Milestone 7: Validation and Verification

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CS 4632: Modeling and simulation

November 25th, 2024

Executive Summary

Throughout the semester, there have been many milestones to keep track of the progress of the overall project of the Golf Course Model and Simulation. The 7th Milestone better known as Validation and Verification, involves use of methodology that ensures that the model and simulation are implemented properly enough to present a working product fundamentally.
Throughout this report, you will find key supporting documented discoveries that will support the overall validity and verification of the project such as:

- References to previous milestones, specifically 6, and how that milestone correlates to the purpose of 7.
- Validation and Verification methodologies and findings.
- An itemized log of the steps taken to complete the Validation and Verification.
- Pitfalls that have been encountered, assumptions, and overall model limitations.
- Concluding statements regarding the overall tact of the project in preparation for the final deliverable.

The primary goal of the milestone is to display the overall functionality of the model and simulation and discuss how well prepared for the last deliverable it is for submission. In documenting these things, I hope to work toward a solution to more confidently display the overall validity and verification of the project as a whole.

Contents

1 Introduction

In golf, time is a crucial aspect of how the game is conducted among its players. The pace of play in golf is a crucial factor that provides the course with a proper standard for how to manage flow among the traffic that builds upon the queuing nature of a course.

In Milestone 6, the sensitivity and scenario analysis, the model and simulation were stress tested using altered input parameters from the static parameters in the code base. The three main parameters that were studied within that report were the changes that would affect the average number of times that the marshal was deployed per tournament run, the number of times that the groups would come ahead of, behind, or within pace of the golf hole, and a roster of average round completion times per group per tournament.

In this milestone, that being milestone 7, the report will focus on testing and documenting the validity and the verifiability of the simulation model. In doing the testing and documenting, the report aims to and will grow closer to properly providing an example of a real world system through the use of a framework.

Within this report, a documentation of testing will provide insight into how the pace of play model can and will most closely resemble the correct nature of a real-world and idealized golf course system pace model.

2 Validation

2.1 Validation Purpose

The reason for the validation of this golf course pace of play simulation model is to provide context in the golf world to better reinforce the nature of the model by making direct correlations to real world examples and structural system standards set within industry.

2.2 Methods of Validation

2.2.1 Parameter Validation

One very important parameter to consider among the golf course pace of play model is the time range that is taken per par standard per hole on the golf course. In this model implementation, a set time standard of 12 minutes for a par 3, 14 minutes for a par 4, and 18 minutes for a par 5 are all created as parameters that the simulated groups are aiming to meet in terms of time based on the hole they are playing. The time range specifically granted to each of the pars where the golfers would randomly complete a hole in those times were for a par 3 ten to fourteen minutes, for a par 4 12 to 16 minutes, and for a par 5 sixteen to 20 minutes. These time configurations were all engendered based off of empirical research done by myself in a personal interview with a local golf course owner and PGA Professional Bryan Raines, where a complete list of tee times and time slots were provided. Based on my own knowledge I provided a range in accordance to this hard data provided with a gap of two minutes on either side of an average standard time needed to complete a par type of a hole on course.

In a tournament setting it is no strange concept that groups will take much longer to complete their rounds based on the conditions of play and money at stake. A prime example of this is the findings of Andrew Tiger and Eric Ellerbrook in their literature review titled, " Improving Golf Pace of Play Using Time Study Analysis: Influencing Factors on the Green and Tee Box" where they include stats based on how time is affected by a competitive setting here; "Competition added 68 seconds to the time on each green." and later concluding that, " Of the significant variables, Competition increases the amount of the time on the green the most compared with the other significant variables."

Another example of literature that specifically mentions the use of time standards is an article titled,"How long should it take to play a par 3, par 4 and par 5 during a round of golf?" where a time standard here on average is calculated at about 10 minutes for a par 3, 13 minutes for a par 4, and around 15 minutes for a par 5. This data is a bit more accurate than the data in this simulation model because it accounts for data based upon more then just one golf course and its holes therefore even though my assumptions of a standard time per par type are mighty close to these standards, they are still slightly off.

