HAL
open science

Improvement of Manufacturing Processes with Virtual Reality based CIP-Workshops

Dirk Ostermayer, Jan Christian Aurich, Christian Wagenknecht

To cite this version:

Dirk Ostermayer, Jan Christian Aurich, Christian Wagenknecht. Improvement of Manufacturing Processes with Virtual Reality based CIP-Workshops. International Journal of Production Research, 2009, 47 (19), pp.5297-5309. 10.1080/00207540701816569 . hal-00513019

HAL Id: hal-00513019

https://hal.science/hal-00513019

Submitted on 1 Sep 2010

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Improvement of Manufacturing Processes with Virtual Reality based CIP-Workshops

Journal:	*International Journal of Production Research*
Manuscript ID:	TPRS-2007-IJPR-0284.R1
Manuscript Type:	Original Manuscript
Date Submitted by the Author:	19-Sep-2007
Complete List of Authors:	Ostermayer, Dirk; University of Kaiserslautern, Institute for Manufacturing Engineering and Production Management Aurich, Jan; University of Kaiserslautern, Institute for Manufacturing Engineering and Production Management Wagenknecht, Christian; University of Kaiserslautern, Institute for Manufacturing Engineering and Production Management
Keywords:	MANUFACTURING PROCESSES, CONTINUOUS IMPROVEMENT, VIRTUAL REALITY
Keywords (user):	CIP-Workshop

scholarONE™
Manuscript Central

International Journal of Production Research
Vol. XX, No. X X, XX.XXXX 2007, xxx–xxx

Improvement of Manufacturing Processes with Virtual Reality based CIP-Workshops

J. C. AURICH [a] , D. OSTERMAYER [a *] , CH. WAGENKNECHT [a]

[a] Institute for Manufacturing Engineering and Production Management
University of Kaiserslautern,
67653 Kaiserslautern, Germany

Abstract

The Continuous Improvement Process (CIP) is a well established method to improve manufacturing processes. A typical CIP-workshop, carried out by a group of workers and engineers directly in the production, often causes unwanted downtimes. Furthermore, improvements have to be realized without reliability testing. Virtual Reality (VR) provides a powerful means to support CIP-workshops. This paper introduces the concept of a VR-based CIP-workshop. User interfaces are proposed to integrate additional elements, e.g. findings of augmented reality, into VR. This allows meeting specific demands of different participants involved in a CIP-workshop. The proposed concept is validated based on industrial use case.

Keywords: Manufacturing Processes, Continuous Improvement, Virtual Reality, CIP-Workshop

1 Introduction

Manufacturing systems, once set up, still have to be improved continuously during operation due to demands for improved productivity and quality or reduced throughput time (Ratering et al. 2002, Westkämper et al. 2001). Planning and implementing these improvements in many cases leads to manufacturing downtimes.
The workshop-based Continuous Improvement Process (CIP) is a well-established method to support manufacturing improvement activities. Typically, for a CIP-workshop, workers from the manufacturing area are directly involved and participate actively in the improvement process.

2 CIP-workshop – typical procedure

The CIP aims at permanently improving manufacturing systems and processes. The central idea is integrating the worker into the improvement process taking direct advantage of his hands-on expertise. A common method to implement this is the so-called CIP-workshop. Such a workshop aims at the systematic detection of improvement potentials with a following quick development and implementation of improvement measures (Deming 1992, Ishikawa 1985). The workshop is carried out as a moderated group work with a typical duration between one and five days and takes place within the running production, which is only temporarily stopped. Workers from the manufacturing area which is to be improved participate along with engineers from manufacturing planning, quality management and other specialized functions in order to jointly secure proper

[*] Corresponding author. Email: ostermayer@cck.uni-kl.de

For Peer Review Only

workshop results. Common issues of CIP-workshops are the reduction of set-up times of machines or layout improvements of a work place.

[insert figure 1 about here]

These improvements are developed directly within the addressed working area (Imai 1986) (see figure 1). Subsequently, the necessary improvement measures are implemented, preferably as a part of the workshop or, in case the time necessary for realization is too long, as a follow-up activity. Such follow-up activities involve typically complex and cost-intensive measures. Finally, the workshop participants compare and evaluate the expected improvements with the realized results. To ensure continuous improvements, the workshop is repeated in defined time intervals.

All major workshop activities, such as the analysis of ongoing manufacturing processes or the identification of improvement potentials, are performed directly within the physical working environment. This direct interference with running production often leads to unwanted manufacturing downtime and is one of the prime disadvantages of CIP-workshops. It represents a drawback which prohibits many companies from implementing a CIP-process.

In order to overcome this drawback, decoupling the elaboration and evaluation of improvement measures from running production is a promising approach. Here, Virtual Reality-technology (VR) provides a powerful means to support and improve the traditional CIP-workshop concept (Aurich et al. 2006). VR-technology is already implemented in various industrial applications, particularly in product development and in the planning stage of manufacturing systems.

3 Virtual Reality Technology

Virtual Reality (VR) is defined as a computer technology to create virtual environments consisting of realistic three-dimensional models and their interrelationships (Bryden et al. 2003). VR-technology is characterized by the three main elements (Wilson et al. 2002):

- visualization of virtual environments,
- immersion of the user into the virtual environment, and
- interaction within the virtual environment.

VR-technology is well known in a wide range of industrial applications and is typically applied during the planning stage of a manufacturing system. Ergonomics in assembly, the simulation, evaluation and visualization of product and production designs and the training of employees (Arkhurst, W. et al. 2001, Blümel et al. 2003, Westkämper et al. 2001) are common examples. The approaches currently proposed put their focus on visualization and immersion as well as on simple real-time simulation. Direct interaction with the virtual objects is an issue of ongoing research. As interaction is a strong element of a CIP-workshop, VR-technology now has the potential for improving the traditional CIP-workshop by performing analysis and planning activities parallel to the running manufacturing process. Moreover, research in related areas, e.g. augmented reality (AR), has shown that such interaction strongly benefits from providing additional, context-sensitive information for the user (Lu et al. 1999, Reinhard et al. 2001). Examples for such additional information are object identification, object parameters or the change history of single objects and the entire manufacturing system

For Peer Review Only

4 VR-based CIP-Workshop

4.1 Workshop characteristics

The VR-based CIP-workshop combines elements of traditional CIP-workshops with approaches only possible within virtual environments. The main characteristics of a VR-supported CIP-Workshop can be described as follows:

- The workshop is performed within an immersive virtual manufacturing environment.
- Thereby, workshop steps are carried out along the traditional workshop sequence.
- Workshop participants develop improvement ideas and selective measures within the virtual manufacturing environment parallel to the ongoing manufacturing process.
- In addition, well-known collaborative creativity tools can be used within the virtual environment to work out extensive and innovative solutions. Examples are brainstorming or mind maps.
- A group size of four to six participants allows to exploit the full potential of VR-supported CIP-workshops. Additionally, a permanent or rotationg VR-specialist can be defined or integrated to the group to handle the VR-technology within the workshop, e.g. the interaction device.
- Results of the different steps of a workshop have to be documented in a proper way to ensure the transfer to the physical manufacturing environment. Examples are special forms that combine both textual as well as visual components.

These characteristics are the basic principles for the basic concept of VR-based CIP-workshops.

4.2 Basic Concept

CIP-workshops within virtual environments require specific concepts for the generation of the virtual manufacturing environment and for carrying out the CIP-workshop. Special requirements apply to the documentation concept, which ensures the transfer of workshop results back into the physical manufacturing environment (Aurich et al 2006).

Generating a virtual environment starts with the entry and analysis of data of the physical manufacturing environment (see figure 2(a)). As a result, either available data are identified or new manufacturing data are created. These data are used to generate an adequate virtual manufacturing environment (see figure 2(b)). Thereafter, the CIP-workshop is performed within the generated immersive virtual manufacturing environment (see figure 2(c)). Finally, the results are transferred in to the physical manufacturing environment. (see figure 2 (d)).

