Adaptive Public Transit Network Design

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The paper proposes a new scheme for generation of public transport by simultaneous adaptation of agents' daily plans (activities), public transport lines, and their schedules.

The idea

Roughly, the procedure consists of two main phases: (1) Spatiotemporal clustering of agents' plans and generation of public transport lines, (2) co-evolution of agents' plans and public transport schedules and updating agents' plans and public transport lines and schedules in respect to the agents' life changes.

1. Spatiotemporal clustering of agents' plans and generation of public transport lines

Consider agents' with repeated travel plans with only two locations home and work; and bus as the only public transport mode. Assume, there is no public transport at first, and agents perform their trips by taxi. Traveling by taxi is costly and repeated trips can become much cheaper if they are shared. That is, given a population with activity-chain plans our goal is to establish a network of repeated shared trips that provides travel options maximally close to those performed by taxi and, thus, minimizing private transport (taxi) usage.

Substitution of taxi by bus is physically possible if agents are able to synchronize their plans *in space and time*, in respect to each other, and create clusters of trip flows. This behavioral adaptation can be performed via shifting activities' location, start and end times, and, possibly, introduction of additional activities.

A scoring function guides the synchronization process. It penalizes agents for walking, using taxi and being late but rewards them for when sharing a mode and being on time. Rewarding agents for sharing a trip leads to the emergence of space-time trips clustering. If clustering is successful, agents that belong to the same cluster share their trips or parts of the trips and, if these agents are many, shared trips can become a bus line. A bus line emerges when N people synchronize a sufficient number A of activities in space-time. For the home-to-work trips, adaptive behavioral clustering demands additional activities: walking from home to collection point of a shared trip, waiting for a shared trip and walking from the point of alighting to work.

The common meeting and alighting points are initial bus stops on which we then fit a coarse bus line network. Taking into account bus capacity and population demand, headways are established afterwards.

The emergence of adaptive transit network can be described as follows:

- Initial adaptive clustering of agents' plans and generation of public transport lines
    - Characterizing clusters of agents' plans in space-time (a known clustering method applied) and establishing passenger flows and shared trips
    - Establishing bus lines in respect to these flows and trips
    - Specifying bus line schedule

Having the initial bus network created, the following phase is simultaneous adaptation of population plans and bus network.

2. Co-evolution of agents' plans and transit network

Another scoring function guides the adaptation process. Agents get a reward for a sharing a trip, which leads to an adaptation process to common travel flows. The latter leads to a bus network evolution.

- Co-evolution of agents’ plans and buses schedules
    - Adapting agents’ plans to a bus schedule (behavioral adaptation)
    - Adapting bus lines to passengers flows – relocate a bus stop, short/extend a bus line, create a new/delete existing bus line (evolutionary approach)
- Change agents’ plans in respect to their life changes (and repeat co-evolution),

<u>Formal description of our behavioral and evolutionary approach</u>

Agents’ plans coding

The following activities in a population’s daily plans can occur:

- Leaving a specific (fixed) location
- Arriving at specific (fixed) location
- Walking (start time, end time)
- Waiting (for a bus; start time, end time)
- Riding (by bus/taxi; start time, end time)

Every activity has a type, location, start and end times. Activities at fixed location, as home or work have only start times. Adaptation is based on memetic algorithms [1]. Every meme in a chromosome has two or three attributes for fixed and other location respectively (fig. 1).

Location 1	Location 2	Location 3	……	Stop location n
Start time	Start time End time	Start time End time	…… ……	Start time

Agent’s plan

Figure 1: Agents’ plans coding representation

The algorithm searches for spatiotemporally “close” plans to modify demand clusters, by shifting location, start and end times of activities for strengthening plans' clusters.

Bus line network coding

An evolutionary approach is applied for adapting the bus network [2, 3]. After phase 1, the bus line can be coded into a chromosome representation (fig. 2). A bus line may be abolished (i.e. “dies”) if activity clusters dissolve, or a new stop may be embedded or an existing one may be removed. These conditions define the genetic algorithm to have variable-length chromosomes. Accordingly, crossover and mutation operators are developed.

Stop location 1	Stop location 2	……	Stop location *n*	Bus capacity
Arriving time Departure time	Arriving time Departure time	…… ……	Arriving time Departure time	

Bus line

Figure 2: Bus line network coding

Each “bus” gene has three attributes (fig. 2): a stop location (x, y), arriving and departure times (hh:mm). For every bus line an additional gene is added representing bus capacity. Given the population demand, capacity determines a number of people in the bus and number of boarding and alighting agents at stops along the line. The adaption process undergoes standard evolution scheme taking into account the constraints imposed on genetic algorithms operators.

Future work

The paper will discuss the deployment of the proposed adaptive dynamic public transport technique. This approach will be applied to a test case “Sioux Falls” in the MATSim traffic simulation platform [4]. The research is now in progress as part of the ERA-NET Transport III funded project SMART-PT.

References

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