1

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Machine changeover
Stanley Black & Decker

2

The problem:
Machine changeovers must be supervised by certified experts

- Scarcity and low availability of skilled labor
- Globally dispersed operations
- Travel restrictions
  - Environmental concerns
  - Cost reduction programs
  - Pandemics, ash clouds etc.
  - Geopolitical conflicts

→Low OEE as machines wait for experts to travel or rush between setups

→Could be improved by using remote and online expert attendance

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State-of-the-art remote access solutions

Video conference
→ real-time and interactive but not immersive

Virtual reality
→ immersive and interactive but not real-time /real-life

Live streaming
→ real-time and immersive but not interactive

Research idea: Let's combine all of these and test it!

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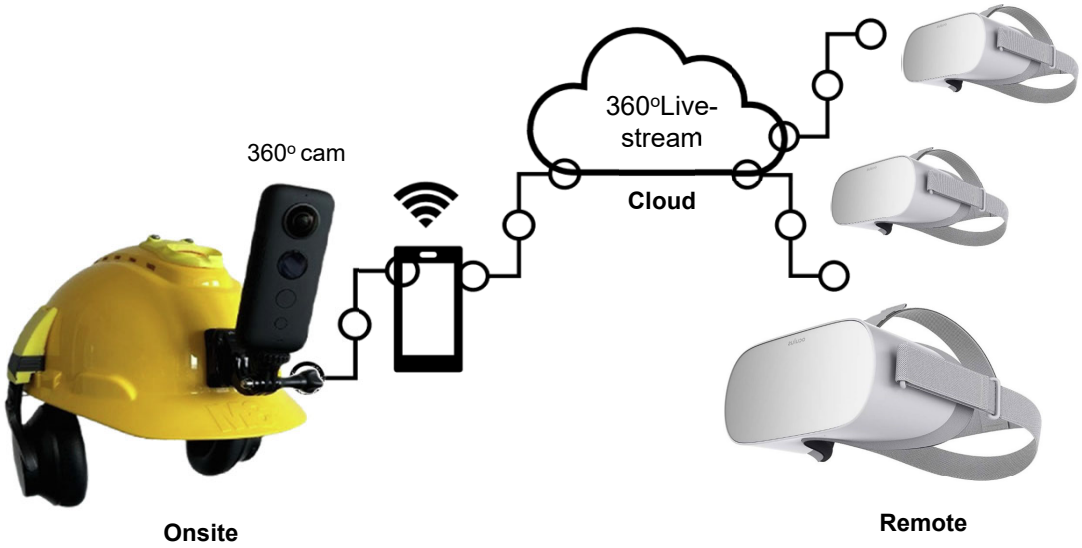
Breaking boundaries: Conceptualize and test interactive MR live-streaming technology in manufacturing



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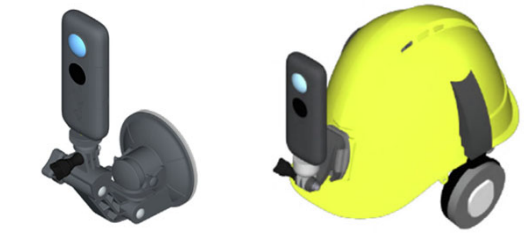
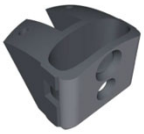
Design science project: Artifact development


Suction cup mounting

First-person view


Lower cam support


Upper cam support


Headphone support

CAD


Prototype in Makerlab

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6

Field test at Stanley Black & Decker Giessen (Germany) & remote 2021

StanleyBlack&Decker

- Identified California startup *Avatour* as (only) available software solution in 2021
- Field test:
  - 3-hour machine changeover
  - 2 researchers onsite in Germany
  - 1 researcher online in Switzerland
  - SB&D operator onsite
  - "Remote" participants from SB&D
- Feedback and evaluation
  - Feedback forms
  - Focus group evaluation

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Field test results

- Interactive real-time remote presence successfully field-tested at TRL 6
- Issues regarding cybersickness, bandwith, audio, and latency expected to be improved/solved
- Not quite ready in 2021 but on the way

"Very good to get an overview of the real production environment. Big improvement compared to usual camera streaming."

