Combining ergonomic and field-of-view analysis using virtual humans

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Abstract

Today, virtual humans are used in the automotive industry especially for ergonomic analysis of a virtual car interior. However, interior design and ergonomics is only one aspect in the development process of a new car. Styling, active and passive security as well as aerodynamics also bias decisions in the development process of a new car. The visibility of the surroundings from inside a car is a major security topic. This paper shows - based on a joint project with BMW - how virtual humans can be used for combined reachability and visibility analysis and how these two topics interrelate.

Keywords: Virtual humans, ergonomic analysis, field-of-view simulation, virtual environments

Introduction

The optimization of product designs based on virtual prototypes has become increasingly important for meeting the growing cost and efficiency demands. In the development of a new car, security, ergonomics, styling and fuel efficiency are additional important factors in the design and decision process which have to be balanced carefully.

Virtual humans - also known as man models - have already shown their potential and advantages in ergonomic simulation and analysis [Jasn97],[RIX98], e.g., for reachability, accessibility of switches on the dash board, etc. The new idea underlying this project is to use a man model to simulate different eye positions and visualize the field-of-view in a virtual environment to give an external observer a feedback on how a human would see the scene under the current conditions. The advantage of using a virtual human in a virtual environment (e.g., a virtual 3D car model) is that many combinations and situations can be evaluated in less time and much earlier in the product development process. Thus, design problems can be detected sooner and optimizations to the design can be performed in a much more efficient way.

Another important feature of the system being developed is, that the field-of-view can be visualized while the virtual human is doing some actions in the car, e.g. switching on the radio. This way, one can inspect how much the virtual human's attention is affected by the action. The interior design can be optimized considering the required level of attention. Moreover, the virtual environment allows to simulate any real-world situation: at crossings one can evaluate whether or not all relevant signs can be seen by different users, whether children of different sizes can be seen by the driver at varying distances, etc. Just generating a 3D model of the scene, placing the virtual car and virtual human into it and interactively performing the simulation can imitate all imaginable situations. Interactivity is another strength of the system: the virtual human can be directly manipulated while the system visualizes in real-time what he sees.

Ergonomics in the automotive industry

Back in the 30s, the automotive industry recognized the importance of a comfortable driving position – this was the starting point of ergonomic aspects in car building.
During the following decades, hundreds of human beings were 'measured' to build up huge data bases capturing the typical shape and size of various human bodies. From these data sets, physical man models and body templates were derived, which are used to roughly size the passenger room of a car [see Fig. 1].

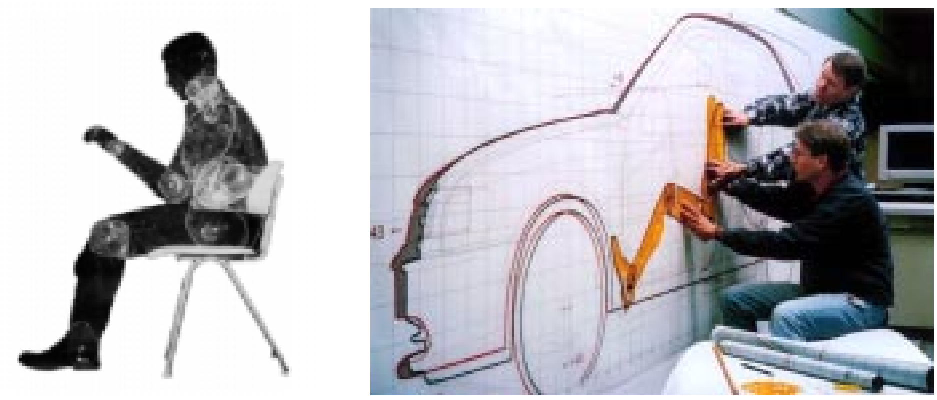


Figure 1: Body template and designers working with a body template (source: Opel)

With these techniques, the reachability of the pedals, the steering wheel and the general seating position can be assessed – more difficult questions, such as the reachability of certain switches are hard to answer.

The next evolution step were mechanical test manikins which allow to investigate the head and leg room more precisely. Figure 2 shows the SAE test manikin J826B in a scenario where the head room and the seating angle is measured.

Figure 2: A mechanical test manikin (source Opel)

With the evolvement of Virtual Reality technology, the sit box appeared. The sit box is a physical model of a car's interior, often stripped down to the very necessary parts, like the dashboard, the steering wheel, gear shift and seats. Now, a user wearing a head-mounted-display (HMD) can take place and evaluate the virtual interior displayed in 3D by the HMD. Tracking the hands and the head via magnetic trackers allowed to determine their position and simulate the behavior of the interior [see Fig. 3].