2.2.2 Cross-Model Validation

A model study done by Qi Fu and Ward Whitt stochastically examines the golf course pace model and how the pace model is directly affected in the nature of a queuing system. If there is a faulty queuing system in place, odds are that the pace of play model will be greatly effected. A large talking point within their research, much like my own, was discussion of a stage based queuing system where a group tees off and its not properly allowed to continue their round until each individual step is completed. An example of this is when group 1 reaches the fairway for their ball and are hitting from fairway to green. If a fairway is open in certain spots, then the ability in the real world to proceed upon open area of land is available. This model would cut that entirely, as does my own. When a group hits the fairway from the tee box, until they make contact with the green the members of the previous group will have no ability to complete their tee shots. Once green contact is made

however, the next group may proceed to the fairway of that hole. The main point of partaking in this methodology is to overall add structure to the system in a way that there is not necessary back up in places there should not be.
The authors of this article found much success in shifting focus away from the overall time structure for the course and provided a mathematical queuing structure that dives deeper into the individualistic characteristics of a golf hole.

2.2.3 Face Validation

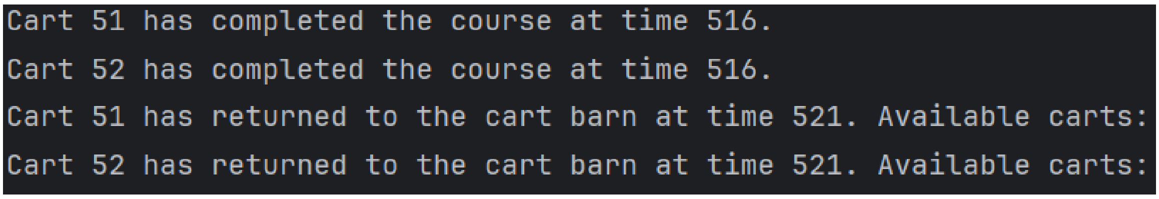
This models implementation and simulation execution accounted for much of the data gathered by experts in its early conception. Now however, the main accounts that should be made should be that of comparing the model to the real world data that can be provided by an expert themselves.

In research, I was able to reach out to Bryan Raines, a licensed PGA Professional and golf course owner to get some insight into how a normal day on course goes just to observe how the pace of the course takes route and also how the pace for the day is manually manipulated to better fit a courses queue.

2.3 Sensitivity Analysis Follow-Up

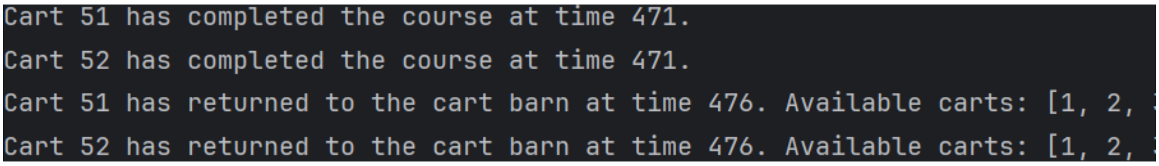
From milestone 6, there were many different configurations that took place. For instance a change in number of groups and increase of time span for the tournament was increased to study how the model would react to a much larger tournament day.
From open, the courses first tee time on the given sample normal day is at 8am and the final for that day is around 1:54pm this would put the days first groups round end time at around 12:19pm and the last groups end time at around 6:13pm. This would put each groups total time range to complete at 4 to 4 and a half hours. This does however account for 45 groups as opposed to my 26 for a tournament setting. Based on my bounds with 26 groups the start and end time stamps between my own data results and that of the hard data provided to me in the Face Validation, the times largely line up with one another somewhat similarly. However there are major pitfalls in the comparison here due to there being a much smaller gap to start groups in the real world data at 8 minutes as opposed to my own 10 minute gap. With a large time bound for 26 groups where there is no practical time limit the tournaments were finishing entirely at around the 515 to 540 minute range. Which, if the tournament starts at 8am, then this would put the tournament ending at the 4:30pm to 5 o'clock mark. If I change this to 8 minutes, the results change significantly down to the mid 400s to high 400s in minutes, therefore bringing the tournament time end closer to that of the real data at around the 8 hour mark. An example of this can be found at the top of the page in final output after altering this time gap. Based on an average of three runs in my own simulation model, the margin of error between my own model and that of the real world data was just within plus or minus 2 percent at around plus or minus 1.7 percent. Each run upon changing the sendoff gap changed minutely and remained around the same time gap as the real world data based on 26 groups. I believe that this is an acceptable margin specifically because it only represents an 8 minute differential between real world data and simulation data.