SB&D Smart Factory Engineer

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Read more

Manufacturing Letters 38 (2023) 6–10

ELSEVIER

Manufacturing Letters

journal homepage: www.elsevier.com/locate/mfglet

Letters

Interactive mixed reality live streaming technology in manufacturing

Torbjørn Netland *, Michael Stegmaier, Cesare Primultini, Omid Maghazei

Department of Management, Technology, and Economics, ETH Zurich, Weinbergstrasse 56/58, Zurich, Switzerland

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9

Related big questions for the APMS community

1. What can metaverse technologies bring to the physical world of manufacturing?
   - Training?
   - Audit?
   - Management?
   - Production control?
2. Can these technologies help us get closer to the fully remotely controlled factory?
   - Next-level Integrated Operations in the process industry?
3. How will such technologies affect manufacturing jobs and work life?
   - Productivity?
   - New forms of organization?
   - Organzational culture?
   - Psychological safety and well-being?

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Related research at APMS 2023

- *Metaverse-based Softbot Tutors for Inclusive Industrial Workplaces: Supporting Impaired Operators 5.0.* **Lara Popov Zambiasi, Ricardo José Rabelo, Saulo Popov Zambiasi,** & **David Romero**, Monday 15.20
- *Application of Digital Tools, Data Analytics and Machine Learning in Internal Audit.* **Jelena Popara, Milena Savkovic, Ciric Lalic Danijela,** & **Bojan Lalic,** Monday 16.00

AR

- *Human-centric Industrial Augmented Reality: Requirements and Design Guidelines for Usability* **Tiberiu Florescu, Sabine Waschull,** & **Christos Emmanouilidi**s, Monday 11.00
- *Challenges in Designing and Implementing Augmented Reality-based Decision Support Systems for Intralogistics: A Multiple Case Study.* **Moritz Quandt, Hendrik Stern, Markus Kreutz,** & **Michael Freitag**, Tuesday 17.20

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2

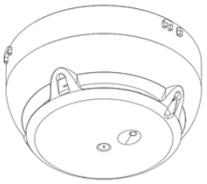
Quality inspection
Siemens

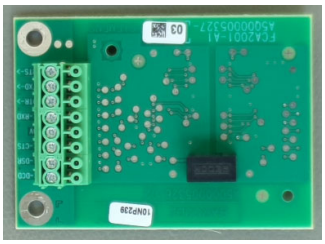
12

The problem: Zero defect manufacturing / Improve manual quality inspections

SIEMENS

Photo: Siemens





Source: Senoner, Kratzwald, Feuerriegel, Netland· Explainable AI improves worker performance, *Working paper*

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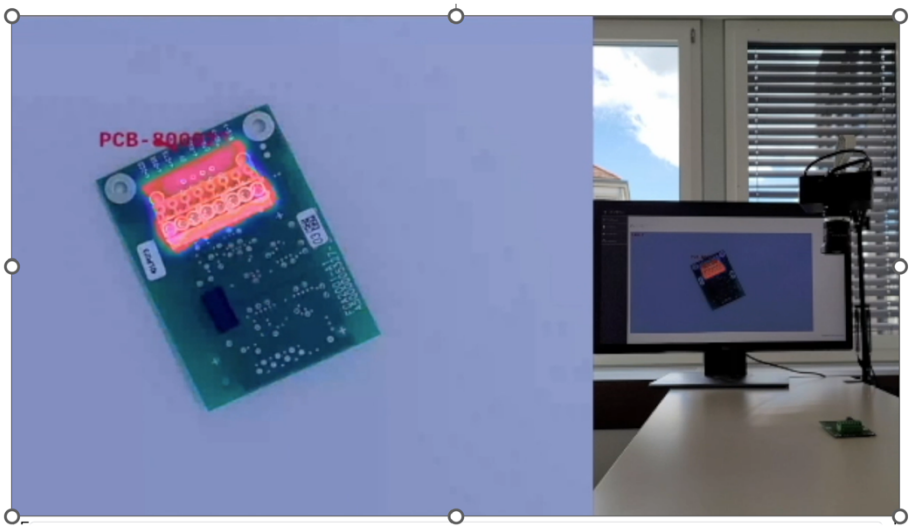
Breaking boundaries: Explainable AI*-powered visual inspection



