ULTraSim traffic simulator

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For future traffic management systems an important question is what effect different vehicle topologies like battery electric vehicles, hybrid electric vehicles or vehicle with internal combustion engine will have on traffic flow, energy consumption as well as route choice.

For this reason the Institute of Energy Conversion and Storage at the University of Ulm developed a quasi-continuous traffic simulator with submicroscopic vehicle models named ULTraSim (Ulm Traffic Simulator).

Beside V2I and V2V communication as well as intelligent traffic light control it is possible to integrate very detailed submicroscopic vehicle models of battery electric vehicles, hybrid electric vehicles, series busses and vehicles with internal combustion engines with different level of electric motorisation. This allows people to simulate future vehicle populations and to analyse their behavior with respect to energy consumption and particularly state of charge (SOC) of batteries.

Simulation Grid

GPS as well as SRTM3 data serve as base for the simulator. With the help of these data sets, a three- dimensional road grid was generated. Due to exact height and slope information, an exact calculation of the regenerated energy of BEVs and HEVs is possible. In addition the road bends were recorded for the simulation of a very realistic velocity course for the vehicles.

With a grid generation tool it is possible to build a detailed road network of any real city and to integrate it into ULTraSim. At the moment the focus is on the town of Ulm in South Germany. Altogether the simulator considers 39 controlled traffic lights, 126 intersections, 694 tracks as well as 385 kilometers segmented into one meter steps.

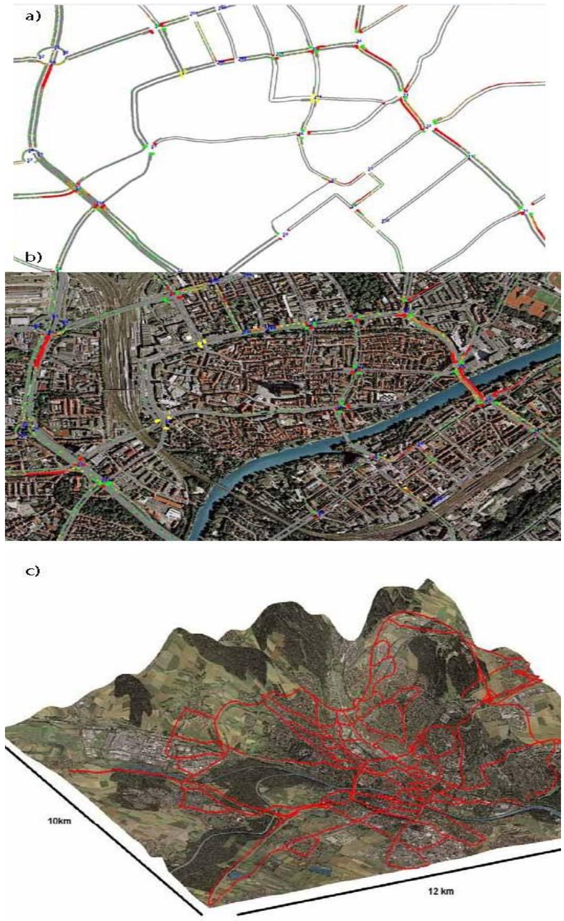

Fig 1 a) Part of the street grid with the vehicles, b) satellite image with the street grid, c) Topography of the simulation grid with a simulation area of around 120 km²

Submicroscopic vehicle models and driver model

For the simulation of realistic vehicle movements, different driver models were implemented. Besides the analytical IDM (Intelligent driver model) the psycho-physical driver model of Wiedemann was implemented. With the help of an individual parameter pool it is possible to simulate a stochastic vehicle population. This results in the individual behavior of every vehicle.

One big advantage of a submicroscopic traffic simulator is that access to all vehicle parameters like torque, motor speed, SOC, energy-, fuel consumption, gear, etc is possible. Thus very detailed and exact calculations of the energy consumption are possible and there is no need for estimations.

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In addition the total dynamic traffic model is simulated, including all aspects of the hybrid drive train including controllers for velocity and braking, meaning the vehicles interact very realistically with the driver model. The advantage of this is that very exact analyses of operation strategies for BEVs or PHEVs in vehicle fleets operating in large traffic volumes are possible.

For the longitudinal dynamics modeling of the vehicle a model of the drive train was built. A detailed model of every component of the drive train like ICE, generator, gear box, clutch, wheels etc. was built and verified with real data. The input parameter of the models is the desired acceleration of the vehicle which is generated by the driver model. In the dynamic model the component models form a chain whose input parameters contribute to the solution of the complete differential equation in the last part. The figure shows the model of a parallel hybrid in the motor mode (driving power flowing to the wheels). For the speed control a PI controller was implemented which compensates the non-linearites of the longitudinal models. Furthermore a brake regulator which adapts the actual velocity to the desirable velocity during deceleration phases is needed.

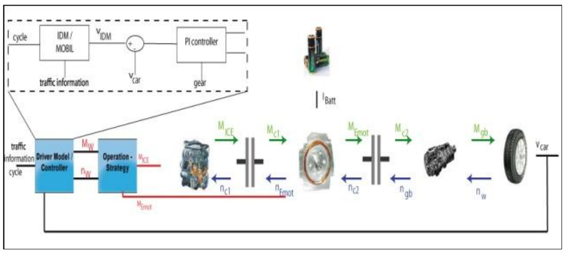

Fig. 2 Dynamic vehicle model, parallel hybrid

Analysis of fleet energy consumption

Because all vehicles are simulated submicroscopically it is possible to compare each value of the drive train of any vehicle in fleets.