[insert figure 2 about here]

4.3 Data entry – Demands for manufacturing system and process data

The sufficient knowledge both of all necessary as well as available manufacturing system and process data is essential for generating an appropriate virtual manufacturing environment. Therefore, data entries have to be performed to collect these data and to fill potential data gaps using methods of process and data analysis (Aurich et al. 2006). Major data to adequately model the working area are:

- 3D-models representing macro-geometric parameters (shape, position, orientation, dimension),
- layers representing micro-geometric parameters (e.g. surface, perspectives, aspects),

For Peer Review Only

- structural data representing manufacturing system elements and relations (e.g. machines and related areas for placing material at disposal, machine components),process data of manufacturing resources (e.g. working plans, process times, material flow simulation) representing dynamic, i.e. timely variable, parameters.

These data are introduced into the virtual manufacturing environment at different point time. Examples are specific object characteristics added during the preparing of the virtual environment or additional information added with the proceedings of the workshop.

Usually, manufacturing data are already to a certain extent partially available out of existing information systems, however typically highly distributed and on a different scale and level of detail (e.g. CAD - Computer Aided Design, EDM – Engineering Data Management, ERP - Enterprise Resource Planning, DF – Digital Factory).

The 3D-models of relevant manufacturing elements enable a realistic visualisation of the addressed working area. Common examples are the equipment of working places or machinery equipment. Detailed information concerning working stages and associated process times provide the necessary interaction options to perform CIP-workshops within a virtual manufacturing environment.

4.4 Virtualization - Preparing the virtual environment

Manufacturing virtualization is an essential step to create the virtual working area. Many constituents of traditional geometry-oriented VR-models of manufacturing environments can be generated by using available 3D-CAD-models from different areas like architecture or machine design (see figure 3). The corresponding software supports native data formats including basic information such as geometry and dimensions. CAD-data from machine design additionally includes specific information like parts lists while architectural data includes building material etc. In addition, the alternative CAD-systems vary in attributes like the structure of the geometry.

[insert figure 3 about here]

Due to the differences between native CAD-formats and data-formats of VR-software, those 3D-CAD-data necessary for manufacturing system representation have to be converted into appropriate formats applicable for VR-software. Therefore, descriptive languages are used. They describe VR-models by defining their body structure as well as their position in the manufacturing system. The Virtual Reality Modelling Language (VRML) is a typical descriptive language. VRML enjoys widespread use in commercial CAD- and VR-software, mainly as a result of its definition as an industrial standard (ISO 2007, Schneider et. al 2004).

However, the resulting loss of information content due to the necessary conversion of CAD-data into VR-data opposes the need to generate adequate and realistic VR-models of the manufacturing system. For example, specific use cases such as the redesign of a work place require specific dimensional data. Therefore, this information has to be added again to the VR-model descriptive formats (Aurich et al. 2005).

Beside 3D-CAD-data, other major sources for geometrical, structural (e.g. engineering data management) and process data (e.g. material flow simulation) must be processed in an analogue manner. Some of these data can be directly integrated by means of a simple format conversion; other data have to be added, very often still manually.

4.5 Workshop procedure

The typical procedure of VR-supported CIP-workshops consists of five different steps (see figure 4). Within the first step, selected working areas with reported problems and improvement potentials are visualized from

For Peer Review Only

the workers perspective. The workers can immediately demonstrate their problems by performing certain work steps within the virtual manufacturing environment. Examples are a specific step-by-step sequence of joining two parts together or a machine set-up with following machining of a variety of parts. Furthermore, workers can propose manufacturing improvements during this early stage of the CIP-workshop. Possible improvements are directly stored within the virtual environment adding textual annotations to the virtual objects or on non-electronic documentation such as flipcharts.

[insert figure 4 about here]

Next, the workshop participants analyze the manufacturing structures and processes in order to detect improvement potentials. The virtual manufacturing environment is scaled in real dimensions to enable the detailed survey of different manufacturing workflows. Even single work steps can be repeatedly performed without disturbing the ongoing manufacturing process. During the following step, based on the previous analysis results, the participants develop specific improvement measures that can be immediately realized within the virtual environment. For example, the participants can relocate elements of working places without affecting the ongoing manufacturing process. The approach allows direct validation of changes within the virtual manufacturing environment. The participants immediately compare different alternatives and their effects within the realistically scaled representation of the physical manufacturing environment. As a result, multiple improved and evaluated manufacturing structures and processes are developed within one CIP–workshop. Additionally, alternative improvement measures can be developed, realized, evaluated and documented within a short time interval.

During the course of the CIP-workshop, descriptions of problems and proposed improvements are added to the VR-model as textual or visual descriptions. Annotations are linked as attributes to the objects of the virtual manufacturing environment. The participants can access them while working within the virtual manufacturing environment. In addition, conventional paper-based media can be used to take notes. Conventional pin boards or flip charts are examples for well-established tools. Participants can permanently access them in parallel to the activities within the virtual environment

Finally, the workshop results must be quickly transferred back to the physical manufacturing environment and implemented in reality (Aurich et al. 2006).

4.6 Transferring the results into the physical manufacturing environment

The workshop results have to be quickly transferred in order to enable successful realisation within the physical manufacturing environment. In most cases, missing interfaces and resulting information losses due to necessary data converting processes prevent a direct electronic data transfer. An example is the often-necessary usage of different data formats such as VRML (Virtual Reality Modelling Language) or native CAD-data (Aurich et al. 2005). The resulting information loss is analogue to the virtualisation step of the VR-supported CIP-workshop as described above.

As a result, specific documentation forms must be used, often accompanied by paper-based media such as flipcharts. This form is used to document small, quickly realisable improvements and their necessary manufacturing data. Editing either electronically or paper-based can be seen as a major advantage of the proposed form. All developed results are finally combined. Examples are separate descriptions of different workshop phases. The documentation concept consists of the following main elements (Figure 6):

- name a function of the workshop participants,
- description of discussed problems,
- proposed improvement,
- results of evaluation,

For Peer Review Only

- additional information, e.g. documentation of effected working process, and
- documented release of the proposed improvement.

The documentation of the improvements developed during a CIP–workshop is necessary to realise them in the physical manufacturing environment. During the realisation, different departments and persons use this documentation. Examples are employees responsible for manufacturing planning, construction or engineering. Therefore, a standardised and appropriate concept for documentation is useful. The documentation should also enhance the realising of improvement measures in the physical environment. The proposed concept of a VR-based CIP-workshop integrates the above described standardized improvement form into the course of the workshop (see figure 5).

[insert figure 5 about here]

The successful implementation of a VR-supported CIP-workshop requires proper usability of the virtual environment at all times. The participants have to be able to perform all necessary steps of the CIP-workshop within the virtual environment. This leads to the need for a VR-user interface specific for CIP-workshops

5 User interface for VR-based CIP-workshops

5.1 Demands for an appropriate user interface

An appropriate user interface for VR-based CIP-workshops has to meet specific procedural demands as well as the demands of the participants.

Procedural demands address the adequate level of workshop-related VR-functionality that must be integrated into the user interface. The participants must be able to properly analyze and evaluate improvements within the virtual manufacturing environment. This requires a high level of user interaction and sufficient user immersion for the participants. Major procedural demands are:

- Enable movement of the participants along different degrees of freedom within the virtual manufacturing environment in order to analyze problems and evaluate improvement measures.
- Easy manipulation of objects within the virtual environment to develop and realize improvement measures, e.g. relocating a machine.
- Support intuitive analysis of the virtual environment and the realized improvements, e.g. measuring distances between elements of working places.
- Closed documentation of realized improvements in order to successfully transfer the workshop results back to the physical manufacturing environment.

Additional user specific demands of the participants are:

- User-friendliness for participants with different levels of knowledge of VR-technology, e.g. workers and engineers
- User-definable functionality for context specific workshop tasks, e.g. changing the workplace layout by moving workplace-related objects or performing detailed assembly studies to compare different assembly steps and sequences.
- Providing additional, object related information, e.g. process data or material flow.

