TJHSST Hallway Simulation 2008-2009

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Abstract

The dynamics of Thomas Jefferson High School for Science and Technology's hallway traffic have changed from previous years. This project aims to understand TJHSST hallway movement by creating a hallway traffic simulation. Areas of focus for this project include the following:

- **Traffic Modeling**: This project models traffic.
- **Computer Simulation**: This project is a simulation.
- **Multi-agent Systems**: This project studies a system with multiple agents.
- **Group Dynamics.** This project studies a dynamic group.

Keywords: traffic, simulation, agents, agent, agent-based, modeling, agent-based modeling, groups, group, dynamic, dynamics, group dynamics, multi-agent, multi-agent systems

1 Introduction

1.0.1 Problem Statement

With changes made to the school, there is reason to believe that the dynamics of TJHSST's hallway traffic differs from its dynamics in previous years. In the past, TJHSST accepted approximately 400 additional students each year. Each student remains at school for approximately four years, so the aggregate of all class sizes predictably neared 1600 students.

However, over the years, TJHSST has increased the number of students it accepts. TJHSST must now accept 450 students–a number that could very well increase in the future. On top of that, the TJHSST building itself has changed with the addition of several new trailers.

In 2006, Olesya Katkova and Peter Riggs began the first projects that increased understanding of TJHSST's hallways. However, it is possible that the results of these experiem-nts could already be outdated. This project will both update and expand upon previous projects.

1.0.2 Project Aim

The aim of this project is to write a computer program that simulates TJHSST hallway movement. The simulation will a heuristic path finding algorith to determine each student's course.

2 Background

Before creating the experiment, extensive background research was conducting. Below is a quick survey of the research utilized in the creation of the simulation.

2.1 Applied Research

- ***Continuum Crowds*** *by Adrian Trueille, Seth Cooper, Zoran Popovic in conjunction with the University of Washington, Electronic Arts.*

  The project studied how to realistically calculate movement without the use of collision detection. The researchers believed crowds tend to have a sense of which areas will be crowded before they reach those areas, and members of this crowd will adjust based on this knowledge when determining his or her path beforehand. The project was able to successfully develop this simulation; in fact, the researchers concluded that the crowds actually moved more smoothly and realistically when calculating the collisions and movement together, as opposed to separately.

- ***Finding Multi-Constrained Feasible Paths By Using Depth-First Search*** *by Zhenjiang L and J.J. Garcia-Luna-Aceves.*

  The focus of this research was developing a depth first search algorithm that operated with an unusual number of restrictions. The algorithm detailed designs for developing routing systems with many constraints.

- ***A New Approach to Cooperative Pathfinding*** *by Renee Jansen and Nathan Sturtevant.*

  This project explains several alternatives to the A* and IDA* searches. It details how to use cooperative algorithms to find paths in a group situation, when calculating each individual path differently would take a long time, and it explains how weighting movement-determining algorithms can help reduce this time significantly.

2.2 Past Research

Past experiments specificic to TJHSST have also been done.

- ***Traffic Dynamics in Scholastic Environments*** *by Olesya Katkova.*

  This program works on finding a

way to map traffic in an TJHSST-esque environment.

- ***Hallway Traffic Simulator*** *by Peter Riggs.*

  The program was designed in Fortran. The purpose of this project was to increase the understanding of TJHSST Hallway traffic and expected student movement tendencies. The analysis was that students effectively moved from place to place. The end result was a program that could be expanded and adapted for several situations.

3 Development Sections

The project is divided into four phases, each lasting approximately nine weeks. The following section contains process and analysis from for each section of the project.

3.1 Phase 1 Develpement

Phase 1 of the project focused primarily on providing a framework for the remaining three phases and testing the overall feasibility of the project's scope.

3.2 Phase 1 Testing

The simulation was then tested with the following process:

1. 1) Implementing a preliminary path finding algorithm

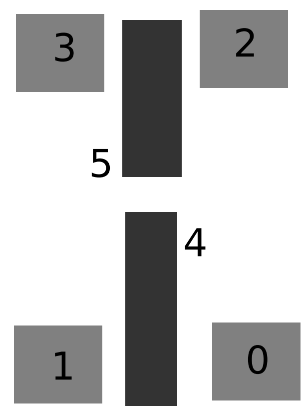

Figure 1: Model mini-building used in simulation phase.

