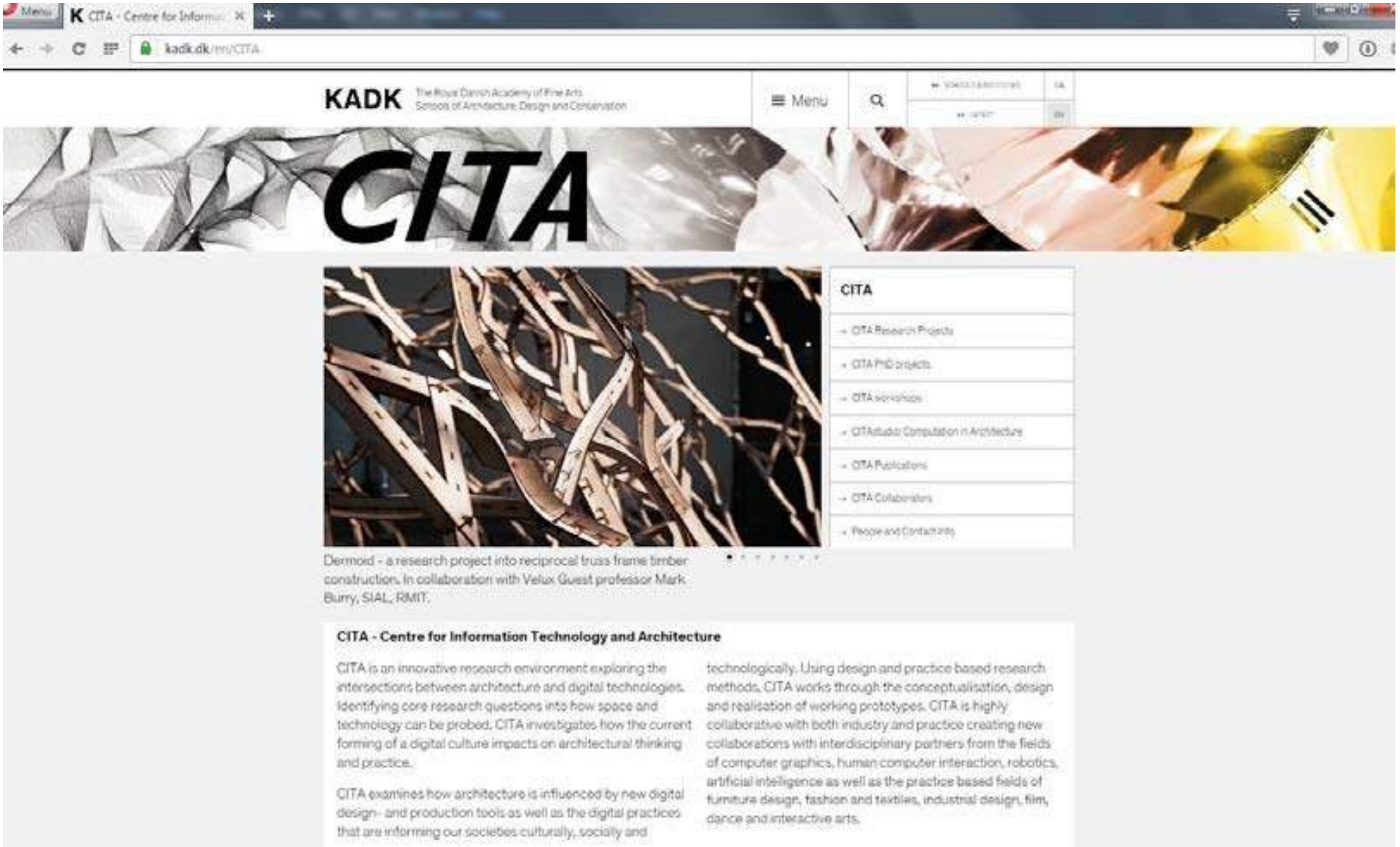
The Royal Danish Academy of Fine Arts
Schools of Architecture, Design and Conservation

COMPLEX MODELLING

CITA /

MARTIN TAMKE



WHAT IS CITA

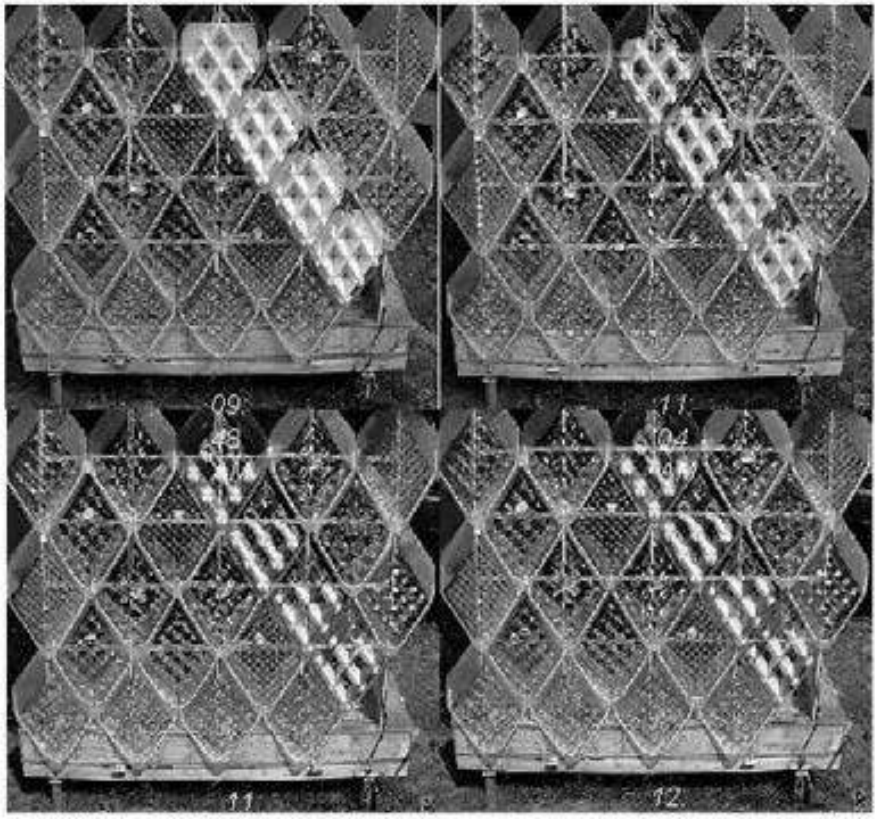
CITA

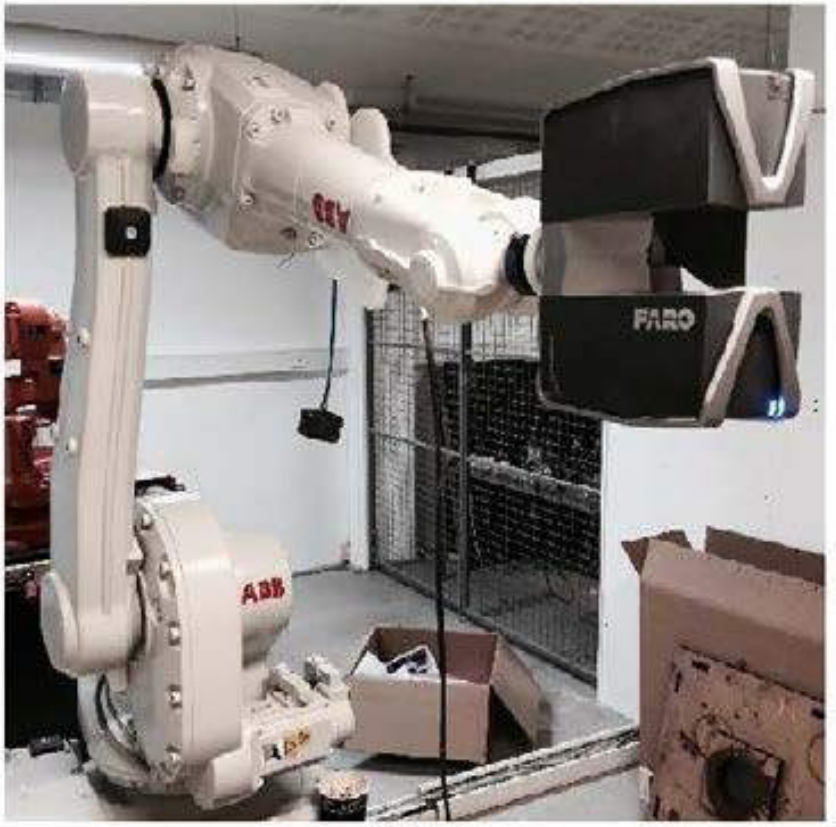
ROBOTIC FABRICATION

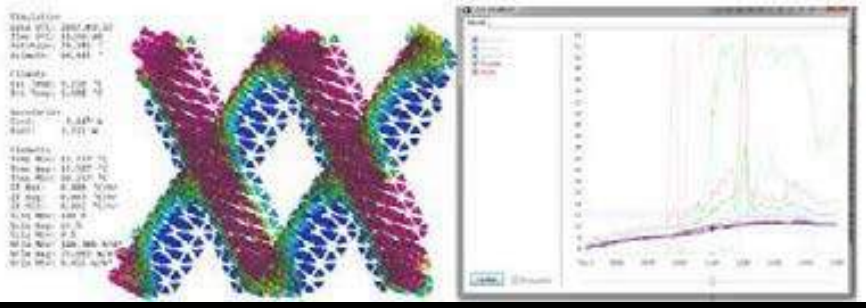
CITA

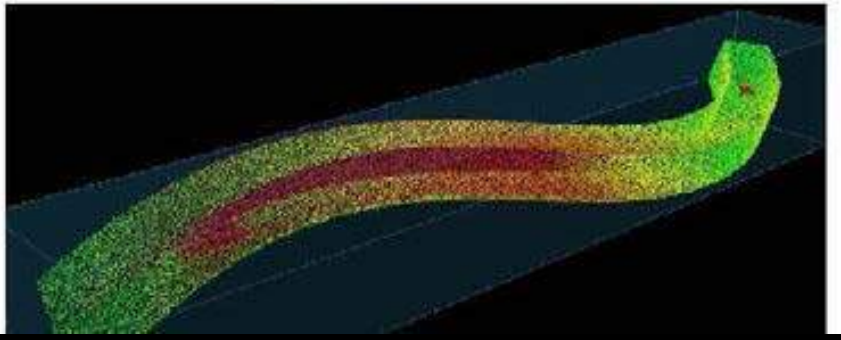
NEW MATERIAL PROCESSES

CITA









BIG DATA AND MACHINE LEARNING

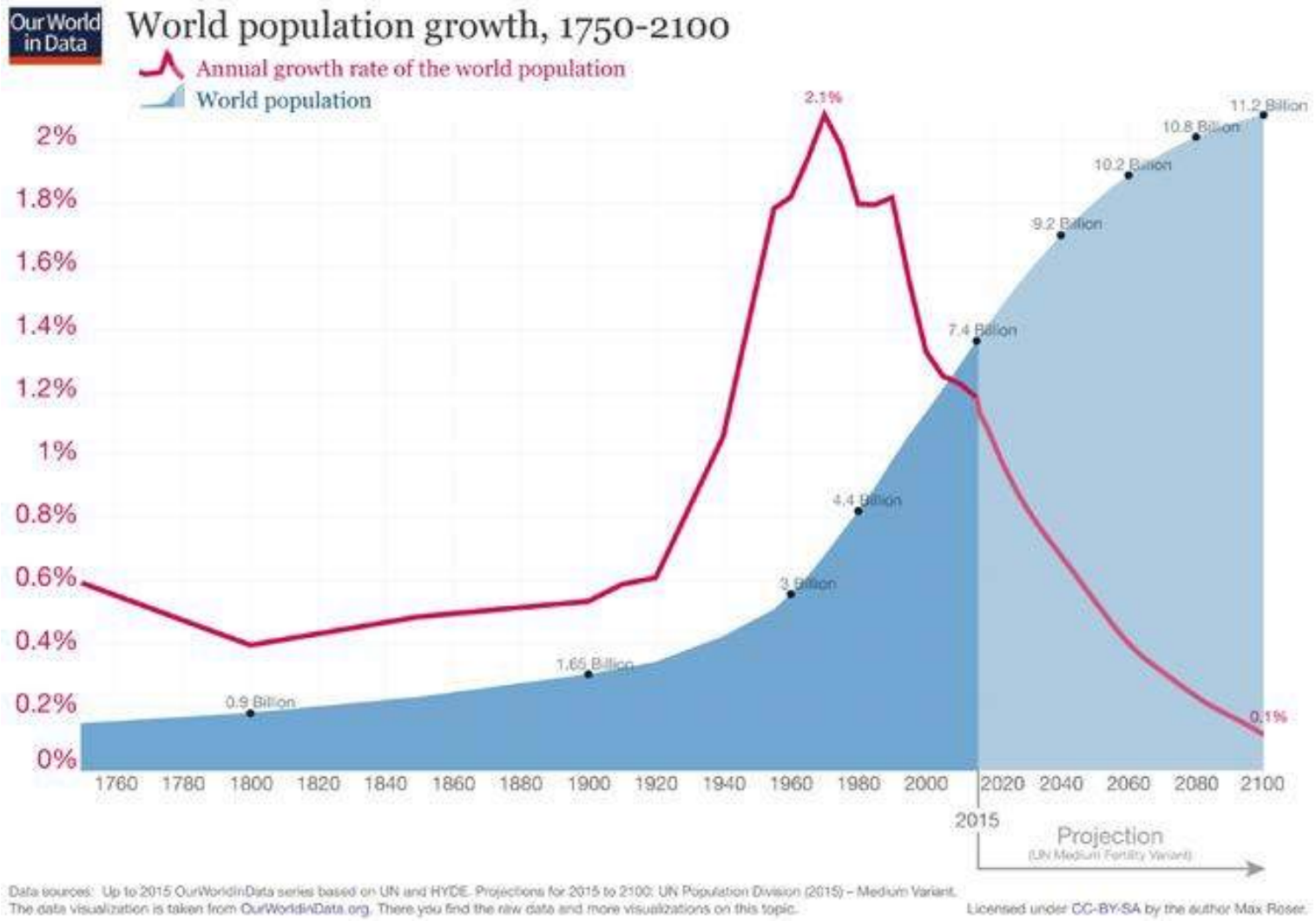
CITA

A CHALLENGE TO MATERIAL PRACTICE

a new relevance ...

CRISIS OF SUSTAINABILITY:POPULATION GROWTH AND URBANISATION

CITA

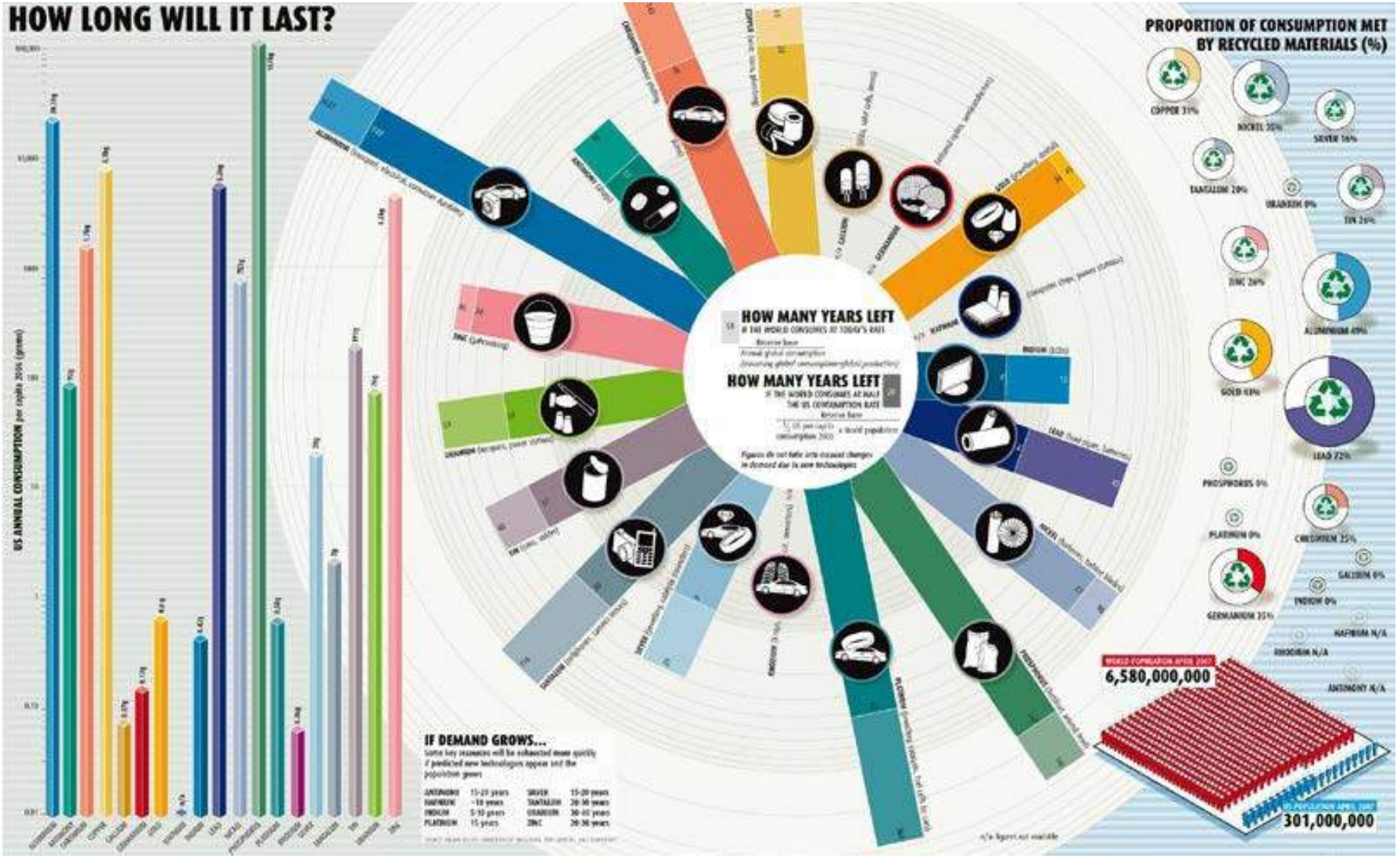


WE ARE SITTING ON AN EXPONENTIAL CURVE

CITA

BY 2050, THE WORLD'S URBAN POPULATION IS EXPECTED TO NEARLY DOUBLE, MAKING URBANIZATION ONE OF THE TWENTY-FIRST CENTURY'S MOST TRANSFORMATIVE TRENDS.

CITA



OUR RELIANCE ON INDUSTRIALISED FABRICATION HAS FOCUSSED MATERIAL PRACTICE ON A SUBSET OF VERY SPECIFIC MATERIALS

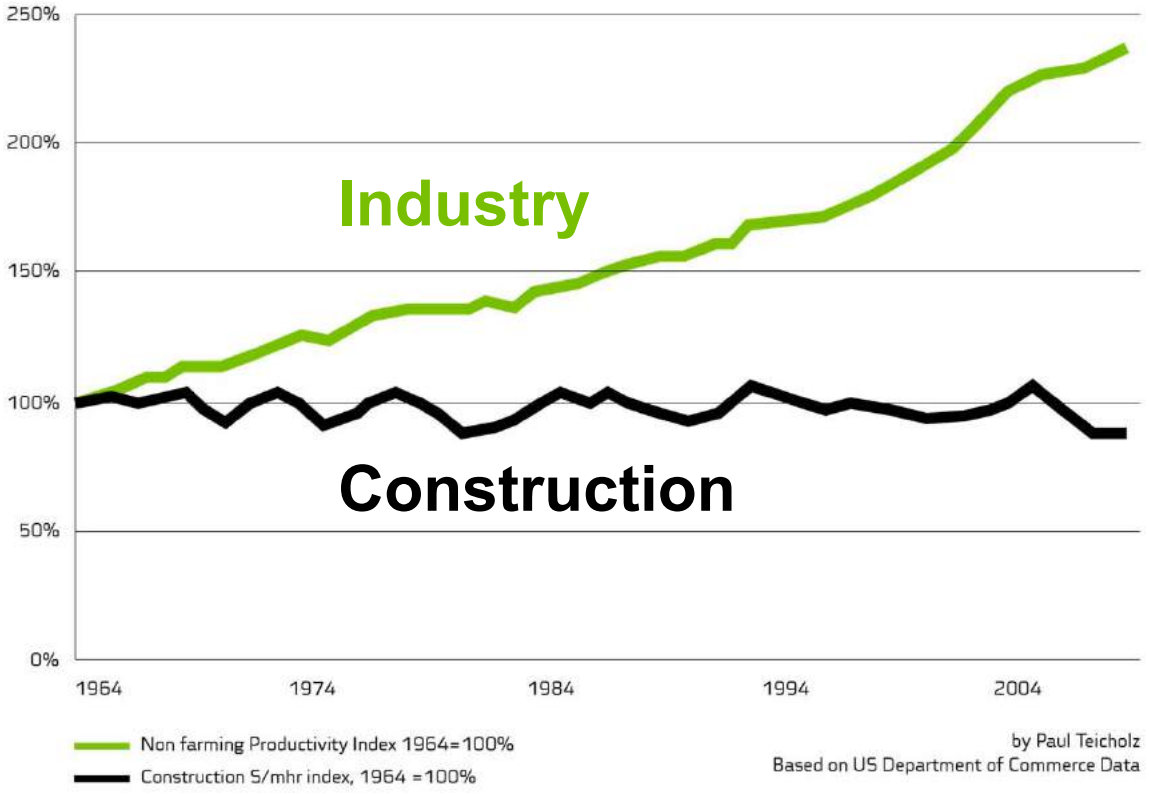
CITA

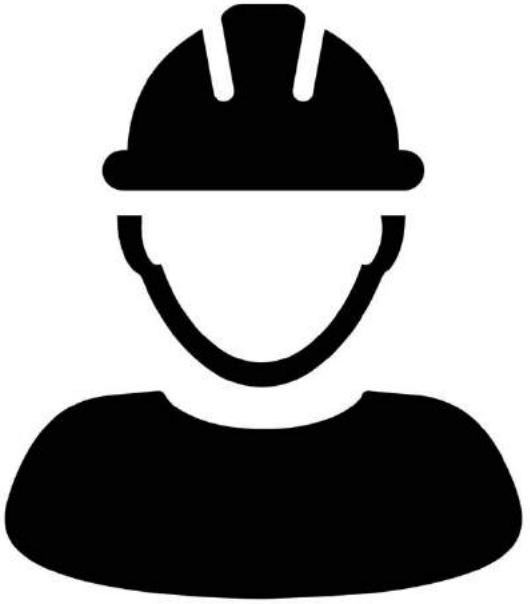
WHERE WE FIND OURSELVES DROWNING IN PLASTIC...

CITA

...WE ARE RUNNING OUT OF BASIC AGGREGATES AND MINERALS...

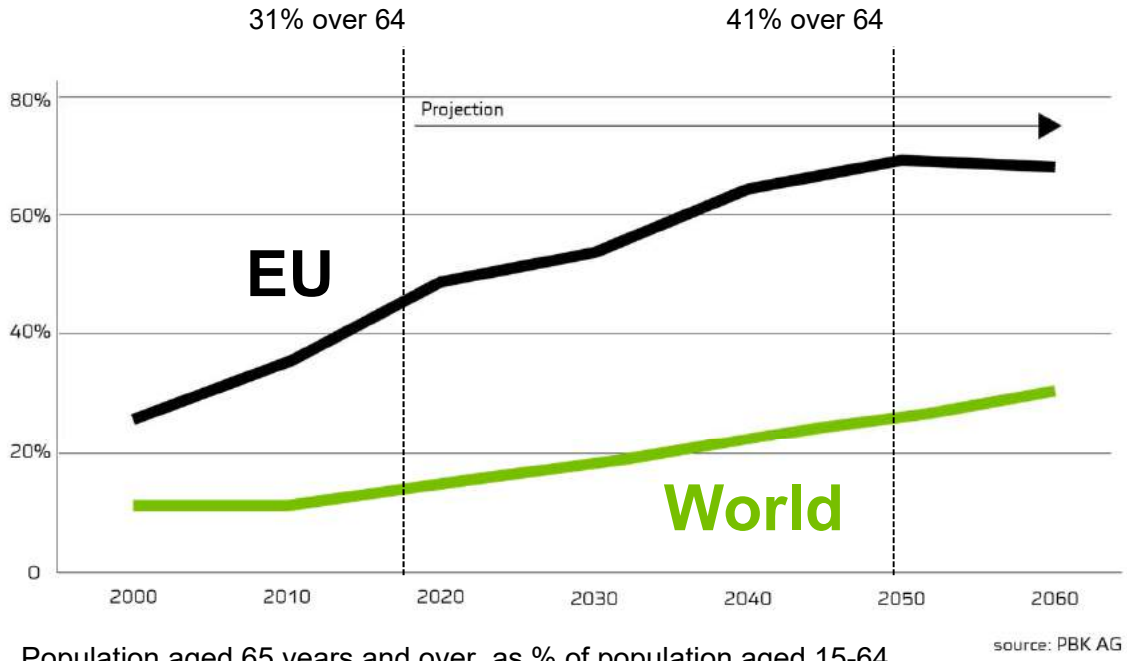
CITA





Zero Increase in Productivity in Construction Industry

CITA



Population aged 65 years and over, as % of population aged 15-64

Challenge of status quo through Demographic Change

CITA

Three ideas:

- *Adaptation*
- *Hyper optimisations*
- *Machine Learning*

THE RISE *EDF Foundation Paris, Martin Tamke, David Stasiuk, Mette Ramsgaard and Hollie Gibbons*

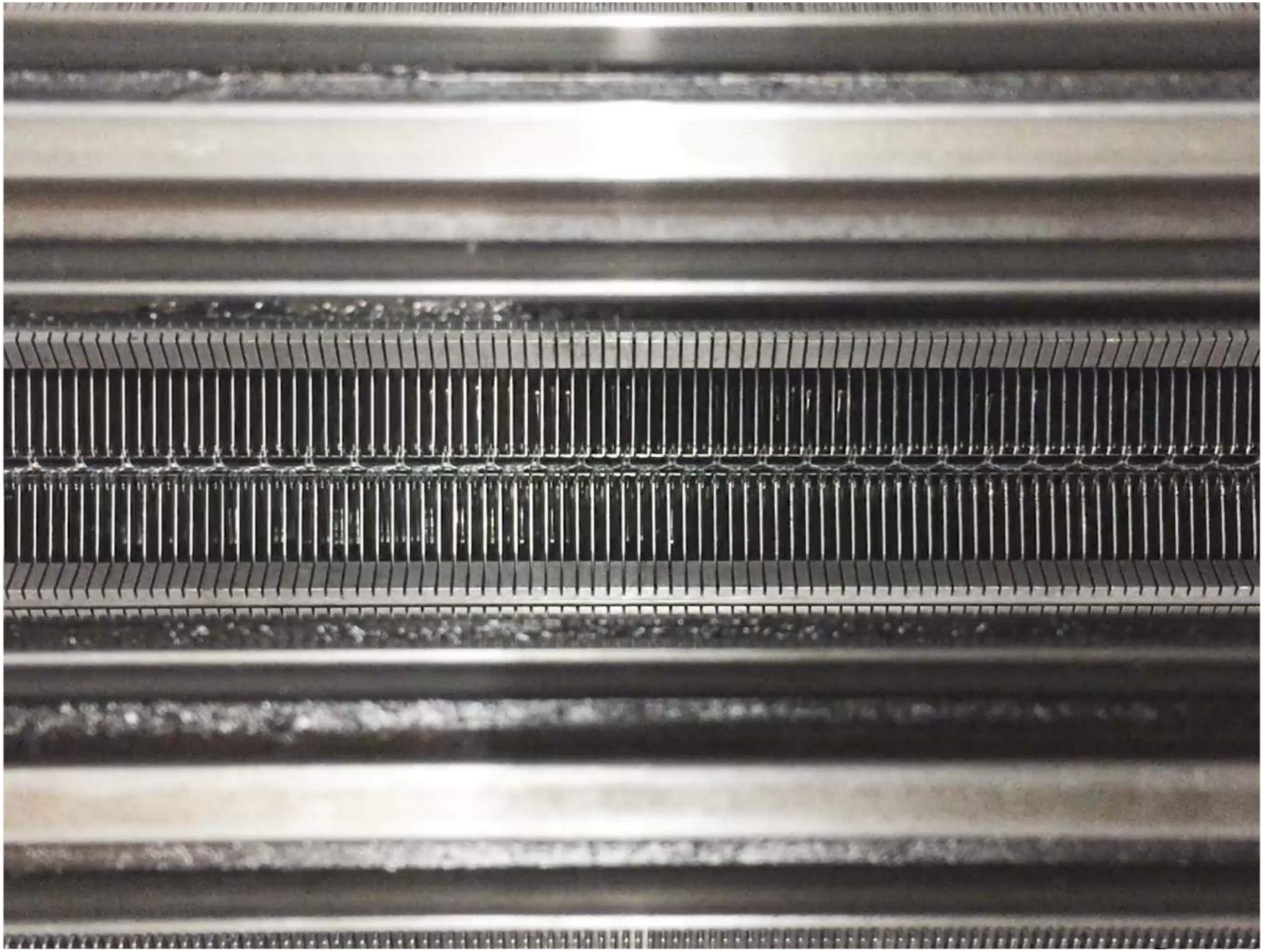
CITA

ISOROPIA *VENICE BIENNALE 2018 Martin Tamke, Mette Ramsgaard Thomsen, Yuliya Sinke with AFF and Str.ucture*