The described demands can be contradictory, e.g. integrating a high number of functions directly leads to a reduced level of user-friendliness. Therefore, overcoming and solving the resulting goal conflicts was a major challenge in realizing an appropriate user interface.

For Peer Review Only

5.2 User interface and functions

The developed user-interface meets the demand for specific VR-functions necessary to perform a CIP-workshop within a virtual environment. An adequate interaction interface supports both direct user interaction using a physical device and textual based input. Being highly intuitive while using to a large extent already available technology it is guaranteed that the CIP-workshop can be performed without comprehensive programming, developing or support efforts. Conventional VR-technology already allows tracking the position of participants (e.g. optical tracking) and interacting within the virtual manufacturing environment (e.g. interaction device). Interaction within a CIP-workshop can be divided into two groups: basic interaction and enhanced interaction (see figure 6).

Basic interaction contains simple and often repeated functions that are not necessarily specific for a CIP-workshop. Examples are moving around within a virtual working environment (e.g. fly, walk) or selecting elements for enhanced interactions. Due to their common use and in order to allow for fast access by the workshop participants, these interactions are performed by a direct input from a physical interaction device. A physical interaction directly supports easy and intuitive acting of the workshop participants within the virtual environment.

[insert figure 6 about here]

Enhanced interactions are rather specific functions within a CIP-workshop. “Manipulation” changes virtual objects respectively their relations. The relocation of elements within the virtual manufacturing environment, e.g. moving along defined degrees of freedom or turning into specific positions, is a common example. Analysis functions support specific testing actions, e.g. measuring distances between virtual elements to check the right position. Snapshots taken from modified manufacturing areas or interesting elements allow to document improvement results. Moreover, specific parameters such as object geometry can be separately extracted in order to be reintegrated into other information systems. Providing additional context-related information within the virtual environment extends the mere visualization of virtual objects and helps the participants to access all necessary object related information within a virtual environment during the workshop, e.g. textual descriptions (see figure 7). Examples for object manipulation and analysis are displaying additional object parameters, assembly times, levels of stock.

[insert figure 7 about here]

As enhanced interaction functions are implemented as textual-based components, participants can select their next action out of a context-dependent menu. The individualized menu structure considers the frequency of a specific action to be performed within the CIP-workshop. Interactions that are often repeated, e.g. object manipulation during reconfiguration of workplace layout, are context-related and easily accessible. Fast access is supported through a user-defined individual textual based interface as well as through the interaction device. To configure the interaction device, participants can select an appropriate input configuration from the textual based menu.

The combination of basic and enhanced interface functions supports the integration of a wide range of interactions without overstraining participants based on mere textual interface components.

7. Validation

The proposed approach of a VR-based CIP-workshop has been validated based on a use case in collaboration witan international agricultural machinery manufacturer. There, an assembly area for large sized components

For Peer Review Only

was identified and selected to be improved in terms of e.g. higher product quality and educed throughput time. The workshop participants have been chosen to represent different manufacturing departments and affiliations, e.g. assembling, welding or manufacturing process and layout planning. The preparation of an immersive virtual environment has been the starting point of the workshop and was mainly based on geometric and process data.

During in total two workshops, the participants worked out specific improvements within the virtual manufacturing environment provided by a 4-sided projection system (3 walls, 1 floor). The workshop participants have been able to realize and evaluate the improvement measures directly within this virtual environment. Therefore, always one participant could access interactions by a flystick (provider: ART/Germany). Basic interactions were directly accessible while enhanced interactions were implemented in textual menus callable by the flystick. The corresponding software (provider: VRCOM/Germany) provides customizable user interfaces. (e.g. textual menus) combined with a wide range of functionality (e.g. collision detection). In addition, this software is widely used in industry. An optical tracking system enabled a barrier-free movement for the participants within the virtual environment. Major workshop results to improve the manufacturing area have been changes in the layout of certain working stations. All results were finally documented and transferred back to the machinery manufacturer for realisation.

All workshop participants reported, that the intuitive access to the virtual manufacturing environment promoted the quick identification of improvement ideas without the common physical limitations of picking just one solution or being forced to pick a solution with predictable results, i.e., in order to minimize the risk of non-controlled changes within the manufacturing environment.

8. Conclusion and future work

VR-technology has the potential to significantly improve the conventional CIP. Unwanted downtimes in manufacturing can be reduced and improvements can be tested prior to their actual physical realization. The proposed approach allows to perform CIP-workshops within a virtual manufacturing environment and to successfully transfer the results back to the physical environment. The presented user-interface supports workshop participants with different levels of abilities and knowledge. Initial industrial case studies have shown promising results and prove the functionality of the VR-supported workshop concept.

Future work will address further enhancements of the described concept. Examples are improved methods for virtual representation of manufacturing systems without having design data or a more realistic visualization. Further development and enhancements of the original documentation-concept will improve the potentials of the VR-supported CIP-workshop. Using appropriate human-VR-interfaces will enable documentation immediately within the virtual manufacturing environment. The documentation forms can then by displayed end exported directly from the virtual manufacturing environment.

Furthermore, alternative user interfaces to interact within the virtual manufacturing environment will be explored. Haptic devices or speech control are promising approaches. In addition, research results from related areas such as integrating CAD- and VR-data will be checked for their suitability and included into the VR-supported CIP-workshop.

8. Acknowledgements

The presented results have been based on a joint research project in collaboration with John Deere Zweibrücken, Germany, and funded by the Rhineland-Palatine Innovation Foundation.

References

For Peer Review Only

Arkhurst, W., Pommert, A., Richter, E., Frederking, H., Kim, S.-I., Schubert, R., Höhne, K. H., A Virtual Reality Training System for Pediatric Sonography, Proc. CARS 2001, Excerpta Medica International Congress Series 1230, 2001, pp. 453-457 (Elsevier: Amsterdam).

Aurich, J. C., Ostermayer, D., Rößing, M., Models for VR-based reconfiguration of manufacturing systems – Basic demands and requirements, In. Proceedings of the ProSTEP iViP, 2005, pp. 148-157 (ProStep: Darmstadt).

Aurich, J.C.; Ostermayer, D.; Wagenknecht Ch., Improvement of manufacturing processes with Virtual Reality-Technology, In: Proceedings 5th CIRP ICME, edited by Teti, R., 2006, pp. 239-244.

Blümel, E., Salem, W., Schenk, M., 2003, Using Virtual Reality in In-Factory Training: Adding more Value to the Production System, In: Proceedings 36th Seminar on Manufacturing Systems, 2003, pp. 219-223.

Bryden, K., Chess, K. L., Virtual engineering offers applications for today, challenges for tomorrow, *Power*, 2003, **147**(2): 67-70.

Deming W. E., *Out of the crisis: quality, productivity and competitive position*, 1992 (Cambridge Univ.: Cambridge, Mass.).

Imai, M., *Kaizen, the key to Japan's competitive success*, 1986 (Random House Business: New York).

ISO/IEC, 2007, 14772-1:1997, available online at: http://www.web3d.org/x3d/specifications/vrml/ISO-IEC-14772-VRML97 (accessed 18th April 2007).

Ishikawa, K., *What is Total Quality Control? The Japanese Way*, 1985 (Prentice-Hall: Engkewood Cliffs, NJ).

Köksal, G., Selecting quality improvement projects and product mix together in manufacturing: an improvement of a theory of constraints-based approach by incorporating quality loss, *International Journal of Production Research*, 2004, **42**(23), 5009-5029.

Lu, S.C.-Y., Shpitalni, M., Bar-Or, R., Gadh, R., Virtual and Augmented Reality Technologies for Product Realization, *Annals of the CIRP*, 1999, **48**(2), 471-495.

Ratering, A. M., Duffie, N. A.: Design and Analysis of a Closed-Loop Single Workstation PPC System, *Annals of the CIRP*, 2003, **52**(1), 355-348.

