Forward! 1

Artificial Intelligence in Architecture

Will artificial intelligence help us become better architects?

We, a team of students from the cross-disciplinary master program Strategic Design & Entrepreneurship, were proposed this challenge by the architecture office 3XN.

Many experts predict that AI will revolutionise our jobs, society and ways of living (Brookshear & Brylow, 2015). Our research has convinced us that there is great potential in implementing AI into the existing processes within architecture practices. If 3XN starts to embrace this game-changing technology now, they have a good chance of being ahead of the curve.

Our main objective is to prepare 3XN for the advent of AI into the architecture business, by proposing a possible future scenario, so the company can start to reflect on how to respond. We hope these ideas will start a discussion on how architects can benefit from this new technology.

Edem Agbodjan, Kristian Prieme, Maja Olsson,
Paul Jaeggi, Sebastian S. Müller

June 2019

AI

Artificial Intelligence (AI) is a vast field of computer science, where the goal is to build machines that behave intelligently. Significant for AI is its ability to perceive (understand data like images and text), reason (select and execute) and learn (independently, through experience) (Brookshear & Brylow, 2015). The power of AI was widely recognised in 2016 as the team behind AlphaGo, DeepMind, created an AI that beat top player Lee Sedol in a Go match (AlphaGo, 2017). 'Go' is a game with a high level of complexity and the sheer amount of possible moves call for a computer that haas learnt to recognise and structure strong playing positions from a massive database. An artificial neural network was trained to predict likely next moves, and by combining these technologies, DeepMind reached it's goal a decade earlier than expected (DeepMind, 2019). Tegmark (2017) states that with this achievement, AlphaGo shows some indications of intuition and creativity.

It is important to acknowledge that AI is nowhere close to possessing true intelligence, feelings comparable to human consciousness. This notion is called strong AI, and one can argue if it ever will exist. The AI used today would be considered weak AI. It is limited in the types of tasks it can complete, but there is a general consensus that technology today can be extremely powerful (Brookshear & Brylow, 2015). The opportunities that AI brings can ultimately change the existing workflow within architecture. The technology is developing fast and in many fields, there is great potential in implementing it. In manufacturing, AI can make production more efficient and precise. In healthcare, it can improve personalised medication and in the transport sector, one can expect autonomous cars to improve road safety (Tegmark, 2017). Those who use a smartphone are already in contact with AI used for image recognition, text translation and assistance from Siri or Alexa etc. (Brookshear & Brylow, 2015) (Marr, 2019). By learning how other industries utilise the technology and by studying the current processes at 3XN, we have explored how architects can be further supported in their work.

When Max Tegmark (2017) discusses how AI will affect the job market, he encourages the young to "Go into professions that machines are bad at — those involving people, unpredictability and creativity." With this statement in mind, we do not expect AI to outperform the architects anytime soon. At work, designers address existing systems, formulate problems and think independently. Not only knowing how to make sense of artistic and scientific research in our daily lives but also having the motivation to do it, makes designers able to come up with new and

* To gain an understanding of key technologies and terminologies within AI please view the AI Taxonomy foldout at the end of this booklet.

innovative solutions (Kesteren, 2017). We believe AI can make a difference by doing mundane tasks that will let the architects do what they do best.

In this project, we have identified three activities where we think AI can have a significant impact. These are Research, Design and Knowledge Management. The ideas are based on the possibilities to collect and utilise data that technology brings. We suggest that architects use AI to help find and organise information, communicate it at the right time and capture relevant learnings and data from each project. The current situation, the purpose of these ideas and the technologies will be explained in more depth.

“Go into professions that machines are bad at — those involving people, unpredictability and creativity.”

