

Poznan University of Technology
Faculty of Computing and Telecommunications

Simulation Techniques - project

-Transport Company-

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Task:

- Simulate a transport company, where k trucks with capacity of u units transport cargo goods between the headquarters and n regional depots.
- Goods arrive in batches of size r units, where r is a random variable following normal distribution with mean μ_r and variance σ_r^2 (but the lowest possible size is 0.1 unit and the highest is 10 units).
- In the headquarters the cargo batch destination depot d_n is a random variable following uniform distribution with equal probability for each depot, while the cargo batch destination for all cargo generated in depots is the headquarters.
- The time interval between the arrival (generation) of two consecutive cargo batches is a random variable with exponential distribution and average c_{hq} and c_d for the headquarters and each depot, respectively.
- Cargo batches wait in queues at the headquarters and the depots until they are taken by the next truck going to the destination point of a cargo batch, where the truck destination at the headquarters is selected with strategy S, while for the depots the destination is always the headquarters.
- After the destination is determined the cargo batches destined to this point are loaded in first-in first-out order (FIFO) until the next one exceeds the truck capacity.
- Only full batch can be loaded, assuming there is enough space in the truck.
- In the headquarters there are M loading/unloading platforms, while in each depot there are N loading/unloading platforms, with single platform able to accommodate one truck.
- Trucks upon arrival enter a free platform unless all of them are occupied – in such a case they wait in queue. Then they are unloaded and later loaded, with the loading and unloading time for each cargo batch determined as $r \cdot T_l$ and $r \cdot T_u$, respectively.
- Delivered cargo batches leave the system. Trucks leave the platform according to strategy P.
- The traveling time for each truck between any depot and headquarters follows normal distribution with average μ_t and variance σ_t^2 .

Simulation Parameters

	D1
k	8
u	10
n	6
(μ_r, σ_r^2)	$(2.0, 0.6^2)$
c_{hq}	2.2
c_d	12.3
(M, N)	(3, 1)
T_l	0.5
T_u	0.7
(μ_t, σ_t^2)	$(20.0, 1.6^2)$

Strategies used in the Project:

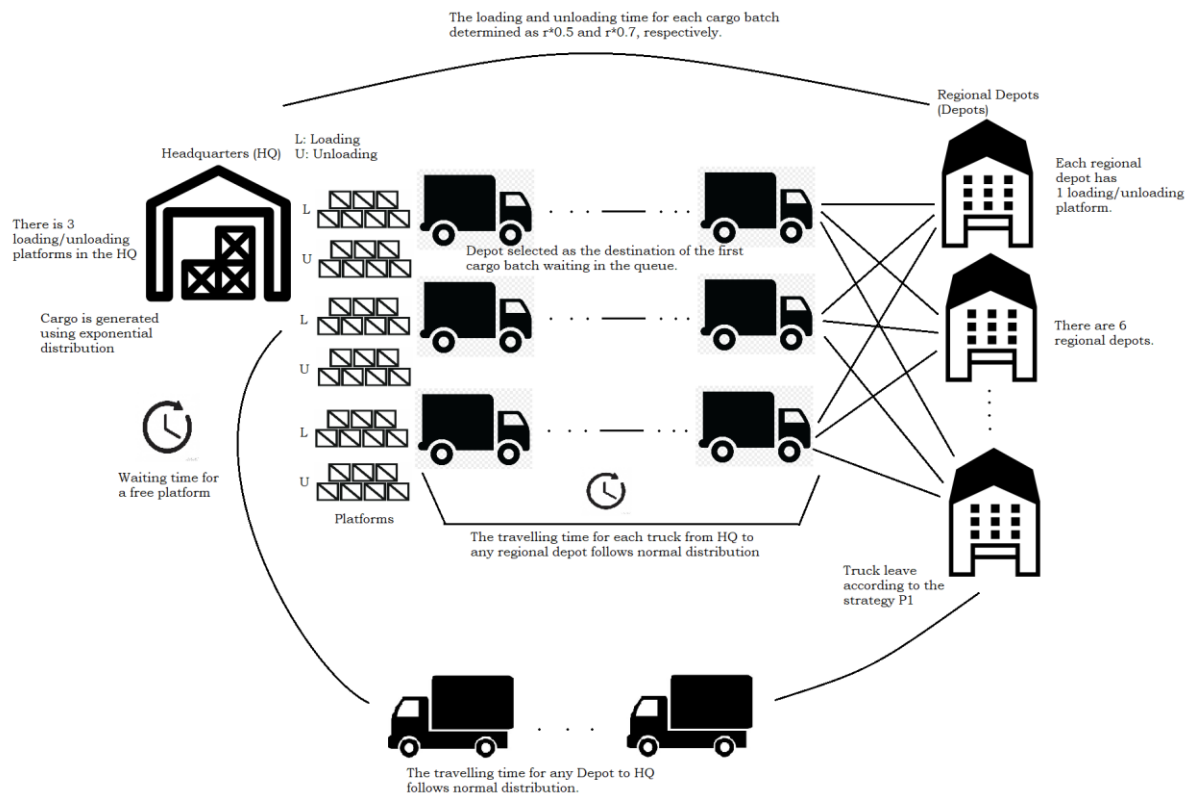
	Destination selection strategy S:
S1	Destination depot is selected as the destination of the first cargo batch waiting in the queue
	Trucks departure strategy P:
P1	Trucks leave headquarters/depot only when the next cargo batch cannot be loaded (exceeds truck capacity)

