Evolutionary artificial intelligence and robotics

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Abstract

Evolutionary artificial intelligence used to solve search and optimization problems, based on genetic processes of biological organisms. In this report, we have focused in some important algorithms to solve some real problems.

0.1 GitHub Repository

https://github.com/Harithelamin/ACIT4610-24H-G13

1 Traffic Management Optimization Using Multi-Objective Evolutionary Algorithms

Urban traffic management requires balancing multiple conflicting objectives, such as minimizing travel time, reducing fuel consumption, and minimizing air pollution.

In this task, we applied a Multi-Objective Evolutionary Algorithm (MOEA) to optimize traffic management strategies for selected New York City (NYC) areas. The goal is to minimize conflicting objectives, Total Travel Time (TTT) and Fuel Consumption (FC), using real-world traffic data from NYC Open Data.

The traffic management strategy has involved controlling traffic signal timings (green, yellow, and red light durations), and setting speed limits on these segments. We have developed an MOEA that optimized these parameters to achieve the best trade-off between minimizing TTT and FC.

1.1 Data Exploration, and pre processing

We have used two datasets from the NYC Open Data portal: 1. NYC Traffic Volume Counts[1]. 2. Traffic Speed Data[2].

The both datasets were collected from New York City Department of Transportation (NYC DOT). The first dataset uses Automated Traffic Recorders (ATR) to collect traffic sample volume counts at bridge crossings and roadways, and contains 31 columns[1], while the second dataset uses average speed of a vehicle traveled between end points, and contains 13 columns[2].

```
Column names in Traffic_Volume_Count_data:
Index(['id', 'segmentid', 'roadway_name', 'from', 'to', 'direction', 'date',
       '_12_00_1_00_am', '_1_00_2_00am', '_2_00_3_00am', '_3_00_4_00am',
       '_4_00_5_00am', '_5_00_6_00am', '_6_00_7_00am', '_7_00_8_00am',
       '_8_00_9_00am', '_9_00_10_00am', '_10_00_11_00am', '_11_00_12_00pm',
       '_12_00_1_00pm', '_1_00_2_00pm', '_2_00_3_00pm', '_3_00_4_00pm',
       '_4_00_5_00pm', '_5_00_6_00pm', '_6_00_7_00pm', '_7_00_8_00pm',
       '_8_00_9_00pm', '_9_00_10_00pm', '_10_00_11_00pm', '_11_00_12_00am'],
      dtype='object')
```

Figure 1: Trafic Volume Count

```
Column names in Average_Speed dataset:
Index(['id', 'speed', 'travel_time', 'status', 'data_as_of', 'link_id',
       'link_points', 'encoded_poly_line', 'encoded_poly_line_lvls', 'owner',
       'transcom_id', 'borough', 'link_name'],
      dtype='object')
```

Figure 2: Average Speed Of A Vehicle

We have focused on optimizing traffic management for the three road segments in New York City, defined as following:
1. 5th Ave between 46th St and 47th St.

id	segmentid	roadway_name	from	to
185	35806	5th AVENUE	EAST 46th STREET	EAST 47th STREET
185	35806	5th AVENUE	EAST 46th STREET	EAST 47th STREET
185	35806	5th AVENUE	EAST 46th STREET	EAST 47th STREET
185	35806	5th AVENUE	EAST 46th STREET	EAST 47th STREET
185	35806	5th AVENUE	EAST 46th STREET	EAST 47th STREET
185	35806	5th AVENUE	EAST 46th STREET	EAST 47th STREET

Figure 3: First 5 columns from First Area

2. Atlantic Ave between ALABAMA AVE and WILLIAMS AVE.

id	segmentid	roadway_name	from	to
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE

Figure 4: First 5 columns from Second Area

3. Queens Blvd between Union Tpke and Yellowstone Blvd (Queens).

id	segmentid	roadway_name	from	to
185	35806	5th AVENUE	EAST 46th STREET	EAST 47th STREET
185	35806	5th AVENUE	EAST 46th STREET	EAST 47th STREET
185	35806	5th AVENUE	EAST 46th STREET	EAST 47th STREET
185	35806	5th AVENUE	EAST 46th STREET	EAST 47th STREET
185	35806	5th AVENUE	EAST 46th STREET	EAST 47th STREET
185	35806	5th AVENUE	EAST 46th STREET	EAST 47th STREET
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE
314	150671	ATLANTIC AVE	ALABAMA AVE	WILLIAMS AVE

Figure 5: First 5 columns from Third Area

In order to use the data from selected area defined above, we have merged all of them in one dataset, which has been merged later with the Trafic Speed Data.

