CPEN 405: ARTIFICIAL INTELLIGENCE COURSE PROJECT TASK 2 GROUP 13

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1 INTRODUCTION

This is a linear Programming problem involving a hospital in California with a decentralized structure for its various clinics and departments. As a result of this confusing and decentralized system, parents do not know the most appropriate clinic or department they must take their ailing kids to, parents must on their own, search for correct phone numbers for the various departments and clinics etc. In an attempt to solve this problem, the hospital decided to centralize its departments and clinics by dedicating a particular call center to receive appointment and registration related calls. The call center is to be operational from 7AM to 9PM of each weekday. In this report, we attempt to find the most optimal way for the hospital to run this call center in terms of the cost of labor.

2 PROBLEM STATEMENT

2.1 Parents do not know the most appropriate department or clinic they have to take their ailing kids due to the decentralized structure of the hospital.

2.2 The hospital does not publish phone numbers of all clinics and departments; hence parents have to go through a lot of stress to find out the correct phone numbers of these clinics and departments on their own.

2.3 The various clinics and departments do not communicate with each other, making referrals very difficult.

These problems are due to the decentralized appointment and registration process. In an attempt to solve this, we use a centralized process, which is devoting one call center to all appointments and registration.

3 THE CENTRALIZATION PROCESS

3.1 The call center should operate from 7Am – 7PM during the weekdays.

3.2 To find the number of calls expected on each day, Creative Chaos Consultants decided to add all registration and appointment-related calls from all departments and clinics. They accounted for the missed calls during the data collection.

3.3 They also accounted for repeated calls coming from the same parent to different departments due to the decentralized structure.

3.4 SUMMARY OF CALLS EXPECTED

WORK SHIFT	AVERAGE NO. OF CALLS
7AM – 9AM	40 calls per hour
9AM – 11AM	85 calls per hour
11AM – 1PM	70 calls per hour
1PM – 3PM	95 calls per hour
3PM – 5PM	80 calls per hour
5PM – 7PM	35 calls per hour

7PM – 9PM	10 calls per hour

3.5 Lenny took interest in:

a). % Of calls from Spanish speakers = 20%

b). It was determined that a call operator could process an average of 6 calls per hour.

c). Full-time workers could work 8 hours per day, but only spend 4 hours a day on phone by switching between answering phone calls and doing the paperwork. Full-time workers can begin their first shift from 7AM-9AM or from 9AM-11AM or from 11AM-1PM or from 1PM-3PM or from 3PM-5PM.

d). Full-time workers can speak either English or Spanish but none of them is bilingual.

e). Full-time workers are paid $10 per hour for work done before 5PM and $12 after 5PM.

f). Part-time workers only work for 4 hours, answering calls only.

g). Part-time workers only speak English.

h). Part-time workers start work at 3PM - 5PM or 5PM – 7PM.

PROBLEM FORMULATION FOR THE CENTRALIZATION PROCESS

Lenny, the manager of the hospital, wants the most optimal way of running this call center, and by optimal, we mean the minimal cost of paying employees who are going to be operating the call center. The hospital has full-time workers, part-time workers and expects calls from both English and Spanish speaking people. The description for each of these four parameters are given above.

The problem here is to find the minimal cost of running this call center for the hospital considering the number of hours spent on phone by the call operators.

SOLUTION APPROACH AND ALGORITHMS

We are going to attempt to solve this problem, that is finding the minimal cost by first generating the objective function and using both Genetic and Simulated Annealing algorithms to find the most optimal cost of running the call center.

Since the goal is to find the minimal cost of running this call this center, we consider parameters that directly affect the cost at which the hospital will run the call center, and by carefully analyzing these parameters, we will arrive at the objective function.

To carefully analyze this problem, we take it shift by shift.

1st Shift (7AM-9AM): From the table of summary of calls expected, we observe that 40 calls are expected per hour in this shift. Given that 20% of the expected calls are from Spanish speakers, we can derive that 8 of the calls will come from Spanish speakers while 32 of the calls will be from English speakers. Having been told that a call operator can process an average of 6 calls in an hour, we make these determinations;

Number of English-speaking operators = 32 / 6

Answer = 5.3

Since we cannot have a fractional human being, we round it up to 6.

