Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 130 (2018) 979–984

Procedia Computer Science

www.elsevier.com/locate/procedia

9th International Conference on Ambient Systems, Networks and Technologies, ANT-2018 and the 8th International Conference on Sustainable Energy Information Technology, SEIT 2018, 8-11 May, 2018, Porto, Portugal

Agent-based Dynamic Rescheduling of Daily Activities

Hui Zhao[a,*], Stéphane Galland[a], Luk Knapen[b], Tom Bellemans[b], Ansar-Ul-Haque Yasar[b]

[a]*LE2I, Univ. Bourgogne Franche-Comté, UTBM, F-90010 Belfort, France*
[b]*Hasselt University, Transportation Research Institute (IMOB), Agoralaan, 3590 Diepenbeek, Belgium*

Abstract

When simulating individuals' daily plan, lots of unexpected events need to be considered, like traffic jam and weather changes. Therefore, there will be a mismatch between the original plan and the executed one. Faced with this situation, individuals need to adjust the rest of the activities to make a new schedule. This paper analyzes the causes of rescheduling, and establishes a new rescheduling model, combining strengths of existing rescheduling models. The model in this paper considers the rescheduling possibilities and choices as much as possible. It takes time pressure and schedule similarity into consideration when updating a schedule. Furthermore, this paper analyzes joint trip/activity execution by studying the cooperation between agents during the rescheduling process.

Peer-review under responsibility of the Conference Program Chairs.

Keywords: Daily Activity Schedule, Rescheduling, Agent-based Model, Coordination, Travel Demand Prediction

1. Introduction

When executing the schedule on the road network, generally there will be a mismatch because of the occurrence of uncertain events. Thus, rescheduling is necessary. Based on the theory of travel demand forecast, this paper analyses several rescheduling models. In a daily activity schedule, it is assumed that the first activity will start with traveling to a particular location in order to spend some time there to perform certain tasks. Consecutive activities follow in a similar way. An episode consists of travel time and activity time [1].

During the execution process, people need to reschedule when faced with schedule conflicts and unexpected events. García-Jiménez et al. [2] propose eight types of events which cause people to reschedule. In this paper, they are classified in short-term and long-term events. Short-term events, which generally occur during the activity process are: (i) *Activity duration determinant* — it is normal to underestimate the time that an activity will take, such as, "I went shopping longer;" (ii) *Social determinant* — it is usually involved with other relatives, like "my friends couldn't meet me that day and we changed to another day;" (iii) *Weather determinant* — it affects certain activities, like it rains so one cannot go hiking or biking; (iv) *Activities determinant* — this may happen for both mandatory activities and flexible activities, like "I was told my class cancelled today;" (v) *Resource determinant* — it may rarely happen, for instance, "I had to leave my car to be fixed." Long-term events, which affect people's daily pattern are: (i) *Individual*

* Corresponding Author.
E-mail address: hui.zhao@utbm.fr (Hui Zhao).

1877-0509 © 2018 The Authors. Published by Elsevier B.V.
Peer-review under responsibility of the Conference Program Chairs.
10.1016/j.procs.2018.04.100

factors, for example, "I change my job, I go to work at another place;" (ii) *Household factors* — it's the family or family members that change the activity pattern, like "Our family move to a new house;" (iii) *Social factors* — it's the environment factor which may change the daily activities. For instance, "There is a new market opening near to my house, then I will not go to the further one before."

The goal of our undertaken research works is to simulate the rescheduling process caused by unexpected events during the execution of a daily activity schedule for which all attributes (location, timing, etc) were fixed before. Hence, the long-term events are not considered in this paper. The class of unexpected events is restricted to what affects people's *belief*, but not their *desire*. Emergency situations (like evacuations) are also out of scope. Since dynamic simulation at individual level is required, an agent-based model is proposed. This model enables to analyze how to reschedule, which factors affect people's rescheduling decisions, and what is the current state in rescheduling research. This paper constitutes the first step for establishing a new rescheduling model based on the previous studies. Schedules are compared by a scoring method which takes both utility and similarity into account. The model also provides joint trip/activity and negotiation between agents.

