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ITU-T Focus Group on Environmental Efficiency for Artificial Intelligence and other Emerging Technologies (FG-AI4EE)

FG-AI4EE D.WG1-09

A method for intuitive human interaction with data model (ML and AI, etc.)

Working Group 1 – Requirements of AI and other Emerging Technologies to Ensure Environmental Efficiency

Focus Group Technical Report

ITU-T

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The procedures for establishment of focus groups are defined in Recommendation ITU-T A.7. ITU-T Study Group 5 set up the ITU-T Focus Group Environmental Efficiency for Artificial Intelligence and other Emerging Technologies (FG-AI4EE) at its meeting in May 2019. ITU-T Study Group 5 is the parent group of FG-AI4EE.

Deliverables of focus groups can take the form of technical reports, specifications, etc., and aim to provide material for consideration by the parent group in its standardization activities. Deliverables of focus groups are not ITU-T Recommendations.

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NOTE

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Technical Report ITU-T FG-AI4EE D.WG1-09

A method for intuitive human interaction with the data model (ML and AI, etc.)

Summary

This Technical Report demonstrates the method of connecting complex data, machine learning (ML) and artificial intelligence (AI), into a system-level solution designed for humans, allowing communication between man and machine, thereby cultivating mutual enhancement.

Interfacing humans to data is key to using its power to accelerate the speed with which we can solve the environmental problems. Machines are very powerful at working with data including ML and AI. Humans need to interact effectively with this information and create healthy human-machine partnerships at the service of the ecosystem and social wellbeing, in summary, in service of the interconnectivity of life. This means building it into an interface that is manageable and allows the comparison between data sources. It also means designers and operators in tune with the greater good, which accessible through the intuitive human capacity. The aim is to create a system for adding many data sets and being able to compare these with one another in a way machines and humans can understand. This could have a measurement score system based on a "traffic light" concept covering environmental factors, for example:

- Heating/cooling and energy consumption;
- Impact on plant and animal life;
- Carbon and other air-based emissions;
- Waste and water management.

Increasing amounts of the world's population live in cities. As this is also the source of many of our environmental key pressures for climate change, cities are used as a model for this Technical Report.

Keywords

Artificial intelligence (AI), environmental impact, key performance indicator (KPIs), machine learning (ML), visualization.

Change Log

This document contains Version 1 of the ITU-T Technical Report on "*A Method for Intuitive Human Interaction with Data Model (ML and AI etc.)*" approved at the ITU-T Study Group 5 meeting held online, 11-20 May 2021.

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1 Scope

A review of the gaps between the needs and tools is performed, together with a case study of the benefits of 4D interactive visualisation of data models for environmentally friendly artificial intelligence (AI) and machine learning (ML).

The report will complement a video on the same topic (deliverable WG1-10). This video will aim to reach a wider audience and raise awareness about this issue.

2 Background

Every day, quintillions of bytes of data (or the size of billions of current PC hard disks) are produced [1]. Parts of these bytes of data are textual and graphical and most of them are incomprehensible to humans yet invaluable. Internet of things (IoT) infrastructure gathers sensor data about our comings and goings and the environment that we live in, in databases with the primary goal of using this data in the future. The virtual economy has never been more brick and mortar and has never been more power-hungry than today. With the rise in hyperscale data centres in every major part of the world, virtual economy is slowly seeing a stellar rise in its fortunes [2]. The environmental impact of emerging technologies seemingly remains invisible to the public eye. Furthermore, despite climate change and its disastrous consequences being a known fact for decades, the world has become indolent to an increase of 2 degrees in the outside temperature. Therefore, it can be acknowledged that invisible, odourless, colourless, and painless changes are difficult to react upon.

Visualizations allow researchers to explore and set hypotheses, confirm, and disseminate results, and interact with the public [3]. Visualizations and animations can also grasp the attention of the audience and raise awareness about the dramatic consequences of the world's inaction.

3 Gap analysis

3.1 State of the art

Figure 1 shows the system architecture where different data formats from various sources are visualized and augmented in a 4D replay infrastructure, with human interaction and cognition as the focus. Table 1 gives an explanation of the terminology used in Figure 1.

Figure 2 depicts the AI and ML modelling cycle.

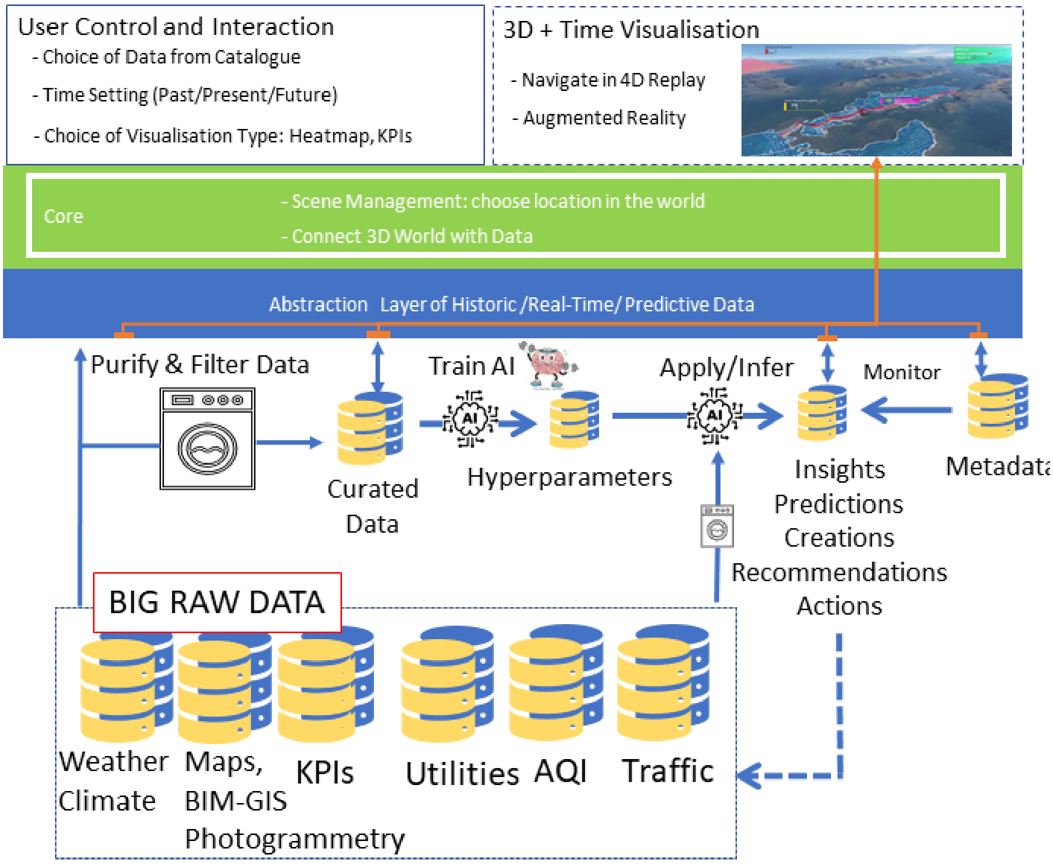

Figure 1 – System architecture

Table 1 – Terminology used in Figure 1

Data type	Description relevant for visualisation
Metadata	#parameters, #hyperparameter, #output parameter, #HVAC POE, training time and frequency, location of centre, megawatt hour (MWh), CO_2/GHG reusable hyperparameters (yes/no)
Insights, predictions	Most insights are visuals in 3D: Traffic, air quality, power consumption
Hyperparameters/models	Currently impossible to visualise hyperparameters
Curated data	Datasets that are consistent, without holes, with proper formatting, units, and sensible range, properly documented
Raw data	Sensor data, often with noise, poor documentation concerning unit, format, range, or domain knowledge

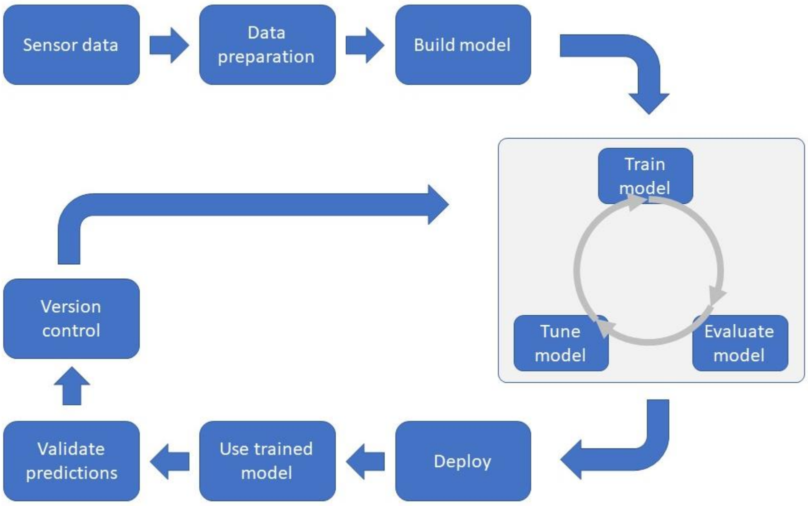

Figure 2 – AI and ML modelling cycle

3.2 Data domain analysis

Table 2 analyses the different types of data that can be visualised.