Number of Spanish-speaking operators = 8/6

Answer = 1.3, approximately 2.

The operators in this shift will all be full-time workers since the part-time workers start their first shift at 3PM. Also, the operators in this shift will start their second shift at 11AM-1PM.

2nd Shift (9AM-11AM): From the table of summary of calls expected, we observe that 85 calls are expected per hour in this shift. Given that 20% of the expected calls are from Spanish speakers, we can derive that 17 of the calls will come from Spanish speakers while 68 of the calls will be from English speakers. Having been told that a call operator can process an average of 6 calls in an hour, we make these determinations;

Number of English-speaking operators = 68 / 6

Answer = 11.33

Since we cannot have a fractional human being, we round it up to 12. This number,12, is the required number of English-speaking operators for this shift but we can have more than 12 and the constraints will still be met. We are therefore deciding to go by 13 English-speaking operators for this shift.

Number of Spanish-speaking operators = 17/6

Answer = 2.83, approximately 3.

The operators in this shift will all be full-time workers since the part-time workers start their first shift at 3PM. Also, the operators in this shift will start their second shift at 1PM-3PM.

3rd Shift (11AM-1PM): From the table of summary of calls expected, we observe that 70 calls are expected per hour in this shift. Given that 20% of the expected calls are from Spanish speakers, we can derive that 14 of the calls will come from Spanish speakers while 56 of the calls will be from English speakers. Having been told that a call operator can process an average of 6 calls in an hour, we make these determinations;

Number of English-speaking operators = 56 / 6

Answer = 9.33

Since we cannot have a fractional human being, we round it up to 10.

Number of Spanish-speaking operators = 14/6

Answer = 2.33, approximately 3.

The operators in this shift will be made of the operators of the 7AM-9AM shift in addition to those who take their first shift at 11AM. Therefore, in order to have 10 English-speaking operators here, 4 English-speaking call operators must take their first shift here while 2 Spanish-speaking operators must take their first shift here to have 4 Spanish-speaking operators here even though the required number is 3, since having more than the required number is not contrary to the constraint.

4th Shift (1PM-3PM): From the table of summary of calls expected, we observe that 95 calls are expected per hour in this shift. Given that 20% of the expected calls are from Spanish speakers, we can derive that 19 of the calls will come from Spanish speakers while 76 of the calls will be from

English speakers. Having been told that a call operator can process an average of 6 calls in an hour, we make these determinations;

Number of English-speaking operators = 76 / 6

Answer = 12.66

Since we cannot have a fractional human being, we round it up to 13.

Number of Spanish-speaking operators = 19/6

Answer = 3.167, approximately 4.

The operators in this shift will be made of the operators of the 9AM-11AM shift in addition to those who take their first shift at 1PM-3PM. Therefore, in order to have 13 English-speaking operators here, No English-speaking call operator must take their first shift here since those from the second shift are already 13 while 2 Spanish-speaking operators must take their first shift here to have 5 Spanish-speaking operators here even though the required number is 4.

5th Shift (3PM-5PM): From the table of summary of calls expected, we observe that 80 calls are expected per hour in this shift. Given that 20% of the expected calls are from Spanish speakers, we can derive that 16 of the calls will come from Spanish speakers while 64 of the calls will be from English speakers. Having been told that a call operator can process an average of 6 calls in an hour, we make these determinations;

Number of English-speaking operators = 64 / 6

Answer = 10.664

Since we cannot have a fractional human being, we round it up to 11.

Number of Spanish-speaking operators = 16/6

Answer = 2.66, approximately 3.

The operators in this shift will be made of the operators whose first shift is 11AM-1PM in addition to the Full-time workers who take their first shift at 3PM and the Part-time workers who take their first shift also at 3PM. Therefore, in order to have 11 English-speaking operators here, 7 English-speaking call operators, made up of both Full-time and Part-time workers, must take his first shift here while 1 Spanish-speaking operator must take his first shift here to have the required 3.

