AI for operator support

Challenges and Approaches

Wietse van Dijk | Michael van Bekkum

Battery

PFB Board A0

Draad & drukknop
Wire & push button

Accu draad 220 mm
Battery wire 220 mm

Accu draad 280 mm
Battery wire 280 mm

Rubber dopje
Rubber cap

LED

Bout M4 x 60
Bolt M4 x 60

Metalen strip lang
Metal strip long

Metalen strip kort
Metal strip short

Moer M4
Nut M4

Veerring M4
Spring washer M4

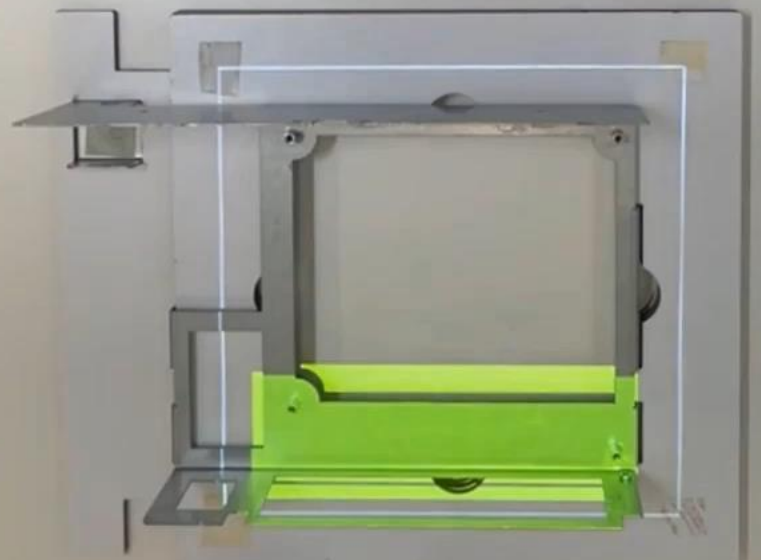
Schroef 3.5 x 16
Screw 3.5 x 16

Schroef 3.5 x 8
Screw 3.5 x 8

Tang

Plaat afdekplaat in frame

Controleer orientatie en montagerichting afdekplaat

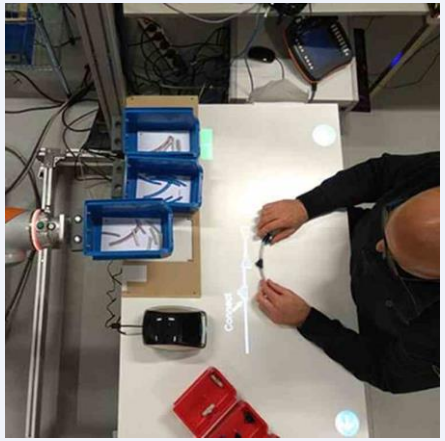


ARKITE TNO

TNO innovation for life

Operator support systems & digital work instructions

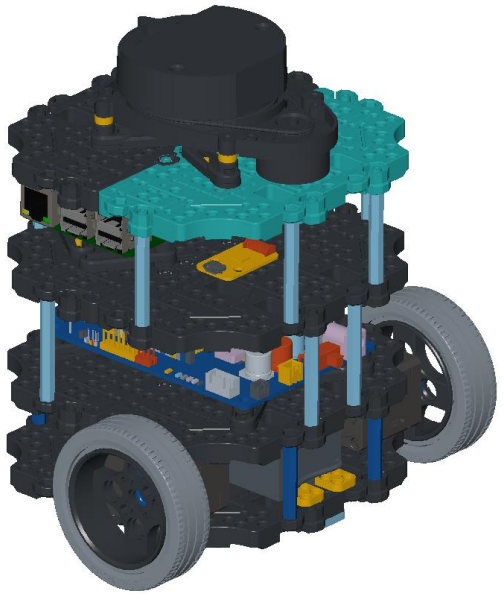
- Operator support systems provide the workers with information to improve their work