Method used in the Project:

	Simulation method MT:
MT1	Activity scanning

Simulation Model Scheme

Please find the simulation scheme I prepared below. I believe that it will help you to picture how events will be carried out in your mind and will give you a chance to understand the process better.



Objects and Attributes

Object Name	Description	Attributes
Cargo	This represents the cargo batch that will be traveling to a single location.	<ul style="list-style-type: none"> • ID of the cargo batch object. • Size of the generated cargo batch object (Between 0.1 and 10 units) • Queueing time of a cargo batch (How long time passed while the batch was in queue?) • Travelling time of a cargo batch
Depot	Represents a depot location with one loading/unloading platform and serves the trucks (In my case there is 6 regional depots).	<ul style="list-style-type: none"> • 1 loading/unloading platform. • Queue of cargo batches (They will wait to the next available truck and then will be taken to the destination selected by the strategy S1) • Queue of trucks • Loading/Unloading time is determined by $r*0.5$ and $r*0.7$ • Batch generation interval is a random variable with exponential distribution and average c_d.
HQ	Represents the headquarters location with 3 loading/unloading platforms and serves the trucks.	<ul style="list-style-type: none"> • 3 loading/unloading platforms. • Queue of cargo batches (They will wait to the next available truck and then will be taken to the destination selected by the strategy S1) • Queue of trucks • Loading/Unloading time is determined by $r*0.5$ and $r*0.7$ • Batch generation interval is a random variable with exponential distribution and average c_{hq}.

Truck	Represents the trucks that will travel towards a destination with the goods in it.	<ul style="list-style-type: none"> • ID of the Trucks. • Destination is set to Headquarters as a default option, and for the depots the destination will be chosen as the the destination of the first cargo batch waiting in the queue. • Maximum capacity, it is the maximum units of goods that can be loaded to one of the trucks. • Current capacity of the trucks, so that we can check whether we can load more or not. • Cargo batches that will be carried by the truck. • Service time (Loading/Unloading/Travel times)
TransportCompany	This is the main object class. It will contain all of the other objects required for the simulation to run.	<ul style="list-style-type: none"> • Some parameters will be taken by the user and if user wants user can specify some custom parameters. • Seed generation, a vector of seeds will be generated and will be passed as a parameter to the Simulation object that will be created. • Start of simulation.