The drawbacks of this approach are:

- one needs to build a real sit box,
- usually the sit box is a default one and does not perfectly fit the virtual scene, so the force-feedback imposed by the physical sit box does not correspond to the virtual scene,
- the test person cannot be changed, the way a virtual human can, so the number of experiments and variations is very limited.

Figure 3: Sit box: User with Boom and data-gloves (source Fakespace)

To overcome these drawbacks, virtual humans were developed, which can be tailored to different scenario during runtime. Virtual humans have build-in knowledge about human kinematic behavior and they can be sized to an arbitrary n-percentile man or woman [see Fig. 4]. Additionally, by reading the head orientation and position, they can be used for field-of-view simulation.

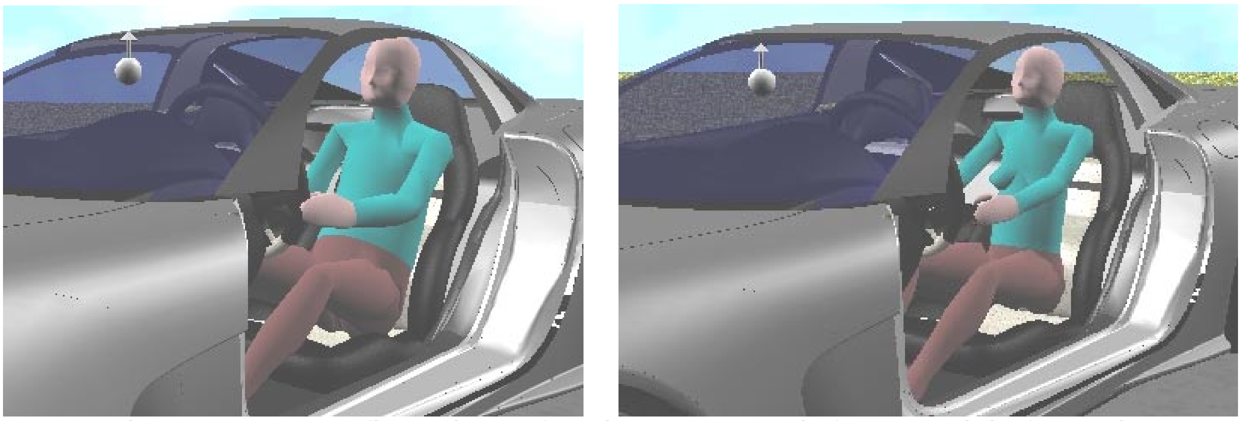


Figure 4: Two configurations of a Virtual Human (left: male, right female)

Field-of-view simulation is an increasingly important security aspect, especially in times where aerodynamics and weight reduction yield less and less window area. Traditionally, a car's surroundings' visibility from its inside, is assessed comparably late in the development process by a number of experts based on a physical mock-up. These experts decide whether something needs to be changed or not. With field-of-view simulation this step can also be done using a virtual prototype of a car. Thus, the styling's impact on visibility can be assessed earlier in the design process. Visibility as one security aspect will play a more weighty role among the parameters to which the design is optimized.

Hardware setup

The system being developed for BMW runs in a hardware setup where all the experiments can be carried out at a usual designers workplace. Additionally, it supports in- and output from a BOOM and a stereoscopic large projection wall. The BOOM as an I/O device is used to position and orient the head of the virtual human as well as to display what the virtual human is seeing. Simultaneously a group of external observers sitting in front of the large screen projection can judge the visibility from the inside to the outside or follow the ergonomic experiments performed by an operator [see Fig. 5].