Max Tegmark, 2017

Adam Mørk, 2015

Research

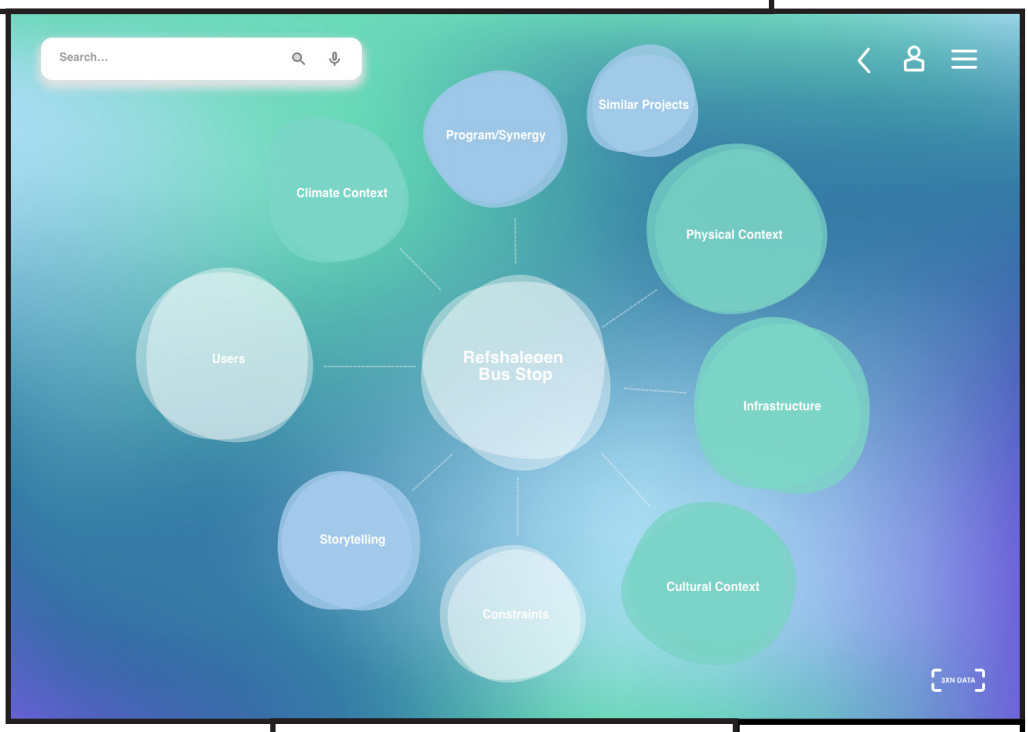
Situation Today

The extensive amount of time spent doing research in the initial phases of a project was addressed by Oanh Nguyen Henriksen, Head of Business Development at 3XN (Nguyen Henriksen, 2019).

In order to gain an understanding of the project, architects need to do research on different factors such as the climate, the users, the cultural and physical context, and the program. This is a time-consuming process, and some of the information might already have been done by the company before, e.g. in a previous project with a similar context. If AI can assist the architect in finding relevant information, there will be more time to find the right approach to the problem and focus on the architectural proposal.

Kyna Lesky, Professor in the Department of Architecture at the Rhode Island School of Design, is comparing the creative process of e.g. architects, poets and scientists with a storm. A dynamic process where the problem making is like the stirring of a storm, initiating creativity. Architects are often given a problem from a client, and Lesky emphasizes the need to question the given assumptions, redefine the problem and by doing so: make a conscious framing of it to find a direction for the project (Lesky, 2015).

We have explored what an interface between architects and databases could look like by devloping a speculative design of an interactive mindmap.



Scan code to view interface animation.

AI Mindmap

By using AI to search databases for information based on a written brief, one can get help to collect and organise relevant research. We have been exploring what an interface could look like and have developed an idea of an interactive mind map. In this digital tool, a selection of topics is generated. By making the data visible, the user can get a quick overview and zoom in on a topic to find detailed information, such as summaries of important documents or maps of users movement patterns from the site. We believe the mind map will not only be a useful tool for doing research, but also for keeping co-workers in the loop.

3XN possess a large amount of data from many previous projects that they can benefit from in their ongoing and future projects. This may be knowledge about how to operate in different cultural contexts or inspirational sets of drawings. For the information to be accessible from a variety of perspectives, it has to be stored in a database.

