# Swarm-Based Traffic Simulation

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## 1. Summary

Traffic congestions emerge as the main problem on the roads nowadays. They not only worsen the mood of travelers, but also have negative economical and ecological impact. Traffic simulation can be viewed as an easy and efficient way to predict the problematic areas on the roads. Additionally, traffic simulation is also a tool that suggests how the traffic situation can be improved.

The two main approaches to simulate the traffic flow are to simulate it either on macro, or on micro level. A macro-model considers traffic flow as a fluid and does not take into account individual agents. In this case the behavior of the flow is usually described by Navier-Stokes equation. A micro-model, on contrary, treats traffic flow as the result of the interaction between individual agents. A well-known example of micro-model simulation is Nagel-Schreckenberg cellular automata. However, recently new approaches to the treatment of micro-simulation are developed. One of the most promising ones, the swarm-based approach, is introduced here.

## 2. Swarm Intelligence

Swarm Intelligence provides the ability for decentralized systems of agents to create global behavior patterns. These patterns emerge from local modifications of the environment performed by each agent. A modification is consistent with the modifications done by other surrounding agents.

A colony of ants can be taken as a good example. Ants have the ability to change the environment by leaving the pheromones, which other ants can sense and then make their decision based on the information received.

Swarm intelligence can be applied not only to the colonies of insects. Some social interactions among humans result in emergent patterns, as if influenced by swarm intelligence. One of such examples is the interaction between cars in the traffic flow. Cars in swarm-based traffic simulation, like ants, are also able “to drop and sniff the pheromones”. The physical interpretation of pheromones is visual and perceptional signals send and received by cars, such as stopping and turning lights, acceleration, and deceleration.

## 3. Pheromones in Traffic Simulation

In swarm-based simulation, cars drop pheromones continuously throughout their journey. Stronger pheromones are dropped whenever the car is braking, stopping, or turning. The sensed pheromones basically signify the following car to adjust the speed according to the car ahead, so that collision can be avoided. This is illustrated in the picture below:

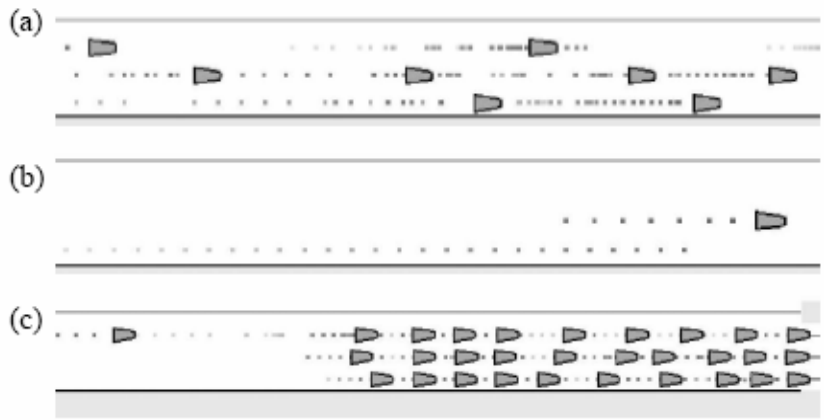


Fig. 1. Car interactions by pheromones: (a) cars on a 3-lane road, dropping pheromones; (b) a car emitting pheromones while changing lanes; (c) cars stopped at a light, emitting pheromones behind them.

Behavior of a car in swarm-based traffic simulation can be described by following rules:

- Car “sniffs” pheromone in front, if not yet arrived to its destination point.
- Car decelerates, if tailing distance to the next car is less than the strength of pheromone suggests.
- Car accelerates, if there is no pheromone or tailing distance is greater than suggested by the pheromone strength.
- Car stops, if needed.
- Car makes the decision about upcoming turn, if the change of lanes is needed.
- Car drops single pheromone, or a trail of pheromones to signify the others about its actions.

## 4. Vehicular Model and Environment

Besides interaction among agents, there are external factors that also influence the behavior of the traffic. The main factor is a vehicular environment. The vehicular environment is modeled by the roads, their connections (usually represented by connected graph), traffic signs, and driving rules.

According to the vehicular environment, each car has to plan its route from starting point to needed destination. It is usually done with the help of Dijkstra's shortest path algorithm. While driving through the route, the car obeys the swarm paradigm. If at some point during its journey the car is unable to follow the previously defined route, i.e. due to congestions, the route should be recalculated. The starting point of the journey is updated to the current position, and new route is calculated.

## 5. Software: SuRJE

SuRJE (Swarms under R&J using Evolution) is traffic simulation software that uses the principle of swarm intelligence. It is developed by the research group at the University of Calgary; chief developers are Ricardo Hoar and Joanne Penner.

The software allows the user to set up the roads and put lights on them, impose speed limits and traffic signs, such as stop sign. There are many parameters that can be tuned by user to simulate the traffic flow as close to real-life scenario as possible. During the simulation run, software is able to adapt lighting sequences in manner that significantly reduces the probability of congestions.

The idea of using swarm-based intelligence for traffic simulation is quite new, not to many matured simulation tools exist by now. SuRJE is thoroughly developed software, and it is also well-documented and described in full detail. Therefore it can be used as a good example of implication of the swarm-based principles.

## 6. Literature

[1] Penner, J., et al., Swarm-Based Traffic Simulation with Evolutionary Traffic Light Adaption, *Proceedings of Applied Simulation and Modeling, 2002,* Crete, Greece

[2] Hoar, R., et al., Evolutionary Swarm Traffic: If Ant Roads had Traffic Lights, *Proceedings of the 2002 IEEE Congress on Evolutionary Computation*, Honolulu, USA, 2002

[3] http://pages.cpsc.ucalgary.ca/~pennerj/SuRJE/