In figure the whole energy consumption of all vehicles of the fleet with reference to the first vehicle is shown. As can be seen the energy consumption of the ICEV has been increasing by 70 %; PHEV and BEV have a much lower increase (15-20 %).

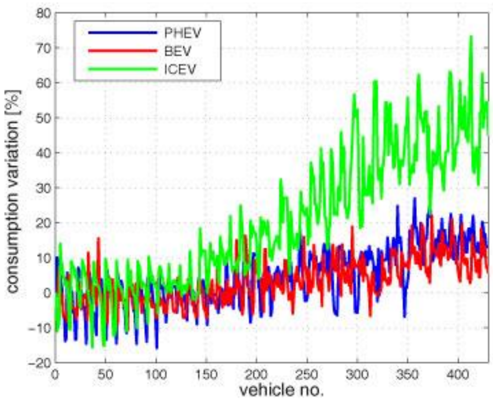

Fig. 3: Energy consumption in fleet traffic of PHEV, BEV and ICEV normalized to vehicle no. 1

Traffic light control

ULTraSim makes a distinction between four different junction types. Besides a simple intersection with right-of-way from the right (as is typical in Germany), there are intersections with a contact loop and fixed dynamically controlled traffic lights. The most significant type of traffic lights for big intersections are dynamically controlled and fixed-time controlled traffic lights. Fixed-time controlled traffic lights find it very difficult to adjust to variations in traffic flow, so that the influence of the traffic is as small as possible for they have a fixed time of circulation but optimal circulation time is a function of the current traffic flow. Because ULTraSim was developed for the investigation of new routing algorithms and to keep the influence of badly adjusted traffic lights as low as possible a large part of the traffic light controlled crossings was equipped with dynamically controlled traffic lights.

In ULTraSim an algorithm was chosen which adds up the waiting time of all vehicles in the intersection accesses. The switching sequence with the minimum waiting time of all vehicles involved is chosen according to the minimisation criterion.

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Vehicle / User Interface

For the exact analysis of the data, every route has three sensors to record the vehicle density, the average velocity as well as many other parameters. For a graphical description the simulator uses several different graphical user interfaces.

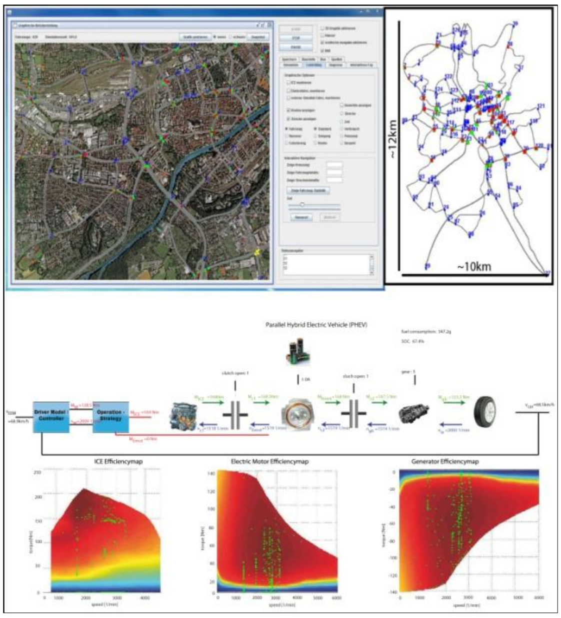

Fig. 4: ULTraSim graphical user interface and submicroscopic vehicle user interface for a PHEV with the motor / generator efficiency maps

On the one hand it is possible to visualise the whole simulation two-dimensionally. On the other hand the simulator employs a three-dimensional visualisation which is implemented in Java3D. Full submicroscopic vehicle data is described in vehicle-GUIs which can be individually selected for each vehicle. Therefore it is possible to display and analyse the detailed data of the respective drive train at anytime. By the detailed representation of the operation points of the various routes in the efficiency maps of the ICE, motor or generator an exact analysis of the operation strategies is possible.

In addition, ULTraSim is able to visualise the data of all vehicles concerning route choice, traffic light waiting time, average velocity, energy consumption and more.

Thread Management

One advantage of the simulator is that with the help of intelligent thread management, very low simulation times are possible at high vehicle density because the submicroscopic vehicles and the traffic simulator are running on different threads. The figure shows the simulation time over the number of submicroscopic vehicles for one simulation of one hour. Up to a number of 5000 vehicles simulation times takes less than 2.35 times the real time. The simulation time is independent of the size of the grid and depends only on the number of the vehicles. The nearly linear dependence is due to the fact that with rising vehicle density, finding the next vehicle ahead is achieved in a shorter time.

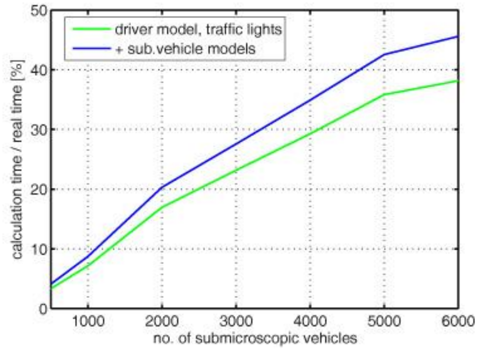

Fig. 5: Calculation time to real time vs. the vehicle number

Conclusion

ULTraSim gives the possibility to analyse future traffic volumes realistically and in detail. Besides that it can integrate different vehicle topologies that will be found in the near future on our roads. Due to the modular programming the simulator is flexible and easy to expand. ULTraSim may also be connected with energy grid simulators in the future. The example scenario demonstrates a small part of analyses which are possible with ULTraSim. Due to the very detailed and different vehicle models ULTraSim is an optimal simulation platform to develop operation and routing strategies of the future.

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