Disruptive Technologies for Future AI-Enabled Smart Building Applications

Kevin Heffner, BSME, Ph.D
Director Innovation
Computer Research Institute of Montreal
Smart Building Applications for the Construction Industry*

*Disclaimer: No large companies from the AEC-FM are cited in this presentation.

Across Building Life-Cycle

• Pre-construction analysis
• Planning & Scheduling
• Compliance
• Inspection
• Visualization
• Operation & Maintenance
• Demolition Planning
• Virtual Design & Construction

SOURCE: https://www.climatetechwiki.org/
Future AI-Enabled Smart Building Applications

Some Disruptive Technologies

- Additive Manufacturing
- Smart Materials
- Autonomous Robots
- Smart Sensors
- 5G
- AI
- VR/AR

Assumption: BIM future includes comprehensive, automated workflows.
Future AI-Enabled Applications in General

4 Complementary Areas of Disruption

- Simultaneous, Real-time Data Collection & Processing
- Extreme Connectivity & Near Real-time Data Transfer
- Near Real-time Information Extraction & Dissemination
- Intelligent, Immersive, Interactive Human-Machine Interfaces

Collaborative, Automated, Near Real-Time Digital Value Chains
Future AI-Enabled Smart Building Applications

**Open Standards, Two-way Interoperability**

“At levels 3 and 4, the importance of data being searchable for both humans and machines will be crucial.”

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Open standards are essential, but: “**Two-way interoperability ensures that useful information is shared in a timely manner.**”

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2. **SOURCE:** TNO Innovation for Life, BIM BOTS Boost Construction Sector Productivity (2018)
Some Examples of Smart Sensors for AEC-FM

- **Wireless Concrete Sensor**
- **Radio Frequency Identification (RFID)**
- **Low-cost Portable LiDAR**
- **High-Res Mobile Mapping**
- **Unmanned Aerial Vehicles w/LiDAR, HR Cameras & others Sensors**
- **Embedded Computer Vision**

SOURCE: [MIT engineers configure RFID tags to work as sensors](https://www.jakarto.com)
AI-Enabled Smart Building Applications

Disruptive Technologies – 5G

5G Disrupted Technologies*

1. Immersive Gaming**
2. Autonomous Driving
3. Remote Robotic Surgery
4. Production-Line Robotics
5. Augmented Reality**

**Relevant to Smart Building Applications

<table>
<thead>
<tr>
<th>Network</th>
<th>Download Speed</th>
<th>Time to download HD Film (4.5 Gb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3G</td>
<td>384 Kbps</td>
<td>26 hours</td>
</tr>
<tr>
<td>4G</td>
<td>100 Mbps</td>
<td>6 minutes</td>
</tr>
<tr>
<td>4G+</td>
<td>300 Mbps</td>
<td>2 minutes</td>
</tr>
<tr>
<td>5G</td>
<td>1-10 Gbps</td>
<td>4-40 seconds</td>
</tr>
</tbody>
</table>

5G brings connectivity, reliability & performance.

*SOURCE: Forbes- 5 Emerging Technologies That 5G Will Positively Disrupt
https://www.forbes.com/sites/danielnewman/2018/08/14/5-emerging-technologies-that-5g-positively-disrupt/#37c05e5b66b6

**Relevant to Smart Building Applications
AI-Enabled Smart Building Applications
A Summary of AI-Related Technologies*

HUMAN INTERACTIONS
Natural Language Processing
Natural Language Generation
Speech & Speaker Recognition
Emotion Recognition
Biometrics
Virtual Agents

ORGANIZATIONAL
Decision Management
Knowledge Worker Aid
Marketing Automation
Robotic Process Automation

MACHINE RESOURCES
Peer-to-Peer Networks
AI-Optimized Hardware
Machine Learning Platforms
Deep Learning Platforms
Image/Pattern Recognition
Cyber Defense

OBJECT REPRESENTATION
Content Creation
Digital Twin/Modeling
Compliance
Visualization

*SOURCE: (With input from) 19 AI Technologies to look for in 2019
A Short History of Artificial Intelligence
The evolution of the relationship between AI & data

“There is no AI without data.”

“There is no AI without **structured** data.”

“There is no [real] AI until data is **fixed**.”

“The future of AI is about **less** data.”

Less is more!
“Data is the new oil”
But it must be refined before use.

**Meaning**

- No pre-defined data model
- Implicit meaning
- Explicit relationships

**Structured (?)**

**Examples**

- video
- images
- audio
- free text
- spreadsheets
- XML
- JSON
- databases
- linked data
- IFC
- IFC-OWL

**MOSTLY HUMAN & NATURAL ORIGIN**

**UNSTRUCTURED DATA (80%)**

**MACHINE ANALYSIS**

**STRUCTURED DATA (20%)**
Types of Machine Learning

- Supervised: Task Driven (Predict next value)
- Unsupervised: Data Driven (E.g. Identify Clusters)
- Reinforcement: Learn from Mistakes

Interactive (not focus of this presentation)

Supervised Learning
- Classification
- Regression
- Diagnostics
- Customer Retention
- Advertising Popularity Prediction
- Weather Forecasting
- Market Forecasting
- Estimating Life expectancy
- Renewable Resources
- Skill Acquisition
- Gama AI