CITA

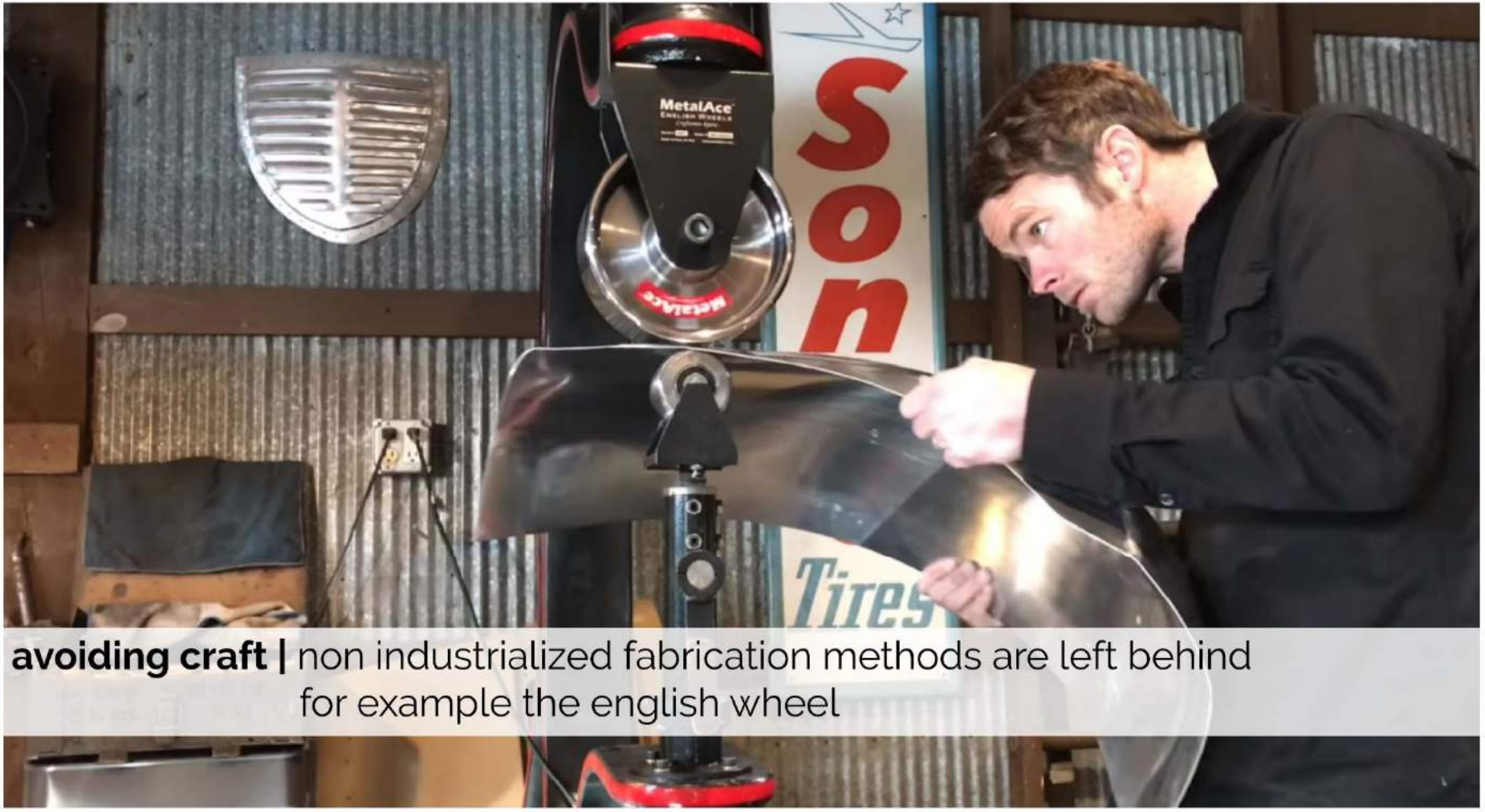
CITA

CITA



ISOROPIA: HYBRID STRUCTURES: COMPRESSION AND TENSION

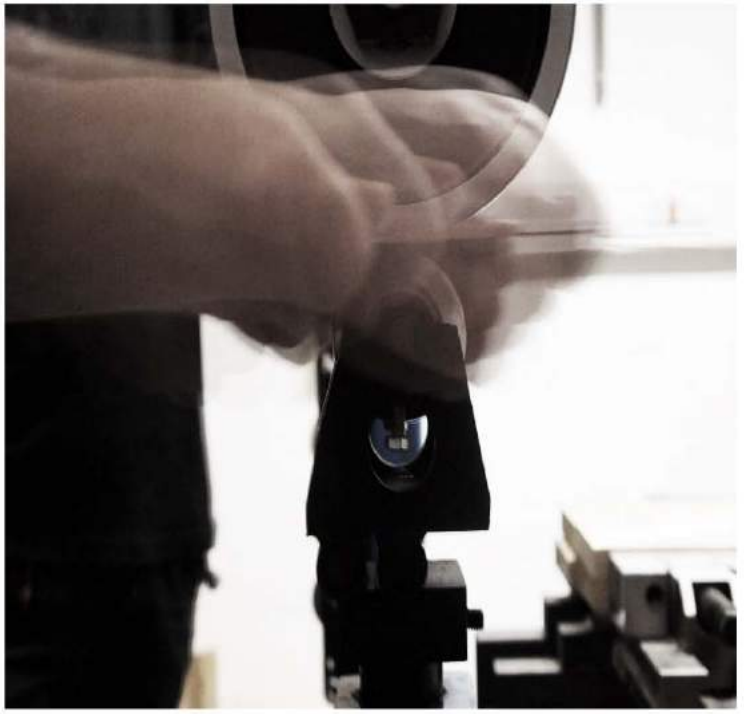
CITA



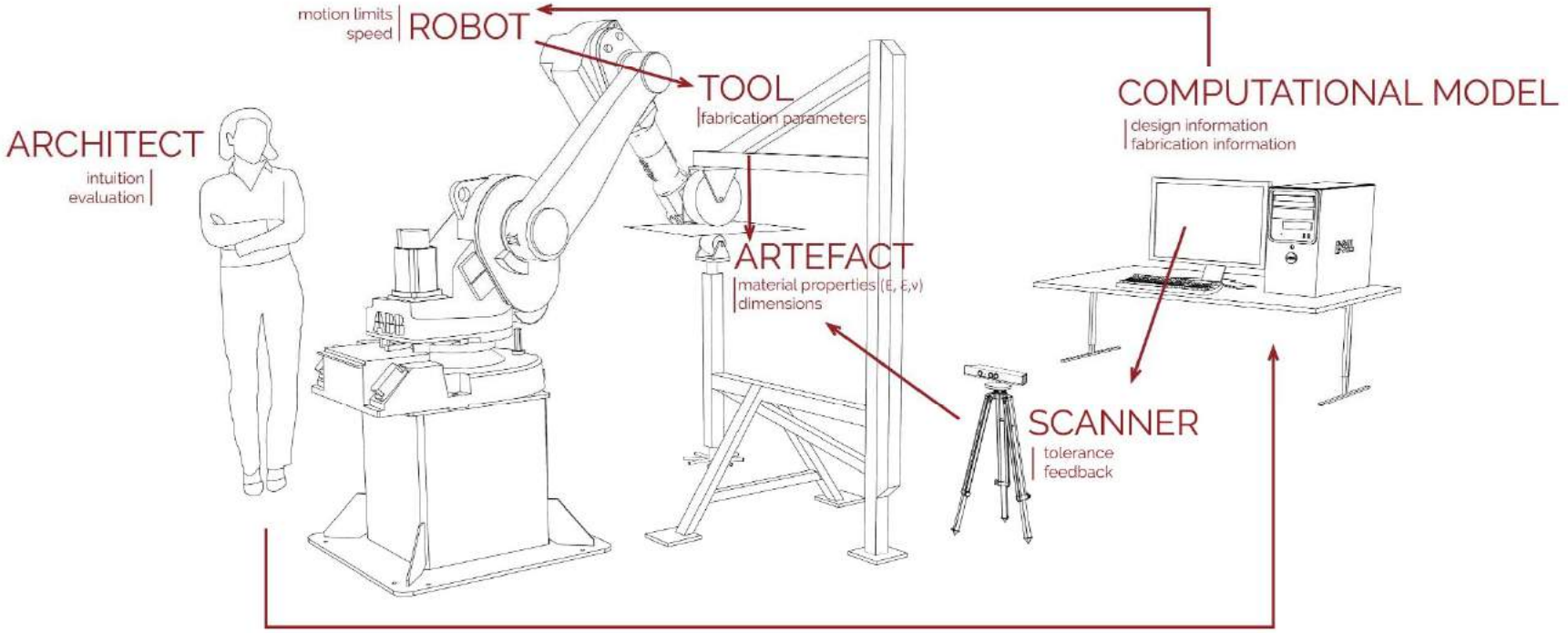
avoiding craft | non industrialized fabrication methods are left behind
for example the english wheel

step 1 | Training the hands - Fabrication parameters

observing a craftsman

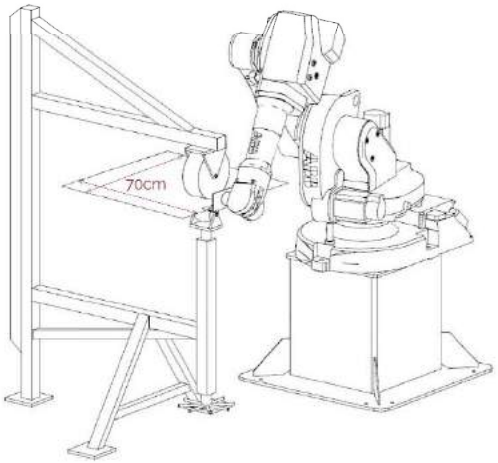


Robot Faber | english wheel cyberphysical system setup

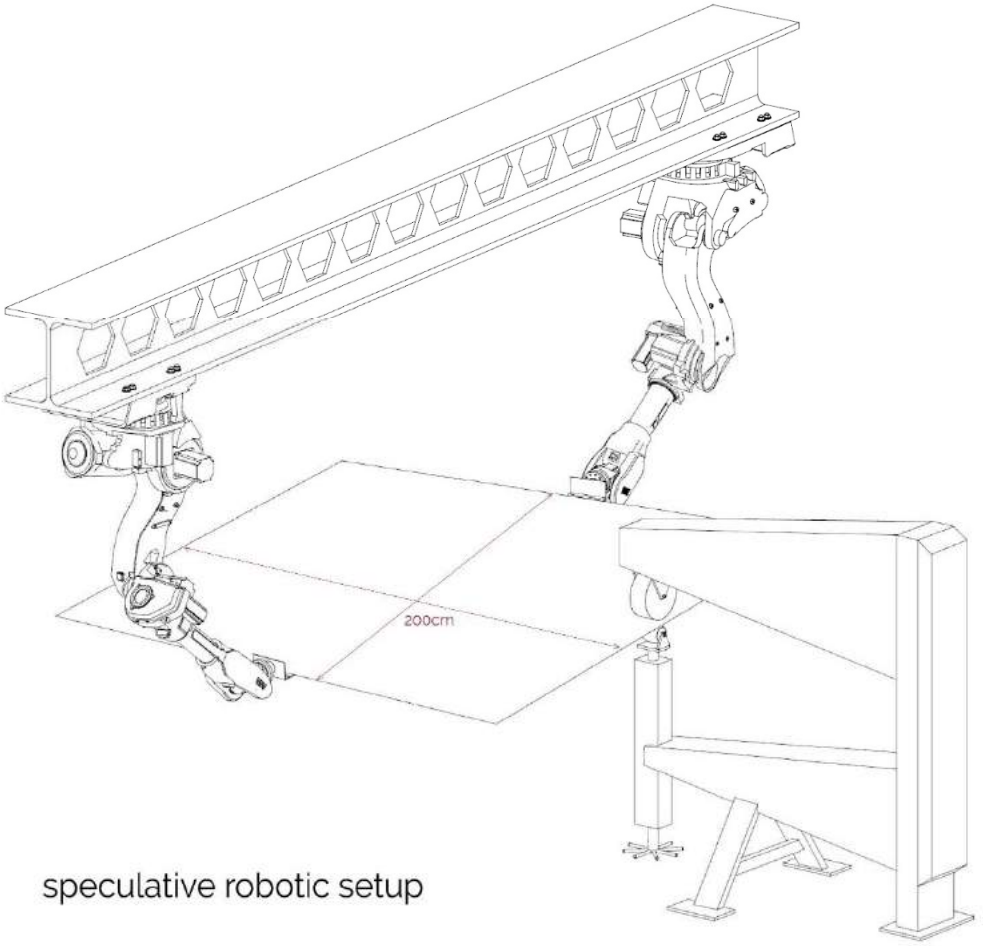


CITA

method results | setup scalability



current robotic setup



speculative robotic setup

CITA

Three Communalities

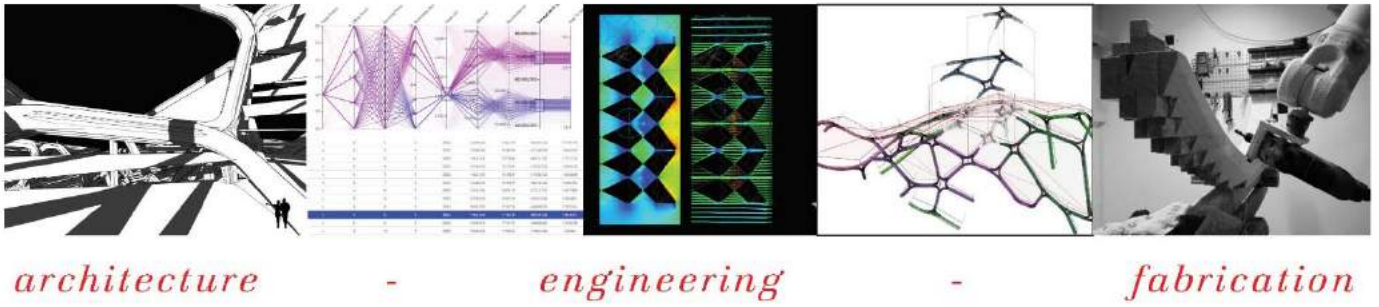
- Integrated multiscalar modelling practice
- Agency – Automatisation and Machine Intelligence
- Feedback - awareness of Environment

DURAARK
DURABLE
ARCHITECTURAL
KNOWLEDGE

www.duraark.dk

www.complexmodelling.dk

www.innochain.net



architecture - engineering - fabrication

DESIGN

ANALYSIS

SIMULATION

SPECIFICATION

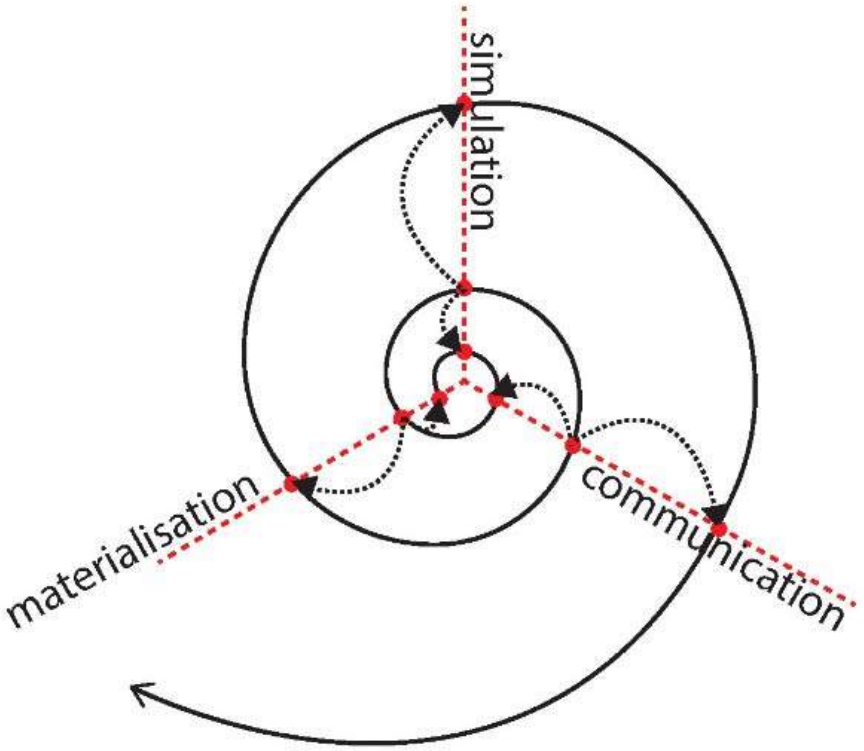
FABRICATION

MATERIAL DESIGN

The Digital Chain

European Commission

innochain CITA



THE OPPORTUNITY OF FEEDBACK IN THE DESIGN CHAIN

innochain

ABOUT PARTNERS RESEARCH PROJECTS TRAINING DISSEMINATION NEWS CONTACT

INNOCHAIN PROJECT

The InnoChain ETN network is a shared research training environment examining how advances in digital design tools challenge building culture enabling sustainable, informed and materially smart design solutions. The network aims to train a new generation of interdisciplinary researchers with a strong industry focus that can effect real changes in the way we think, design and build our physical environment.

CITA

THE INNOCHAIN PARTNERSHIP

FOSTER + PARTNERS -
ARCHITECTURE

STR.UCTURE -
ENGINEERING

S-FORM -
FABRICATION

INTERDISCIPLINARY & INTERSECTOR

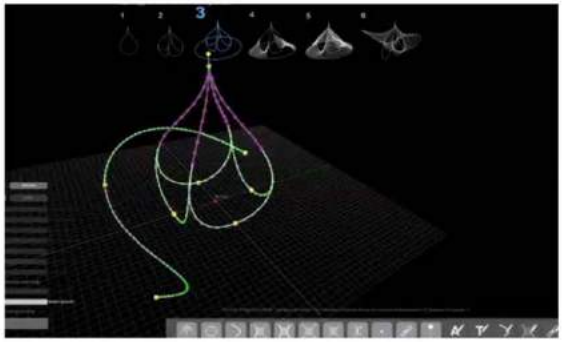
European Commission

innochain CITA

ESR08- VIRTUAL PROTOTYPING FRP

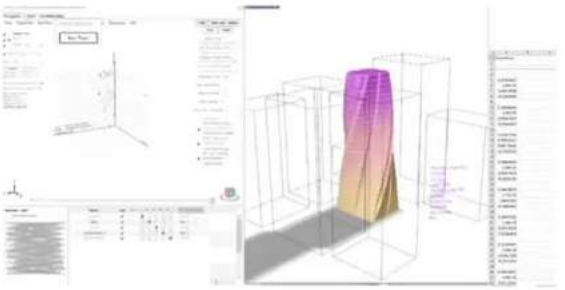
ESR13- APPLIED ROBOTICS – CONTROLLED MATERIAL DEPOSITION

ESR09- SIMULATING CONCRETE FORMWORK



ESR01- INTEGRATING ISOGEOMETRIC ANALYSIS

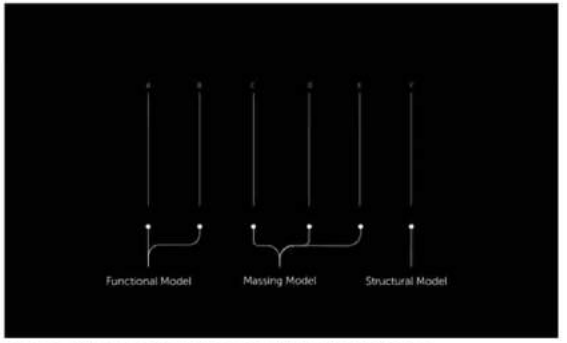
ESR15 – SMALL SCALE ROBOTIC MANUFACTURING



ESR04- MULTI-CRITERIA OPTIMISATION IN EARLY

ESR12- MATERIAL GRADIENT FRP

ESR10- SIMULATING ROBOTIC FEEDBACK

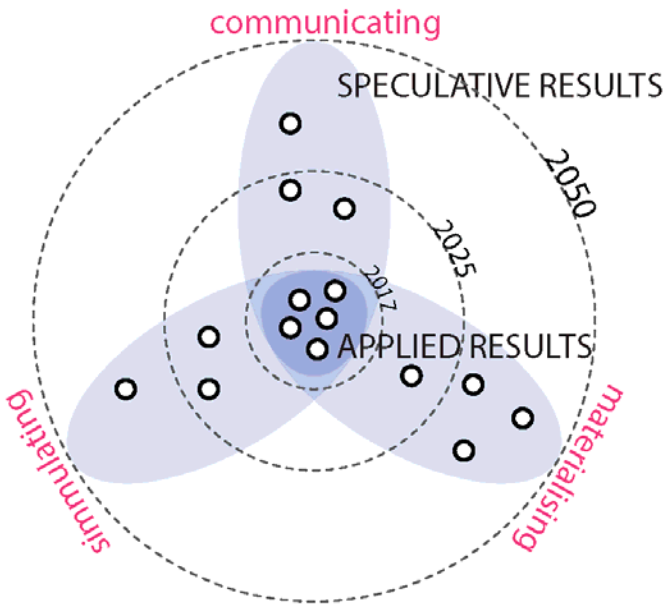


ESR01- INTEGRATING ISOGEOMETRIC ANALYSIS

Projects

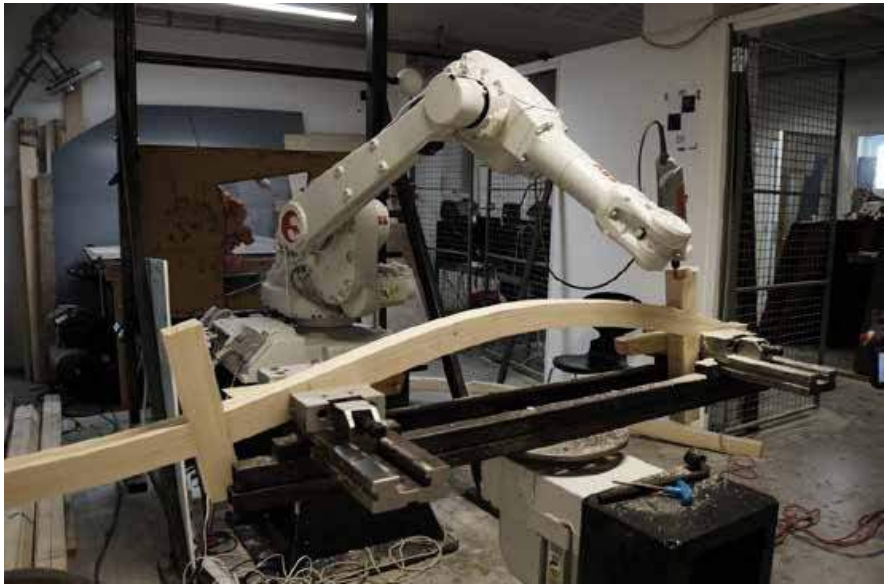
European Commission

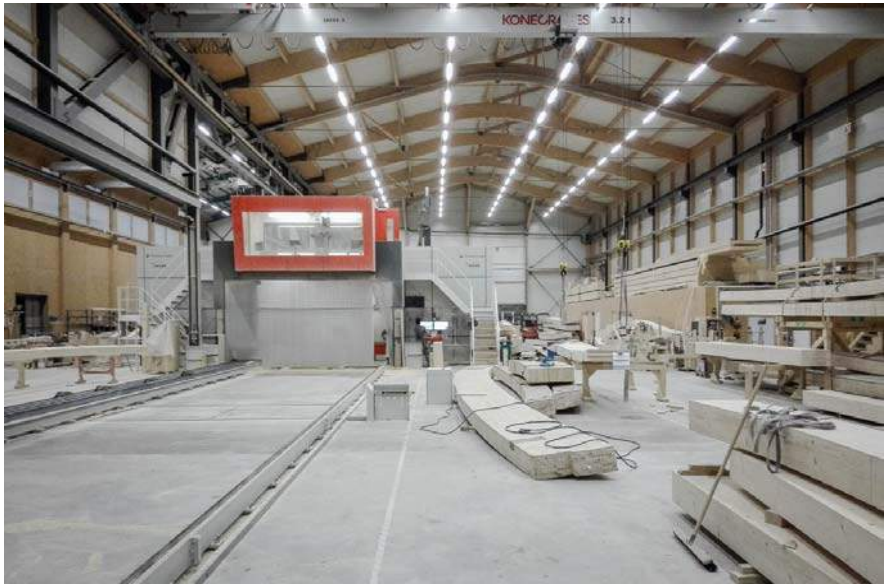
innochain CITA



ESR 9 - VASILY SITNIKOV / ICE FORMED CONCRETE CASTING

PROJECT DESIGN: APPLIED RESEARCH <--> BASIC RESEARCH





ESR 2 - TOM SVILANS - ROBOTIC TOOLSET AT CITA AND INDUSTRIAL PARTNERS BLUMER LEHMAN

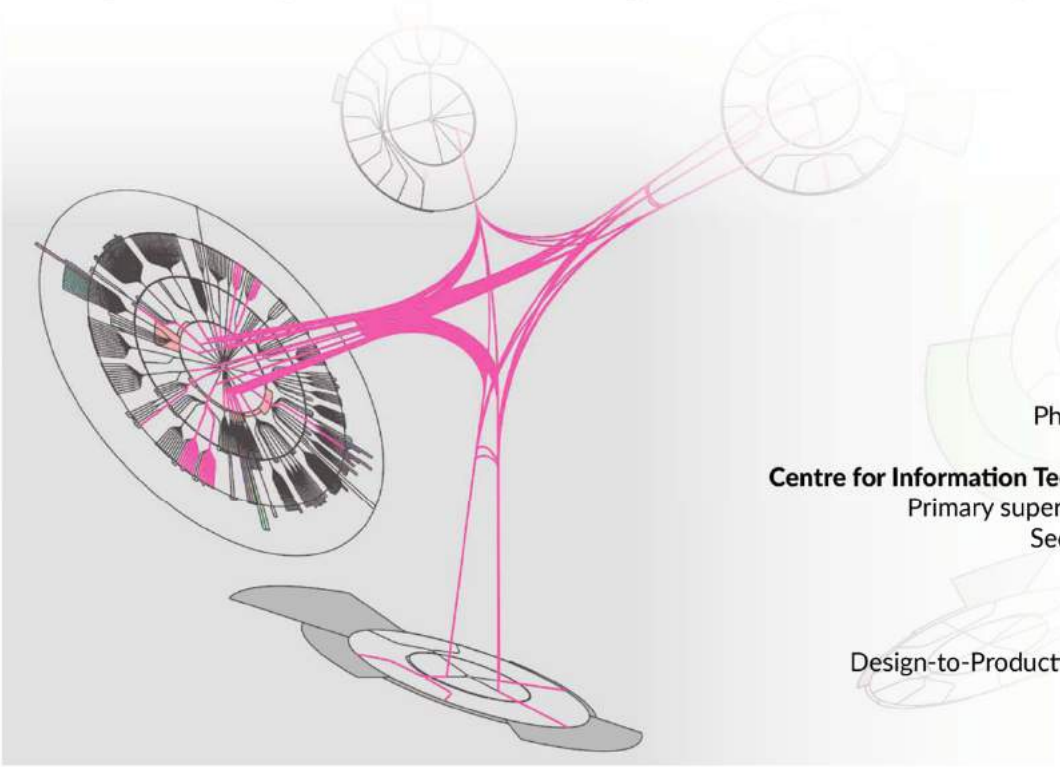
ACADEMIA – INDUSTRY:
SHARED METHODS AND PRACTICES

European Commission

innochain CITA

Multi-Scalar Modelling, Schema-Based Workflows and Search Interfaces for Building Design

Learning and building from the current challenges faced by the AEC industry



Paul Poinet - B.Arch., M.Sc.