* Explainable artificial intelligence (XAI) is a set of processes and methods that allows human users to comprehend and trust the results and output created by machine learning algorithms (Source: IBM)

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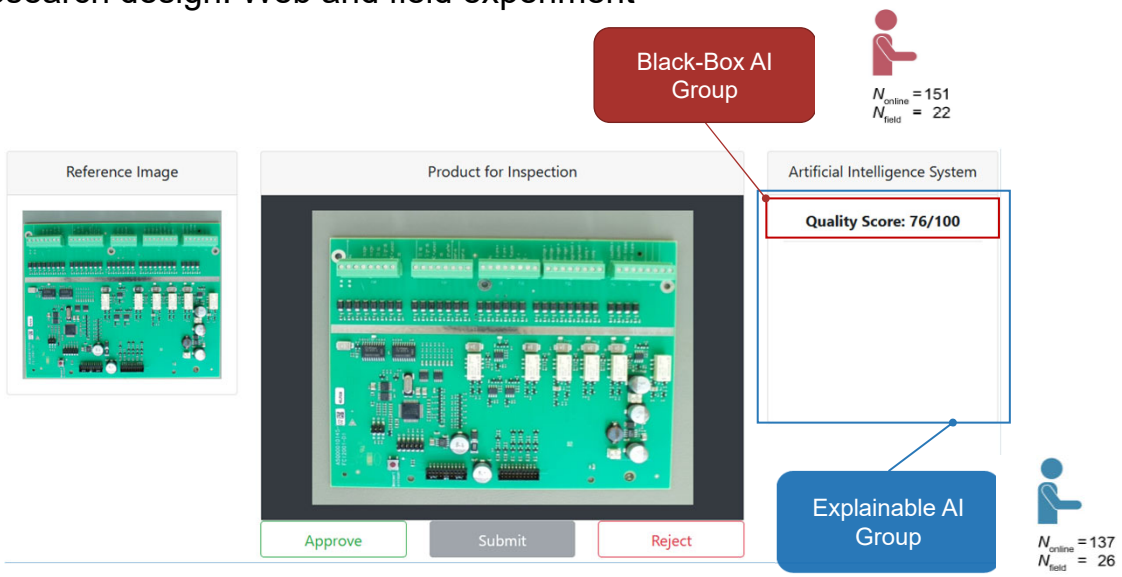
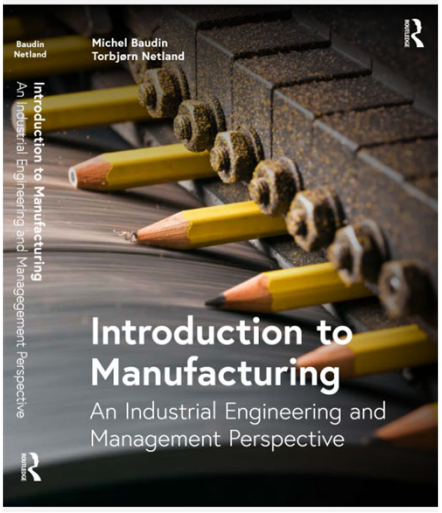
Research design: Web and field experiment



Source: Senoner, Kratzwald, Feuerriegel, Netland Explainable AI improves worker performance, *Working paper*

Read more (while waiting for the research paper)



Chapter 17 Improving Quality
17.2 Data Science for Quality Improvement

Page 715

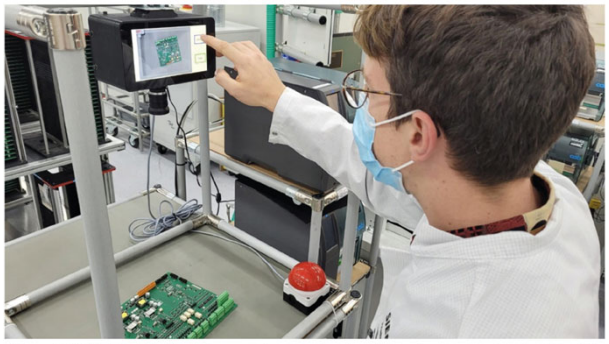


Figure 17.12 Explainable AI used in a quality control task with visual inspection (Credit: EthonAI)