Average Standard Time Calculation based on 3 runs:
(465+460+476) minutes/3 runs = 467 minutes
Margin of Error:
(467-459) minutes/459 minutes = 0.01743 = 1.7% error



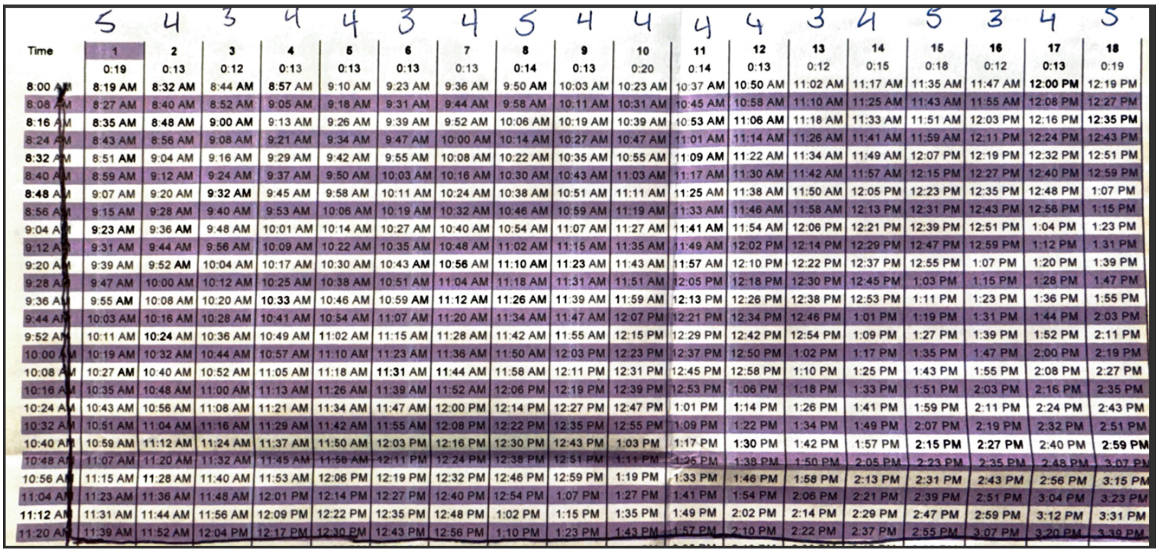
```
Cart 51 has completed the course at time 516.
Cart 52 has completed the course at time 516.
Cart 51 has returned to the cart barn at time 521. Available carts:
Cart 52 has returned to the cart barn at time 521. Available carts:
```

Figure 1: Standard tournament time ends with 10 minute start gap.



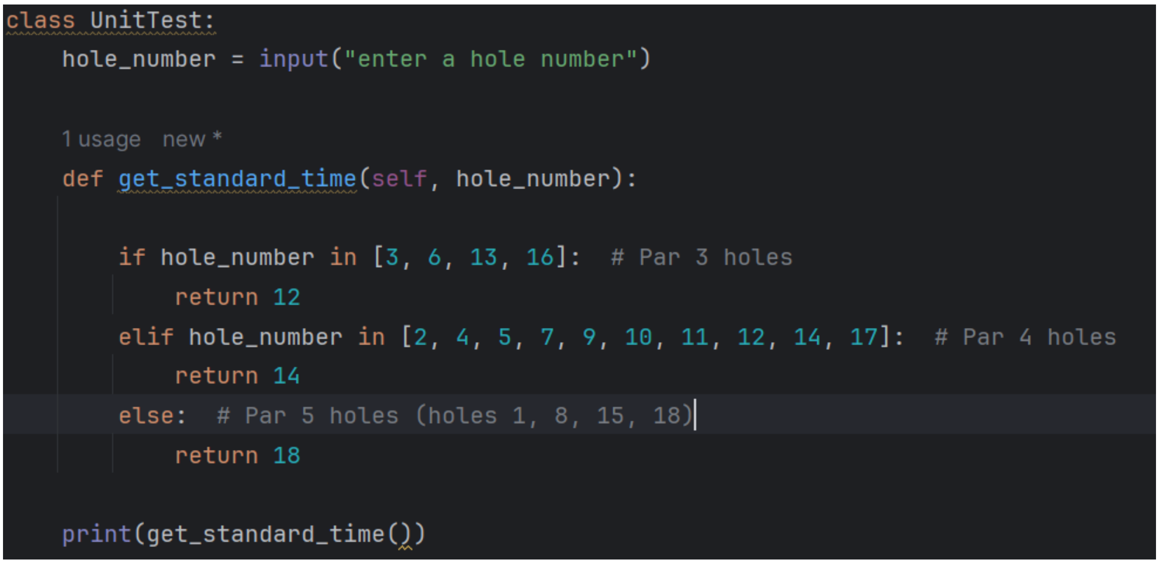
```
Cart 51 has completed the course at time 471.
Cart 52 has completed the course at time 471.
Cart 51 has returned to the cart barn at time 476. Available carts: [1, 2,
Cart 52 has returned to the cart barn at time 476. Available carts: [1, 2,
```

