Virtual Reality and Augmented Reality in Assembly Applications
VDC Whitepaper

Prof. Dr.-Ing. Dipl.-Kfm. Christoph Runde
Virtual Dimension Center (VDC) Fellbach
Auberlenstr. 13
70736 Fellbach
www.vdc-fellbach.de
Content

- challenges & opportunities in assembly
- assembly line planning
- product evaluation
- assembly workplace ergonomics
- assembly process evaluation
- assembly process support
- summary

Fig.: Daimler car assembly line at Daimler
Assembly overview

- in industrial production, assembly is the entirety of all processes for the assembly of bodies with a geometrically determined shape (lengths, angles).
- in addition to work preparation and parts production, assembly forms part of the production system of an industrial company.
- the essential partial operations of an assembly process are:
  - connecting (screwing, nailing, welding, gluing, soldering, clipping)
  - handling (grab, place, turn over, move, secure, control)
  - check
  - adjust (e.g. settings)
  - auxiliary operations (e.g. cleaning, heating or cooling for press connections, deburring, unpacking, sealing, oiling, ...)
Assembly Challenges

- permanent market changes
- need for transformation ability of assembly systems
- growing and falling lot numbers
- competition leads to need for high assembly efficiency
- new products and shorter product life cycles
- mass customization, individualized products with high variance
- increasing work safety regulations
- increasing age of work force

Assembly Opportunities

- digital design as provider for 3D planning and simulation data
- hardware and software for 3D simulation, 3D visualization and virtual reality:
  - new and cost-effective solutions available
  - increasing performance
  - increasing acceptance
Assembly Planning Functional Requirements

- collision checks
- assembly tree for sequence planning
- product variations for sequence planning
- spatial assembly paths
- expand and melt parts for clearance checks
- represent assembly tools
- represent flexible parts (cables, seals, hoses, ...)
- represent assembly aids within product design
- 3D model intersections
- forward and backward kinematics
- space requirements for workers, manufacturing resources, goods, stocks, conveyors, factory building and infrastructure

- representation of arms and hands
- visualization and documentation of reaching distances
- visualization and documentation of area of visibility
- link to MTM tables, to not-traceable human operations, e.g. picking screws
- ergonomic analysis
- efficiency assessment
- speech recognition to control mobile AR solutions and to add new content to them during assembly process
Assembly Line Planning

Use of Virtual Reality (VR)

- combined layout of
  - conveyors,
  - robots and
  - other delivery systems
- robot programming, ensuring
  - collision free synchronization of robots
  - synchronization of robots with conveying systems
  - process efficiency
- line production versus dock production
- choice of conveying / transportation systems
- space requirements of work places, scaffolds
- interactive VR exploration of virtual assembly line mock-up
Assembly Line Planning

Use of Augmented Reality (AR):

- graphical overlay of new, digital 3D content (assembly systems) onto existing / brown field factory structure
- graphical overlay of new, digital 3D products onto existing / brown field factory structure
- visual check for
  - collisions
  - spaces for transportation systems such as forklifts
- avoiding LASER scan of factory structure
- photo documentation

Fig.: Volkswagen
brown field planning of robots (coloured) using augmented reality

Bild: TU München
brown field planning of new conveying system (coloured) using augmented reality

Fig.: Volkswagen
collision check of new (digital) car body within existing conveying line
Product Evaluation

- virtual check of design-for-assembly (DFA)
- subjective evaluation of buildability due to interactive exploration by experienced product assembly expert
- accessibility studies
  - by vision
  - by hands
  - with tools
- two-hand exploration is feasible
- use of projection based VR, however could lead to visual conflict with own physical hands
- user of head mounted display (HMD) based VR and controllers or VR gloves
Work Place Ergonomics

- processing of assembly tasks within a virtual environment
- figuring out ergonomic process properties
- approaches:
  - interaction with virtual environment through a virtual avatar. This avatar is controlled
    - either by a motion capturing (MoCap) system or by
    - programmed animation
    The avatar may deliver objective and documented ergonomic analysis data.
  - direct interaction with virtual objects, also through a MoCap system, however the obtained results are depending on the user (subjective)
Work Place Ergonomics

Use of Augmented Reality:

- graphical overlay of different work space zones, e.g.
  - red area: contains all elements within a grasping distance, thus with no need to bend forward
  - other area: out of direct grasping distance, thus walk and/or bend forward

- the AR user may walk around the work stations and inspect all cask and tools, if necessary correct their positions