Database

A database is a collection of data where the information is accessible from different perspectives, opposite to a traditional file system, which shows the information from one point of view. When using a file-oriented information system there is a risk that much of the information within a company is duplicated and stored in separate places. In database systems, the information can be stored in one place, and this allows us to use the same data in many ways. Today, database technology and data mining techniques (the process of generating new information by finding patterns in large databases) are important and powerful tools to discover the right information from huge amounts of data (Brookshear & Brylow, 2015). We produce more and more data every day, and it is expected to grow in a much faster pace as The Internet of Things and various apps are collecting and sharing data all the time (Marr, 2018).

To support architects in their research process we suggest that the mind map is connected to different types of databases, to find and make sense of a lot of data much faster than we could ever do manually. An inspiration to our idea is Iris.ai, which is a digital search tool for scientific research. By giving it a problem statement, Iris.ai can find relevant information by searching a database of more than 120M open access research papers. Documents that are covering similar topics are clustered for the user to navigate the outcome fast, this works thanks to Natural Language Understanding (Iris.ai, 2019). The team interviewed the Head of Community at Iris.ai, Ami Defesche, to learn more about the potential to connect a system like Iris to different types of databases. Today, Iris.ai is trained on a very large database of academic papers. The challenge in architecture is that interesting information comes in many forms. Today, different types of text-based information are easy to organise with Iris.ai, and for architects, it would be relevant for e.g. laws and regulations, but it is not yet developed enough to comprehend visual data like maps, drawings and 3D models. As soon as a database is developed, that is large enough to train Iris.ai, it will, in theory, be possible to use in any field, according to Defesche (Appendix, p. 34).

Adam Mørk, 2015

Design

Situation Today

Though a series of meetings and interviews with the management of 3XN, the team ascertained that the company is facing three main challenges in their creative design process.

3XN would like to focus more of their time on the concept and development stages of the design process. When working on architecture projects, a large part of their time is spent on repetitive design tasks, which requires little creative thinking. Tasks such as detailing floor plans and drawing repetitive elements are time-consuming, and thus, architects are spending a lot of energy engaging in tasks which are not related to their core competencies. Producing the design variations and simply getting an idea from mind to paper is also time-consuming. The architects often have to do a lot of iterations before reaching a satisfying final design.

About 80% of 3XN's projects are done overseas. Since the task of finding new partners and establishing healthy and productive cooperation takes time and effort, the more of the work process that can be moved into the main company itself, the more time and money can be saved. In other words, 3XN would like to have more control of the process as contrary to collaborating with local partners.

Another challenge 3XN are facing is dealing with regulations from different countries. It takes a lot of time to acquaint oneself with regulations from different cultures, and thus 3XN hopes that AI can be at help optimising this process.

The aim is to challenge the way 3XN designs today, and hopefully present an idea for a possible future scenario for some of the issues they are facing in their creative design process.

"A way to think about these new tools is as a method for creating more holistic designs which allow us to take more factors into account simultaneously"

(Andrew Witt, 2019)

Visualising information

On the basis of our research, the team believes that AI could be used to visualise data from the mindmap inside a 3D modelling program and provide relevant suggestions as the architects are developing their designs. When you are able to see a lot of information at the same time, you can get a more nuanced understanding of the project The architect would be able to see different layers of information such as local building regulations, local weather conditions, user-behavior, specific site conditions, relevant data from prior projects etc. This tool will be helpful when you are working in areas around the world that are unfamiliar. For instance, the architect should be informed if the design is violating any legal requirements. This means that the architect won't have to spend a lot of time setting up most of the basic parameters; saving the company a lot of hours.

What would it be like to work and design in a 3D modelling software, as the relevant data is visualised? In the program, the architects are able to see information about the site such as the flow of people, traffic, possible bus routes and suggested locations for the bus stop. The architect would be able to choose which information to display or get more information by accessing the mindmap via a link directly from the 3D CAD software.

The tool would help too; give 3XN more control of their overseas projects; improve the usage of 3XN's research, knowledge and existing data; give 3XN a competitive advantage by increasing their efficiency.

