategy is a bit more robust in the way it forms lines even in the multiplayer games however we did notice occasions where we did not form lines, but we did not have the time to go back and fix it before the submission deadline.

Multiplayer performance

Using our own mini-tournament runs, our results we not was consistent as we would have liked. In some cases we were unable to avoid the blocking players and were subsequently hindered, at times we would escape but by then we have lost significant ground. Barring being blocked we were able to gain the second or third place medals with a bit more consistency, based on runs using the player submissions of 12/06/2004, whether this also occurs during the tournament remains to be seen.

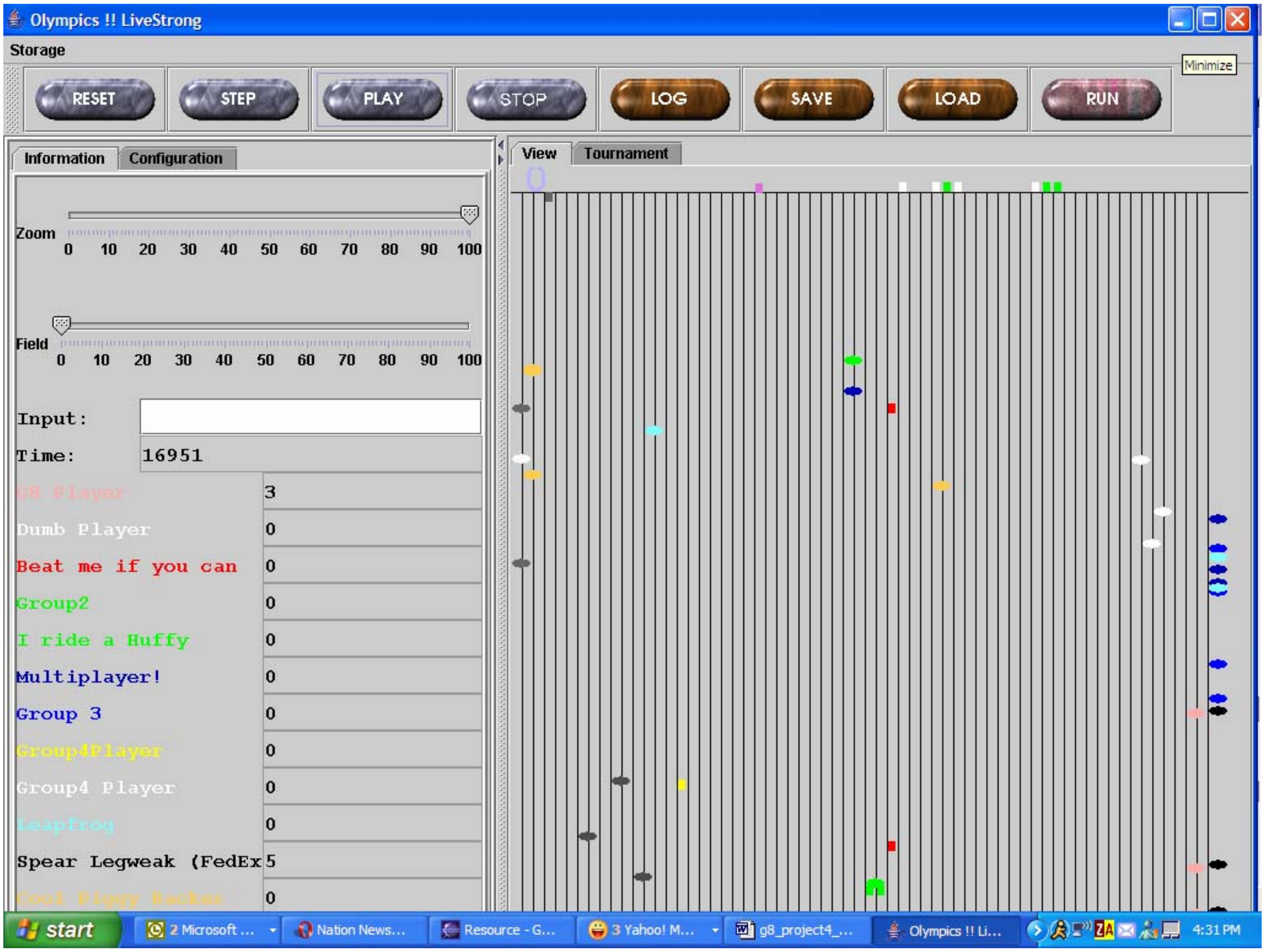

Figure 5 Multi-player run using Internal Leech strategy - silver medal

Leeching

The most optimal way to implement the strategies would be to utilize the idea of team leeching. In this scenario the leader is also drafted increasing the time when the leader will die from exertion.

PiggyBack

Initial version was simply to use our simple strategy and choose our leader who is the furthest ahead in the race however this is not always ideal because the player may wear himself out and die causing us to also use too much energy and die. Leading us to a better version of leeching

SmartLeechStrategy

In smart leech we take care of checking when a player is burning himself out by only choosing our leader as a player who is riding between two optimal speed ranges, maximum solo speed for all players to cross the finish line and maximum for only the fourth player in the line to cross the finish line. If the player falls between that range then we choose to follow them.

