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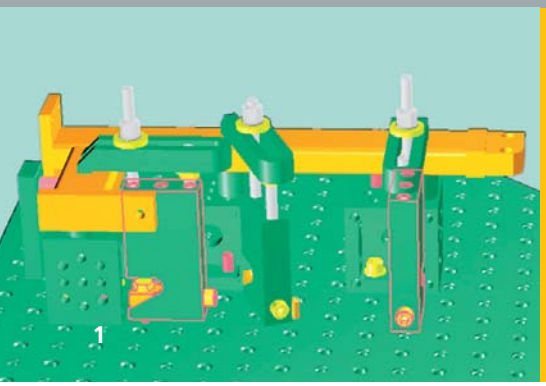

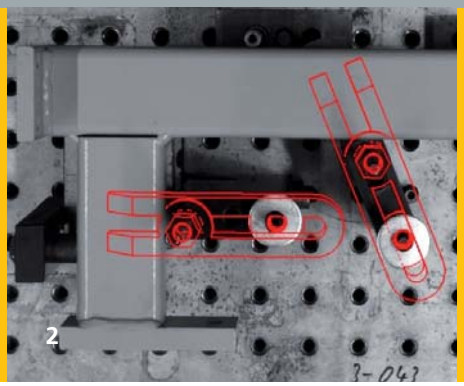

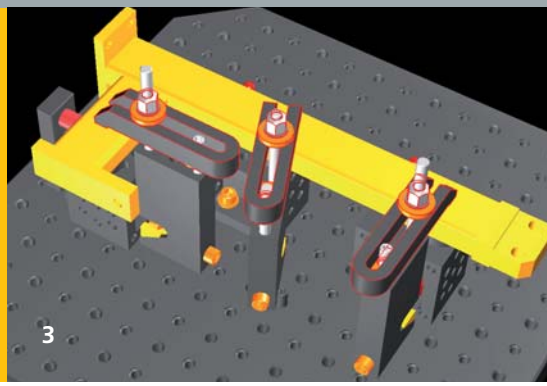

1 *Representation of an assembly operation.*
2 *Assistance overlay in a camera image. Photo: Fraunhofer IFF*
3 *CAD assembly scene model.*

WORKER ASSISTANCE AND QUALITY INSPECTION FOR MANUAL ASSEMBLY PROCESSES

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Initial Situation and Motivation

A multitude of industrial assembly processes have many variants because of the high individuality of products. Manual assembly work subjectively influences the quality of an end product. Errors that occur in production increase costs. Systematic assistance is an option to support human action and prevent errors. By providing visual information on a component or assembly being assembled, clear instructions are furnished, which make processes highly reliable even when variants and types of assembly keep changing. Such systems can be extended to supplement the assistance function with automatic quality inspection after every step of assembly. This further enhances process reliability.

Functional Principle of Assistance

Data from a video camera monitoring the workplace and 3-D CAD models of design data on an assembled assembly including every single component are available to the system as input information. For stationary structures, the camera's spatial position and orientation (Perspective) relative to the assembly field is initially determined one time with the aid of an external reference system located in the camera's field of vision and a fixed reference to the assembled assembly or its holder. Assistance or inspection of an assembly for one assembly step may be organized by employing data on camera position and orientation to align the visual perspective of the 3-D CAD model identically to the camera perspective and generate a virtual image of the real camera view. Afterward, the CAD models of the components being assembled may be overlaid in the correct position and ori-

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entation of the camera image's view of the real assembly scene. This "virtually" adds the view of the real camera image to the current work step. This information on the position and orientation of the component being assembled systematically supports workers. A simultaneously displayed text version of the assembly operation presents the type of component and the sequence of assembly steps. Additional information such as bolting torque and the like is displayed for the current work step and special instruction are integrated in the visualization.

Alternatively to this fixed camera arrangement that monitors the assembly scene, another camera that is fixed or even has defined movement may be used. This allows different perspectives of the assembly scene and has many benefits particularly when assemblies are large and complex. In addition to overlaid and textual assistance information, an interactive 3-D CAD model viewer provides workers further support.

Functional Principle of Assembly Inspection

Accompanying inspection of the result of assembly further enhances process reliability. Once an assembly step has been completed, the presence of the mounted component and the correctness of its position and orientation as well as the completeness of the step are inspected by scanning the 3-D geometry. The assistance setup is extended by another camera to generate a second view of the assembly scene. The mounted component's object geometry is determined three-dimensionally in real time with the aid of stereo triangulation. The resultant set of points is compared with the CAD data to generate quality data on a component's presence, correctness and correct installation position. The result is visualized immediately upon the conclusion of an assembly step and enables workers to directly inspect their own work themselves.

Assembly Operation Generation

The sequence of an assembly operation's steps may be defined by an assembly operation editor or already in the assembly's design in the CAD program. The assembly operation editor computes and proposes a possible assembly sequence based on the CAD data of the component to be mounted. The user may choose between alternative proposals or define a sequence manually.
The assistance and inspection system can be adapted to changing assembly scenarios flexibly and quickly by selecting an assembly sequence dataset.

Visualization and Operation

In the simplest case, the assistance functions and the inspection results can be visualized by a monitor set up in the worker's field of vision. An alternative is expedient for select applications. A projector projects assistance information directly onto the component and thus provides workers intuitive support. Workers may enter operating instructions by touchscreens or by manual or pedal buttons. Alternatively, hand gestures may be employed to instruct the system.

Benefits

Such systems help efficiently organize complex and varied assembly processes with a high level of objective product quality. They speed up operations significantly while enhancing process reliability at the same time. In-process integration of assistance and quality inspection generates direct feedback, thus eliminating time-consuming and costly reworking.