The idea of having AI translate data such a text and numbers into visual 3D images is not yet existing as described above, thus we are assuming it will take some time before the tool is fully developed. The Big Picture team at Google Inc. is one example of researchers experimenting with translating data to a visual format in order to get a more nuanced understanding of large datasets. In one experiment they took a large piece of text and programmed the AI to place the words inside a three-dimensional virtual space. The words were analysed, categorised and positioned according to their resemblance. By doing this the researchers could see the affinity between different words, in relation to their meaning and the way they are used. (withgoogle.com, 2019)

Adam Mørk, 2015

Generative Design

In order to improve efficiency, and give the architects more time to explore design ideas, we believe Generative Design tools can be at help.

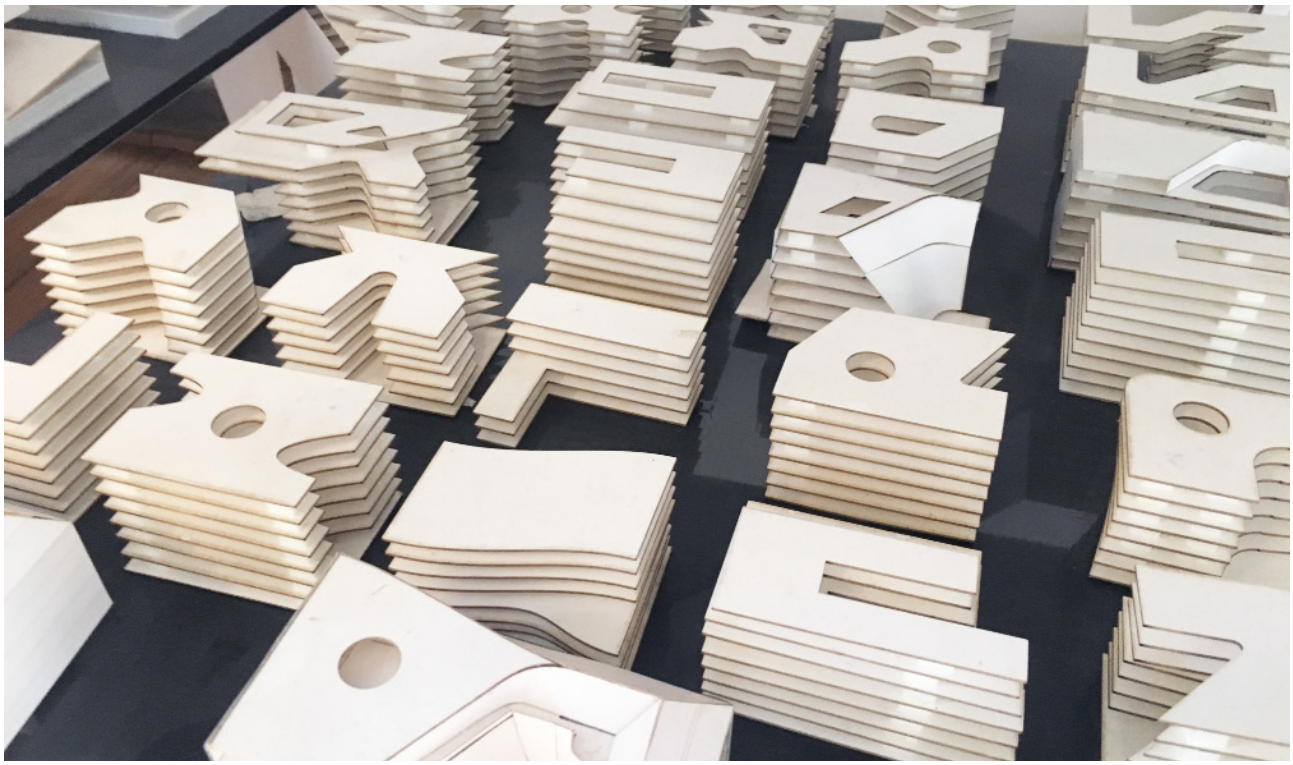
The idea of a Generative Design plugin builds on existing software programs and are by no means new to the field. The software could be based on a system called Dreamcatcher developed by Toronto based software company, Autodesk.