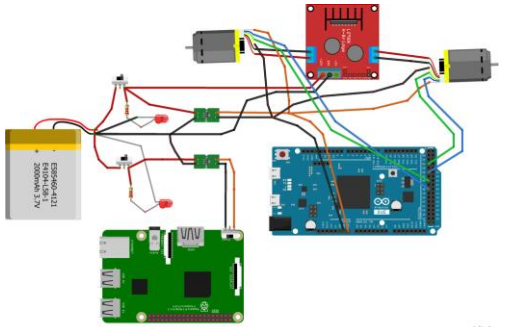
- Example: digital step-by-step instruction have proven to:
  - Reduce learning times
  - Prevent errors
  - Upskill workers

- The generation of work instructions is labour intensive and requires specialized personnel
- SME's with limited number of products. Low volume-high mix
- Adoption of digital work instructions is low

Components



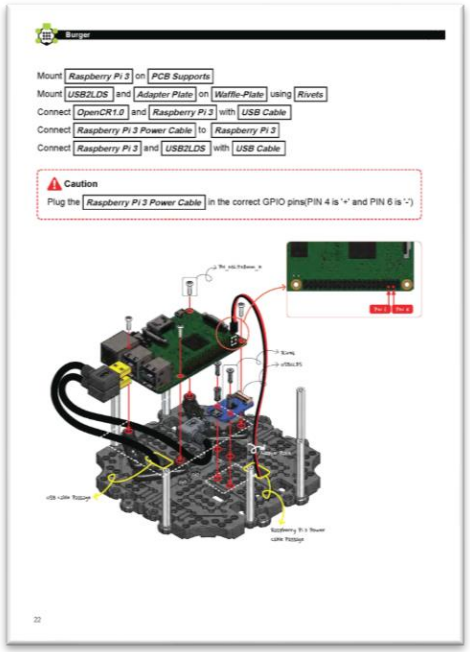
CAD model



Connection diagram

+

Human knowledge



Building instructions

Instructions and AI

Instruction challenge	Role of AI	AI challenge
Combining all data sources	Automated analysis of structured and unstructured data	Know your data: meaning of data sources and relating them
Adapt to changing circumstances	Incorporate real-time data and feedback from shopfloor	Interact with a human in case of missing data or ambiguities
Frequent changeovers and adjustments from small batches	Adapt, incorporate changes in reinforcement loop	Knowledge retention: capture and generalize knowledge from previous batches
Tailored instructions	Incorporate equipment availability, worker skills, resource constraints	Human-understandable instructions and adaptive operator support

Generate instructions

Top-down approach

- Use CAD models to create an assembly sequence
- Geometric features and relations between individual parts are used to determine the assembly sequence order