Table 2– Data type analysis: Source IEEE IMM in proceedings

Type	Description	Relevance	Scalability	Privacy
BIM	Building and road information CAD, timed BIM	Current and future city, contextualise energy consumption, infrastructure needs	Local and private data, international standard format	Occasionally critical
Energy and water	Energy and water usage in districts kWh/hour, m^3/day geolocalised time series	Civil defence, current and future infrastructure needs	National database	Critical
Weather	Historic and forecast geolocalised time series	Contextualise outdoor activities, civil defence	Worldwide service	Irrelevant
Air quality	Historic and forecast geolocalised time series PM10, PM2.5, PM1, NOx, SO_4	Health and environmental consequences	National service	Irrelevant
Traffic	Inductive loop data geolocalised time series vehicles/hour/day etc.	Network utilisation of vehicle and bike infrastructure, emissions, congestion	National service	Occasionally critical
Public transport	Automatic passenger counting Per bus, ferry line, and stop passenger; revenue	Monitoring and planning of infrastructure	Regional service	Critical
Demographics	Historic and forecast geolocalised time series (age, sex, wealth, school pupils)	Contextualise and plan infrastructure needs: schools, roads, bus lines	National service	Irrelevant
U4SSC KPIs	91 sustainability KPIs	Identify priorities for sustainable planning	Worldwide service	Irrelevant
Emergency response	Fire and ambulance response time minutes to destination geolocalised time series	Identify areas with poor coverage, plan infrastructure	National service	Critical
AIS	Automatic identification system geolocalised time series	Air quality correlations, traffic planning	Worldwide and national service	Occasionally critical
Outdoor activity	Geolocalised time series outdoor activities with strava outdoor path	Contextualise outdoor activities, identify preferred routes	Worldwide service	Occasionally critical
IT metadata	Power consumption, logs, etc.	Visualises the hidden part of the virtual economy	Worldwide	Business critical

3.3 Civil defence

3.3.1 Sea-level rise

During the second half of the 21st century, global warming, and sea-level rise were considered a distant and abstract menace. Scientists struggled in fighting environmental myopia and communicating with decision-makers, industry leaders, and the population about the devastating climate change would bring. One of the reasons being attributed towards few people understanding statistics. Since personal images create bigger impacts than impersonal ones,[1] climate-change communication must be brought in the local context of the receivers: showing how their surroundings will be affected and how it will look like in 20 to 30 years: burnt forests, flooded streets, deserted neighbourhoods and so on. Moreover, recent advances in gaming technologies allow real-time three-dimensional (3D) / 4D rendering of districts.
The following clickable picture illustrates how simple animations of sea-level rise can foster the imagination and facilitate the understanding of its consequences for future everyday life.

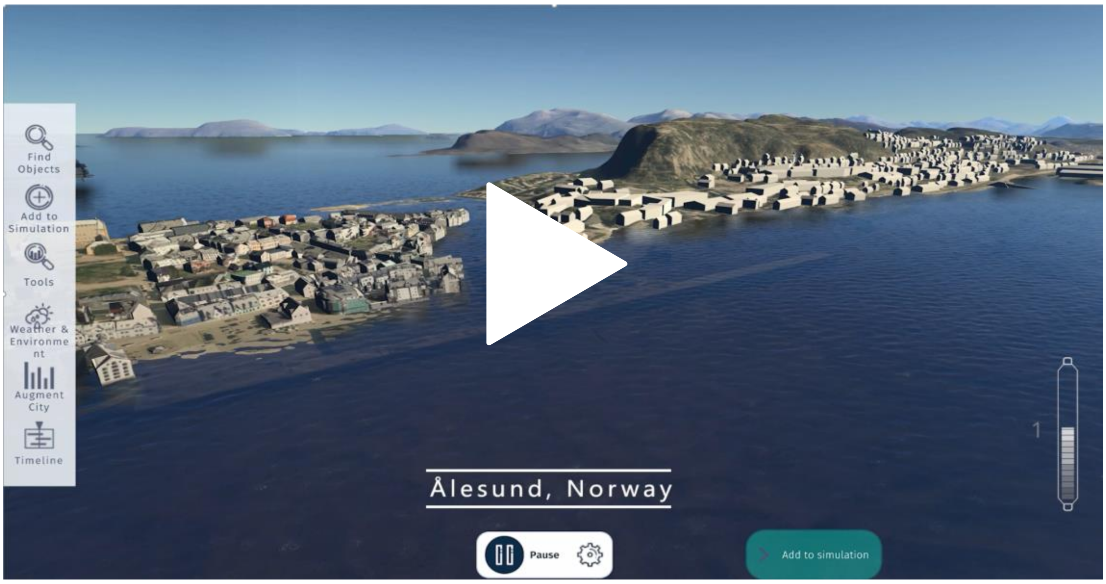

Figure 3 – Visualizing the impact of sea level rise

3.3.2 Disaster planning and response

3.3.2.1 Summary

Typhoons form under specific sets of conditions between the ocean and the atmosphere. For example, warm sea surface temperature and humid atmosphere favour typhoon formation (cyclogenesis). As these weather conditions are commonly seen in Southeast Asian countries, the region is prone to frequent typhoons [4]. Climate change is making disasters more intense and unpredictable. Therefore, a good disaster preparedness and a plan need to be in place [5].
The goals of disaster planning are to reduce the impact of the disaster within communities, evaluate the economic consequences and ensure that proper mitigation plans are put in place. The fundamental tool for any city to plan is to have a digital twin of the city. Digital twin provides a holistic visualisation of a large expanse of land.
Humans provide visual insights to identify potential flood-prone areas including the number of houses that will likely be submerged. Machines provide detailed information on the number of people, area measurement of pieces of land, and the height of the riverbank. With this information, humans can increase the strength of riverbanks, build retaining walls or plant more trees. Artificial intelligence takes in the images and recognition of the houses to provide suggested recommendations over time. These recommendations can be used to relocate frequently flooded households.

[1] Sasha Luccioni interview in «Are you a robot?»

3.3.2.2 Recommendations

Key strategies for minimizing the impact of disasters are to allocate resources ahead of time thereby mitigating potential risks. Machines can be trained to learn based on the types of resources and data provided, and AI techniques such as image recognition and classification can help in assessing the damage by analysing and observing the images. They can immediately and efficiently filter these images, which would have required months if it was sorted manually.

Machine learning can be used to analyse past events, identify and extract patterns and population density for predictive analytics. This is used to identify risk areas and improve predictions of future events plus relocation of new and old buildings or even rebuild buildings and infrastructure. In the event of a real disaster, predictive machine learning can help cities distribute the right amount of food and supplies based on a temporary re-routing of logistics. AI-enabled drones can be used for new navigational routes to deliver food or medicine to areas cut out by flooding.

This can be done via analysing behavioural patterns and the movements of people. AI can then provide insight for understanding the impact – economic and people – post disaster plus predict the potential monetary aid that is needed. Frontier technologies however do not resolve the problem automatically due to multiple organizational cultures which are often in place, which is required to harmonize norms, communication protocols, or priorities. For instance, in cases where civilian-military adaptiveness is required for effective management in emergency or disaster relief situations. Human intuition and empathy can allow the facilitation of smooth collaboration in partnerships along with practical checklist tools!

Sentiment analysis via social media channels is a major source of information today. Most of the actionable information, especially during or post disaster (assuming there is connectivity in the region affected), comes from social media users. These users upload real-time images and comments which can be further analysed using AI. In a more predictive capacity, sentimental analysis can also be factored in through online survey platforms by applying AI-driven text analysis of unstructured comments. Through sample anonymous audiences this could allow isolation of hidden trends and identification of deeper meanings for faster adaptation.[2]

In a case study, developed by the World Bank's geospatial operations support team (GOST) drone and street-level imagery were fed to machine learning algorithms to automatically detect "soft-story" buildings or those most likely to collapse in an earthquake.[6] The World Bank used imagery from satellites, aerial images from drones, and 360 street views from ground photos to identify homes that were at high risk of collapse from an earthquake. The algorithms used were a combination of three factors: (1) slope of the land (2) large first floor openings (3) roof-top materials.

3.3.2.3 Interaction process between ML/AI and humans

Figure 4 shows the areas where machines and humans interact.

[2] https://www.qwary.com/text-analysis

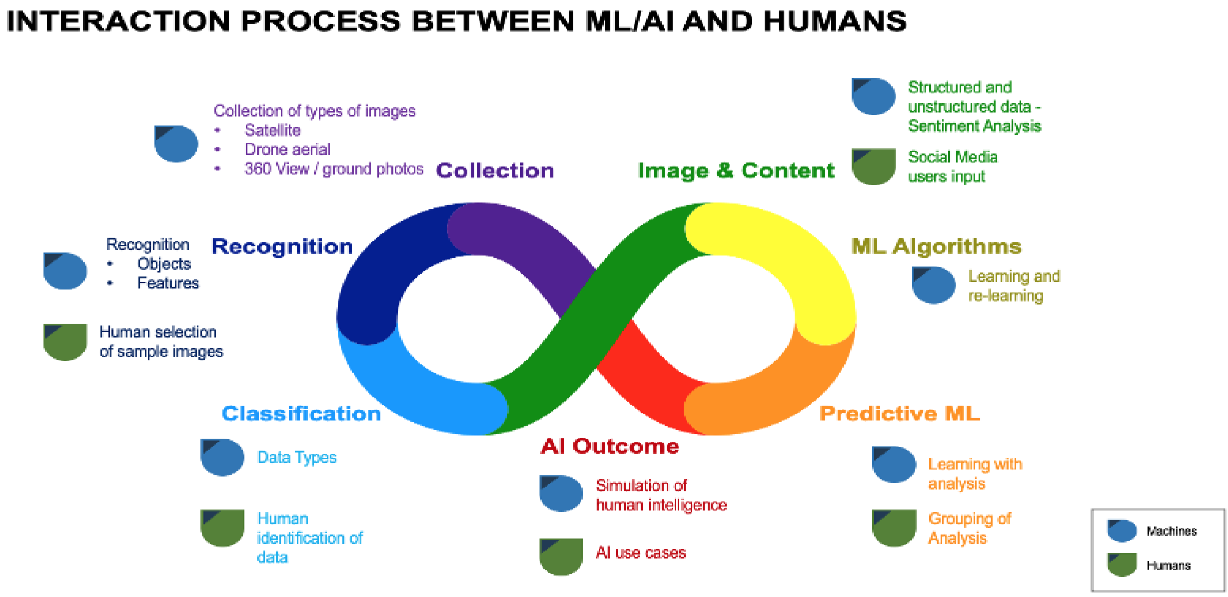

Figure 4 – AI and humans

In this figure, the area that merits ongoing research is the concept of "simulation of human intelligence". This is done for specific emphasis on certain components of human intelligence that will drive specific outcomes. A holistic take on human intelligence will also nurture holistic AI outcomes.