“Generative design is using the power of computation to automatically generate evaluate and evolve hundreds or thousands of different design options by specifying high-level goals, parameters and constraints“ - David Benjamin, Founder of The Living, an Autodesk studio.
In the time an architect can create a design idea, the generative design can create thousands, along with the data to substantiate which designs perform best. Generative design lets you create complex shapes, some of which are impossible to make with traditional manufacturing methods. This process can save material, while not compromising on the structural strength(Autodesk.com, 2019).

The combination of generative design and the ability to connect databases to the 3D modeling software could be

very beneficial because the number of parameters included in the generative design setup could be increased a great deal. With large datasets and advanced generative design programs, we believe that this can have an impact on the process in many ways.

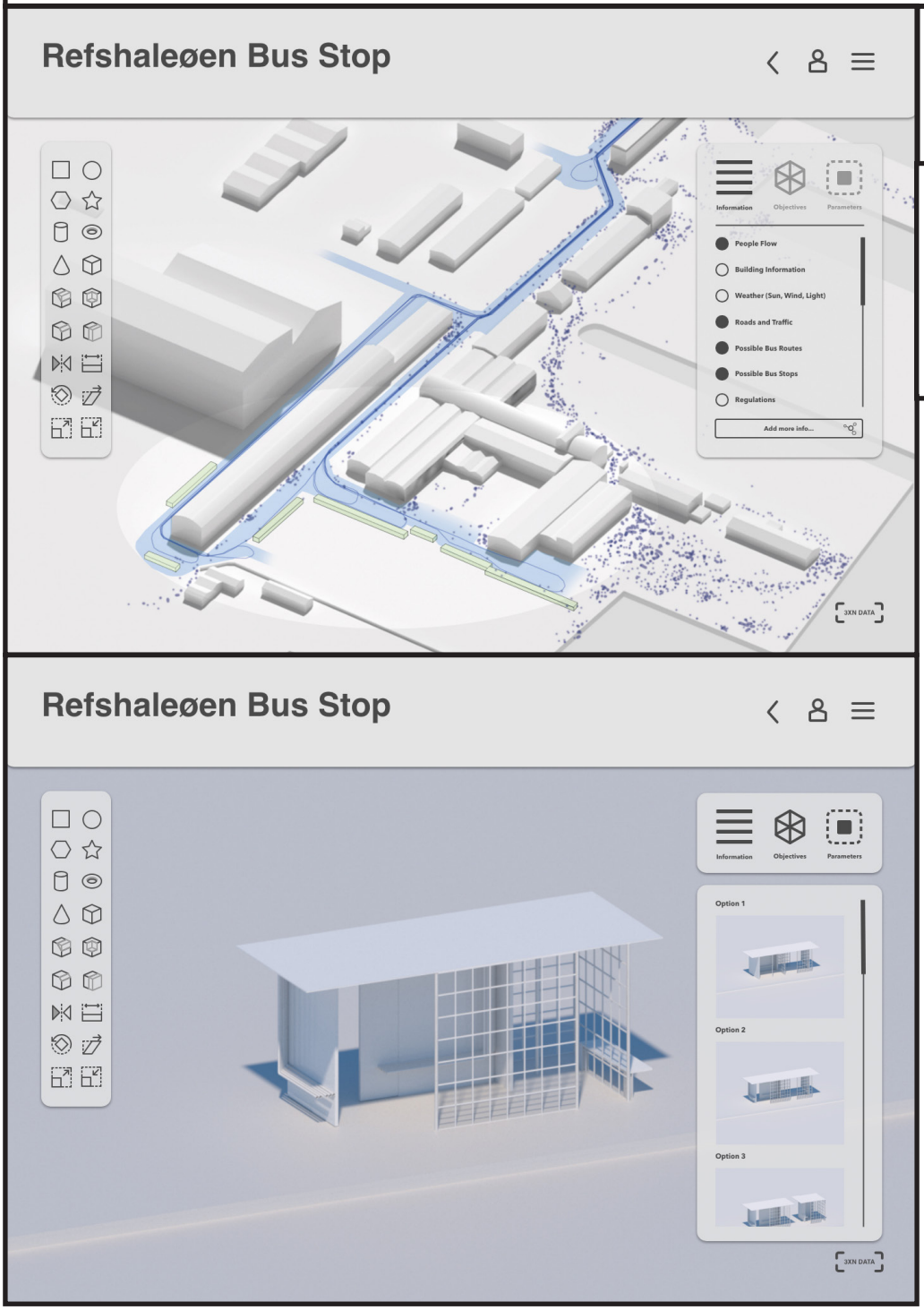
“A way to think about these new tools is as a method for creating more holistic designs which allow us to take more factors into account simultaneously. And at the same time, we can give provisional solutions to problems that would have been necessary to grind out and draw out in a very laborious way. I think that has the potential to be really powerful, when we become curators or conductors of a certain process, as opposed to drawing explicitly every line in the building for example”
(Andrew Witt, 2019)