InnoChain ETN Network
PhD Candidate - Marie Curie Fellow

Centre for Information Technology and Architecture (CITA)
Primary supervisor: Mette Ramsgaard Thomsen
Secondary supervisor: Martin Tamke

Industrial Partners
Buro Happold (UK) : Al Fisher
Design-to-Production (Switzerland): Fabian Scheurer

innochain CITA BUROHAPPOLD ENGINEERING

29-01-2019 - KADK

CITA

Academia

The computational "jewelery"
Material specific, seamless design...


Panikkar, 2014, CODA


ICD/ITKE Research Pavilion 2013-14


A Bridge Too Far, 2016, CITA


ICD/ITKE Research Pavilion 2014-15

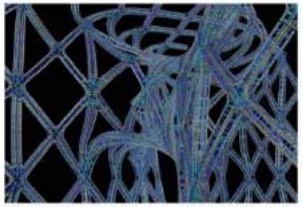

Hybrid Tower, 2016, CITA

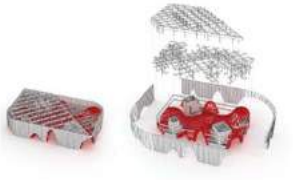

ICD/ITKE Research Pavilion 2015-16

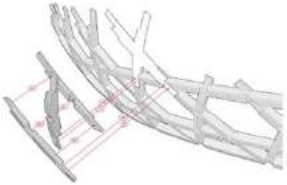
Industry

The Building Industry
Element clashes, large diversity of elements/materials...

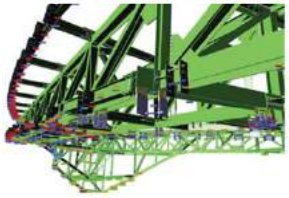

Louisiana State Sports Hall Of Fame


City of Dreams (Zaha Hadid Architects)


French Pavilion at the Expo 2015


Cité Musicale (Shigeru Ban, 2017)


Louis Vuitton Foundation (Frank Gehry).


Barclays Center (ShoP Architects, 2012)

innochain CITA BUROHAPPOLD ENGINEERING

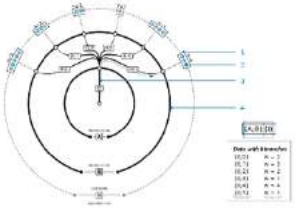
CITA

Academia

1. the **generation of data** and its **classification** are **highly intertwined** and **integrated**: the **generation of data leads directly to its classification.**

2. **the user can't or can hardly operate any changes on the data classification** itself, **without affecting the generative design process.**

3. **hardly sustainable** at late design stages.



The "dynamic" DataTree

Industry

1. the **generation of data** and its **classification** are **independent from each other**: **they can be** (but are not necesseraly) **intertwined.**

2. **the user is free to operate classification changes whenever he wants during the design process. Classification features** (such as names and attributes) **can be introduced/developed/refined before, during and after the generation of data.**

3. **proved to be sustainable** at late design stages.

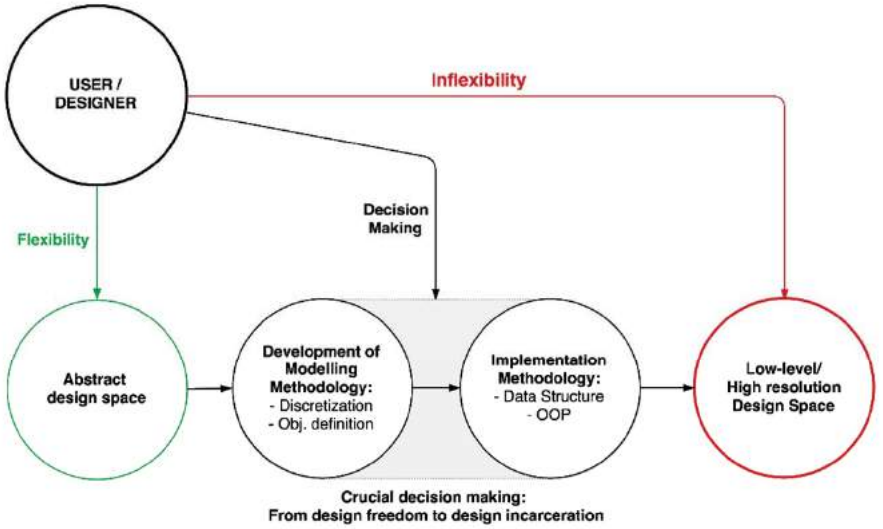
The "static" LayerTable

Academia

We have **the luxury to have a total control over the design intent across all scales and predict perfectly the outcome at early design stages**. Integrative design workflows can be deployed until all parameters are fullfilled.

Industry

The **design intent is a fallacy**. **Design happens throughout the project with the participation of all trades until completion of the building**.



"Premature optimization is the root of all evil." (Knuth, 1972)

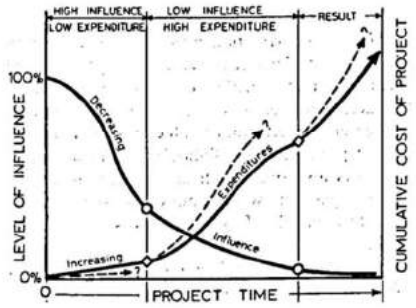
Early design strategies

Facing the classical "cost-of-change problem"...

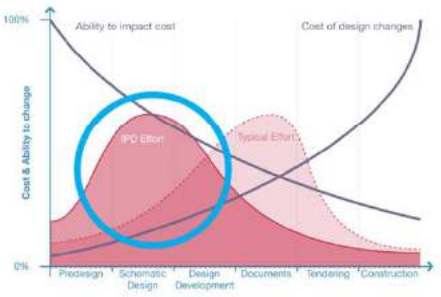
*...the usual "**early design**" answer...*

...and methods.

PROBLEM OBSERVATION	PROPOSED SOLUTION	PROPOSED METHODS
The cost of design changes increases during the timeline of the project	***The design effort should be placed at early design stage in the project***	***Early design research activies***



Paulson's curve (1976)

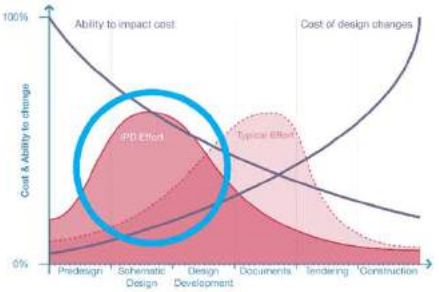


Paulson and MacLeamy's curve (Davis, 2013)

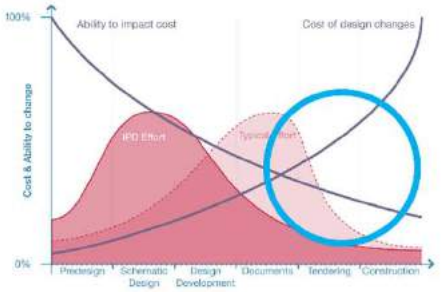
- ***early design*** analysis
- ***early design*** decisions
- ***early design*** data management
- ***early design*** simulations
- ***early design*** optimizations
- ***early design*** machine learning
- ***early design...*** ?

We need to tackle the problem from the other end of the spectrum...

Late changes can be prevented...

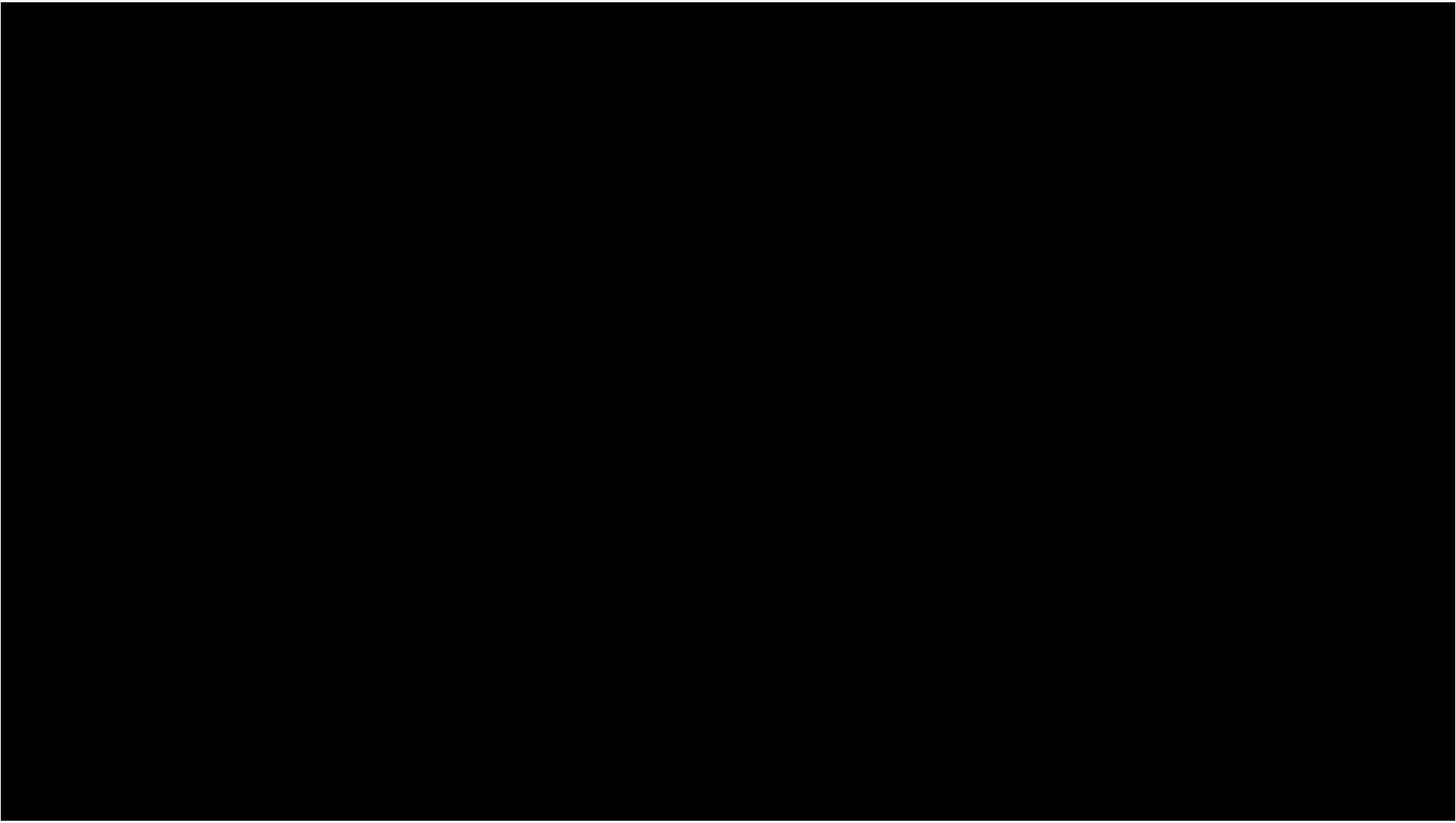


...but they will most probably have to be challenged...



Paulson and MacLeamy's curve (Davis, 2013)

The **late stages** of **large scale and complex architectures** remain challenging because it contains a **huge amount of intricate data** that needs to be **communicated and accessed between different trades and across scales**. In the best scenario, this large data set is well **organized** through a **selectable Directory Structure**, or a **Layer Table**.

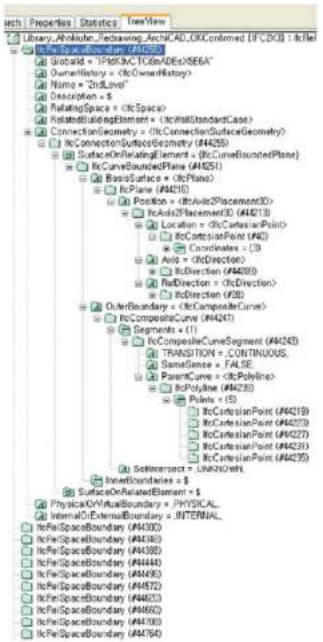


State of the art in organizing data

The LayerTable in Rhino3D

The Tree Directory in Digital Project

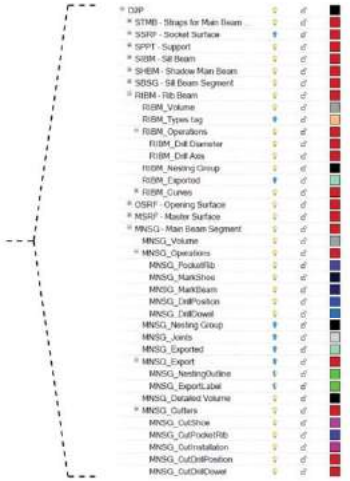
The IFC Tree Structure for BIM

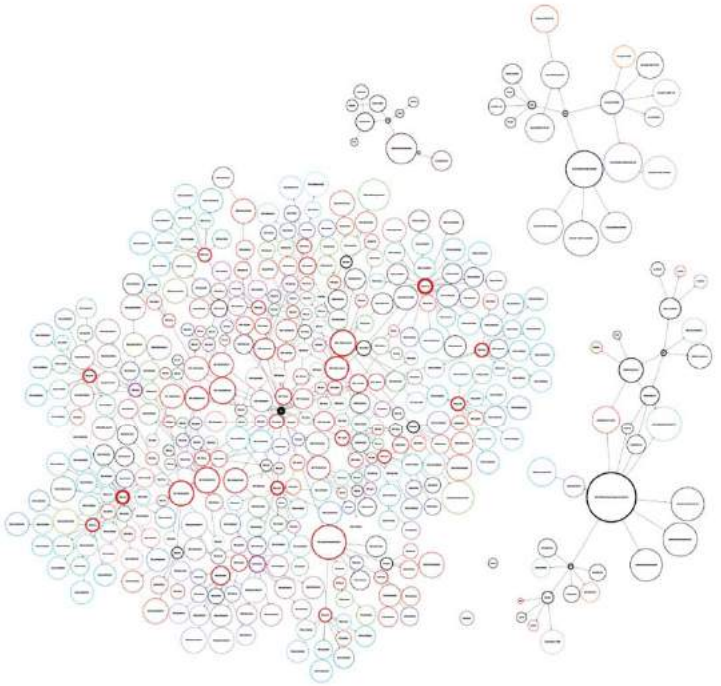


CITA

Investigation of the data structure developed at Design-To-Production

3D Model | *Corresponding LayerTable* | *Corresponding Directed Acyclic Graph (DAG)*



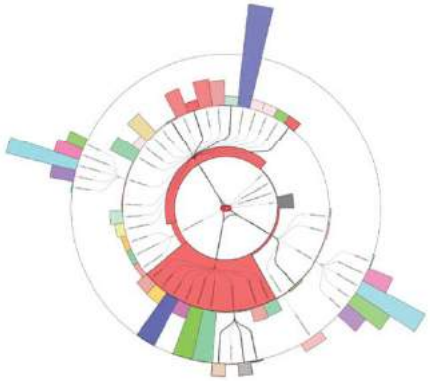


CITA

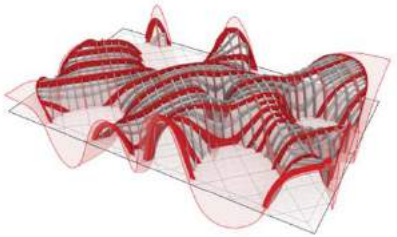
Comparing the “DNA” of different building models...

Scale: 19 meter high
Elements: More than 600 CNC-cut timber panels

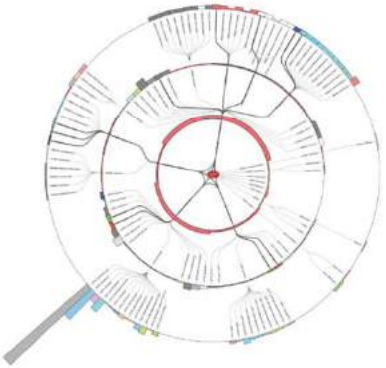
Ski World-Championship (St. Moritz, Switzerland, 2017)
Image Courtesy of Design-To-Production



Scale: 12 meter high
Elements: 730 curved structural segments

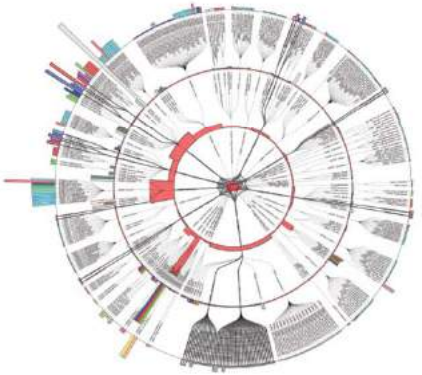


French Expo-Pavilion (Milan, Italy, 2015)
Image Courtesy of Design-To-Production



Scale: 7-8 meter high
Elements: 1300 unique timber parts

Terminal Pavilions Oslo (Oslo, Norway, 2016)
Image Courtesy of Design-To-Production



innochain CITA BUROHAPPOLD ENGINEERING

29-01-2019 - KADK

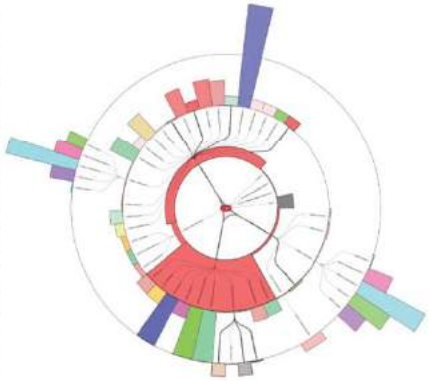
CITA

Comparing the "DNA" of different building models...

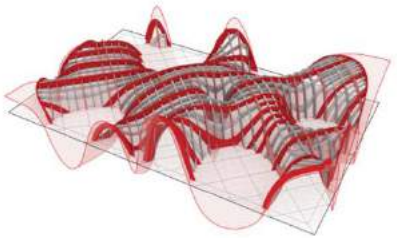
Embedded Rationality / Pre-rationalization

Scale: 19 meter high
Elements: More than 600 CNC-cut timber panels

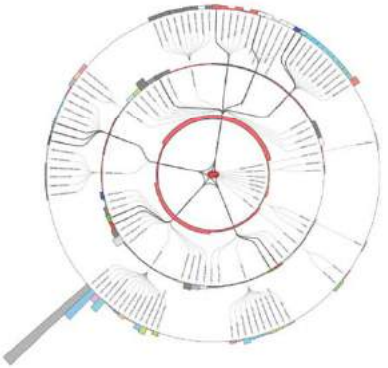
Ski World-Championship (St. Moritz, Switzerland, 2017)
Image Courtesy of Design-To-Production



Scale: 12 meter high
Elements: 730 curved structural segments



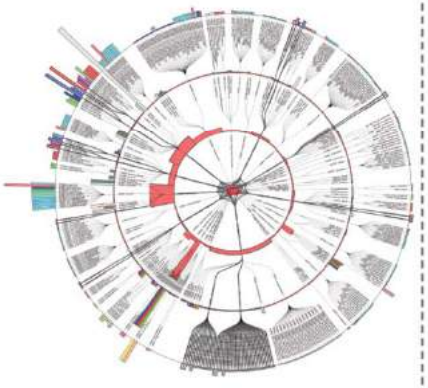
French Expo-Pavilion (Milan, Italy, 2015)
Image Courtesy of Design-To-Production



Post-rationalization

Scale: 7-8 meter high
Elements: 1300 unique timber parts

Terminal Pavilions Oslo (Oslo, Norway, 2016)
Image Courtesy of Design-To-Production

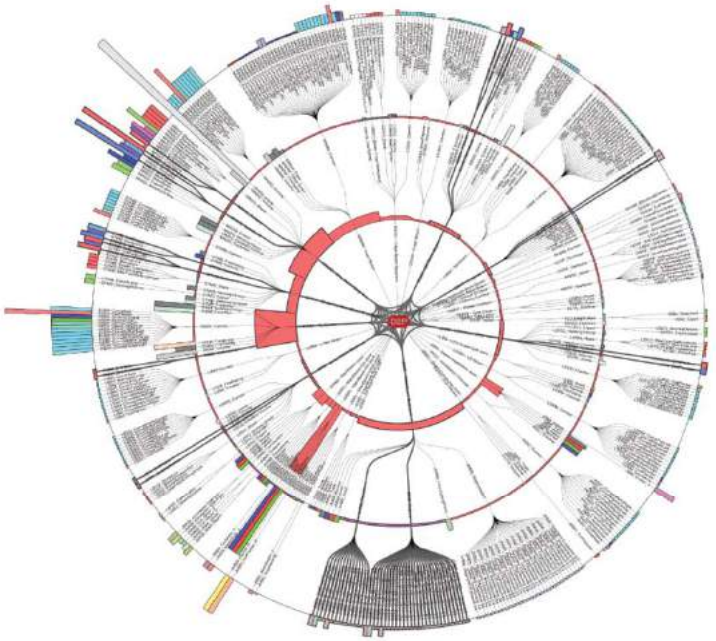


innochain CITA BUROHAPPOLD ENGINEERING

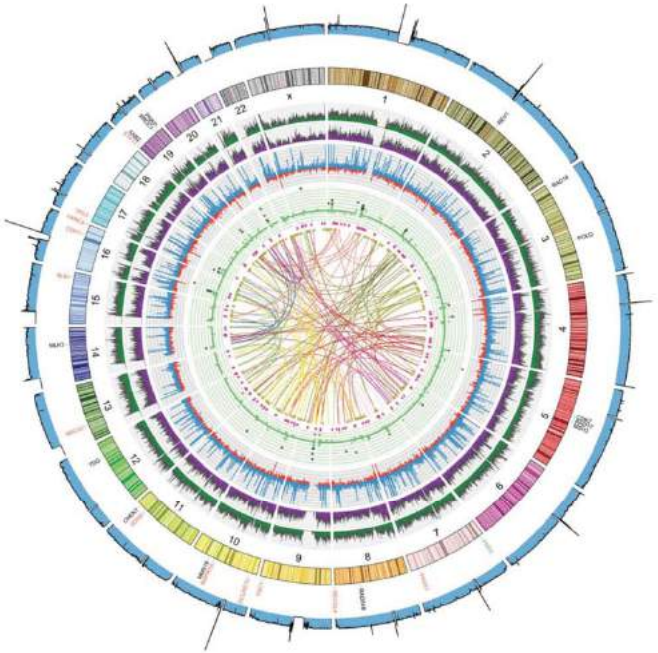
CITA

Spheres of knowledge

Comparison between the building model and existing applications in other fields, such as genomics



3D Model's LayerTable plot of the M3 Terminal Pavilion in Oslo

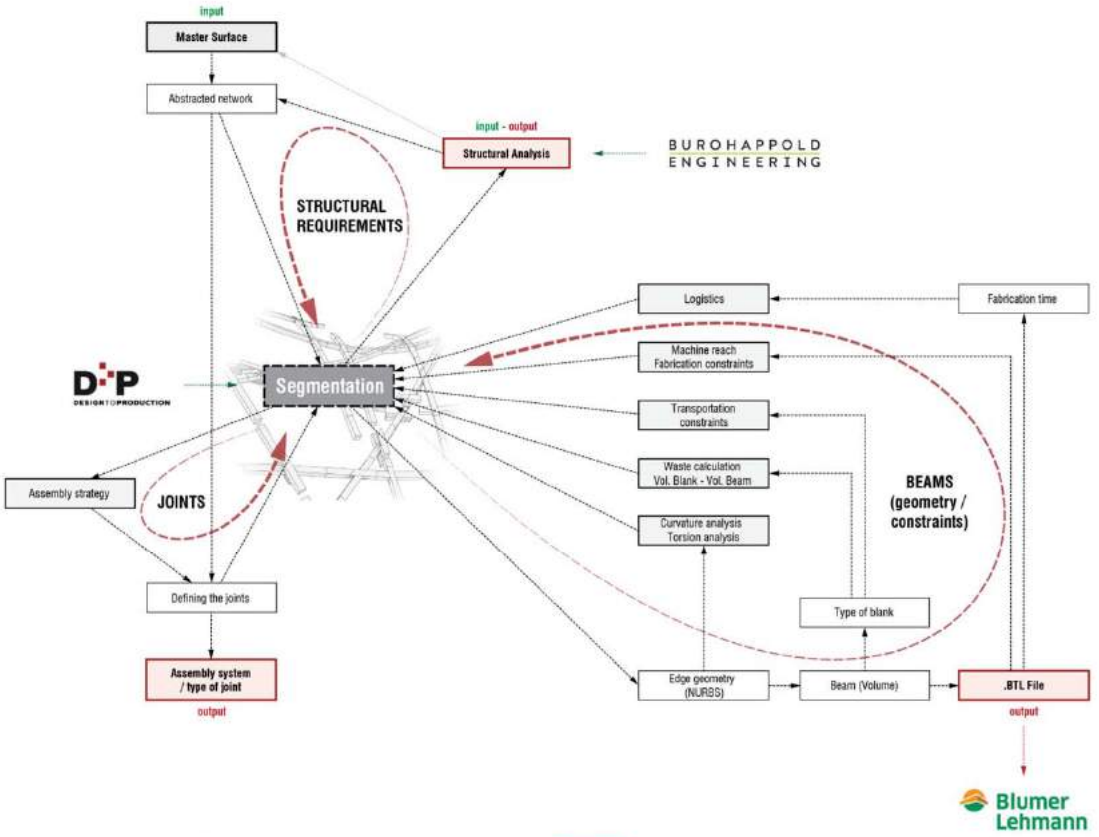


Circos plot summarizing the overall patterns of genetic variants (Xiaoyuan Li et al. 2015)

innochain CITA BUROHAPPOLD ENGINEERING

CITA

Extending the design concerns to the external stakeholders?



innochain CITA BUROHAPPOLD ENGINEERING

CITA

Recurring pattern: the wicked problem of design interoperability

Proposing local solutions for local problems

There are many decentralised and local communication bridges that attempt to overcome the constantly growing multitude of centralized software solutions. Nevertheless, most of them are bespoke plugins that use closed protocols, resulting into a fragmented landscape that limits the interoperability.