Figure 2: A display of output in console to display the final carts in the tournament being returned with a round start gap of 8 mins mimicking real world data.



	5	4	3	4	4	3	4	5	4	4	4	4	3	4	5	3	4	5
Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	0:19	0:13	0:12	0:13	0:13	0:13	0:13	0:14	0:13	0:20	0:14	0:13	0:12	0:15	0:18	0:12	0:13	0:19
8:00 AM	8:19 AM	8:32 AM	8:44 AM	8:57 AM	9:10 AM	9:23 AM	9:36 AM	9:50 AM	10:03 AM	10:23 AM	10:37 AM	10:50 AM	11:02 AM	11:17 AM	11:35 AM	11:47 AM	12:00 PM	12:19 PM
8:08 AM	8:27 AM	8:40 AM	8:52 AM	9:05 AM	9:18 AM	9:31 AM	9:44 AM	9:58 AM	10:11 AM	10:31 AM	10:45 AM	10:58 AM	11:10 AM	11:25 AM	11:43 AM	11:55 AM	12:08 PM	12:27 PM
8:16 AM	8:35 AM	8:48 AM	9:00 AM	9:13 AM	9:26 AM	9:39 AM	9:52 AM	10:06 AM	10:19 AM	10:39 AM	10:53 AM	11:06 AM	11:18 AM	11:33 AM	11:51 AM	12:03 PM	12:16 PM	12:35 PM
8:24 AM	8:43 AM	8:56 AM	9:08 AM	9:21 AM	9:34 AM	9:47 AM	10:00 AM	10:14 AM	10:27 AM	10:47 AM	11:01 AM	11:14 AM	11:26 AM	11:41 AM	11:59 AM	12:11 PM	12:24 PM	12:43 PM
8:32 AM	8:51 AM	9:04 AM	9:16 AM	9:29 AM	9:42 AM	9:55 AM	10:08 AM	10:22 AM	10:35 AM	10:55 AM	11:09 AM	11:22 AM	11:34 AM	11:49 AM	12:07 PM	12:19 PM	12:32 PM	12:51 PM
8:40 AM	8:59 AM	9:12 AM	9:24 AM	9:37 AM	9:50 AM	10:03 AM	10:16 AM	10:30 AM	10:43 AM	11:03 AM	11:17 AM	11:30 AM	11:42 AM	11:57 AM	12:15 PM	12:27 PM	12:40 PM	12:59 PM
8:48 AM	9:07 AM	9:20 AM	9:32 AM	9:45 AM	9:58 AM	10:11 AM	10:24 AM	10:38 AM	10:51 AM	11:11 AM	11:25 AM	11:38 AM	11:50 AM	12:05 PM	12:23 PM	12:35 PM	12:48 PM	1:07 PM
8:56 AM	9:15 AM	9:28 AM	9:40 AM	9:53 AM	10:06 AM	10:19 AM	10:32 AM	10:46 AM	10:59 AM	11:19 AM	11:33 AM	11:46 AM	11:58 AM	12:13 PM	12:31 PM	12:43 PM	12:56 PM	1:15 PM
9:04 AM	9:23 AM	9:36 AM	9:48 AM	10:01 AM	10:14 AM	10:27 AM	10:40 AM	10:54 AM	11:07 AM	11:27 AM	11:41 AM	11:54 AM	12:06 PM	12:21 PM	12:39 PM	12:51 PM	1:04 PM	1:23 PM
9:12 AM	9:31 AM	9:44 AM	9:56 AM	10:09 AM	10:22 AM	10:35 AM	10:48 AM	11:02 AM	11:15 AM	11:35 AM	11:49 AM	12:02 PM	12:14 PM	12:29 PM	12:47 PM	12:59 PM	1:12 PM	1:31 PM
9:20 AM	9:39 AM	9:52 AM	10:04 AM	10:17 AM	10:30 AM	10:43 AM	10:56 AM	11:10 AM	11:23 AM	11:43 AM	11:57 AM	12:10 PM	12:22 PM	12:37 PM	12:55 PM	1:07 PM	1:20 PM	1:39 PM
9:28 AM	9:47 AM	10:00 AM	10:12 AM	10:25 AM	10:38 AM	10:51 AM	11:04 AM	11:18 AM	11:31 AM	11:51 AM	12:05 PM	12:18 PM	12:30 PM	12:45 PM	1:03 PM	1:15 PM	1:28 PM	1:47 PM