2. 2) Outputting the total time of path finding for each hall
3. 3) Analyzing the resulting output

The input the program consisted of the following:

1. 1) A hash containing the information necessary to construct a small-scale model room and hallway layout. The layout constructed using this data is shown in Figure 1.
2. 2) A randomized schedule for each student.
3. 3) Data for initializing input constants,

To test the program in its current state, the simulation started started students in one area and be required to find their way to the designated path. This preliminary simulation assumed the following:

1. Each room is located approximately three minutes apart from each other.
2. Students will attempt to take the quickest possible path to their destination.
3. Students will stay in their destination once they arrive.
4. Students move at the same speed, regardless of traffic conditions.
5. All students left their initial location at 10:05 and tried to make sure they arrived at their next location by 10:15.

Once the program ran, it output data about where students moved and which hallways were crowded. This data is shown in Figure 2.

Note: At this point, this data was input directly; there was no point in inputting data by reading a file because the map size manageable. The time and processing used to open and read an input file did not make such a method useful.

Hall Traffic Given Time:

Hall	10:08	10:11
4	60%	10%
5	40%	60%

Figure 2: Table showing results of Phase 1 Testing.

3.3 Phase 1: Results and Discussion

Every student was able to locate his next period and arrive before the start of the next class (10:05). However, by looking at the data, it was clear that the hallways were not utilized efficiently. For instance, at 10:11, the Hall5 hallway had six times as much traffic as Hall4. Every student was not only able to locate his or her destination, but he or she was able to arrive before there before the start of the next class (10:15).

However, there were some problems. Looking at the data, it was clear that the hallways were not utilized efficiently. For instance, at 10:11, the traffic through Hall5 hallway was 600 percent as much as the congestion through Hall4.

This may have been a result of the fact that students did not take into account traffic when selecting movement. Also, the order of the schools could have been switched so to alleviate the traffic.

The output and results were as expected.

StudentName	Start	10:08 AM	10:11 AM	Finish
Student0	Area3	Area5	Area2	Area2
Student1	Area1	Area4	Area5	Area3
Student2	Area1	Area4	Area5	Area3
Student3	Area2	Area5	Area4	Area0
Student4	Area1	Area4	Area5	Area2
Student5	Area3	Area5	Area2	Area2

Figure 3: Phase 1 Student Movement Output.

The program effectively stores all forms of data, such as student name and hallway connections. These hashes and arrays are all necessary to implement movement algorithms, which will be refined. The Output is shown below.

3.4 Phase 2 Development

The aim of Phase 2 of the project was to create a simulation that accurately simulates a portion of the school. Phase two of the program was tested and implemented in the C programming language. The testing process consisted of the following steps:

1. Running the path-finding algorithm algorithm
2. Students will attempt to take the quickest possible path to their destination.
3. Outputting program data to a text file
4. Reviewing the output to test feasibility and realism

This new version of the program runs much more quickly and efficient than the old code.

This new program ads several new components and functions. OpenGL has been added as a critical component. Testing has been performed, and while the the visualization did not work at this stage, OpenGL does print the initial screen and window successfully.

The program could possibly receive information from alien sources in later stages of development, though the program currently receives input from itself throughout the code execution. The current focus is not on efficiency or storage, but rather on functionality. In later stages, the entire school will be mapped out, not just a small previously input sample.

One other key change is that hallways and rooms are now stored separately as different entities, which was not the case with the Phase 1 program.

The input the program receives consists of several things. Some of the most important pieces of data are listed below:

1. Information about hallways
2. Information about rooms
3. Student name data
4. Student schedule data

A sample of the program output is shown on following pages.

Students:
jon
sally
hill
karel
jim
greg
megan
joe
sarah

Figure 4: Phase 2 name input.

Student Num	Name	Eve nt0	Eve nt1	Eve nt2	Event3
0		0	0	0	0
1	jon	0	1	2	1
2	sally	0	2	3	2
3	hill	0	2	1	1
4	karel	0	2	3	2
5	jim	0	3	2	3
6	greg	0	2	1	1
7	megan	0	2	2	3
8	joe	0	3	1	1
9	sarah	0	3	3	3

Figure 7: Phase 2 Student Scheduling Data

RoomN umber:	RoomN ame	Hall 1	Hall 2	Hall 3	Hall4
0		0	0	0	0
1	r1230	2	3	0	0
2	r1240	1	0	0	0
3	r1250	4	2	0	0

Figure 5: Phase 2 Room/Hall Input.

