Adding intermodality to the microscopic simulation package SUMO

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It is shown how the traffic simulation SUMO which traditionally focused mainly on individual road traffic could be extended to serve the purpose of a general traffic simulation (including transport of individual persons) while retaining most of in- and output formats and the performance of the original system. The approach presented is still work in progress and will serve as a first step in the direction of coupling SUMO with demand generation models and allow intermodal routing strategies to be tested.

1 Introduction

The simulation package SUMO[2] which is available for about nine years now started with the promise to give a full range city traffic simulation including individual persons and public transport[3]. While the individual road traffic simulation is already quite mature, the public transport part as well as the simulation of individuals are available only recently. To the best of our knowledge this makes SUMO the first all purpose microscopic traffic simulation available as open source.

The steps taken to include the simulation of single persons were chosen carefully in order not to invalidate the previous data model of SUMO but rather extend it with a few ingredients to fit our current needs. The requirements formulated are:

1. Inclusion of public transport with timetables
2. Simulation of the complete journey of a person with switches between modes (public / individual transport)
3. Respect walking times of persons
4. Delay of a single person could influence departure times of vehicles later that day
5. Simulation of car pooling
6. Multimodal route finding

All requirements (except for the last one) could be meet with only a small number of changes to the original SUMO data model which will be described next. Furthermore, the changes to the code and the car model are very limited which gives rise to the conjecture that also the impact on performance will be negligible. First experimental results presented in the last part support this view.

The paper contains the following parts:

Description of the SUMO model A short description of the input data needed for a SUMO simulation and the car following model used.

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Additional items for multimodality How the SUMO software package was extended to simulate individual persons traveling.

Results and future work How the person framework integrates with the rest of the simulation and what still needs to be done.

2 Modeling vehicle traffic with SUMO

Unlike other traffic simulations SUMO models each vehicle and each route individually. This allows for a very fine grained control of the behavior of the cars and their interaction. Usually a vehicle is completely defined given its physical parameters like length, maximum acceleration and maximum speed (see description of the car following model below) and its route (consisting merely of a list of consecutive edges in the net) together with a departure time. In this section we will describe these parts of the input a little closer but will neglect the sometimes very complex description of the network (including traffic lights, lane connections and so on).

2.1 The car following model

The model used currently within SUMO is a variation of the Krauß-model (invented and described in [4]). It is capable of displaying main features of traffic like free and congested flow. In each time step the vehicles speed is adapted to the speed of the leading vehicle in a way that yields to a collision-free system behavior within the following simulation step(s). This velocity is called the safe velocity v_s, and is computed using the following equation:

$$v_s = v_s(t + \Delta t) = \sqrt{\tau^2 b^2 + v_l^2(t) + 2bg(t)} - \tau b$$

$v_l(t)$ speed of the leading vehicle in time t

$g(t)$ gap to the leading vehicle in time t (in seconds)

τ the drivers reaction time (usually 1s)

b the deceleration.

To bind the acceleration to the vehicles physical abilities, the resulting wished or desired speed (v_d) is computed as the minimum of the vehicles possible maximum velocity, the vehicles speed plus the maximum acceleration with the safe velocity computed as shown above, therefore a vehicle will not drive or accelerate faster than is possible for it:

$$v_d = v_d(t + \Delta t) = \min(v_s, v(t) + a\Delta t, v_{\max})$$

Further, the driver is simulated by assuming he is making errors and so fails to perfectly adapt to the desired velocity. This is achieved by subtracting a random "human error" which is uniformly distributed in a fixed interval:

$$v(t + \Delta t) = \max(\mathrm{rand}(v_d - \epsilon\Delta t a, v_d), 0)$$

$v(t)$ the current speed

a the acceleration

$v_{\max}$ the maximum speed of the vehicle

ϵ the drivers imperfection (between 0 and 1).

A vehicle type is fully described with the set of (time independent) parameters from the equations above, which are a, b, $v_{\max}$, τ and ϵ together with its length. Each vehicle in the simulation has exactly one fixed vehicle type.

With recent versions of the simulation it is possible to change the time step size Δt to any multiple of a millisecond. which allows for a very fine grained simulation even of complex situations.

2.2 Input data and formats

The routes and types of vehicles are defined in XML files with the following structure:

```
<routes>
    <vtype id="t" length="5"
           accel="0.8" decel="4.5"
           maxspeed="70"/>
    <route id="r0"
           edges="beg middle end"/>

    <vehicle id="1" type="t"
             route="r0"
             depart="10"/>
</routes>
```

Thus the definition of a vehicle needs nothing more than a vehicle type and a route it refers to. The simplicity of description shall be retained in the extension to intermodality.

3 Adding intermodality

3.1 Public transport

To keep our extension simple we work under the assumption that a train or a bus is not fundamentally different from a car concerning the car following model mentioned above. This allows for a very straightforward extension of SUMO by adding just another type (where type means the collection of model parameters mentioned above) of vehicles for every mode of transport. For rail transport the street network has to be augmented by the train network which are usually disjoint. The SUMO network model (which is not discussed in detail here) is flexible enough however to cover the case of overlapping streets and train nets (think of tramways) as well. This is achieved via the concept of allowed vehicle classes for certain lanes in the net.