Reinhart, G.; Patron, C., Integrating Augmented Reality in Assembly Domain – Fundamentals, Benefits and Aplications, *Annals of the CIRP*, 2001, **50**(1) , 9-12.

Schneider, F. J., VR-Einsatz in der Fabrikplanung, *CAD-CAM-Report*, 2004, 10, 44-49.

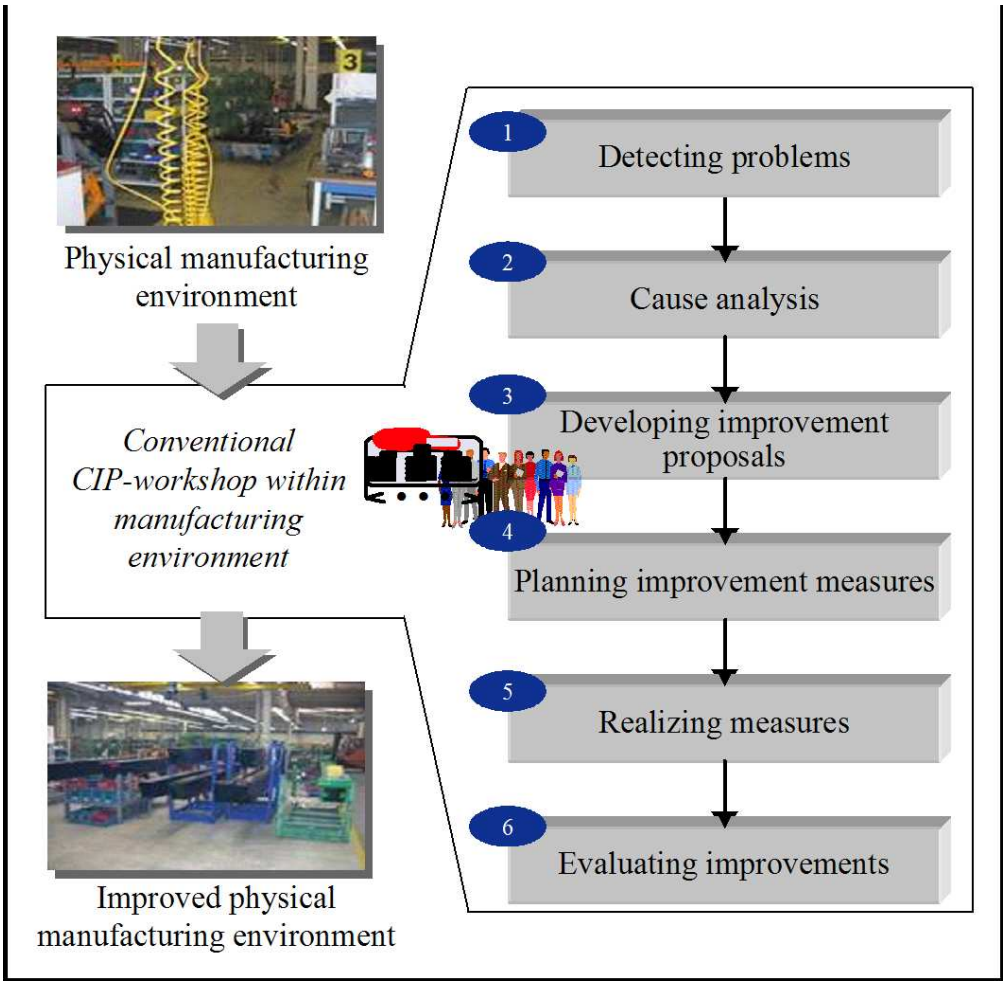
Westkämper, E., Briel, R. von, Continuous Improvement and Participative Factory Planning by computer systems, *Annals of the CIRP*, 2001, **50**(1): 343-346.

For Peer Review Only

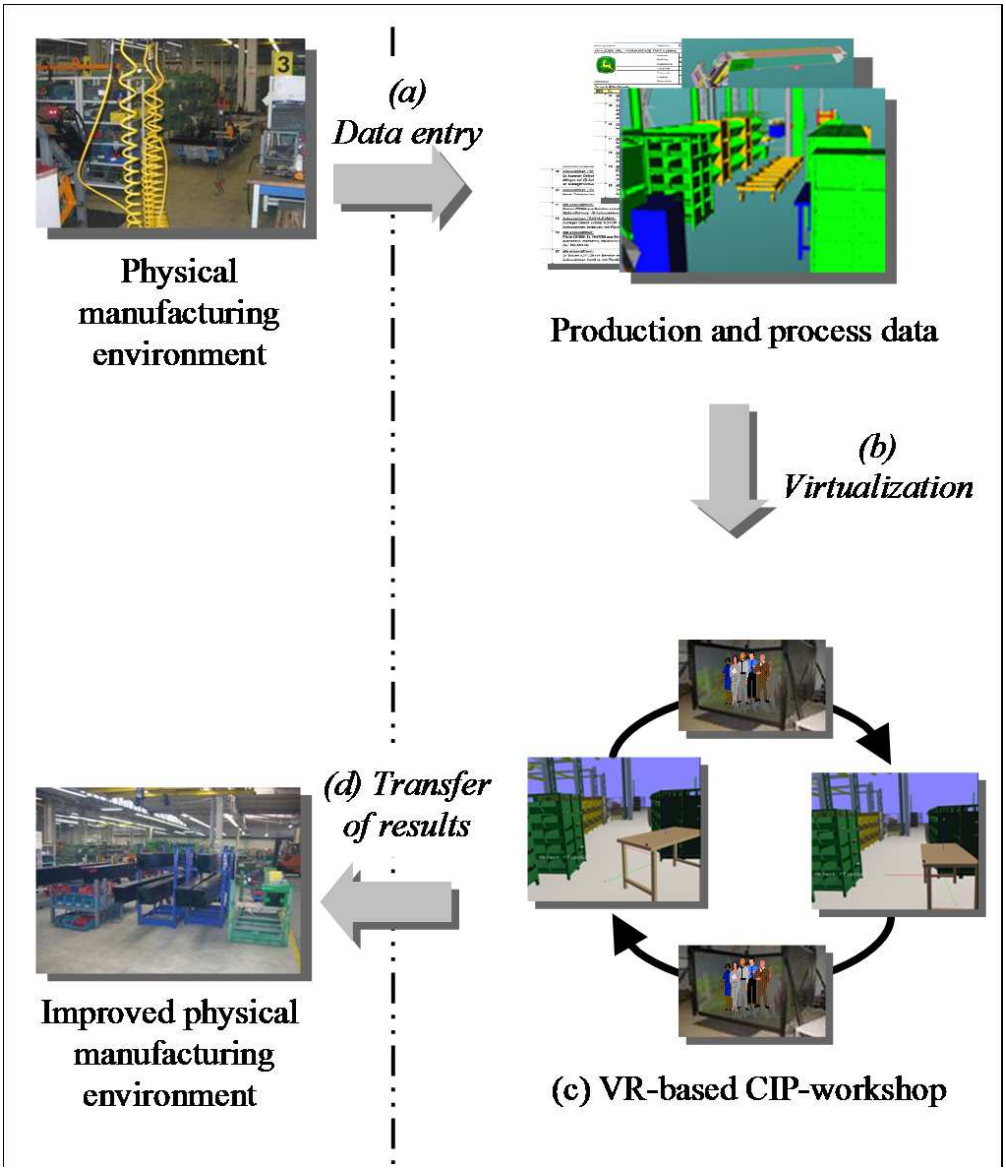
Wilson, J. R.; Eastgate, R. M.; D'Cruz, M., Structured Development of Virtual Environments, In: *Handbook of virtual environments*, edited by Stanney, K. M, 2002, pp. 353-378 (Lawrence Erlbaum Associates: Mahwah).