9:36 AM	9:55 AM	10:08 AM	10:20 AM	10:33 AM	10:46 AM	10:59 AM	11:12 AM	11:26 AM	11:39 AM	11:59 AM	12:13 PM	12:26 PM	12:38 PM	12:53 PM	1:11 PM	1:23 PM	1:36 PM	1:55 PM
9:44 AM	10:03 AM	10:16 AM	10:28 AM	10:41 AM	10:54 AM	11:07 AM	11:20 AM	11:34 AM	11:47 AM	12:07 PM	12:21 PM	12:34 PM	12:46 PM	1:01 PM	1:19 PM	1:31 PM	1:44 PM	2:03 PM
9:52 AM	10:11 AM	10:24 AM	10:36 AM	10:49 AM	11:02 AM	11:15 AM	11:28 AM	11:42 AM	11:55 AM	12:15 PM	12:29 PM	12:42 PM	12:54 PM	1:09 PM	1:27 PM	1:39 PM	1:52 PM	2:11 PM
10:00 AM	10:19 AM	10:32 AM	10:44 AM	10:57 AM	11:10 AM	11:23 AM	11:36 AM	11:50 AM	12:03 PM	12:23 PM	12:37 PM	12:50 PM	1:02 PM	1:17 PM	1:35 PM	1:47 PM	2:00 PM	2:19 PM
10:08 AM	10:27 AM	10:40 AM	10:52 AM	11:05 AM	11:18 AM	11:31 AM	11:44 AM	11:58 AM	12:11 PM	12:31 PM	12:45 PM	12:58 PM	1:10 PM	1:25 PM	1:43 PM	1:55 PM	2:08 PM	2:27 PM
10:16 AM	10:35 AM	10:48 AM	11:00 AM	11:13 AM	11:26 AM	11:39 AM	11:52 AM	12:06 PM	12:19 PM	12:39 PM	12:53 PM	1:06 PM	1:18 PM	1:33 PM	1:51 PM	2:03 PM	2:16 PM	2:35 PM
10:24 AM	10:43 AM	10:56 AM	11:08 AM	11:21 AM	11:34 AM	11:47 AM	12:00 PM	12:14 PM	12:27 PM	12:47 PM	1:01 PM	1:14 PM	1:26 PM	1:41 PM	1:59 PM	2:11 PM	2:24 PM	2:43 PM
10:32 AM	10:51 AM	11:04 AM	11:16 AM	11:29 AM	11:42 AM	11:55 AM	12:08 PM	12:22 PM	12:35 PM	12:55 PM	1:09 PM	1:22 PM	1:34 PM	1:49 PM	2:07 PM	2:19 PM	2:32 PM	2:51 PM
10:40 AM	10:59 AM	11:12 AM	11:24 AM	11:37 AM	11:50 AM	12:03 PM	12:16 PM	12:30 PM	12:43 PM	1:03 PM	1:17 PM	1:30 PM	1:42 PM	1:57 PM	2:15 PM	2:27 PM	2:40 PM	2:59 PM
10:48 AM	11:07 AM	11:20 AM	11:32 AM	11:45 AM	11:58 AM	12:11 PM	12:24 PM	12:38 PM	12:51 PM	1:11 PM	1:25 PM	1:38 PM	1:50 PM	2:05 PM	2:23 PM	2:35 PM	2:48 PM	3:07 PM
10:56 AM	11:15 AM	11:28 AM	11:40 AM	11:53 AM	12:06 PM	12:19 PM	12:32 PM	12:46 PM	12:59 PM	1:19 PM	1:33 PM	1:46 PM	1:58 PM	2:13 PM	2:31 PM	2:43 PM	2:56 PM	3:15 PM
11:04 AM	11:23 AM	11:36 AM	11:48 AM	12:01 PM	12:14 PM	12:27 PM	12:40 PM	12:54 PM	1:07 PM	1:27 PM	1:41 PM	1:54 PM	2:06 PM	2:21 PM	2:39 PM	2:51 PM	3:04 PM	3:23 PM
11:12 AM	11:31 AM	11:44 AM	11:56 AM	12:09 PM	12:22 PM	12:35 PM	12:48 PM	1:02 PM	1:15 PM	1:35 PM	1:49 PM	2:02 PM	2:14 PM	2:29 PM	2:47 PM	2:59 PM	3:12 PM	3:31 PM
11:20 AM	11:39 AM	11:52 AM	12:04 PM	12:17 PM	12:30 PM	12:43 PM	12:56 PM	1:10 PM	1:23 PM	1:43 PM	1:57 PM	2:10 PM	2:22 PM	2:37 PM	2:55 PM	3:07 PM	3:20 PM	3:39 PM

