THE NEED OF COMBINING DIFFERENT TRAFFIC MODELLING LEVELS FOR EFFECTIVELY TACKLING COMPLEX PROJECT

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Abstract

This paper makes reference to the debate currently existing in the transport modeling community about which is the most adequate traffic flow representation for tackling traffic simulation studies. Instead of answering this question, the present article underlines the benefits of each of the existing modeling level and, instead of comparing them, suggest an integrated solution where all levels could be used in a unique environment in order to get the best benefits of them.

Keywords: Integrated framework, Traffic Modeling, Aimsun.

Presenting Author's biography

Josep M. Aymamí received a Master Degree in Civil Engineering in 2007 by the Polytechnic University of Catalonia, specialized in Transportation and Urban Planning. He also studied a Post-graduated diploma in transportation planning and management. From 2003 to 2006 he collaborated in master plans for the villages of Sitges and Mont-Roig del Camp, Spain, as well as for projects for Ports de la Generalitat, related to harbour planning. Since 2006 he joined TSS' Consultancy Department, where he worked as a projects engineer at TSS, in charge of planning, traffic management and public transportation optimisation projects. From 2006 he also participated in the TSS contributions on the 6th. Framework Program European Research Projects (INTRO: Intelligent Roads and eMOTION: Europe-wide multi-Modal On-trip Traffic InformatiON), and in the National Research Project MARTA. Since 2009 Josep M. is Project Manager at TSS.

1 Introduction

Transport engineers have, for decades now, been relying increasingly on the use of mathematical models and specialist software for analysing the performance of current and future transportation networks. Macroscopic software packages, generally based on static paradigms, pioneered the field, to be followed later by more disaggregated and dynamic models. Benefiting from the steadily increasing availability of affordable computing power, these more detailed models have become the tool of choice for operational studies, commonly in the form of microscopic simulators. Among other dynamic models, mesoscopic ones have more recently started to receive attention as a viable and interesting compromise between the macro and micro levels. With the introduction of new technologies, data of unprecedented quantity, detail and ultimately quality is set to become available making nanoscopic models a viable future prospect and an interesting research direction.

2 Different modeling levels

The proliferation of levels, approaches and software packages inevitably creates a temptation to compare. Comparisons quickly mutate into contests that focus on limitations; after all, those can be easily identified by taking a critical look at a model's underlying assumptions. For example, a static model is, by definition, not appropriate for studying the impact of different adaptive control regimes. A dynamic equilibrium assignment approach is probably not the most realistic way of predicting driver response to a non-recurrent incident. Using a micro-simulator for a 35-year strategic plan without information on the location and capacity of roads - let alone traffic control plans, types of vehicles and driver behaviour – is a likely waste of resources. Mesoscopic models, whether working with platoons or individual vehicles are not the most precise when dealing with merging, oversaturated flows, actuated detection and interactions with pedestrians at crossings. And the list continues: today's fastest micro-simulator may be good enough to run a simulation of the entirety of Singapore faster than real time; but it is still way too slow for carrying out real-time traffic analysis in the entire Los Angeles metropolitan area. With its detailed modelling of a driver's decision-making process every fraction of a second, a nanoscopic model seems a promising and more appropriate way of analysing aspects such as emission patterns or ADAS. But what about its (currently) disproportional calibration and computing time requirements?

The obvious conclusion is that there is no overall "contest winner" and that each model has its limitations and strengths and those depend on the intended application, data availability, time horizon and evolution of computing and ITS technology. In that sense, promoting a model, principle or approach, no matter how well conceived and developed, as a one-size-fits-all solution seems doomed to fail. However this is only the theory. In practice, model developers and practitioners need to do the best job with what they have available so they often have to deal with the temptation to cross a model's "natural" boundaries. Working with a particular model over several years allows one to develop intelligent "work-arounds" which virtually extend the model's applicability by masking some of its limitations. The use of devices which vary by model and include penalties, dynamic approximations, fictitious entities etc. is sometimes deployed in real-life projects to include, in proxy form, aspects which were not originally included within a particular modelling framework. Still, no amount of creativity and enthusiasm will make micro-simulation the most suitable approach for a 50-year strategic plan or a static traffic assignment approach the best platform for real-time traffic forecasting. Some boundaries are hard.