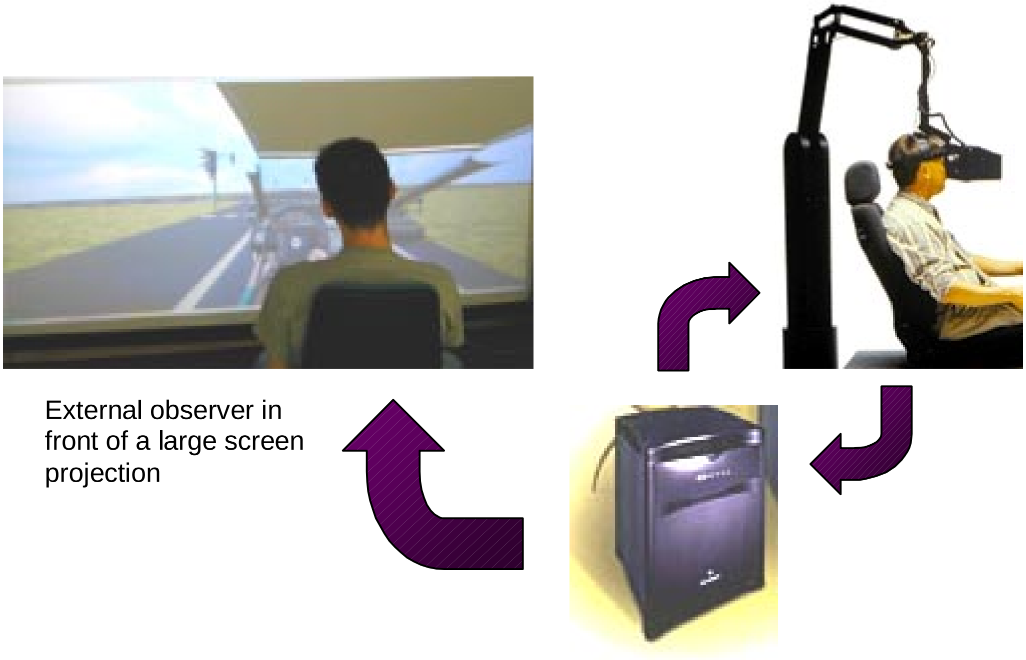


Figure 5: HW-setup

The software system VIRGO

The software system VIRGO [JAS97] (virtual ergonomic test suite) was adapted and extended to fulfill BMW's needs and requirements. The system allows to carry out ergonomic simulation and analysis in an interactive 3D environment. Furthermore, the field-of-view of differently parameterized virtual humans can be rendered during user-defined movements. As virtual human we apply RAMSIS [RAM97]. The 3D scenario and the virtual prototype of a car can be modeled with any CAD-system (CATIA in case of BMW) providing a converter to the OpenInventor file format or VRML.

System Architecture

The system is build-up from 4 major modules [see Fig. 6]:

- CAD data import filter
  For those CAD systems which cannot export OpenInventor or VRML file format, we provide VDAFS, IGES, etc. import.
- Input manager
  The input manager handles events from several 2D and 3D devices, such as mouse and keyboard, SpaceMouse and BOOM.
- 3D visualization component

The visualization component renders the 3D scenery taking the current field-of-view settings into account.

- RAMSIS
  RAMSIS is the virtual human we use (see below). It calculates the allowed postures of the man model given the motion events and taking the kinematic chains and constraints from its database into account. The result of this calculation is visualized in each step entailing real-time simulation and visual feedback.

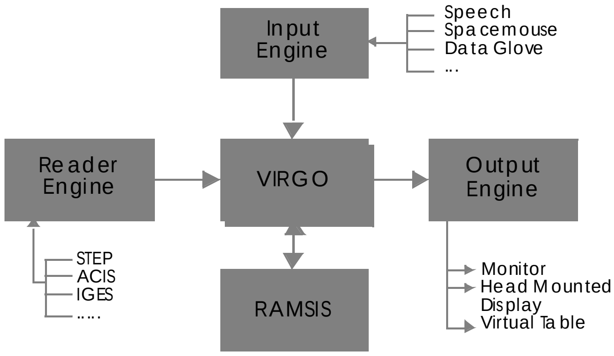


Figure 6. System architecture [JAS97]

System Functionality

In this sub-section an overview over the functionality of the system VIRGO+FOV is given.

The user can import a car model and a scenery and precisely position the car in the environment. Posture data can be stored and loaded to the currently selected man model. This way, the user can build-up a database of postures and then apply them to differently parameterized virtual humans.

One set of functionality is dedicated to specify the current kinematic chain of the man model, e.g. from the shoulder to the right hand to test the reachability of the radio in the console. By picking the right hand and the radio a real-time simulation of the movement can be triggered.

A view menu allows the user to select between showing the virtual human's view on the BOOM or an the large screen projection. More importantly, the user can change the field of view between several angles, e.g. the complete viewing angle or the sharp viewing angle, i.e. the region that is recognized sharply by a human observer. Additionally, the view region can be visualized as a semi-transparent cone [see Fig. 7]. This allows an external observer to see which part of the scene is visible with the BOOM even if he has a different point of view.