Related big questions for the APMS community

1. How can AI augment humans at work?
   - What is the need for explainability and interpretability in manufacturing?
   - What about other technologies?
2. What is the effect of human augmentation?
   - Operational performance?
   - Worker satisfaction and well-being?
3. Can new technologies help attract needed talent or bridge the skill gap?
   - Is it dumbing down work or making it more enjoyable?
   - What's the role of technology in attracting GenZ or GenTikTok to manufacturing?

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Related research at APMS 2023

Lots of related and relevant papers! Here's a brief selection:

- *The Role of Human Factors in Zero Defect Manufacturing: A Study of Training and Workplace Culture* **Foivos Psarommatis, Gökan May,** & **Victor Azamfirei**. Monday 10.20
- *A Reflective Framework for Understanding Workforce Evolutionary Pathways in Industry 5.0* **Alexandra Lagorio, Chiara Cimini,** & **David Romero**, Monday 10.20
- *Data Preparation for AIAssisted Video Analysis in Manual Assembly Task: A Step Towards Industry 5.0.* **Yongkuk Jeong, Magnus Wiktorrson, Donggyun Park, Jesper Gans,** & **Linda Svensson**, Monday 16.00
- *Evaluating Augmented Reality, Deep Learning and Paper-based Assistance Systems in Industrial Manual Assembly.* **Alexander Riedel, Johanna Gerlach, Maximilian Dietsch, Frank Engelmann, Nico Brehm,** & **Tobias Pfeifroth**, Monday 15.20
- ***APMS Talks:*** *Operator 5.0 and Human Factors in smart manufacturing and logistics*. **Chiara Cimini**, Monday 16.40
- Effects of Lean and Industry 4.0 Technologies on Job Satisfaction: A Case-based, Analysis. **Matteo Zanchi, Andrea Lorenzi, Matteo Prezioso, Daryl Powell,** & **Paolo Gaiardelli,** Tuesday 14.40

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3

Root cause analysis
Lindt & Sprüngli

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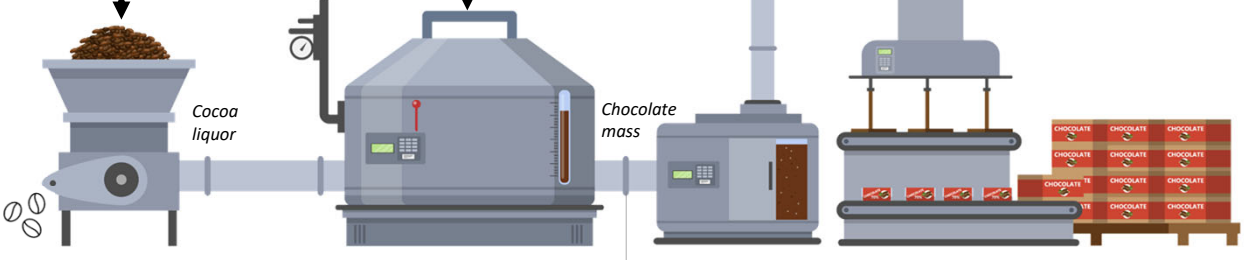
Chocolate production

Cacao beans:
1. Harvesting
2. Fermenting 6 days
3. Sundrying

Additional ingredients:
sugar, milk powder, cocoa butter…

Additional ingredients:
nuts, fillings etc.