HallN um	hall0	hall1	hall2	hall3
Hall0:	0	0	0	0
Hall1:	2	4	0	0
Hall2:	1	3	0	0
Hall3:	2	0	0	0
Hall4:	1	0	0	0

Figure 8: Hall Data Input.

HallNumber :	Room0	Room1	Room2	Room3	Room4	Room5
0	1	3	0	0	0	0
1	2	0	0	0	0	0
2	1	3	0	0	0	0
3	1	0	0	0	0	0
4	3	0	0	0	0	0

Figure 6: Phase 2 Room/Hall Output Based on Transposed Input.

Event	Time
0	0
1	905
2	915

Figure 9: Time of Events Data.

3.5 Phase 2 Organization

The new project code is organized differently than the Phase 1 version. Several layers of organization include hallways, rooms, and students. This new organization allows printing functions to be separated from other functions, though functions can still be called as a result of code written near the top of the program. This new organization is necessary, as the code has reached the point where it spans a length of over eight hundred lines. Confusion and coding inefficiency made this new organization necessary.

The new simulation works with regard to student data, hall data, room data, and other forms of crucial data. Most of this data was stored in hashes, and was tested extensively several times. While these areas of the program work fine, at this point, there were still several areas that are under construction.

The code currently has the necessary frameworks for graphics. However, the graphics do not work. Ultimately, the graphics component was removed from the project.

3.6 Phase 3: Development

The goal of Phase 3 testing was to create an accurate simulation for all TJHSST hallways. For phase 3, the simulation simulated over an electronic version of the TJHSST Hallway Map and the graphics component was removed. This map including the hallway numbers used in the simulation is shown. The program was modified to calculate output student path data correctly, and an OpenOffice document was created which imports the data (and can update it as the code outputs new data). The table in this document is included below.

The simulation program works with 800 students (as opposed to 1600) due to memory issues, though this will likely be tackled in a later phase. The table accounts for this by multiplying each value by 2. The OpenOffice spreadsheet graphs teh of the output, which is also included on the following pages. The output was analyzed to make sure it made sense this analysis is included below.