As noted in the summary, integrating human emotions in AI design will greatly mimic how humans store memories, make decisions and increase wellbeing. In this way it will make AI more empathic. We assign the emergence of human intelligence to the sudden growth of cognitive ability that our ancestors experimented with about 100'000 years ago, with the rise of modern humans. Through a new awareness called self-other splitting, i.e., being separated from others and the environment, the paradoxical sentiment of empathy starts to develop, along with a sense of being connected while separated. This is the oldest mode of consciousness known in our evolutionary journey.[3] For empathy to happen the affective and cognitive psychological components need to remain separate while coexisting, despite their apparent contradiction quality. It is similar to the experience of creativity, often called "Janusian thinking" in recalling the mythical figure, from where it gets its name – Janus, a Roman god, where the two heads face opposite directions, often referred to as the simultaneous use of antithetical concepts.[4]

This dual aspect that underlies the human capacity to connect and communicate despite a self-awareness of individuality also reflects at a physiological level. Heart science research highlights the importance of energetic heart-brain communication pathways to achieve a physiological state of coherence, which has been associated with heightened empathic connection to others. This occurs through internal stability, allowing for enhanced ability to register electromagnetic signals and information patterns encoded in fields radiating from other people's hearts.[5] In a way, using the traffic analogy where chaotic signals in the environment are aptly managed by a stable and smart traffic agent who spots external needs and organizes information flow around efficiently.

This type of intelligent management of resources stems from what has been called heart intelligence and correlates with increased access to intuitive information, which communicates via the

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3 Berman, M. (2000). *Wandering God: A Study in Nomadic Spirituality*. New York: State University of New York Press.

4 Kaplan, A. G. (1991). Empathic communication in the psychotherapy relationship. In J. V. Jordan, A. G. Kaplan, J. B. Miller, I. P. Stiver, & J. L. Surrey. *Women's growth in connection: Writings from the Stone Center* (pp. 44-50). New York- London: Guildford Press.

5 https://www.heartmath.org/research/science-of-the-heart/energetic-communication/

emotional energetic system to the mind and brain systems. Although research points to emotions as the primary language of intuition, it can also encompass cognitive content and perception of information. Nevertheless, the three categories of intuition identified through heart science appear to be accessible through increased capacity for heart-rhythm coherence: *implicit knowledge or implicit learning* (what we know from the past even if forgotten), *energetic sensitivity* (our nervous system's ability to detect and respond to environmental signals such as electromagnetic fields), *and nonlocal intuition* (knowing or sensing something that cannot be explained by the other two types).[6] These conclusions seem to align with other findings from research in the field of design, which point that intuitive and rational thinking coexist effectively and result in inspired design through reflective practices.[7]

Amongst the aforementioned three types of intuition, humans can teach machines to learn (pattern recognition identification through neural networks) and to detect signals (i.e., to predict an earthquake), the third being inaccessible to machines as it suggests that this capacity is a property of all physical and biological organizations due to their interrelated nature in the universe.

The capacity of the human heart for both coherent and incoherent states is already drawing attention for implications in the emerging artificial intelligence, robotics, and machine learning fields.[8]

We can summarize a prediction as follows: an intuitive way for designers and operators to interface with AI, ML, and robotic systems which stem from a stable inner coherence state in tune with the interconnectedness of life. On the contrary, lack of empathy with fellow humans or the wellbeing of the planet's diverse ecosystems would pose a danger of designing from an unnatural sense of dissociation, which can foster adverse technological solutions that will tend to overpower, and not aid in any kind of partnerships.

3.3.2.4 ML and AI classification

Table 3– Use of ML and AI classification

Recognition and classification	Data	Potential ML/AI usage
Land area	Cadastre information	• Satellite and aerial drone images • Terrain or lidar
Agriculture crop damage	Area of damage	• Satellite, aerial drone images, and 360 street view ground photos • AI-enabled drones
Mobility	Existing routes and temporary mobility	• Re-routing road access • AI-enabled drones
People - safety	Temporary shelter, evacuation centre	• Face recognition AI to analyse demographics • Closed-circuit television (CCTV) AI for shelter safety • Tele-medicine
People – living and working	Households and income affected	• Agriculture crop damaged vs salvaged

6 https://www.heartmath.org/research/science-of-the-heart/intuition-research/

7 https://www.designsociety.org/publication/35199/HOW+INTUITION+AFFECTS+DESIGNERS%E2%80%99+DECISION+MAKING%3A+AN+INTERVIEW+STUDY

8 https://www.heartmath.org/research/research-library/relevant/heartmath-coherence-model-artificial-intelligence-and-robotics/

Table 3– Use of ML and AI classification

Recognition and classification	Data	Potential ML/AI usage
		• Aerial drone images and 360 street view ground photos for future planning • AI to identify owner, livelihood and aid needed to rebuild
Commercial buildings	Businesses affected	• AI on number of businesses affected, how fast can the businesses recover
Public amenities	Parks, street and traffic lights, community halls	• Calculate building materials needed and predict estimated completion time • Aerial drone images and 360 street view ground photos for future planning
Infrastructure	Roads, bridges, water and sewage pipes, electricity poles	• Calculate repair and rebuild costs • Impact to economy • Sensor fed AI to identify weak structures • AI rebuilding or flood resistant materials
Transportation / logistics	Roads, airports, ferries	• Calculate repair and rebuild costs • Impact to economy
Mobility	Existing routes and temporary mobility	• Re-routing road access • AI-enabled drones
Connectivity	Telecommunication 3G, 4G	• Behavioural usage of mobile phones during disasters for better planning
Social media channels/survey platforms[9]	Upload photos, comments, tag location/unstructured comments	• AI sentiment analysis

GISAID

GISAID, an open scientific platform is an example of the synergy that exists between AI and big data. The GISAID initiative promotes the rapid exchange of data on all influenza viruses and the coronavirus that causes "COVID-19". This includes the genetic sequence and related epidemiological and clinical data associated with human viruses, and geographic and species-specific data associated with avian and other animal viruses, to help researchers understand how viruses evolve and spread during epidemics and pandemics.

The initiative ensures that open access data present in GISAID is provided free of charge to all people who agree to identify themselves and respect the GISAID exchange mechanism that is governed by its database access agreement (DAA).

All bonafide users with access credentials to GISAID agree to the basic premise of maintaining a scientific label, recognizing the source laboratories that provide the samples and the shipping laboratories that generate the sequence and other metadata, thereby ensuring fair exploitation of the

9 https://www.qwary.com/text-analysis

data. Results that are derived from the data present in GISAID will allow users to accept that no restrictions, will be imposed on the data sent to GISAID, and it will be used to promote collaboration between researchers based on the exchange of open data and a respect for all rights and interests.
https://www.gisaid.org/

3.4 Cultural heritage

There are over 200 world heritage sites (WHS) worldwide and 38 heritage sites in Southeast Asia under the United Nations Educational, Scientific and Cultural Organisation's (UNESCO) list of world heritage sites. Unfortunately, some WHS have been listed under the International Union for Conservation of Nature's (IUCN) recent lists of "significant concern" and "critical" conservation outlook. In 2017, the IUCN world heritage outlook showed that climate change is the fastest growing threat. Climate change has effectively become the most prevalent threat in the world. Overall, it is assessed as a high or a very high threat in 83 out of 252 world heritage sites [6].
What a city requires is something similar to a photo-album that will become an archive of snapshots of their heritage sites over time. This will provide insights as to whether these world heritage sites are maintained and restored to their original grandeur. Humans at a glance can decipher shades of colours and if re-painting is needed. Machines also need to learn this technique with many photo-realistic image processing.

