# Using Scalable, Interactive Floor Projection for Production Planning Scenario

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## Abstract
This paper introduces a novel system for interactive evaluation and verification of manual assembly processes. The approach utilizes a scalable, interactive augmented floor surface in combination with a tangible tabletop hardware and a material zone planning software. The floor projection hardware is used for true to scale assembly station layout visualizations. The advantages and drawbacks of a low-cost, true to scale visualization will be discussed. A preliminary evaluation of the proposed system during a production planning workshop has shown that the low-cost implementation is suitable for reaching the production planning goals. Additionally true to scale visualizations support users to estimate distances, speeds and spatial relationships within the digital layout. In future work, motion capture and tracking systems will be integrated and registered to the augmented floor surface area, the projection area will be extended and efficiency improvements will be showed up.

## Author Keywords
manual assembly; true to scale; interactive augmented floor surface; shop-floor; floor projection

## ACM Classification Keywords
H.5.m. Information interfaces and presentation

Figure 1: Hardware setup consisting of SUR40 tangible tabletop display and augmented floor surface

## Introduction

Original equipment manufacturers in automotive industry work hard to acquire key market shares and intensify customer dedication via customization and a bigger model variety. This leads to higher requirements on production preparation in final assembly stage and lower set-up times during model change. Virtual technologies like virtual reality and augmented surfaces will help handling the raised complexity during production planning, ramp-up and production phase. Physical prototypes serve as an opportunity to evaluate, verify and optimize the planned manual assembly processes. Since prototype building is a major cost driver in vehicle development there is the tendency to build less prototypes or completely abolish them. Additionally physical prototypes are now being built later during production planning phase. The reduced number of physical prototypes must be compensated by new technologies and tools. Virtual technologies and the increasing quality of digital models are potential solutions to fill this gap.

## Current Situation in Production Planning

The overall goal for production planners of the end assembly is ensuring a punctual, smooth and efficient series production. Traditionally the process of planning and validating is based on hardware prototypes and done under conditions close to productive ones. The whole process for production planning is changing towards the use of virtual models. The evaluation and verification goals must be achieved without the presence of physical prototypes. Roughly summarized, there are several planning phases: During product verification phase, changes in the product design are still possible, due to the relative long lead time to start of production. During the phase of planning and validation of manual assembly processes, the definition of assembly sequence, the specification of the assembly work tasks, the assignment of assembly tasks to physical stations of an assembly line and the configuration of the assembly station will take place. Based on this information the station layout will be developed. Yet production engineers still prefer to work with physical methods and are fond of the proximity to real production environment.

## Advantages of Virtual Production Planning

Despite many production planners would like to use physical prototypes, there are several advantages by using virtual technologies:

- Complete simulation of processes in a factory
- Easy optimization in virtual models and instantaneous simulation
- No hardware setup times
- Automatic deduction of various parameters: duration, efficiency, ergonomics, cost, use of resources, logistic, production forecast
- Finding the optimal solution between various conflicting parameters
- optimal line balancing for model-mix production
- No limitation of combinations between products, configurations and factories

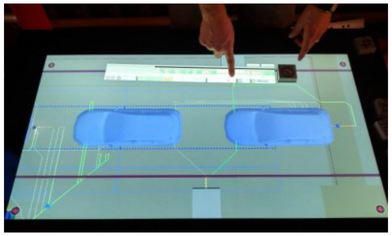

Figure 2: Interactive 2D tabletop material zone planning software with phicons

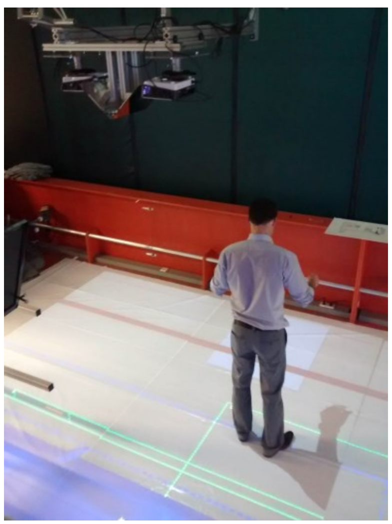

Figure 3: Production planner in front of virtual box carrier and virtual walking paths

## Interaction Concept for Interdisciplinary Production Planning Workshops

We present a novel system and interaction concept for interdisciplinary production planning workshops. The system consists of a tabletop hardware with tangibles, a material zone layout planning software and the visualization hardware for a true to scale, bird's eye view visualization.

For material zone planning, a special system has been developed employing an interactive tabletop hardware with tangibles as user interfaces and specialized software, which offers a strong perceptual coupling between the tangibles and visual representations of the station layout. The user interface was designed as intuitive as possible, supporting the collaboration between the workshop participants and engaging all participants to interact with the virtual model. Each participant should have the possibility to visualize his idea of an improved station layout and to manipulate it on his own. The presented interactive tangible tabletop system is the essential interface and serves as the visualization system for the augmented floor surface. Workshop participants are encouraged to interact with the digital models without using traditional interfaces on a desktop PC like mouse and keyboard. Instead they are doing spatial planning tasks with touch inputs, gestures and phicons. No static menus are visible throughout regular use. As depicted in Figure 2 all menu items are accessible by using the haptic phicons, like "menu, process, objects, properties, etc."