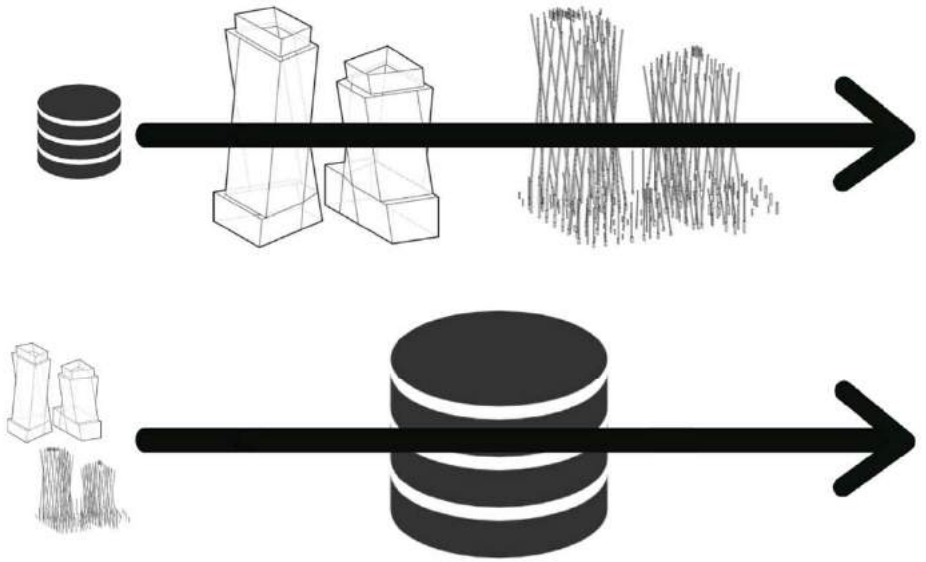
Models should be derived from the database, and not the opposite.

03 Where should we put model intelligence? Interoperable platform connections

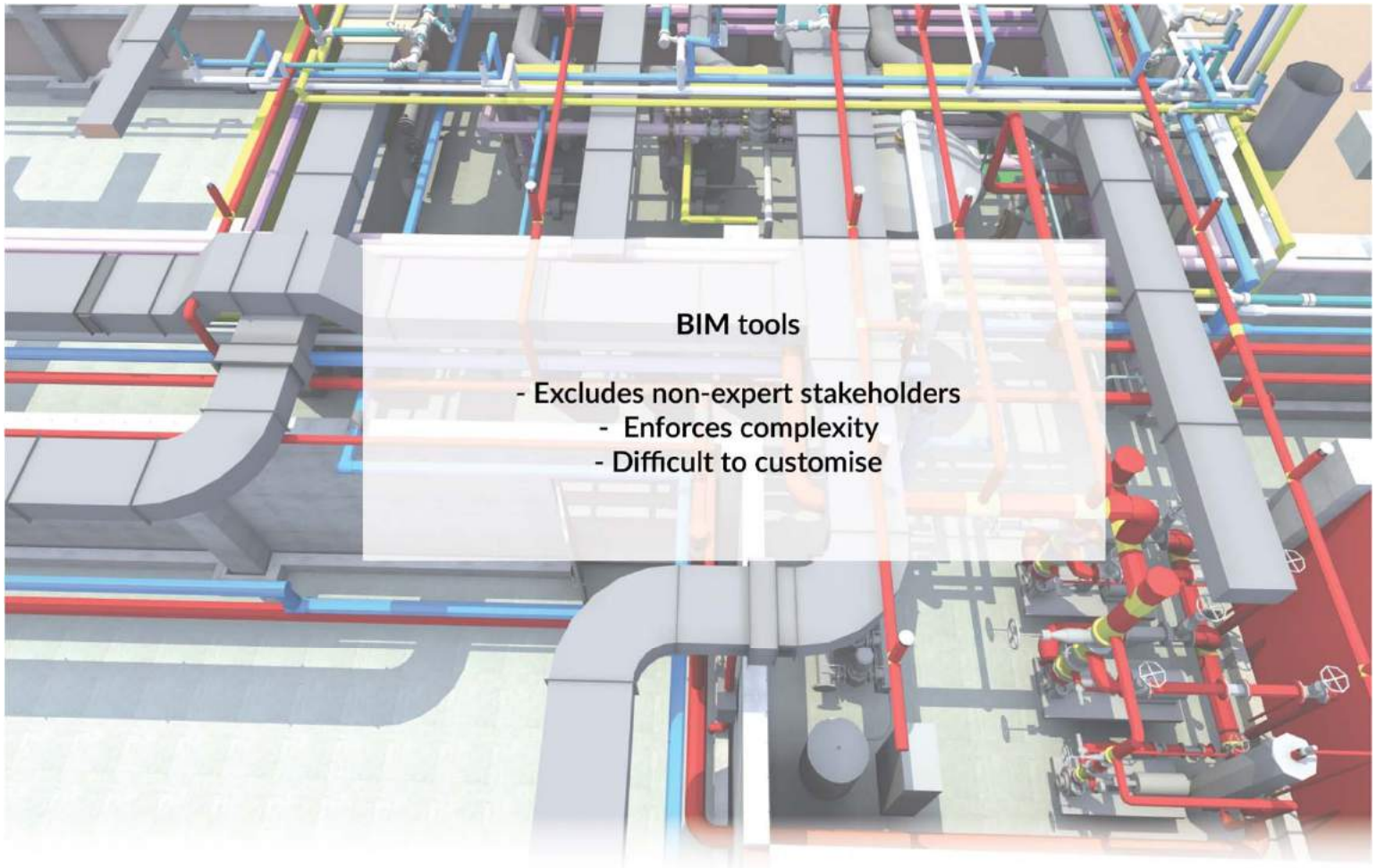
Data/Model Inversion

At first glance, we are facing the technical challenge of migrating interoperable data sets through a myriad of platforms that all interpret elements differently.

What may prove to be a smarter approach is a stable data set through which various models pass through and manipulate. Autodesk's concept software "**Project Quantum**" proposes to do just this.



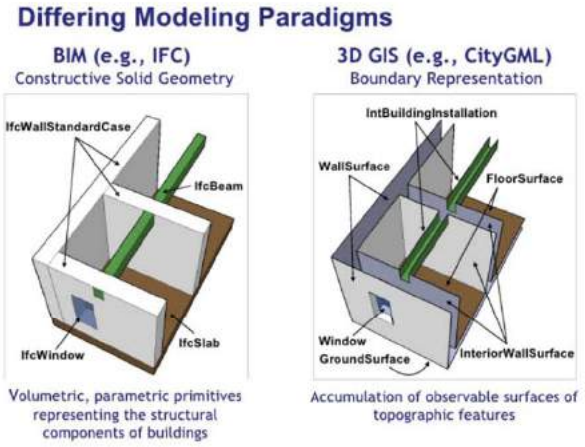
Brian Ringley, "What's the point of Dynamo?", June 14, 2017

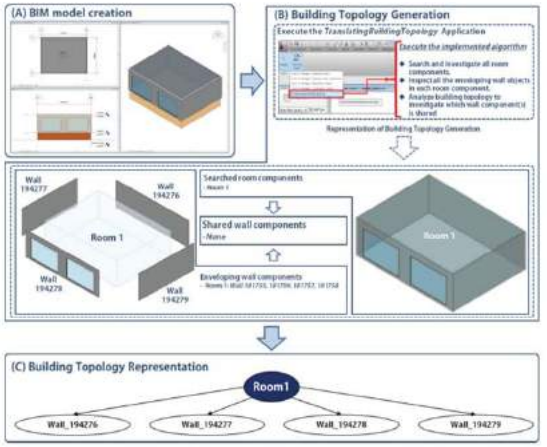

BIM tools
- Excludes non-expert stakeholders
- Enforces complexity
- Difficult to customise

CITA

BIM imposes a modelling paradigm as a standard (IFC)

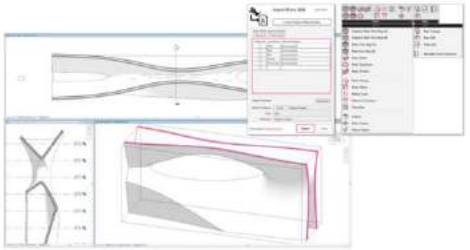
BIM is actually one approach amongst others, its essence being that of a domain specific object oriented model that one has to embrace in order to meet current required specific standards. Once embraced, just like with DAG models, operating changes becomes a time consuming effort.



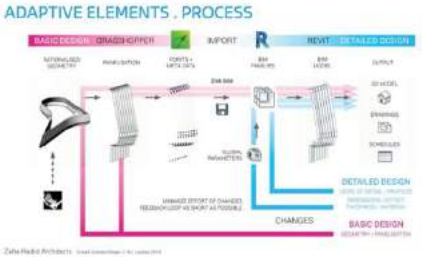


State of the art, existing approaches to collaborative workflows

Different existing modelling approaches have proven the benefit of enhancing collaborative workflows

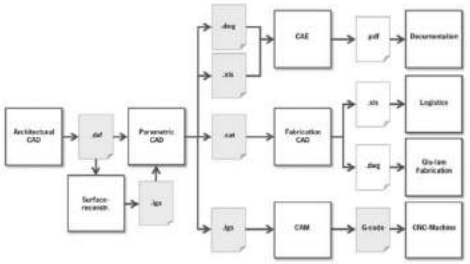


Proving Ground research and tools development

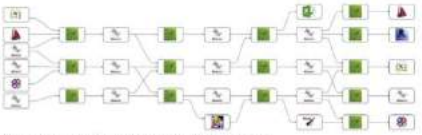


ZHA BIM collaborative and interoperability workflows

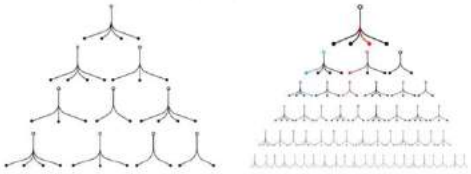
Speckle.Works: an open source AEC protocol and platform



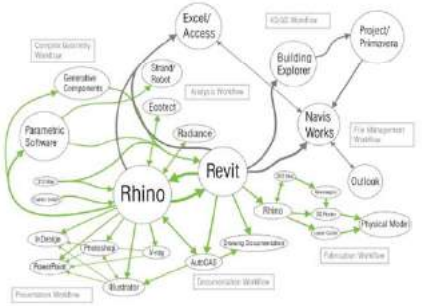
Design-to-Production's filing ecosystem



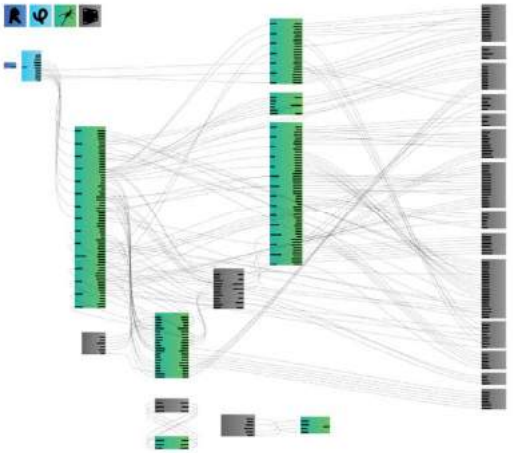
Front's modelling strategy with Elefront



TreeGram's Directory Tree Structures



Shop Architect's software ecosystem



Woods Bagot's MetaGraph (Ringley & Heumann)

innochain CITA BUROHAPPOLD ENGINEERING

CITA

Open formats

The fact that data must constantly be parametrically linked prevents the possibility to share it in a transparent way. Open Formats, on the other hand, work well as containers to hierarchize, share and query information.

XML

```
‹Data Set›
   ‹Data Subset›
      ‹Key› Value ‹/Key›
      ‹Key› Value ‹/Key›
      ‹Key› Value ‹/Key›
   ‹/Data Subset›
‹/Data Set›
```

JSON

```
{
   Data Set: {
      Data Subset: {
         Key: Value,
         Key: Value,
         Key: Value
      }
   }
}
```

Using Speckle as a platform to genericize the previous experiments

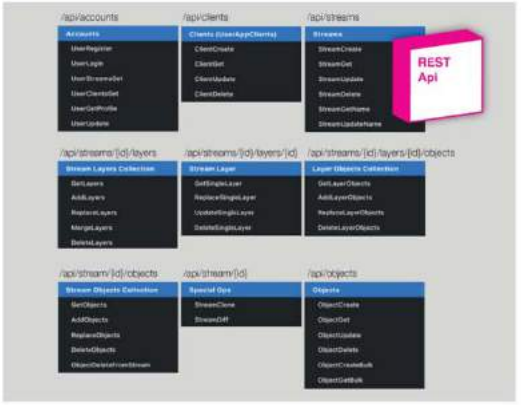
An extensible Design & AEC data communication protocol and platform.

speckle.
works

API
(verbs, actions)

Objects
(nouns)

Database / Storage
(paper)



innochain CITA BUROHAPPOLD ENGINEERING

CITA

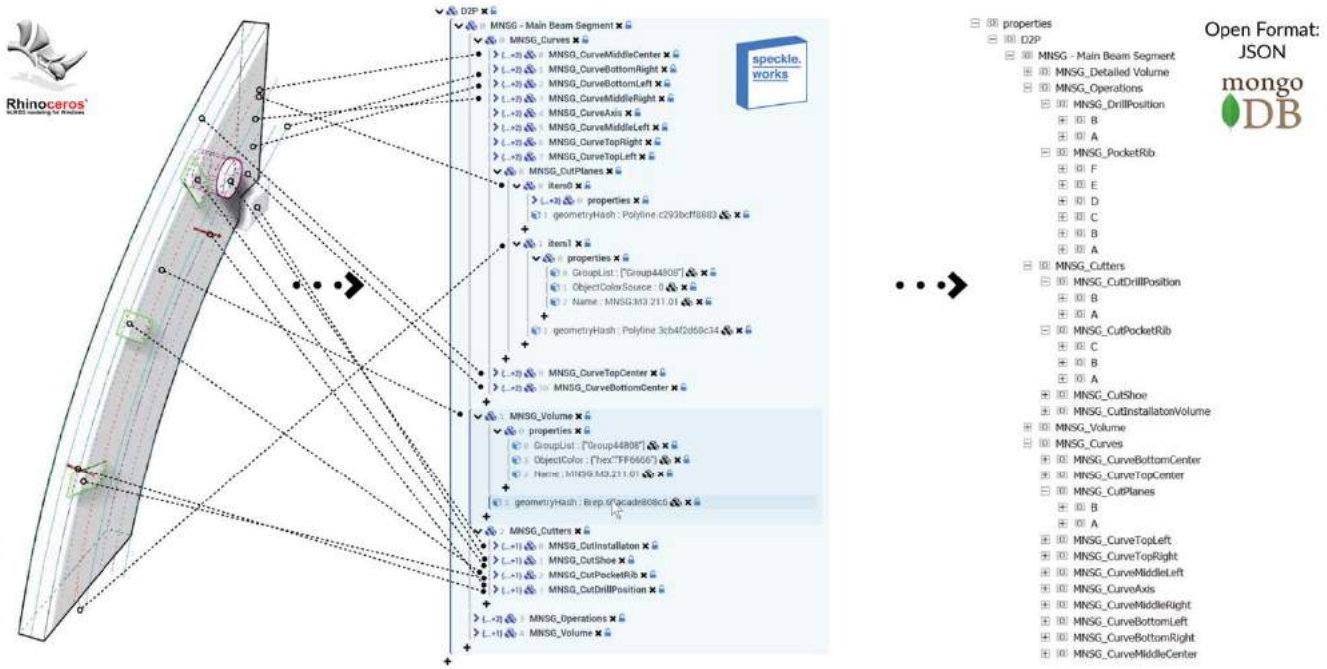
Building Custom Schemas through the Speckle's API

innochain CITA BUROHAPPOLD ENGINEERING

29-01-2019 - KADK

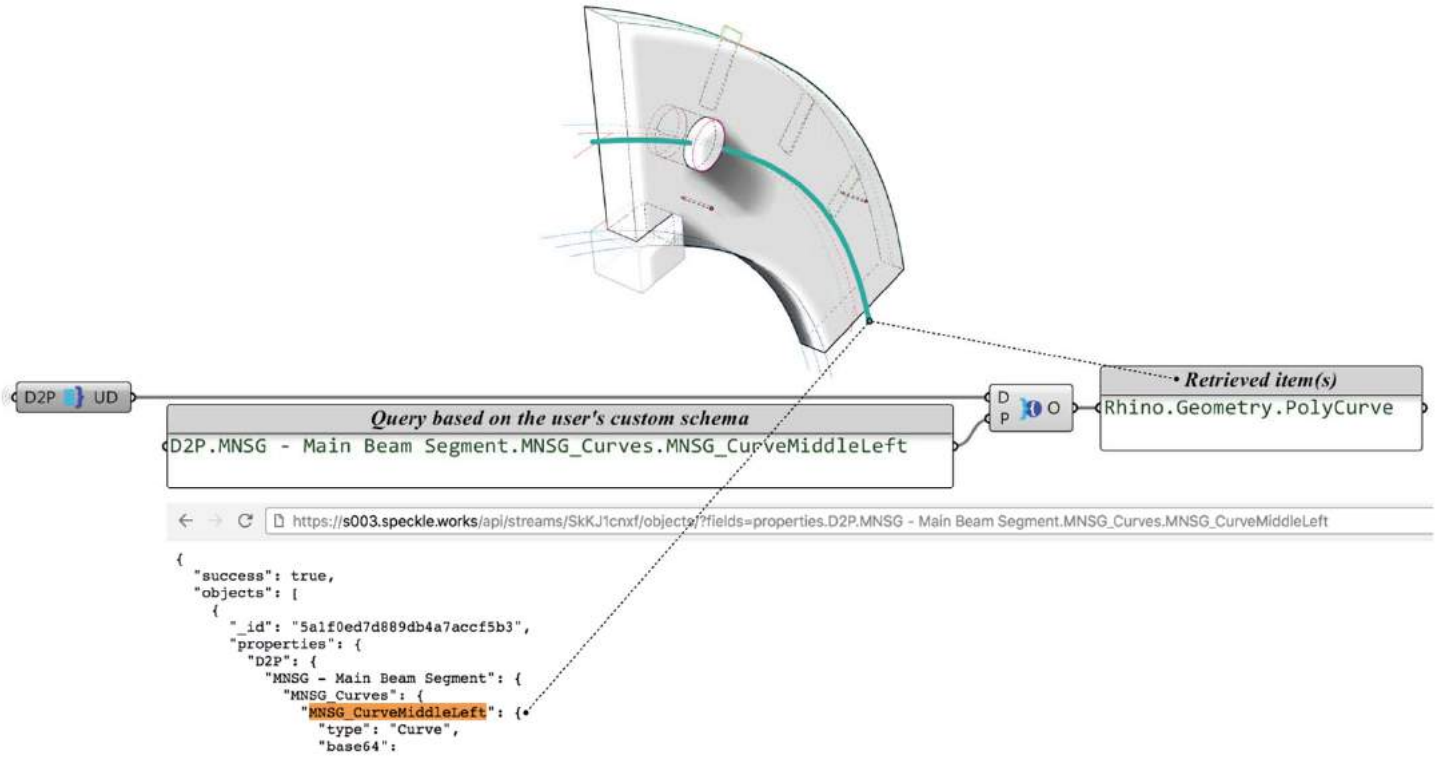
CITA

Building Custom Schemas through the Speckle's API



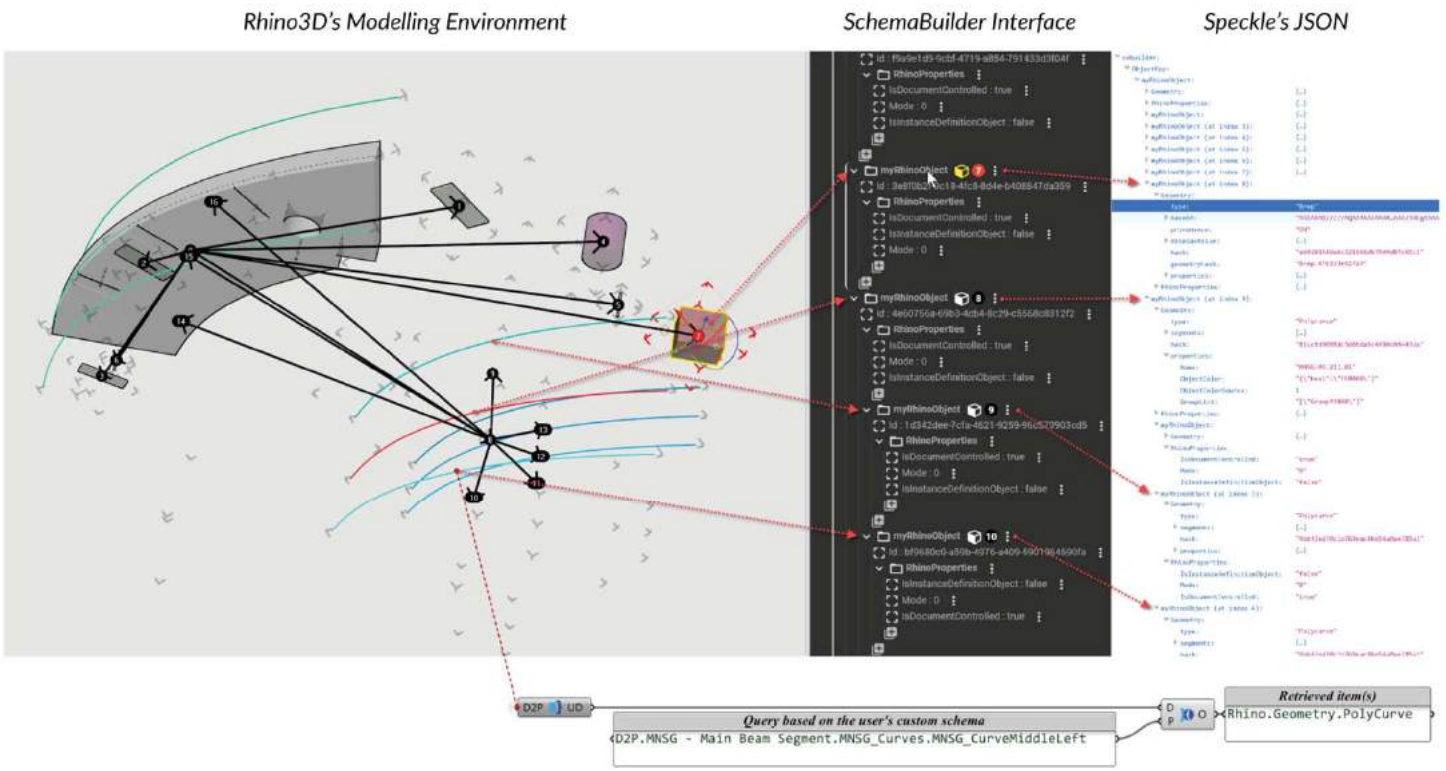
Neutral, Extensible Format

The need for extensible objects that are able to react to change and embed adjacent properties



Neutral, Extensible Format

The need for extensible objects that are able to react to change and embed adjacent properties

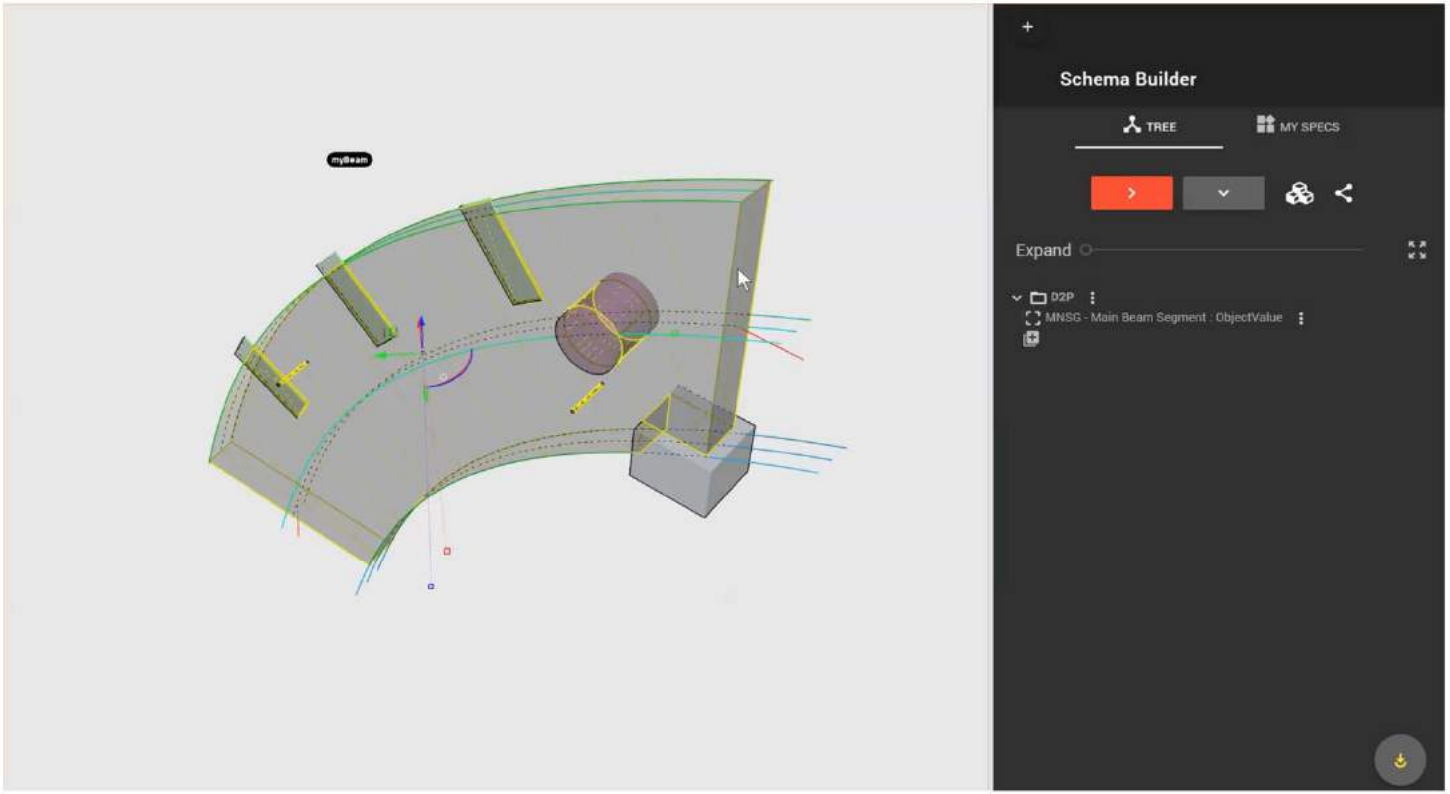


innochain CITA BUROHAPPOLD ENGINEERING

29-01-2019 - KADK

CITA

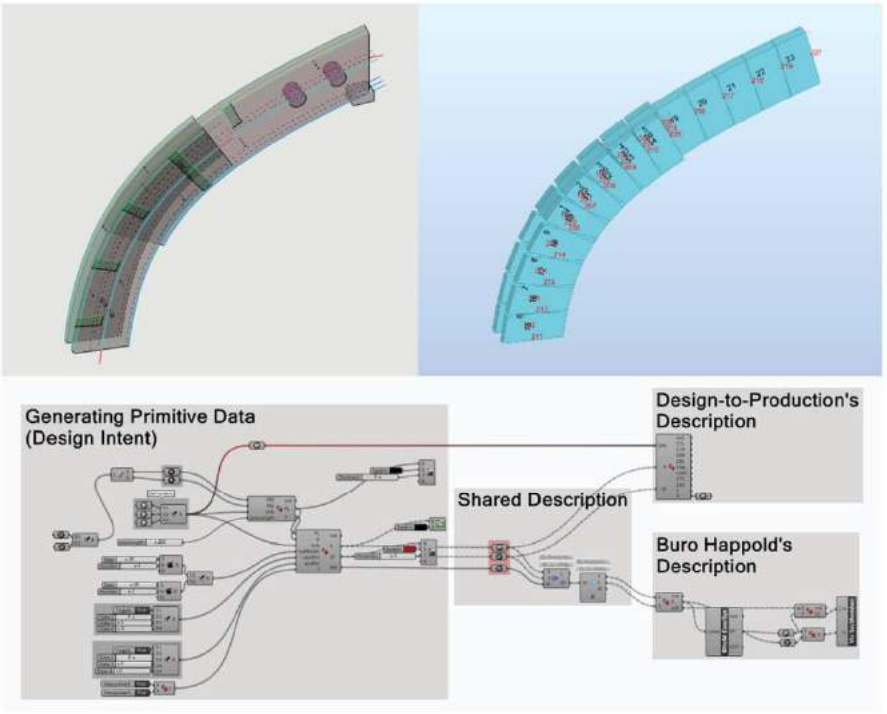
Case-study: setting up a D2P Beam-object through SchemaBuilder