+ Highly automated

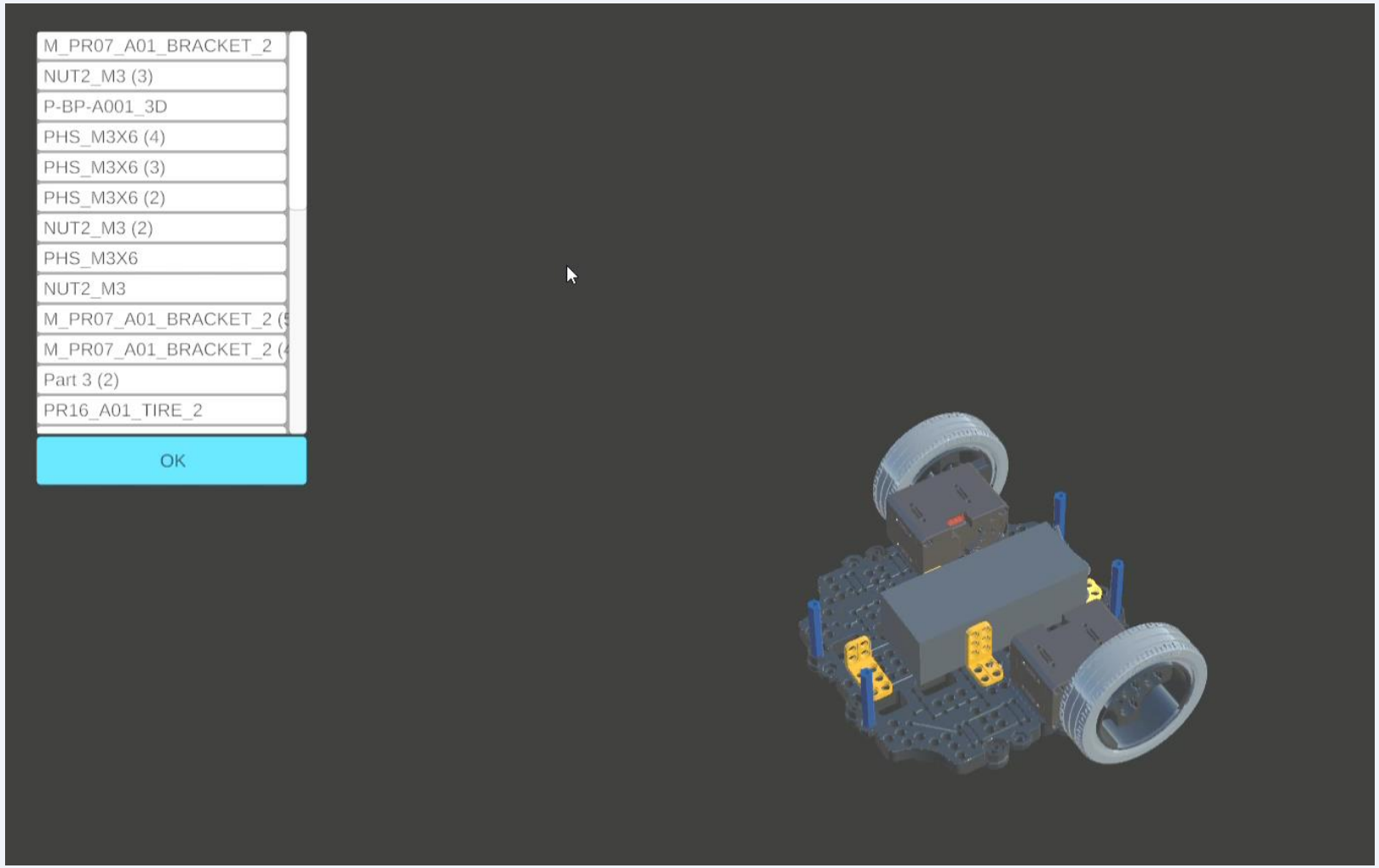
+ In advance of assembly

- Computationally intensive

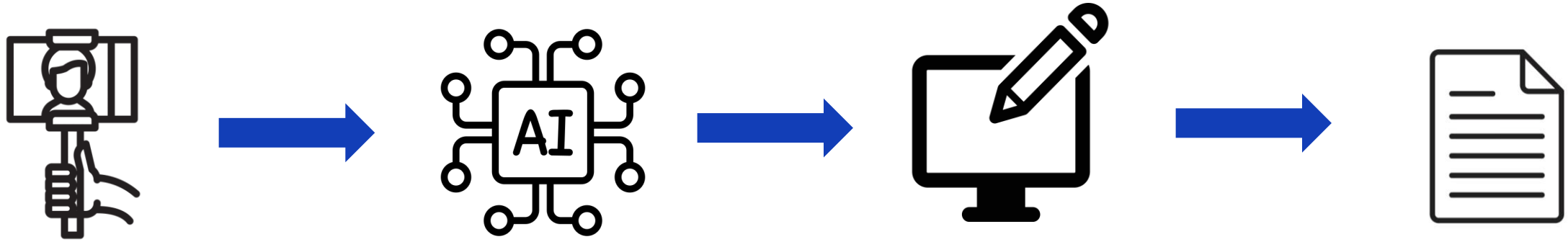
- Rework by process engineer required

Neb, A. (2019). Review on approaches to generate assembly sequences by extraction of assembly features from 3D models. Procedia CIRP, 81, 856-861.
Gors, D. et al (2021). Semi-automatic extraction of digital work instructions from CAD models. Procedia CIRP, 97, 39-44.
Grappiolo, C. et al (2021). ViTroVo: in vitro assembly search for in vivo adaptive operator guidance. The International Journal of Advanced Manufacturing Technology, 117(11), 3873-3893.

