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Statistical Analysis of Somalian Pirate Activity through Simulation Software

Brett William Harris Melton

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by

Brett William Harris Melton

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Honors Capstone Director: Dr. Harry Delugach

Brett Melton
_____ May 4, 2020
Student Date

_____
Director Date

_____
Department Chair Date

_____
Honors College Dean Date

HONORS COLLEGE
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Honors College
Frank Franz Hall
+1 (256) 824-6450 (voice)
+1 (256) 824-7339 (fax)
honors@uah.edu

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Brett William Harris Melton_____
Student Name (printed)

Student Signature

May 4, 2020_____
Date

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Abstract

In my CS 499 course, my group was assigned a project called “Somalian Pirate Simulation”. The basic synopsis of the project was to develop software that ran a simulation between cargo ships, patrol ships, and pirate ships using grid-based movement and writing output of all interactions occurring between the entities to screen at the same time. The simulation can be run at various speeds such as 1x, 2x, 5x, and 10x. All the entities were set to have a static probability to be created on the map such as cargo ships having a 50% chance to be created every second, while pirates may only have 20% chance. However, as part of my Honors Capstone, I was able to work with my project director to make the probability be something that was able to be edited by a user as an additional requirement to the project. This feature would allow the software to produce different scenarios to test what possible outcomes could occur based on increased or decreased pirate activity in an area. It also demonstrates how much patrol ships should be deployed to combat pirate activity.

The purpose of this paper is to use the aforementioned software to test how changes in the frequency of certain ships has an effect on pirate activity in the Gulf of Aden. By examining situations such as increase or decrease of trading ships or an increase in naval patrols of the gulf, we can examine if the outcome of the simulation reflects current events.

Introduction

Before I go into the statistical analysis behind the simulation, it is important to list the program requirements and how it functions. The simulation runs on a grid of 100 x 400 squares. Cargo ships enter the map from the west, patrols enter from the east, and pirates enter from the south. Once a ship has moved off of the map, it removes itself from the program. Each ship type has unique methods of movement and interactions with other ships. Cargo must move directly east, pirates move directly north to intersect the cargo ships' routes, and patrols move west to attempt to intercept pirate vessels. If a pirate is within 1 square of a cargo ship, it captures the ship and forces it to go south to escape to mainland. A patrol ship can rescue a captured cargo ship if it gets within 3 squares of it and also defeats any pirates within 3 squares. The simulation records the total amount of each ship that entered the map, how many ships are currently on the map, how many cargo ships are captured and rescued, and how many pirates have been defeated by passing patrols. Using this data alongside various probabilities can produce interesting scenarios that can help distinguish the minimum amount of patrol ships needed to defend cargo ships against pirates as well as how dangerous pirates become if their numbers increase significantly.

As a note, it is also important to understand that this simulation only tests ideal weather conditions as a baseline and does not take severe weather conditions into account as per the program requirements. Another crucial factor to consider, is that the data produced at the beginning of the simulation is not indicative of future data in later parts of the simulation. This is due to the fact that the map is not fully populated with ships at the

