APPLICATION OF EXPERT SYSTEMS IN PERSONALIZED TRIP PLANNING

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Abstract

The last decades brought an enormous information boom generated by community-, enterprise- and personal activities. Net mobile technologies appeared which made former unrealistic theories come true or at least realistic such as gaining exact information about town dwellers' activities and traveling customs. Our current research investigates how these technologies can serve a personalized trip planning application relating smart city concept.

One aspect of Smart City concept is to aid the people scheduling their daily activities according to certain constraints. The cost of time is on a constant increase in today's society. Therefore the personalized activity scheduling for individuals is gaining major interest. The feedback of this scheduling can be connected to smart city controlling and planning participants.

This paper provides an overview of the input data collection methods, demand forecasting and scheduling logic of the individual activity-based trip planning.

Key words: *Smart City, Demand analysis, Trip optimization, Activity based planning*

1 INTRODUCTION

The spread of smart phones and the development of mobile phone mobile communication technologies (3G, 4G) made it possible to implement formerly developed theories in reality. Several planning methods presume the existence of representative data sets about commuters, city dwellers traveling habits. Reliable transport controlling and monitoring tools can be developed as part of the smart city concept using business, individual but not personalized, and public transport data.

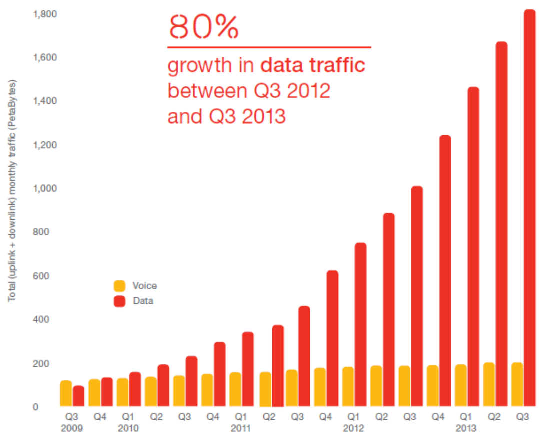

Figure 1: Data traffic growth (Ericsson 2013)

The latest Ericsson mobility report (Ericsson 2013) gives a shocking view about the growth of exchanged data in the recent years (Figure 1).

The mobile data traffic is estimated to be tenth times bigger than the traffic realized in 2013 which is 1.9 EB per month. In 2012 the same was 1.1 EB. The mobility report predicts that the current smartphone subscriptions will grow from 1900 millions to 5600 millions by 2019. The LTE mobile subscriptions will have an increase from 175 to 2600 millions.

2 SMART CITY CONCEPT

Interesting question that how can we use this enormous data in the SC conception. Several researches highlight one dedicated field or function of a city (e.g.: smart logistics, smart transportation, smart IT network, smart energy supply) but a real smart city concept incorporates all participants, processes, and infrastructure in a town. Cohen made a comparative formula for ranking cities. This formula involves all relevant fields of "smartness" (Figure 2):

- Economy
- Environment
- Government
- Living
- Mobility
- People

The focus of our research is on the smart transportation (mobility) but interacts with other fields like government and living.

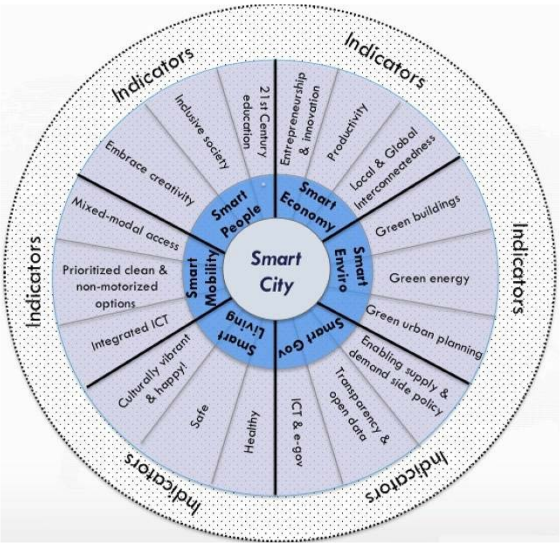

Figure 2: The Smart Cities Wheel (B. Cohen 2012)

3 PERSONALIZED TRIP PLANNING

This research was launched because of the unequivocal need for information systems supporting the daily trip planning of individuals.

Several researches deal with this topic and many applications are developed to handle similar problems on a certain level (Lechter 2012). As more and more smart elements of cities and residents are appearing the availability of possible input data gradually increases.

Interesting idea for data processing is a Personal Assistant (PA) plan, which goal is a daily activities list planning, when the personal assistant will assist the costumer (human operator) for planning an optimum succession of desired activities.