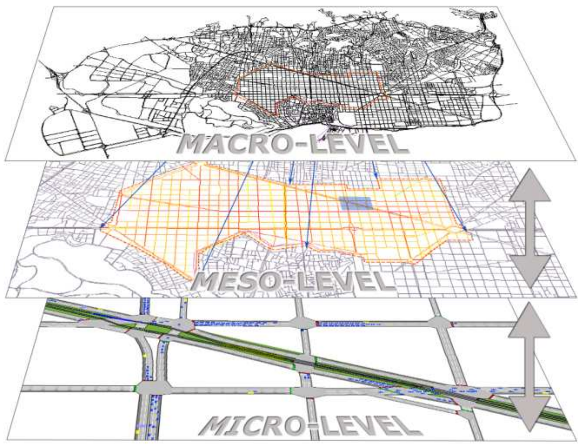

Fig. 1: The different modeling levels

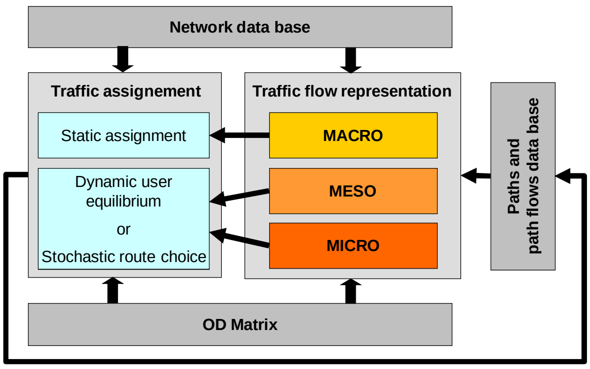

Fig. 2: The Integrated environment in Aimsun

Specialist consultants typically adopt an impartial approach opting to acquire and learn a variety of tools and to use "the right model for the right job". From a practical point of view, it is both attractive and appropriate to devise informed rules of thumb for choosing a particular approach. While this is clearly less error-prone than a dogmatic approach, one might question whether it is actually possible to compartmentalise transport engineering projects in such a neat way. Is it really possible to speak of a "static assignment project" and a "micro-simulation project"? What if one needs both models within the project? And what about mesoscopic approaches? Should we look for "mesoscopic project" opportunities? What's more, what if one needs to use two types of models iteratively or even concurrently?

3 The integrated approach

The model integration seems therefore the obvious solution. It is possible to implement it either within a single multi-level framework or by integrating modelling approaches originally developed independently. The second method relies on the exchange of information via files and lacks some of the convenience, possibilities and economy of the first method: multiple tools imply duplication of cost, effort and data and propensity for error. That said, the multi-tool approach is feasible and can be considered in projects where different models are used in sequence. Where we believe that a single model and software architecture has a distinct advantage is when models must be used concurrently or iteratively. Working inside the same software is not just a case of convenience for the user (or the developer): for one, the coherence of the two models forming a hybrid is a necessary condition for its robustness and fidelity and the ultimate reason why fusion is the way forward.

The development of this concept of integration into Aimsun is resting on three pillars, shown in Fig. 2:

1) An object orientated data base that contains all the information forms both the demand (mainly OD matrices per vehicle type and time periods and PT schedules) and the supply (Road infrastructure, traffic management actions, incidents, traffic signals, PT lines, etc.). The object oriented data base will therefore contain all the information needed to feed the network loading and assignment processes. Each entity (road section, node, turn, VMS, controller, etc) is described through different attributes (in the same way as a GIS). Some of the attributes will be used only by a specific model while others will be shared by all of the models. In this last case, speed limit is a perfect example: such road section attribute is used by the three network loading models. Fig. 3 shows in detail this concept of the shared data base.

