Combined in assignment UML, Agent-based Simulation and Geo-computation

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Part1. Problem definition: Traffic congestion is a big problem in a lot of cities in China, especially Shanghai. The traditional way to solve this problem is: GPS takes traffic congestion into account and provides the most time-saving route to drivers. GPS only predicts a SINGLE best route. This causes a new problem: a lot of drivers move onto this best route. The best route become congested. Therefore, it is necessary to provide a solution that distributes the vehicles and prevent the occurrence of new congestion.

Part2. Research question: whether or not providing drivers with multiple routes will prevent the occurrence of new congestion?

Part3. Conceptual model by applying Agent Based Modeling

1. Purpose. The goal of this agent based model is to predict multiple optimal routes in order to prevent the occurrence of new congestion.
   Boundaries of this model are:
1) The model only focuses on one city, instead of multiple cities.
2) Route-searching will start at the moment that a driver departure from his/her origin. When a driver is on his/her road, the route-searching process will start when the driver asks it to start.
   This is a predictive model. It predicts whether the potential new congestion will or will not happen, if drivers are provided with a group of optimal routes. This model is used for extrapolation of trends and evaluation of this scenario.

2. Entities, Status and Scales

Figure 1 scenario

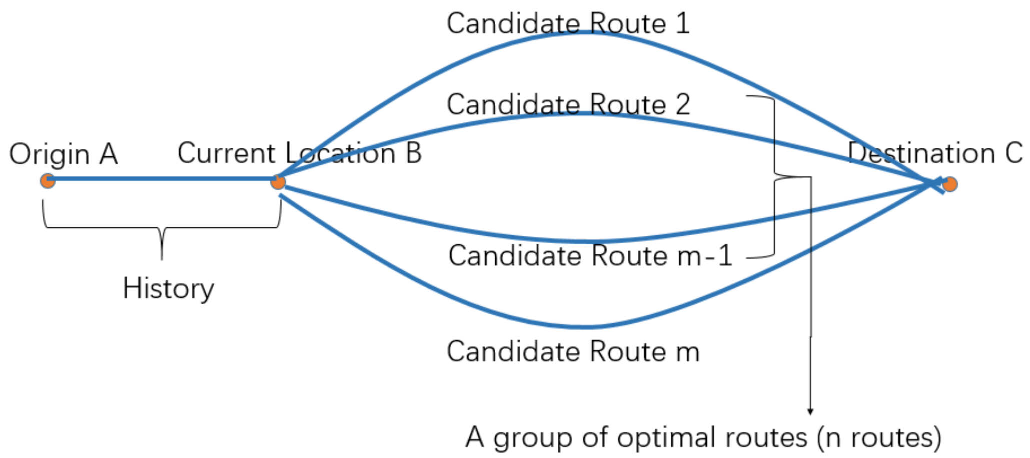
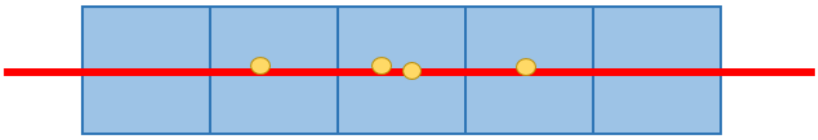