6th Shift (5PM-7PM): From the table of summary of calls expected, we observe that 35 calls are expected per hour in this shift. Given that 20% of the expected calls are from Spanish speakers, we can derive that 7 of the calls will come from Spanish speakers while 28 of the calls will be from English speakers. Having been told that a call operator can process an average of 6 calls in an hour, we make these determinations;

Number of English-speaking operators = 28 / 6

Answer = 4.66

Since we cannot have a fractional human being, we round it up to 5.

Number of Spanish-speaking operators = 7/6

Answer = 1.16, approximately 2.

The operators in this shift will be made of the Full-time operators whose first shift is 1PM-3PM in addition to the Part-time workers who took their first shift at 3PM-5PM and Part-time workers taking their first shift at 5PM-7PM. Therefore, in order to have 5 English-speaking operators here, 5 Part-time call operators whose first shift is 3PM-5PM must take this shift, which means the Full-time workers whose first shift is 1PM-3PM is 0 and the Part-time workers who took their first shift from 5PM-7PM is also 0 while 2 Spanish-speaking operators from the 1PM-3PM must take this shift also to have the required 2.

7th Shift (7PM-9PM): From the table of summary of calls expected, we observe that 10 calls are expected per hour in this shift. Given that 20% of the expected calls are from Spanish speakers, we can derive that 2 of the calls will come from Spanish speakers while 8 of the calls will be from English speakers. Having been told that a call operator can process an average of 6 calls in an hour, we make these determinations;

Number of English-speaking operators = 8 / 6

Answer = 1.3

Since we cannot have a fractional human being, we round it up to 2.

Number of Spanish-speaking operators = 2/6

Answer = 0.3, approximately 1.

The operators in this shift will be made of the Full-time operators whose first shift is 3PM-5PM in addition to the Part-time operators whose first shift was

5PM-7PM. Therefore, in order to have 2 English-speaking operators here, 2 Full-time call operators whose first shift is from 3PM-5PM must take this shift since no Part-time worker took his first shift at 5PM-7PM while 1 Spanish-speaking operator from the 3PM-5PM must take this shift to have the required 1.

All the information given can be represented in tabular forms as follows:

1. Table For Required Number of English and Spanish Speakers

Shift	Wage/hour	Number of Eng calls	Number of Spa calls	Number of Eng Op	Number of Spa Op
7AM-9AM	$10	32	8	6	2
9AM-11AM	$10	68	17	12	3
11AM-1PM	$10	56	14	10	3
1PM-3PM	$10	76	19	13	4
3PM-5PM	$10	64	16	11	3
5PM-7PM	$12	28	7	5	2
7PM-9PM	$12	8	2	2	1

2. Table To Derive Cost for English-Speaking Operators

Shift	First Shift	First Shift	First Shift	First Shift	First Shift	First Shift	First Shift	Totals	Required

	at 7AM - 9AM	at 9AM - 11AM	at 11AM-1PM	at 1PM - 3PM	at 3PM - 5PM	at 3PM - 5PM (P)	at 5PM - 7PM (P)		number of operators
7AM - 9AM	1							6	6
9AM - 11AM		1						13	12
11AM-1PM	1		1					10	10
1PM - 3PM		1		1				13	13
3PM - 5PM			1		1	1		11	11
5PM - 7PM				1		1	1	5	5
7PM - 9PM					1		1	2	2
Unit Cost	$40	$40	$40	$44	$44	$44	$48	$1228	Total cost
Solution	6	13	4	0	2	5	0		

3. Table to Derive Cost for Spanish-Speaking Operators

Shift	First Shift at 7AM-9AM	First Shift at 9AM-11AM	First Shift at 11AM-1PM	First Shift at 1PM-3PM	First Shift at 3PM-5PM	Totals	Required number of operators
7AM-9AM	1					2	2
9AM-11AM		1				3	3
11AM-1PM	1		1			4	3
1PM-3PM		1		1		5	4
3PM-5PM			1		1	3	3
5PM-7PM				1		2	2
7PM-9PM					1	1	1
Unit Cost	$40	$40	$40	$44	$44	$412	Total Cost
Solution	2	3	2	2	1		

We derive two objective functions for this problem for clarity, one for English-speaking operators and one for Spanish-speaking operators.