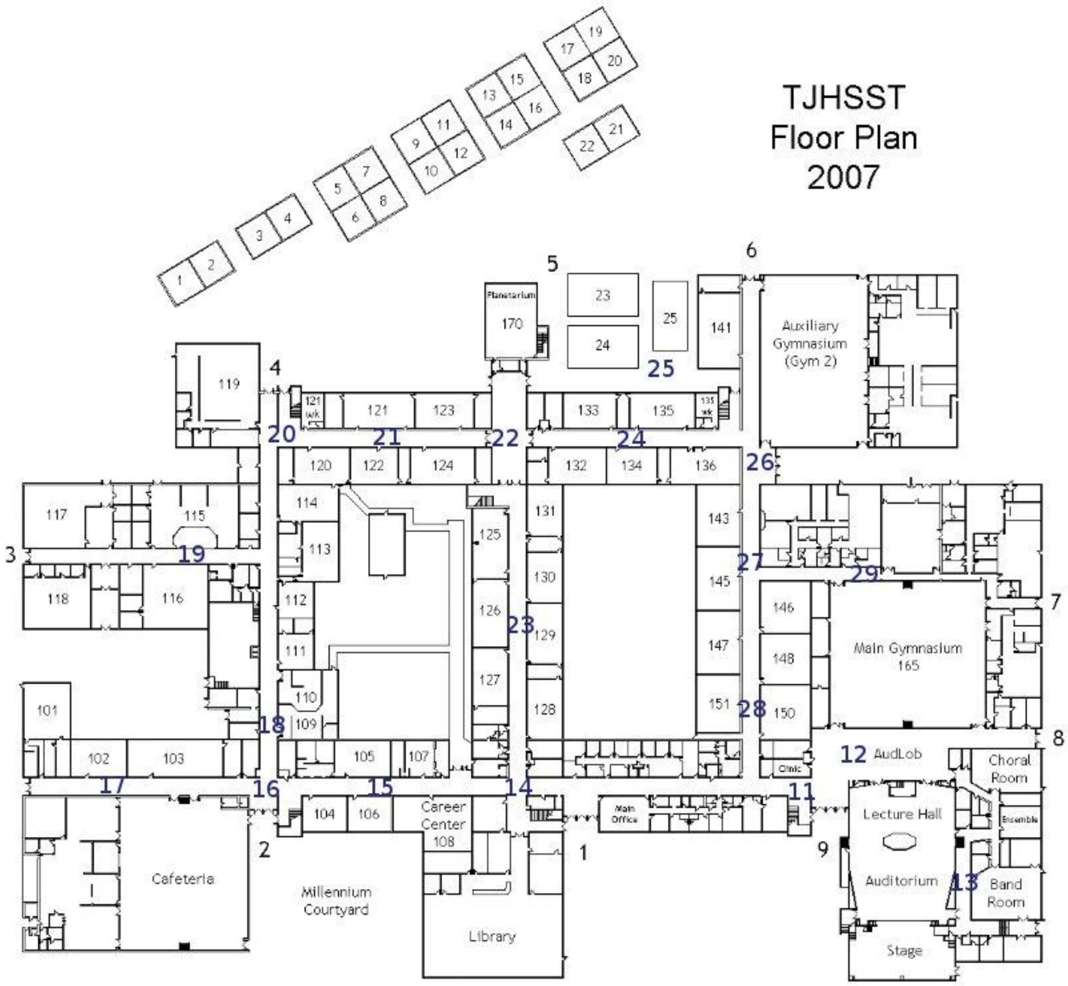

Figure 10: Model mini-building used in simulation phase.

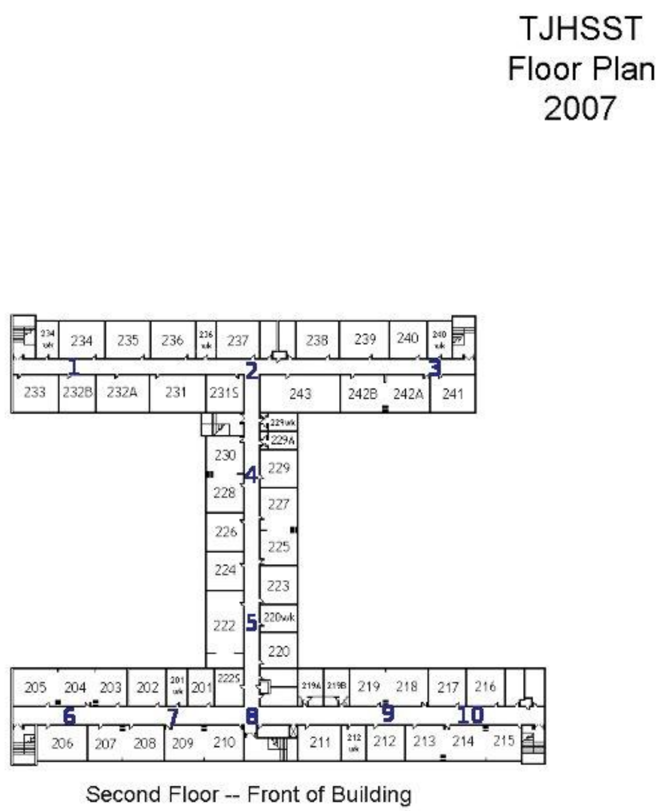

Figure 11: Table showing results of initial experiment.

3.7 Phase 3: Results

Top 5 Most crowded hallways in the simulation:

1. The 2nd floor intersection of hallways near the backside of the school. This is the location of a 4-way intersection (hallways in three direction and stairs leading to the 1st floor (2)

2. The 1st floor intersection near the front of the school (14)

3. The Junior Lounge, which intersects 3 hallways, an exit, and a pathway leading to trailers (22)

4. The 1st floor hallway in which many physics classes are taken (23)

5. The hallway leading to the Millennium Courtyard (16)

Top 5 Least crowded hallways in the simulation:

1. The hallway leading to one of the entrances to the boys locker room and the back door entrance to the main gym (29)

2. The pathway to the section of trailers located between Dr. Acios room and the Junior lounge (25)

3. The hallway leading to and fro the cafeteria (17)

4. the hallway leading to the band and chorus rooms (13)

