Vaccinating People Against COVID-19 with Fuzzy Control

Vaccination v1

1.1 Set Partitioning

I partitioned the input set into three fuzzy set. They are given below:

First set PS: [-1e-10,0,0.6]

Second set PM: [0.5,0.6,0.7]

Third set PL: [0.6,1,1+1e10]

Each set is a three-element vector where the elements of a vector have a form of [low point, mid point, high point]

I partitioned the output set into three fuzzy sets. They are given below:

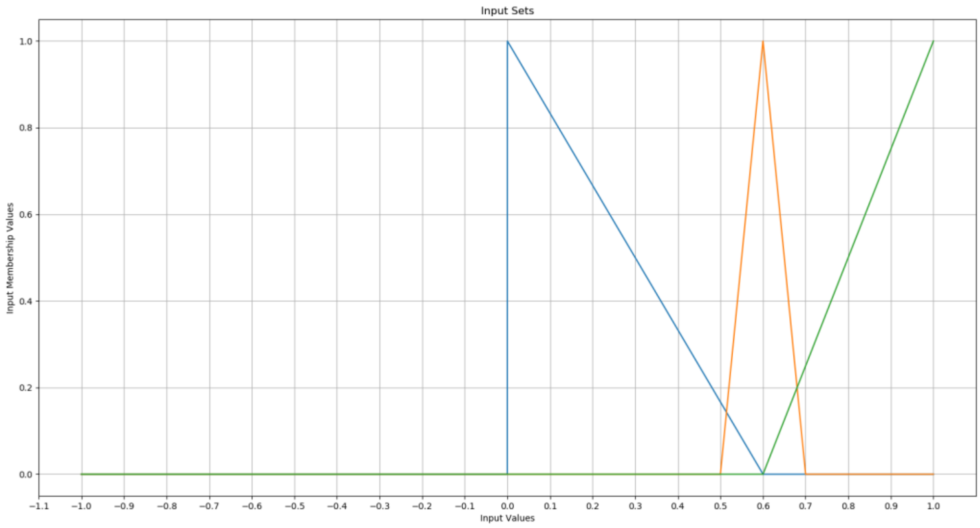
First set NS: [-0.2,-0.1,-0.01]

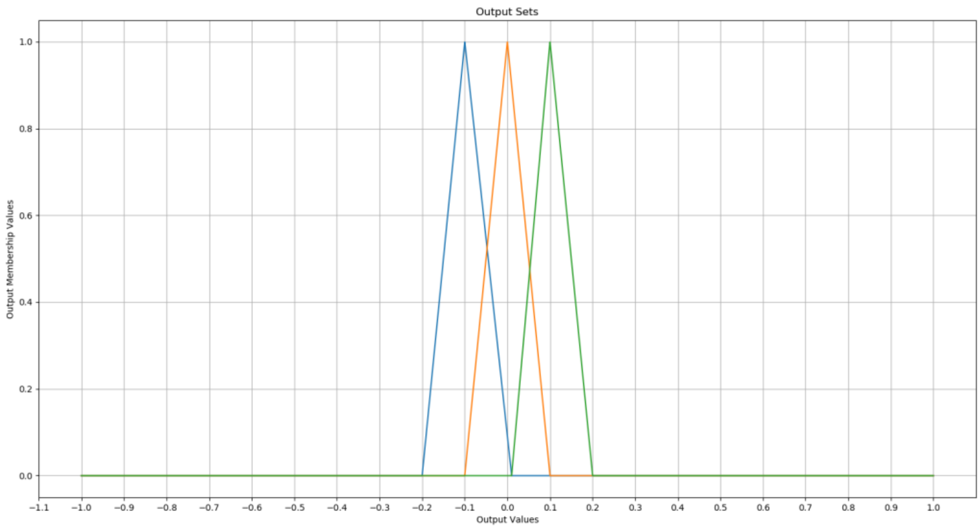
Second set AZ: [-0.1,0,0.1]

Third set PS: [0.01,0.1,0.2]

Each set is a three-element vector where the elements of a vector have a form of [low point, mid point, high point]

I tried different boundary values of all of the input and output partitioned sets (6 sets in total), and I decided to proceed with the values given above. Even though I did not check all possible boundary values, the values given above can make the algorithm converge fast.