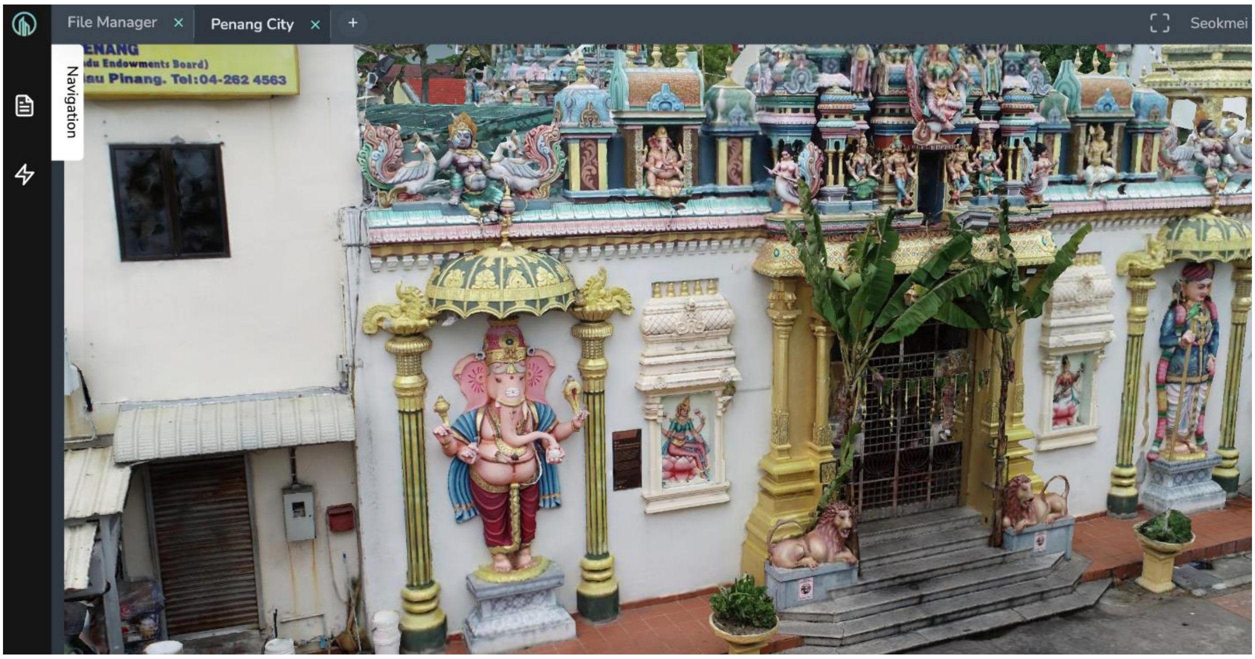

Figure 5 – 2D/3D view of a temple in Penang City

Compared to other applications that have gained large success in AI (e.g., speech recognition has been successfully used in many AI devices), vision-based AI is relatively preliminary. Although the breakthrough in using deep learning methods for object recognition has driven a large number of research investigations, its practical uses are limited by (1) processing 2D/3D signals associated with AI tasks are far more complicated, and (2) there is, in general, a lack of representatives and large enough datasets for various photogrammetry and remote sensing-based applications. Thus image-based AI in the field of photogrammetry is still a topic of exploration and scientific investigation [7].

3.5 Environmental preservation

Many environmental datasets are available around the world, such as the farmers portal (Figure 6) or climate change AI.[10] All are data-driven, but not all are AI-driven, as it first promotes an understanding of the fundamental principle where the data is too scarce to be fed to AI algorithms. In any case visual and data literacy are useful to understand the challenges at play.

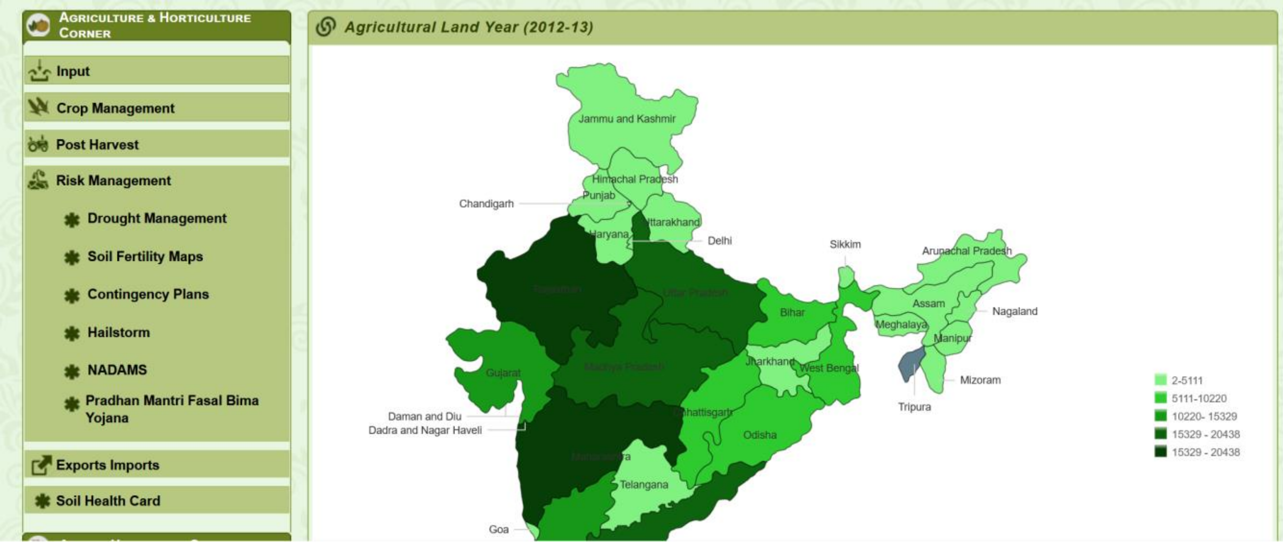

Figure 6 – India's farmers portal

3.6 Data centre energy consumption

During the 3rd industrial revolution, the use of telecommunications and computing brought digitization to the masses, in the same way the combined use of AI, IoT, and HCI technologies which is currently the foundation of many multinational tech companies in this era of the 4th industrial revolution, it is gaining rapid adoption among the masses. From a consumer perspective, the human/computer interactivity from multinational tech companies is so seamless that it is no longer considered out of the ordinary. However, the same explosion of growth is still in its infancy outside the scope of multinational tech companies, and we are still in the early stages of the AI arms race.

The use of deep learning, which is a subset of AI, is now able to offer significant accuracy improvements over historical statistical models, which were once AI's foundation. The significant increased adoption of deep neural networks has been driven by increasing volumes of data now estimated at 40 zettabytes (40'000'000'000'000'000'000 bytes or 40 million high-end desktop hard drives) at the end of 2020, which is 90% of all data created in the last two years. The increasing use of IoT devices which was estimated at 31 billion at the end of 2020, and the computing power with acceleration through graphical processing unit (GPU) and tensor processing unit (TPUs), has driven performance increase of at least 2x year on year.

The size of deep learning models being trained is doubling on an average in every three to four months. This will come as no surprise to the semiconductor market, as AI related semiconductor production is growing at five times the non-AI related semiconductors. In addition, while forecasts related to IT shows that AI is growing at approximately 43% every year, it is in fact the hardware element which is growing the fastest [10] [11].

Over the past two years, large organisations have doubled up on data science employees, where the top three use cases are reducing costs, improving customer experience, and generating customer insights. It is expected that smaller organisations will follow a similar path. While there are enormous benefits to building a data strategy, there is still a large failure rate within AI related projects.

While deep learning continues to reap benefits against traditional statistical models, there are energy considerations that need to be considered due to the enormity of energy consumption. For example,

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[10] https://www.climatechange.ai/resources

carbon dioxide (CO_2) for a car through its lifetime is a fifth of the CO_2 required to train the latest large scale NLP transformer models [8].

Deep learning often dictates that larger models offer improved accuracy, albeit with diminishing returns. The model size is taken into consideration. The growth in model size has been in the ballpark figure of 300'000 times between 2012 and 2018. While this may sound extreme, GPT-2 in 2019 had 1.5 billion parameters, its successor generative pre-trained transformer 3 (GPT-3) now has 175 billion parameters, and there is no sign of model growth slowing down [11]. Figure 7 illustrates the recent exponential evolution of the model and dataset sizes [14].

Year	Model	# of Parameters	Dataset Size
2019	BERT [39]	3.4E+08	16GB
2019	DistilBERT [113]	6.60E+07	16GB
2019	ALBERT [70]	2.23E+08	16GB
2019	XLNet (Large) [150]	3.40E+08	126GB
2020	ERNIE-Gen (Large) [145]	3.40E+08	16GB
2019	RoBERTa (Large) [74]	3.55E+08	161GB
2019	MegatronLM [122]	8.30E+09	174GB
2020	T5-11B [107]	1.10E+10	745GB
2020	T-NLG [112]	1.70E+10	174GB
2020	GPT-3 [25]	1.75E+11	570GB
2020	GShard [73]	6.00E+11	–
2021	Switch-C [43]	1.57E+12	745GB

Figure 7 – Overview of recent large language models

Almost every online business has no choice but to adopt an AI strategy. If there is one thing, the 3rd industrial revolution taught us is that those that fail to adapt or adopt a very cautious strategy will cease to exist or be acquired. This means data centre energy consumption, irrespective of the size and locality of the data centre, is about to skyrocket. This is determined by the logic that the latest deep learning models can be far more accurate than their statistical counterparts and against human-level performance with an increase in the range of tasks.

To put into perspective the size of the problem that we face, if we assume there are a quarter of a billion businesses now, and only 0.1% of those businesses decided to train an off the shelf BERT transformer, then in five years assuming expected model growth, and no efficiencies in semiconductor technology, then this would result in double the global CO2 output than what we have now. This is through considering the 2019 global CO_2 emissions of 36 billion tonnes [9] and considering that the BERT transformer generates 0.65 tonnes of CO_2 now. Factoring the growth of the model over five years considering the model size doubling every 3 months, this would relate to 45.5 billion tonnes of CO_2 if each of the 250'000 businesses are trained with this model.

The recommendations are published for providing guidance to:

- Provide recommendations to measure the impact when training models.
- Provide recommendations to drive efficiency when training models.
- Provide guidance to data centre providers to model the data centre power usage effectiveness (PUE) to offer optimum cloud compute packages, based on heating, ventilation, and air-conditioning (HVAC) efficiencies.