Massing Models by 3XN, Maja Olsson 2019

In order to make use of the information gathered from the mindmap, the interface visualises the data collected, such as the flow of people, possible bus routes etc. This, in turn, will allow architects to be able to interpret data in a more dynamic way rather than reading text from a document.

We have also visualised, what it would be like to test different design variations based on a selection of parameters. AI will generate it autonomously and modify the design based on the characteristics of that specific material.



Scan code to view interface animation.

“I think there are specific areas, in the design process where these tools can be helpful. Especially if you think about the details. I think it’s a really interesting opportunity to think about details from a machine learning point of view and collect those details to create certain kinds of intuitions about how the detail could be laid out”

(Andrew Witt, 2019)

Knowledge Management

Situation Today

Today data has become one of the major and important by-products of the 21st century. Data is being produced at any given moment, when we are liking/posting pictures on Instagram, purchasing a piece of clothing online or buying groceries. Furthermore, a greater number of new technologies are being developed and designed to fit within our built environments such as sensors and smart devices are adding to the emerging area of the Internet of Things (IoT).

In the case of architecture, we are in a stage where clients are starting to demand more than just drawings and requesting additional data. In particular, the data being produced via BIM (Building Information Modeling) which is a platform for creating and managing information on a construction project across the project lifecycle. This type of data can be valuable as these insights throughout the process could be used as learnings for future projects.

Clients are also demanding data from the building itself. This data generated from buildings allows clients to measure, analyse and improve the performance of their buildings quantitatively. Potentially, clients could also begin to evaluate architects performances based on these insights, which highlights the importance of data when it comes to designing buildings.

Data is not only changing the output but is also creating a shift within the process of designing itself. The outcome will still be a building or even a smart building but the process itself will have to be rethought through in order to adapt to the inevitable changes within the landscape of architecture. Many questions will arise such as: how will architects process the data they produce? How will data be exchanged between partners? Who

will own and be responsible for the data, legally? What type of services will be created as a result of the data? What competencies will be required within a practice and how will that shift the dynamics within the practice?

Models by 3XN, Maja Olsson 2019

Knowledge Management

Knowledge Management (KM) is a discipline that promotes an integrated approach to the creation, capture, organisation, access and use of an organisation's information assets.
These assets include structured databases, textual information such as policy and procedure documents, and most importantly, the tacit knowledge and expertise resident in the heads of individual employees (Online Journal of Applied Knowledge Management, 2015).

The practice of Knowledge management (KM) with the help of AI will be possible with the creation of an internal database while utilising Machine Learning (ML) during the Research and Design activities as well as the use of Internet of Things (IOT) devices in order to aggregate and analyse data for real operational use.

When seeking to implement KM, it is essential to understand the different levels of knowing. By using the Data, Information, Knowledge, Wisdom (DIKW) hierarchy model one is able to question initial data in order to find ways to add value to it.

Data is a collection of raw and unorganised existing in any form, usable or not. However, it does not have meaning without any context. Information is the "filtered" data that has been given meaning through relational connections, making it easier to visualise, measure and analyse. Fundamentally, questioning 'who', 'what', 'when', 'where', etc., one is able to make the "filtered" data more useful thus making it more valuable. Knowledge distinguishes "how" the information from the data can be relevant and applied to a specific task or goal an organisation has. If data and information look at what has been, knowledge and wisdom can be seen as what is needed now and in the future. Wisdom calls upon a humans programming relating to their morals, ethics, interests etc, and the previous levels of consciousness.

