Hybrid Visualization of Manufacturing Management Information for the Shop Floor

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Abstract

Despite years of research activities concerning human-machine-interfaces in industrial manufacturing environments, innovative forms of visualization (e.g. three-dimensional or realistic visualization) have yet to be thoroughly experimentally examined from software ergonomic and cognitive psychological points of view. Even though realistic forms of visualization has been implemented in an array of fields (e.g. architecture), there are relatively few statements as to when it is recommendable to chose such a visualization form in the industrial manufacturing.
With help from a recently concluded examination (cf. Stowasser 2002), it should be methodically determined, for the first time, in which way realistic elements should be used for the presentation of manufacturing information on the shop floor and for the surveillance and controlling of shop floor processes. Such human-computer-interfaces should support the employees in performing operative tasks like the observation and monitoring of manufacturing processes, checking the conditions of machines and tools, assigning materials to orders, tracing breakdowns and so on. Incorrect decisions in shop floor management (e.g. due to insufficient presentation of the information needed for process execution) have a direct influence upon the utilization, deadline adherence, costs situation and thus the competitiveness of the manufacturing.

1 Introduction into Shop Floor Controlling Systems

1.1 Visualisation Forms for Shop Floor Controlling Systems

Shop floor controlling is defined as the short-term controlling and monitoring of shop floor processes. It is responsible for the planning compatible execution of shop floor orders while considering human, economic, quality and deadline demands. In order to execute shop floor orders in a planning compatible manner the appropriation of personnel, equipment, material and other necessary resources, as well as the execution of work tasks, are initiated, surveyed and secured by the shop floor controlling system.
The goal of the current work is to provide a contribution to the experimental analysis and configuration of computer supported, process-orientated visualization forms using the example of enterprise shop floor processes within the operative shop floor controlling. Various research studies have found that the available, shop floor controlling systems, usually window-based, have deficits with respect to their user-friendliness and information transparency (see Greenough, Kay, Fakun & Tjahjono, 2000; Kasvi & Vatiainen 2000; Stowasser 2002).

1.2 Today´s Shop Floor Controlling Systems

The window technique has been established as a standard in all enterprise application areas. In the window technique the entire screen surface is divided into individual logical groups. One differentiates between information, controlling, processing and notification parts. A perception psychologically suitable arrangement of these groups serves to ease the registration of information as well as its quick interpretation. Taking these groupings into account, the arrangement of the information occurs according to information classes. Status information and control information is required for user orientation and for the control of the dialogue. The information required for the tasks to be carried out immediately is presented in the processing part. If the user makes an error in the handling of the computer system or disregards restrictions to the input, notifications are delivered by the system. Notifications can apply to "autonomous" objects.

2 Window-based versus realistic shop floor visualization

The basis for the comparative investigation study are two forms of visualizing industrial manufacturing information on the shop floor: a traditional window-(text-)based visualization *FEWER* (Fensterbasierte Werkstattsteuerung) and an innovative realistic form of visualization called Virtual Shop Floor (*VISOR*) (see Zülch & Stowasser 2001; Stowasser 2002).

2.1 Window-based shop floor visualization *FEWER*

Within the context of this work, the shop floor system *FEWER* (cf. Stowasser 2002) bases on text formulas, masks and dialogues. Text or graphic information as well as interaction possibilities are provided to the user within the structure. Figure 1 clarifies the structure of the user interface *FEWER*.