CITA

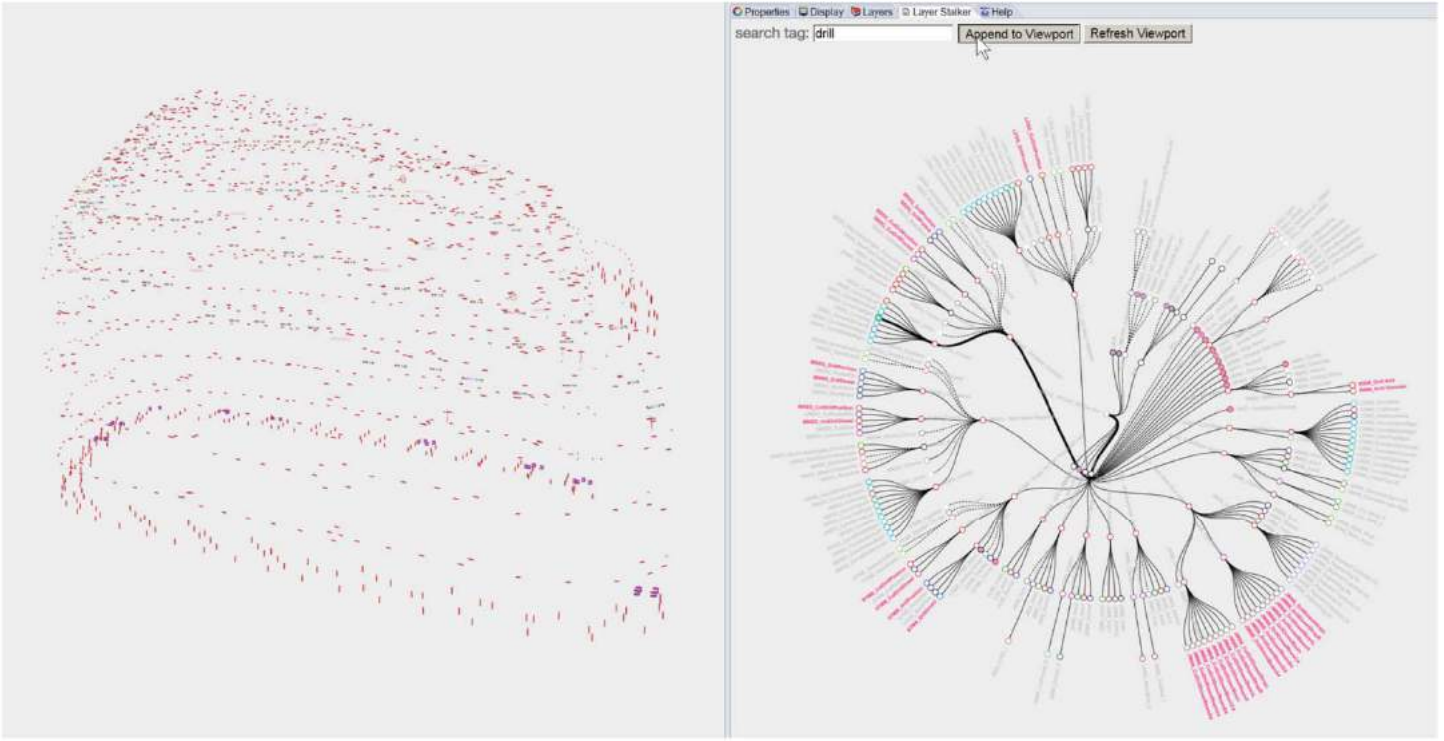
Cross-Practice Collaboration: sharing schemas through common descriptions

A speculative scenario between Buro Happold and Design-to-Production object descriptions



Mass Object Instanciation

Scaling up from the object level to the project level

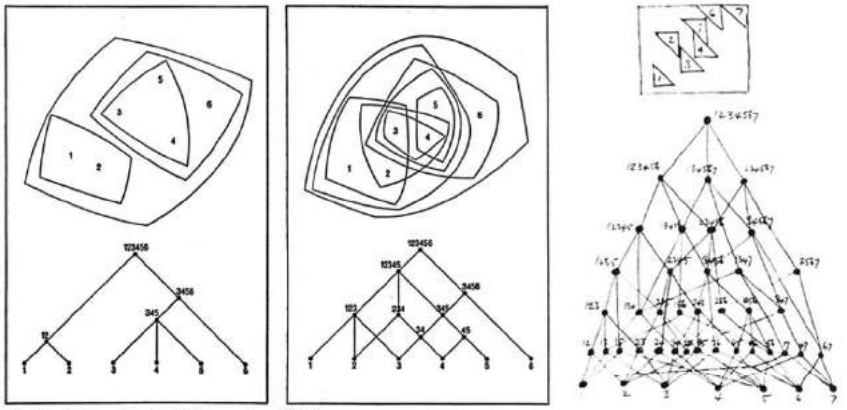


innochain CITA BUROHAPPOLD ENGINEERING

CITA

Christhopher Alexander on design patterns: "A City is Not a Tree."

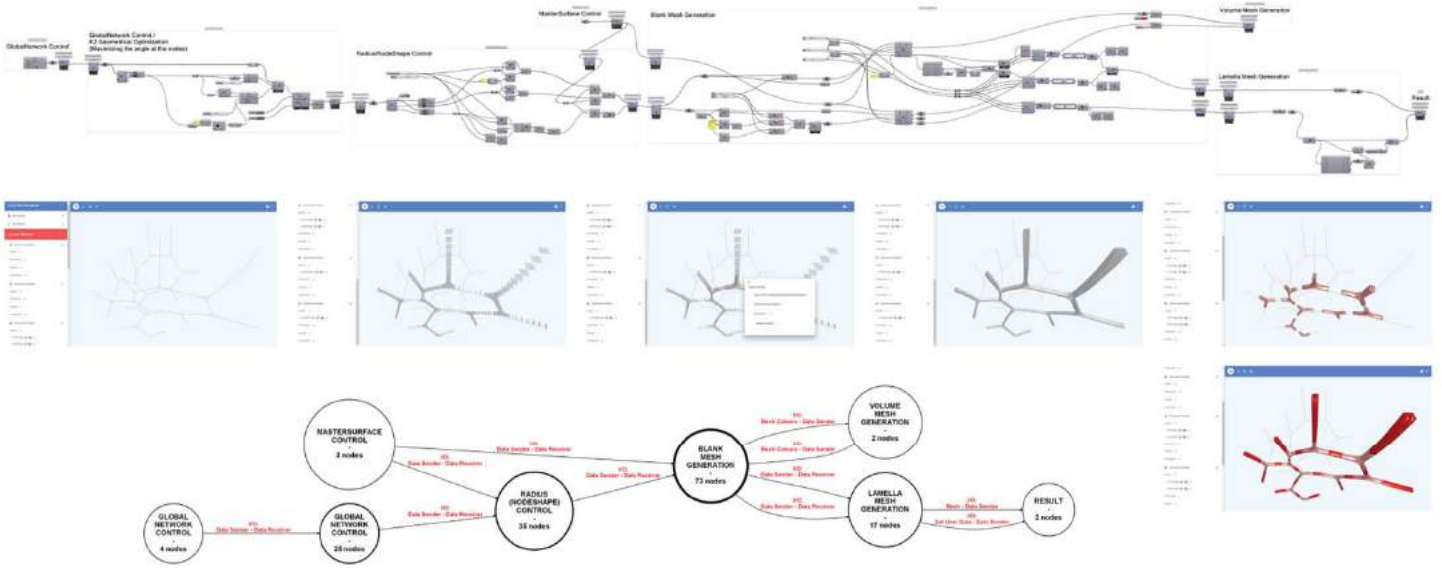
Shifting from a pure hierarchical model to a more decentralized model (here, the semilattice) in which persist many different implicit relationships.



"A City is Not a Tree" (C.Alexander, 1965)

Open Collaborative Design, Simulation & Analysis Flows

Case study at SimAUD 2018 (w/ Dimitrie Stefanescu)

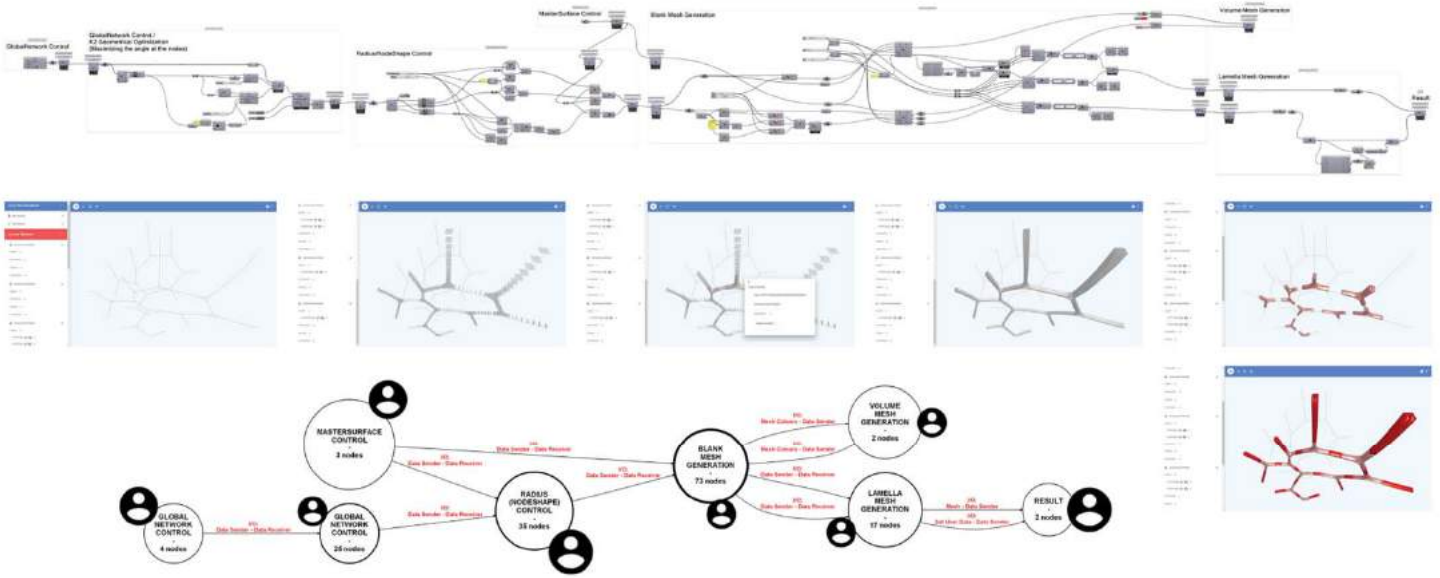


29-01-2019 - KADK

CITA

Open Collaborative Design, Simulation & Analysis Flows

Case study at SimAUD 2018 (w/ Dimitrie Stefanescu)



Open Collaborative Design, Simulation & Analysis Flows

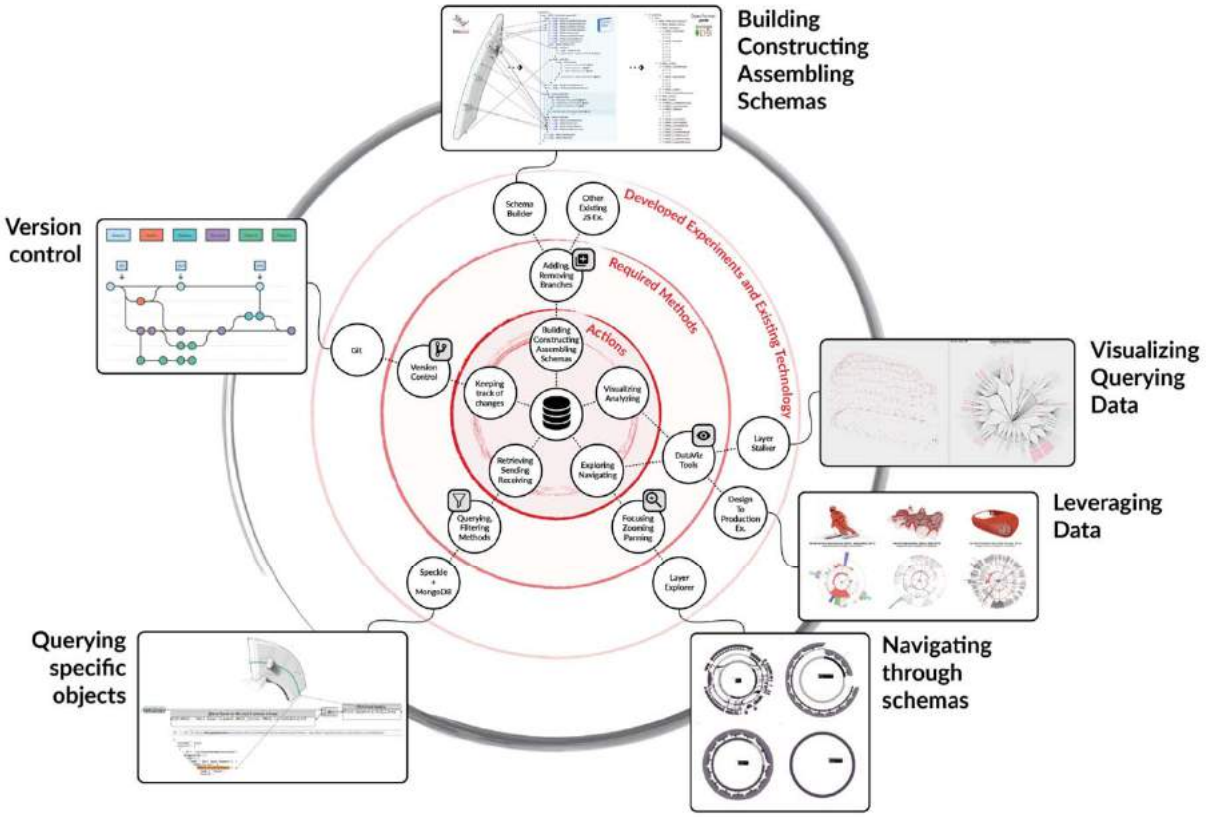
Case study at SimAUD 2018 (w/ Dimitrie Stefanescu)

innochain CITA BUROHAPPOLD ENGINEERING

29-01-2019 - KADK

CITA

Mapping and reflecting upon the experiments



CITA

What can we hope for the future?

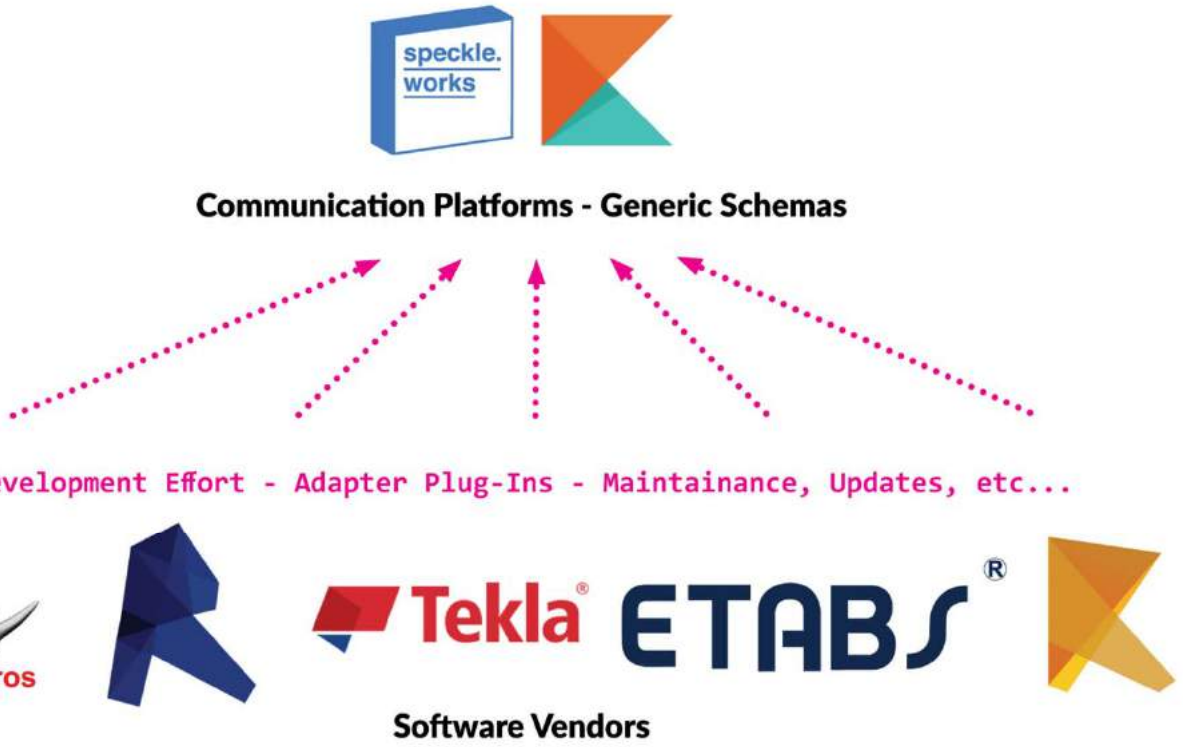
Development Effort - Adapter Plug-Ins - Maintainance, Updates, etc...

Communication Platforms
Generic Schemas

innochain CITA BUROHAPPOLD ENGINEERING

CITA

What can we hope for the future?



Three Perspectives

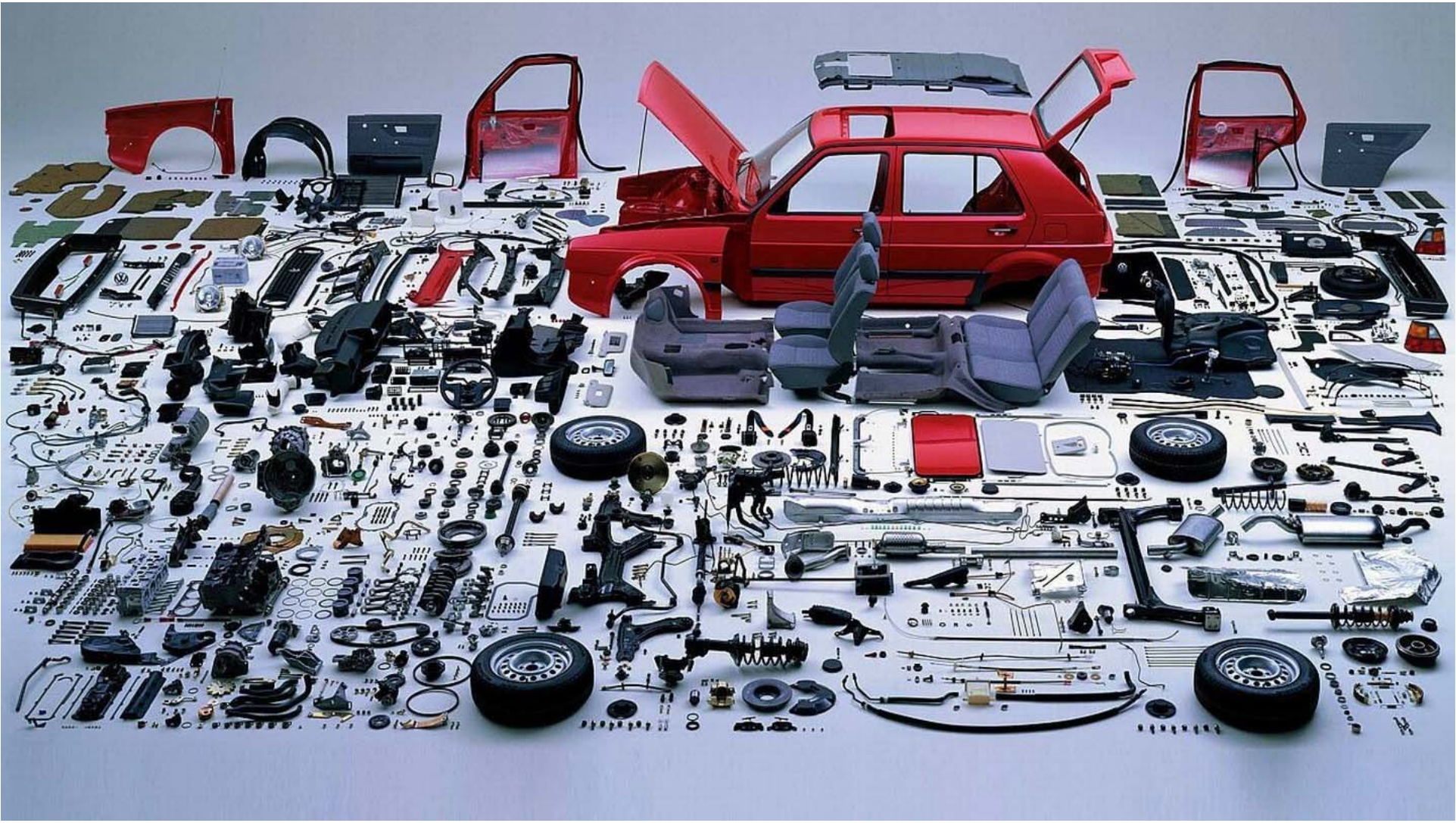
- Integrated multiscalar modelling practice
- Agency – Automatisation and Machine Intelligence
- Feedback - awareness of Environment

Assembly Information Modeling (AIM)

Ayoub Lharchi, Mette Ramsgaard Thomsen and Martin Tamke

Institution
Center of Information Technology and Architecture (CITA)
Royal Danish Academy of Fine Arts – Copenhagen, Denmark