For English-speaking operators, we define 7 decision variables in total. 5 of them for Full-time workers and 2 of them for Part-time workers. They are;

1. The number of Full-time operators having their first shift from 7AM-9AM, denoted by a.
2. The number of Full-time operators having their first shift from 9AM-11AM, denoted by b.
3. The number of Full-time operators having their first shift from 11AM-1PM, denoted by c.
4. The number of Full-time operators having their first shift from 1PM-3PM, denoted by d.
5. The number of Full-time operators having their first shift from 3PM-5PM, denoted by e.
6. The number of Part-time operators having their first shift from 3PM-5PM, denoted by x.
7. The number of Part-time operators having their first shift from 5PM-7PM, denoted by y.

The constraints:

a>= 6	b >= 13	c >= 4	d>= 0
e>= 2	x >=5	y >= 0	

The objective Function for English-speaking operators is therefore: Cost = 40*a + 40*b + 40*c + 44*d + 44*e + 44*x + 48*y

= 40*(a + b + c) + 44*(d + e + x) + 48*y

For Spanish-speaking operators, we define 5 decision variables in total. They are;

1. The number of Full-time operators having their first shift from 7AM-9AM, denoted by f.
2. The number of Full-time operators having their first shift from 9AM-11AM, denoted by g.
3. The number of Full-time operators having their first shift from 11AM-1PM, denoted by h.
4. The number of Full-time operators having their first shift from 1PM-3PM, denoted by i.
5. The number of Full-time operators having their first shift from 3PM-5PM, denoted by j.

The constraints:

f>= 2 g >= 3 h >= 2

i>= 2 j >= 1

The objective function for Spanish-speaking operators is:

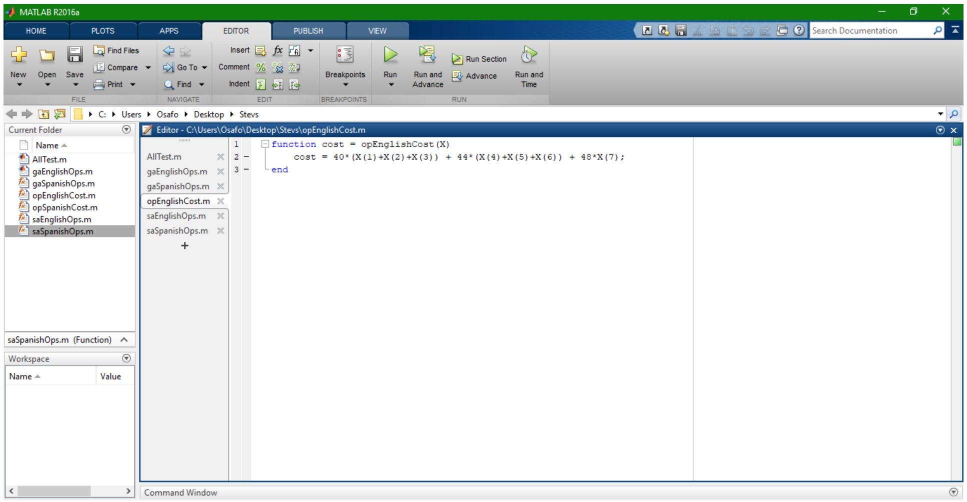
Cost = 40*f + 40*g + 40*h + 44*i + 44*j

= 40*(f + g + h) + 44*(i + j).

Having determined the objective functions for both English and Spanish speaking operators, we now use Matlab software to determine the minimum cost of paying both English and Spanish speaking operators, given the constraints using the Matlab optimization toolbox, Genetic and Simulated Annealing algorithms in Matlab.

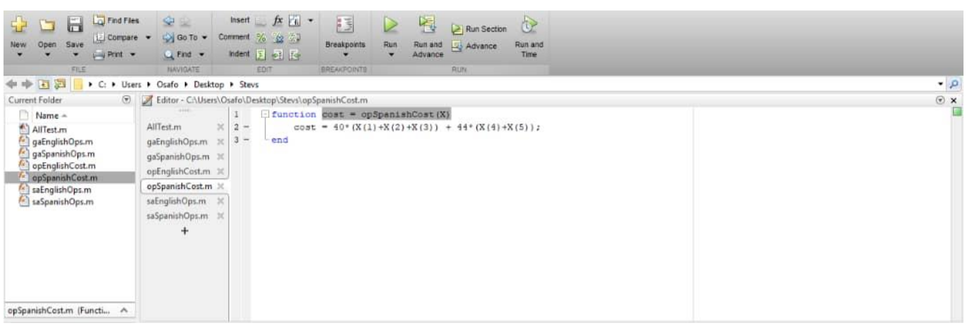
Matlab Optimization Toolbox use.