The mentioned true to scale visualization offers new possibilities in workshop situations. The realization of the floor surface can be seen in Figure 3. There are two main advantages of using a huge augmented floor surface: Human beings are able to estimate lengths, spatial relations and speeds in reality linearly and precisely. True to scale visualizations support the planners to verify their digital model very intuitively. Additionally passive workshop participants will be engaged to play a more active role. The degree of activation of passive workshop participants is hard to measure, but first pilot use-cases have shown an increase of discussions on the solutions. Starting the simulation, the participant can easily step into the augmented workspace and verify the planned assembly process steps in regard to planned times, position, dependencies, effective work time and the ergonomic aspects of the assembly station.

*"Interactive surfaces are another promising approach to support collaborative design and simulation that has been explored by many researchers in the past years to support a variety of spatial applications" [1].*

The floor projection system does not display tracked single user's perspectives in order to support multi user collaboration. Due to the isometric bird's eye-view camera, objects with height, like carriers and products, are displayed as flat 2D objects on the floor (see Figure 3). Since the floor plane does not display depth information and has no stereoscopic view, all workshop participants see a realistic true to scale information. Therefore mutual awareness in co-located collaborative workshops is an important aspect. Single-user tracked bird's eye view in workshop situations will be evaluated in future work.

Typical use-cases for this interaction and visualization system are to define ideal position of carriers, reduce walking paths, unnecessary work tasks, dependencies

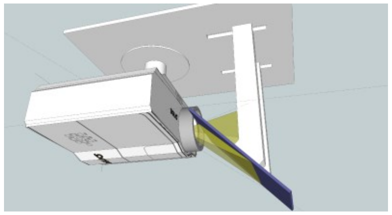

Figure 4: Rendering of a single projector mount with front surface mirror

Figure 5: Projector mounts with true to scale floor visualization

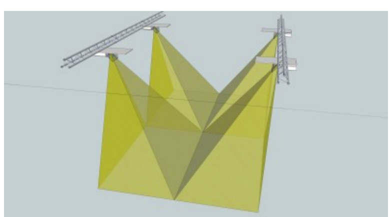

Figure 6: Rendering of projection cones for 2x2 projector arrangement

between workers and process steps and to assess the vagueness in planning quality [2]. Similar questions are often assessed during continuous improvement process workshops, which take place after start of production and take advantage of similar methods. Unwanted downtimes can be avoided by using virtual technologies in advance to direct physical changes at the assembly line. Aurich et al. also presented a virtual reality based system for CIP workshops [3].

## Hardware Implementation of Floor Projection

Hardware implementations of floor projection systems have been described in literature several times [4],[5]. The system is composed of at least four overhead short-throw DLP projectors, four mirrors, a video wall controller and several pieces of event trussing and profiles. The system can be massively scaled up to 32 projectors without altering the hardware setup (see Figure 5).

The projectors used in this setup are off-the-shelf, semi-professional projectors, which offer a good price per lumen ratio. Each overhead projector is combined with front surface mirrors in order to be able to mount the projector horizontally and redirect the beam to the floor. These projectors are not mountable in each possible orientation, because the air flow for transporting hot air out of the package is designed only for upside-down ceiling mount and up-right mounting. If mounted vertically, the projector would be damaged quickly. Each projector has a short throw lens with a variable throw ratio from 0.72 to 0.87. The luminous flux of each projector is specified to 2500 lumens have been integrated to redirect the picture to the floor. Since the optically effective coating of the mirror is located directly on top of the surface of a glass, a good imaging quality can be achieved with this mirror. Regular back surface coated mirrors would have created ghost imaging. The minimum size of each mirror depends on the throw ratio, optical offset, distance of the projector to the mirror, the elevation angle of the mirror and the projector.

A multi display signal controller for four outputs is used, which can be driven as DVI display and can represent an arbitrary crop region of the original input signal. Input images can be croped, scaled, mirrored and bezel corrected. Input signals are accepted up to 4k x 4k resolution via Dual Link DVI signal.

The hardware setup consists of a 4x1 or a 2x2 (see Figure 6) configuration. Each single picture has a size of 3m x 1.68m and the resulting augmented floor area has a size of 6.75m x 3.00m or 6m x 3.36m respectively. This is sufficient for a true to scale visualization of a station on one working side. The stiffness and tolerances of the ball joint mountings could still be improved. The adjusted picture offered edges, which differed less than 10mm.

## Preliminary Evaluation

The evaluation is an ongoing process, whether the depicted system reduces planning time and improves the quality. The following results do not claim statistical significance due to the low number of participants. Thirteen production planning engineers have taken part in this expert survey, which took place during an interdisciplinary production planning workshop. The overhead projector system was created under several constraints, like low-cost, portability and limited ceiling heights. Therefore some trade-offs had to be made.