Input Sets
Input Membership Values
Input Values
0.0
0.2
0.4
0.6
0.8
1.0
−1.1
−1.0
−0.9
−0.8
−0.7
−0.6
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0


Output Sets
Output Membership Values
Output Values
0.0
0.2
0.4
0.6
0.8
1.0
−1.1
−1.0
−0.9
−0.8
−0.7
−0.6
−0.5
−0.4
−0.3
−0.2
−0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

1.2 Fuzzy Control Rules

Negative Small (NS) (Green Output)	Approximately Zero (AZ) (Orange Output)	Positive Small (PS) (Blue Output)
pi≤0.6	0.5≤pi≤0.7	pi≥0.6

If pi is in the first input set PS, the output is NS. If pi is in the second input set PM, the output is AZ. If pi is in the third input set PL, the output is PS.

When the current percentage of vaccinated people is below 0.6, the control variable is mostly negative, which decreases the vaccination rate. When the current percentage of vaccinated people is above 0.6, the control variable is mostly positive, which increases the vaccination rate. When the current percentage of the vaccinated people is around 0.6, the control variable is around zero, which makes the vaccination rate steady.

1.3 Fuzzification and Defuzzification Interface

First step: Get the input variable value which is the current percentage of the vaccinated people in the first part.

Second step: Calculate μ for each input set. Let's say that our input value is 0.2. Calculate $\mu_{PS}(0.2)$, $\mu_{PM}(0.2)$, $\mu_{PL}(0.2)$

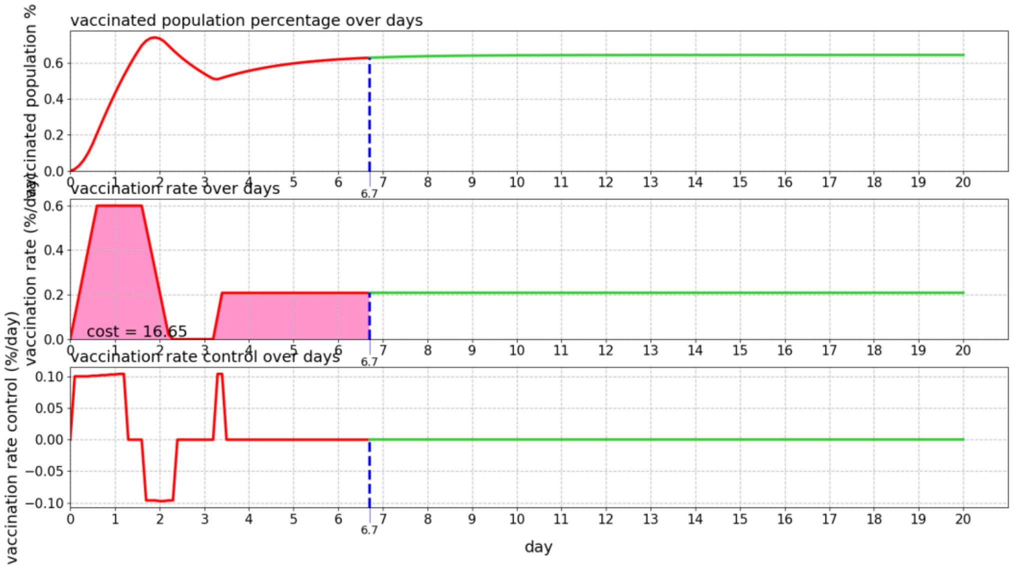
Third step: Combine all μ values for each input set in one array. It will be useful later.

Fourth step: Select the set with the maximum μ value.

Fifth step: Apply the mean of the maxima defuzzification step.

Sixth step: Calculate the iteration number where the vaccination comes to equilibrium at 60%.

1.4 Simulation



According to the figure given above, it can be seen that after 6.7 days, the vaccinated population comes to an equilibrium. The cost value is 16.65.

