A Collaborative Approach for the Preparation of Co-operative Multi-User Driving Scenarios

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Abstract

The design of scenarios for driving simulators gets more and more complex due to the upcoming need of creating scenarios where different types of interactions are tested. This includes the driver-vehicle as well as driver-traffic, driver-driver or vehicle-vehicle/vehicle-infrastructure interactions, e.g. by using V2X technology. This paper describes a new collaborative approach as part of a PhD-thesis making it possible to design such scenarios in short time: The Exploratory Scenario Design. The theoretical background of the approach is sketched as well as the current step of implementation, using e.g. a multi-touch table.

State of the Art Driving Scenarios

Since the first development of computer systems such systems were used to simulate complex system behaviors as simulation has a very high reproducibility and standardization, making it possible to alternate parameters and to isolate specific effects, often in a cheap way without any hazards.

During the last decades, and esp. since computer graphics were able to produce virtual realities with a high level of realism, this became also true for the automotive domain. In order to understand drivers and their abilities, driving situations and their challenges, or driving phenomena at all, it was necessary to perform lots of driving simulator experiments with a big number of variations.

In the first years of driving experiments in virtual worlds, driving scenarios were simple: As the simulators lacked realism the first simulated driving scenarios using computer generated graphics according to Pollock et al. (1999) were highway or rural road scenarios without any traffic (e.g. Witt & Hoyos (1976) or Donges (1978)). As computer performance rose, it became possible to realize other vehicles and afterwards more complex traffic behavior and traffic situations in more complex environments, leading to first scenarios in urban conditions.

In the same time, driver assistance systems and afterwards Advanced Driver Assistance Systems came onto the market, obtaining more and more control over the vehicle and interacting more and more with the drivers. From now on, driving scenarios had to cope not only with the interaction between driver and car or driver

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and traffic, but also with the interaction between the driver and the assistance system on board.

Current scenarios go even beyond: As modern ADASs not only focus on the behavior of the host car, but aim at the interaction between road users or infrastructure, directly or via V2X, the focus of driving scenarios changed accordingly.

Furthermore, it has been found that people behave different in pure simulation environments than in environments with both human and computer-controlled vehicles (Winner & Hermann, 2012).

DLR's driving simulation environment kept up with the times: Starting with simple fixed-based simulators, the realism was raised up to a motion-based simulator. Current scenarios with the focus on interaction between road users can be implemented using the new Modular and Scalable Application Platform for ITS Components (MoSAIC, see Lorenz et al., 2011). In MoSAIC, the different driving simulators are connected to each other, making it possible to test a wide spectrum of interactive scenarios with multiple human drivers.

The MoSAIC setup is currently in use at various international projects, e.g. the European Artemis SP8 D3CoS project (see Heesen et al. 2012).

Challenges in Scenario Design

At the beginning of any driving scenario design, there is an interesting effect that stimulates a research question, and a hypothesis about the causal mechanism for this effect as a possible answer for this research question. This is combined with the expectation that this research question can be answered by performing experiments with subjects. The general challenge of scenario design, as in any experimental design, is the transformation of the research question into a sound experiment. As shown in figure 1, in a first step the research question has therefore to be transformed into a rough idea of a possible driving situation.

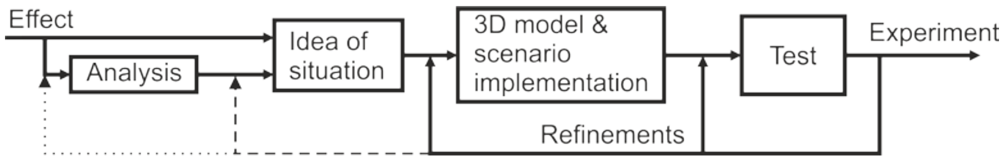

Fig. 1: Common scenario design

Whenever there is a first idea of a situation, this situation has to be modeled in detail, including the environment of the situation, i.e. the road network, buildings etc., and the behavior and point of (dis-)appearance of the road users surrounding the subject. Esp. this part of the transformation is challenging due to the following reasons:

- *Level of detail:* A modeled situation needs the specification of exact road user positions, velocities, etc., mostly unknown to the requester of a scenario.
- *Generalization:* The requested situation should occur in any case, fully independent of the driving behavior of the subject.

- *Involvement of different people:* The requester of a scenario shown in a driving simulator is commonly not the implementer of the model. Therefore a requirement specification has to be formulated which mostly (according to the first point) lacks details. In addition, the requester and the implementer often have different backgrounds, which may lead to misunderstandings or different interpretations of the specification.
- *Time:* A realistic scenario needs often more time for preparation as estimated, esp. due to the involvement of different people or the lack of knowledge on features of the used software.
- *Virtualization:* Driving simulators differ in terms of the grade of reality between each other and compared to real driving situations. Therefore, results of other studies may not be adopted wholesale and will need time consuming fine tuning.