1. English-speaking operators.



Here, we created a function called opEnglishCost that takes input values from the user to calculate the minimum cost of paying the English-speaking operators.

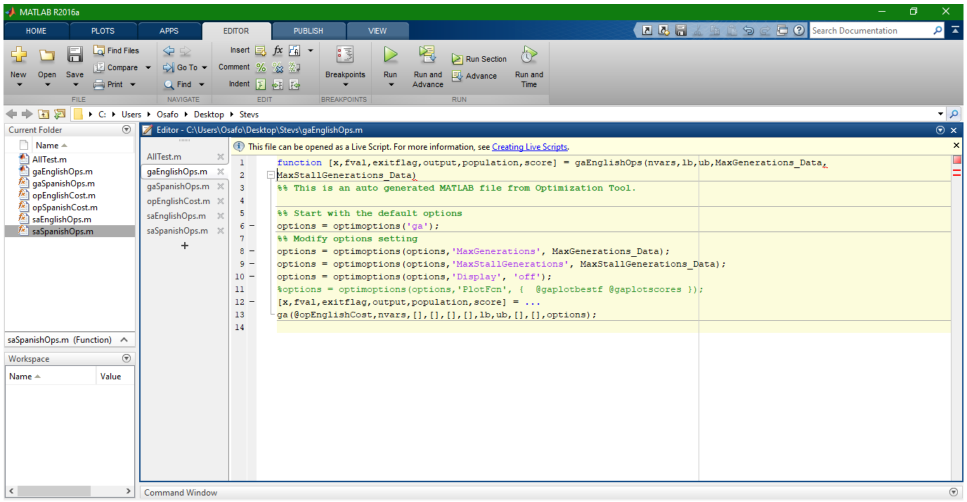
2. Spanish-speaking operators.



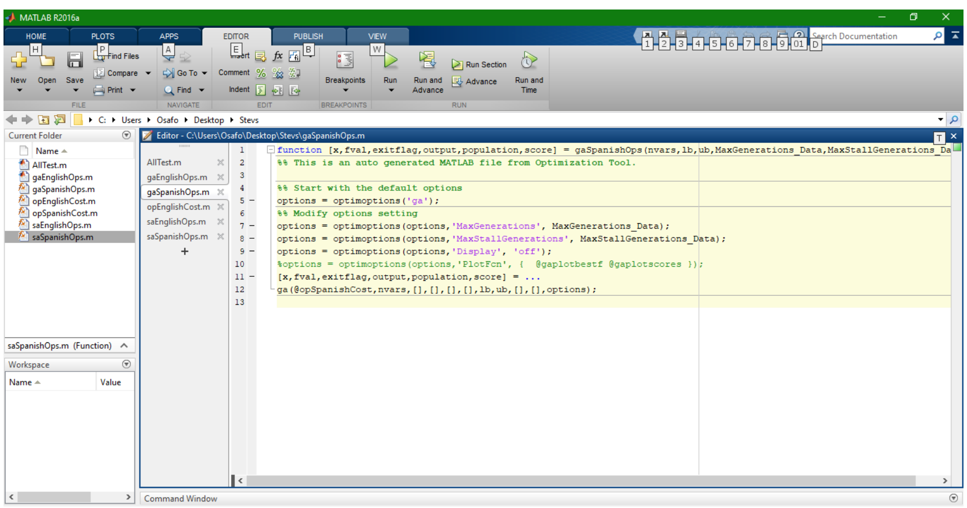
Similarly, we created a function called opSpanishCost that takes input values from the user to calculate the minimum cost of paying the Spanish-speaking operators.