CITA



European Commission

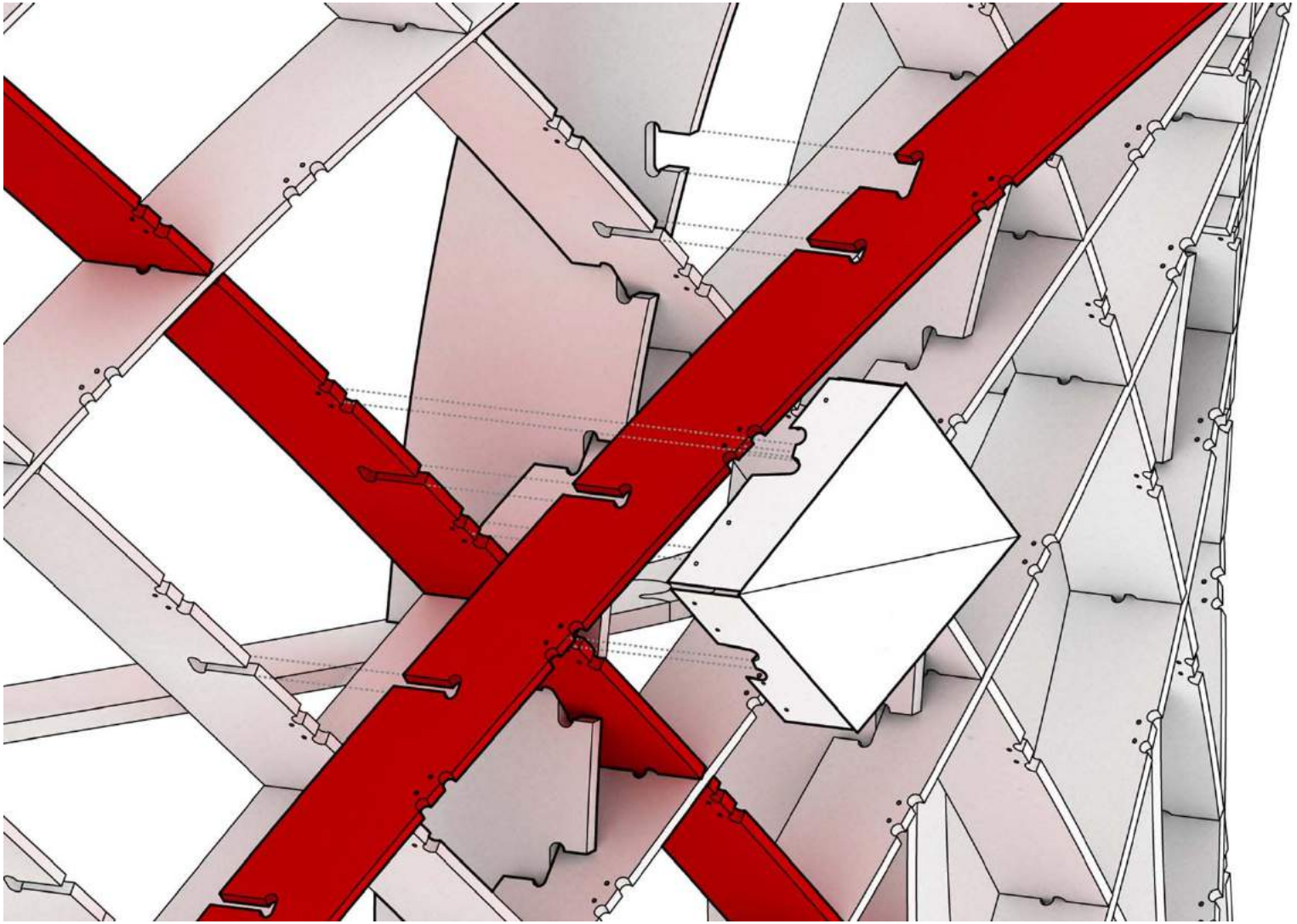
innochain CITA

Source: Blumer Lehman

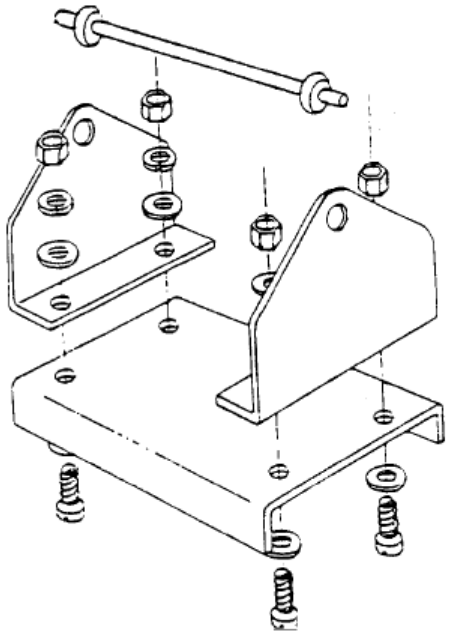
Source: Blumer Lehman

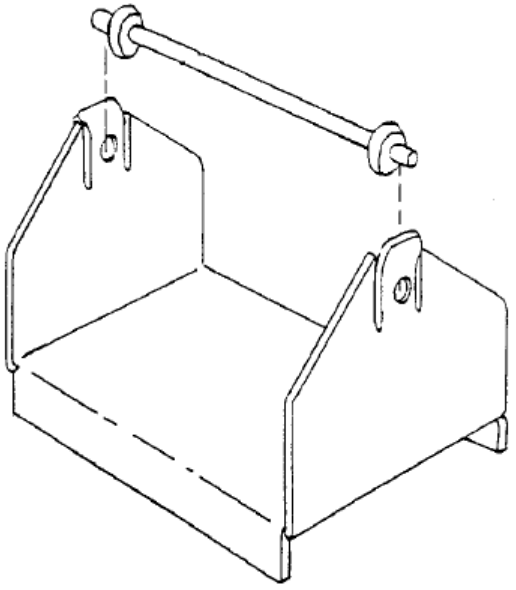
Source: Shigeru-Ban


Source: Blumer
Lehmann

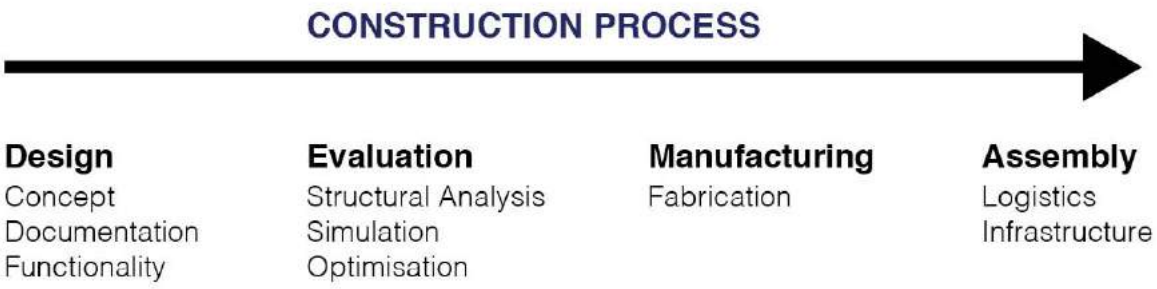


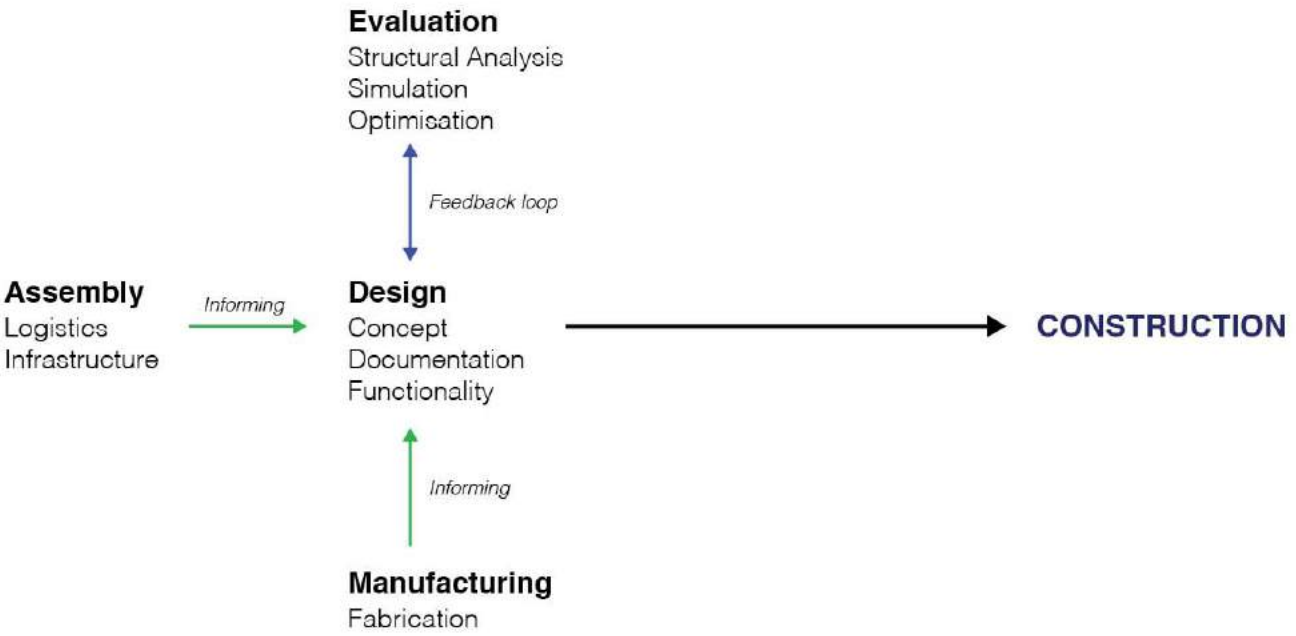
Courtesy: Design to Production



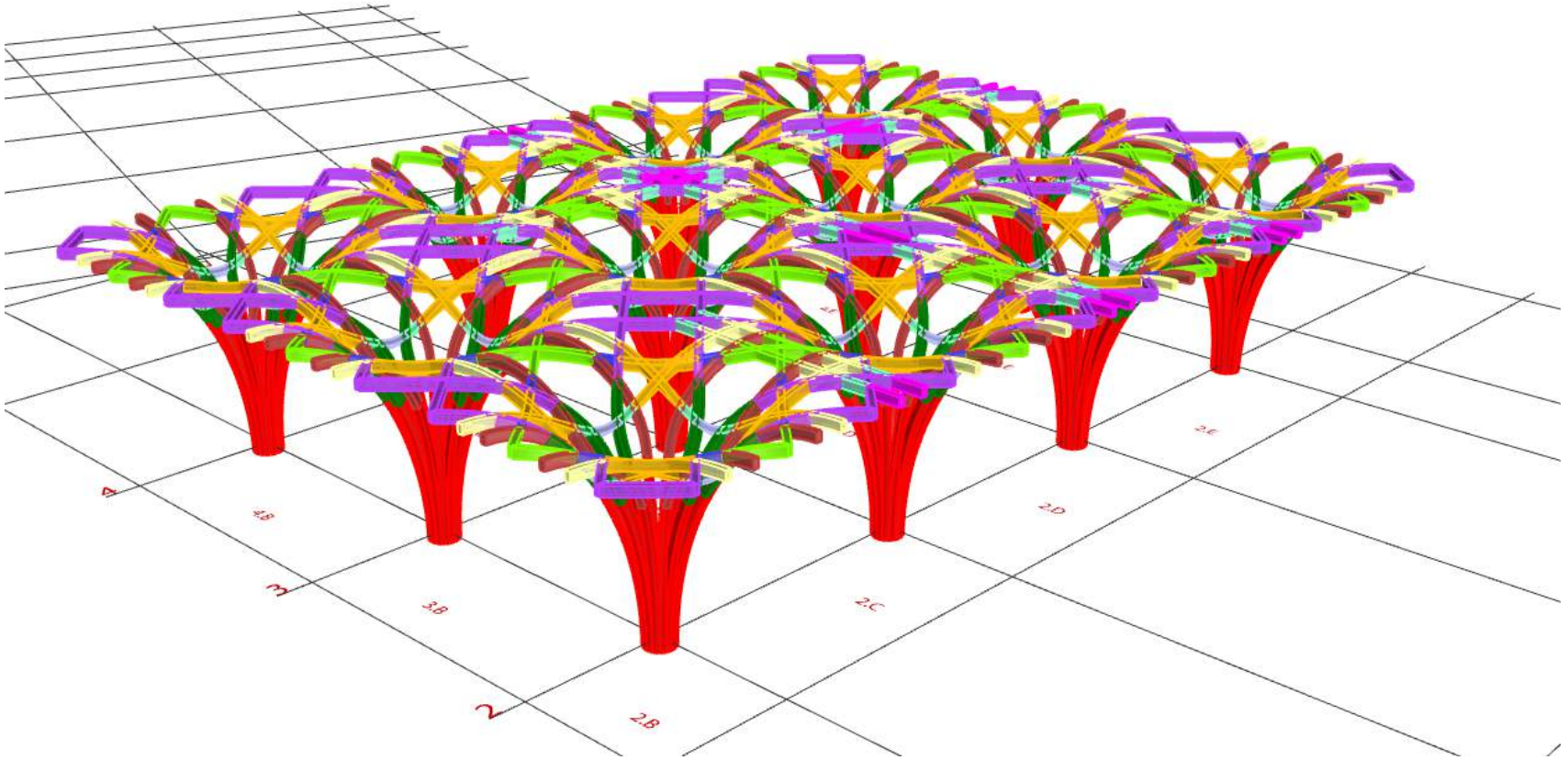


HOW CAN WE ENABLE ASSEMBLY DECISIONS IN THE EARLY DESIGN PHASES USING DIGITAL ASSEMBLY MODELS?

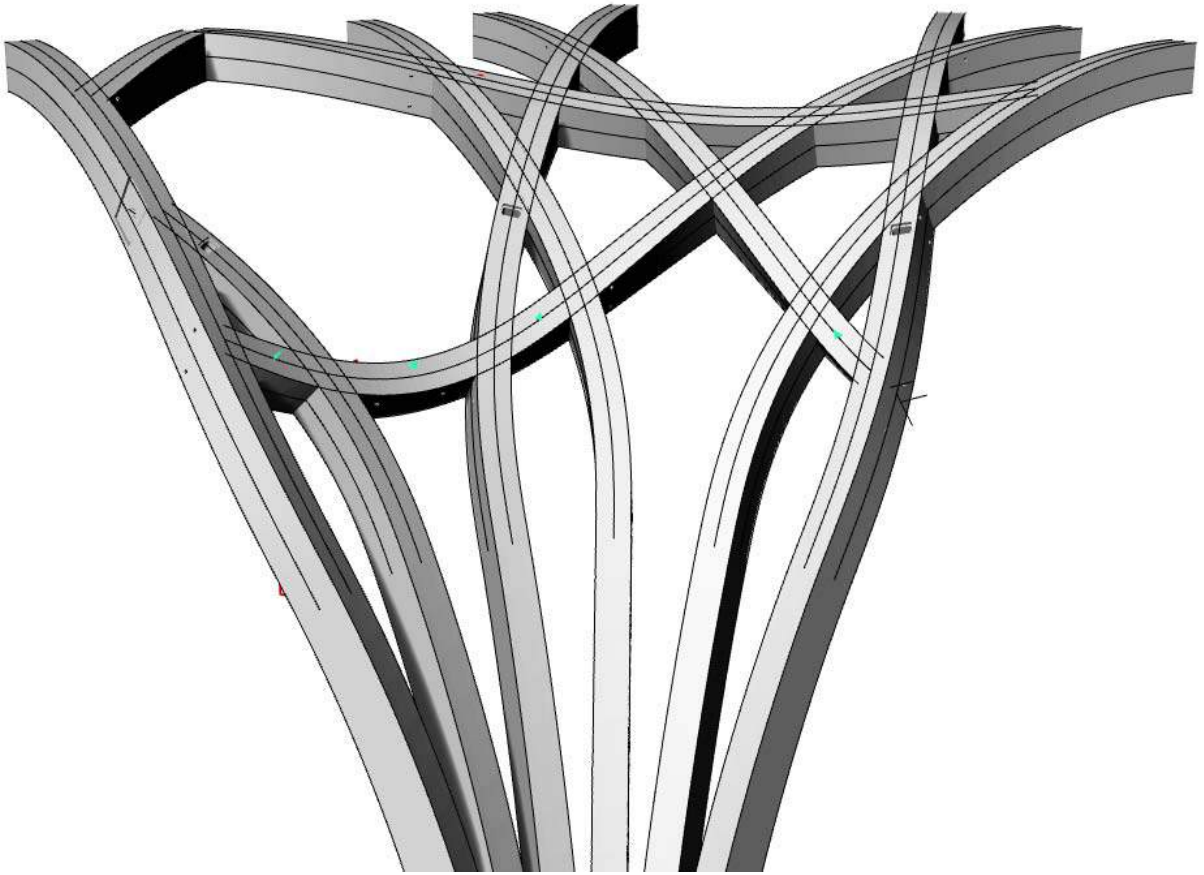

CONSTRUCTION PROCESS
Design
Concept
Documentation
Functionality
Evaluation
Structural Analysis
Simulation
Optimisation
Manufacturing
Fabrication
Assembly
Logistics
Infrastructure


Evaluation
Structural Analysis
Simulation
Optimisation
Feedback loop
Assembly
Logistics
Infrastructure
Informing
Design
Concept
Documentation
Functionality
CONSTRUCTION
Informing
Manufacturing
Fabrication

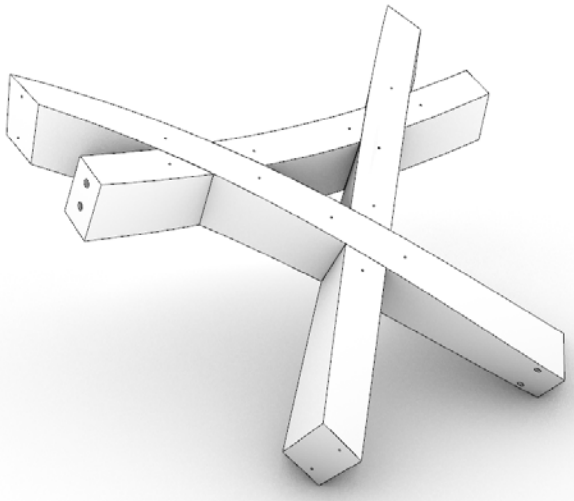
ASSEMBLY INFORMATION MODELING (AIM)

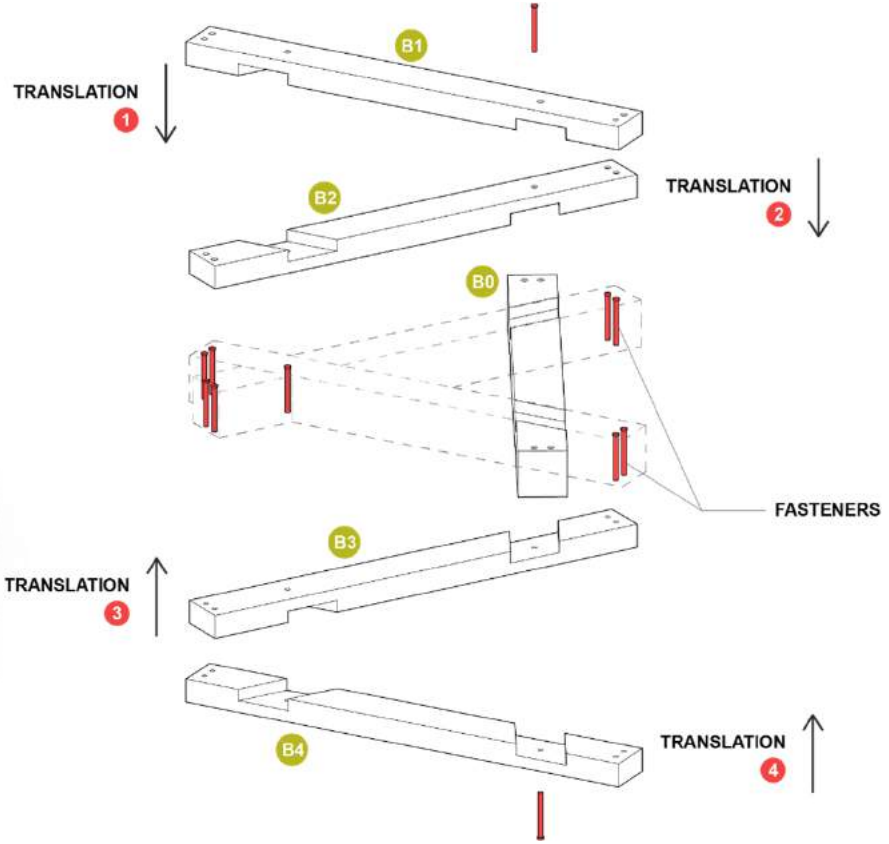


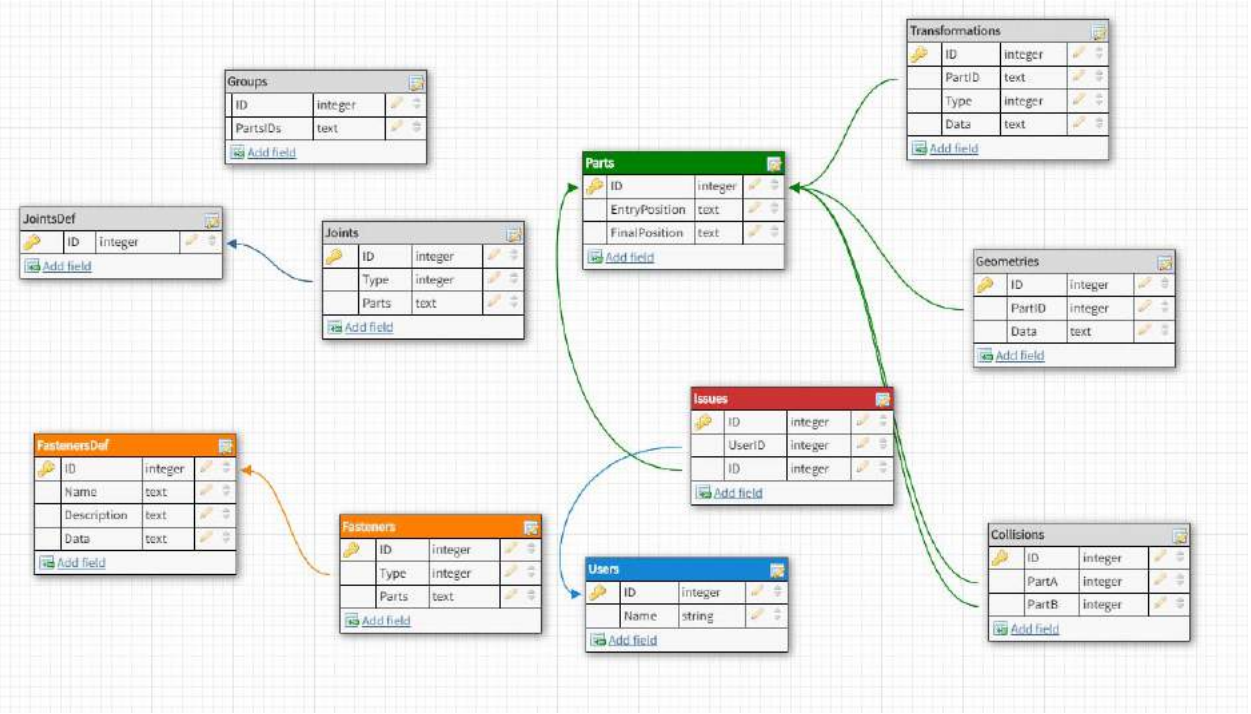
Source: Design To Production

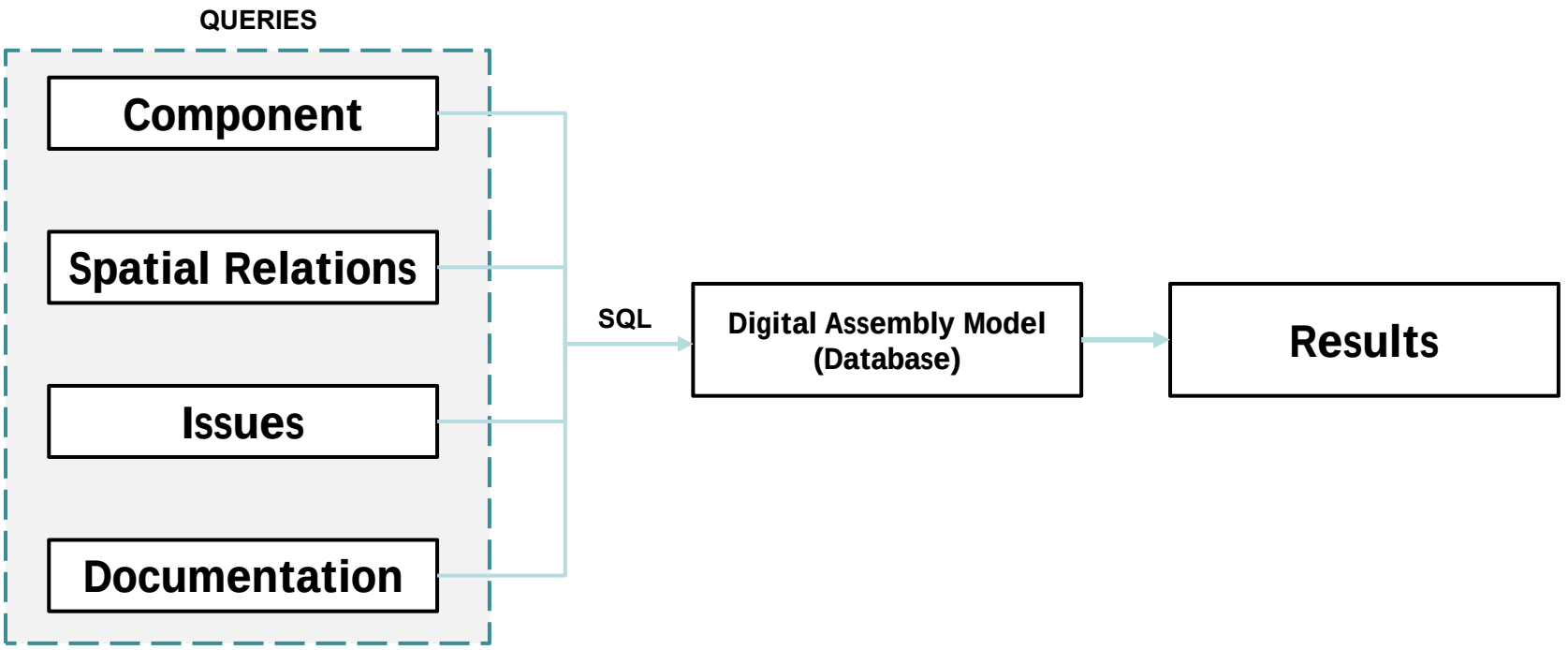


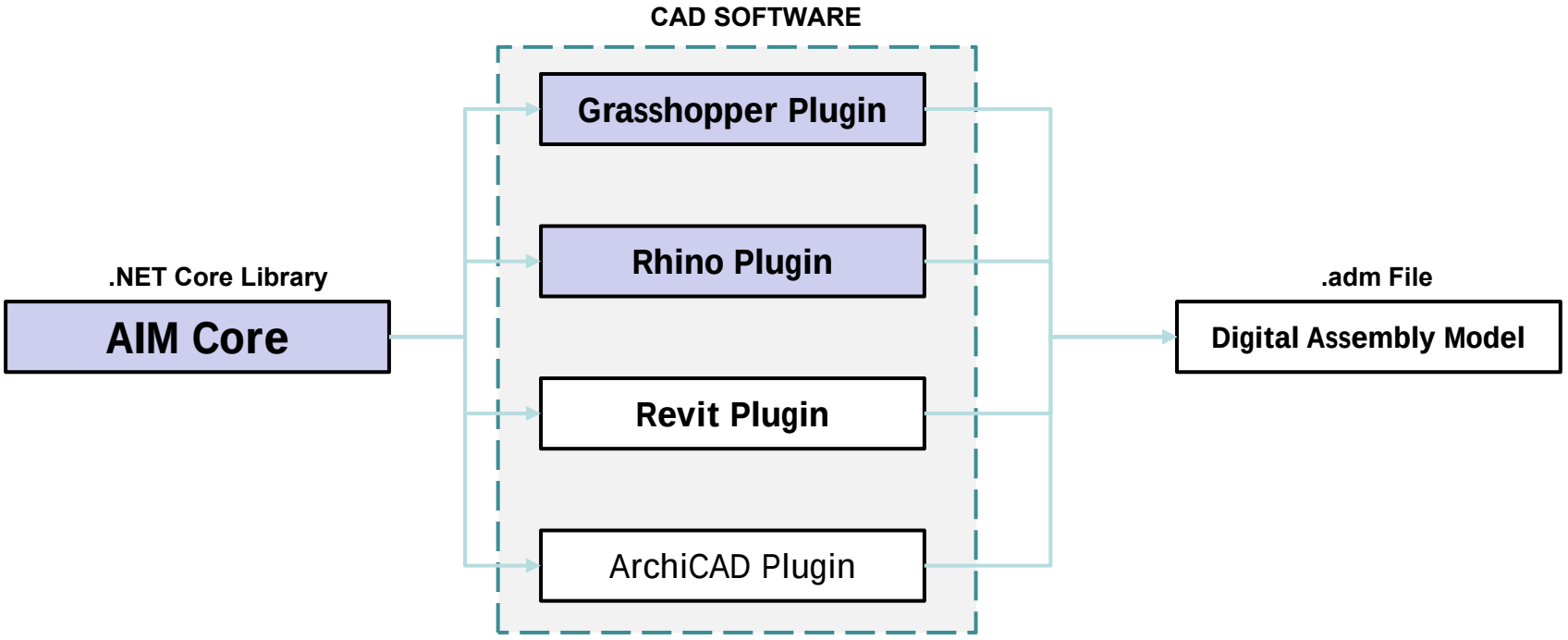
Source: Design To Production

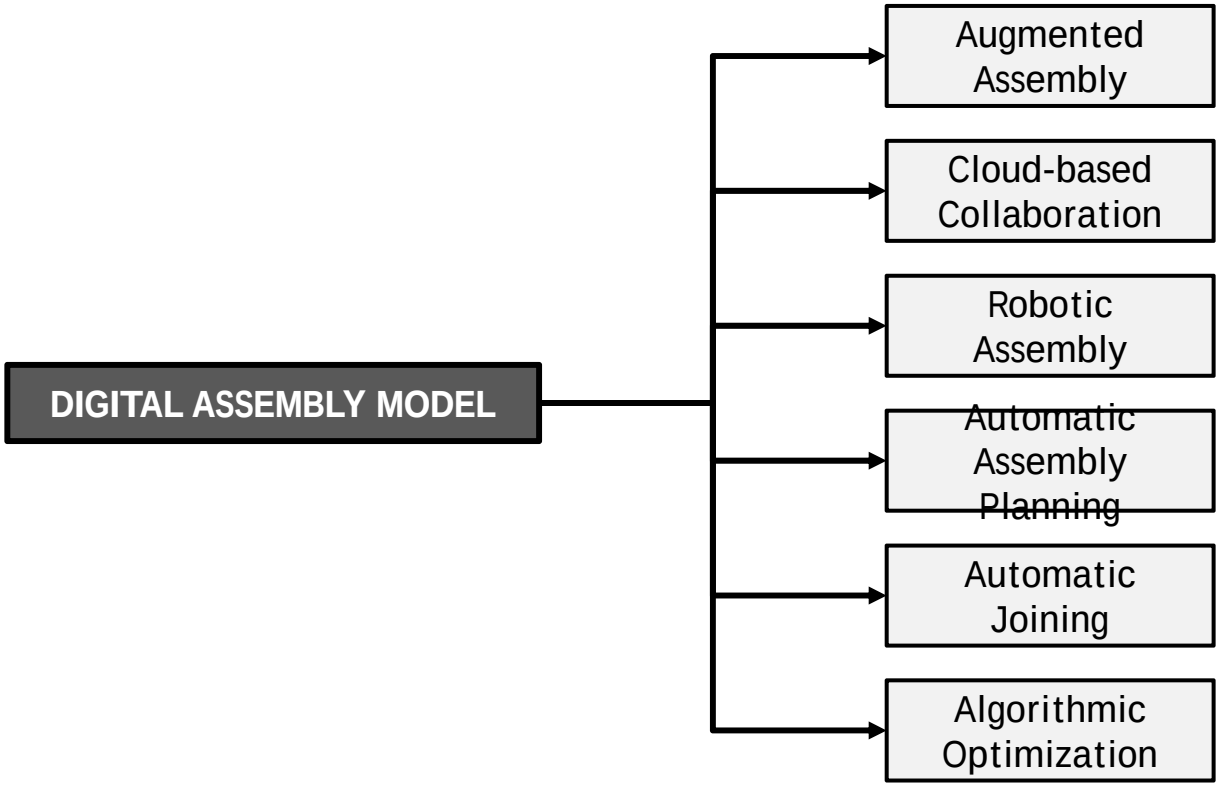





Groups
ID integer
PartsIDs text
Add field
Transformations
ID integer
PartID text
Type integer
Data text
Add field
Parts
ID integer
EntryPosition text
FinalPosition text
Add field
JointsDef
ID integer
Add field
Joints
ID integer
Type integer
Parts text
Add field
Geometries
ID integer
PartID integer
Data text
Add field
Issues
ID integer
UserID integer
ID integer
Add field
FastenersDef
ID integer
Name text
Description text
Data text
Add field
Fasteners
ID integer
Type integer
Parts text
Add field
Users
ID integer
Name string
Add field
Collisions
ID integer
PartA integer
PartB integer
Add field