5. The hallway leading to the Systems Lab (19)

Time (minutes) \ Hall Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29		
0	82	26	94	92	44	74	50	16	82	34	24	48	70	48	54	24	68	92	42	24	94	38	112	80	42	40	18	66	20	1598	
1	22	98	18	24	52	48	30	82	16	60	62	68	18	108	4	196	0	42	36	84	6	144	34	6	6	142	56	46	18	1526	
2	88	102	132	56	12	146	0	104	50	22	104	18	34	80	30	62	0	62	16	14	42	16	110	12	26	60	24	54	14	1490	
3	42	136	30	54	28	56	16	60	50	40	22	34	16	192	4	140	0	22	42	14	14	72	64	8	6	146	38	80	26	1452	
4	40	124	140	88	2	74	14	70	94	18	90	16	14	58	32	52	0	80	10	6	14	78	152	8	12	46	24	50	16	1422	
5	56	182	28	22	24	18	12	100	38	52	56	14	2	204	20	84	0	24	4	60	14	122	92	2	4	110	32	24	10	1410	
6	82	102	76	82	28	32	12	38	78	42	48	2	4	164	70	10	0	10	2	60	36	94	204	38	0	36	18	32	6	1406	
7	70	162	64	22	62	8	14	86	24	42	84	4	0	172	76	44	0	40	2	42	42	172	64	14	6	34	16	36	0	1402	
8	22	214	20	22	20	6	22	150	26	26	144	46	2	74	10	118	0	70	0	76	12	174	14	16	2	62	38	16	0	1402	
9	84	36	86	72	40	42	52	20	76	50	28	62	46	32	38	10	68	84	60	32	58	22	62	76	32	42	14	68	8	1400	
Sum	588	1182	688	534	312	504	222	726	534	386	662	312	206	1132	338	740	136	526	214	412	332	932	908	260	136	718	278	472	118		14508
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Figure 12: Table showing results of experiment.

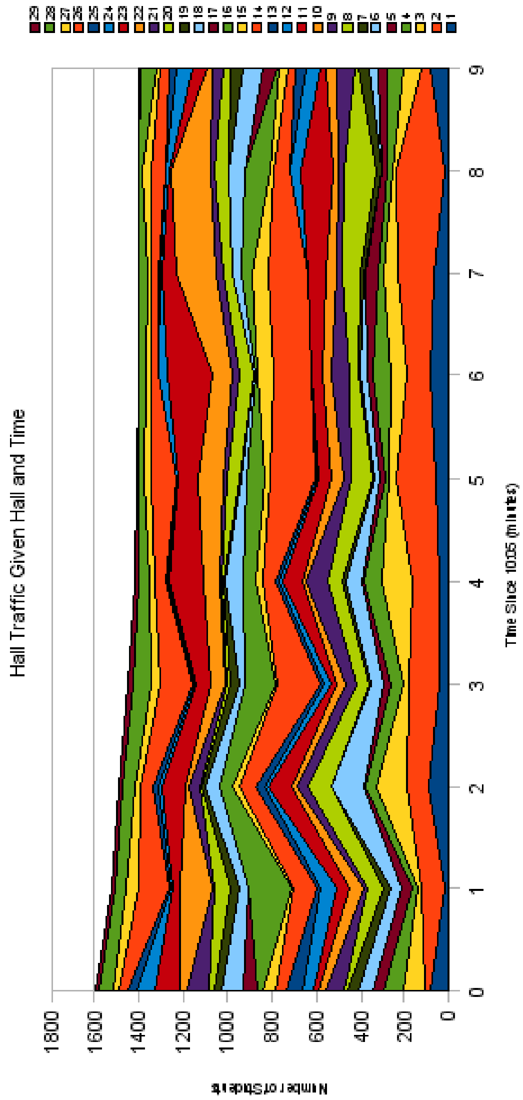

Figure 13: Graph of results.

3.8 Phase 3: Analysis

Most of the hallways identified the two Top 5 categories matched personal experiences from real life. However, two in particular (hallways 17 and 16) do not match individual experiences. The reason why the movement through hall 17 is underestimated is likely that the program treats each room equally when determining student schedules, and it also does not take into account the beginning and end of the day. Since one of the primary reasons for moving through hallway 17 is going to and fro buses and cars and going toward the cafeteria and senior lounge (whose sizes far exceed that of the average classroom), the simulation underestimates the traffic. To fix this, the simulation can take into account class sizes when determing student schedules.