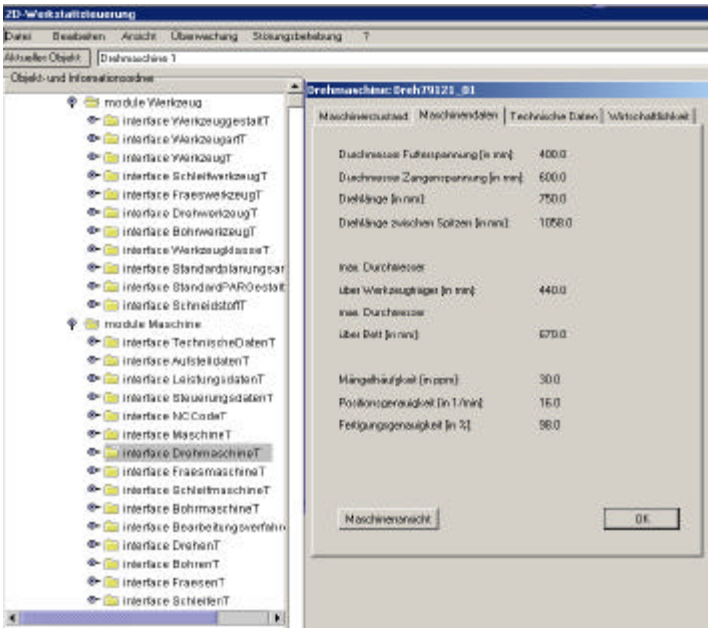

Figure 1: Window-based visualization *FEWER*

In the information part the current mask is indicated and the name of the program and the shop floor object being considered are given. With a menu selection in the control part the user is presented with a list of the functions at his disposal. The processing part of the screen mask offers a workspace for the execution of the operative shop floor controlling tasks needing to be dealt with, namely: Surveillance of preparation, quantities and deadline monitoring, quality controlling, tracing breakdowns, determining the causes for disturbances as well as intervening in the manufacturing procedure.
The processing part in *FEWER* contains a list of the shop floor objects (e.g. machines, orders) and their possible attributes. Using these lists, the user can find the objects required for the control and surveillance of the shop floor.

2.2 Virtual Shop Floor Visualization *VISOR*

VISOR (Virtual Shop Floor) is a realistic representation form based on the use of the graphic, multimedia possibilities of current computer systems. The realistic visualization is, in the context of this work, defined as (cf. Stowasser 2002) a spatial-perspective model of a three-dimensional scene, which can be considered from varying views. The model is visualized using graphic computer support. The degree of the visualization reaches an accurately detailed, objective (photographic) level. The dynamic shop floor environment is represented with *VISOR* in a spatial-perspective manner. The user can "place" himself in the realistic shop floor and move about in all three directions by using the spacemouse.
For operative shop floor observation, meaning the surveillance of appropriation (of e.g. resources, personnel), quantities, deadlines and quality, the user requires information about the current shop floor events. Such information is displayed in *VISOR* as text or graphics, whereby the information subject matter plays an important role in the conception (cf. figure 2). The data to be visualized can refer to abstract as well as to concrete circumstances.

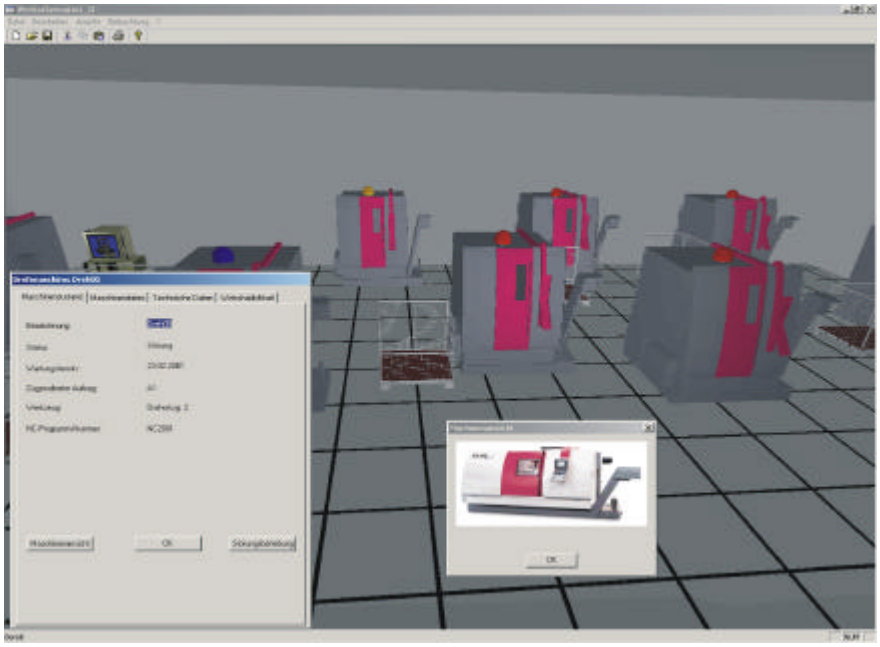

Figure 2: Realistic shop floor visualization *VISOR*

Concrete information is arranged metaphorically at the location of creation (e.g. material stocks in the warehouse) or use (e.g. NC-programs at machines). Metaphoric means that objects in an interactive system are represented in such a way that the users are familiar with them from their daily life or from their work environment. Thus, the worker can move around in the realistic shop floor and call up information at the representation of the respective object. It is for example possible to access order data (e.g. status of the current process, previous lead time, adherence to delivery dates) at the presented boxes, each representing an order. In particular fixed images (e.g. photos, sketches) or multimedia, dynamic visualization elements are used to represent current process states. Abstract information, which cannot be directly assigned to an object, is also visualized with metaphors in the representation. This functionality allows for the integration of, for example, general announcements (represented with blackboards).

3 Hybrid Visualization

The empirical methods used for the investigation of both visualization forms at the "Laboratory for Human-Machine-Interaction" of the ifab-Institute at the University of Karlsruhe are:

- eye movement registration to find out in which way the cognitive information process proceeds,
- log-file analysis to examine the interactions (e.g. mouse, keyboard) of the test persons,
- video-recording to observe the gestures of the test persons, and
- structured interviews to record the demographic data and to analyse the processing strategies used by the test persons in detail.