Ultimately, the more an organisation is able to enrich their data with meaning and context, the more knowledge and/or insight they will gain to maximise learning experiences in order to inform future actions. The team has suggested through the speculative interfaces, ways in which context can be added to new data throughout activities in focus.

Adam Mørk, 2015

“Data is the most basic level; Information adds context; Knowledge adds how to use it; Wisdom adds when and why to use it.”

Gu Jifaa, Zhang Lingling, 2014

Internal Database + Machine Learning (ML)

Having highlighted the importance of Knowledge Management we propose the creation of an internal database that utilises the capabilities of Machine Learning (ML). Aggregating data throughout the duration of an ongoing project, while adding context to all the knowledge that is being gathered, especially within the Research and Design activities previously discussed.

Machine learning is when computers teach themselves how to intelligently process big data by using statistical learning algorithms. If the computers are fed more data, they will be more capable to complete tasks of higher complexity.

There are many fields of machine learning:
Unsupervised learning: training machines to identify untagged images.
Supervised learning: training using labelled or annotated information.
Reinforcement training: training via rewards for correct actions.
Deep learning: using complex neural networks. Neural networks are inspired by flows of information through human brains and they can deliver either general AI (solving various tasks) or narrow AI (expertise at one or two specific tasks). (Jackson, 2018)

In the case of the Research activity, supervised learning can be applied to the generated mind-map information. By labelling and annotating information one would be training the database to make new connections and providing new learnings to be integrated. These connections and learnings will become better over time, thus allowing for more relevant

knowledge and insights to be gained.

During the Design activity, various types of machine learning can be applied. This is achievable because of the vast amounts of data each practice possesses, such as sketches, technical drawings, models etc. By training the AI on a purely architectural data set it will begin to understand anything from floorplans, constructions details to building regulations in a specific region. Ultimately, valuable knowledge during the course of projects will remain in the organisation. It will be available at any point during the process and will not leave the organisation if an employee leaves.

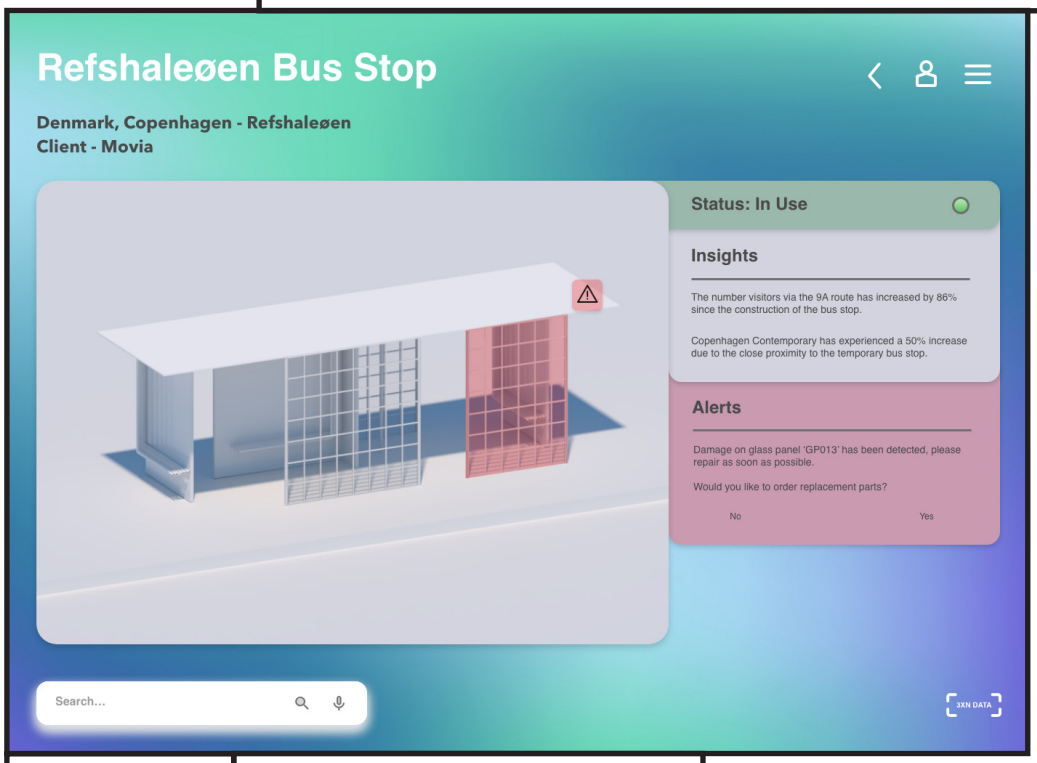
Internet of things (IOT)