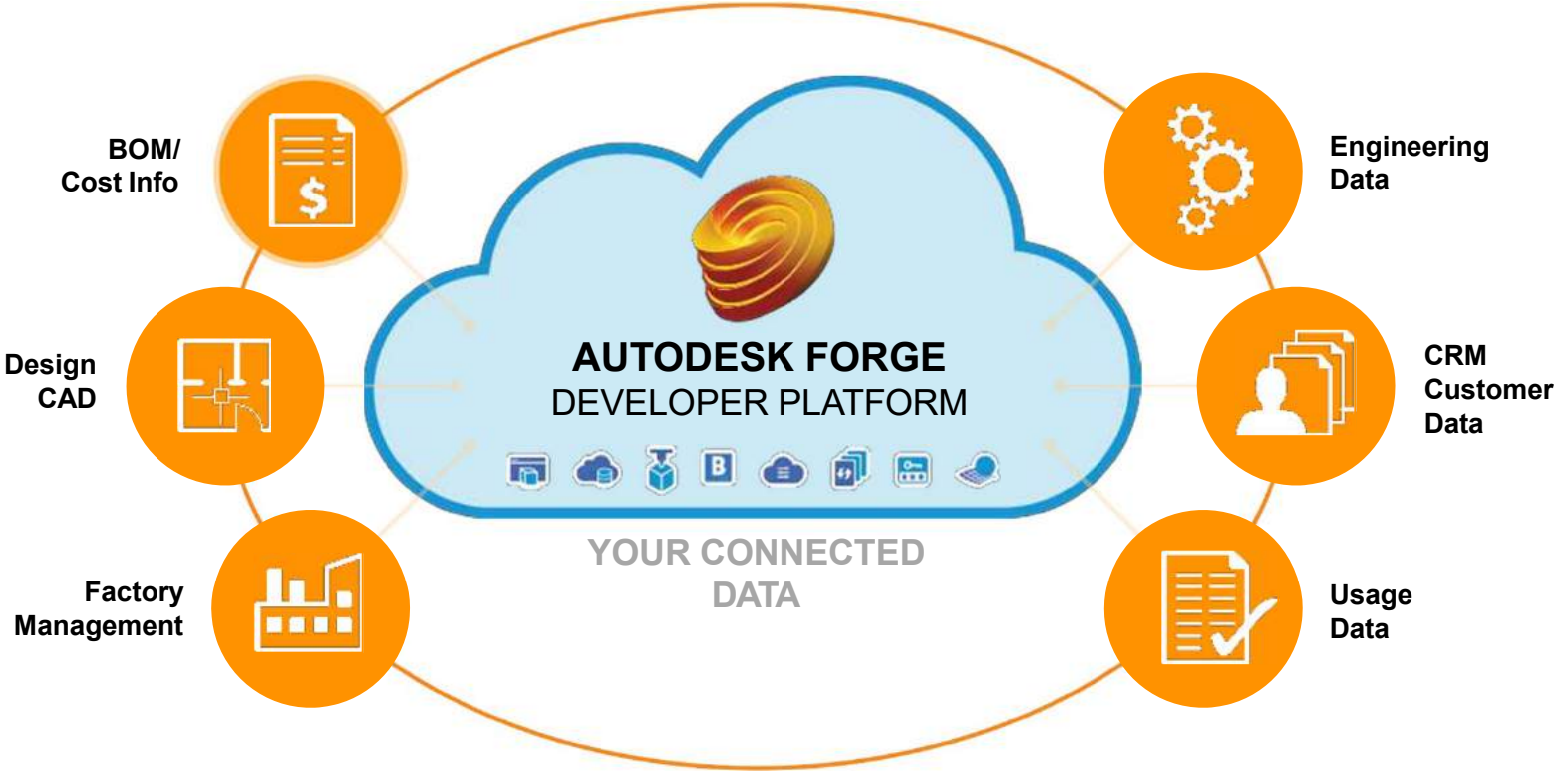

QUERIES
Component
Spatial Relations
Issues
Documentation
SQL
Digital Assembly Model
(Database)
Results


CAD SOFTWARE
Grasshopper Plugin
Rhino Plugin
Revit Plugin
ArchiCAD Plugin
.NET Core Library
AIM Core
.adm File
Digital Assembly Model



Potentials use of the Digital Assembly Model

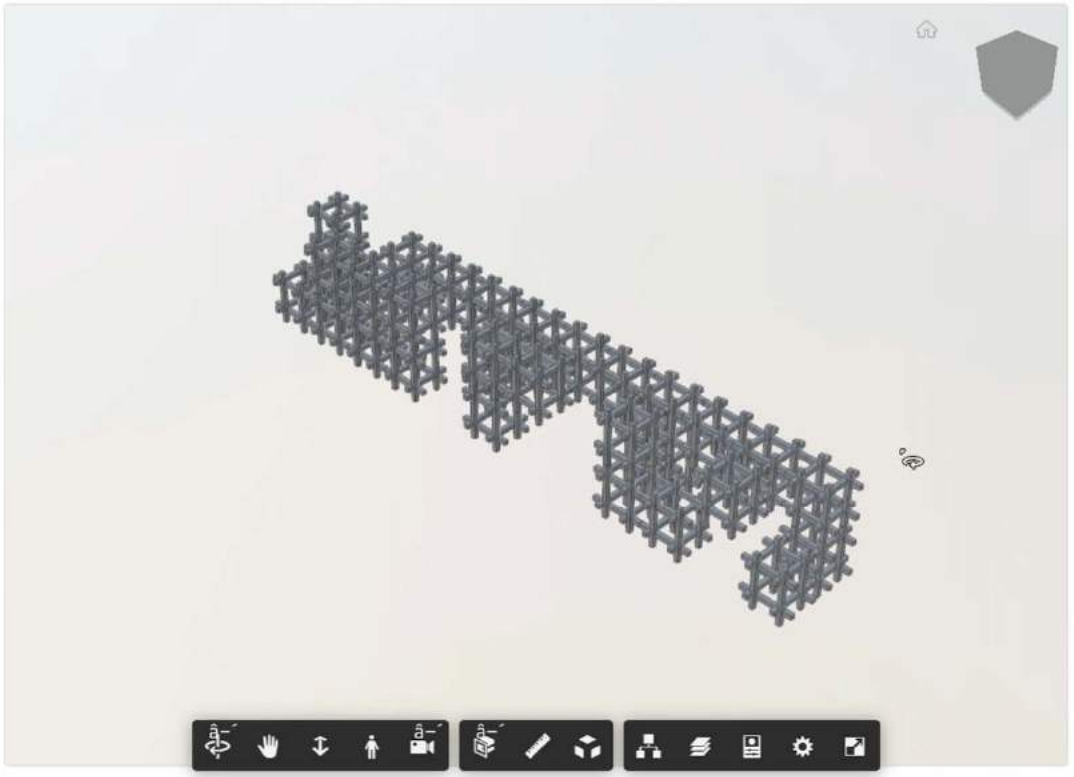
CLOUD BASED COLLABORATION


BOM/
Cost Info
Design
CAD
Factory
Management
AUTODESK FORGE
DEVELOPER PLATFORM
YOUR CONNECTED
DATA
Engineering
Data
CRM
Customer
Data
Usage
Data

AIM Manager

- Home
- Assembly Models
- Parts
- Fasteners
- Joints
- Viewer
- Issues
- Export

Viewer

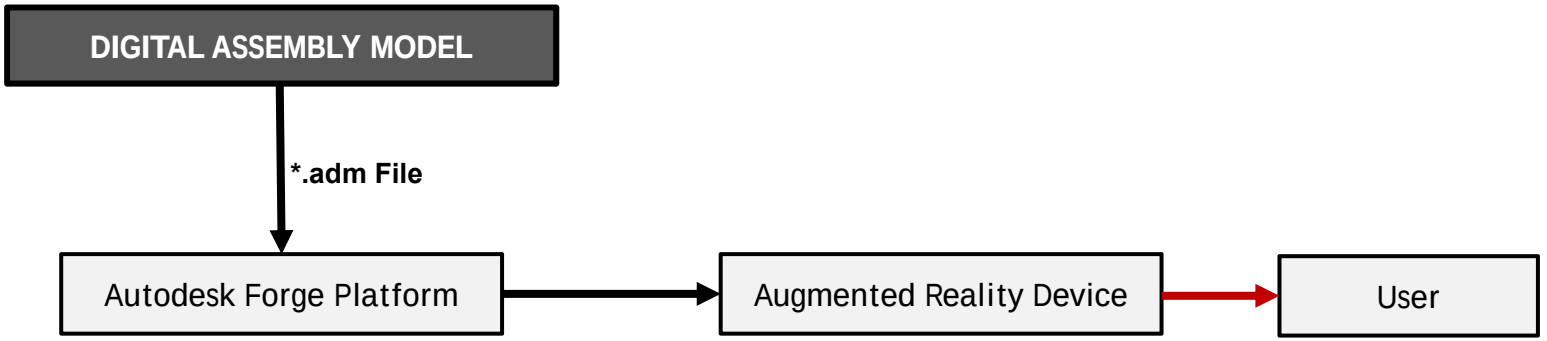


Tools

- Get Drawings
- Get Relations
- Isolate
- Issue

European Commission
innochain CITA

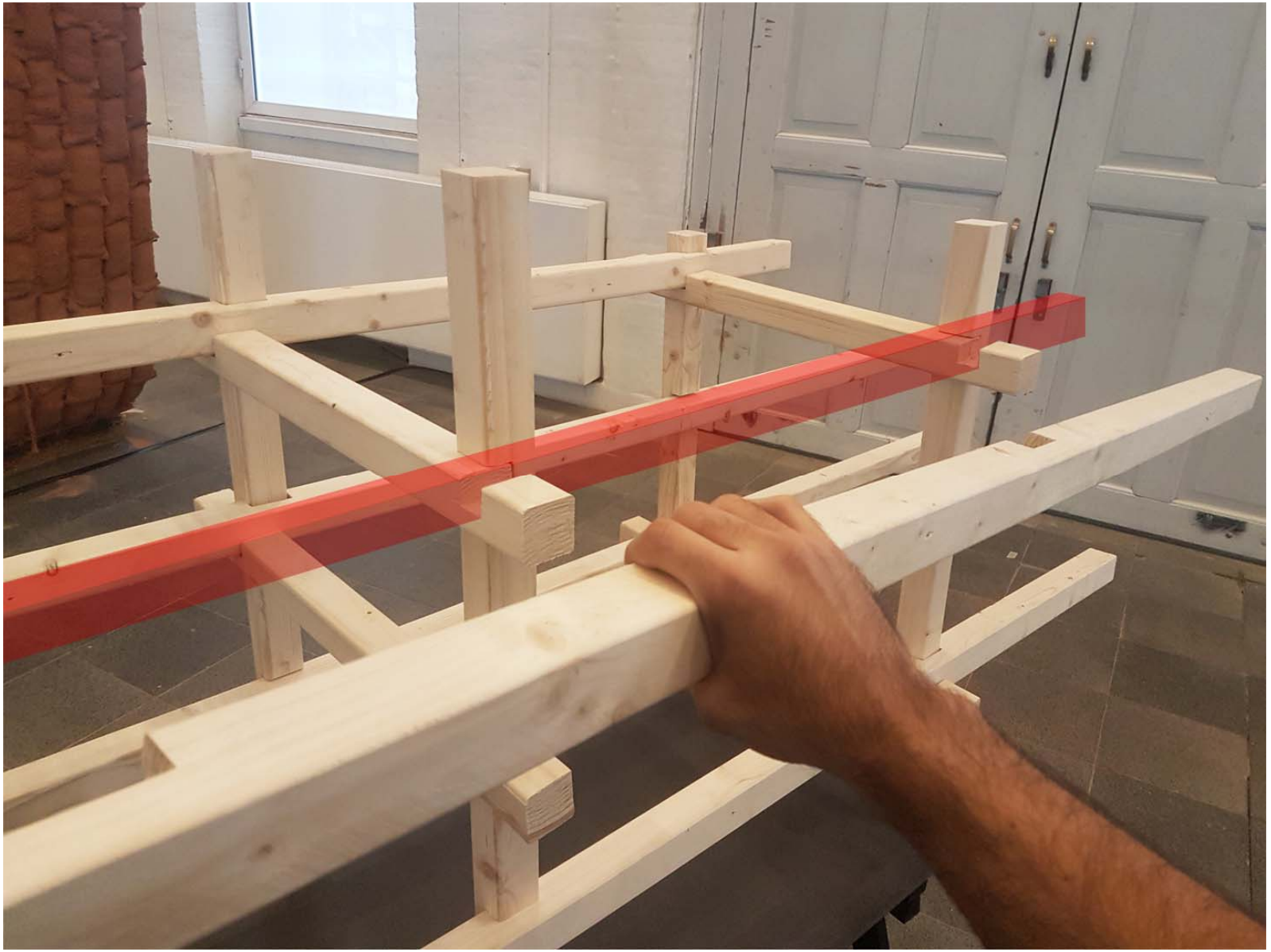
AUGMENTED ASSEMBLY



OVERVIEW OF THE AUGMENTED REALITY SCHEME

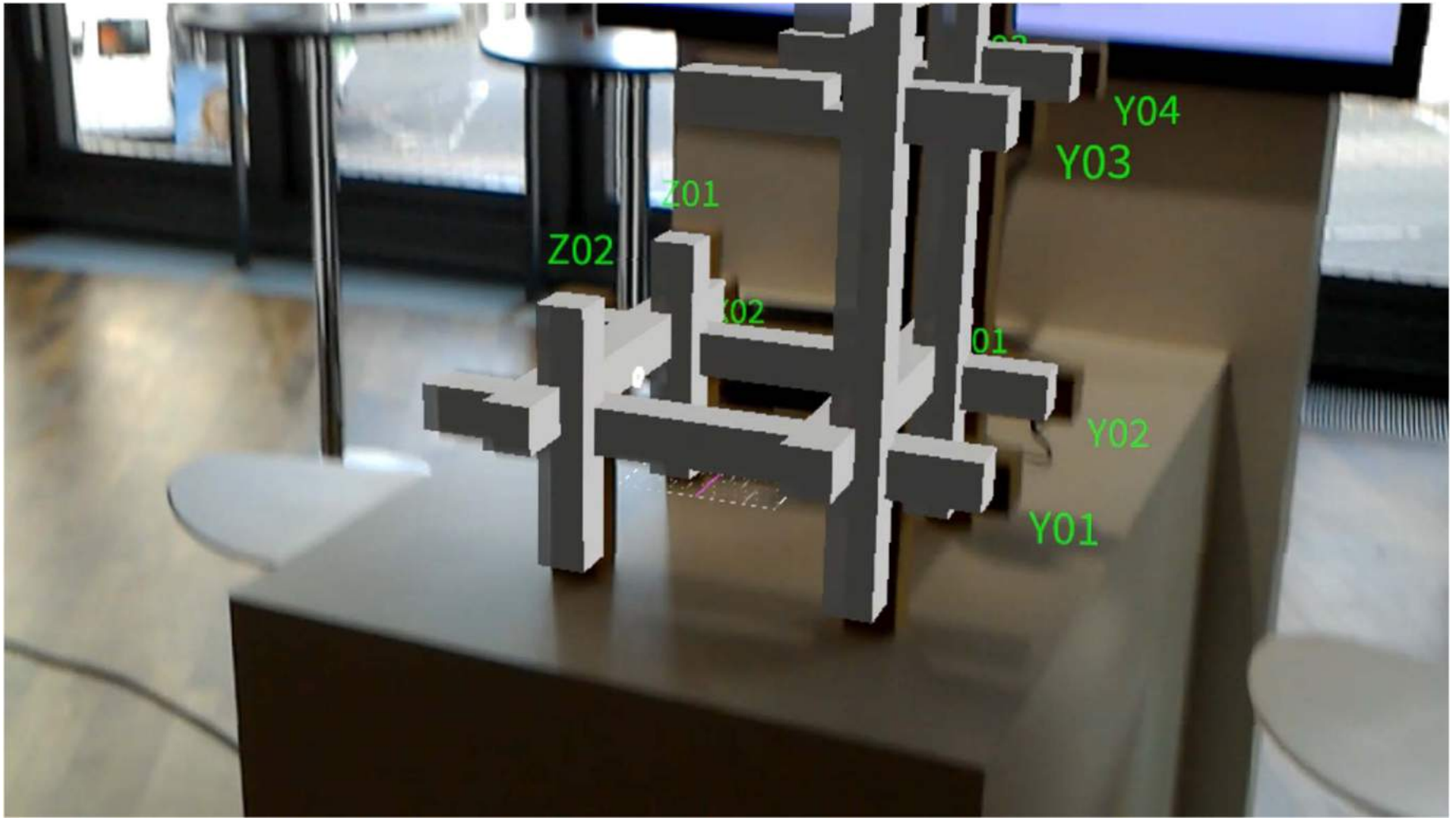
European Commission

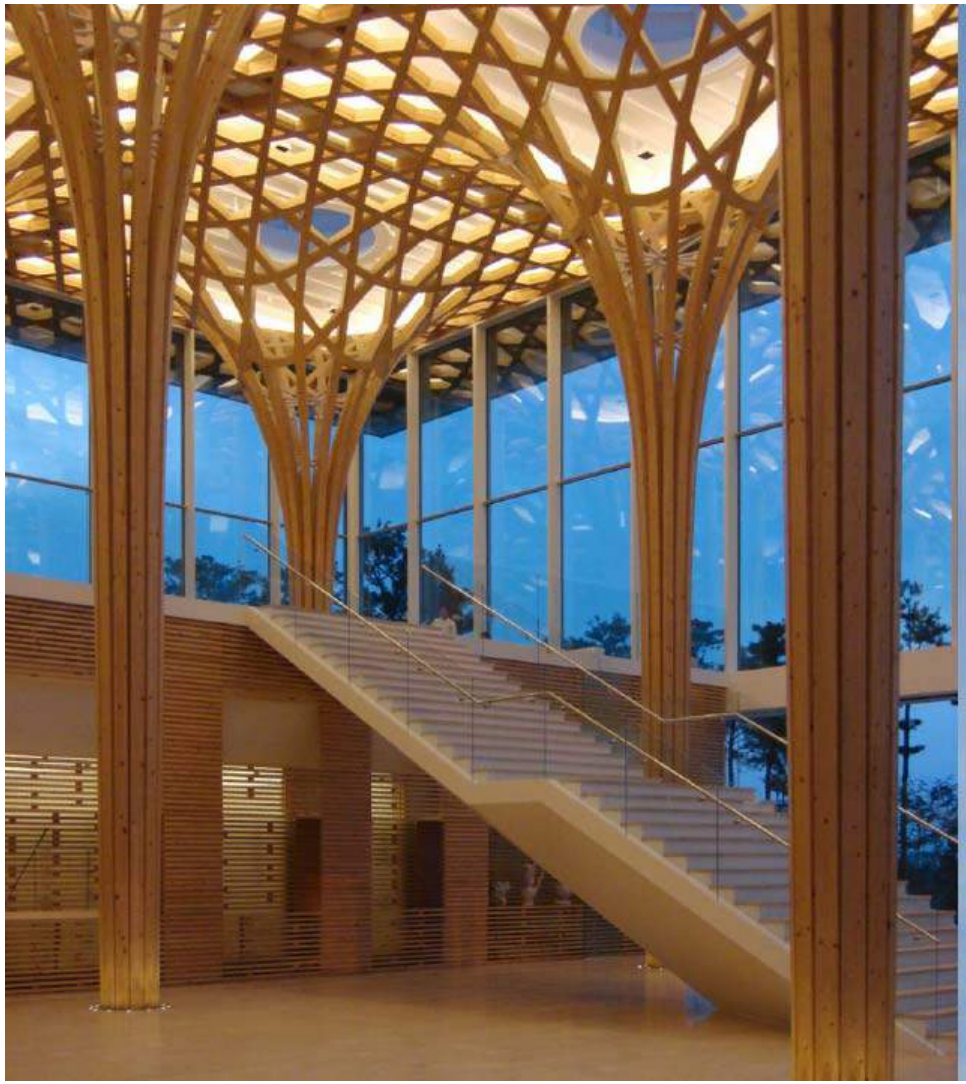
innochain CITA



European Commission

innochain CITA


Y04
Y03
Z01
Z02
Y02
Y01

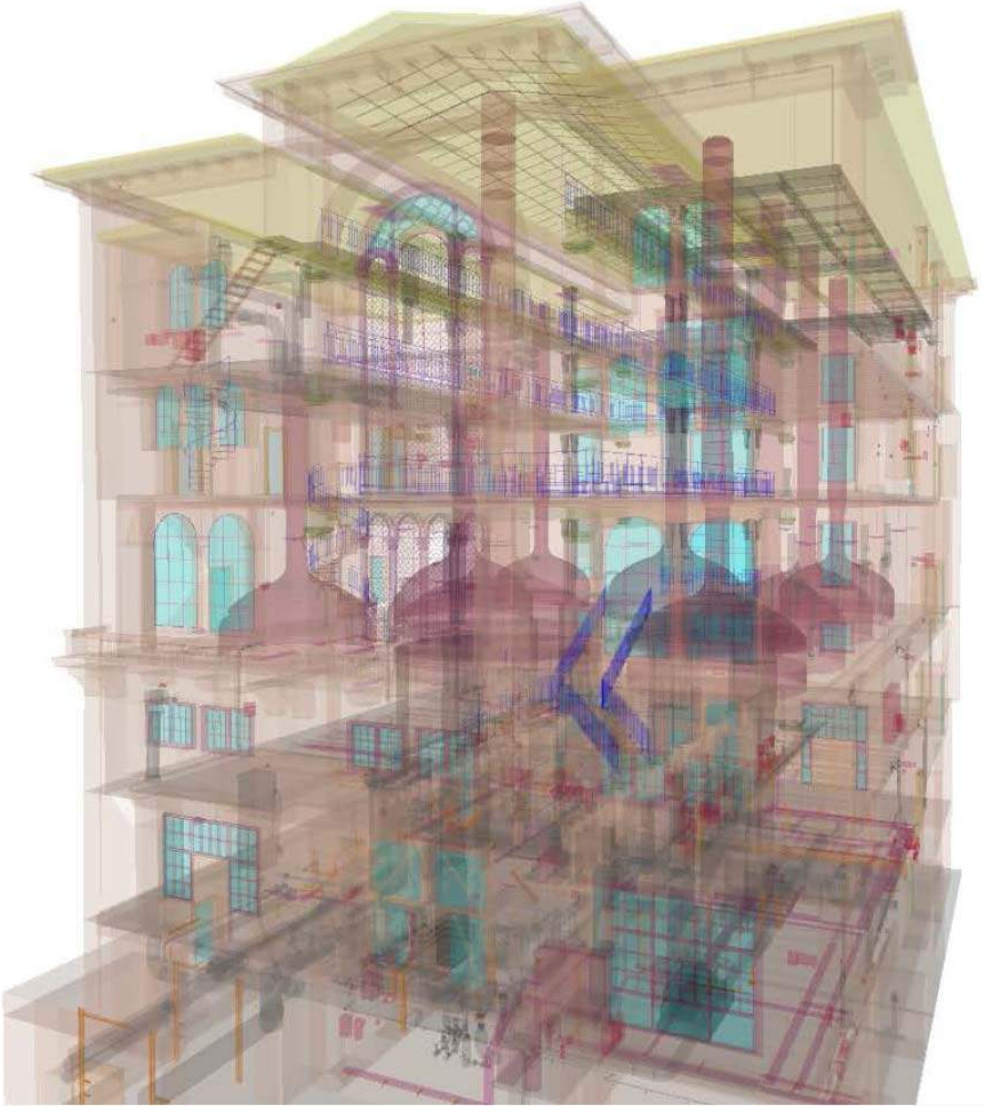


European Commission

innochain CITA

Three Perspectives

- Integrated multiscalar modelling practice
- Agency – Automatisation and Machine Intelligence
- Feedback - awareness of Environment



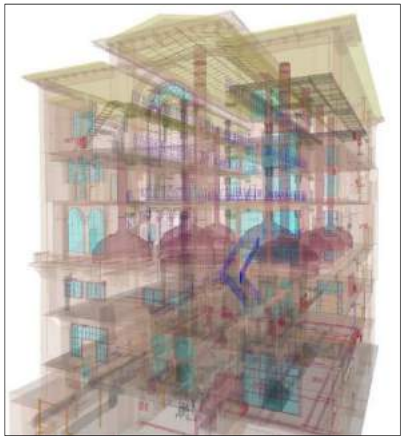
Carlsberg Brewery/Copenhagen Source LE34

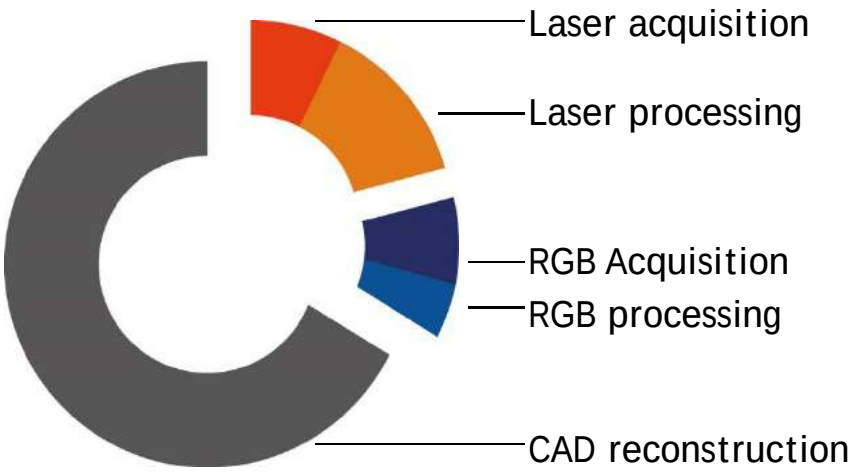
Feedback: Semantically Poor and Rich Data

European Commission

DURAARK DURABLE ARCHITECTURAL KNOWLEDGE

CITA

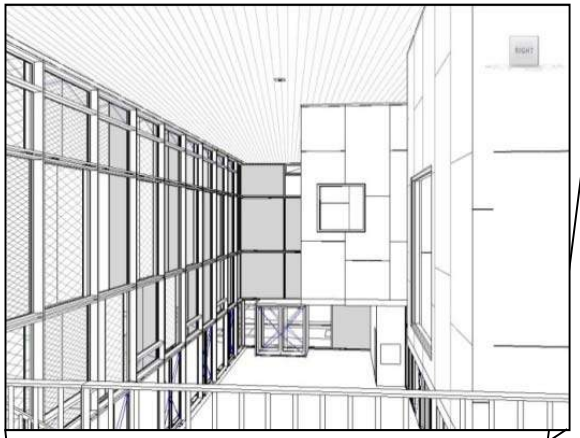




source: J.-F. Hullo, G. Thibault, C. Boucheny (2015) Advances in multi-sensor scanning and visualization of complex plants: the utmost case of a reactor building. In: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-5/W4, 2015

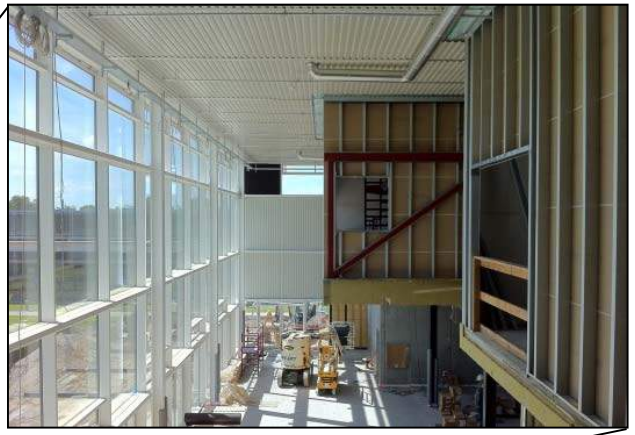
Global Time allocation for creation of Architectural Data from 3D Laserscans