Vaccination v2

2.1 Set Partitioning

I partitioned the current rate input set into three fuzzy set. They are given below:

First set PS: [-1e-10,0,0.6]

Second set PM: [0.55,0.6,0.65]

Third set PL: [0.6,1,1+1e10]

Each set is a three-element vector where the elements of a vector have a form of [low point, mid point, high point]

I partitioned the failure rate input set into three fuzzy sets. They are given below:

First set NS: [-1,-0.5,1e-10]

Second set AZ: [-0.1,0,0.1]

Third set PS: [1e-10,0.5,1+1e-10]

Each set is a three-element vector where the elements of a vector have a form of [low point, mid point, high point]

I partitioned the output set into five fuzzy set. They are given below:

First set NM: [-0.2,-0.15,-0.05]

Second set NS: [-0.15 ,- 0.05, -1e-10]

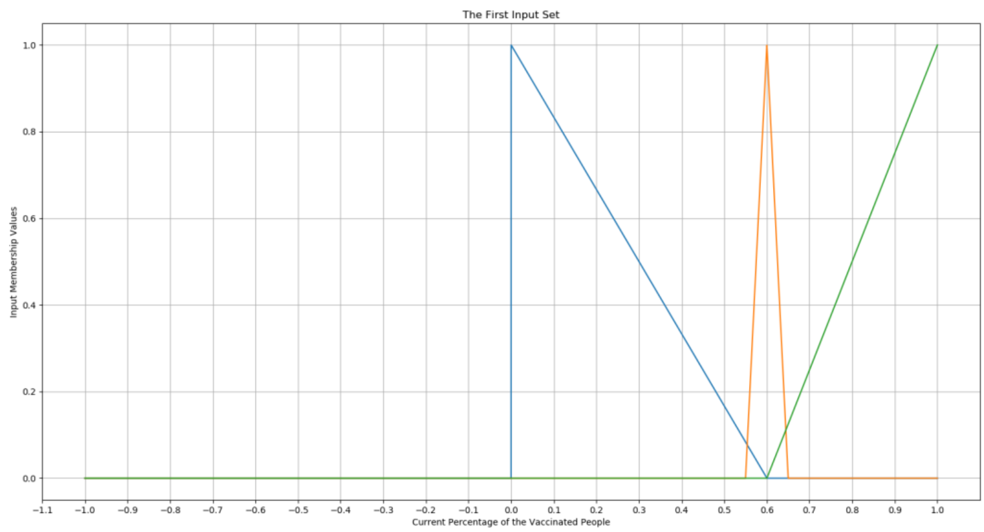
Third set AZ: [-0.05, 0, 0.05]

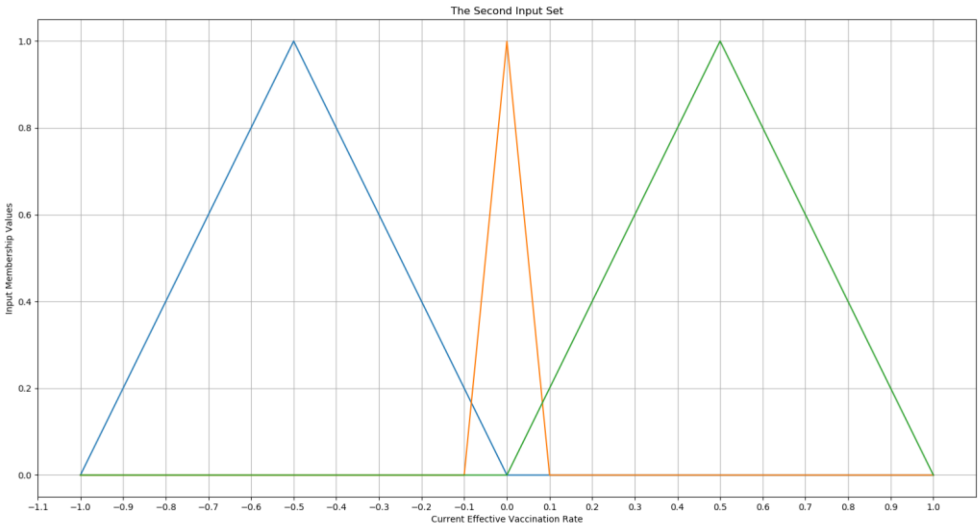
Fourth set PS: [1e-10, 0.05, 0.15]