Figure Caption
Figure 1: Conventional CIP-workshop
Figure 2: Basic concept of a VR-based CIP-workshop
Figure 3: Data transfer Virtualization
Figure 4: Proceeding of VR-based CIP-workshops
Figure 5: Documentation of workshop results
Figure 6: Functions of the specific user-interface
Figure 7: Providing additional information within virtual environments

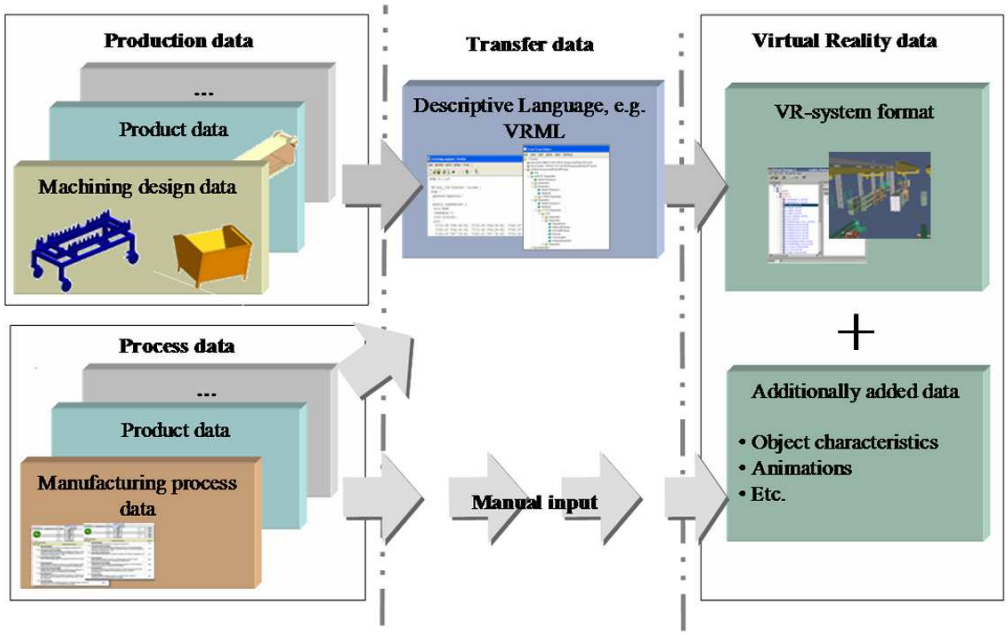
For Peer Review Only



Typical procedure of conventional CIP-workshops
179x174mm (150 x 150 DPI)

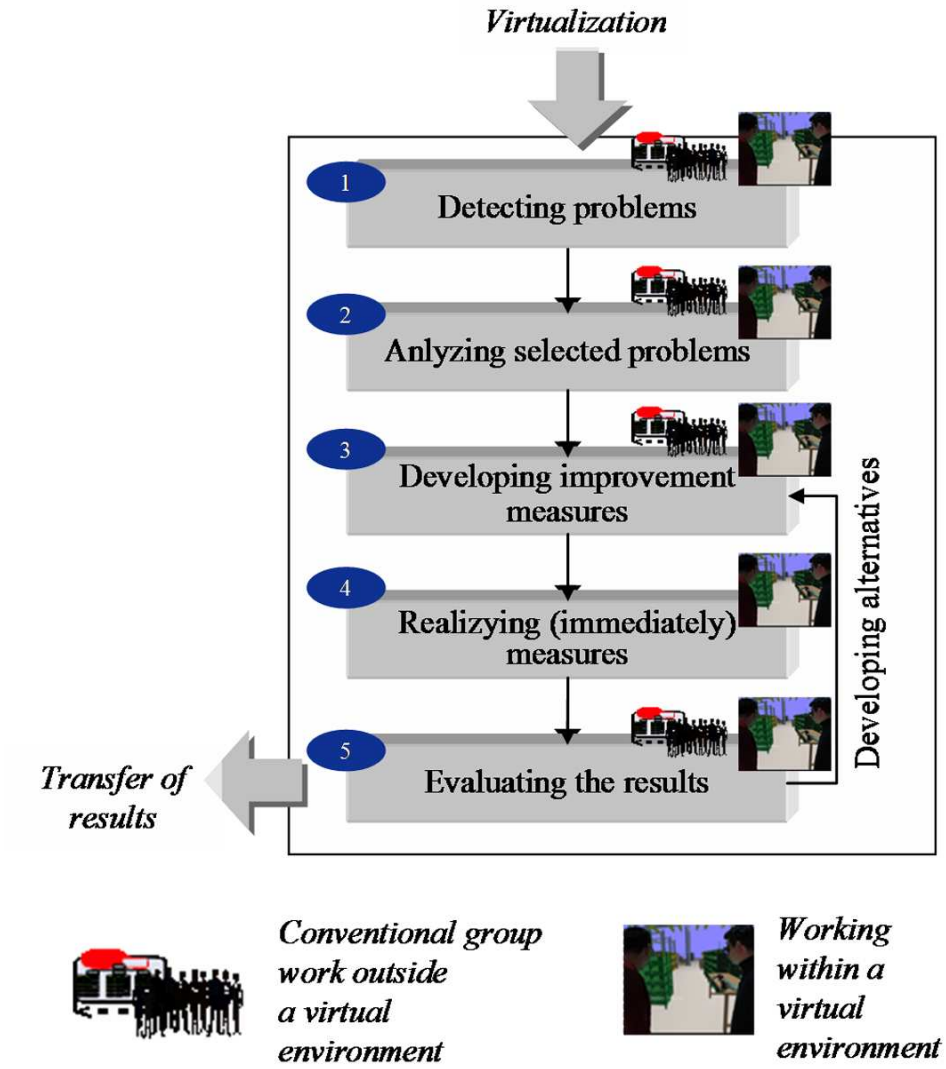


Basic concept
172x200mm (150 x 150 DPI)