	speed	travel_time	borough	roadway_name	date
0	19.26	353	Queens	TRAVIS AVENUE	2012-01-12T00:00:00.000
1	8.07	1440	Queens	LEWIS AVE	2012-01-10T00:00:00.000
2	8.07	1440	Queens	3 AVENUE	2012-10-12T00:00:00.000
3	8.07	1440	Queens	3 AVENUE	2012-10-13T00:00:00.000
4	8.07	1440	Queens	3 AVENUE	2012-10-14T00:00:00.000
5	8.07	1440	Queens	3 AVENUE	2012-10-15T00:00:00.000
6	8.07	1440	Queens	3 AVENUE	2012-10-16T00:00:00.000
7	8.07	1440	Queens	3 AVENUE	2012-10-17T00:00:00.000
8	8.07	1440	Queens	3 AVENUE	2012-10-18T00:00:00.000
9	8.07	1440	Queens	3 AVENUE	2012-10-19T00:00:00.000

Figure 6: Average Speed Of a Vehicle

Finaly we get one data set named Traffic Volume Count Data For Selected Area. This new dataset contains the sum of the columns of the two original datasets should be 31 + 13 = 44 columns. However, We got an extra column due to the suffixing.

```
print(Traffic_Volume_Count_data_for_selected_area.columns)
```

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```
Index(['id', 'segmentid', 'roadway_name', 'from', 'to', 'direction', 'date',
       '_12_00_1_00_am', '_1_00_2_00am', '_2_00_3_00am', '_3_00_4_00am',
       '_4_00_5_00am', '_5_00_6_00am', '_6_00_7_00am', '_7_00_8_00am',
       '_8_00_9_00am', '_9_00_10_00am', '_10_00_11_00am', '_11_00_12_00pm',
       '_12_00_1_00pm', '_1_00_2_00pm', '_2_00_3_00pm', '_3_00_4_00pm',
       '_4_00_5_00pm', '_5_00_6_00pm', '_6_00_7_00pm', '_7_00_8_00pm',
       '_8_00_9_00pm', '_9_00_10_00pm', '_10_00_11_00pm', '_11_00_12_00am',
       'speed', 'travel_time', 'status', 'data_as_of', 'link_id',
       'link_points', 'encoded_poly_line', 'encoded_poly_line_lvls', 'owner',
       'transcom_id', 'borough', 'link_name'],
      dtype='object')
```

Figure 7: Traffic Volume Count Data For Selected Area

We have Identified and preprocess relevant data points, such as:
A. Peak-hour traffic volumes. It has been calculated based on number of travel time in selected hours. In order to achieve this, we have made a list of hourly columns in NewYork City Data. The list defined as following:

To get Overall peak hour, We have identified overall peak hour across all records

```
# List of hourly columns in NewYork_City_Data
hourly_columns = [
    '_12_00_1_00_am', '_1_00_2_00am', '_2_00_3_00am', '_3_00_4_00am',
    '_4_00_5_00am', '_5_00_6_00am', '_6_00_7_00am', '_7_00_8_00am',
    '_8_00_9_00am', '_9_00_10_00am', '_10_00_11_00am', '_11_00_12_00pm',
    '_12_00_1_00pm', '_1_00_2_00pm', '_2_00_3_00pm', '_3_00_4_00pm',
    '_4_00_5_00pm', '_5_00_6_00pm', '_6_00_7_00pm', '_7_00_8_00pm',
    '_8_00_9_00pm', '_9_00_10_00pm', '_10_00_11_00pm', '_11_00_12_00am'
]
```

Figure 8: Traffic Volume Count Data For Selected Area

in dataset, then, we have calculated total traffic for each hour, and got the max volume for each record across the dataset. In the result, the peak hour in New Your City was 7:00 to 8:00 PM, with Overall 8150688 volume.