The simulation likely overestimates the traffic through hall 16. Though, personal experiences do not match real life, a real-life test can be performed to be sure of this. The reason, though, that it may underestimate the traffic is by overestimating the level of traffic to to rooms that are often reached through hall 16 (Rooms 101, 102, 103, 109, 110, 111, 112, 104, 105, 106, and Millennium Courtyard Exit). In addition, one major flaw of the current program is that it treats bathrooms as classrooms, so hallway 16 treats the girls and boys bathrooms as a single 30-student room in which students take classes in. This use, however, never has and hopefully never will match real-life.

While the simulation underestimates traffic to the cafeteria, which must also be reached through hall 16), the overestimates of the other rooms more likely than not would balance this out, especially since the Cafeteria and Senior Lounge are only goals during select periods of the day. To fix these models, the next simulation must contain student class sizes and more realistic scheduling, eliminating the treatment of bathrooms, exits, and gyms as equals to normal classrooms.

On top of that, while the number of students in the hallway decreases over time (as evidenced by the graph), the decrease likely does not mimic real-life. This is because the program only requires that students find a path, but not necessarily the most realistic path, to their classes. The only constraint is that they must reach their destination in time. The model also does not account that students will go out of their way to reach certain destinations, linger in a certain hall talking to their friends, or leave class early and arrive to class late. Accounting for this will more likely than not increase the accuracy of the results.

3.9 Phase 4: Development

The goal for the fourth phase of research was to improve the overall quality of the simulation. This is the final phase of the project.

The path finding method for the final phase of the project version uses heuristics. Each hallway is placed in a spot on a 7 X 6 grid based on its coordinate position from a bird's eye point of view of the school. This grid is then used to sort the array of possible halls that the student can move to from his current location. With the sort, the hallway most directly in between the student's current location and his or her destination is put in the first position of the array. The new path finding function then looks at this hall first (as opposed to selecting a random hallway from the list of possible hallways).

Another Phase 4 development is the input the simulation receives. The simulation now iterates over 887 students, half the size of the current TJHSST student body. This data is then multiplied by a factor of two. The school's hallways were reapportioned in order to make them more equal in terms of overall area. Bathrooms and exits not leading to trailers were removed from student schedules. Rooms that are not used as classrooms were also removed. The program also now iterates over 8 steps (as opposed to 9 steps in Phase 3), meaning students must find their classrooms by 10:15 (as opposed to by 10:16 in Phase 3).