Figure 2 spatial relation amount road, road cell and vehicles

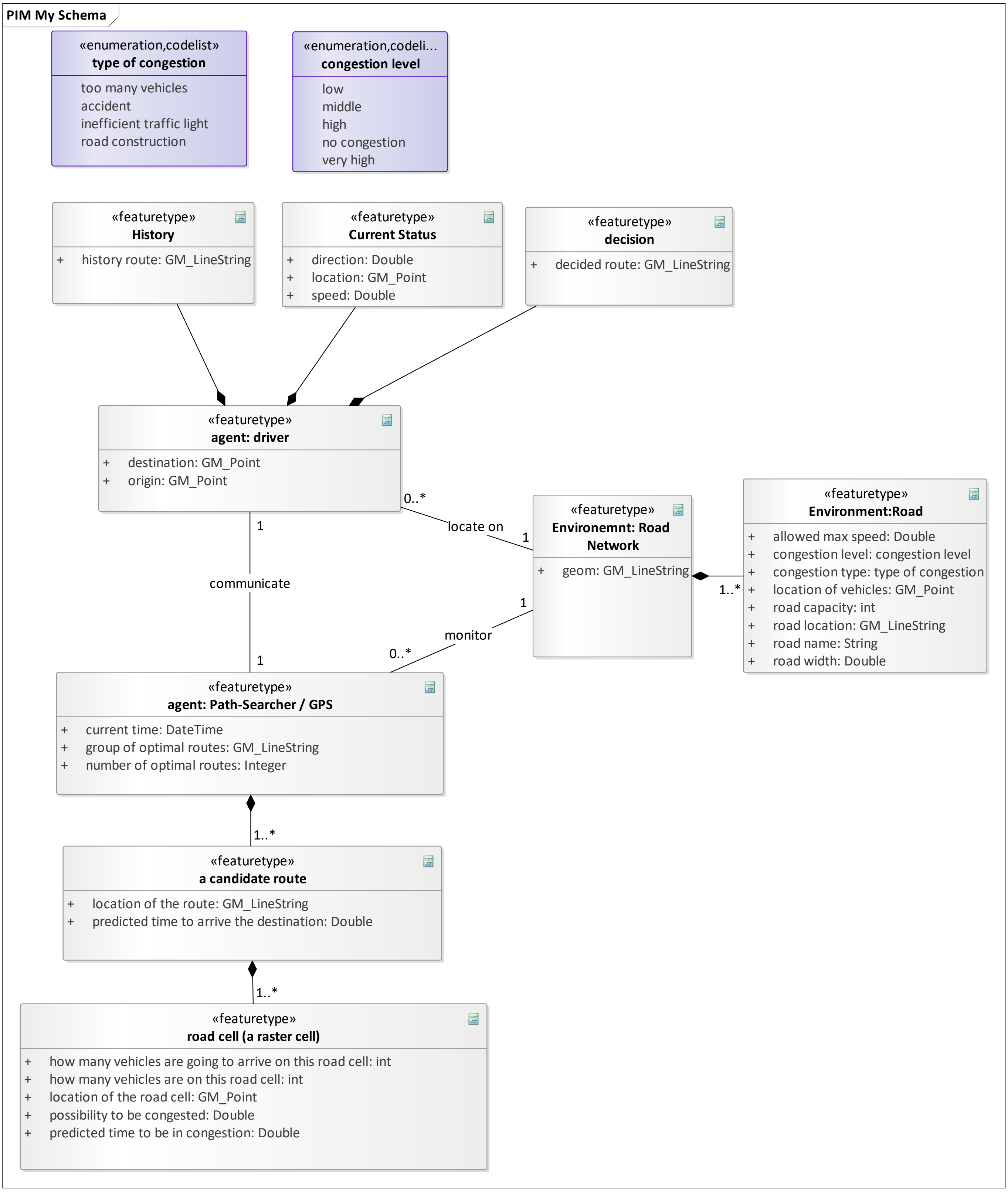


Red line: road

Blue Cell: a road cell. It is a raster cell

Yellow dots: vehicles on the road

Figure 3 UML diagram



2.1 Entities:

The simulation will have two types of agents:

1) Driver: His / Her goal is to arrive his/her destination in as shorter time as possible.
2) Path-searcher. Path searcher can also be seen as GPS. Its goal is to provide a group of optimal routes to the driver. “Optimal” means the routes with shortest time.

The simulation will have one environment: Road network.

Road network is composed of roads. Road network is a physical environment. Each road has both static attributes and dynamic attributes. The static attributes contain: road name, road location, road width, road capacity, ect. Besides, each road provides dynamic attributes: congestion level. The congestion level is divided into 5 levels: no congestion, low, middle, high, very high. The decision of an individual driver triggers the change in the environment. In this case, drivers' decisions trigger the congestion level of roads. The congestion level of a road might be increased or decreased. So road network is a dynamic environment.

2.2 State variables:

Status of driver is “wait for the solution of path searcher” or “think which path to choose” or “accept one of the suggested paths” or “refuse all the suggested paths”.

Status of path-searcher is “in rest” or “in searching process” or “have found a group of optimal routes”.

Status of each road is its congestion level, ranging from “no congestion” to “high”.

2.3 Scales:

Temporal scale: The time is set in rush hours during weekdays. For example, Monday 7:00 to 9:00. Rush hour means the time that most of the people go to work or go to school. The time that GPS needs to finish a path-searching task is in several seconds. The total duration of simulated period is in hours. Length of each time step is in second.

Spatial scale: total map extent is a road network in a city. In this model, the map extent is road network in Shanghai. The road network is a raster data. The agents are vector data.

3. Process overview:

3.1 Each driver has the following behavior: move the vehicle, make a turn, stay statically, increase/decrease speed, ask the GPS to start searching for paths, tell the GPS how many optimal routes to be provided, wait for the solution of GPS, think of which path to choose, accept one of the suggested paths, tell GPS which path that he/she decides to follow, refuse all the suggested paths, arrive at his/her destination.

3.2 Each path-searcher has the following behavior:

step1. gets input from two sides: the road network and the driver. senses a driver's current location and direction, record the original and destination of this driver. senses the current congestion level of all the roads. Senses how many vehicles are currently moving on which road, senses how many vehicles are soon going to arrive on which road.

Step2. The analysis process is divided into 3 stages. Stage 1) for each road cell, predict the possibility to be congested and the time to be in congestion. For example, road cell (x1, y1) will be in congestion for 30 minutes with 90% possibility. A road cell is a raster cell that locate on a road. Stage 2) generate all the possible routes to reach the destination. Predict the traveling time of each possible route. Stage 3) generate a group of optimal routes. The optimal routes are found out by applying genetic algorithm. Optimal means “the most time-saving”. To sum up, a group of optimal routes is composed of candidate routes. Each candidate route is composed of a large amount of road cells.