```
   speed travel_time     peak_hour  peak_hour_volume
0  10.56         239  _7_00_8_00pm              1893
1  16.15         155  _7_00_8_00pm              1893
2  32.93          76  _7_00_8_00pm              1893
3  47.84          52  _7_00_8_00pm              1893
4  46.60          54  _7_00_8_00pm              1893
5  47.84          53  _7_00_8_00pm              1893
New Your City Overall peak hour: _7_00_8_00pm, Overall volume: 8150688
```

Figure 9: New Your City Peak Huour Time

B. Average speeds.
In order to calculate the average speed, we have to ensure that the speed data is in numeric type. The mean is a python function allow us to calculate the mean/average of input values or data set. As the result, we found that the average speed is: 2513.80934 mph.

1.2 Fuel Consumption Calculation

Fuel consumption measures the amount of fuel a car consumes to go a specific distance[4]. We used the common fuel Consumption equation, defined as following:

Fuel Consumption = a × V + b × [1/v] + c

Where:

• V is the average speed (in mph).
• a, b, and c are empirical const, which a indicating an increase in fuel consumption with speed, while b representing a decrease in fuel consumption as speed, and c represents the base fuel consumption, as very low-speed conditions.

However, we sitting a, b, and c values as following:
Coefficients for the Fuel Consumption Model
a = 0.01 Coefficient for speed (V)
b = 2 Coefficient for 1/V
c = 0.1 Constant term Then, we have updated the code to calculate Total Fuel Consumption For each road segment, and time interval by defining the formula as following:
$FuelConsumption = \sum_{i=1}^{n}(volume_i \times (aV_i + b\frac{1}{v} + c) \times segment_Length_i)$

where:
n is the number of time intervals.
Volume is the vehicle count in interval i from the Traffic Volume dataset.
Vi is the average speed in interval i from the Traffic Speed dataset.
Segment Length is the length of the road segment.

However, from the selected area dataset,
peak hourvolume is the vehicle count in the peak hour (Volume).

speed is the average speed in mph.
segmentid is the Segment length in miles.

The following figure shows the data we have used.

	speed	travel_time	peak_hour	peak_hour_volume	segmentid
0	19.26	353	_4_00_5_00pm	717.0	4853
1	8.07	1440	_8_00_9_00am	552.0	43218
2	8.07	1440	_8_00_9_00am	1603.0	36272
3	8.07	1440	_1_00_2_00pm	1872.0	36272
4	8.07	1440	_11_00_12_00pm	1554.0	36272
...	...	...	...	...	...
18049	36.66	250	_4_00_5_00pm	920.0	42542
18050	36.66	250	_4_00_5_00pm	910.0	42542
18051	36.66	250	_2_00_3_00pm	879.0	42542

Figure 10: Selected Area Dataset

The follwoing polt shows the fuel consumption for each time interval.

Calculate Total Fuel Consumption:

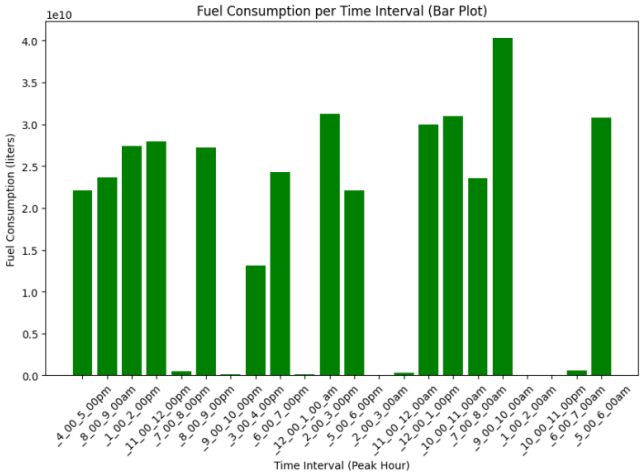

Figure 11: Fuel consumption per time interval

$$[\sum_{i=1}^{n}(Volume_i \times (a \times V_i + b \times \frac{1}{V_i} + c) \times segmentLength_i)]$$

1.3 Formulate the Optimization Problem

First, we have defined the Decision Variables:
A. signaltiming represents the green, yellow, and red signal durations for each intersection.
B. Speed limit

1.4 Implement the MOEA

genetic algorithm

1.5 Analysis and Results

2 Task 2

This is the introduction of the document. Here we will cite some references, for example, [1].

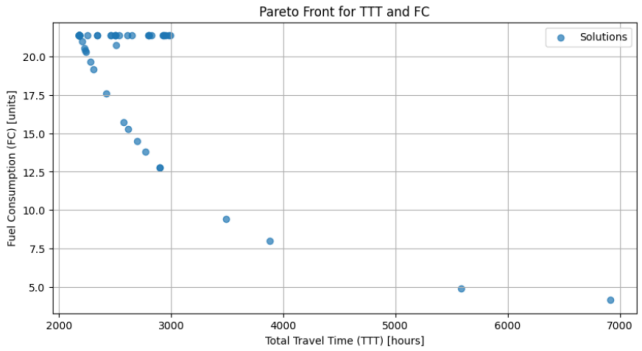

Figure 12: TTT

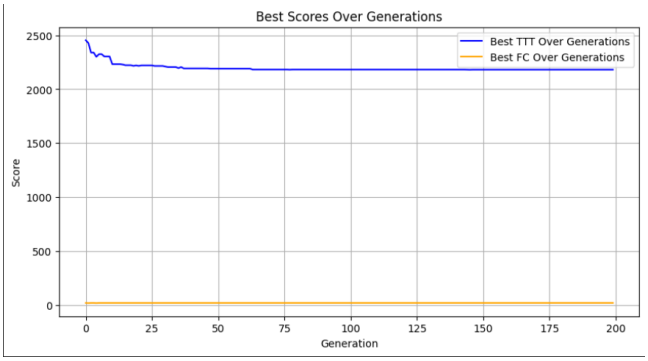

Figure 13: The best score over generation

3 Task 4

This is the introduction of the document. Here we will cite some references, for example, [1].

4 Refrences

[1] NYC Open Data. "Traffic Volume Counts". 2022. Available at: https://data.cityofnewyork.us/Transportation/Automated-Traffic-Volume-Counts/7ym2-wayt (Accessed: 2024-11-04).
[2] NYC Open Data. "DOT Traffic Speeds NBE". 2017. Available at: https://data.cityofnewyork.us/Transportation/DOT-Traffic-Speeds-NBE/i4gi-tjb9 (Accessed: 2024-11-04).
[3]Krivoshapov, S, Nazarov, A , Mysiura, M , Marmut, I , Zuyev, V , Bezridnyi, V , Pavlenko, V. (2020). Calculation methods for determining of fuel consumption per hour by transport vehicles. IOP Conference Series: Materials Science

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