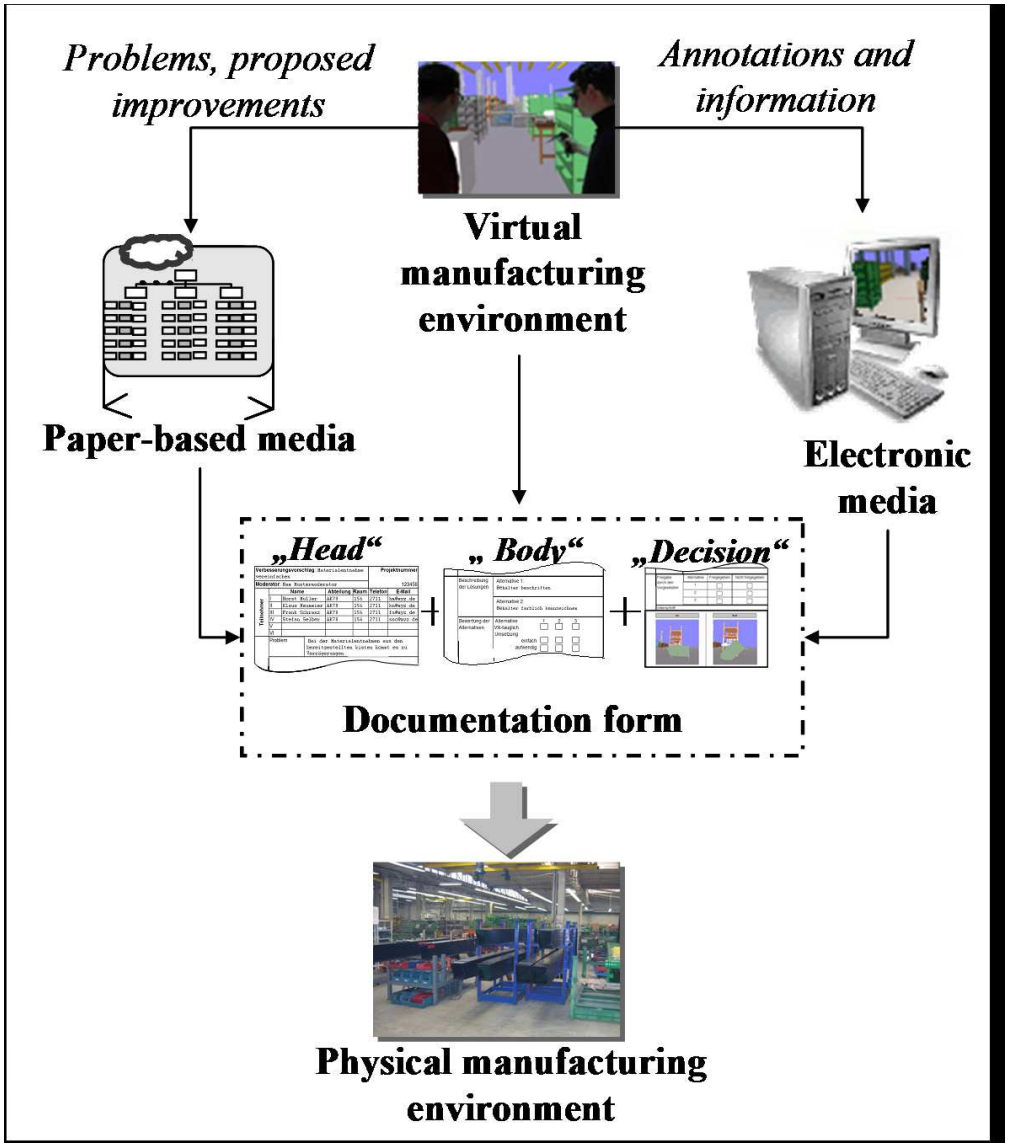


Virtualization
130x82mm (220 x 220 DPI)

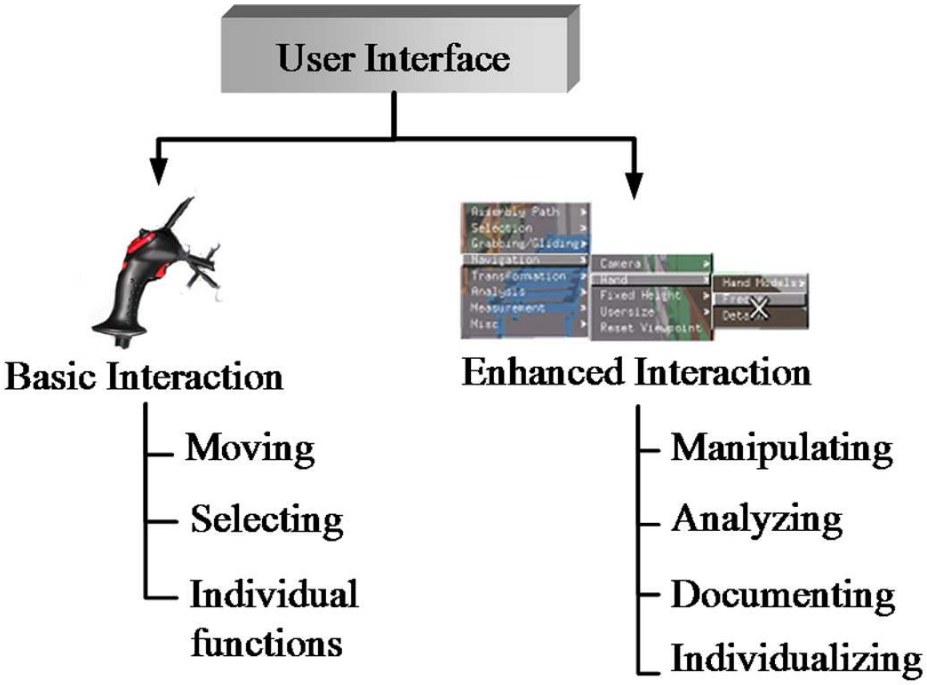
Review Only



Typical procedure of VR-supported CIP-workshops
130x140mm (220 x 220 DPI)



Documentation
201x228mm (150 x 150 DPI)

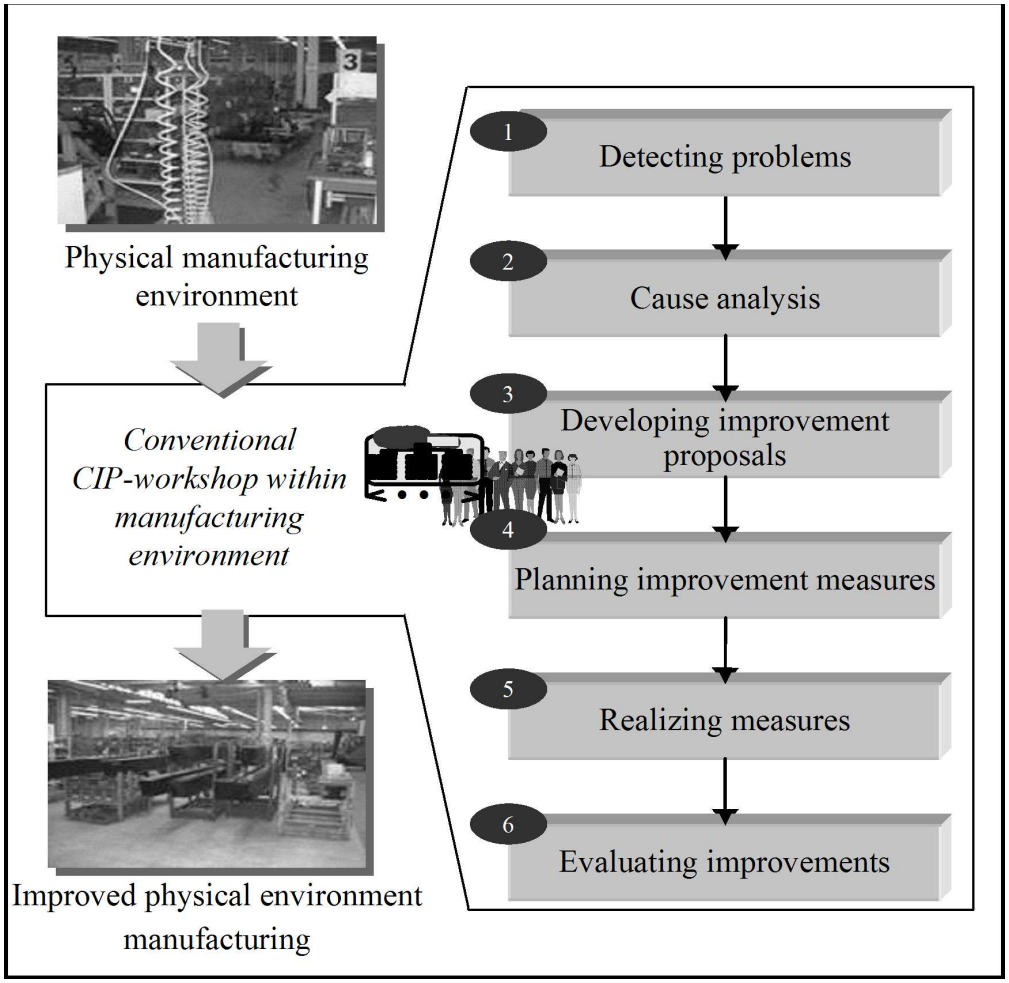


Interaction within a CIP-workshop
130x93mm (220 x 220 DPI)