Figure 7. Ramsis' viewing cone seen by an external observer

A manikin menu supports the placement and configuration of the virtual manikin. The user can specify whether the manikin shall be female or male, the age, the proportions and tallness. He can load one of the user-defined postures and apply it to the current model. The comfort values of the current posture can either be displayed in an extra window or as pseudo-colors at/on the human model [see Fig. 8].

Figure 8.: Ramsis with comfort values rendered in pseudo-colors

The Virtual Human: RAMSIS

In our system we use RAMSIS [SEI96], [SEI97] as the underlying man model. RAMSIS is a software product from TECMATH.

The history of man models goes back to 1967; Sammie (System for Aiding Man-Machine Interaction Evaluation) was the first virtual human available for industrial purposes. In 1978 Chrysler developed Cyberman aiming at evaluating the freedom of movement for the driver's legs and arms. Ergoman - developed in 1984 at the Laboratoire D'Antropologie Appliquee et d'Ecole Humain in Paris – focussed on reachability of the driver's arms. None of the virtual human developed so far, provided both the analysis of reachability and field of sight and allowed to measure the comfort values for a driver's position objectively. Thus, TECMATH started to develop RAMSIS in 1987 [HEL98].

RAMSIS contain a mathematical model based on measurements of about 7.000 persons. It supports the prognosis of expected postures and the analysis of reachability, freedom of movement and field of view. Based on the antropologic data base, comfort valued for certain postures or movements can be derived.

Ergonomic analysis

How ergonomic a car's interior is, depends on several influencing factors:

- Seating position, variability and quality of the seats,
- Position and adjustability of the steering wheel,
- Reachability and readability of gear shift, knobs and switches,
- Position and reachability of pedals,
- Leg room, knee/steering-wheel interference,
- Head room, etc.

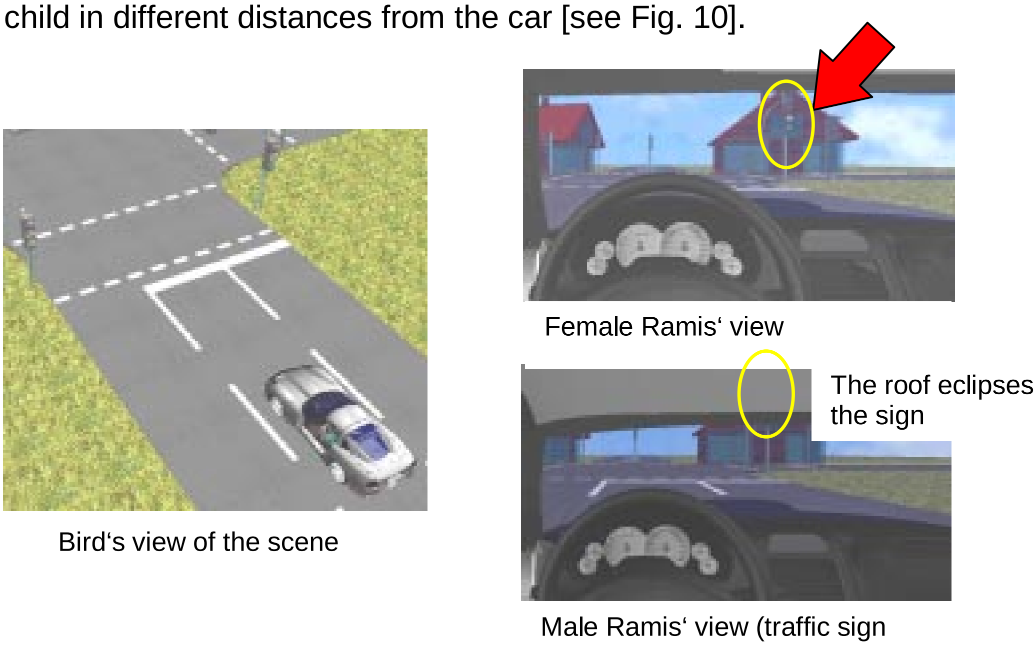
Today car builders and especially seat makers have to take drivers from 5 up to 6.5 foot into account (and the range is constantly increasing), i.e. the seats must be moveable for almost one foot. While the steering wheel can be adjusted axially, the dashboard can't move along with it. Thus, optimizing an interior design is to find the best compromise for the variety of possible drivers plus maintaining the corporate identity in interior design.
Since, not all combinations can be evaluated with real test persons and physical mock-ups, virtual humans become more and more present.
By placing a virtual human in different virtual designs and specifying test suites, a much broader set of alternative designs can be investigated in early stages of the design. Instead of subjective statements from some test persons, one has access to the whole database underlying the virtual human.
Having optimized a design for reachability and comfort, new aspects, such as visibility come into play.