Recommendations to measure the impact when training models.

Currently, there is little guidance in understanding the impacts of training models, and HCI methodologies to visualise the environmental impact of the model being trained. There are two reasons; firstly, the most popular deep learning frameworks require open-source development of libraries to measure environmental impact during the training, and secondly, as the optimum accuracy is often obtained by vast data points, this has forced businesses to adopt cloud services. This nearly always removes the core metrics available from the underlying hardware from the users of the cloud services.

There is currently no standard method to measure deep learning model efficiencies, and while there are many ways to extract measurements at the hardware and software level, the acceleration within both semiconductor technology evolution and complexities of models using deep learning frameworks means we are addressing a moving target. Some challenges are addressed in the published paper *Estimation of energy consumption in machine learning* https://doi.org/10.1016/j.jpdc.2019.07.007.

Recommendations to drive efficiency when training models

The advancements of modern deep neural networks now have many ways to drive efficiencies, both in time and energy when training models. A very positive impact of the model size doubling every three months to get the best efficiencies has driven the adoption of transfer learning. This is where a pre-trained model, which would normally require months of training on hardware typically used by mid-size businesses is taken from a similar task and fine-tuned to meet an individual business requirement. This enables models to be trained in hours, and not days, weeks, and months. Some notable examples are in image processing and natural language processing.

The gap in accuracy from a model being trained from scratch and fine-tuned for transfer learning is getting wider. This is due to the overall size of models doubling every three months. This not only benefits businesses but also has a significant effect on the CO_2 output, as 99% of the training takes place through pretransfer learning.

Provide recommendations to data centre providers to model the data centre PUE to offer optimum cloud compute packages based on HVAC efficiencies.

The power usage effectiveness (PUE) is a common measurement used in understanding the efficiency within a data centre. This is one of many metrics used to measure data centre efficiencies along with other standards and measurements, including LEED, PAR4, ASHRAE and CCF. PUE is a relatively straightforward measurement that considers total power entering the data centre versus the power being drawn by computer equipment in the data centre. Currently, the 2018 global PUE average has been estimated at 1.58.

While standards and recommendations are aimed at driving efficiencies within data centres, it is possible to measure PUE within any given time at extremely fine granularity. This is possible due to the sheer volume of useful sensor data that building management systems are capable of generating, be it from the power distribution units, HVAC systems, UPS, or others. As heat and external environmental influences are a by-product of computer equipment running at a load that affects the PUE, this enables data centre service providers to offer variable tariffs to drive data centre consumer behaviours. Considering the two key factors of co-location in data centres are power and space, where the power is the higher cost of the two, this offers the data centre provider to vary tariffs based on real-world power charges linked to PUE measurements.

3.7 Heating, ventilation, and air-conditioning (HVAC)

3.7.1 General

Buildings account for an estimated 40% of total energy consumption. Heating, cooling, and hot water represent 60 percent of energy demand in buildings. Energy efficiency and conservation in buildings are often referred to as the lowest hanging fruit in combatting climate change.

A below 2°C pathway requires reducing global energy and process-based carbon dioxide by 60% in 2050 compared to 2012. For the building section, this means avoiding at least 50% of projected growth in energy consumption through energy-efficient, near-zero, net-zero energy, and energy-plus buildings [12].

3.7.2 Building HVAC

A HVAC system takes care of the total control of temperature, moisture in the air (humidity), supply of outside air for ventilation, filtration of airborne particles, and air movement in the occupied space. HVAC systems play an essential role in ensuring occupant comfort and are among the largest energy consumers in buildings. Performance enhancements to HVAC systems offer an exciting opportunity for significant reductions in energy consumption.

Today, HVAC systems are more efficient, safer and have lesser environmental impact. Ozone-depleting refrigerant gases have been phased out and the co-efficient of performance of systems have also improved. However, controlling a system can be a technical challenge.

Designers in the HVAC industry must be familiar with codes and standards. Standards define the industry's agreed-upon minimum technical requirements, procedures, guidelines, and instructions for engineers, designers, or manufacturers. They also establish the industry's minimum standard of care, such as ANSI/ASHRAE/IES Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Buildings and the International Energy Conservation Code (IECC).

An HVAC system is designed on thermodynamics models. The building temperature is affected by many factors, including the surrounding environment, the various sources of heat gains, including the occupants and equipment. Therefore, building a dynamic model with inputs that are constantly changing is challenging.

Effectively controlling a HVAC system is difficult because building conditions are constantly changing:

- The outdoor temperature is constantly changing, affecting the heating, or cooling required to keep a suitable indoor temperature.
- People enter and leave buildings all the time, which affects the ventilation needs and temperature control.
- The activities performed indoors also affect HVAC needs. For example, a commercial kitchen needs more ventilation and cooling than an office of the same size.

Since ventilation, heating and cooling needs of a building are constantly changing, a HVAC system with manual controls cannot reach peak performance due to the variable working conditions.

Therefore, data-driven approaches are critical to leverage fluctuating real-time data inputs. Smart control systems have been developed to process all this data in real-time and adjust the HVAC system accordingly.

AI is beneficial to the HVAC industry because it allows the equipment to automatically perform work that once required human effort or work previously unavailable [13].

Many buildings have ventilation systems that operate at full airflow all the time. It represents a significant waste of energy. Overventilation means a waste of energy, while underventilation is detrimental to indoor air quality. Ventilation control with AI helps to prevent both.

When ventilation controls have AI, they can determine the optimal airflow required by the building. The system can also track the number of occupants and the concentration of key air pollutants like VOCs and particulate matter. Systems already exist where occupants' heat signatures are detected, and the vane is automatically adjusted to blow conditioned air to the occupant. AI is used to monitor and analyse real-time data collected and make the required adjustments according to the environment.

Another application of AI is for predictive maintenance. AI-enabled systems use predictive modelling to avoid breakdown or detect parts that are underperforming and require replacing. Some systems notify the maintenance manager, log a service call to a contractor, check the store for the replacement part, and even order the part if it is not in stock. An enabler for predictive maintenance is often the result of applying machine learning to historical data. Machine-to-machine (M2M) learning can provide general trend analyses and diagnostics, providing reports and recommendations. Predictive maintenance results in a reduction in energy savings, and invariably, a reduction in CO_2 emissions.

Internet-of-things, intelligent edge devices, controls, improved data collection capacity and information exchange in buildings offer AI opportunities in managing systems, optimise operations, improve indoor air quality, reduce operating costs and downtime and save energy.

3.7.3 District heating and district cooling

Cities host over half the world's population, consume over two-thirds of the world's energy and account for more than 70 percent of CO_2 emissions.[11] Energy use in buildings and for building construction represents more than one-third of global final energy consumption and contributes to nearly one-quarter of greenhouse gases (GHG) emissions worldwide.[12]

District heating (also known as heat networks or teleheating) is a system for distributing heat generated in a centralised location through a system of insulated pipes for residential and commercial heating requirements such as space heating and water heating. Centralised systems are equally used for cooling. An example of a district cooling system is the seawater air-conditioning system using cold seawater. Figure 8 depicts district heating systems and provides an understanding of the network required and the physical principles that the various systems are based on.

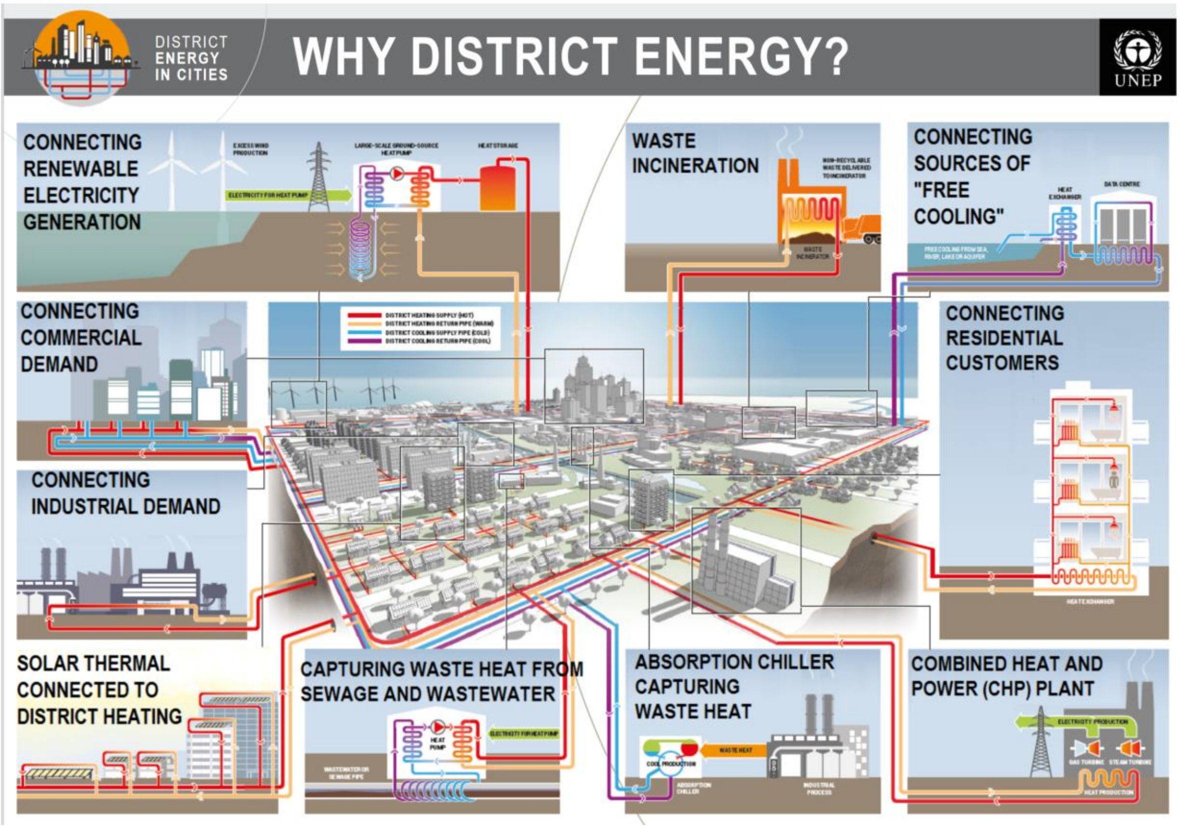

Figure 8 District energy in cities[13]

District heating and cooling systems have to balance comfort with energy efficiency. Inclusive communication efforts must be constantly deployed to guarantee compliance and engagement from citizens and inhabitants. Visualizations such as Figure 8 and Figure 9 raise awareness and understanding of the challenges and the priorities that are needed to solve them.