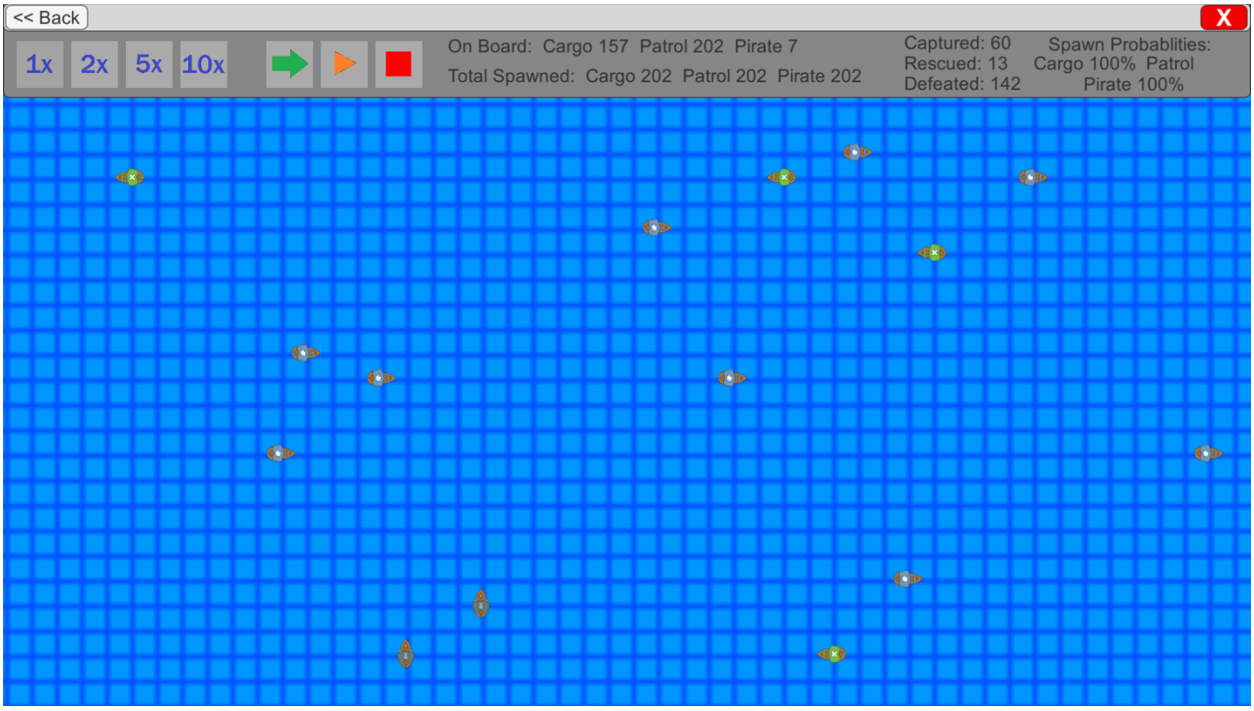
start of the simulation and it takes 200 seconds at time speed of 1x for all ships to reach the opposite end of map. Once all ships have been given the allotted time to exit the region, then the trends of data will begin to stabilize.

As for programming difficulties that I, as well as my team, ran into, we first had to determine what method of probability distribution would be most appropriate. One option was to give each ship type its own probability for entering the map without regard for the other ships i.e. Cargo at 70%, Patrols at 50%, and Pirates at 60%. Another method would have been to distribute the probability between the three ship types which would mean that their total probability to enter the map would not surpass 100%. i.e. Cargo% + Patrol% + Pirate% = 100%. My team came to the conclusion that the probability method that would be most appropriate would be the former approach as the ships should all be independent in their creation without being influenced by the values assigned to other ships, it would create a wider variety of simulations, and it would allow multiple ships to enter the region simultaneously rather than one at a time.

I will introduce multiple scenarios that will test for trends in the simulation data. The important feature to look for in these tests is to see at what point a trend begins to change.

Scenario 1 – Cargo 100%, Patrol 100%, Pirate 100%

To begin, it is important to establish data using a control scenario. In this scenario, I will analyze how the ships interact when all each ship type enters the map equally at the same rate.