2. Definitions

Episode. Each episode e consists of a journey (trip) and an activity. The trip $r \in \mathbb{T}$ is characterized by its origin $o_r \in \mathbb{L}$, start time $t_r \in \mathbb{N}$, its duration $d_r \in \mathbb{N}^+$, its destination, which is the activity location of the same episode, $l_a \in \mathbb{L}$, its transportation mode $m_r \in \mathbb{M}$, the agents $H_r \subseteq \mathbb{H}$, which are participating to the trip, and the maximum number VR of agents that could be involved within r, such that $1 \leq |H_r| \leq VR$. A joint trip is a trip, which involves more than one participants, e.g. a carpooling trip.

$$r = \langle o_r, t_r, d_r, l_a, m_r, H_r, VR \rangle \tag{1}$$

Let an activity $a \in \mathbb{A}$ be defined by its its duration $d_a \in \mathbb{N}^+$, its location $l_a \in \mathbb{L}$, the agents $H_a \subseteq \mathbb{H}$, which are participating to the activity, and the maximum number VA of agents that could be involved within a, such that $1 \leq |H_a| \leq VA$. A joint activity is an activity, which involves more than one participant.

$$a = \langle d_a, l_a, H_a, VA \rangle \tag{2}$$

All trip's attributes, except for the mode m_r can be derived from the two activities that are enclosing the trip within the daily schedule.

Schedule. Schedule $s \in \mathbb{S}$ is a sequence of episodes for a period, $s = \langle e_1, e_2 \ldots e_n \rangle$, such that $n \geq 1$.

Scheduling. Scheduling is the action to order a set of episodes in order to create a sequence s. In addition to the episodes' sequence, other constraints C are considered for re-ordering, e.g. travel time and vehicle capacity.

$$\begin{aligned} schedule : \mathcal{P}(\mathbb{A}) \times \mathcal{P}(\mathbb{C}) &\to \mathbb{S} \\ (A, C) &\mapsto \langle a_1, ..., a_n \rangle \,\Big|\, \Big(\forall k \in (1;n], \forall a_j \in A, t_{r_{k-1}} + d_{r_{k-1}} + d_{a_{k-1}} \leq t_{r_k}, \forall k \in (1;n]\Big) \wedge C \end{aligned} \tag{3}$$

where $\mathcal{P}(\mathbb{A})$ and $\mathcal{P}(\mathbb{C})$ respectively denote all possible sets (or powersets) of activities and constraints.

Re-scheduling. Rescheduling is to update an existing schedule, according to some constraints, and starting the changes when unexpected events happen.

$$reschedule : \mathbb{S} \times \mathcal{P}(\mathbb{C}) \times \mathbb{N} \to \mathbb{S} \tag{4}$$

Initial demand. Initial demand is the input of the simulation process. It is the daily schedule derived from FEATHERS[3]. While, in the model of this paper, agents will start rescheduling when unexpected event occurs, our utility function may have not exactly the same perception of optimality as the functions used in FEATHERS. Therefore, it may need a burn-in period.

Similarity. Similarity is the lack of difference between two schedules w.r.t, activity type, execution order, location, travel mode, and accompanying-person[4]. In this paper we focus on individual's schedule similarity, not the household's schedule similarity.

Time Pressure. Generally, time pressure is considered as a feeling not able to perform activities and continuously experiencing feeling of rush. García-Jiménez et al.[2] argue a lack of control over one's actions limits the individual's capacity to consider all the information available and to make a decision in optimal conditions. A mathematical formulation to express time pressure and its effect on perceived utility is being currently investigated.

3. Existing Scheduling Models

3.1. Criteria for Comparing Rescheduling Models

There are several models about rescheduling (see Section 3.3), and in order to analyze and discuss them, this paper puts forward to six comparison criteria.

C1. **Agent-based model.** The goal of this paper is to simulate a dynamic situation at individual level. An agent-based model is therefore well adapted. It regards each individual as an agent, an agent has the characteristics of the corresponding individual, and makes rescheduling decisions according to a set of rules. Agents not only communicate with each other, but also with the environment. It is the most significant criterion. The value of this criterion is yes or no.

C2. **Rescheduling during the simulation process.** The purpose of this paper is to simulate the rescheduling decisions during the real execution of daily simulation. This means: when people execute their schedules and an unexpected event happens, they need to consider how to execute the current activity and the remaining activities of the schedule. The decision is made at the occurrence of unexpected events. The value of this criterion is yes or no.