11 https://www.unep.org/news-and-stories/story/district-energy-secret-weapon-climate-action-and-human-health

12 https://c2e2.unepdtu.org/wp-content/uploads/sites/3/2016/11/gabc-global-status-report.pdf

13 https://c2e2.unepdtu.org/wp-content/uploads/sites/3/2016/04/district-energy-in-cities.pdf

Figure 9 – Categorization of building energy efficiency for district heating (with colours)

3.8 Traffic and public transport

Modern mobility in cities, agglomerations, and regions typically involves multi-modal operators and potentially millions of users, devices, vehicles. Visualisations such as top-level dashboard solutions and 4D visualizations of digital twin cities can not only improve the understanding of past and current situations, identify patterns, and quantify pollution, but are also capable of providing short-term forecasts and long-term simulations by taking into account future infrastructure improvements such as new bridges and tunnels, ferries, buses or train lines.

The following software platforms are examples of how big data generated by real-time traffic information and traffic simulation can be displayed in graphical digital twins for better comprehension of the conveyed insights and apparent patterns.

-AugmentCity

AugmentCity decreases the gap between man and machine by humanizing and contextualizing complex data. AugmentCity offers smart and sustainable solutions throughout the urban development process involving inhabitants, politicians, private and public decision-makers. The cloud-based platform enables cities to benchmark on sustainability key performance indicators (KPIs) and their stakeholders to collaborate on urban or territorial development through visualisation by importing digital elevation and building and road information (BIM) models and integrating different data APIs for rich and immersive modelling of future scenarios: one platform – multiple datasets – cross-disciplinary collaboration for a smarter and more sustainable future.

Recent reality augmenting projects include the instant simulation of mobility, improving energy efficiency in office buildings, live-editing terrain, and simulating sea-level rise in coastal cities.

AugmentCity builds digital twins of cities. It is a visualisation and simulation technology that enables urban planners to replace time-consuming paper-based processes with data-driven models and 3D visualisations for traffic simulation, urban traffic planning and optimisation. This will contribute to a better understanding of the causes of congestion, pollution and risk, and what zoning plans have to create for travel patterns and people's lives and welfare. Though Ålesund was selected as a test city, the solution was sold to 17 cities during the project period and used in far more projects. The project partners include the Norwegian Public Roads Administration, Trondheim Municipality, Telenor ASA, Easy park AS and VY Mobility AS.

-C³PO

C³PO aims to provide a semantic and collaborative platform in the cloud for the co-design of cities. The C³PO platform is unique because it covers the entire urban project development process where cities empower, encourage, and guide different actors (citizens, decision-makers, architects, etc.) to develop an urban project together. C³PO does not intend to replace or modify existing applications by offering unique but partial city co-design solutions (simulation tool, open API, 3D modelling and visualisation, game tool, etc.) but it can be seen as an open and generic intermediary that allows interaction between existing applications through a unique multi-dimensional semantic repository (covering the different types of information in city codes such as GIS, BIM, electrical networks, traffic, etc.)

https://itea3.org/

https://itea3.org/project/success-story/c3po-success-story.html

3.9 Air quality

Poor air quality affects billions of people's lives; even in advanced and highly regulated economies poor air quality has significant economic and health-related effects. Meanwhile, in emerging economies, industrial development is having a major impact on population health. The direct impact of poor air quality is itself a sufficient justification for monitoring, modelling, and mitigating the impact of air pollution. However, it also serves as a key indicator of other important factors like energy consumption, economic activity, traffic movement, and the overall environmental impact.

In the context of population health and wellbeing, it is essential to measure the air that people in their daily lives experience. This includes external air quality – the air experienced when people move about the landscape/city space, as well as internal air quality at home and at work.

Accurate localise air quality data brings numerous benefits.

The ability to monitor air quality at a hyper-local level brings numerous health, wellbeing, and economic benefits.

In the context of human health, the cost to health systems of treating chronic respiratory illness continues to grow at an alarming rate. By gathering data about the "experienced air quality" of people with respiratory conditions, medical practitioners can develop more effective (and often lower cost) modes of treatment and help to mitigate any problems thereby improving the lives of patients and reducing the cost of their treatment on the health system.

Air quality is also a powerful economic indicator; it helps city planners determine the economic activity of a city and to identify issues that may be limiting the economic prosperity of the city space. To put it another way, congestion on city streets is not just bad for the people who walk on those streets and the environment, in general, it also highlights an economic cost that is incurred by the city – cars and delivery vehicles that are stuck in traffic that do not produce economic benefits.

Current approaches to air quality monitoring do not produce enough data to provide a hyper-local model of air quality.

Current approaches to air quality monitoring cannot provide enough data to establish the impact of air quality on individuals because air quality is typically measured using a small number of highly precise (and expensive) monitoring stations whose data is then used to determine an overall air quality index (AQI) for a given area. This approach tells us nothing about the differences in air quality within that area, and it is well-known that air quality can vary dramatically street-by-street.

The challenge is to develop a way to evaluate and report on air quality on a hyper-local scale, enabling people and the relevant authorities to respond to differences or changes in air pollution in real-time.

To create a hyper-local model of air quality, we need to develop models that enable us to make use of the data that we have, to derive accurate models that enable us to generate an accurate air quality map of geographic space (whether that is a section of a city or the inside of an office building).

To measure air quality in real-time, it is necessary to deploy sensors across the space to be monitored, but this represents a major practical and economic challenge which for many cities/economies (notably in emerging economic zones), the cost of implementing hyperlocal air quality monitoring is prohibitively expensive.

While a lot of work has been done to lower the cost of environmental monitoring, there is still a lot more work that is needed to be done; the accurate measurement of key pollutants like particulates, nitrogen dioxide, and ozone still requires relatively expensive sensor technology, which must be maintained and recalibrated on a regular basis.

Recommendation: Use AI and ML to lower the cost of air quality monitoring in three steps

AI and ML have a critical role to play in making air quality monitoring accurate and economically viable, but without the learning and validation phases, it will be almost impossible to gather enough data to train models with enough confidence to produce real-time hyper-local air quality data.

AI and ML offer the potential to dramatically lower the cost of hyper-local air quality monitoring by enabling to deploy sparser networks of sensors from which hyper-local air quality can be inferred. The key to effective application of AI and ML for this problem lies in establishing a sufficient base of data to enable effective training of AI/ML models.

This challenge can be addressed in three phases:

1. Data gathering and learning
2. Algorithm testing and validation
3. Optimisation and audit

In the first phase (data gathering and learning) many sensors need to be deployed in order to establish a sufficient base of data for analysis. The sensors that are deployed need not be expensive "lab-grade" sensors; hybrid networks containing a blend of different sensors which acquire data at different levels of precision (and consequently different levels of cost) can gather enough data for analysis by ML/AI algorithms.

A second phase can commence (algorithm testing and validation) where the predictions made by models can be compared with observed levels of air quality to refine the algorithms that underpin the model. In this second phase it should also be possible to identify "proxy phenomena" which are inexpensive and/or easy to measure but which provide a strong indicator of other phenomena which may be more difficult and costly to monitor. For example, once the correlation between traffic and pollution is established, it should be possible to infer the polluting effects of traffic using inexpensive sound/vibration sensors rather than having to deploy a battery of sensors to measure ozone, nitrogen dioxide, particulates, etc.

In the final phase (optimisation and audit) the number of deployed sensors can be greatly reduced with a smaller number of sensors that are used to verify the output of the air quality models on an on-going basis.

3.10 Other technologies

The emerging technologies succinctly defined in clause 5 should be analysed with respect to cost/benefits and human understanding of climate change challenges.

4 References

None.

5 Terms and definitions

This Technical Report defines the following terms[14]

[14] The definitions used in this document are defined in FG-AI4EE input document FG-AI4EE-WG2-I-023 Taxonomy of Emerging Technologies.

5.1 Predictive crime prevention

The use of sociometric sensors coupled with neural networked computers to statistically determine the probability of crime (or other anti-social behaviour) taking place before it happens.

5.2 Predictive group sentiment analysis

Predicting the likely behaviour of large groups of people based on sociometric input variables like social tension, weather variation, pedestrian flows and degree of agitation is becoming increasingly possible.

5.3 Neural network image recognition

Using hundreds of thousands of processor cores programmed to algorithmically determine a given image's content. This is different from reverse image search, as neural network image recognition has the capacity to successfully understand the photo, for example, learning to identify a cat, based on thousands of cat pictures.