Workflows with Point Clouds - The challenge

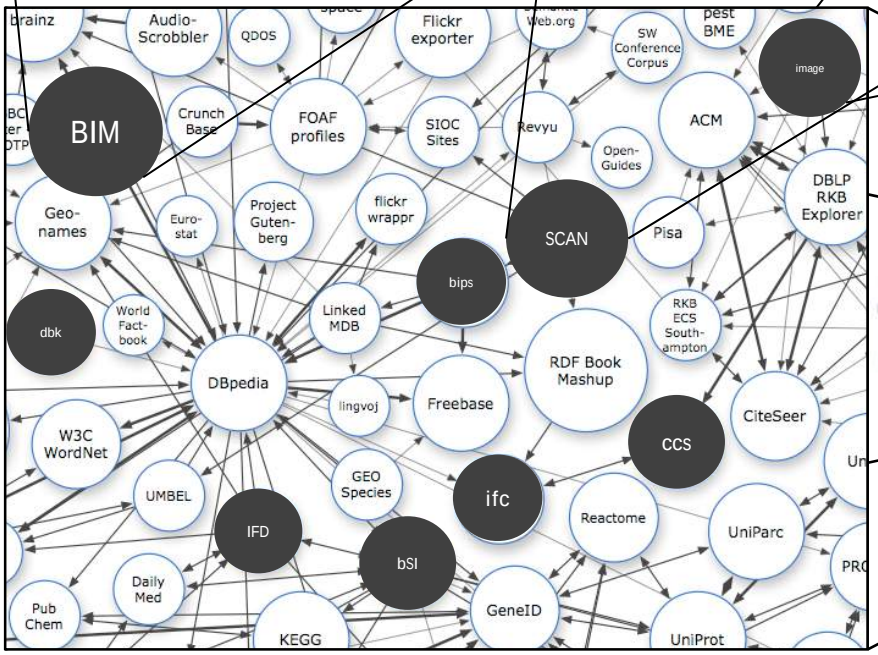


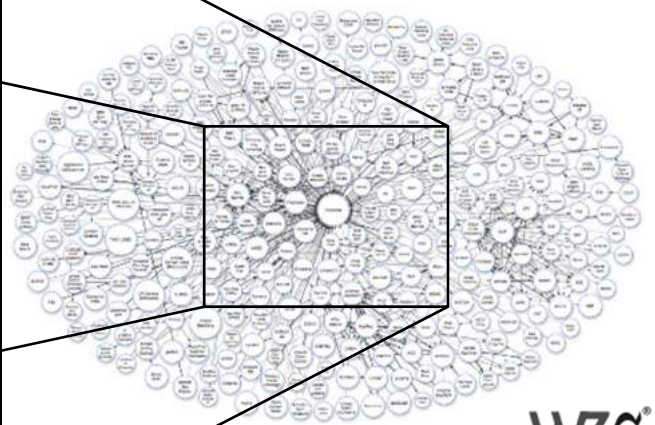
BIM

Scan



Foto





W3C Semantic Web

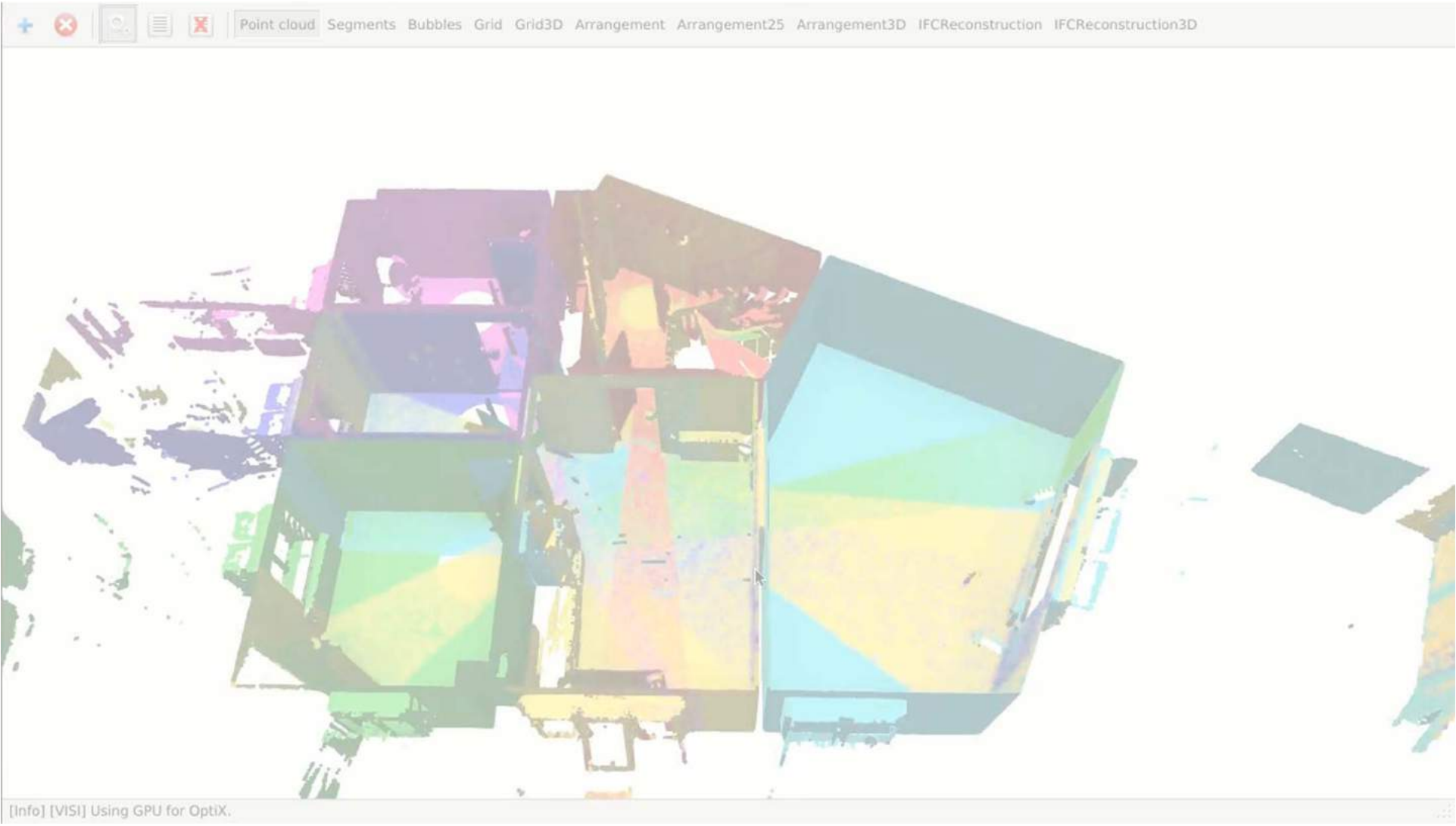
DURAARK

Create semantic linkage with web technologies

European Commission

DURAARK DURABLE ARCHITECTURAL KNOWLEDGE

CITA



Automatic Reconstruction - Point Cloud to BIM

European Commission

DURAARK
DURABLE
ARCHITECTURAL
KNOWLEDGE

CITA

Automatic Reconstruction - Point Cloud to BIM

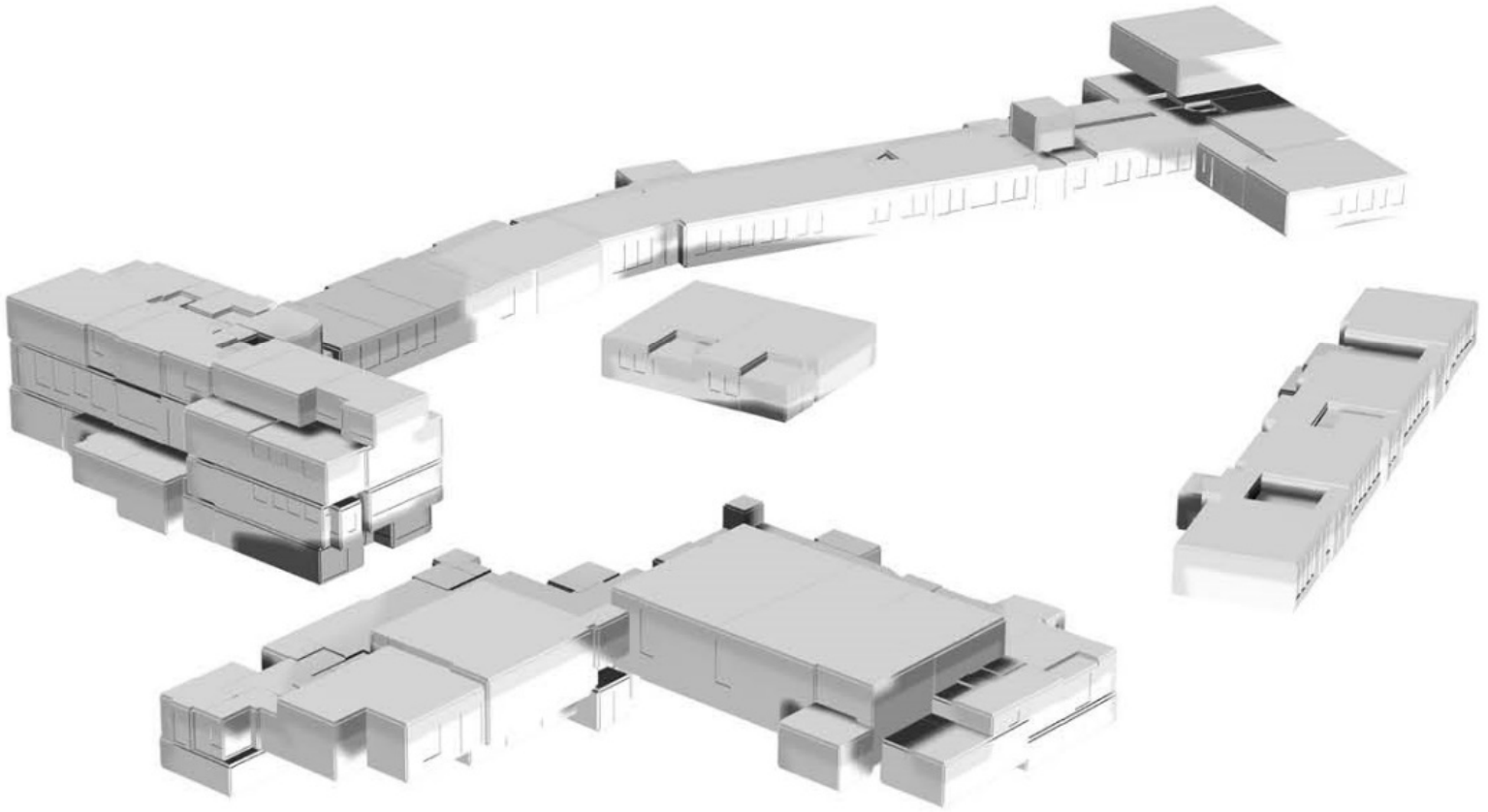
359 scans
Screenshot from a subsampled version loaded into Volvox
(Rhino Grasshoper Plugin) with 84 Mio. Points

Automatic Reconstruction - Point Cloud to BIM

European Commission

DURAARK
DURABLE
ARCHITECTURAL
KNOWLEDGE

CITA



Automatic reconstruction of BIM model from PointCloud.
Resulting BIM model (output as IFC Format).
Time needed for automated reconstruction: 10min per Floor/Building

Automatic Reconstruction – Cad-Q Højskolan

European Commission

DURAARK
DURABLE
ARCHITECTURAL
KNOWLEDGE

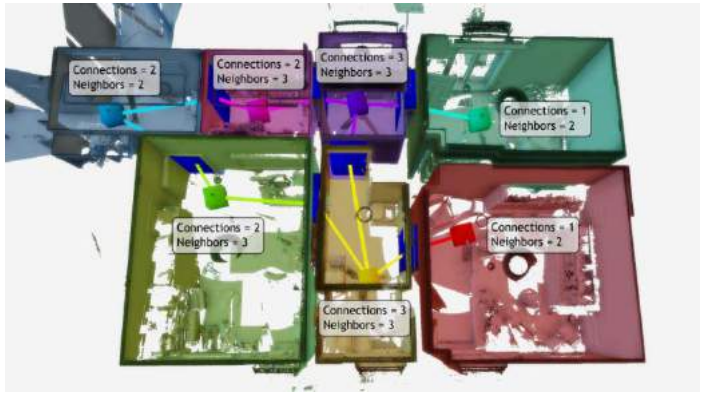
CITA

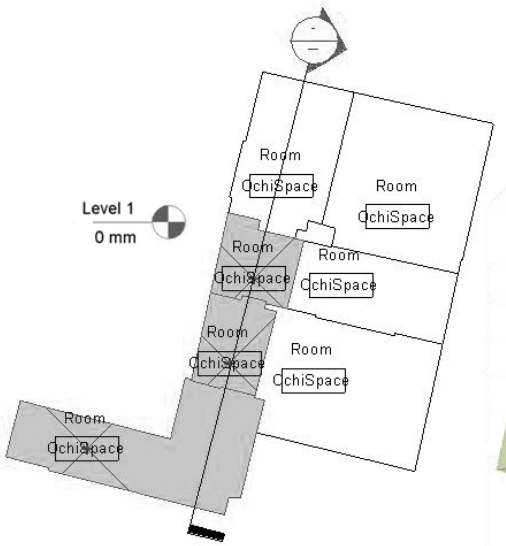
Detection of Spaces / Room Connectivity

European Commission

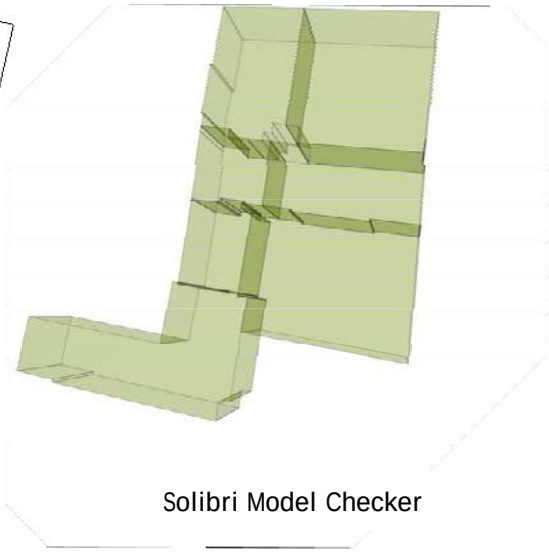
DURAARK
DURABLE
ARCHITECTURAL
KNOWLEDGE

CITA



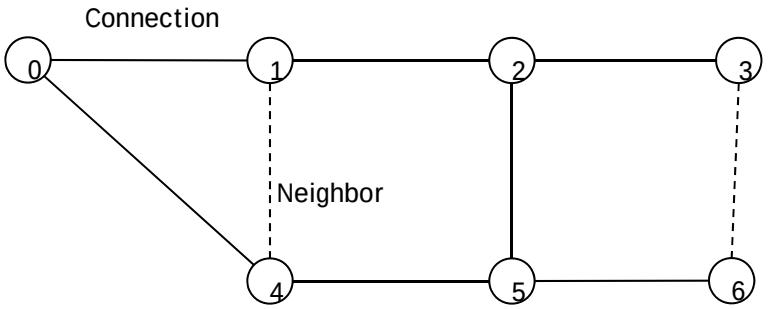


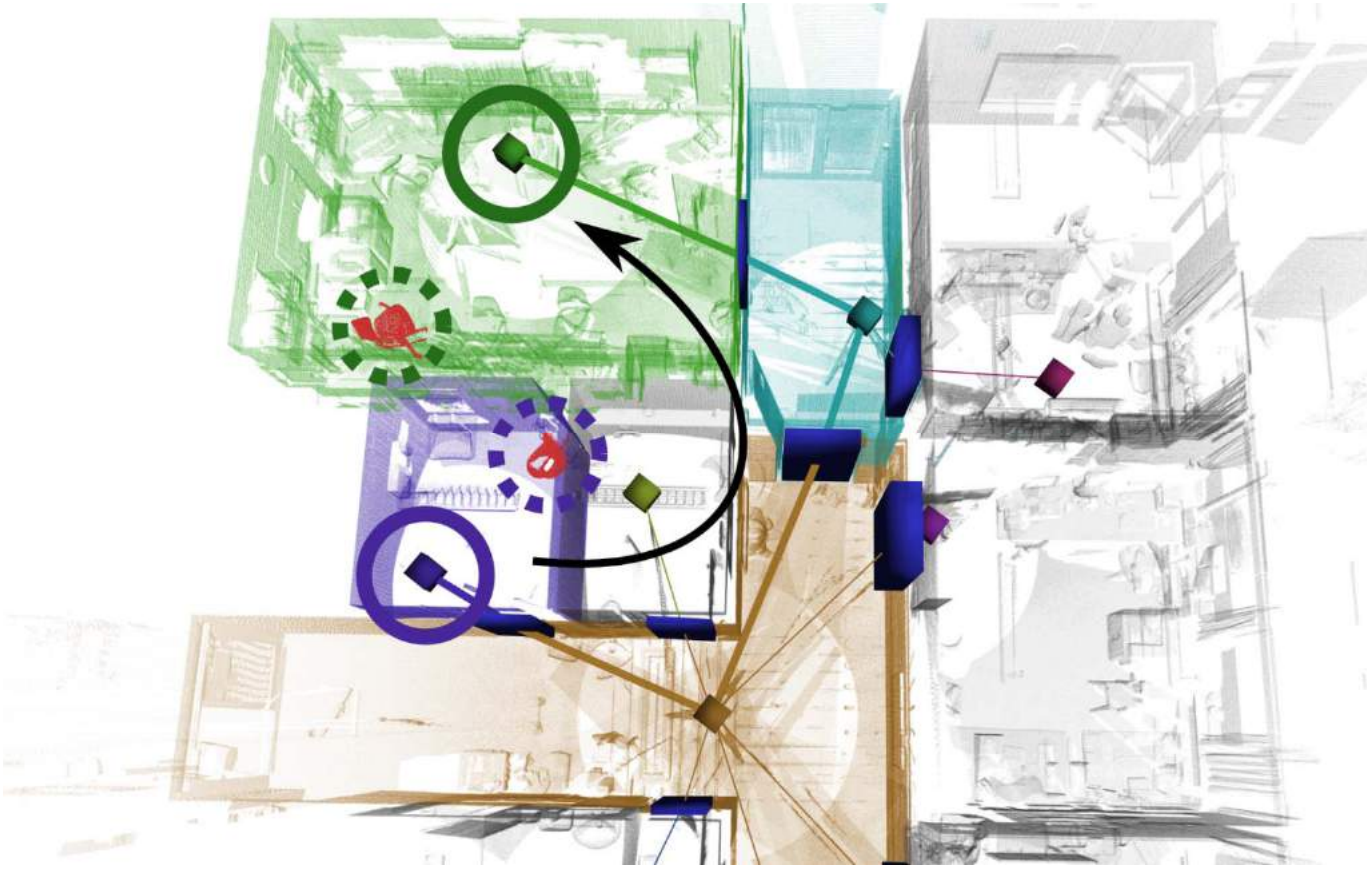
Autodesk Revit



Solibri Model Checker

Detection of Spaces / Room Connectivity

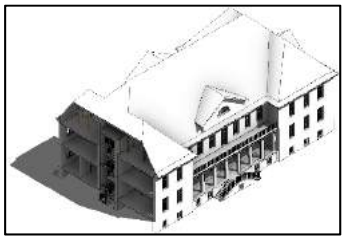




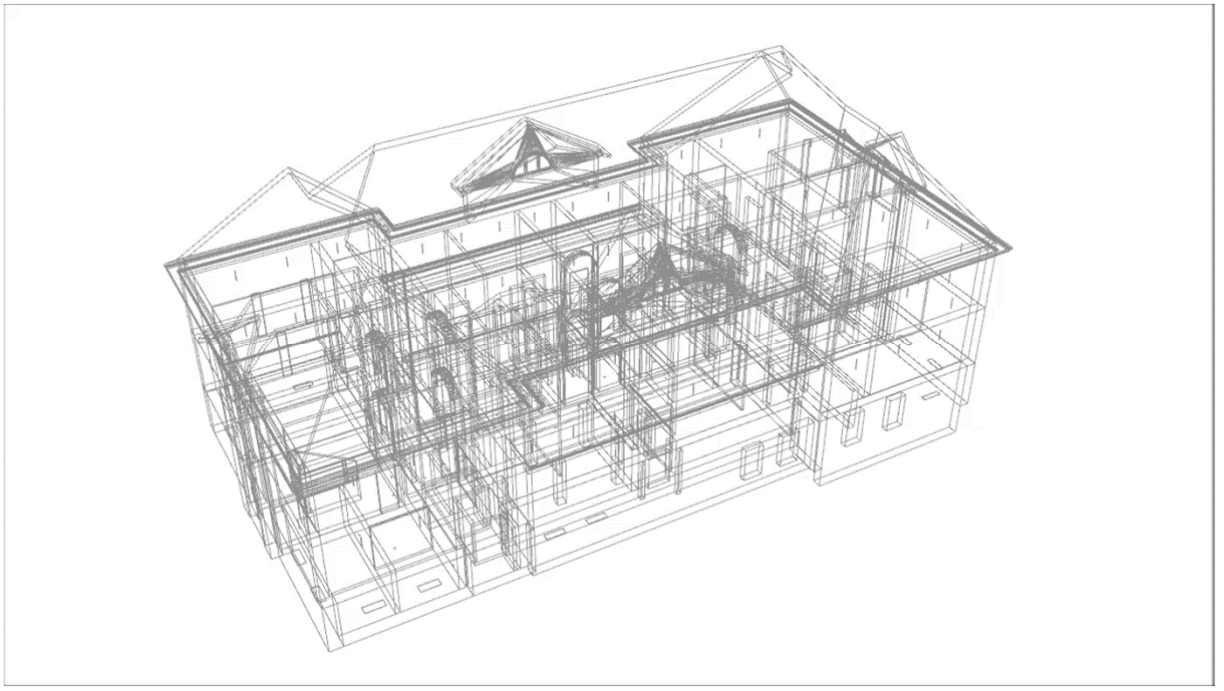
Detection of Spaces / Room Connectivity

Point Cloud Data

?



BIM



Semanticaly aware Difference Detection

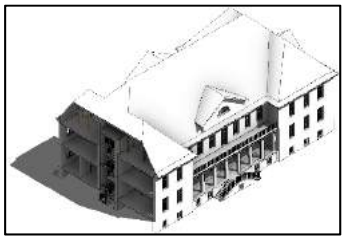
European Commission

DURAARK
DURABLE
ARCHITECTURAL
KNOWLEDGE

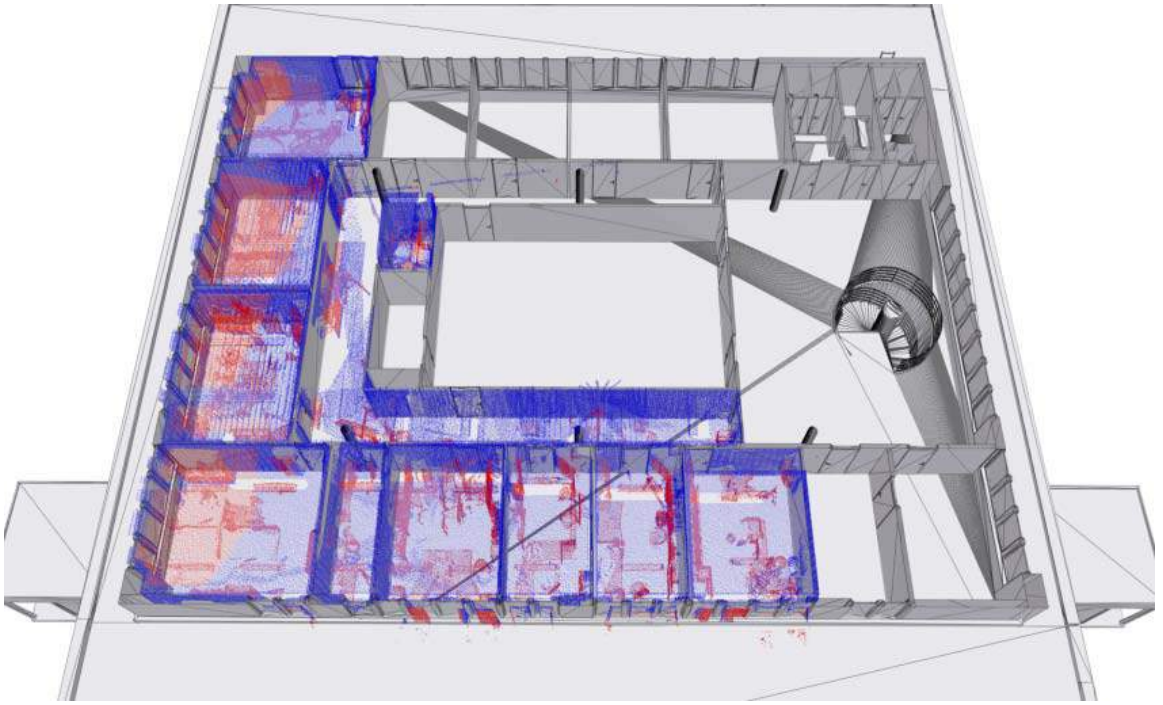
CITA

Point Cloud Data

?



BIM



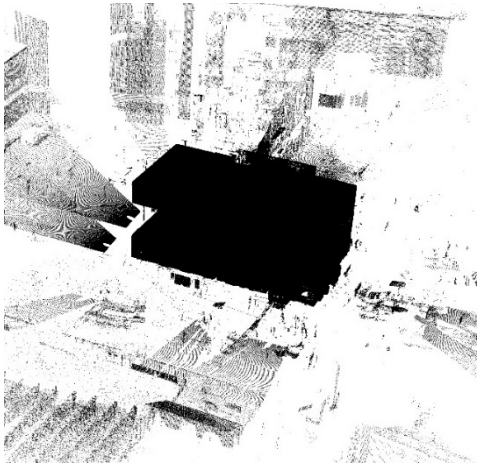
Semanticaly aware Difference Detection

European Commission

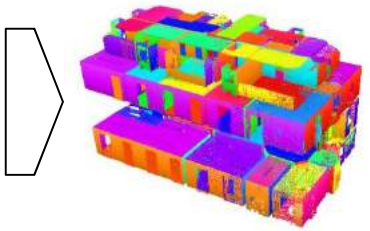
DURAARK
DURABLE
ARCHITECTURAL
KNOWLEDGE

CITA

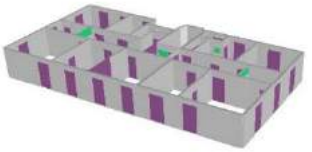
Research Prototype:
Automation of 3D-Scan to BIM processes



Point Cloud

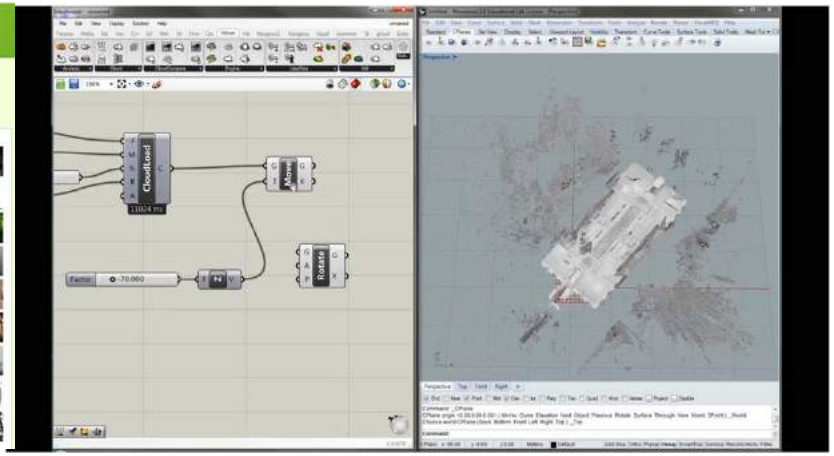


Identification of Elements and Spaces



BIM models

Volvox for
Grasshopper/Rhino
3259 Downloads within 1. Year



Main Outcome: Tools and Techniques

European Commission

DURAARK
DURABLE
ARCHITECTURAL
KNOWLEDGE

CITA

Towards:

- Integrated multiscalar modelling practice
- Agency – Automatisation and Machine Intelligence
- Feedback - awareness of Environment