Unsupervised Learning
- Clustering
- Customer Segmentation
- Unsupervised Learning
- Structure Discovery
- Image Classification
- Identity Fraud Detection
- Regression
- Customer Segmentation
- Text Mining
- Item Recommendation
- Big Data Visualization
- Anomaly Detection
- Sensor Analytics
- Text Mining
- Sentiment Analysis
- Time Series Analysis
- Feature Extraction
- Image Classification
- Diagnostics
- Customer Retention
- Advertising Popularity Prediction
- Weather Forecasting
- Market Forecasting
- Estimating Life expectancy
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Reinforcement Learning
- Learning Tasks
- Image Classification
- Diagnostics
- Customer Retention
- Advertising Popularity Prediction
- Weather Forecasting
- Market Forecasting
- Estimating Life expectancy
- Renewable Resources
- Skill Acquisition
- Gama AI

SOURCE: MEDIUM.COM-REINFORCEMENT LEARNING 101. MAR 19, 2018
SOURCE: DHL, ARTIFICIAL INTELLIGENCE IN LOGISTICS, 2018 (PDF, 45 PP., NO OPT-IN)
Supervised ML: Data must be structured \textit{before} “training”.

Unsupervised ML: Data structure is extracted \textit{during} “learning”.

\textbf{Unsupervised Learning}

\textbf{Supervised Learning}
To reap the benefits of many future AI-enabled smart building applications, data needs to be implicitly structured or explicitly labeled.
"Data is the new oil…"
"…but it must be refined to be useful."

Data collection
- Data capture, Sensors & tags

Pre-processing
- Validation, Corrections & Conversions

Communication
- Edge Networks, Cloud Storage, Data Transport

BIM
- RAW

Data Analytics
- Unstructured data
- Semi-structured
- Structured data

Consumer

Data must flow!
<table>
<thead>
<tr>
<th>Automation, AI &amp; Standardization</th>
</tr>
</thead>
<tbody>
<tr>
<td>What does it mean for the AEC-FM Industry?</td>
</tr>
</tbody>
</table>

**Workflow Automation**
Automated workflows are no longer an option. They are required.

**Machine Learning**
Machine Learning will be useful... and can also be used to structure data: E.g. *Unstructured data + annotations = structured data!*

**Deep Learning**
Deep Learning, e.g. for anomaly detection and object identification.

**Standards (BIM, GIS, ...)**
Both an **enabler** and an **obstacle** to achieving automated workflows. Maturity of standards needs to increase to reach full potential.

**Technical Interoperability**
Should be a technology enabler... and not a corporate business model or a source of competition among stakeholders!
Current/Future Datasets and Applications

**DATASETS**
- High-resolution
- High accuracy
- 3D structured
- Geo-localized
- Integrated GIS Data
- Multi-sensor

**APPLICATIONS**
- Object Recognition
- Object Identification
- Anomaly Detection
- Compliance
- Visualization
- VR/AR Applications

**EXAMPLE INFORMATION PRODUCT**

“AI can detect changes in the data and indicate that there is a reason to be alerted.” [1]

“An AI system analyses photos of a structure and indicates whether a line in the photo is a real crack or something else”. [1]

“We need to be able to explain how the invisible algorithms of the AI systems arrive at their recommendations.” [1]

IMAGE: Jakarto, [http://www.jakarto.com](http://www.jakarto.com)

1SOURCE: TNO, *Artificial Intelligence for Reliable Infrastructure (2019)*
Virtual Reality (VR) & Augmented Reality (AR)
What’s in it for the AEC-FM Industry?

• Already commercially available today
• Ubiquitous, low-cost VR/AR Headsets
• Address many (but not all) needs
• Technology gaps still exist!

SOURCE: readwrite: Feb 6, 2019
https://readwrite.com/2019/02/06/6-ways-to-implement-ar-vr-into-your-business-today/
Yes, for a subset of applications… but

- Depth perception limitations
- Adverse side effects
  - Nausea, headaches, dizziness, fatigue, seizures…
- Limited duration of use < 30 min.

The makers of the most popular VR headsets, the Oculus Rift and HTC Vive, recommend taking "at least a 10 to 15 minute break every 30 minutes, even if you don't think you need it."

SOURCE: Business Insider, Mar 4, 2018,
VR & AR for the AEC-FM Industry

Source: Imagine-4D Inc., http://www.imagine-4d.com

Real-time Video Fusion & 3D Rendering

Suited for Operational Use
- i.e. realism and duration of use

Intelligent Adaptive Interfaces
- Operator State Monitoring
- Display & Controls

Multimodal Interfaces
- Voice Commands
- Facial Analysis
- Gestural Control
- Emotion Detection

Holograms

What’s next?

Realistic 3D Immersion + Intelligent Adaptation + Extreme Interactivity

Future AI-Enabled Smart Building Applications

Conclusion – A Current Project Proposal

5G Edge-Computing Data Collection & Information Sharing Infrastructure

Field data collection

5G Network

3D Immersion Station

Embedded computing resource
Thank you for your attention.