Field of view analysis

Who of us didn't yet made the experience that - for instance - the rear mirror partially occludes the field-of-view when looking to the right at crossings? Did the experts neglect visibility aspects in the design? Certainly not, but the parameter space for the optimization process becomes increasingly unmanageable. Maybe, placing the mirror 5cm higher would have solved the problem. And what about the visibility of crossings, signs and kids if the window area of a car is getting smaller and smaller to save weight?

The visibility is at least as important as ergonomic factors in car styling. This time, interior and exterior aspects come together: the position and height of the dashboard, the shape of the front window frame. Again, virtual humans can help to find better solutions in earlier phases of the design process by placing them in a virtual car, varying the parameters and simulation their field-of-view.

In the following two examples are shown. Firstly a crossing scenario where the visibility of the signs can be evaluated depending from the driver's size [see Fig. 9]. Secondly, the visibility of a child in different distances from the car [see Fig. 10].

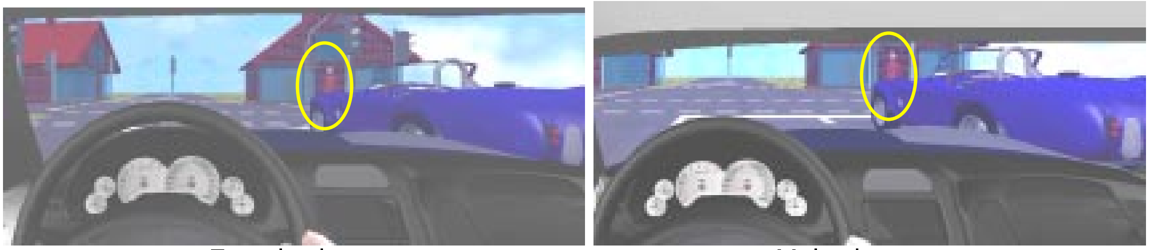


Bird's view of the scene

Female Ramis' view

Male Ramis' view (traffic sign disappeared)

Figure 9: Visibility analysis of a traffic sign



Female view Male view

Figure 10: Visibility analysis of a child

Combining ergonomic analysis and field-of-view simulation

Up to now, ergonomic aspects and field-of-view analysis were discussed independently. But, the two points can be combined to yield new insights on how the driver's attention to the traffic is affected by certain movements and task, e.g. switching on the radio or the air condition.

Given an antropologic model of a human being and a kinematic motion chain, movements of the hand can have implications to the head position and therewith to the field of view. Moreover, whenever the user has to move his head his attention to the traffic is somewhat disturbed, if he has to move his eyes things become even worse. The latter case cannot yet be simulated with RAMSIS.

Thus, when evaluating the reachability it is not only important to consider the comfort values for a movement but also its impacts on the head position; our system allows to recognize such situations. While carrying out a hand movement – for instance – the scene that is visible to RAMSIS can be rendered in a special window. An external observer sees the impacts to the field-of-view and can subjectively assess how much this affects the virtual driver's attention to the traffic [see Fig. 11].

Figure 11: Ramsis reaching for the radio (top) and the impact to the field of view (bottom)

Motion in visibility analysis

Another advantage of a virtual environment is to simulation motion effects of the observer and/or the artifacts in the scene, e.g. the car containing the virtual human can be moved to inspect the visibility from distinct positions (see Fig. 12). Moreover; it would be possible to model simultaneous motions of the car and the artifacts and superimpose them. Then, from the artifacts position a ray can be fired to Ramsis' eye point to determine if the artifact is already in the field of view. This way, visibility analysis can be half-way automated – certainly a task for further work.