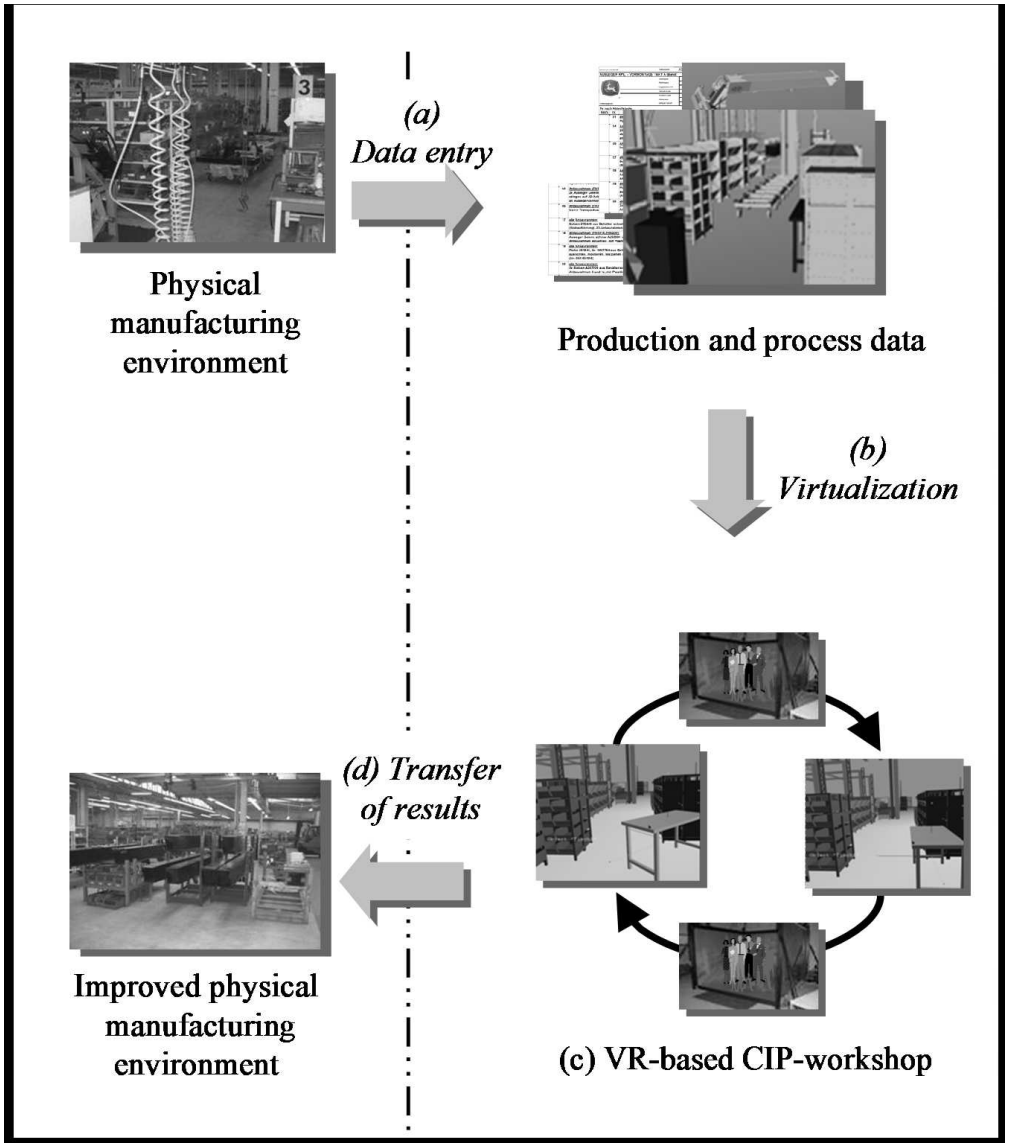
iew Only

Additional information accessible within a virtual environment during the workshop
130x94mm (220 x 220 DPI)

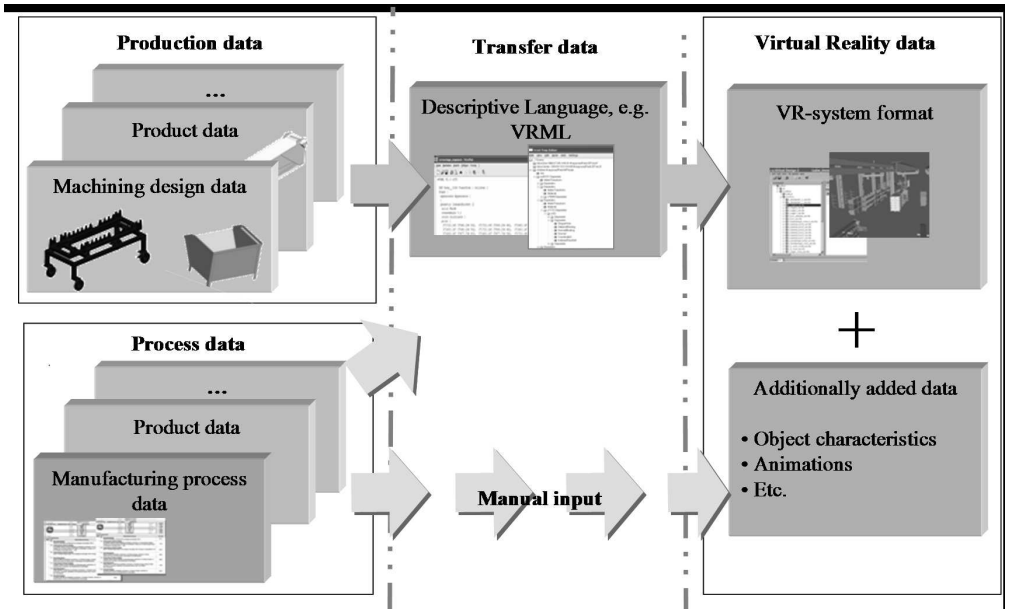
iew Only



Typical procedure of conventional CIP-workshops
294x286mm (150 x 150 DPI)