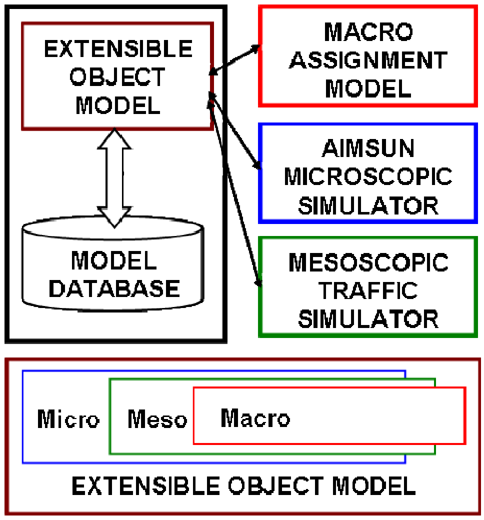

Fig. 3: Object oriented data base

2) Three different network loading models (macroscopic, mesoscopic and microscopic)

3) Three traffic assignment techniques, one static and two dynamic.

Concerning these last two elements, the network loading and the traffic assignment, the authors want to emphasize here that, given the adopted data architecture (e.g. sharing the same network representation), there is no need to tie any dynamic traffic assignment (DTA) to a network loading process. The intention of this comment is to clarify a common misunderstanding in the modelling community which is the habit of linking DTA with a meso network loading which is an overly restrictive vision of what an integrated framework can offer.

Indeed, DTA and even static traffic assignment are fed by travel times calculated by a model, whatever this model might be. The only difference, from a technical point of view, between the static assignment and the dynamic one is that the latter is time-dependent and produces various sets of paths and path flows, one per time period. One of the clear advantages of using a common road network representation is that traffic assignment results produced by any type of network loading modelling can be stored and reused for another simulation run, without having to apply the same model that was used to produce these paths.

From a practical point of view, this architecture allows running scenarios such as:

- Running a macro static assignment
- Using these results to start a Dynamic User Equilibrium (DUE) assignment process with meso
- Using the results from the meso DUE for a microsimulation in which the Stochastic Route Choice only applies to informed (VMS, radio, navigation system) vehicles [2]

This assignment results data flow capability is detailed in Fig. 4. In fact, such a conceptual approach has been described in the literature for several years now [7]. Separation between DTA and networking loading is, in fact, a fundamental criterion for hybrid simulation consisting of running simultaneously microscopic and mesoscopic network loading, each technique being applied in a different part of the network. This concept is described in the next section.

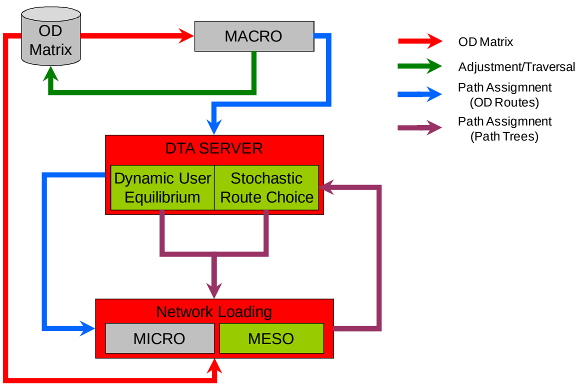

Fig. 4: Paths assignment and OD matrices data flow chart

4 A Hybrid Framework

As stated in section 2, microscopic models are usually appropriate for operational analysis due to the detail of the information provided by the simulator. However, they are data intensive and have a significant computational cost. Mesoscopic models combine simplified flow dynamics with explicit treatment of interrupted flows at intersections and allow modelling of large networks with high computational efficiency. However, the loss of realism implied by a mesoscopic model makes it necessary to emulate detailed outputs; for instance, detector measurements or instantaneous emissions.

Also for the modal integration, like the addition of the pedestrian interaction into traffic models, the microscopic level is required.

The above give rise to the need to combine meso and micro approaches with new hybrid traffic simulators where very large-scale networks are modelled mesoscopically and areas of complex interactions benefit from the finer detail of microscopic simulation. Combining an event-based mesoscopic model with a more detailed time-sliced microsimulator raises consistency problems on the network representation and the meso-micro-meso transitions.