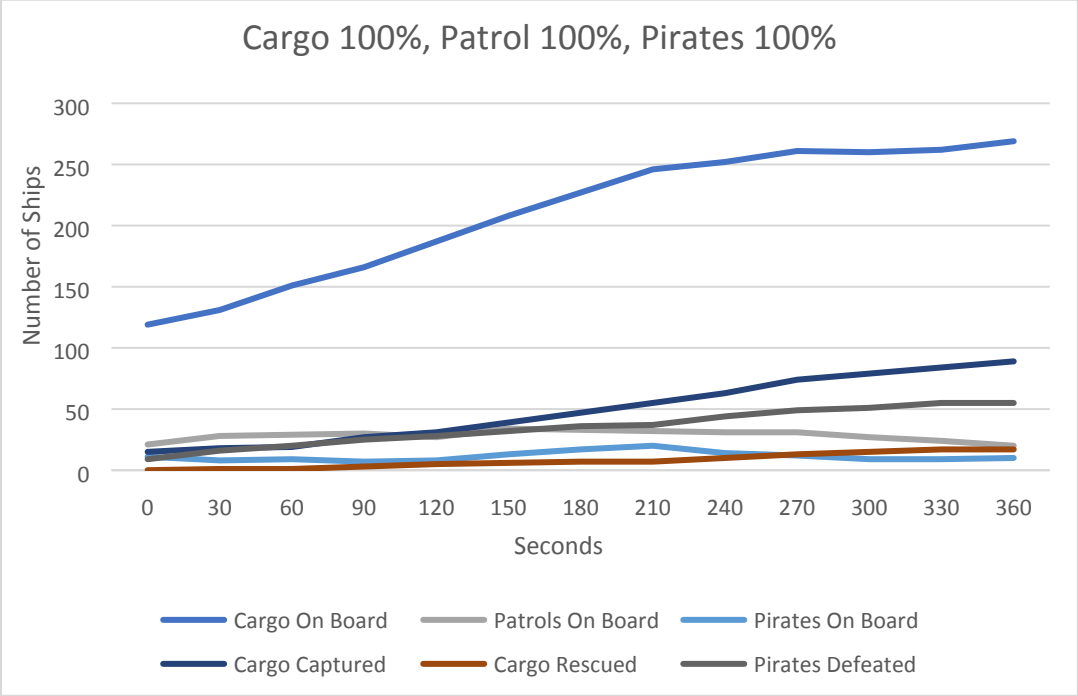


The image above shows a small portion of the map once it has been fully populated. This data will be used as starting point and data will be collected 30 seconds apart to see the change in trends

To clarify some information in the table below, “On Board” refers to the fact of how many of a particular ship type is currently within the region of the gulf. Once a ship exits the map or is destroyed, they are no longer considered “On Board”. However, an important detail is that even if a cargo ship has been captured by pirate, it is still considered “On Board” until the pirate sails off the map with them. “Spawned” means that a ship has entered the map.

Also, to provide better understanding of how simulation time corresponds to real life time, I will explain as well. While the map is technically 100 x 400 squares, it would be more accurate to say that it is 100 x 400 nautical miles and each square represents a single square nautical mile of the gulf. Cargo ships move 1 knot east every time step, so 30 units of time equals 30 knots of movements for all cargo ships. I discovered that cargo ships can sail around 15 knots which means that every time iteration shown in the table below is the equivalent of 2 hours passing.

Time	Cargo On Board	Cargo Spawned	Patrols On Board	Patrol Spawned	Pirates On Board	Pirates Spawned	Cargo Captured	Cargo Rescued	Pirates Defeated
0	157	202	202	202	7	202	60	13	142
30	185	233	202	233	7	233	66	16	170
60	213	263	202	263	10	263	72	17	195
90	236	293	202	293	0	293	80	20	229
120	263	323	202	323	2	323	88	25	251
150	289	353	202	353	1	353	98	30	278
180	315	383	202	383	0	383	107	36	306
210	341	413	202	413	0	413	114	39	332
240	354	443	202	443	0	443	120	43	361
270	360	473	202	473	0	473	137	52	382
300	356	503	202	503	0	503	149	60	408
330	362	533	202	533	0	533	158	64	437
360	365	563	202	563	0	563	167	72	465
Average	292	382.9231	202	382.9231	2.076923	382.9231	108.9231	37.46154	304.3077
Average Difference	17.33333	30.08333	0	30.08333	-0.58333	30.08333	8.916667	4.916667	26.91667



Some important trends have been discovered through this control scenario. First, as the patrol ships currently do not have any entity that aids in their removal, this results in patrol ships entering the map at the same rate that they exit which explains their stable population. Second, due to the presence of patrol ships, pirate ships are rarely able to stay on the board before they are defeated, but still managed to capture some cargo ships that

crossed near the bottom edge of the map. Despite 82.5% of the entire pirate population being defeated by patrol ships, pirates still managed to capture cargo ships at twice the rate of patrol ships rescuing them.