The solution is based on objective and subjective information. (Pozna 2013)

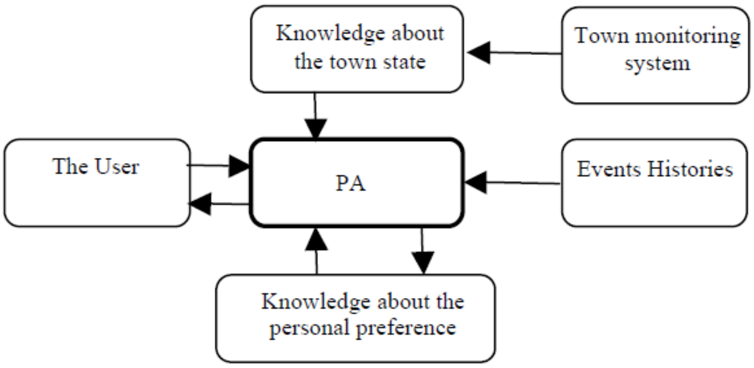

Figure 3: Envisioned PA system (Pozna 2013)

The personalized trip planning is basically an extension of the classic trip optimization problem. It combines the elements of the traveling salesman problem, route optimization, and allocation problem.

The input data of the daily schedule plan are the following:

- List of daily tasks (operations)
- Possible location(s) of the tasks – so called demand points
- Transfer times between demand points (time and route dependent)
- Duration of operations (time and location dependent)
- Minimal – maximal duration of operation determined by the person (e.g.: 50 - 70 minutes in a swimming pool)
- Time windows of demand points

The volume and the intensity of the traffic can be expressed by certain attributes:

- Fix attributes:
    - Vehicle type, transportation mode
    - Network connections
    - Average speed
- Variables
    - Weather
    - Traffic
    - Extra-ordinary event
    - Traffic of touristic locations, public institutions,
    - Time windows of demand points
    - Traffic of a specific deman point

The classic TSP usually considers only the transfer times/distances between the demand points attached to a transportation network. However in this case the time (traffic) dependent duration of operations are also considered.

The transportation tasks and operations together are forming a task list. The personalized trip planning sorts these tasks in a row (trip) so that:

- each operation is assigned to a location
- constraints of time windows and fix appointments are considered
- the selection of a transport relation is determined by its antecedent and subsequent activity location (quickest/cheapest/shortest route)
- the trend based and seasonal demand time series are considered (certain demand is assigned to a time segment of the day).

$$\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{l}\left[x_{i,j,k}\cdot\left(t_{i,j,k}+a_{j,k}\right)\right] \qquad (1)$$

Where:

- i=1..n: location of antecedent activity
- j=1..n: location of subsequent activity
- k: time segment of the day
- ti,j,k: transfer time between activity locations in a time segment
- aj,k: duration of the j. activity in a time segment
- xi,j,k=0,1: assignment variable

The application of the classic 4-step-model has some restrictions which are handled by the activity based models (Y. Shiftan 2012). The activity based models focus on the examination of the demands of individual trips.

The trip planning of a whole household reveals even more opportunities for optimization because the allocation of certain tasks/operations on demand points are not individual dependent and can be allocated to more than one member of the household.

During the trip development the constraint of minimal time need of the total of trips. E.g.: “If Dad does the shopping in the lunchtime instead of Mom after work the family would save 10 minutes travel by going home before the peak and 20 minutes by avoiding queuing time in the shop”.

4 DEMAND ANALYSIS ON DEMAND POINTS ALONGSIDE A PERSONALIZED TRIP

The duration of the activities depends on the number of visitors of the particular place. Also a minimal staying time can be assigned to the certain location.

The transfer time between demand points depend on the traffic density.

The demand points of the urban mobility can be classified as the followings:

- Nature of activity
  - Work related
  - Residence related
  - Other
- Time dependent availability:
  - Fixed
  - Semi fixed (Time window)

- Flexible

- Can be approached by
  - Individual motorized transport
  - public transport
  - other (walking, bicycle)
- Existence of alternative demand point

The historical data - which usually form the basis of demand forecast - can be collected by fixed measuring devices installed on the certain demand point.

Other possibility is to equip the vehicles (traveling to the demand point) with measuring devices.

These devices are capable of measuring the

- traffic volume
- distance between vehicles
- speed of vehicles

The moving of individuals also can be observed by several techniques:

- Personal data collection techniques, devices
  - RFId
  - Camera
  - Turnstile
  - Smart phone

The most robust pillar of data collection is the business expert systems of demand points. Commercial stores (supermarkets, restaurants, etc), public places and institutions (university, utility customer service office, bank, etc.) and event organizers (concert, farmers' market, etc.) are collecting data for their own purpose about the traffic realized at their premises.

The purpose of this data collection may be the followings:

- human resource planning,
- inventory replenishment planning,
- marketing related survey, etc.