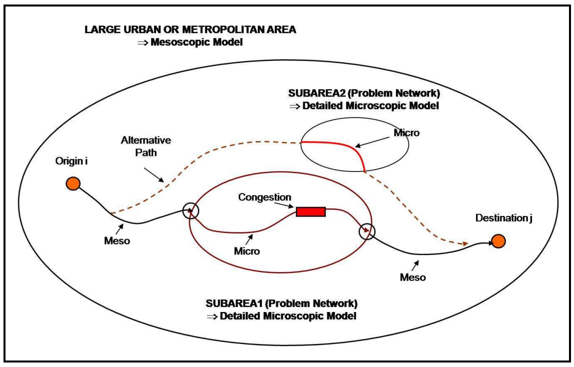

Fig. 5: Scheme of a hybrid approach to a traffic model, meso with micro subzones

This section extends the Computational Framework for implementing the hybrid meso-microsimulation framework presented in [6], that completes the conceptual scheme of the diagram in Fig. 6 where the Path Calculation and Selection module is implemented using the Dynamic Traffic Assignment Server and the Dynamic Network Loading by the microscopic and mesoscopic network loading modules, each one implementing their specific behavioural models (car-following, lane changing and gap acceptance models).

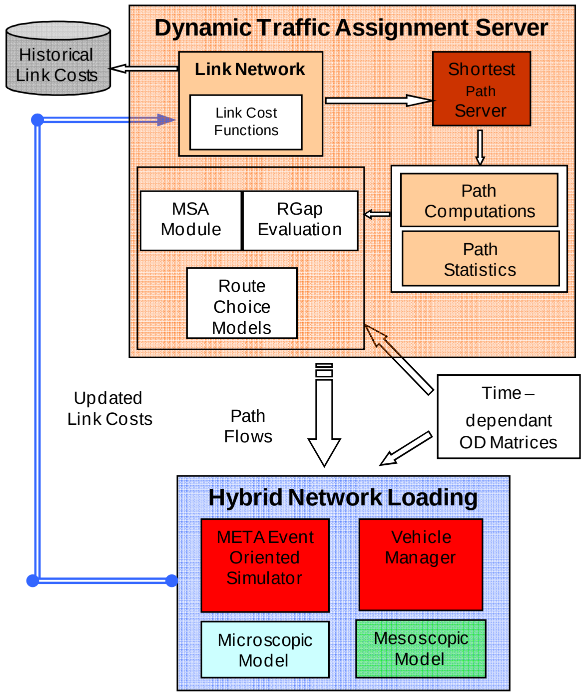

Fig. 6: Integration of the Dynamic Traffic Assignment Server and the Hybrid Network Loading

In order to develop reliable hybrid models, there are some key requirements that the integration of micro and meso needs to satisfy [5]:

- Consistency in network representation.
- Consistency in route choice representation.

- Consistency of traffic dynamics at meso-micro boundaries.
- Consistency in traffic performance for meso and micro submodels.
- Transparent communication and data exchanges

All requirements in the presented hybrid framework are almost satisfied taking into account the unique network representation and the integrated framework architecture. Analyzing each requirement:

- Consistency in network representation: In the integrated platform, explained above, both models share a unique network representation, which means each model has its specific view of the same object in the network. As a consequence of this common representation, this consistency requirement is always satisfied because there is a unique network representation. However, each submodel (meso and micro) has an internal representation in order to model the traffic dynamic in the links.
- Consistency in route choice representation: The integrated model architecture guarantees consistency in route choice representation because the dynamic traffic assignment server module has a unique route choice representation, independent of whether the links are defined as mesoscopic or microscopic.
- Consistency in traffic performance for meso and micro submodels: This consistency is determined by the correct calibration of each submodel and to establish the relationship between the calibration parameters of both models.
- Consistency of traffic dynamics at meso-micro boundaries: This consistency is guaranteed by the vehicle manager module that transfers the boundary conditions between the mesoscopic and microscopic in all sections in the border.
- Transparent communication and data exchanges: The exchange of information is carried out by the Vehicle Manager module, which has a unique representation of each vehicle and is shared by both submodels. Regarding communication, the synchronization of the two submodels is managed by a dedicated META Event Oriented Simulator.

The following chapters add further detail to the specifications of the META Event Oriented Simulation and the Vehicle Manager.

5 META Event Oriented Simulator

Besides the information exchange there is another important issue to take into account, the synchronization of both models. As the mesoscopic approach is based on an event oriented approach, [1] and [3], and the microscopic approach follows a time discrete simulation approach, [1]. This is the role of the META Event Oriented Simulator.

