



# Connecting the knowhow of design, production and construction professionals through Mixed Reality

**Dr. Rizal Sebastian**

Dr. Rosamaria Olivadese, Prof. Emanuele Piaia, Prof. Roberto Di Giulio, Dipl.-Ing. Jan-Derrick Braun, Dipl.-Ing. Günther Riexinger

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# 1. Problem statement

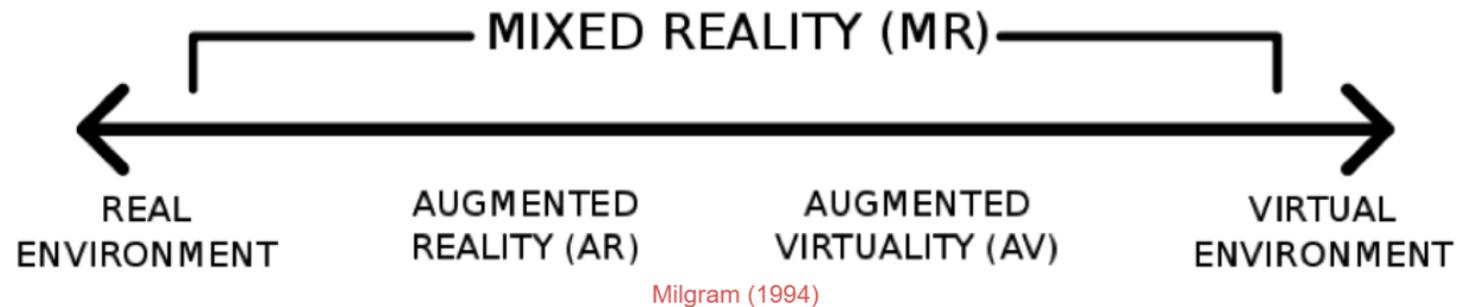
- **Buildings typically consume 2 to 5 times more energy than predicted at the design stage**  
(source: Chartered Institution of Building Services Engineers (CIBSE), 2012)
- This fact is hard to accept since:
  - Modern buildings are largely made of certified prefabricated components
  - Advanced technologies for minimizing energy consumption in buildings are applied
  - Energy performance simulation at design stage is a prerequisite for the building permit
- So, the research questions are:
  - Which factors cause or influence the performance gap?
  - How to resolve this gap?

## 2. Hypothesis

- Factors that cause or influence the performance gap between design, production and construction:
  - Non-compliance and large variations in the occupants' behaviours (*just blame the users!*)
    - ...but, the performance gap is already detected at project delivery, thus before occupancy
    - ...and there are new norms, methods and tools for calculating dynamic energy loads
    - ...so, this factor is excluded from the scope of this research paper
  - Climate change (*just blame the nature!*)
    - ...but, it is concerned with long-term effects
    - ...so, this factor is also excluded from the scope of this research paper
  - **Gap in knowhow between design and construction professionals** (*lay the blame on ourselves!*)
    - Construction workers do not implement the design properly and make ad hoc changes
    - Designers do not take full account of the production and construction implications
    - This is the focus of this research paper