The study with 20 test persons (industrial shop floor experts and academic students) helped to sort out specific situations in the shop floor in which a specific visualization technique is most helpful. The design of these visualization techniques takes perceptual psychology models (e.g. theory of action regulation of Hacker, mental activity model of Rasmussen) into consideration.
The results of the experimental investigation significantly show that the visualization is markedly important for the cognitive performance of and the strain to the user during the execution of shop floor tasks. The compatible representation of mental models, upon which the shop floor worker's cognitive operation planning is based, is suitably supported by the realistic visualization. If one considers the average fixation duration as a measure for example, the test persons´ strain was approximately 25% lower when *VISOR* was used. This effect must be considered as particularly important when unforeseen operation requirements with high cognitive demand arise, in which an error-free intervention in the shop floor process is necessary.
The investigation also shows, however, that the realistic visualization is not preferred for all shop floor tasks. The choice of information coding and visualization is thus dependent upon the type of task and the information required for it. The test persons preferred the realistic visualization in particular for the execution of those tasks for which a spatial perception of the shop floor and of the object arrangement is helpful and for those for which a general overview of the shop floor is advantageous. The window-based visualization form is however more suitable for the representation of abstract management information.
The advantages of both forms of navigation, in other words the realistic and window-based forms, can be combined in a hybrid visualization form using multiple information coding. Order and organizational principles, meaning a hierarchical structuring and semantic grouping of the shop floor objects, can thereby be achieved. Additionally, already present, realistic perception experience, stored in the form of a mental model, can be supported by the realistic representation.
The hybrid shop floor visualization thus takes the cognitive psychological position, that human thought processes are marked by concentration on local detail and by a global overview of impor-

tant information, into account. This should make it possible for the user to apply the visualization form most suitable for him and to dynamically vary it depending on the task, information needs, individual preferences and personal abilities. This requirement is also fulfilled by adaptive visualizations.

Figure 3 provides, as an example, the vision of a hybrid shop floor controlling visualization. The text-based, hierarchically arranged object list allows for a quick object-orientated access to a sought shop floor element. A realistic animation of shop floor occurrences, through the effect of immersion, and the visual-spatial representation would enhance this even further. Disturbances in the shop floor process, error messages and alarms would have to be shown repeatedly and coded in various forms. (e.g. pop-up disturbance dialogue).

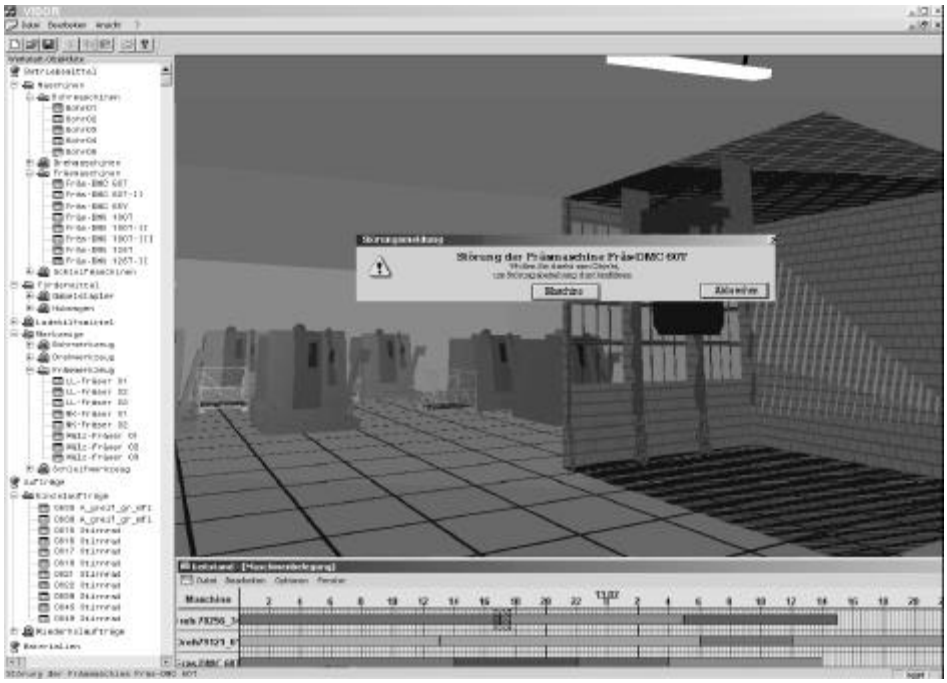

Figure 3: Hybrid visualization of the shop floor

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