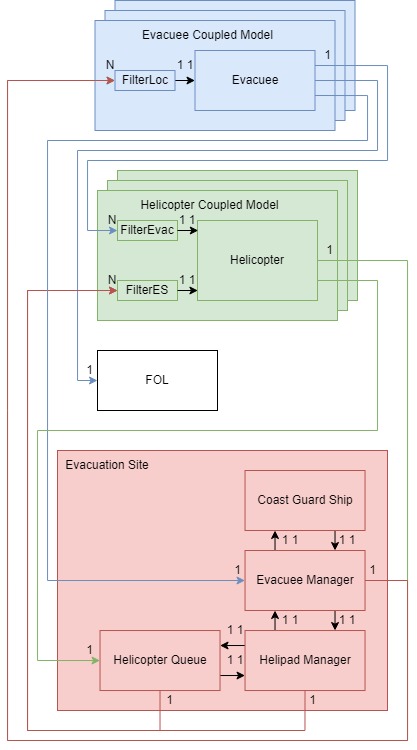
**Conceptual Model Design**

**Description**

I am expanding upon the model I created for assignment one by adding the coast guard ship from the paper, “Modeling a Major Maritime Disaster Scenario using the Universal Modeling Framework for Sequential Decisions” [1]. In the paper a coast guard ship arrives to provide medical aid to the evacuees, but has a maximum capacity of 50 people standing. Policies for who to load and unload the ship are based upon the triage status of the evacuees. By adding this model of the coast guard ship I aim to replicate the results found from the case study conducted in the paper.

**Model**



**Components**

It has the same components as the earlier model but with an added Coast Guard Ship atomic model that accepts a Boolean input from the Evacuee Manager model and sends a Boolean output to the Evacuee Manager. In this way it is a part of the Evacuation Site coupled model. The coast guard ship model keeps track of when the coast guard ship arrives, when it loads people on board, and when people must disembark. The evacuee manager model manages the loading and unloading policies. The evacuee model now has a new location represented by the coast guard ship. If they are in the ship their triage status improves instead of deteriorating.

**References**

[1] M. Rempel, “Modelling a major maritime disaster scenario using the universal modelling framework for sequential decisions”, Safety Science, Volume 171, 2024, 106379, ISSN 0925-7535, <https://doi.org/10.1016/j.ssci.2023.106379>.

**Specification Document**

**Coupling Scheme**

|  |  |
| --- | --- |
| **Atomic Models** | **Coupled Models** |
| FilterLoc, FilterEvac, FilterES, Evacuee, Helicopter, FOL, Helicopter Queue, Helipad Manager, Evacuee Manager, Coast Guard Ship | Evacuee Coupled, Helicopter Coupled, Evacuation Site |

The coupling scheme is unchanged except for the coast guard ship model now being coupled with the evacuee manager. It has one Boolean input from the evacuee manager, and one Boolean output to the evacuee manager.

**Coupled Models Formal Specification**

Only the Evacuation Site is different so only it will be listed here.

Evacuation Site=

< X, Y, {HelicopterQueue, HelipadManager, EvacueeManager, CoastGuardShip}, EIC, EOC, IC, SELECT >

X = inEvac, inHelo

Y = outHelo, outEvac

EIC = {(EvacuationSite.inEvac, EvacueeManager.inEvac), (EvacuationSite.inHelo, HelicopterQueue.inHelo)}

EOC = {(HelicopterQueue.outHelo, EvacuationSite.outHelo), (HelipadManager.outHelo, EvacuationSite.outHelo), (EvacueeManager.outEvac, EvacuationSite.outEvac)

IC = {(HelicopterQueue.outHM, HelipadManager.inHQ), (HelipadManager.outHQ, HelicopterQueue.inHM), (HelipadManager.outEM, EvacueeManager.inHM), (EvacueeManager.outHM, HelipadManager.inEM), (EvacueeManager.outCGS, CoastGuardShip.in), (CoastGuardShip.out, EvacueeManager.inCGS)}

SELECT : ({HelicopterQueue, HelipadManager, EvacueeManager, CoastGuardShip}) = HelicopterQueue

({HelipadManager, EvacueeManager, CoastGuardShip}) = HelipadManager

({EvacueeManager, CoastGuardShip}) = CoastGuardShip

**Atomic Models Formal Specification/Model Testing**

Only the Evacuee, Evacuee Manager, and Coast Guard Ship models are different, so only those models’ DEVS graphs are shown here.

Evacuee Model

A diagram of a company

Description automatically generated

Evacuee Manager model

A diagram of a company

Description automatically generated

Coast Guard Ship

A diagram of a coast guard ship

Description automatically generated

Unit tests were completed for each atomic model. Then the unit tests for each coupled model were updated and completed successfully. Lastly integration testing was completed for the top model where bugs were found in the Evacuee Manager model and corrected. One such bug was how more people were being loaded on to the ship than the ship’s capacity should allow. This was an easy fix completed by replacing the max capacity value with the capacity that would be currently available on board the ship every time evacuees were loaded on board.