Figure 3: Extraneous data provided by the local owner of a local course that was used for comparisons in time taken for 26 groups at 8 minute start intervals.(Apologies for the sloppiness of the paper. This was a vital piece of data that has been used through the semester and the only medium I had to provide access to this data via the report.)



```
class UnitTest:
    hole_number = input("enter a hole number")

    def get_standard_time(self, hole_number):

        if hole_number in [3, 6, 13, 16]:  # Par 3 holes
            return 12
        elif hole_number in [2, 4, 5, 7, 9, 10, 11, 12, 14, 17]:  # Par 4 holes
            return 14
        else:  # Par 5 holes (holes 1, 8, 15, 18)
            return 18

    print(get_standard_time())
```

Figure 4: Code Snippet for the individual unit test done on the hole standard time classification.

3 Verification

3.1 Purpose of Verification

Verification is used here to ensure that real world functionalities of a golf course are properly implemented in the given simulation environment. Verification will provide key insights into how the model will react based on an individual component-based level.

3.2 Verification Methods

3.2.1 Unit Testing

In Unit Testing, I came to a large crossroads in the actual execution of the testing itself. The first scenario that I had planned on testing was the hole classification function titled get_standard_time(). After countless tries at debugging I was unable to get the individual unit working. Above you will find the snippet of code used to test this function alone in figure 4.

3.2.2 Integration Testing

Within integration testing, I was able to test the interactions between separate functions within a run of the entire code base. I chose to initially study the interactions of the detect slow, and send marshal functions in the course operator class to see how the interaction of the two with no outside influence would work with one another. Outside of this with its issues, the approach that I took to do this was to study the interactions between the methods within the output of the overall entire code base within the console. The reason I opted for this is because much like the Unit Testing, I ran into problems where even loading the functions into the unittest environment was nonfunctional no matter what I tweaked or added.

3.2.3 Regression Testing

In rerunning the code base to check for changes in results after modifying the time gap parameter, I can confirm that the results of the program run almost identically to the results of the previous program run with the exception of total time period of a tournament on course.

3.2.4 Code Review

The primary issue that was found within my program were a couple of inefficiencies such as the actual array list of holes itself where the groups are queued. This specifically being a hard coded value restricts the customization and adaptability of the program that essentially would provide the ability for it to be used based on a multitude of different course layouts as opposed to just the one that it is modeled after.

Most other warnings that were found within the code base were warnings relating to the data.py file that gathers data and puts it into a study using the Reg Ex package to gather data based on keywords. These warnings were mainly petty warnings regarding whitespace issues in the list of files that data was gathered from and an issue with the end_time variable regarding type. Although these warnings are present, the code still performs as needed and work efficiently for its designated purpose.