Genetic and Simulated Annealing Algorithms in Matlab

Genetic Algorithm

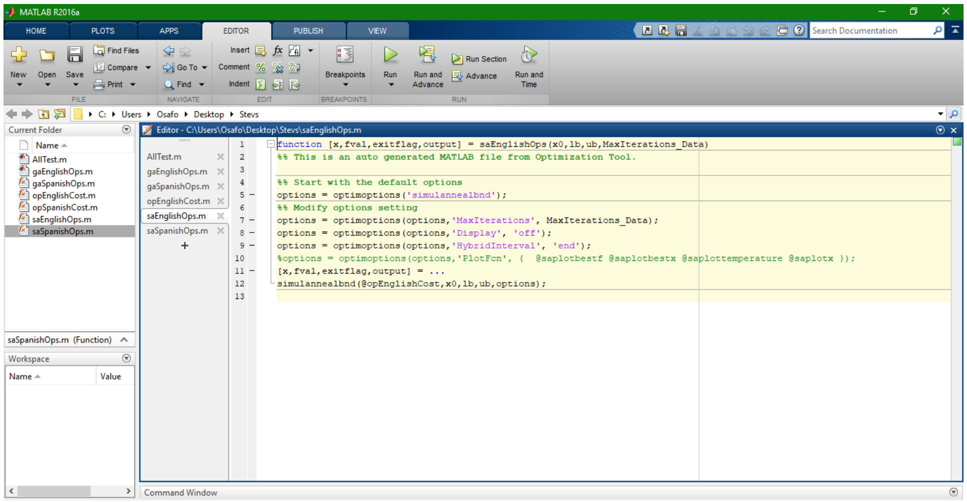
1. 

We generated this code to calculate the minimum cost of paying English-speaking operators using Genetic algorithm.

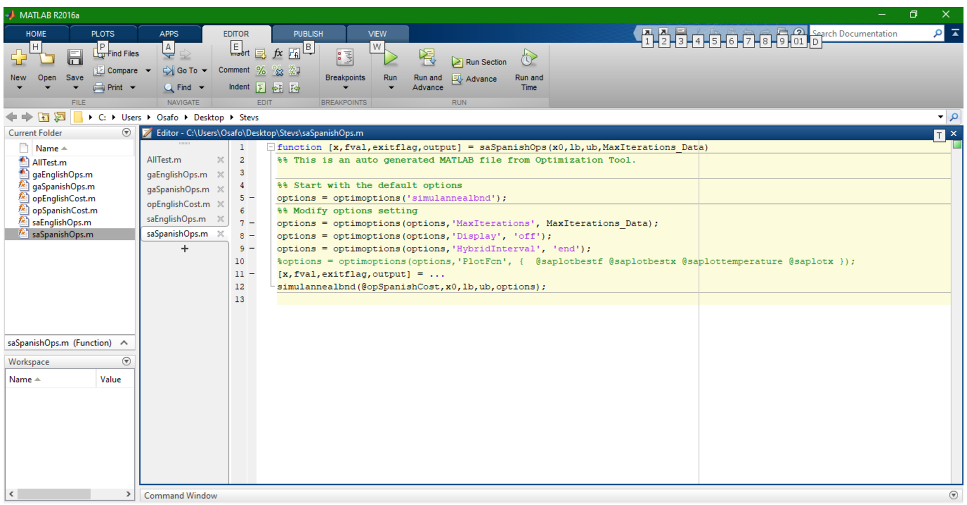
2. 

This code is also to generate the minimum cost of paying Spanish-speaking operators using Genetic algorithm.