5.4 Emotion tracking

Using sensors, computer vision and algorithms to correctly identify the likely emotions displayed by individuals in a crowd. Useful in airports and other high-risk facilities.

5.5 Proactive software agents

Software applications with the capacity of discerning and predicting likely future needs for whoever is being served. Intelligently scheduling meetings, sorting email and selectively notifying the user are potential usages.

Networked computers to statistically determine the probability of crime (or other anti-social behaviour) taking place before it happens.

5.6 Neuro-prosthetics

Neural devices capable of substituting motor, sensory or cognitive modalities that might have been damaged as a result of an injury or a disease. Applications include neural enhancements, advanced cognitive features and extended physiological senses.

5.7 Next-generation neuropharmacology

Both behavioural and molecular neuropharmacology are benefitting from rapidly accelerating change. With an increase in technology and improved understanding of the nervous system, the development of drugs will continue to rise with an increase in drug sensitivity and specificity.

5.8 Micromachined ultrasonic transducers

A relatively new concept in the field of ultrasonic capacitive transducers where the energy transduction is due to change in capacitance. Can be used to remotely improve alertness, awareness in soldiers, etc.

5.9 Neural biofeedback

Biofeedback using real-time EEG or fMRI to illustrate brain activity, often with a goal of controlling the central nervous actions.

5.10 Brain-to-brain interfaces

The hypothetical implementation of brain interfaces that translate thoughts, sensations, or impulses into a digital signal, and converting the data back into the recipient's brain to enable a certain response from both ends. Since it is loosely interpreted as telepathy, brain interfaces would be able to transmit information from one person to another without any mediation other than the internet, allowing the brain at the receiving end to perform behavioural tasks without training.

5.11 Optogenetic implants in humans

The combination of genetic and optical methods to control specific events in targeted cells of living tissue, even within freely moving mammals and other animals, with the temporal precision (millisecond timescale) needed to keep pace with functioning intact biological systems.

5.12 Next-gen BCI

Hypothetical interfaces to be used for assisting, augmenting, or repairing human cognitive or sensory-motor functions and communicate thoughts and intentions to the internet.

5.13 EEG brain-to-computer interfaces

Electroencephalography remains the most feasible practice of executing and implementing brain-to-brain interfaces. It represents the best temporal-resolution tool for getting a picture of the brain in action, it is portable, non-invasive, and extremely affordable compared to other methods.

5.14 Medical tricorder

A hypothetical handheld portable scanning device to be used by consumers to self-diagnose medical conditions within seconds and take basic vital measurements. A common view is that it will be a general-purpose tool similar in functionality to a Swiss army knife to take health measurements such as blood pressure, temperature and blood flow in a non-invasive way.

5.15 Biohacking

A techno-progressive cultural and intellectual movement which advocates for open access to genetic information and defends the potential of the democratic technological development. Biohacking can also refer to managing one's own biology using a combination of medical, nutritional, and electronic techniques. This may include the use of nootropics and/or cybernetic devices for recording biometric data.

5.16 Lab-on-a-chip (LOC)

Devices that integrate one or several laboratory functions on a single chip having a millimetre to a few square centimetres in size. LOCs deal with the handling of extremely small fluid volumes down to less than pico-litres. They represent safer platforms for chemical, radioactive, or biological studies.

5.17 Biometric sensors

The use of biometrics to telecommunications and telecommunications for remote biometric sensing. Potential applications include monitoring blood levels, infections and efficacy of vaccines.

5.18 Infrastructural health sensors

Can be used for monitoring vibrations and material conditions in buildings, bridges, factories, farms, and other infrastructures. Coupled with an intelligent network, such sensors could feed crucial information back to maintenance crews or robots.

5.19 Livestock biometrics

Collars with GPS, RFID and biometrics can automatically identify and relay vital information about the livestock in real time.

5.20 Crop sensors

Instead of prescribing field fertilization before application, high-resolution crop sensors inform application equipment of the correct amounts needed. Optical sensors or drones are able to identify crop health across the field (for example, by using infra-red light).

5.21 Equipment telematics

Allows mechanical devices such as tractors to warn mechanics that a failure is likely to occur soon. Intra-tractor communication can be used as a rudimentary "farm swarm" platform.

5.22 Air and soil sensors

Air and soil sensors are the fundamental additions used in automated farms, these sensors would enable a real time understanding of current farms, forests, or body of water conditions.

5.23 Rapid iteration selective breeding

The next generation of selective breeding where the end-result is analysed quantitatively and improvements are suggested algorithmically.

5.24 Nano electric-mechanical systems

Devices integrating electrical and mechanical functionality on the nanoscale. NEMS typically integrate transistor-like nanoelectronics with mechanical actuators, pumps, or motors, and may thereby form physical, biological, and chemical sensors.

5.25 Graphene

A substance composed of pure carbon with atoms arranged in a regular hexagonal pattern similar to graphite, but in a one-atom thick sheet. With a one-square-metre sheet weighing only 0.77 mg, the material is incredibly light yet strong. Potential applications are incredibly diverse and include components with a higher strength to weight ratios, lower cost solar cells, lower cost display screens in mobile devices, storing hydrogen for fuel cell powered cars, medical sensors, faster charging batteries, ultracapacitors, chemical sensors and many others.

5.26 Meta-materials

Materials with a precise shape, geometry, and arrangement which can affect light and sound in unconventional manners. Potential applications are diverse, including remote aerospace applications, infrastructure monitoring, smart solar power management, public safety, improving ultrasonic sensors, and even shielding structures from earthquakes.

<u>Storage</u>

5.27 Thermal storage

Often accumulated from active solar collectors or from combined heat and power plants and transferred to insulated repositories for use later in various applications, such as space heating, domestic or process water heating.

5.28 Lithium-air batteries

Advances in materials technology is enabling the advance of high energy Li-air batteries which promise an energy density that rivals gasoline, offering a five-fold increase compared to traditional Li-Ion batteries. By using atmospheric oxygen instead of an internal oxidizer, these batteries could dramatically extend electric vehicle range.

5.29 Fuel cells

Unlike batteries, fuel cells require a constant source of fuel and oxygen to run, but they can produce electricity continuously for as long as these inputs are supplied. They inherently displace the need for natural gas turbines and are ideally used for stationary power generation or large passenger vehicles such as buses (especially at energy-dense future iterations of the technology).

5.30 Hydrogen energy storage & transport

Hypothetic evolution of existing power grids, transporting and storing hydrogen instead of electricity. Could be used in combination with various kinds of energy transformation methods, minimizing loss and maximizing storage capacity.

Smart grid

5.31 Smart energy network

Speculative global energy and power infrastructure and set of standards which can be used interchangeably. Could theoretically mimic characteristics of the internet in channelling heat, energy, natural gas (and conceivably hydrogen) from local and distant sources depending on the global demand.

5.32 Distributed generation

Generates electricity from many small energy sources instead of large centralised facilities. Centralised power plants offer economies of scale, but waste power during transmission, and are inefficient in rapidly adapting to grid needs.

5.33 First-generation smart grid

Electrical meters that record the consumption of electric energy in real time while communicating the information back to the utility for monitoring and billing purposes. Can be used for remote load-balancing such as disabling non-essential devices at peak usage.

Electricity generation

5.34 Space-based solar power

Collecting solar power in space, beamed back as microwaves to the surface. A projected benefit of such a system has much higher collection rates than what is possible on earth. In space, transmission of solar energy is unaffected by the filtering effects of atmospheric gases.

5.35 Thorium reactor

Thorium can be used as fuel in a nuclear reactor to produce nuclear fuel in a breeder reactor. Some benefits include: thorium produces 10 to 10'000 times less long-lived radioactive waste and comes out of the ground as a 100% pure, usable isotope, which does not require enrichment.

5.36 Micro stirling engines

Micrometre sized power generators that transform energy into compression and expansion strokes. Could hypothetically be 3D-printed on the fly and cover entire heat-generating surfaces to generate power.

5.37 Third-generation biofuels

Moving beyond today's organisms, 3rd generation biofuels involve genetic modification of organisms to produce new fuels by unconventional means. Examples include direct production of hydrogen from highly efficient algae and production of energy-dense furans for automotive use.

5.38 Micro-nuclear reactors

A small, sealed version of a nuclear reactor (approximately a few tens of metres in length) capable of being shipped or flown to a site. Currently able to provide 10 MW of power, 50 MW capacity is planned for the future.

5.39 Inertial confinement fusion

An approach to fusion that relies on the inertia of the fuel mass to provide confinement. To achieve conditions under which inertial confinement is sufficient for efficient thermonuclear burn, a capsule (generally a spherical shell) containing thermonuclear fuel is compressed in an implosion process to conditions of high density and temperature.

5.40 Photovoltaic transparent glass

Glass with integrated solar cells which converts IR and some visible light into electricity. This means that the power for an entire building can be supplemented using the roof and façade areas.

5.41 Tidal turbines

A form of hydropower that converts tidal energy into electricity. Currently used in small scale, with the potential for great expansion.

5.42 Solar panel positioning robots

Small-scale robots able to re-position solar panels depending on weather conditions. More efficient than attaching each panel to motorized tracking assemblies.

Electronics

5.43 Smart dust sensors

A system of many tiny micro-electromechanical systems such as sensors, robots, or other devices, that can detect light, temperature, vibration, magnetism, or chemicals.

5.44 Memristors

The memristor is different from the other three basic circuit elements as it can retain memory without power. It is a new material that promises computers two orders of magnitude more efficient from a power perspective than traditional transistor technologies. It contains multiple petabits of persistent storage and can be reconfigured to be either a memory or CPU in a package as small as a sugar cube.