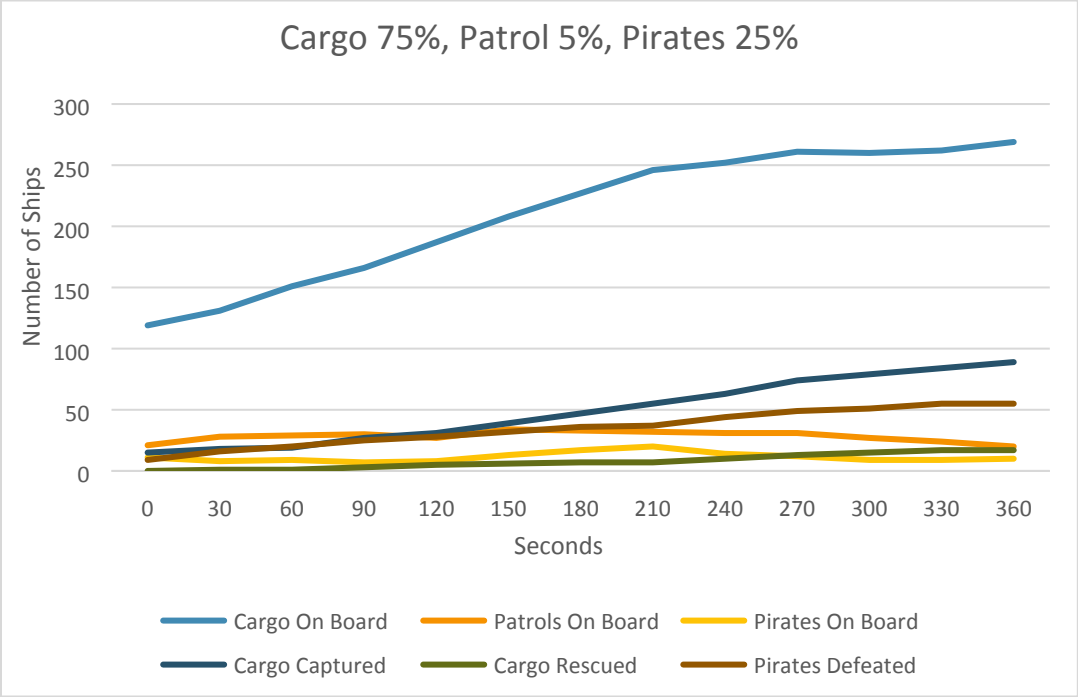
Scenario 2 – Cargo 75%, Patrol 5%, Pirate 25%

I hypothesize this scenario to be the most realistic simulation compared to modern anti-pirate approaches handled by naval forces.

The reasons why I believe this to be the most realistic is based on a few key aspects. First, the average number of ships that travel through the Gulf of Aden every year is estimated to be 33,960 according to an article from the SPF, the Sasakawa Peace Foundation, a private non-profit that works alongside Japan's Ocean Policy Research Foundation on marine issues. However, another number listed by an article from the U.S. Naval Institute states that the amount of annual ships is actually quite lower, around 20,000 cargo ships. Even though both figures seem to have a strong claim of authority, I will assume the U.S. Naval Institute's number as it is more recent. This number means that there should be approximately 93 ships passing through gulf daily. From the same website, it also states that the amount of naval patrol vessels deployed by EUNAVFOR, which is short for European Naval Force, is between 10 to 15. Additionally, the total number of Somalian pirates in this region isn't an extraordinarily high number considering that at the height of pirate activity from 2010 to 2014 the number of pirate attacks reached 358, according to statista.com, which would mean that there was 25% chance every day for pirates to attack a cargo ship.