Cleaning, Roasting, Winnowing, & Grinding

Mixing & Conching
T→50-75°C
4-8 hours

Tempering
T→28-33°C

Molding

Wrapping & Packaging

Couverture to bakeries and chocolateries

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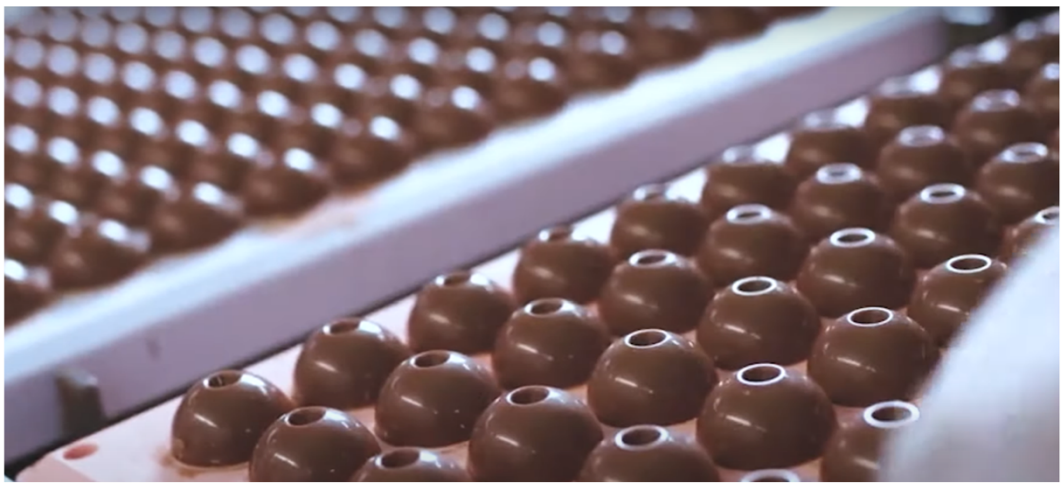
What's the **root cause** of yield loss?



1. Credit: Lindt & Sprüngli USA, M. Cavanaugh for Boston Globe, 2011, https://youtu.be/tTvQvNMDi-Q

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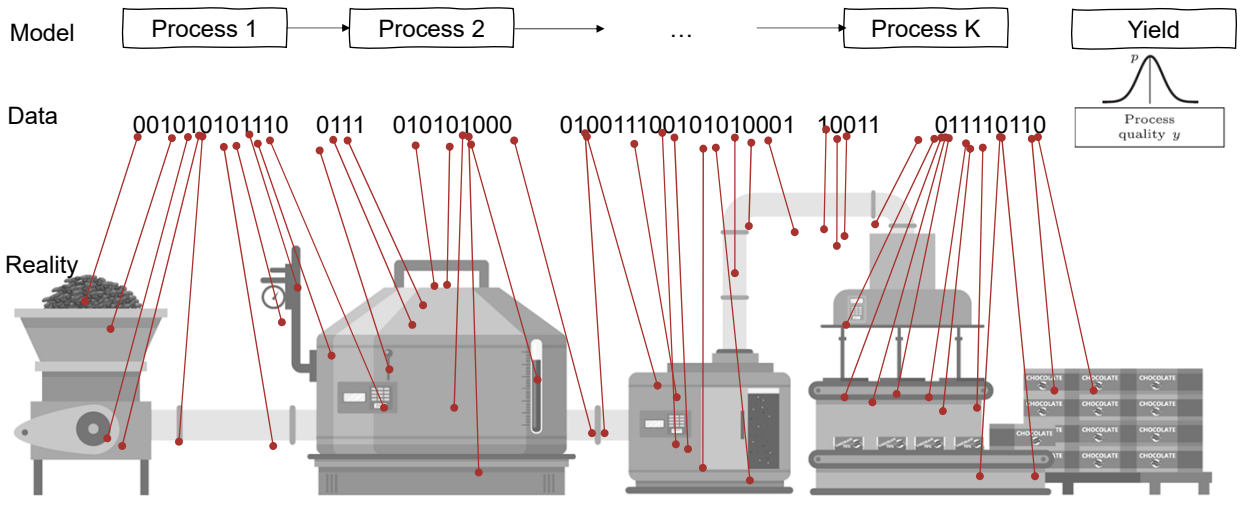
Breaking boundaries: Explainable AI for Root Cause Analysis



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Read more

informs
http://pubsonline.informs.org/journal/mnsc

MANAGEMENT SCIENCE
Articles in Advance, pp. 1–20
ISSN 0025-1909 (print), ISSN 1526-5501 (online)