The synchronization process between the Mesoscopic model and the Microscopic model has to consider the nature of both models. The function of the META Event Oriented Simulator is to synchronize both models. The synchronization is achieved by changing the time discrete approach on which the microscopic simulator is based, into the event oriented approach used in the mesoscopic simulation. The change is made by adding an “artificial” event generator to the microscopic simulation model by which each event corresponds to each simulation step.

6 Vehicle Manager

The vehicle manager module has the following roles:

- Unique vehicle generation process
- Exchange of boundary conditions
- Look Ahead model

6.1 Vehicle Generation

The vehicle generation is a unique process for both models, which means once a vehicle is generated it assigns all behavioural parameters (meso and micro) and they are kept during its trip.

The Vehicle Manager has this responsibility and it generates all vehicles according to the arrivals distribution defined by the user and gives control to the behavioural model assigned to the entrance section in the system. Once a vehicle exits from one meso section to one micro section, or vice versa, the vehicle manager acts as a bridge between the two models, removing the physical vehicle from the first behavioural model and generating one entrance to the other, but keeping the initial assigned parameters.

6.2 Look Ahead model

One aspect to point out is the consistency between a meso or micro simulation compared with the hybrid simulation in terms of the lane changing models. The lane changing model implemented in Aimsun [1] is based on a decision tree where one component is the decision of target lanes in each section. This decision is not only based on the traffic conditions present in the section but include the traffic conditions and the feasible lanes for reaching the turning movements determined in its path plan (a maximum distance exists that determines the look-ahead capability of each vehicle). According to this requirement, is it necessary to have a common look-ahead procedure, implemented within the vehicle manager module, which enquires about the traffic conditions for each section independently of the type of model.

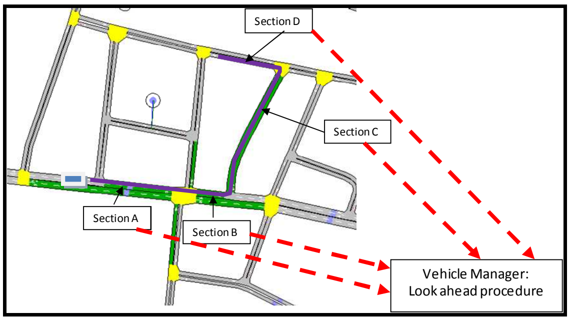

Fig. 7: look ahead procedure for one specific vehicle

Fig. 7 depicts an example of how the Look Ahead procedure for calculating the target lanes is applied to one specific vehicle. This procedure takes all sections in the vehicle path plan, in this example Sections A, B, C and D, and for each individual section the Look Ahead process obtains the local traffic conditions from both submodels, in this example the traffic conditions of sections A, B and C are requested from the microscopic submodel and of section D from the mesoscopic submodel.

The traffic conditions requested from each submodel get the feasible lanes considering the following criteria:

- Incident presence
- Compulsory reserved lanes
- Closed lanes
- Presence of a Public Transport stop (in case of a Public transport vehicle)
- Feasible lanes for reaching the turning movement

6.3 Boundary conditions

A key point is the treatment and the consistency of the boundary conditions, a process that is also dealt with by the vehicle manager. The process of moving a vehicle from one model to the other requires the answer to the following question: Has the other model space to enter the vehicle? If the answer is yes, then the process of transferring the vehicle between models begins and according to the new behavioural model, it then calculates the new vehicle state (position and speed) and this information updates the internal structures to the upstream model. If the answer is no, the vehicle transfer is not carried out and it creates the boundary conditions creating a fictitious vehicle stopped at the end of the lane.

7 Conclusions

This paper has detailed a new approach to the integration that is intended for expanding the traffic simulation into a wider range of uses. From the traditional approach of selecting one level of simulation for each purpose, benefits of its combination and the cooperation between levels show better flexibility to adapt to current ongoing traffic related projects and its use as test bed for ITS technologies.

Thus, beyond the exchange of information between levels, the logical step to follow is the hybrid meso-microsimulation, allowing obtaining further benefits and proper performance for each of the described applications, among others.

The hybrid meso-microsimulation has some requirements to enable communication and consistency, which can be solved with the use of a Vehicle Manager module, to establish the exchange of information; and through a dedicated META Event Oriented Simulator, to ensure the synchronization of the two submodels. The authors are currently working, to demonstrate its feasibility at research but also at practical projects level.

8 References

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