Time	Cargo On Board	Cargo Spawned	Patrols On Board	Patrol Spawned	Pirates On Board	Pirates Spawned	Cargo Captured	Cargo Rescued	Pirates Defeated
0	122	135	9	9	13	39	18	0	3
30	140	156	11	11	12	42	19	0	4
60	161	180	9	12	13	49	22	0	5
90	178	203	10	15	13	57	31	0	5
120	194	224	11	17	20	69	34	0	5
150	213	249	15	21	23	80	44	0	7
180	228	273	14	22	13	84	52	1	10
210	245	297	16	25	16	95	61	1	11
240	259	318	14	25	13	98	68	2	12
270	263	337	13	25	8	101	72	3	13
300	264	360	12	27	5	107	80	4	14
330	266	382	11	29	6	112	84	4	14
360	270	408	10	31	4	118	90	4	15

Average	215.6154	270.9231	11.92308	20.69231	12.23077	80.84615	51.92308	1.461538	9.076923
Average Difference	12.33333	22.75	0.083333	1.833333	-0.75	6.583333	6	0.333333	1



Within this scenario, we can see that the average number of patrol ships active in the gulf at any one time is around 12 ships which falls into the same range reported by EUNAVFOR. The majority of cargo ships pass through safely while about 22% of them are attacked by pirates. Approximately 13% of the pirates were defeated by patrols and while rescues do occur, they only have a success rate of 4%.

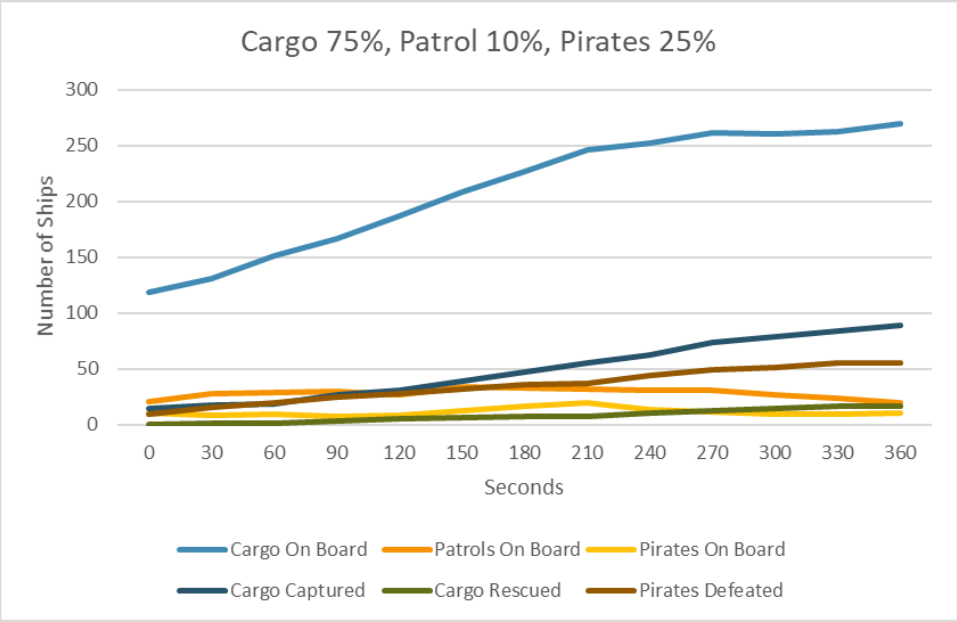
This data could be used to reinforce the idea that more naval patrols might need to be deployed if we want to see a higher increase in the number of pirates defeated and cargo ships rescued. Next, it would be highly interesting to see the effect of doubling the amount of patrol vessels would have on combating pirate activity.