- photo documentation
Assembly Process Evaluation

Use of assembly tools:
- relevant aspect of assembly analysis
- examples:
  - power screwdrivers
  - lifting appliances
- check for accessibility
- check for ergonomics using tools
- co-working
Assembly Process Evaluation

Assembly path identification:
- identification of optimum assembly paths by interactive assembly studies in VR: recording part movement
- identification of impossible paths
- simple VR system: collision detection and 3D controllers (e.g. flystick, gesture recognition)
- technical approaches:
  o direct interaction with virtual environment
  o programming a virtual avatar
- check of assembly process considering flexible parts (push aside, stretch away from interfering region)
Assembly Process Evaluation

Assembly path identification:
- in addition to visual and/or acoustic collision response, haptic force feedback may be used
- intuitive 6DOF directing of physical handle will control virtual object position and orientation
- haptic system blocks in case of collision
- two force feedback systems may be joined to achieve 6DOF (force and torque) feedback
- assembly path generation
- 3D prints of additive manufacturing may be attached to the handle to simulate realistic grasping (grasp type and grasp point) by human hand
Assembly Process Evaluation

Assembly sequencing:
- evaluating correct assembly sequencing by variant comparison
- in principle all aspect mentioned in this presentation (line planning, product evaluation, ergonomics) can be checked within this step

Virtual prototyping of assembly process:
- for process optimization
- for product optimization (e.g. assembly support features)
- standard times determination with MTM (methods time measurement)
Process Support in Assembly

- assembly assistance systems using augmented reality
- showing next process step during assembly itself
- indicating tools and parameters (e.g. torques)
- applicable technologies:
  - AR projection
  - AR smart glasses
  - AR tablet PCs and AR smartphones

Assembly positions and instruction are projected as AR onto aircraft body

Perspective through AR smart glasses, showing assembly instructions, part positions, tools and tool parameters

Disassembly instruction as an AR overlay shown on a tablet PC
Process Support in Assembly

- assembly assistance systems: remote assistance with shared camera view
Process Support in Assembly

- Quality assurance in assembly using augmented reality
- comparison of planned versus as-built status
- visual check of deviations
- check of installation space and positions
- photo documentation
- technologies tested in practice:
  - AR tablet PCs and AR smartphones
  - offline AR systems (screen and camera detached)

Fig.: Metaio
Comparison of planned versus as-built status of weld studs at car assembly using AR

Fig.: Daimler
Check of installation space and part positions after assembly using AR

Fig.: Testia / Airbus
Quality check of assembled parts using AR comparison on a tablet PC
Process Support in Assembly

- Quality assurance in assembly

Quality check of assembled parts: Augmented Reality overlay shows assembled clip as-planned and its status in reality. The user visually compares both and either confirms or rejects the quality.
Summary

- diverse field, many assembly applications for VR and AR
- many specific VR / AR tools, thus no single solution for all
- digital 3D design data is a necessity

Main benefits of VR / AR use

- virtual prototyping of assembly process, optimizing and supporting
  - assembly lines,
  - products (DFA),
  - workplace ergonomics and
  - assembly process
  already in a early, digital planning stage
- human-integrated manufacturing engineering, considering
  - human factors
  - subjective assessments and tacit knowledge
Requirements on VR / AR products for assembly applications

- CAD import
- CAE import
- collision detection
- physics and sliding simulation
- forward / backward kinematics
- tolerance analysis
- flexible components (cables, hoses, seals)
- demonstrate (design-based) assembly aids
- adding and melting of material for clearance tests
- priority graph for assembly order planning
- present assembly sequence variations
- identification of assembly paths
- cuts through the 3D model
- illustration of assembly tools
- illustrate and document manual reach distances
- illustrate and document visible areas
- illustration of arms / arm movements
- anthropometric human model with ergonomic analysis
- consider space requirements for operating equipment, products, people, materials handling technology, building technology
- links to MTM tables, for example to detailed manual work which is hard of impossible to track (e.g. separation of screws)
- evaluation not only of working hours, but also of ergonomics, distances
- AR engine for process support
- speech recognition to easily supplement documentation with spoken annotations
- content authoring for training applications
Literature

- ESI: VR im Mittelpunkt der Produktionstechnik; online unter: k https://www.virtual-reality-magazin.de/vr-im-mittelpunkt-der-produktionstechnik; abgerufen am 13.5.2018
VDC members in VR / AR assembly applications
Thank you very much for your attention

If you are interested in further details of this topic, please refer to

Virtual Dimension Center (VDC) Fellbach
Auberlenstr. 13
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www.vdc-fellbach.de
info@vdc-fellbach.de