## 2. Hypothesis

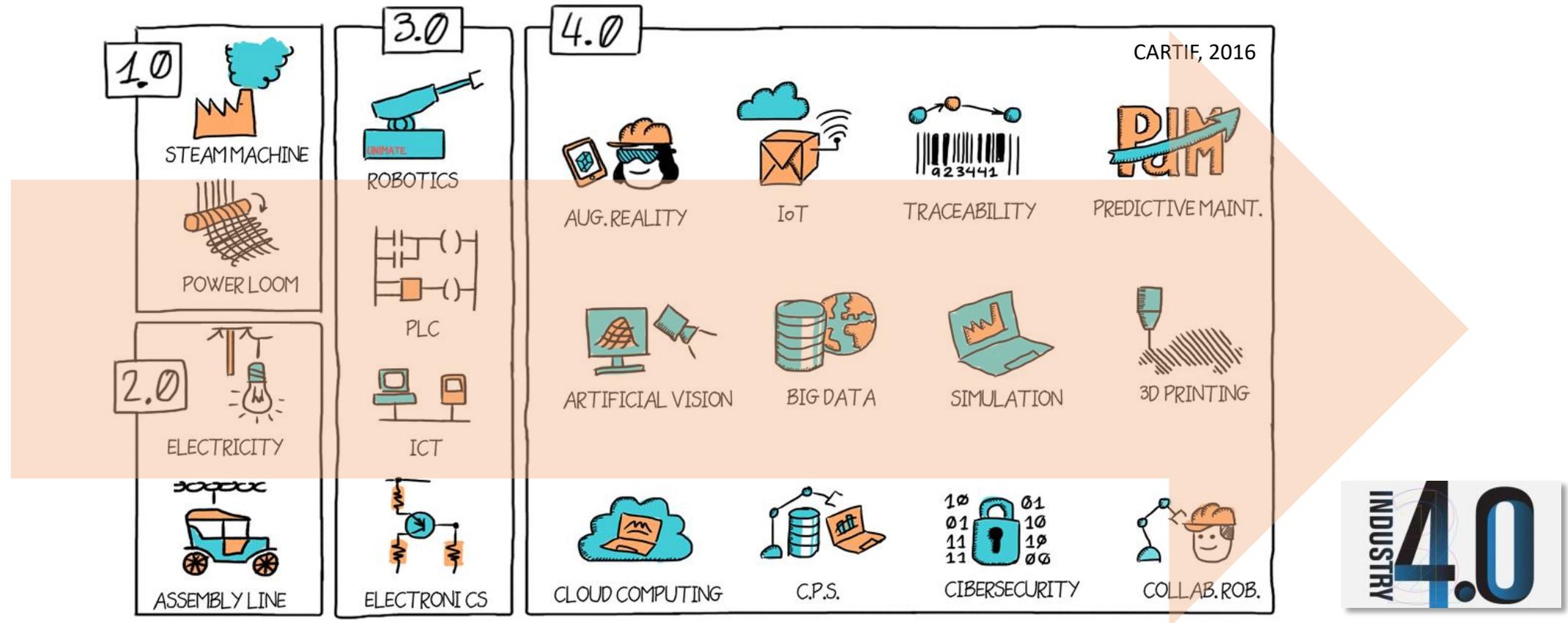
- Mixed Reality technologies can bridge the knowhow gap between design, production and construction
  - Mixed Reality continuum



- Augmented Reality based on Building Information Model (BIM-based AR)
  - Specific development for construction
  - Growing maturity and rapid adoption of BIM
  - Increased cost-effectiveness of BIM for AR in construction

# 3. Theoretical review

- **Industrial revolution** and its implication on the **evolution of knowhow gap** in construction



# 3. Theoretical review

- **Industrial revolution** and its implication on the **evolution of knowhow gap** in construction
  - Architects in pre-industrial era was fully involved and responsible for the whole building process, from design until on-site realization
  - Since the First Industrial Revolution in the 18th century, more and more specializations have been introduced while the gap between white and blue collar workers has grown larger
  - This trend continued in the Second Revolution in early 20th century where mass production entered the building sector
  - As part of the Third Revolution, computers began to contain design into a digital / virtual environment
  - Segmentation (specialisation, narrowed down) and fragmentation (isolated, breaking apart) of design, production and construction knowhow

# 4. Research methodology

- Mixed Reality technologies to bridge the knowhow gap between design and construction:
  - Digitalizing (BIM) followed by deploying 3D BIM in real environment (Augmented Reality)
  - Associating activities and time with 3D objects (4D BIM) and visualizing the processes in AR
  - Reviewing ‘clashes’ in AR and giving feedback to optimize the design
  - Training both designers as well as construction workers using AR in an iterative way

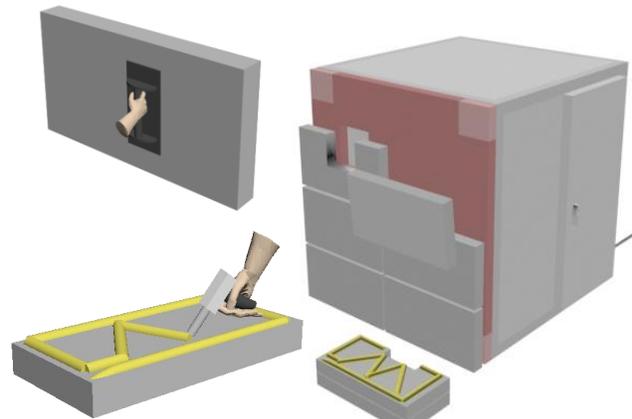
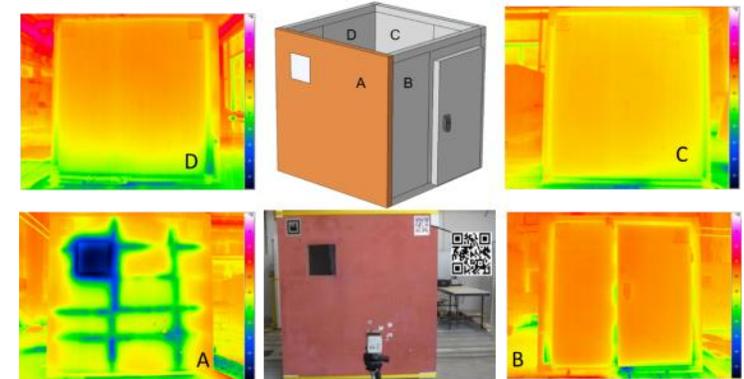
# 4. Research methodology