Time and Conditional Events

Event Time	Event Type	Description	Event Procedure
Truck Arrival at the HQ or one of the Regional Depots	Time	A truck arrives at a HQ or one of the depots.	Place the truck in a queue at the HQ or Depot.
Start of Service	Conditional	A truck enters one of the platforms starts unloading cargo	If there is a truck in the truckQueue and there is a free platform then check whether the truck is full or not. If not set ready to load as true. If the truck is full then calculate the unloading time and set a new event and end the process.
End of Unloading	Time	A truck finishes unloading	Set the truck status as unloaded. Make the ready to load true and reset the capacity (0).
Start Loading Cargo	Conditional	Start the loading process for the cargo batch that will go to the selected destination.	Check if the controlled truck is ready to load. If so check its current location. Then check if there is cargo that can be loaded in the specified location. If all conditions are met then Set its destination as the destination of the first cargo waiting in the queue. Calculate the loading time and set a new

			event of loading event and make isreadytoload false.
End of Loading	Time	Finish loading Cargo	If conditions are met then complete loading and set the status as idle.
Truck Departure	Conditional	Loaded truck leaves the platform	If the conditions are met it means that the truck is loaded and can be removed from the platform. Set new truck arrival event for the calculated time.
Cargo Generation	Time	New cargo batch arrives at the given location (Depots/HQ)	Generate the cargo batch. Decide to the destination of the cargo batch. Place it in the queue.

Simulation Results

In the beginning I asked user to enter the duration of the simulation and initial time. Also, if user wants to use his/her own generation times then there is a possibility to do that. Lastly there is an option to create a graph of initial phase. In order to be sure that the simulation works properly I run it 10 times at once. Actually, I had so much problems doing that but then discovered that the problem is related to the updateTime() method I used. Then I put more reasonable values for the maximum simulation time and finally was able to succeed.

```
Please indicate the length of the simulation time:22
Please indicate the duration of the initial time:0
Do you want to use time specified by you to generate cargo? (1 = yes, 0 = no):0
Do you want to generate an initial phase graph? (1 = yes, 0 = no):1
Please indicate the number of simulations you'd like to execute:10
```