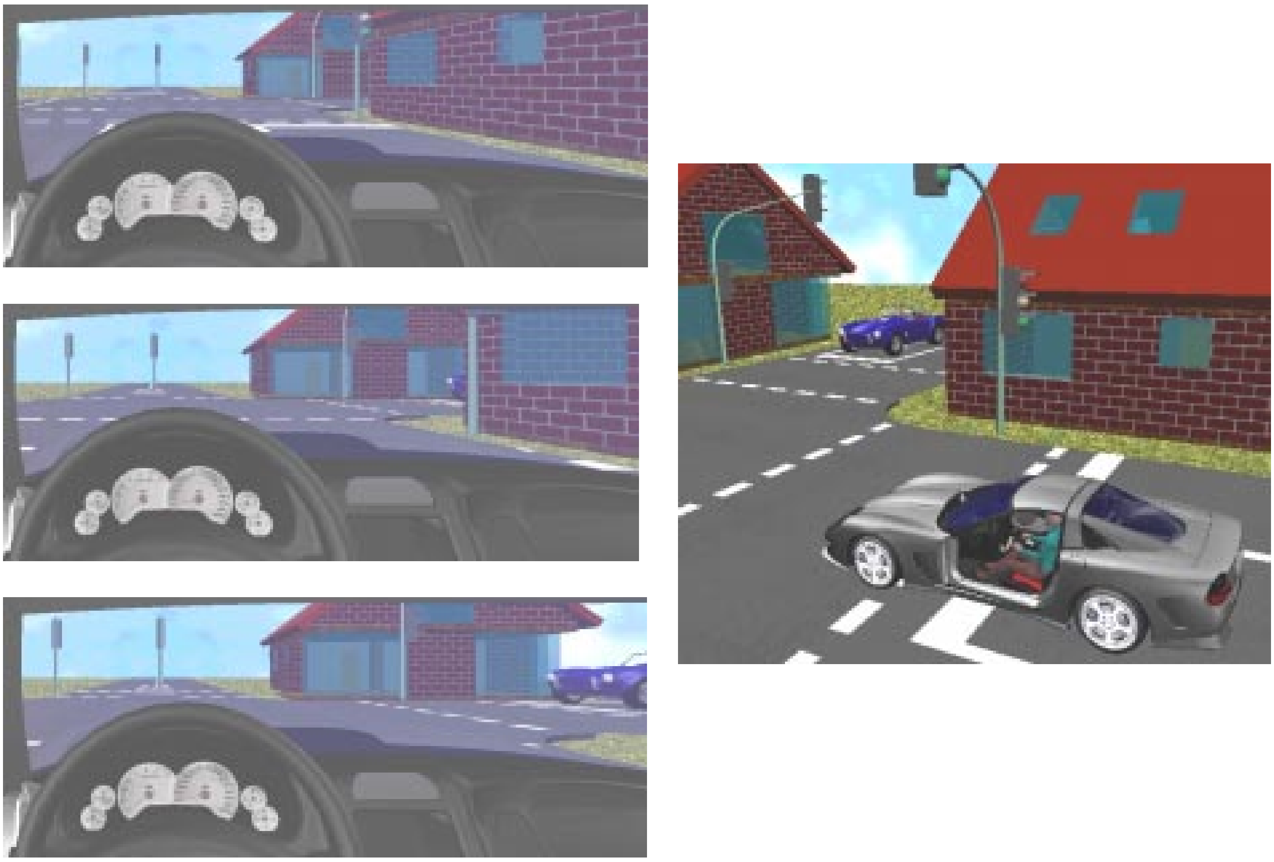


Figure 12: Field-of-view from a moving car (left), scene overview (right)

Conclusions and Further Work

In this paper we presented how virtual humans can be used for reachability and visibility analysis in an interactive 3D environment. Up to now, reachability (ergonomics) and visibility analysis were mostly treated individually. It was shown that both aspects should be treated in conjunction in times where styling, active and passive security as well as aerodynamics also bias decisions in the development process of a new car.

The possibility to simulate motion sequences of a virtual human in a virtual car, opens the possibility to directly investigate the impacts of such motions onto the driver's attention to the traffic and add a new dimension to visibility analysis so far mainly focussed on the visibility of the exterior from inside a car.

This new aspect is an interesting topic for further work. Up to now, there are no objective measures to determine the level of attention and the impacts of head movements. The virtual human does not allow for simulating eye movements. Eye tracking of a set of test persons could expand the database for the man model and add another parameter to the simulation process.

The current implementation can be improved in rendering quality and the possibility to model the human's perception processes, such as reduced sharpness with increasing viewing angles. Another topic for further work is the introduction of motion for the car and the artifacts.

Finally, as the parameter space for the optimization is exploding, optimization strategies are required to limit the number of configurations to evaluate – also based on experiments and experience already made in the development of former models.

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