- Development of BIM-based AR in INSITER research project:
  - Transferring knowledge of AR in manufacturing to construction
  - Decomposing BIM (IFC) into sequential components for self-instruction for the workers
  - Displaying the work processes in AR animation
  - Integrating laser/thermal/acoustic scan data to BIM
  - Performing clash detection in BIM and generate 'clash cubes' deployable in AR
  - Discussing the 'clashes' on-site and give feedback to the design team for value re-engineering
  - Using AR for interactive training involving designers and construction workers



# 5. R&D achievement

- Prototype solutions subjected to lab testing



Simulation Steps **A** - **D** see Fig. 29



3D BIM Model - Cooling Room With Facade Panel and Insulation



4D BIM-based simulation of construction processes

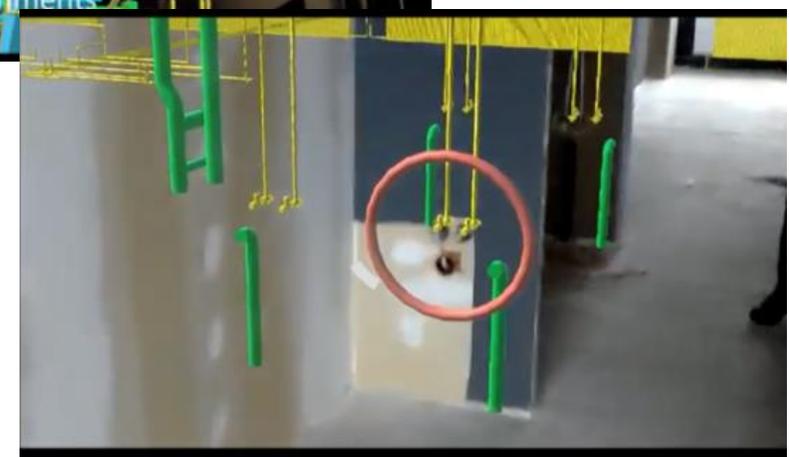
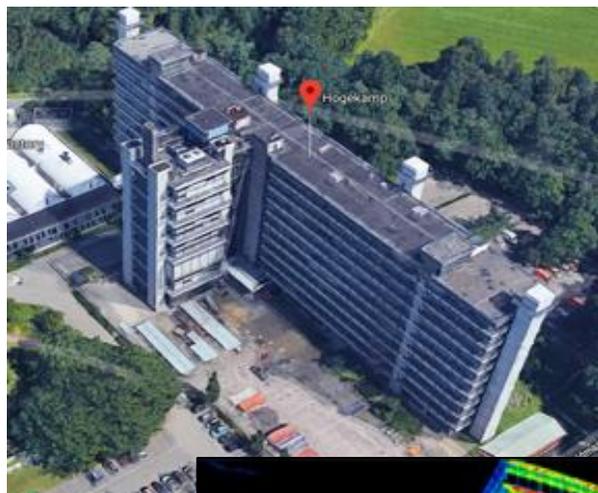


4D BIM-based simulation of processes visualized in AR

Scan images integrated in BIM and visualizes in AR

# 5. R&D achievement

- Prototype solutions subjected to real demonstration



# 6. Conclusion and discussion

- Conclusion: Innovative aspects of this research
  - Industry 4.0 technologies have the potential to bridge the knowhow gap between design, production and construction professionals, or between white collar and blue collar workers
  - Prototype applications for BIM-based Augmented Reality on Microsoft HoloLens and tablets have been developed in the INSITER project
  - 4D BIM, including 3D scanning and measurement data, can be deployed in AR for construction workers during on-site assembly
  - This tool can help to minimize the building's performance gap between design and construction

# 6. Conclusion and discussion

- Discussion: Scientific contribution of this research paper
  - Follow-up studies on knowledge management in “Construction 4.0”
    - Addressing Mixed Reality for resolving knowhow fragmentation and segmentation
    - Investigating the role of Machine Learning / Artificial Intelligence for performance assurance
  - Follow-up research on BIM-based AR
    - Taking a step forward with BIM as the ‘Digital Twins’:  
BIM-based AR brings the two worlds where these ‘twins’ live in closer to each other, for example by giving back the real sense of dimension and space to designers (beyond virtual models)
    - Enhancing DFMA and Lean Construction / Value Re-engineering for Circular Economy:  
designing for manufacturing and assembly, and eliminating process and material waste as designers can anticipate production and construction implications

## Contact:

Dr. Rizal Sebastian (Project Coordinator)



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