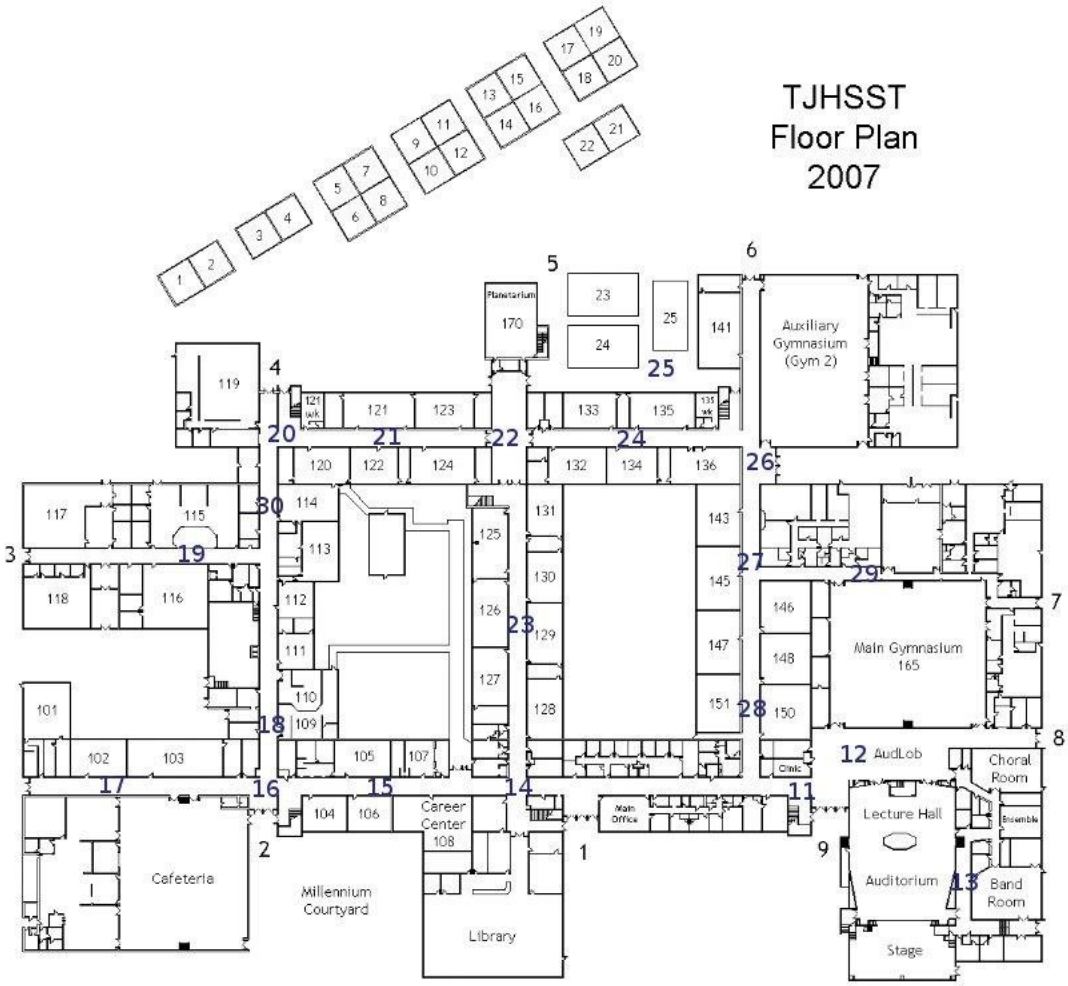

Figure 14: Model mini-building used in simulation phase.

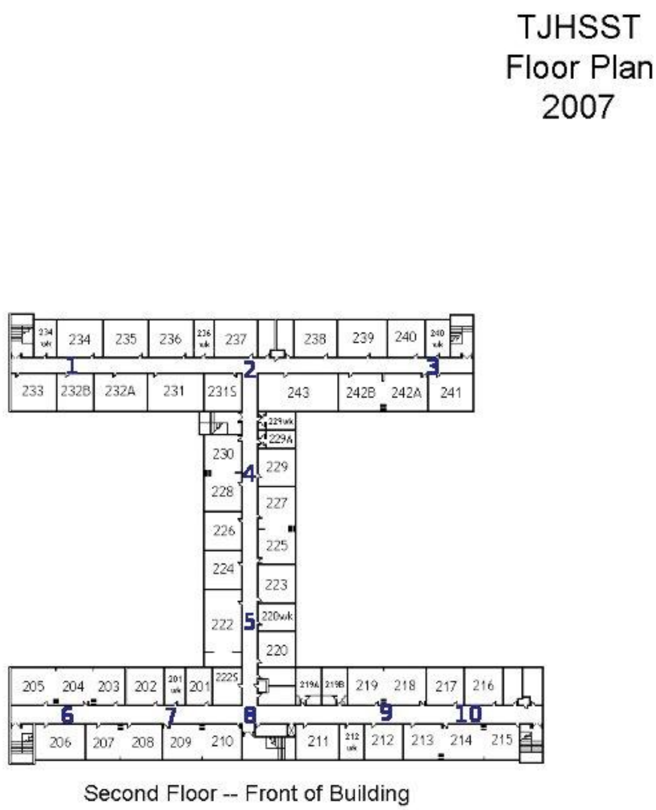

Figure 15: Table showing results of initial experiment.

3.10 Phase 4: Results

The results of the simulation are shown in Tables 16 and 17.

Top 3 Most crowded hallways in the simulation:

1. Upper Front Hallway Intersection Area (8)
2. Entrance Hallway Intersection Area (14)
3. Tech/Gym/Clinic 3-way intersection (11)

Top 3 Least crowded hallways in the simulation:

1. Boys Locker Room Hallway (29)
2. Systems Lab Hallway (19)
3. outside Trailer Path with Accio (25)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	
0	118	10	120	124	72	84	66	12	102	64	0	52	74	14	52	0	94	12	52	34	108	42	142	72	60	60	28	96	0	10	0	0	0	1774
1	8	66	14	54	60	22	56	118	38	40	114	68	8	78	0	158	0	6	0	98	24	128	8	36	8	128	56	8	2	68	84	58	62	1676
2	18	134	36	38	80	96	14	116	36	38	110	12	20	50	64	22	4	44	0	50	54	106	54	54	14	40	68	84	0	76	32	24	32	1620
3	30	32	28	114	56	22	10	48	86	38	50	28	2	122	8	134	10	62	8	30	70	42	50	44	16	64	42	108	0	30	24	48	18	1474
4	50	26	48	50	80	72	2	52	36	78	108	4	4	32	24	62	4	66	6	42	8	34	96	6	0	42	36	32	0	46	36	4	20	1206
5	18	38	16	20	24	16	36	72	36	42	88	14	0	128	6	60	18	52	6	50	18	20	38	20	14	32	6	52	0	62	38	14	26	1080
6	4	52	22	4	8	22	2	118	32	6	64	40	4	122	74	20	4	32	8	46	32	68	14	4	10	22	34	8	0	50	8	4	6	944
7	34	10	8	20	48	6	52	46	30	2	12	40	40	38	38	70	8	16	16	16	30	32	56	26	16	48	14	30	0	22	2	8	12	846
8	16	0	32	50	22	48	26	4	4	16	0	6	28	0	30	0	42	6	12	6	6	0	20	30	16	0	4	12	0	12	0	0	0	448
	296	368	324	474	450	388	264	586	400	324	546	264	180	584	296	526	184	296	108	372	350	472	478	292	154	436	288	430	2	376	224	160	176	

Figure 16: Table showing results of experiment.

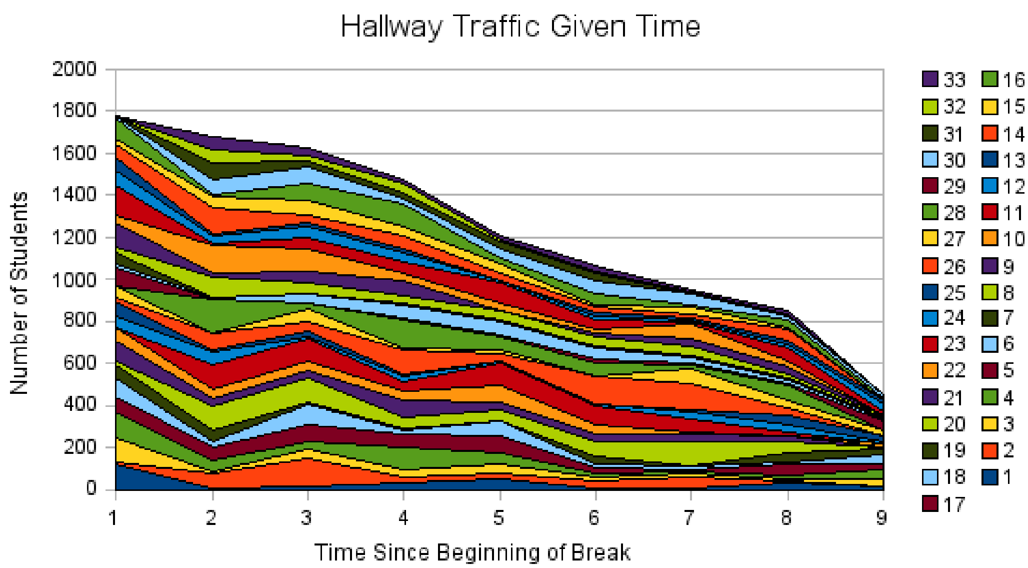

Figure 17: Graph showing results of experiment.

3.11 Phase 4: Analysis

The results of the simulation showed that:

1. All students find their destination location before their next class starts,
2. Students take much more direct paths to their next class,
3. Students arrive at their next class more quickly.

Overall, the results of the simulation are accurate compared to observation of and experience with TJHSST hallway traffic. The code works and prints out the correct output. In the Phase 4 simulation, students head more directly to their destination and find it more quickly than they did in Phase 3.

4 Recommendations

The following is possible for future research:

1. Utilize the TJHSST hallway simulation to analyze traffic during an emergency exit from TJHSST,
2. Change the input data to analyze other schools,
3. Expand the program to simulate a traffic on special events or during summer school.

References

[1] Olivia Kotkova. "Traffic Dynamics in Scholastic Environments." 2007.

[2] Peter Riggs. "Hallway Traffic Simulator." 2007.

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