Using Explainable Artificial Intelligence to Improve Process Quality: Evidence from Semiconductor Manufacturing*

Julian Senoner,[a] Torbjørn Netland,[a] Stefan Feuerriegel[a]

[a] Department of Management, Technology, and Economics, ETH Zurich, 8092 Zurich, Switzerland

*Note: This research was conducted in Hitachi ABB, but principles apply broadly. Transfer to Lindt & Sprüngli and others via spinout EthonAI, ethon.ai

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23

Related big questions for the APMS community

1. What's next for AI in manufacturing?
   - Use cases—from predictive maintenance to scheduling and beyond?
   - Role of Generative AI? Causal AI? …
2. What is the needed data coverage for a good model representation?
   - Digital twin or digital shadow?
3. What is the role of lean/process improvement in the age of AI?
4. How can we accelerate the adoption and use of AI tools?
   - How to deal with algorithm aversion/ behavioral issues in adoption?
   - Decision support and human-machine interface consideration?
   - Ethical and accountability considerations?

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Related work at APMS 2023

Also here, lots of related and relevant papers! A selection:

1. *Developing Data Models for Smart Environmental Performance Management in Production* Mélanie Despeisse, Qi Fang, Ebru Turanoglu Bekar, Nils Ólafur Egilsson, Karolina Kazmierczak, Lena Moestam, Helena Söderberg, **Dennis Andersson, Jenny Hörnlund** & **Björn Molin**, Monday 10.20
2. *Model Simplification: Addressing Digital Twin Challenges and Requirements in Manufacturing Adria Sánchez de Ocaña,* **Jessica Bruch** & **Ioanna Aslanidou**, Tuesday 14.40
3. *Data at the Heart of the Industry of the Future: New Information Issues from an Information and Communication Sciences Perspective.* **Nathalie Pinède** & **Bruno Vallespir**, Tuesday 17.40
4. *Critical Factors for Selecting and Integrating Digital Technologies to enable Smart Production: A Data Value Chain Perspective.* **Natalie Agerskans, Mohammad Ashjaei, Jessica Bruch,** & **Koteshwar Chirumalla**, Wednesday 09.40
5. *Production Scheduling using Production Feedback Data; An Illustrative Case Study.* **Mina Rahmani, Anita Romsdal, Øyvind A.M. Syversen, Fabio Sgarbossa,** & **Jan Ola Strandhagen**, Wednesday 12.40

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Call to action

Call to action

Research foci

1. Focus on a specific technology to solve a real problem in a specific context
   - Many good examples at APMS2023: Cobots, Additive Manufacturing, Blockchain…
2. Conversely, high-level research about “industry 4.0,” “digital transformation,” “cyber-physical production system,” or “smart manufacturing” tends to have low practical impact
   - A few good examples at APMS2023 here too :P
3. Process understanding and lean thinking remain key to all technology projects
   - Solving real problems, not pushing technologies for the sake of the technology

Research methods

1. Engage with practice
2. Experimental methods are the gold standard; why not use them?
3. Design science, case studies, and action research (e.g., via field tests) are good alternatives
4. Careful with cross-sectional surveys asking about the implementation of a range of technologies

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Enjoy the conference and wonderful Trondheim ☺

Photo: T. Netland

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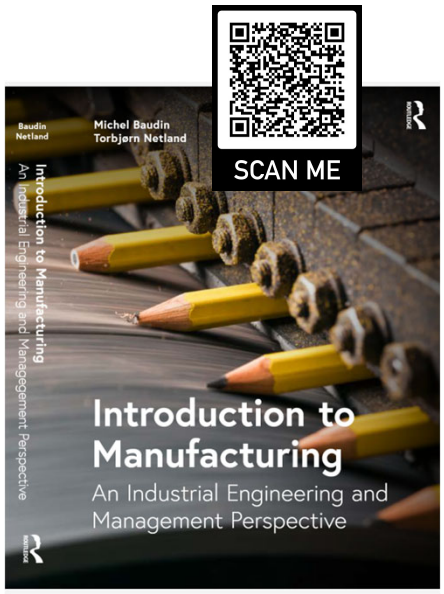

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Thank you!

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