Some parts of output: (Randomly chosen)

```
Truck: 2 has arrived to depot: 5 with time: 19.8059
Truck: 2 has been added to the platform of the depot: 5 and the truck is empty
Truck: 2 is about to complete loading cargo in depot: 5 with time: 0
Truck with id: 2 is about to complete loading cargo and it is ready to go.
Truck: 2 leaves depot: 2
Truck with id: 2 finish : 39.3861
Truck: 4 has arrived to depot: 3 with time: 19.9245
Truck: 4 has been added to the platform of the depot: 3 and the truck is empty
Truck: 4 is about to complete loading cargo in depot: 3 with time: 0
Truck with id: 4 is about to complete loading cargo and it is ready to go.
Truck: 4 leaves depot: 4
Truck with id: 4 finish : 39.4188
Truck: 5 has arrived to depot: 2 with time: 20.3557
Truck: 5 has been added to the platform of the depot: 2 and the truck is empty
Truck: 5 is about to complete loading cargo in depot: 2 with time: 0
```

```
Simulation 10 starts....
The simulation just started
FYI, The stats have been reset.
Truck: 0 has arrived to HQ and time: 0
Truck: 1 has arrived to HQ and time: 0
Truck: 2 has arrived to HQ and time: 0
Truck: 3 has arrived to HQ and time: 0
Truck: 4 has arrived to HQ and time: 0
Truck: 5 has arrived to HQ and time: 0
Truck: 6 has arrived to HQ and time: 0
Truck: 7 has arrived to HQ and time: 0
Truck: 0 has been added to one of the platforms in HQ and the truck is empty:
Truck: 2 leaves HQ
Truck with id: 2 finish : 16.7334
Truck: 3 leaves HQ
Truck with id: 3 finish : 21.8372
Truck: 4 leaves HQ
Truck with id: 4 finish : 20.2892
Truck: 5 leaves HQ
Truck with id: 5 finish : 20.4087
Truck: 6 leaves HQ
Truck with id: 6 finish : 22.9528
```

```
Truck: 7 has arrived to depot: 1 with time: 21.3443
Truck: 7 has been added to the platform of the depot: 1 and the truck is empty
Truck: 7 is about to complete loading cargo in depot: 1 with time: 0
Truck with id: 7 is about to complete loading cargo and it is ready to go.
Truck: 7 leaves depot: 7
Truck with id: 7 finish : 41.4247
The average queuing time of a cargo batch: nan
The average number of queued cargo units in headquarters: 5
Depots:
0 : 2.5
1 : 1
2 : 2
3 : 1.5
4 : 1
5 : 1.5
the average transport time for a cargo batch: nan
the average utilization of truck: 2.41748

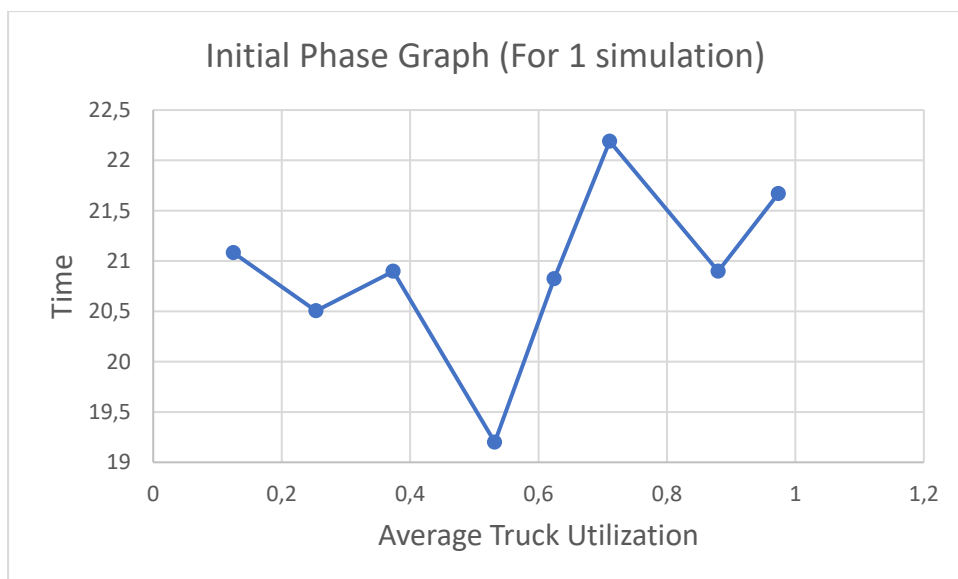
Process finished with exit code 0
```

Statistical Results:

Simulation Nr.	Average Number of Queued Cargo Units (HQ)	Average Number of Queued Cargo Units (Average of Depots)
1	3.28571	1.75
2	3.14286	2.5
3	4	1.8
4	5.09091	2.083
5	6	2.167
6	6	2.167
7	5.38462	1.5
8	6.75	1.5
9	4.91667	2
10	4.27273	1.875

Simulation Nr.	Average Queueing Time of a Cargo Batch	Average Utilization of Truck
1	0.245871	1.46837
2	1.88375	0.996255
3	0.794369	1.58132
4	0.21269	0.874774
5	0.0530326	1.26312
6	8.32852	1.05
7	5.03165	0.915138
8	5.22729e-318	1.35497
9	3.32546	1.43366
10	0.736621	1.5951

Initial Phase Graph



Conclusion: It wasn't easy to construct but when I pay enough attention, I was finally able to make it. I was working on multiple languages for a long time and it wasn't easy to remember C++ syntax with the other languages I should use almost every day so I was doing so many mistakes and going backwards again and again but at the end I was able to make a working project with the given features.