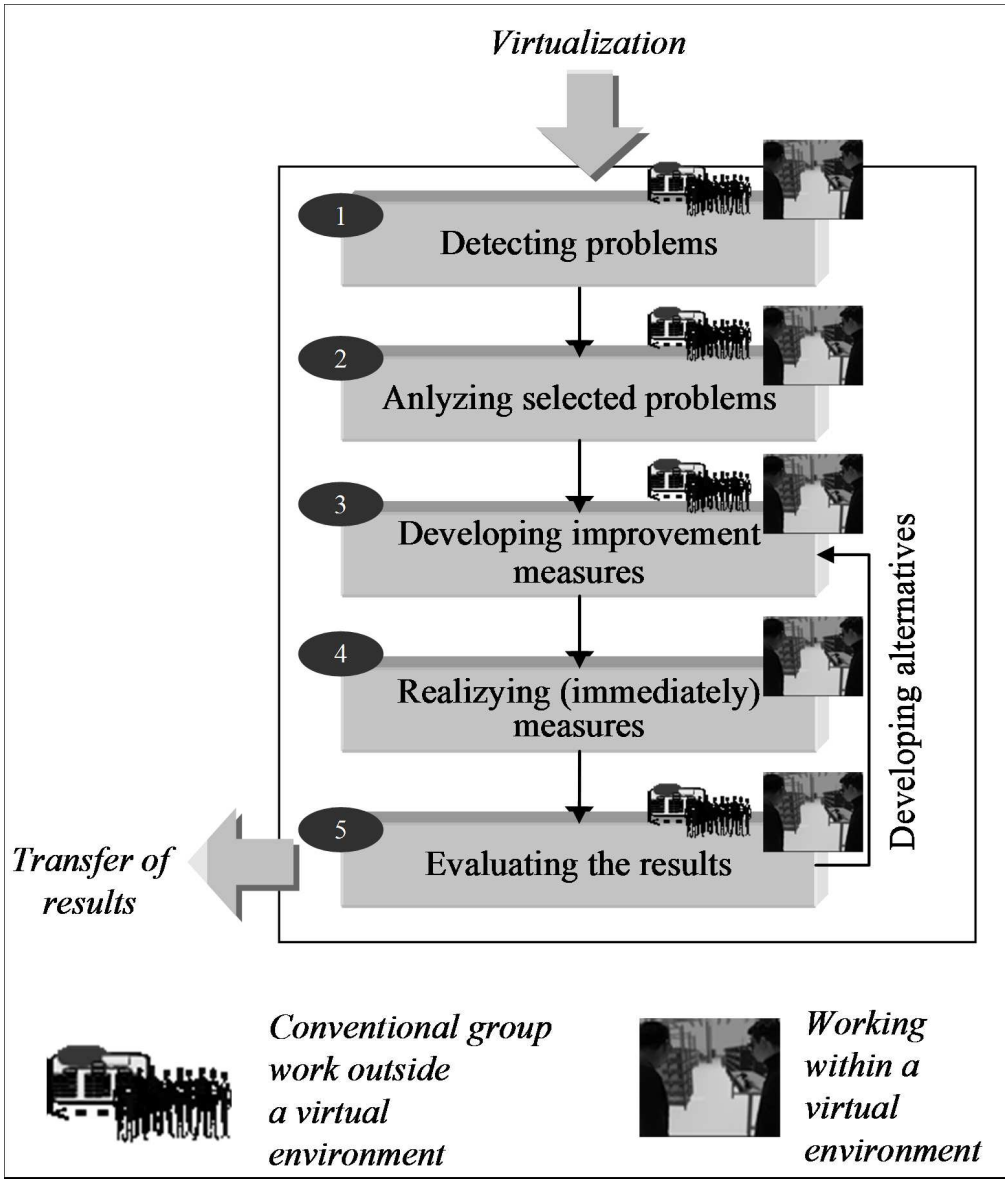


Basic concept
227x259mm (150 x 150 DPI)

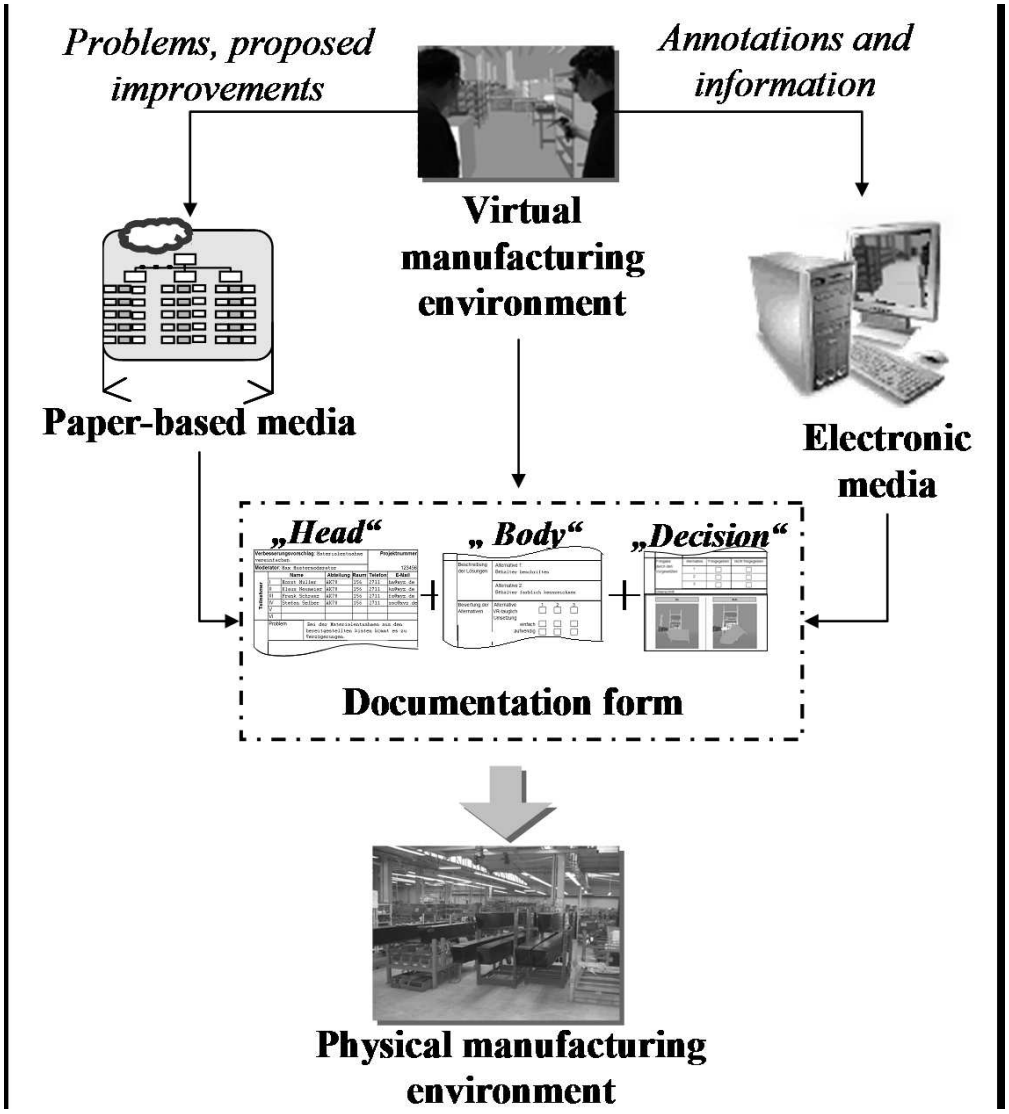


Virtualization
290x175mm (150 x 150 DPI)

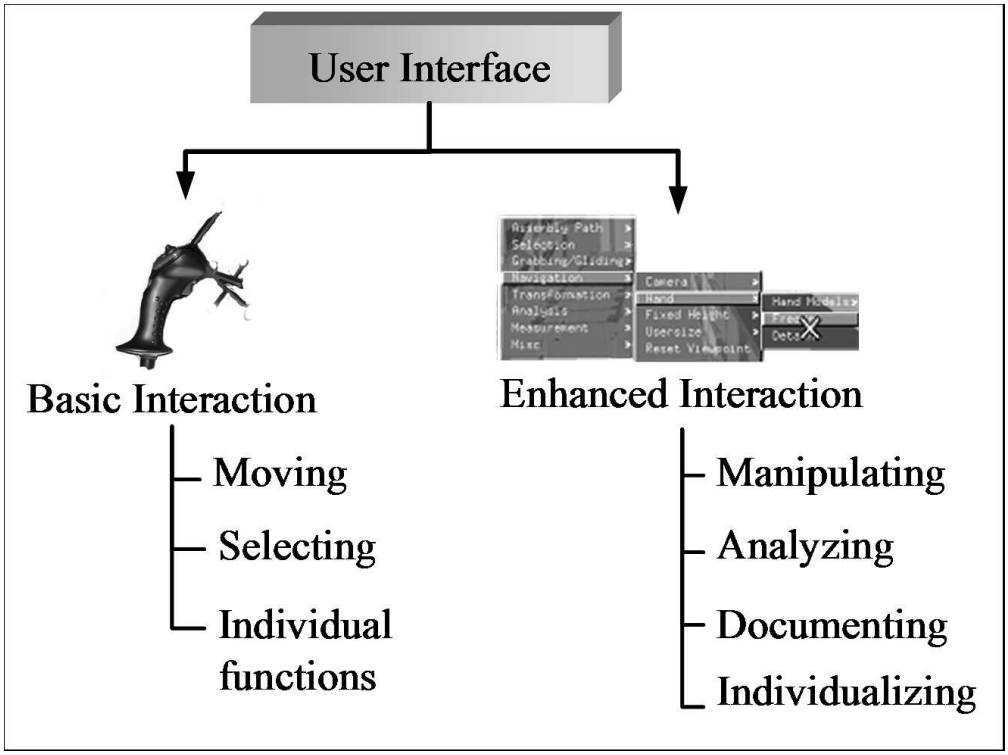
Review Only



Typical procedure of VR-supported CIP-workshops
261x307mm (150 x 150 DPI)



Documentation
192x213mm (150 x 150 DPI)



Interaction within a CIP-workshop
223x166mm (150 x 150 DPI)

For Review Only

Additional information accessible within a virtual environment during the workshop
238x173mm (96 x 96 DPI)

iew Only