When the scenario is implemented, it needs to be tested best by one or more persons other than the implementer. During these tests, in most cases issues are found in the scenario and it needs to be fixed or even re-implemented with the mentioned challenges, making the whole procedure very time-consuming.

While this is already true for simple scenarios it becomes a real challenge when handling current complex scenarios like those sketched in the beginning, using e.g. cooperation between the subject vehicle and its surroundings or even more than one subject vehicle. Esp. those multi-user scenarios create many new challenges, as the reproducibility of the scenario stays in conflict with the individual behavior of the different drivers, esp. when they have to meet each other in one special situation after a while of driving.

Existing Approaches

Some of the above mentioned points have already been addressed by the major suppliers of driving simulator software: Instead of bothering the implementers with low level details of vehicle behavior when writing the scenario scripts, often a higher level language is used including virtual driver skills and vehicle skills or maneuvers, applying an artificial intelligence to the virtual vehicles (see e.g. Olstam (2009) or VIRES (2006)). Instead of using scripts at all, which can be hard to read and which require a special and mostly non-standard syntax to be learned by the implementers in advance, most driving simulator software is already shipped with a scenario editor providing a Graphical User Interface (GUI).

These two points already lead to a tremendous speed-up in the scenario design, as e.g. Drag-and-drop is supported by the GUIs, the learning phase is shortened, the skill requirements are reduced and therefore the software can be used by more people. On the other hand, the creation of artificial intelligence in vehicle behavior may result in new challenges as those vehicles tend to behave always correctly esp. in terms of traffic regulations, which often differs from the requirements of the scenario, as non-conformant behavior is the key to many effects of driving.

In order to avoid the problems with fully autonomously controlled vehicles it is of cause possible to manually control all the road users surrounding the subject vehicle, like e.g. already done by Currie (1969). This brings a huge benefit in flexibility but lacks in terms of reproducibility. Therefore, Olstam & Espié (2010) suggested to control the traffic cars manually in predetermined situations at which measurements are taken and to shift the control in a non-conspicuous way to a fully autonomous mode in-between. This "theatre metaphor" leads to a better reproducibility while still keeping the flexibility, but additional trained personal and infrastructure is needed to drive the vehicles.

Independent of using manually or autonomously controlled vehicles, as the requester of a scenario often does not equal the implementer as described above, the problem of misunderstandings and different interpretations of possibly too vaguely formulated requirements for the scenario design can only be reduced when tools promote the mutual understanding of the desired scenario, for example by facilitating the discussion between both parties. Tönnis & Klinker (2009) developed a collaborative approach for discussion and development of traffic scenarios by using a table-top platform. In their approach, real toy cars could be moved on a table-top display showing a bird view of the scenario, directly creating a virtual representation moving in the same way in an attached driving simulator in driver's view. Trajectories from start to end could be recorded and replayed, making it possible to iteratively build up a set of fixed trajectories for all autonomously controlled vehicles, resulting in a complete scenario. See also Tönnis (2007) for further details.

Although this kind of setup is very intuitive, its approach is limited in the fact that subjects do not behave equally in every situation, making pre-recorded trajectories unusable when the delta between the assumed position of the subject and the real position gets too high. The possibility of the platform to directly sketch the scenario by manually controlling vehicles on the table while a subject is driving has its pros and cons as described before.

When thinking of scenarios with several human drivers this approach comes to its limitations very fast, as the display size is limited and therefore it is impossible for the "implementer" to control cars spread in the virtual world, and the number of surrounding vehicles will increase. The key challenge is to develop a collaborative approach which copes with the diversity of subjects, focusses on a good usability while still having the ability of changing every low level detail which might be of interest in the scenario design.

A new Collaborative Approach

In order to deal with this challenge, the common scenario design shown in figure 1 has to be adapted. This is esp. true for the implementation and testing phases of the design, as they have been identified as difficult and very time consuming. A possible solution of this has been found in the Exploratory Design (Flemisch et al., 2008) as used for ADAS development (e.g. Schindler et al., 2010). Within the Exploratory Design, the user of a system gets directly involved into the design process. In terms of scenario design this can be achieved by the collaboration of the requester, implementer and tester of the scenario as early as possible.