Simulated Annealing Algorithm

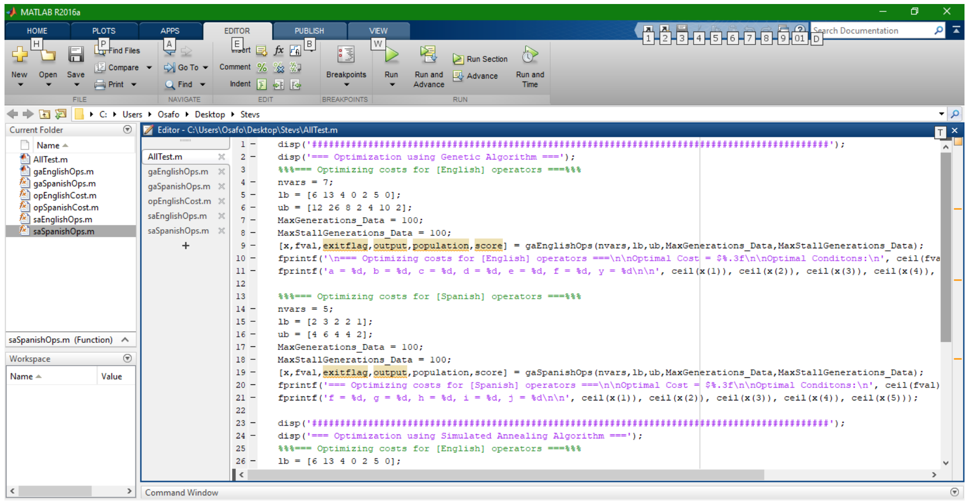
1. 

This code is to generate the minimum cost of paying English-speaking operators using Simulated Annealing algorithm.

2. 

This code is to generate the minimum cost of paying Spanish-speaking operators using Simulated Annealing algorithm.

Testing code:



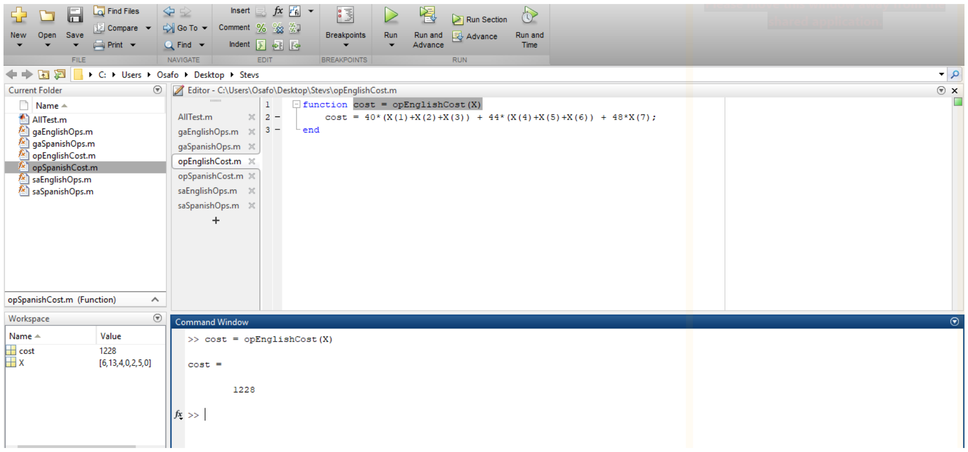
This code is meant to test all the functions to ensure they all work as they should.

RESULTS AND DISCUSSION

We observe from Tables 2 and 3 the minimum cost of paying English-speaking and Spanish-speaking operators respectively. We arrived at these manually and had \$1228 as the cost of paying English-speaking operators and had \$412 as the cost of paying Spanish-speaking operators.

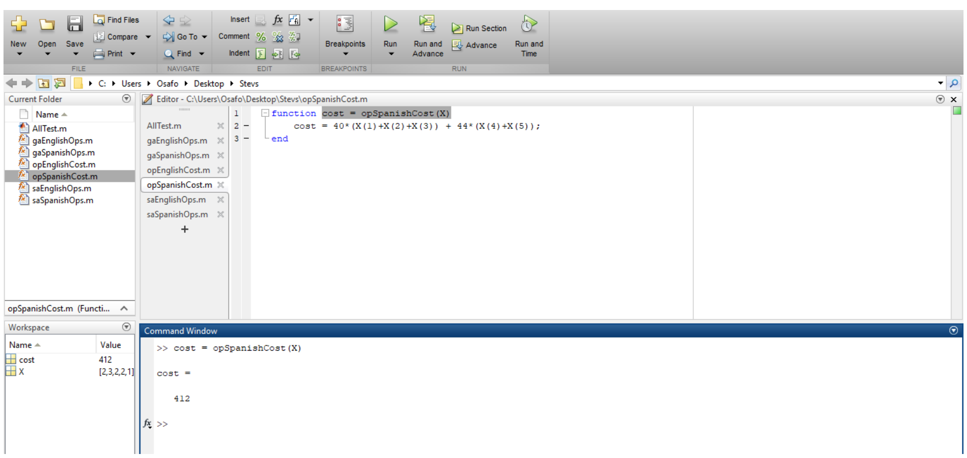
We then used Matlab to find the minimum cost for both English and Spanish speaking operators using the Matlab Optimization toolbox, Genetic and Simulated Annealing algorithms.