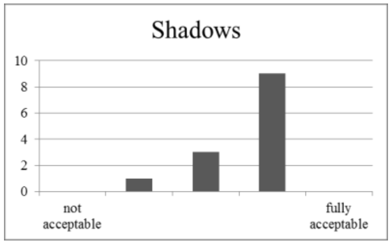


Figure 7: Survey results on: shadowing effects of human bodies

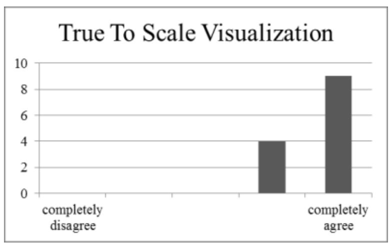


Figure 8: Survey results on: true to scale visualization

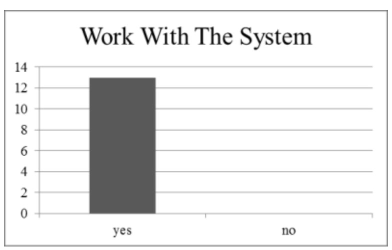


Figure 9: Survey results on: Whether the experts would like to work with the system or not

In order to understand the importance of these factors, several potential drawbacks have been discussed. By tendency, the thirteen asked production planning engineers agreed, that the height of the projectors at 2,5m is absolutely sufficient. All engineers rated the color differences as fully acceptable, because they are not crucial for reaching their goals and they are hardly recognizable. The same holds for the resolution of the augmented floor surface image. The hard-edging property of the system has been rated more diversely but by tendency still positive. Discussions with experts pointed out that a small gap between the projections areas can be accepted more easily than a small overlap with double the brightness. More expensive projectors offer soft-edging ability natively. Since each projector only offers 2500 ANSI lumen per image, the results on the brightness issue are surprising. The experts rated the brightness all in all as sufficient. Since the brightness of projection systems can easily be raised, the only limiting factor is the available budget. Interestingly, some people feel dazzled with light, when walking through the projection cone. By tendency the majority of people can cope with this property.

The most diverse results and most discussions of the experts were related to shadowing effects. By tendency, the people still found it "neutral to acceptable" for their purpose (see Figure 7), but this is the biggest drawback of the hardware implementation. There are several solutions to eliminate shadowing effects using LED or LCD floors or rear projection systems[4], but the investment costs of these systems are the limiting factor as-well. To put it in a nutshell, the experts were satisfied with the hardware implementation with some potential for improvements.

An unambiguous result of the survey is that the true to scale visualization helps the experts in spatial tasks like material zone planning. All engineers supported the statement by tendency (Figure 8). It is better suitable for estimating lengths, spatial relations and speeds than using common desktop displays or a power wall. Asking about possible efficiency improvements and the possibility to reduce the number of physical prototypes by using true to scale visualization in contrast to common desktop systems or a power wall, the results are diverse. By tendency, the engineers see this fact given for assessing walking. The given answers on the efficiency improvements and the possibility to substitute physical prototypes highly depend on the existing software. More specific experiments will be carried out in order to better understand and distinguish between the performance of the visualization software and the abilities of an augmented floor surface.

The experts were asked in a final, overall question whether they would like to use the system in general (see Figure 9). 13 out of 13 answered the question with "yes" and therefore would like to use the system operatively. This fact has proven the big potential of the system.

## Conclusion and future work

We presented a scalable augmented floor surface in combination with true to scale visualization for final assembly line station layout use cases. The proposed hardware setup is movable, easy to use and scalable. The introduced hardware setup offers a station-sized visualization area realized with low-cost hardware. The system was installed, introduced and piloted during on-site production planning workshops for a mid-size premium car. A preliminary evaluation with thirteen participating production engineers found that, by tendency, true to scale visualization using the interactive augmented floor surface supports the workshop participants to better estimate sizes, speeds and spatial relationships than on traditional desktop displays. The tangible user interface on the tabletop system in combination with the augmented floor surface offers a new interaction possibility for intuitively interacting with the virtual models within production planner use-cases. In general all survey participants wanted to use the system for their work.

By improving the accessibility and making virtual environments look closer to real world situations, the acceptance of production planners for virtual methods will increase. A closer look will be taken at, whether the workshop participants reach their verification goals faster at a higher quality level or not.

Future development will head to fully augmented workshop situations. The projection cascade will be enlarged for showing multiple station layouts in true to scale visualization at the same time. Additionally a tracked virtual arena will be built on the basis of the true to scale augmented floor surface. The augmented interactive floor will cover the whole room, powerwalls will display the assembly status. In order to interact with the digital model and automatically adapt the simulation, the augmented floor surface will be registered to a motion capture tracking system. Other display technologies will be registered to the augmented floor surface as well, so that the workers can align themselves via the floor projection and assess and train the station's tasks.

## Acknowledgements
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