3.3 Results

Overall, the results were not entirely fruitful, but also not entirely a failure either. I came to some crossroads in efforts to conduct adequate Unit Tests and Integration Results, however there was fruit in regression testing where I found that the code has not changed for the worst as time has progressed, and I also successfully conducted a code review of all of the code base and was able to bring to light the advantages and inadequacies in the sim model.

Overall in unit testing, I would have farther tested the golf hole classification function for standard par time to check to see what the function would return given a user input of what hole they would like information on. Also within integration testing, I would have tested the contents of the course_operator class by providing alternate parameters for the actual wait time and par standard times variable to more adequately represent the use case of the detect_slow and the send_marshal functions in conjunction with one another.

3.4 Issues

There were a few issues that were encountered in both the unit testing and the integration testing of the code and the integration testing of the code. Every time that I tried to put individual functions into a unittest, it seemed as if I could nver get an output. I succumbed to a pitfall where it seemed as if no matter how hard I tried, the overall solid results that you would get from a unit or integration test could not be readily achieved. I did however document some hypotheticals and how I would envision testing go if there werent issues with output.

3.5 Version Control

GitHub, throughout the semester, has been used rigorously to document any and all changes regarding the model from its infantile stages in basic cart queuing structures all the way to its now more developed stage where the simulation model is more complete. Through the semester I primarily developed within a master branch and within the last month and change I pivoted to working more in a secondary branch after the 5th and 6th milestones due to changes in the main code base for data manipulation. The code base along with version control can be found here with the most recent changes on the secondary branch:

https://github.com/amill0156/mod-sim-Proj/tree/secondary

4 Validation and Verification Checklist

4.1 Validation Checks

- Have you compared simulation outputs with real-world data?
  - Through the testing of my simulation and the study of its outputs I have compared them to real world data found in data pools suuch as and similar to figure 3.

- Are all model parameters within reasonable and justified ranges?
  - My parameters were slightly overzealous with a set time gap at 10 minutes instead of the much faster real world example sample of 8 minutes.

- Does the model's behavior align with expert expectations?
  - By studying the data, it would align with the objective data that is gathered from professionals in the field.

- Have you documented all validation results using appropriate visuals?
  - To the best of my ability, yes.

- Have you performed historical data validation?
  - No, this is not necessary here due to the game consistently changing in terms of ball flight, course sizes, etc.

- Did you conduct cross-model validation where applicable?
  - Yes, a comparison was made to a couple of different literary references.

4.2 Verification Checks

- Have you tested the model with boundary and edge conditions?
  - No, I primarily focused on Unit Testing and Integration testing plus a review of the code base.

- Did you verify that all input parameters are properly handled?
  - Yes, everything is in line.

- Have you checked for mathematical and logical consistency in your code?
  - Yes, mathematically everything is sound. Time function and overall order of operations all work within need.

- Is the model's behavior reasonable across different time scales or scenarios?
  - Yes, I found that changing these parameters in milestone 6 proved this to be true. Also the new inclusion of changing the start time gap in the base simulation proved to improve flow of the course for the day as well and get it closer to real world data.

- Have you systematically documented all testing results?
  - To the best of my ability, yes.

- Did you perform unit, integration, and regression testing?
  - I performed integration testing, as testing the individual functions of the code base proved to be much more difficult after multiple attempts. I was never able to come to a resolution there.

- Are you following version control best practices?
  - Yes, I have rigorously updated the code base in GitHub to accurately reflect the progress made in the semester.

4.3 Doc Checks

- Is all documentation up to date and reflective of the current model?
  - Not entirely, there are still some edits to be made to accurately reflect the changes and progress that have been made so far.
- Have you documented all assumptions and limitations?
  - Across multiple milestones there have been opportunities that I have taken to do this.
- Are test cases and results properly recorded?
  - For the most part I believe so, yes. Although there have been some shortcomings in data display when it comes to neatness and presentation of graphics.

4.4 VC Checks

- Are all changes committed with descriptive messages?
  - Yes.
- Have you tagged versions appropriately?
  - Yes.
- Is the repository synchronized with the remote server?
  - I am not entirely sure, but it is accessible through the GitHub web application and desktop application.