The sharing of these data is just the question of business safety. The technological conditions for electronic data interchange are provided.

For example taking a banks customer service records exact information exists about the followings if a client queuing machine is applied at the customer service office:

- the starting time of the client's waiting period
- the starting time of the client's service
- the starting time of the next client's service
- type of service the client is waiting for

Figure 4: Queue Management System (source: www.juumei.com)

This way in theory exact data could be provided about the expected waiting time in the office and duration of the service at a certain period of the day. A client who is intended to arrange his business in the bank any time during the day could select an out-of-peak period. It could be also beneficial for the bank because the load of capacity would balance itself.

There are classic demand forecast techniques which can be applied to evaluate the traffic data provided by expert systems. These techniques are for example:

- Moving average
- Weighted average
- Exponential smoothing
- Linear regression
- Double exponential smoothing
- CMA

Stationary time series are quite rare in real life processes usually the features of trend based and seasonal time series can be observed (Figure 5).

The expected value of the demand, the expected waiting time, the service time and the expected traveling time between activity locations regarding a given time interval can be stored in central databases.

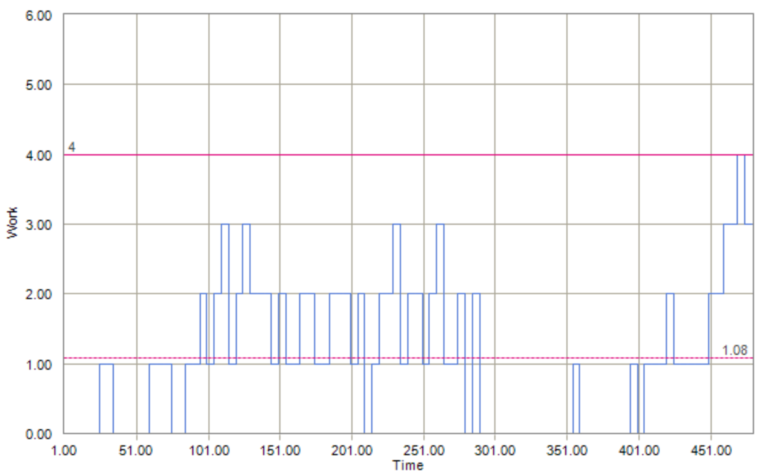

Figure 5: Daily seasonal data series of a customer office

The data stored in databases have to be indexed according to their location in the time series (like periodicity index, season index). Based on these indexes the forecast system can sort out relevant data and arrange for example Sunday morning customer numbers accordingly.

Expert systems should adjust their forecasts if outstanding events, actions are expected or observed. Such outstanding event can be the launch of a marketing campaign, black Friday sales, etc.

The adjustments have to consider seasonal effects and trends.

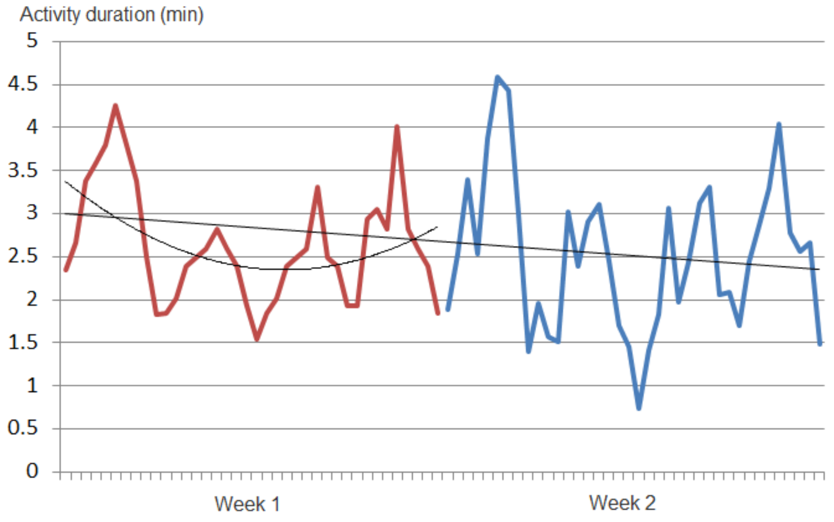

Figure 6: Daily seasonal data series of a customer office

The transfer times between activity points or the duration of an activity can be represented by fuzzy time series. The mobility is affected by subjective choices so it cannot be estimated by statistical forecasting. In order to analyze the fuzzy time series a hybrid expert system can be applied which can be operated among uncertain input circumstances. The optimization problem can be effectively solved by memetic bacterial algorithms (Foldesi 2011) (Foldesi 2012). As the other part of the hybrid system a neural network can be applied which flexibly solves non-linear problems. The only disadvantage of neural networks is that the teaching phase needs a considerably large database.

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