C3. **Considering similarity.** People want to avoid tedious modification when rescheduling. They would like to maximize the similarity to the previous plan[5]. Rescheduling decisions are made to satisfy the newly emerging circumstances, and try to keep the new plan similar to the previous one. The value of this criterion is yes or no.

C4. **Considering all the rescheduling possibilities and choices.** Most models don't consider the change of activity schedule sequence, and except for traffic jam, they don't consider other causes of rescheduling. Our research wants to study more possible causes for rescheduling, and more rescheduling choices. Events that may cause rescheduling are analyzed in Section 1, and all the rescheduling choices are discussed in Section 3.2. The value of this criterion is yes or no.

C5. **Considering activity involving more than one person.** For the activities involving more than one person, negotiation should be taken into consideration. Participants need to negotiate with each other to make decisions, the preferences and requirements of each participant should be considered. The value of this criterion is yes or no.

C6. **Considering time pressure, time pressure also affects people's decisions.** Time pressure depends on the needs and time desirable for mandatory activities, and it also differentiates from woman and man. Usually, woman perceives time pressure more frequently than man[1]. The value of this criterion is yes or no.

3.2. Reschedule Choices

During the situations described in Section 1, there are several ways to reschedule: (i) change the activity location l_a (ii) change the trip transport mode m_o (iii) shorten the activity duration d_a. In addition, changing the sequence of activities, adding, deleting and substituting activities are essential choices. All these choices depend on the activity attributes, e.g. transport mode, time at which the activity is planned, activity frequency, and regular and alternative locations. The preference of each choice depends on characteristics of individuals, e.g. gender, age, education, profession.

3.3. Reschedule Models

Following agent-based rescheduling models will be analyzed in this section: MATSim, Aurora, the model of Within Day Re-Scheduling (WIDRS) and Househould Activity Pattern Problem (HAPP).

MATSim consists of simulation, scoring and rescheduling parts. The main modules of rescheduling in MATSim are the optimization of activity duration and routing by means of an algorithm to calculate time-dependent shortest paths[6]. There are other choices, like changing transport mode and activity location. MATSim computes the utility of a schedule as the weighted sum of particular monetary and timing constraints related properties, it can adapt the activity timing by means of a genetic algorithm. The newly found schedule does not necessarily have a higher utility than the previous ones. A small set (typically five) of best schedules is kept for each agent. MATSim is not appropriate for activity reordering, dropping and addition. It begins to reschedule after running the final activity (not just limited to a day). MATSim satisfies the criteria of “agent based model.”

Aurora reschedules with more ways, it has activity addition, activity substitution and activity dropping in addition to what MATSim has[7]. While, the utility function of Aurora is more reasonable than MATSim, utility function used in Aurora considers the duration of each activity and the uncertain factors. Aurora reschedules from the beginning of the plan, and there is no consideration of traffic problem and emergency events. Aurora meets the criteria of “agent based model’ and ’considering all the rescheduling possibilities and choices.”

WIDRS is a macrosimulation model. It takes advantage of the output of FEATHERS, and calculates the road network load every 15 minutes. By receiving the network state evaluation, individuals have access to be aware of the incidents. And then individuals will adapt the activity start time or end time to reschedule, not by other ways like relocation, activity dropping etc[8]. Therefore, WIDRS satisfies the criteria of “rescheduling during the simulation process”, “considering similarity” and “considering time pressure .”

HAPP is an activity-based model, it combines utility and similarity to optimize a schedule. When scoring a new plan, similarity is thought more important than utility. It assumes that there is a known moment to change the schedule of remaining not-yet-completed activities. In order to minimize changes to the preplanned schedule, it tries to minimize the number of affected persons[5]. HAPP meets the criteria of “rescheduling during the simulation process”, “considering similarity” and “involed more than one person.”

The comparison results of the four models can been seen in Table 1.

Models	MATSim	Aurora	WIDRS	HAPP
Agent-based model	YES	YES	NO	NO
Rescheduling during the simulation process	NO	NO	YES	YES
Considering similarity	NO	NO	YES	YES
Considering all the rescheduling possibilities and choices	NO	YES	NO	NO
Considering activity involving more than one person	NO	NO	NO	YES
Considering time pressure	NO	NO	YES	NO

Table 1. Comparison of four rescheduling models.