4.5 Data Validation Completeness Checks

- Is the data used for validation complete and reliable?
  - Yes, these are real world data points gathered from a local golf course PGA Professional and Owner.
- Have you checked for data inconsistencies or anomalies?
  - Yes, at the conception of the project when data was being gathered, I checked rigorously for inconsistent data or anomolies and was never able to find anything out of the ordinary.

5 Common Pitfall Avoidance

- Validation:
  Through the process, I ensured that the data that was provided to myself via personal relationship to the owner of the local course and also the data provided in the reports found through internet research were reliable by carefully studying for any consistency discrepancies.
- Verification:
  To my own ability, I believe that most of the testing done in this milestone and previous ones have been successfully conducted. Within verification however, I did run into problems conducting individual unit tests and successfully conducting integration tests. However, the code review was successful in that I was able to adequately reiterate some key points about my code base and the regression testing was successful as well.

6 Documentation

- Assumptions Made During Validation and Verification

  - The main assumption that I had in going into the V&V process was that the data that I gathered from personal empirical research and online data research were going to ill reflect the efforts that have been made in my model through the semester. I have come to realize in this portion of this milestone specifically that I was more successful than I had anticipated.
    With verification on the other hand, testing was assumed to be a lot easier than it really was. I came to several crossroads in the testing of individual units where I would get never ending error messages in trying to test one functions ability, therefore I resulted to testing the best way I knew how, integration testing. Even in integration testing I ran into major issues while trying to couple functions together in functionality. My main goal for integration testing was to test the course operator class so that I could see the marshal doing its job in an isolated setting. One main issue that I kept running into was that no matter what I had tried it honestly felt as if the code running in separated functions was impossible. Although i know it is not, I ran tests with the whole code base anyhow.

- Comparison Results
  - In comparing the results of the code base re run in the validation section, I found that the data that I had gathered from local professionals initially was much more efficient than my own. Through thorough search in the code, I came to the conclusion that the reason for my efficiency inadequacies was the sendoff time gap set at 10 minutes instead of 8 like that of the real world data. Once my sim model was implemented with this change it became very apparent how much closer my results were to the actual real world data. initially my final ending time stamp per tournament hovered around the 515 to 540 mark with the real world data set hovering at around 459 minutes. After careful considerations and code changes, I was able to bring this time down to the high 460s and low 470s just by changing the scheduling time gaps between groups.

- Model Limitations
  - This model is complete in a sense of its primary purposes being readily fulfilled, however, the overall ability of it as a whole is not entirely fulfilled. An important aspect of this project in its conceptualization was that the user experience as a whole would have to be completely there on a front-end to better suit the needs of a consumer using the application. However, with the current time restraint on the semester, something like this would not be entirely feasible. Another limitation of the model is that it only accounts for the frame of a tournament and not the frame of an entire days worth of golf including the regular non-tournament participating golfers. This model strictly monitors the pace of groups that fall within the 26 group and 52 cart tournament bound. Of course there is also the margin of error of a few minutes of pace being neglected when it comes to more accurately representing a real world dataset, however the margin is minimal at most at around less than 2%.

7 Conclusion

Overall, I believe that the model, while primarily relying on the entire code base to test the moving parts, was adequately studied within this specific milestone, primarily in the validation section. For validation I was able to compare results of data runs with real world data, find discrepancies and rectify them to better reflect the data found in the real world. As for verification, as there were limitations to my data studies, I did find there were useful insights into where my simulation model sits in terms of being completed for the final package. With Integration testing, Regression testing and code review I was able to closely analyze where the code base stands and put together some valuable conclusive information. The overall purpose of both of these concepts is to allow the developer to ask themselves hard hitting questions about the path and the future of the project. I firmly believe that this project is on the right track to become a very useful niche tool in the industry. To answer the ”Are we building the model right?” and the ”Are we building the right model?” questions, I would absolutely confirm the answer to be yes. With just a bit more work it could potentially allow me to take the project into another development phase in the future as a passion project.

To conclude, this milestone as a whole has contributed greatly to my knowledge of my own code base and has given me great insight into how long term stages of a sim models development should and should not be carried out.

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