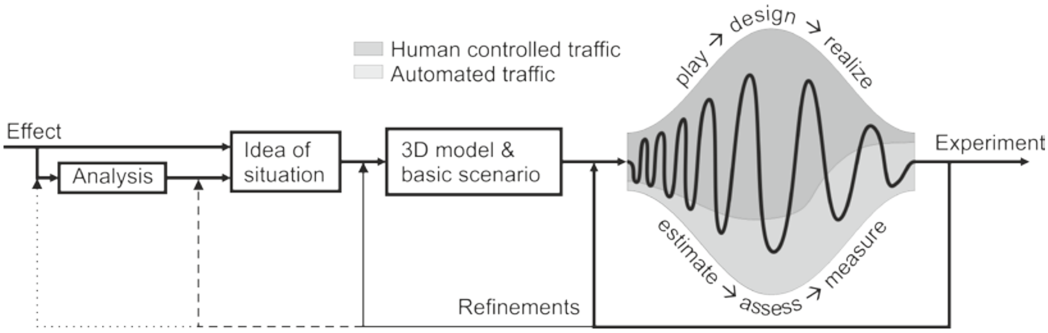

Fig. 2: The Exploratory Scenario Design process adapted from Flemisch et al. (2008)

As shown in figure 2, a basic 3D model where the situation is generally planned to take place is needed in advance, i.e. a model of an urban, rural or highway area, combined with a basic scenario, e.g. consisting of mean traffic densities only. Starting with this setup, the detailed scenario design can start.

In order to promote the collaboration, an Ideum MT 55” Multi-Touch-Table with a maximum of 32 parallel touch points has been equipped with a bird view perspective on the driving scenario. It serves as a fully functional graphical scenario design tool by making it possible to easily insert traffic cars into the scenario by Drag-and-drop gestures and to change their parameters, e.g. their routing information or their behavior, in low level or higher level format at any time by simply pointing at the corresponding menus with a finger. As the Multi-Touch-Table is a table for discussion, it is controllable from every place around the table, including the possibility to pick shown menus or program interactions, and to rotate and translate them on the screen as needed.

Furthermore it is capable of showing the scenario online with the possibility to directly control the vehicles on the table with a fingertip. In difference to the approach of Tönnis, no “tangible cars” (Tönnis, 2007) are used on the table, bringing the benefit that a car can be driven with one single finger instead of controlling it with one hand. The driving is done in a way that one finger drags to the target-point the vehicle aims to go, and the vehicle moves there under its physical restrictions. As the vehicles are virtually present only, there are no scaling restrictions on the table, making the zoom into the scenario continuously adjustable.

Alternatively, as the implementation is part of the DOMINION software framework (Köster et al., 2008), any traffic vehicle can be controlled by mouse, keyboard, any standard joystick or game wheel, or by attaching any complete driving simulator. In the current implementation, up to 32 vehicles can be theoretically controlled on the table while at the same time up to four vehicles can be controlled by driving simulators or other control devices. The driving simulators can additionally be used to get an impression of the perspective the subject will have.

Due to the lack of exact reproducibility when controlling many vehicles manually, one of the key features of the Exploratory Scenario Design is the transferability of the control to an autonomous mode. In difference to the Tönnis approach, not only trajectories, but also meta-data of the manually driven vehicles is recorded. This meta-data includes e.g. aspects of the traffic situation, for example distances and time-headways to other road users, and behavioral data in terms of driven maneuvers and its parameters.

Fig. 3: Scenario preparation around the Multi-Touch-Table at the DLR MoSAIC Lab

The recorded data can afterwards be replayed directly, promoting the discussion. Nevertheless, the major benefit is that it facilitates the transfer into automated traffic vehicle behavior on a higher level, as it gives hints on the conditions where a driving maneuver should occur and on the parameters of this maneuver. Therefore, the scenario designers can directly pick the relevant conditional parameters of the situation, change the constraints if necessary, combine them with a maneuver to be performed and specify the tolerated deviation of the maneuver execution parameters. By this it is possible that even automated traffic vehicles can adjust their behavior according to different subject behavior in well-defined borders.

The different steps of the Exploratory Scenario Design process can be iterated as needed, leading to a crisp scenario design already after a minimum of time.

The shown tools are currently under preparation and are already partly usable (see figure 3). The current implementation stage already consists of the touch framework and the (meta-)data recording, already speeding up the scenario design in a perceptible way. Further implementations will follow.

Conclusion

It has been shown that scenario design is getting more and more complex and therefore challenging. The approach of Exploratory Scenario Design helps to solve this issue by using a multi-touch table which facilitates discussions. In presenting the possibility of attaching driving simulators and different input devices directly, the testing of the scenario is already included in the design phase. While scenario data including meta-data is recorded during the design phase, vehicle behavior can directly be adapted as needed.

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