Step3. Shows a group of optimal routes to the driver.

Step4. Ask the driver which route he decides to follow.

Step5. Tell other drivers that one more vehicle is on the way to arrive at a certain road. This is necessary. Because the decision of one single driver has an influence on the decisions of the other drivers. When too many drivers decide to move on the same road, this road could be predicted as "very possible to be congested". When less drivers decide to move on a road, the road could be predicted as "less possible to be congested".

3.3 Interactions between agents and agents:

Each driver has exactly one GPS. A Driver and a GPS communicate with each other. This is a one-to-one communication. The driver tells the GPS when to start searching and how many number of routes to provide. The GPS tells the optimal routes to the driver. The driver tells his/her decision to the GPS (this is an optional behavior, but not mandatory). The GPS keeps sensing: the location and the direction of the driver. The GPS memorize the diver' s path that he has passed.

3.4 Interactions between agents and environment:

Drivers and roads: A Driver is located/is moving on a road network. A road network could contain multiple drivers. The amount of vehicles and the location of vehicles has an influence on the congestion level of each road.

GPS and roads: a GPS monitors the whole road network. One road network is monitored by all the GPSs.

4. Design concepts

Objective: drivers aim at find the most time-saving route to reach his/her destination.

Adaptation: If GPS detects that a lot of drivers have decided to move on to the same road, it will suggest its driver to choose other roads.

Learning: If a driver always chooses the first route in the solution, and he always experiences "new congestion", then next time he will adapt this behavior and choose other optimal routes.

Prediction: GPS predicts the future congestion level of each road cell. For example, road cell (x1, y1) will be in congestion for 30 minutes with 90% possibility.

Sensing: GPS senses the driver's location and the road network.

Interaction: see section 3.3 and 3.4.

Stochasticity: It is assumed that drivers randomly choose one route from the provide routes.

5. Initialization

The first initialization is: all drivers randomly follows a route from the provided routes. The other initialization includes: 1) a road network 2) the origin and destination of each driver. 3) the number of drivers. 4) how often does a driver ask GPS to do a path-searching task for him (per 5 min or per 10 min). 5) where the congestion triggers are located initially (accident, road construction, inefficient traffic light). These values are not randomly chosen. They are decided based on statistical data.

The statistical data includes: where the schools are located, where companies are located, where residential places are located, what the population density is in Shanghai, how many people travel by car, how many vehicles usually move on which road and so on.

Based on these information, we are able to catch the main characteristics of drivers in Shanghai. After that, we will make a close-to-reality initialization.

6. Input data

Environment: Road network of Shanghai. It is a raster data. Location of schools, companies and residential places. All roads have their corresponding attributes (name, location, capacity, width…).

Agent: Number of drivers. Location of drivers. Origin and destination of drivers. Speed of vehicles.

Agent: how many optimal routes are required to be generated by GPS

7. Calibration, Sensitivity analysis, Verification, Validation.

Part 4. Geo-computation

Genetic algorithm (GA) will be applied in this model. GA is suitable for this model. Because it is good at solving non-standard optimization problems. The following algorithm shows the process from candidate routes to a group of optimal routes. It is assumed that the driver asks the GPS to generate n optimal routes. This means that the group contains n optimal routes.

Candidate route: Each candidate route has an attribute: predicted time to arrive the destination. The predicted time has been calculated based on the attribute of road cells. Each candidate route is a linear string. This means that each candidate routes is composed of a set of points {point A, point B, point C, …} and a linear interpolation function.

Individual: a group of candidate routes. A group is a list. The list has length n. Each individual is [candidate route1, candidate route2, .., candidate route n]

Population: the size of the population can be set as 100. Initially, the population is 100 individuals. They are randomly selected.

Fitness function: the output of the function is time. The function could be the mean time of the group.
Fitness value: mean time of the group. Fittest group is in rank 1. Least fit group is in rank 100.

Selection: The best fitness value is the smallest one. Select the first 2n (if n=4, then 2n=8) individuals with smallest fitness value. This means the shortest time.

Parents: The selected 2n individuals are the parents.

Crossover or Mutation: In order to avoid duplication in the outcome, it is necessary to apply the GA rule. It can be either crossover or mutation.

Children: after crossover or mutation, new 100 individuals will be generated. They are the children. A new iteration will start.

When the time of iteration increases to a certain amount, the convergence will occur. The final outcome is a group of n optimal routes.

Part 5. Innovation

The innovation of this simulation is that it improves the traditional path-searching algorithm. The GPS provides multiple routes, instead of only one path. The GPS is able to keep monitoring other drivers' decision, and predict the possibility of road congestion level.

Part 6. References

Oh et al., Genetic algorithm-based dynamic vehicle route search using car-to-car communication. Advances in Electrical and Computer Engineering. Vol 10. 2010

Vi Tran Ngoc Nha, Soufiene Djahel and John Murphy Lero. A Comparative Study of Vehicles' Routing Algorithms for Route Planning in Smart Cities. UCD School of Computer Science and Informatics, Ireland

Chapter 8 in blackboard.