**Experiments**

Experiment type 1 from the paper, “Modeling a Major Maritime Disaster Scenario using the Universal Modeling Framework for Sequential Decisions” revolves around testing the impact of deploying 1, 3, or 6 helicopters on the number of lives saved, given the coast guard ship might arrive immediately or at any time up to a week later. Like in the paper I plan to collect the expected number of lives saved with each experiment type. In the paper they conduct 30 trials per experiment type as parts of the model are decided randomly. This is likely because under the central limit theorem this is considered the minimum number of samples to have a normal distribution. I would like to have a similar if not smaller confidence interval than those obtained for each experiment type in the paper, but when I conduct only 30 trials the confidence interval I receive is higher. As each simulation takes less than a second to run I have chosen to run 100 trials for each experiment type. The confidence intervals are now within the desired range. The following table shows the expected values and their 95% confidence intervals for each experiment type.

|  |  |  |  |
| --- | --- | --- | --- |
| 100 Trials Each | Expected Number of Lives Saved (95% CI) | | |
| Ship Arrival Time (h) | 1 Helo | 3 Helos | 6 Helos |
| 0 | 167.18 ± 0.7153 | 195.42 ± 0.8017 | 209.18 ± 0.9127 |
| 12 | 159.71 ± 0.6859 | 187.82 ± 0.9093 | 201.39 ± 0.8940 |
| 24 | 153.06 ± 0.6806 | 179.61 ± 0.9108 | 194.27 ± 0.9479 |
| 36 | 143.75 ± 0.6606 | 170.93 ± 0.7282 | 185.73 ± 0.8626 |
| 48 | 135.56 ± 0.5397 | 163.89 ± 0.7433 | 178.71 ± 0.8204 |
| 60 | 127.12 ± 0.5615 | 157.3 ± 0.7611 | 172.19 ± 0.9128 |
| 72 | 119.51 ± 0.5095 | 147.61 ± 0.8240 | 166 ± 0.8486 |
| 84 | 114.1 ± 0.5692 | 145.98 ± 0.5863 | 165.78 ± 0.7743 |
| 96 | 104.81 ± 0.7040 | 146.03 ± 0.7261 | 166.69 ± 0.8580 |
| 108 | 101.8 ± 0.5770 | 145.75 ± 0.6809 | 166.89 ± 0.7962 |
| 120 | 101.9 ± 0.5651 | 145.44 ± 0.6676 | 166.81 ± 0.9677 |
| 132 | 101.79 ± 0.5511 | 146.04 ± 0.7210 | 166.63 ± 0.7784 |
| 144 | 101.85 ± 0.5678 | 145.64 ± 0.7970 | 167.25 ± 0.7896 |
| 156 | 101.73 ± 0.5029 | 144.99 ± 0.7565 | 167.06 ± 0.8258 |
| 168 | 101.94 ± 0.5646 | 145.71 ± 0.6933 | 166.53 ± 0.7732 |
| No Arrival | 101.43 ± 0.5573 | 146.04 ± 0.7036 | 166.33 ± 0.7968 |

Table #1: Experiment 1 results from the DEVS model

A table with numbers and numbers

Description automatically generated

Table #2: Experiment 1 results from the paper [1]

The results appear slightly different from the results obtained in the paper, so I will check if the difference is significant by using a Mann-Whitney U test. I chose this test because the results don’t appear to be normally distributed and the sample size is less than the central limit theorem’s minimum sample size of 30 for it to be considered normally distributed. This test is also the non-parametric equivalent of the unpaired t-test, so it is suitable for testing if there is a significant difference between the results. The first Mann-Whitney U test was done to compare the results from using one helicopter. With a U statistic of 98 which is greater than the critical U statistic of 75 at an alpha of 0.05 I cannot reject the null hypothesis that these results come from the same distribution, therefore there is no significant difference between them. For the second Mann-Whitney test I compared the results from using 3 helicopters and obtained a U statistic of 72 which is less than the critical U statistic of 75, therefore there I can reject the null hypothesis and there is a significant difference. Lastly, when I conducted the third Mann-Whitney U test where I compared the results from using 6 helicopters, I obtained a U statistic of 59 which is less than the critical U statistic of 75. Therefore, I can say there is a significant difference between the results for 3 and 6 helicopters obtained from the DEVS model in comparison to those obtained from the paper.

It can be seen that the results from the DEVS model converge at the same ship arrival time as those results shown in the paper, except for when 6 helicopters are used and the convergence happens 12 hours earlier in the paper’s results. For each group of results the value they converge to is different from the value the paper’s results converge to. For one helicopter and 6 helicopters there is a difference of around 10 lives, whereas for 3 helicopters the difference is only 2 or 3 lives.

I think these discrepancies between the DEVS model results and the results from the paper might be because of a mistake I made when designing the Helicopter atomic model. In the paper it says that it takes 3 hours total for a helicopter to load individuals from the evacuation site, fly back to the FOL, unload the individuals, and then return to the evacuation site. I must have missed the last part where the time includes the time to return to the evacuation site, because in the DEVS model it currently takes helicopters 3 hours to load individuals, return to the FOL, and unload the individuals. This would thankfully be an easy fix of changing their current travel time from 2.5 hours to 1.25 hours. However, while this is a mistake, it seems that if the helicopters were taking longer to evacuate people fewer lives should have been saved, but in my results that use 3 and 6 helicopters more lives were saved on average than in the results from the paper.

In the future I will continue searching for a fix to validate the results from experiment 1, and then move on to replicating the results from experiments 2 and 3. Though for the purposes of the SYSC 5104 class project this seems sufficient.