5.45 Printed electronics

A set of printing methods used to create electrical devices on various substrates. Electrically functional or optical inks are deposited on the material, creating active or passive devices, such as thin-film transistors or resistors. Printed electronics is expected to facilitate widespread, very low-cost, low-performance electronics for applications such as flexible displays, smart labels, decorative and animated posters, and active clothing that do not require high performance.

5.46 Bot-sourcing

The assignment of physical and online tasks traditionally performed by human agents to an autonomous software agent.

5.47 Digital currencies

Electronic money that acts as an alternative currency. Currently, alternative digital currencies are not produced by government-endorsed central banks, nor are they necessarily backed by national currencies. It differs from virtual money used in virtual economies due to its use in transactions with real goods and services; not being limited to circulation within online games.

Networking

5.48 High-altitude stratospheric platforms

A quasi-stationary aircraft that provides means of delivering networking to a large area while flying at a very high altitude (17–22 km) over cities for several years. They are effectively low-orbit regional communication satellites.

5.49 WiGig

Wireless gigabit will deliver up to 6 Gbps [6,000 Mbps] connections between devices in interior spaces. This will enable wireless displays, similar to what Wi-Fi did for wireless networking.

5.50 5G

A predicted future fifth generation of mobile telecommunications, expected to be the next major phase of mobile telecommunications standards as well as a proposed single global standard.

5.51 MOOCs

Massive open online courses are a type of online course aimed at large-scale participation and open access via the web.

Interfaces

5.52 Immersive multi-user VR

A fully immersive virtual reality environment to which the user connects through direct brain stimulation. All senses are stimulated, diffusing the boundary between reality and fiction.

5.53 Telepresence

A set of technologies which allow a person to feel as if they are present, to give the appearance of being present, or to have an effect, via tele-robotics, at a place other than their true location.

5.54 Wall-sized screens

Interactive screen-wallpapers are expected to dominate all types of surfaces for domestic and professional uses. Wrap-around screens recruit peripheral vision and create a truly immersive experience.

5.55 Annotated-reality glasses

Much like Google's glass project, these allow contextual information to be overlaid on the user's field of vision.

5.56 Context-aware computing

Computers that can both sense and react to their environment. Devices will have information about the circumstances under which they operate, and based on rules and sensor inputs, react accordingly. Context-aware devices may also learn assumptions about the user's current situation.

5.57 AERIAL-CORE project: Drones with artificial intelligence for maintenance of power lines

A research and innovation project of the Horizon 2020 program led by Spain has developed drones with artificial intelligence (AI), capable of inspecting and manipulating lines to reduce maintenance costs for power lines and reducing accidents while carrying out work at a certain height.
These drones have the ability to land automatically, even on the same cables; they can also manipulate with robotic arms. They can perceive the environment and change shape during flight to consume less energy to fly longer and longer distances. The project is aimed at consolidating European leadership in the field of robotics for the maintenance of infrastructures and facilities.
https://aerial-core.eu/

5.58 Growing wood-equivalent fibres in a laboratory

An investigation published in the 'Journal of Cleaner Production' points out the advances in the creation of fibres equivalent to wood in a laboratory as if it were to plant a tree, but without the need for soil or sunlight. The MIT researchers "grew structures made from wood-like plant cells in a laboratory, suggesting the possibility of more efficient biomaterial production." This MIT research will make it possible in prohibiting cutting down of trees, thereby making a decisive contribution in fighting deforestation.
Although the project is not finished, it opens up the possibility of using the 3-D printing technique with vegetable cards in moulds. The method of this research consists of "extracting cells from the zinnia plant to cultivate them in a liquid growth to metabolize and proliferate. It is then transferred to a gel and "tuned in". This procedure is much more efficient as it takes many years for the cells to grow, which may help contribute to the effectiveness of meeting the goals and objectives set out in international CO_2 reduction agreements.
The idea behind this technique is similar to producing laboratory-grown meat, and although research is further behind than that of cultured meat, the potential of this new way of producing wood is

enormous. "Agriculture uses the energy of the sun through photosynthesis, except in irrigated land, and natural rain. It does not require buildings, heat or artificial light."
https://news.mit.edu/2021/lab-grown-plant-tissue-0120

5.59 DroneSeed. swarm of bees

DroneSeed is a startup based in Seattle (USA) that aims to mitigate climate change by recovering forests using drones, artificial intelligence and biological engineering. The drones of this startup operate in the form of swarms, by having up to five drones simultaneously in the air. The technology it uses allows each unit to be autonomous when analysing a burnt area through a multispectral camera, radar, laser, etc.
This new tool for the reforestation of forest fires helps in creating 3D maps of the vegetation of the land, an analysis of the soil and the plant life of the area. It also maps every inch of the area by identifying objects and plants that are present for spraying and identifying the best ones for replanting trees.
https://www.droneseed.com/

5.60 Autonomous drone that pollinates with a bubble gun

Due to climate change, habitat and human compartments, some pollinators have difficulty thriving in some parts of the world, which is essential for the pollination of fruit plants. Many plants depend on bees for pollination to produce food, but as we know, bees population has been on a dramatic decline in the recent years.
A study from the Japan Advanced Institute of Science and Technology in Nomi, Japan in the journal iScience suggests that soap bubbles may present a low-tech complement to robotic pollination technology designed to complement the work of missing bees. It was seen that soap bubbles helped in pollinating a pear orchard easier by delivering pollen grains to the selected flowers, demonstrating that this whimsical technique can successfully pollinate fruit plants.
Research summary: Soap bubbles facilitated pollination of a pear orchard by delivering pollen grains to selected flowers, demonstrating that this capricious technique can successfully pollinate fruit plants. It is a drone that can pollinate an orchard in a very similar way to these insects.
Reference: Cell Press. "Soap bubbles pollinated a pear orchard without damaging delicate flowers." ScienceDaily, June 17, 2020.
www.sciencedaily.com/releases/2020/06/200617150033.htm

5.61 LitterDrone, the plastics detector 'Made in Galicia' Spain

Plastic waste has become a problem on a global scale that is difficult to solve, with islands of garbage adrift in different seas and oceans. Although authorities of developed countries have repeatedly launched awareness campaigns for citizens to become aware of the challenge posed by the high level of plastic pollution, for humanity, the solutions to be applied need to be more radical.
A project funded by the European Union called the LitterDrone project is one of the projects of the European Union used for the detection and classification of plastics in the water. The research and development project carried out by the University of Vigo, the GSA company, and the Marine Litter Association (AEBAM) has aimed at an approach towards fighting marine pollution. The program is specifically dedicated to the development of monitoring and managing service for the 'detritus' deposited on the European coasts through the use of a fleet of drones.
The LitterDrone project seeks the use of drones equipped with high-resolution cameras and image analysis software for remote inspection and detection of the presence of plastic garbage on the coasts, as well as its composition and quantity.
In this way, the drones become an unmanned vehicle that has high-resolution cameras and image analysis software to detect plastic-related litter on the coasts. With the information collected by the drone fleet from the 'black' spots due to the presence of garbage, more effective decisions can be made to eliminate it without making unnecessary efforts, in addition to helping with preventive tasks.
An example of characterization of waste is seen through the collection of images by drones in the Cíes Islands which put the program to the test in its beta phase. Using a database, the software for

the detection and classification of garbage present on the beaches was developed. The development of the technologies used has been adapted to the standards established by the "Joint Research Center MSFD technical group". This project, once finalized, the technical potential will be exploited as one more tool at the service of the European authorities as part of the integrated maritime surveillance system".
https://ec.europa.eu/easme/en/development-and-exploitation-innovative-tools-remote-marine-litter-control-and-management-through

6 Terms defined here

This Technical Report defines the following terms:

6.1 Transferable model / transfer learning

In AI, any method or technique allowing a transfer of knowledge and insight from a trained algorithm to another. Training algorithms is resource-intensive (quality datasets, time, energy, and hard-ware) and reuse of these learnings can save huge amounts of resources.

6.2 Intuitiveness

The quality of being easy and natural to learn, use, or understand.[15]

6.3 Intuition

Knowledge from and an ability to understand or know something immediately based on your feelings rather than facts.[16]
Intuition (Reference: https://www.heartmath.org/research/science-of-the-heart/intuition-research/): "Affectively charged judgments that arise through rapid, nonconscious and holistic associations".

6.4 Heart intelligence

(Reference: https://www.heartmath.org/research/science-of-the-heart/intuition-research/): "The flow of higher awareness and the intuition we experience when the mind and emotion are brought into synchronistic alignment with the energetic heart". [17]

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[15] https://dictionary.cambridge.org/dictionary/english/intuitiveness

[16] https://dictionary.cambridge.org/dictionary/english/intuition

[17] The editor interprets the definition as a metaphor.

Abbreviations

AI	Artificial Intelligence
AQI	Air Quality Index
BIM	Building and Road Information
CCTV	Closed-Circuit Television
CO_2	Carbon dioxide
3D	Three-dimensional
GHG	Greenhouse Gases
GOST	Geospatial Operations Support Team
GPT-3	Generative Pre-trained Transformer 3
GPU	Graphical Processing Unit
HVAC	Heating, Ventilation, and Air Conditioning
IoT	Internet of Things
IUCN	International Union for Conservation of Nature
KPIs	Key Performance Indicator
ML	Machine Learning
MWh	Megawatt hour
PUE	Power Usage Effectiveness
TPU	Tensor Processing Unit
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WHS	World Heritage Sites

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