For the Matlab Optimization toolbox, the image below shows the result for the minimum labor cost for English-speaking operators.



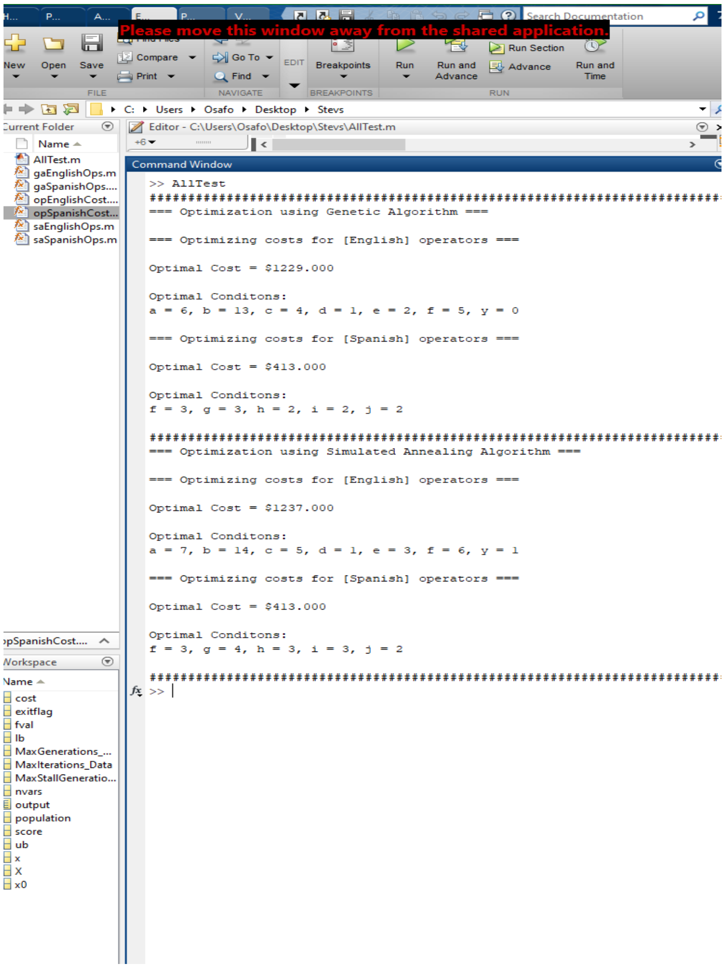
We can observe that the result after optimization is $1228 given the constraints. This is exactly what was derived from the tables above.

The image below also shows the result for the minimum labor cost for Spanish-speaking operators.



We can observe that the result after optimization is $412 given the constraints. This is exactly what was derived from the tables above also.

Simulated Annealing and Genetic Algorithm results:



It can be seen that the minimum costs for both English and Spanish speaking operators ($1229 and $413 respectively) under Genetic algorithm are just 1 more than the results found under the Matlab Optimization toolbox for both cases hence not showing much of a difference in the results.

It can also be seen that the minimum costs for both English and Spanish speaking operators ($1237 and $413 respectively) under Simulated Annealing algorithm are also not so far away from the results found under the Matlab Optimization toolbox and Genetic algorithm for both cases hence not showing much of a difference in the results.

REFERENCES

[1] F. S. Hillier and G. J. Lieberman, Introduction to Operations Research, 7th ed. New York: McGraw-Hill, 2001

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[3] An Analysis of Multi objective Optimization within Genetic Algorithms - Bentley P.,Wakefield J., Division of Computing and Control Systems Engineering, The University of Huddersfield the University of Huddersfield