However, one issue with the simulation is that the current probability value for cargo ships is way too high. Using the USNI's number of 20,000 cargo ships annually, we should expect an average of approximately 55 cargo ships to be passing through the gulf daily. Instead, the value above showed 408 cargo ships entered the gulf which is 8 times larger than our average value in reality.

Scenario 3 – Cargo 75%, Patrol 10%, Pirate 25%

Now with the probability of patrol ships spawning being doubled, we can observe whether or not this increase has any positive effect of defeating pirates and rescuing civilian ships.

Time	Cargo On Board	Cargo Spawned	Patrols On Board	Patrol Spawned	Pirates On Board	Pirates Spawned	Cargo Captured	Cargo Rescued	Pirates Defeated
0	119	131	21	21	11	43	15	0	9
30	131	148	28	28	8	53	18	1	16
60	151	168	29	31	9	58	19	1	20
90	166	186	30	35	7	65	27	3	25
120	187	210	27	38	8	73	31	5	28
150	208	236	34	49	13	88	39	6	32
180	227	261	33	52	17	102	47	7	36
210	246	287	32	56	20	113	55	7	37
240	252	310	31	59	14	124	63	10	44
270	261	338	31	62	12	132	74	13	49
300	260	356	27	63	9	135	79	15	51
330	262	383	24	65	9	142	84	17	55
360	269	407	20	69	10	147	89	17	55
Average	210.6923	263.1538	28.23077	48.30769	11.30769	98.07692	49.23077	7.846154	35.15385
Average Difference	12.5	23	-0.08333	4	-0.08333	8.666667	6.166667	1.416667	3.833333



The important statistics that we need to acknowledge to see if there was a true positive increase in patrol vessel performance is both the total amount of rescue out of the total

number of captures and the percentage of the pirate population that was defeated by the naval patrols. Previously, the success rate of rescues before was only 4%. Now the total number of rescues was 17 out of 89 captures which results in a success rate of 19%. By doubling the amount of naval patrol, the number of rescues quadrupled. Also, the patrol ships were also able to defeat 55 pirate ships out of a total of 147 which is approximately 37%. With this increase, the amount of pirate defeated almost tripled.

Statistical Analysis of Current Events

According to the International Maritime Bureau, sea piracy activity is declining. In 2019, there were a total of 119 incidents reported of vessels interacting with pirates. Back in 2018, the number of incidents was 156. While the frequency of pirate attacks appears to be declining, it is important to be cautious of sudden spikes of pirate activity and sending out a patrol force big enough to handle it.

Conclusion

This program was able to produce various outcomes according to the requirements given and provide outputs that are useful for statistical analysis. While I believe that further details could have been added to make the simulation more dynamic such as weather conditions and path finding, I think that my team and myself were able to effectively deliver software that could be useful in visualizing pirate activity within the Gulf of Aden.

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David Cook <dac0010@uah.edu>

Brett Melton's Honors Capstone

Harry Delugach <delugach@uah.edu> Tue, May 12, 2020 at 9:59 AM
To: William Wilkerson <wilkerw@uah.edu>, David Cook <dac0010@uah.edu>
Cc: Brett Melton <bwm0009@uah.edu>

Attached is my approved version of Brett Melton's Honors Capstone report. He has been responsive to my comments and suggestions, and has presented his results in an understandable and informed way.

Please consider this my approval of his Honors Capstone.

Sincerely,

Harry S. Delugach, Ph.D.

Associate Professor
Computer Science Dept.
OKT N-351
University Of Alabama In Huntsville
Huntsville AL 35899 U.S.A.
voice: +1 256.824.6614 fax: +1 256.824.6239
delugach@uah.edu
http://www.cs.uah.edu/~delugach

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