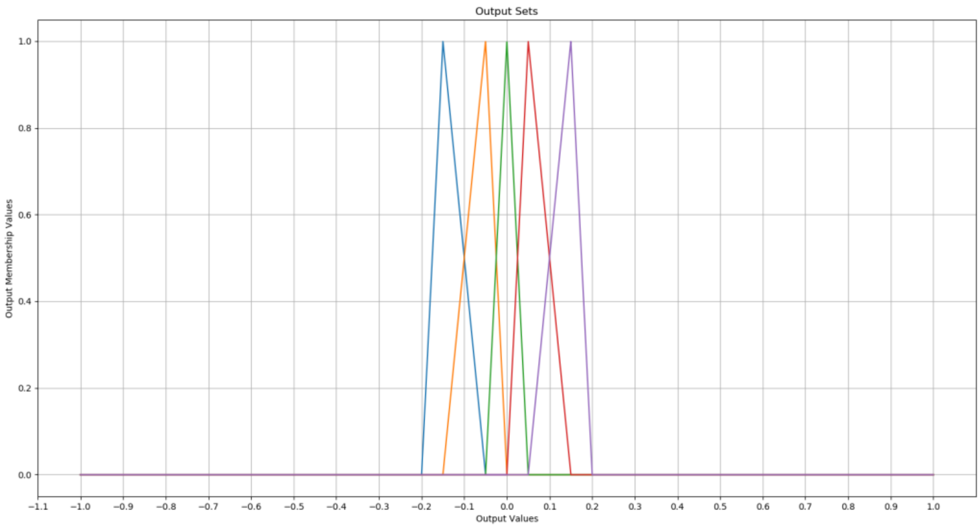
Fifth set PM: [0.05, 0.15, 0.20]

Each set is a three-element vector where the elements of a vector have a form of [low point, mid point, high point]

I tried different boundary values of all of the input and output partitioned sets (11 sets in total), and I decided to proceed with the values given above. Even though I did not check all possible boundary values, the values given above can make the algorithm converge fast.







2.2 Fuzzy Control Rules

		The current percentage of the vaccinated people		
		PS	PM	PL
The current effective vaccination rate	NS	PM	PS	AZ
	AZ	PS	AZ	NS
	PS	AZ	NS	NM

2.3 Fuzzification and Defuzzification Interface

First step: Get two input variable values which are the current percentage of the vaccinated people and the effective vaccination rate in the second part.

Second step: Calculate μ for each input set (6 sets in total). Let us say that our input value is 0.2. Calculate $\mu_{PS}(0.2)$, $\mu_{PM}(0.2)$, $\mu_{PL}(0.2)$

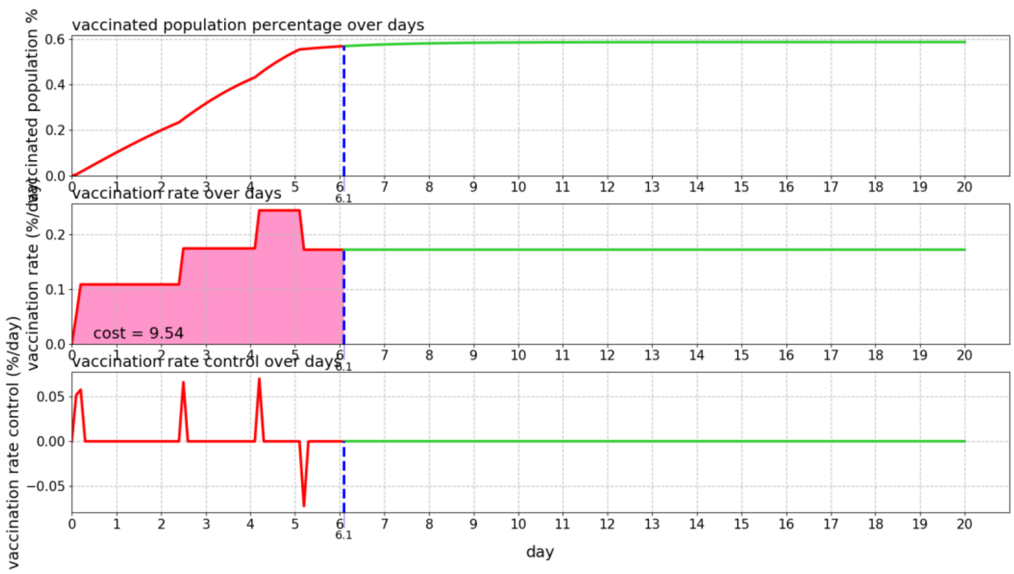
Third step: Select the sets with the maximum μ value for each input type (the current percentage of the vaccinated people and effective vaccination rate)

For example, select AZ and PL input sets.

Fourth step: Apply the mean of the maxima defuzzification step.

Fifth step: Calculate the iteration number where the vaccination comes to equilibrium at 60%.

2.4 Simulation



According to the figure given above, it can be seen that after 6.1 days, the vaccinated population comes to an equilibrium. The cost value is 9.54.