According to the comparison results, none of them meets all the criteria. WIDRS and HAPP are not agent-based models. Although WIDRS only reschedules by adapting duration time, it is the only model which takes time pressure into consideration. Also, only HAPP considers *schedule similarity*; agents can communicate with each other in this model, while, it just studies the rescheduling by activity insertion and duration adjustments.

4. Proposals

We take each individual as an agent. Agents can communicate with the environment and with each other at any time. They receive information and give feedback. Since rescheduling takes time and mental efforts, we assume that people reschedule only when it is necessary. During the simulation of a planned daily schedule, whenever unexpected events happen, they will trigger the rescheduling module. After rescheduling, an updated schedule is built up, and used in the following steps of the simulation process. The schematic representation of the whole re-scheduling process is illustrated by Fig. 1.

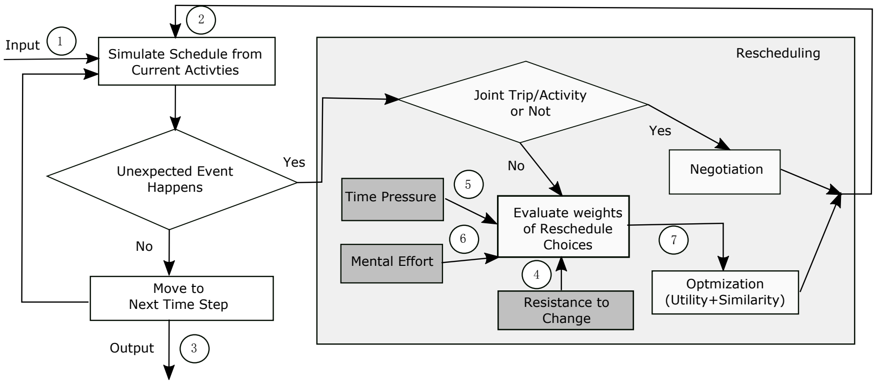

Fig. 1. Schematic Representation of the Re-Scheduling Process

There are three main modules in the proposed model: (i) *simulate schedule from current activities*, (ii) *reschedule process* and (iii) *move to next time step*. In Figure1, the numerical symbols stand for the input and output of each module. For the whole model, ① is the initial demand; ② is the updated demand; and ③ is the final version of the schedule. During the simulation process, the initial input is the initial demand. Agents execute the planned daily schedule, and interact with the dynamic environment and other agents. The rescheduling modules are explained below.

4.1. Rescheduling Module

Firstly, the rescheduling module determines if the trip/activity is a joint trip/activity or not (see Section 2). Then, the module branches to one of the two following cases:

1. Joint trip/activities - Negotiation Process

   If the unexpected event happens when simulating a joint trip or activity, and the group composition did not change: loosing a participant from the group by an unexpected event is an example that does not match the condition. The Negotiation Process is initiated for obtaining the updated schedule. Negotiation is a dialogue among activity parties, possibly having conflicting interests. It is intended to reach an acceptable agreement between the partners, or to collectively search for a coordinated solution to the planning problems. While, there will be time limitation for this process, it is decided by the begin time of next activity, if rescheduling time is beyond the limitation, the negotiation failed.

   When starting the rescheduling process: $S \overset{negotiation}{\longrightarrow} S'$, agents need to negotiate to get a new schedule. The new schedule should satisfy the time tolerance of every agent. The involved agents communicate to each other, and eventually get the updated schedule reaching the requirements of all. Under the constraint of time window, each agent has a preference for rescheduling. It can be seen as a bargaining problem: for every rescheduling method, a cost function c_i is provided by each agent i. The cost of the schedule before any change is c_i^-. The agent utility is defined as $U_i = c_i^- - c_i$[9]. We choose the new schedule with the the highest utility in this model.

$$\text{maximize}\left(U = \sum_{i=1}^{n} U_i\right) \text{ where } n \text{ is the number of agents involved in the negotiation} \tag{5}$$

2. Solo trip/activities - Making personal rescheduling decisions

   If unexpected event happens when simulating a solo trip/activity, the rescheduling process is based on: resistance to change ④, time pressure ⑤, the mental effort ⑥, and weight of each rescheduling choice ⑦. The rescheduling process is described as: $S \times W \overset{optimization}{\longrightarrow} S'$.

   The rescheduling choices are defined by the type of activities, and the attributes changes are defined by set W. For the weight of each rescheduling choice, people with different characteristics will have different preferences.