A second point which makes public transport different from individual driving is that there are a number of pre-defined stops on the route which may or may not be time triggered (fixed timetable) or person triggered (car pooling or taxi traffic). This leads to the introduction of the concept of a *stop* into the route description of a vehicle. A stop may have different properties which reflect different peculiarities of the transport mode. The vehicle may move to a parking site (allows others to overtake) it may wait for individuals to appear (car pooling), it may have a fixed (minimum) waiting time or a fixed (earliest) time when to move on (timetable) or both. Thus an example stop description may look as follows:

```
<stop lane="beg_0"
      startPos="10"
      endPos="20"
      until="100"
      duration="30"
      parking="false"
      triggered="false"
/>
```

A vehicle having this stop in its route will stop at lane 0 of street beg until simulation second 100 but for at least 30 seconds. It will not be removed from the network during the stop and an arriving person will not trigger an ending of the stop.

A third point is that it is usually not important which individual train or bus a person takes as long as it is the desired *line* taking it to the correct destination. This gives rise to a new attribute for vehicles which groups them together in order to let individual persons identify which vehicle they could possibly take (see next subsection).

Last but not least it should be easier to emit vehicles repeatedly into the simulation thus reflecting the nature of public transport with regular intervals. This leads to the introduction of the *flow* concept which is very similar to a vehicle but allows the definition of a repeat period for the creation of multiple vehicles. The following listing shows how a bus line may be defined.

```
<routes>
    <vtype id="b" length="15"
           accel="0.8" decel="4.5"
           maxspeed="50"/>
    <route id="busroute"
           edges="beg left end">
        <stop lane="beg_0" endPos="50"
              duration="30"/>
    </route>
    <flow id="bus" type="b"
          route="busroute" line="l100"
          begin="0" period="120"/>
</routes>
```

3.2 Persons and plans

A single person is a new independent concept to be introduced into the simulation framework. The requirements do not include a realistic walking movement, thus SUMO is not going to be extended by a "person following model", persons should simply serve either as traffic generator or as links between different traffic modes or as obstacles to the traffic flow in the sense of vehicles waiting for persons will hinder the normal flow of traffic.

A person may be in one of four states:

1. Waiting for a vehicle
2. Moving with a vehicle
3. Walking
4. Stopping (i.e. doing nothing traffic related)

Except for the first one all of them need to be modelled explicitly and the day of a person or her *plan* will be a list of items chosen from the ones above. Thus a person is completely defined with a plan together with a (desired) departure time while the single items need to include at least a start and a destination edge (street) in the network.

The following listing shows how to use such a person driving one of the busses defined in the previous subsection.

```
<routes>
    <person id="p1" depart="20">
        <ride from="beg" to="end"
              lines="l100"/>
        <stop duration="20"/>
        <walk edges="end" speed="2"/>
    </person>
</routes>
```

4 Results and future work

There are two things to be discussed:

- is it possible to fulfill all requirements with the changes mentioned, and
- how is the impact on the rest of the simulation.

Revisiting the requirements from the first section we can draw the following conclusions:

1. Public transport

   Adding public transport was possible by introducing stops on routes which can be time triggered and by allowing vehicles to have a line attribute which groups vehicles together.

2. Person journeys

   Individuals have a plan of single trips they are going to follow. This models a complete journey (even a set of journeys) possibly over a whole day.

3. Walking times

   Persons walk fixed street lists with a fixed (configurable) speed which is an (albeit simple) representation of walking travel times.

4. Person plans delay vehicles

   Departure and stop leaving of cars may be time triggered and person triggered. If the person has a planned stop with a fixed duration, leaving the stop will be delayed if the first trip leading to the stop was delayed.

5. Car pooling

   Every stop of a vehicle may be specified as being person triggered. If the person arrives, the car will leave the stop which allows the simulation of car pools. Furthermore every person may have an individual destination edge even if they are on the same vehicle.

6. Multimodal route finding

   Since the router was not adapted this is the only requirement which could not be adapted so far.

First experimental results on simple networks show that the effect of traveling persons is negligible. A run of 5000 vehicles through a small network has a mean running time of 8407 ± 410 milliseconds (based on 100 runs on an Athlon64 at 2.2 GHz). The same network with person induced traffic has a running time of 8711 ± 531 milliseconds. While those measurements are by no means complete, they indicate that the person simulation does not affect the traffic simulation considerably.

4.1 Ongoing work

There are a number of things which are going to be improved in this system, the most prominent is of course the possibility to actually route the persons over several modes of transport (last requirement). Using approaches from existing work on intermodal routing this is going to be implemented in the near future.

The second thing is to perform a visualization of the person simulation. Especially for debugging purposes it would be very helpful to get a feedback on the precise position of the persons at any time step.

Another thing missing is an import facility for existing timetables. At the moment every timetable has to be edited by hand which may be a cumbersome task. For the simulation of whole cities an interface to timetable data is a necessary condition.

After implementing all of these interfaces at least as a prototype we are going to couple the simulation model with the demand generation model TAPAS developed at DLR [1] which will use the travel times from the simulation to revalidate the choices of their agents.

4.2 Conclusions

It has been demonstrated, that it is possible to add intermodality to the SUMO package without re-inventing the simulation. The set of changes necessary to add public transport and person simulation fits nicely into the existing framework and seems to be almost imperceptible concerning the performance of the system. It is our hope that with support from the SUMO user community we can reach the last steps concerning the full integration of public transport within one years time and have an all mode open source transport simulation by the middle of 2011.

References

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