Critique

Although this is optimal to ensure the most number of medals there were many counter strategies made by other teams in the class. The first counter strategy is leech detection which made it hard to find a team who did not use any sort of leech detection. The other counter strategy teams in class made were blockers who tried to block a whole team and would bring the speed of the line down to 0. This ultimately became a tedious task to find a player who we would be able to follow without exerting all our energy in the process. Since this player only did well in possible cases where R was equal to 1 we decided there was no point to submit this player. Although we would have liked to come up with better way to get this to work since this could insure multiple medals to a team, there was not enough time to implement a player to keep track of which players we should and should not follow.

Tournament results

In the tournament we did not fare as well as we had hoped. Based on our own mini-tournaments we had expected to do better on small team, small R tournaments. We started off well being ranked first overall in the R = 1 tournament, but otherwise our performance was less than stellar. Our wins were sporadic over all of the remaining tournament runs.
From the results our average rank was 10 out of 15. We feel that players that repeatedly do their calculations would have performed better. For some reason, even though we did this in our first player we were not able to keep doing this calculation in the final version of our player. We think there could have been a slight rounding issue with our speed calculation. We did not want to add a small factor because if we add 5 to the distance to take care of small rounding factors another team could add 2. Thus this was not the best way to do a calculation because it is not precise anymore nor flexible when race parameters change.

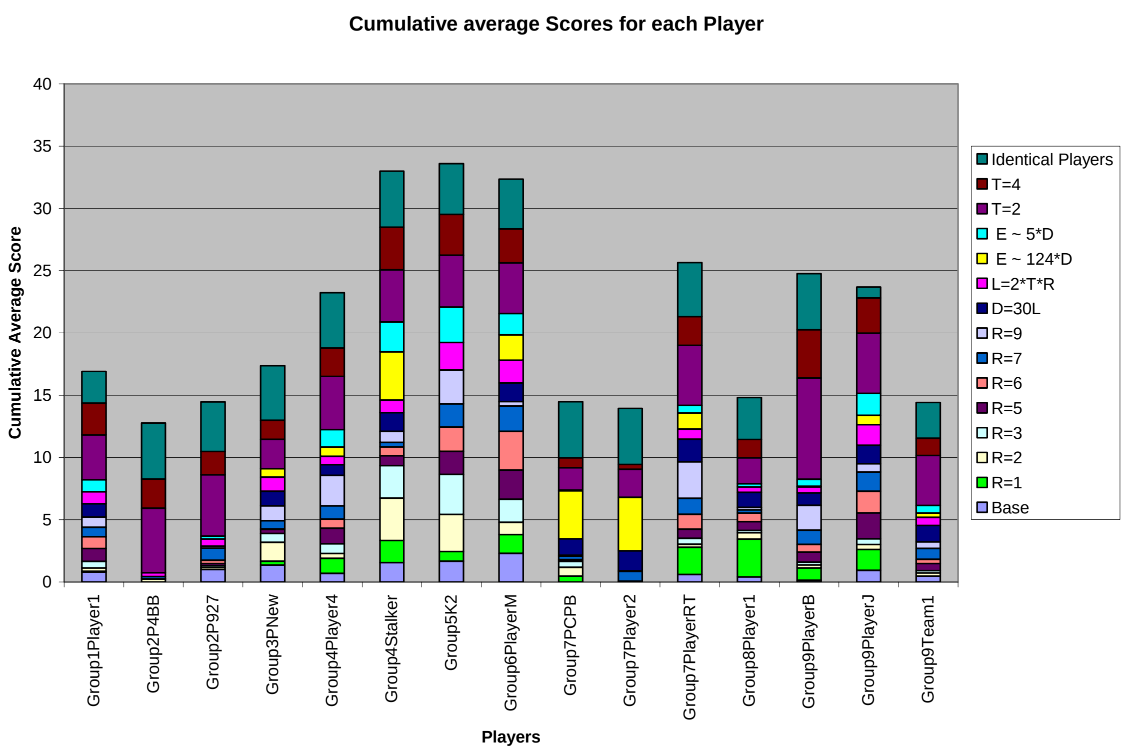

Figure 6 Cumulative average score per player

Contributions

Developers

BugStrategy	Deepti not explained in report because this strategy was formed early on in the project only if simulator issues were not fixed with random acceleration
SimpleStrategy	Deepti/Rean
LateRandomStrategy	Deepti
FastSoloStrategy	Rean/ Deepti
FastTeamStrategy	Rean/ Deepti
PiggyBack	Deepti/Rean /Suchita
smartLeechStrategy	Rean/ Deepti
Internal Leech	Rean

Other

Suchita	Testing of our player with tournament configurations
Suchita	some contribution to idea of SimpleStrategy, changed target lane to be left most lane in case of a tie
Deepti/Rean	Report/Presentation
Deepti	Tournament Result Compilation

Acknowledgements

Group 5's use of the acceleration sequence:

1 acceleration
(R – position)*2 waits (Acceleration = 0)
1 deceleration (Acceleration = -1)

had a lot of success in getting riders to line up in the target lane with reasonable spacing between them.