Taking the use of AI a step further into the physical realm, the Internet of Things (IoT) is a way to aggregate and analyse data from IoT devices for real operational use with the use of sensors and other recording devices, creating ‘smart buildings’. IoT will also create new opportunities for a practice as they will be able to receive real-time information from their buildings which could result in future work and additional services. These services can relate to reducing energy consumption, operational challenges, occupant comfort and productivity and cybersecurity. (Stephan Haller, 2010).

Ultimately, data will lead to more certainty and confidence for better design decisions and insights allowing for real-time monitoring and adaptions to projects during its lifecycle.

Randy Deutsch, 2015

We have explored what an interface visualsing real-time data would look like with the use of IoT devices.



Scan code to view interface animation.

References

Autodesk, 2019, Generative Design, Autodesk, viewed 1st. of June 2019, <https://www.autodesk.com/solutions/generative-design>

Brookshear, G. & Brylow, D., (2015). “Computer Science: An Overview”, 12th edn. Essex: Pearson Education

DeepMind, (2019). ”The story of AlphaGo so far”. Accessed in June 2019, <https://deepmind.com/research/alphago/>

Deutsch, Randy, (2015) “Data driven design and construction”, Wiley, 1.st edition.

Experiments with Google, 2019, “Visualising high-dimensional space”, Google inc, 5 th. of June 2019, <https://experiments.withgoogle.com/visualizing-high-dimensional-space>

Girard,John, Girard, JoAnn, 2015, “Online Journal of Applied Knowledge Management”

Haller, S., 2010, “The things in the Internet of things”, Research Gate, Zürich

Iris.ai, (2019). “Research faster, better. AI charged”, Accessed in May 2019, <https://iris.ai/features/>

Jackson, D., 2018, “Data Cities: How Satellites Are Transforming Architecture And Design”, none edition, Lund Humphries, London

Jifaa, G., Lingling, Z., 2014, “Data, DIKW, Big data and Data science”, Elsevier, open access, p. 814-821

Jongewaard, R. & Keresten, A., (2017), “Changemakers”, Rotterdam: Museum Boijmans Van Beuningen.

Lesky, K., (2015), “The Storm of Creativity”, Cambridge: MIT Press.

Marr, B., (2018). “How Much Data Do We Create Every Day? The Mind-Blowing Stats Everyone Should Read”, The Forbes, accessed in May 2019, <https://www.forbes.com/sites/bernardmarr/2018/05/21/

how-much-data-do-we-create-every-day-the-mind-blowing-stats-everyone-should-read/#18e8a66060ba>

Marr, B., (2019). “Are Alexa And Siri Considered AI?”, Bernard Marr & Co, accessed in May 2019, <https://bernardmarr.com/default.asp?contentID=1830>.

Nguyen Henriksen, O., (2019) “Architectural Intelligence” [PowerPoint presentation]. Available at: https://rum.kadk.dk/modulrum/F19_514/_layouts/15/WopiFrame.aspx?sourcedoc=/modulrum/F19_514/Undervisningsdokumenter/4.0%20PRESENTATIONS/Company%20presentations%20 20190221/3XN%20190121%20KADK_CBS%20intro%202.pptx&action=default (Accessed in May 2019.)

Samuel, F. Hay, R. Bradbury, S. Dixon, D. Martindale, K. Tait, A., 2017, “Building Knowledge: Pathways to Post Occupancy Evaluation”, University of Reading and RIBA (Royal Institute of British Architects), London

Tegmark, M., (2017). “Life 3.0: Being Human in the Age of Artificial Intelligence”, New York, Alfred A. Knopf