Example


M_PR07_A01_BRACKET_2
NUT2_M3 (3)
P-BP-A001_3D
PHS_M3X6 (4)
PHS_M3X6 (3)
PHS_M3X6 (2)
NUT2_M3 (2)
PHS_M3X6
NUT2_M3
M_PR07_A01_BRACKET_2 (5
M_PR07_A01_BRACKET_2 (4
Part 3 (2)
PR16_A01_TIRE_2
OK

Bottom-up approach



- An experienced operator provides an example
- Record a video tutorial style
- Process the video with AI to extract instruction steps

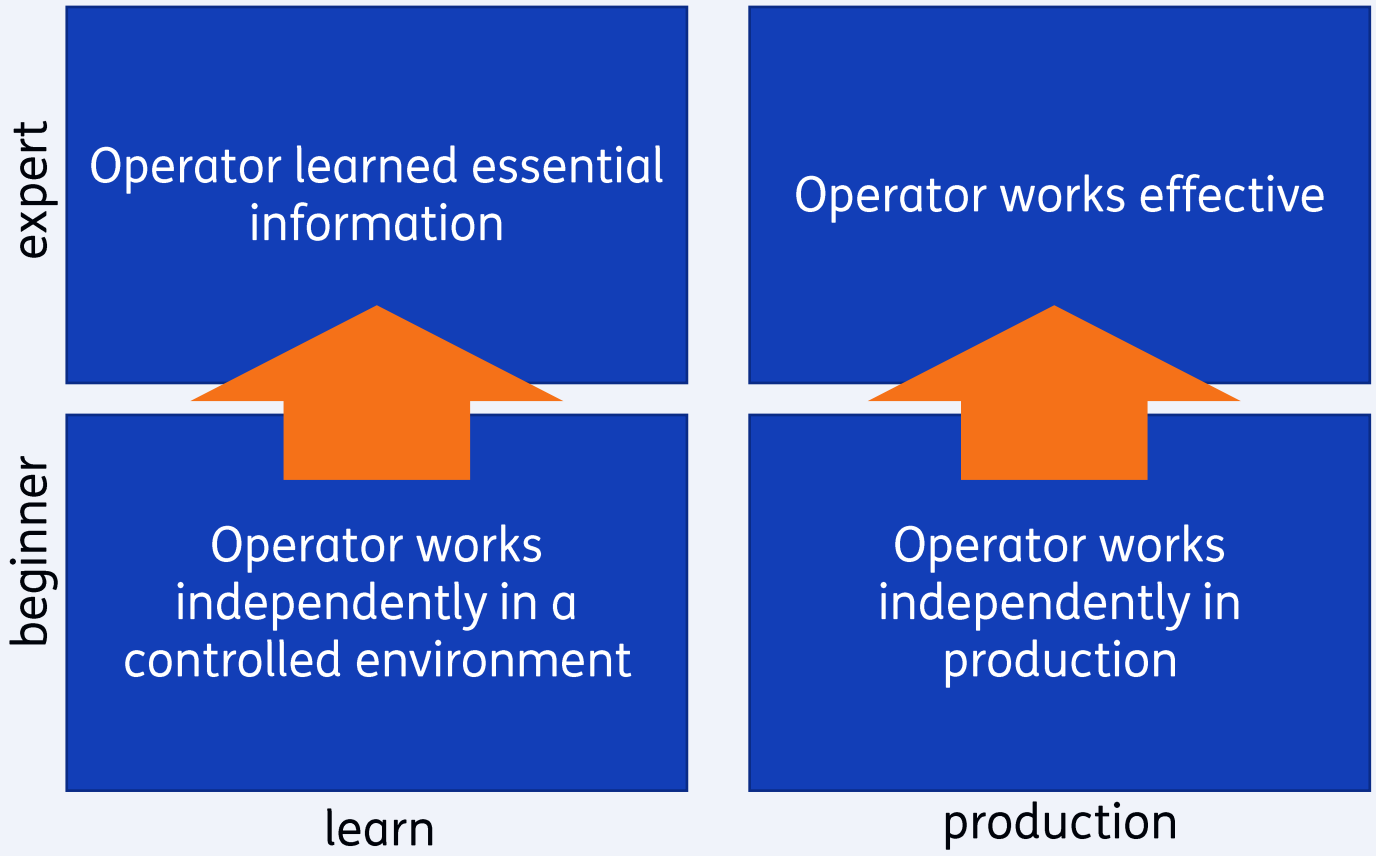
+ Work-as-done

+ Use of existing skills

- Product changes and version management

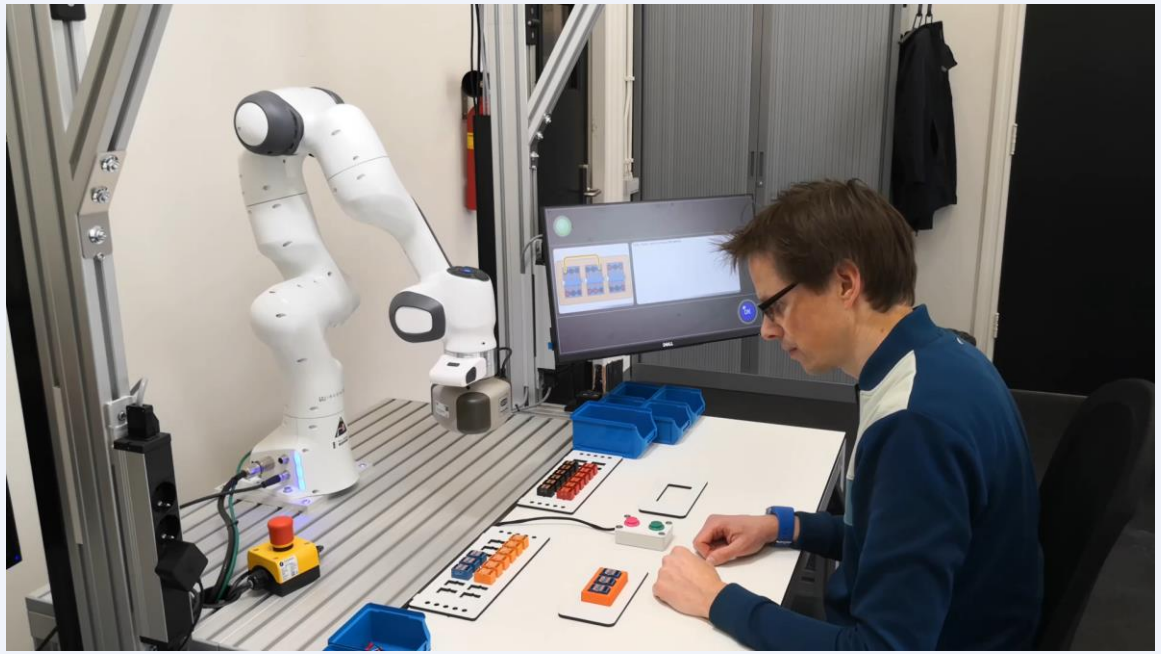
Tailored instructions

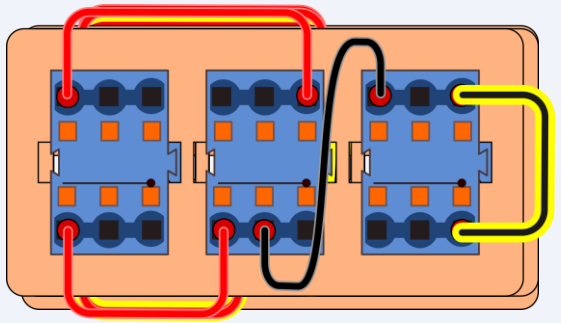
Adaptive operator support

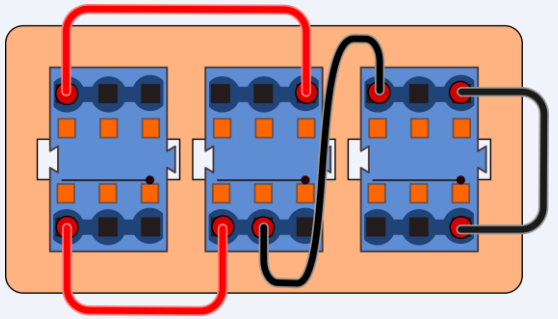


- Processing the instructions takes up a relative large part of the work, especially when instruction steps need manual confirmation
- Operator might become ignorant to essential (new) information

Instruction levels







Outlook

Takeaways

- Keeping the human in the loop is essential to ensure correct and easy-to-use instructions
  - AI needs to learn from human feedback
- Systems that generate instructions without use of an AI-expert is essential for bridging the gap between domain expert and AI
  - AI requires capture of tacit knowledge
- High-mix, low-volume production mandates generalization across product and processes (first time right)
  - AI needs to work with small data sets
- Tailored instructions are key to adoption by workers
  - AI requires operator models

- Combination of top down and bottom up approaches as a way forward