Furthermore, mental effort, time pressure and resistance to change also affect people's tendency to particular rescheduling choices. Both the mental effort and resistance to change are individual-specific functions. The former focus on the number of changes, and the latter for the type of changes. Mental effort generates a tendency to avoid to reschedule activities, because each schedule adaptation will increase the mental fatigue. And resistance to change implies the preferred ways of rescheduling[10]. Time pressure also affects people's preference for rescheduling choices. It is assumed that lack of decision time budget will result in experience of high time pressure.

In order to get the best new schedule, it has the scoring function in the optimization part, considering both individual's schedule similarity and activity utility. Agents will choose the new schedule with the highest score. The score of reschedule decision is defined as Z, the utility is defined as U, similarity is defined as M, the weight of utility and similarity is respectively β_U and β_M. The formulation is:

$$maximize\,(Z = \beta_U \times U + \beta_M \times M) \tag{6}$$

In this paper, the authors will use S-shaped utility method[11]. Furthermore, specifying an appropriate similarity measure is a difficult problem. Both topics are the subject of ongoing research in the literature. Finally, the values of β_U and β_M are to be studied in the future.

5. Conclusion and Perspectives

The purpose of this paper is to establish an agent-based reschedule model from a new view. It aims to simulate the rescheduling during the real execution process when unexpected events happen. It not only considers the individual rescheduling decision making, but also the rescheduling decisions made by several persons. What is more, it wants to simulate the rescheduling possibilities and choices as much as possible. Rescheduling research covering similarity, negotiation and time pressure is scarce. Since the topic is relevant we present a (simple) skeleton model that allows for incremental modular development. The detail of each module will be studied in the future. And the model will be implemented by SARL language, which is running on Janus platform.

Acknowledgements: This work is supported by the China Scholarship Council Grant 201604490095.

References

1. Batool, T.. *Time Pressure and Flexibility in Daily Agendas*. Master's thesis; UHasselt; 2016.
2. García-Jiménez, M.E., Ruíz, T., Mars, L., García-Garcés, P.. Changes in the scheduling process according to observed activity-travel flexibility. *Procedia-Social and Behavioral Sciences* 2014;**160**:484–493.
3. Bellemans, T., Kochan, B., Janssens, D., Wets, G., Arentze, T., Timmermans, H.. Implementation framework and development trajectory of feathers activity-based simulation platform. Transportation Research Record: Journal of the Transportation Research Board; 2010, p. 111–119.
4. Joh, C.H.. *Measuring and predicting adaptation in multidimensional activity-travel patterns*. Ph.D. thesis; Technische Universiteit Eindhoven; 2004.
5. Gan, L.P., Recker, W.. A mathematical programming formulation of the household activity rescheduling problem. *Transportation Research Part B: Methodological* 2008;**42**(6):571–606.
6. Waraich, R.A., Charypar, D., Balmer, M., Axhausen, K.W., Waraich, R.A., Waraich, R.A., et al. Performance improvements for large scale traffic simulation in matsim. In: *9th Swiss Transport Research Conference, Ascona*. 2009, .
7. Arentze, T., Pelizaro, C., Timmermans, H.. Implementation of a model of dynamic activity-travel rescheduling decisions: an agent-based micro-simulation framework. In: *Proceedings of the Computers in Urban Planning and Urban Management Conference*; vol. 48. 2005, .
8. Knapen, L., Bellemans, T., Usman, M., Janssens, D., Wets, G.. Within day rescheduling microsimulation combined with macrosimulated traffic. *Transportation Research Part C: Emerging Technologies* 2014;**45**:99–118.
9. Cho, S., Knapen, L., Bellemans, T., Janssens, D., Wets, G., et al. A conceptual design of an agent-based interaction model for the carpooling application. *Procedia Computer Science* 2012;**10**:801–807.
10. Joh, C.H., Arentze, T., Timmermans, H.. Modeling individuals' activity-travel rescheduling heuristics: Theory and numerical experiments. *Transportation Research Record: Journal of the Transportation Research Board* 2002;(1807):16–25.
11. Van Bladel, K., Bellemans, T., Wets, G., Arentze, T., Timmermans, H.. Fitting s-shaped activity utility functions based on stated-preference data. In: *the 11th International Conference on Travel Behaviour Research*. Jyoto, Japan; 2006, .