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- PhD (International Finance, Business Administration, Economics) U. of British Columbia, Vancouver, BC, Canada – 1974

- Senior Research Fellow, empirica Communication and Technology, Bonn, Germany - since 1992
- Lifetime Fellow, Royal Society of Medicine (RSM), London, UK – since 2005
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- Digital Health, Health Systems, Social Care & Older People



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Epigraph

“We must shape technologies in accordance with *human values and needs*, instead of allowing technologies to shape humans. Our task is not only to rein in the downsides of information and communication technologies, but to *encourage human-centered innovation*”

Vienna Manifesto On Digital Humanism, Vienna, May 2019

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Contents

- **Artificial Intelligence (AI) – How is it defined?**
- **History**
- **Technology: Status-quo and trend**
- **Applications in Health**
- **Challenges**
- **Outlook**

Artificial Intelligence (AI) – How is it defined?

Intelligence

- **High mental capacity**
  - ✓ **capacity for learning, reasoning, understanding,**
  - ✓ **aptitude in grasping truths, relationships, facts, meanings**
- **Ability to solve a problem within a certain time limit** ***(Marcus Gabriel, 2018)***

Antonyms

- **Ignorance, stupidity, ineptness**

https://www.dictionary.com/browse/intelligence

:

Biological intelligence

- **Living organisms**
  - **“Bacterial Cybernetics Group - cybernetic sophistication by bacteria”**
  - **Plants/trees**
  - **Animals (ants, bees, birds, monkeys, apes…)**
  - **Homo sapiens**

- **Intelligent materials?**

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AI and *General* Intelligence

General Intelligence: "A robust theory of general intelligence, human-like or otherwise, remains elusive"

Original ambitious **goal of the AI field:**

"The creation … of **software or hardware systems with *general intelligence*** comparable to, and ultimately perhaps greater than, that of human beings"

Searle, J. (1980). Minds, brains, and programs. Behavioral and Brain Sciences, 3(3), 417-424

Ben Goertzel. Artificial General Intelligence: Concept, State of the Art, and Future Prospects. Journal of Artificial General Intelligence 5(1) 1-46, 2014

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Artifical

- ✓ **Manufactured (man-made), unnatural/non-biological**
- ✓ **Antonyms: natural, biological, real**

https://www.thesaurus.com/browse/artificial

Definitions/Types of AI

Weak (or cautious) AI

"Systems that carry out specific 'intelligent' behaviors in specific contexts" = **task or problem-specific** capability

Artificial General Intelligence (AGI)

Fuzzy concept: "AGI may be thought of as aimed at bridging the gap between current AI programs, which are narrow in scope, and the types of AGI systems commonly seen in fiction"

Strong AI:

"No program by itself is sufficient for thinking" – and/or for "intentionality"

Searle, J. (1980); Ben Goertzel (2014)

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Functional capabilities of AI applications:

- **Perception**
  - ... to find out what the world around “looks” like
- **Machine Learning (Deep Learning)**
  - ... to automatically build/adapt models of reality
- **Knowledge Representation**
  - ... to represent, process, and communicate models of the environment
- **Reasoning**
  - ... to infer and generalize new models based on existing knowledge
- **Planning**
  - ... to plan and simulate in the virtual world, exploring possible options, evaluating their performance, and making decisions
- **Acting**
  - ... to manipulate and move around in the real/virtual world

Source: Philipp Slusallek “Artificial Intelligence & Digital Reality”

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Short History of Artificial Intelligence

Short History of AI

- **1315 – "Ars Magna"- Reasoning may be artificially implemented in a machine** (Ramon Llull)
- **1600 – Francis Bacon [1561—1626] „Attempting to fetter discovery by artificial rules"** (David Brewster, 1831)
- **1805 – Least square method for regression** (Basis for many of today's machine-learning models; Adrien-Marie Legendre)
- **1940/1943 - Basic AI concepts** (Alan Turing, Warren McCulloch/ Walter Pitts)
- **1948 – "Cybernetics: Or Control and Communication in the Animal and the Machine" (**Norbert Wiener)
- **1950 – "Turing Test"** (Alan Turing)
- **1958 – First self-learning algorithm** (Frank Rosenblatt)
- **1965 – Birth of deep learning** (Alexey Grigorevich)

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Underlying Technology and Trends

Underlying technology (I)

Algorithms

- **“Algorithm”: A self-contained sequence of mathematical instructions or rules that will give us a result for a specific problem. For example, standardised clinical guidelines used for patients assessment and decision support“**
- **Statistical methods**
- **Deep learning, machine learning: pattern recognition using deep neural networks (DNNs)**
- **Natural language processing**
- **Complex analytics for knowledge discovery**
- **Simulation (Virtual Physiological Human – VPH)**

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Underlying technology (II)

Huge **advances** in

- ✓ **Computing power/hardware/chips**
- ✓ **Theory, algorithms, models and software**
- ✓ **Storage capacity and access speed**
- ✓ **Big Data sources (shared, annotated medical data & images)**
- ✓ **Interoperability / data integration**
- ✓ **Cloud services (storage, computing power, software, sharing)**
- ✓ **Networking / Internet of Things (IoT)**

Merging of such techniques: AI

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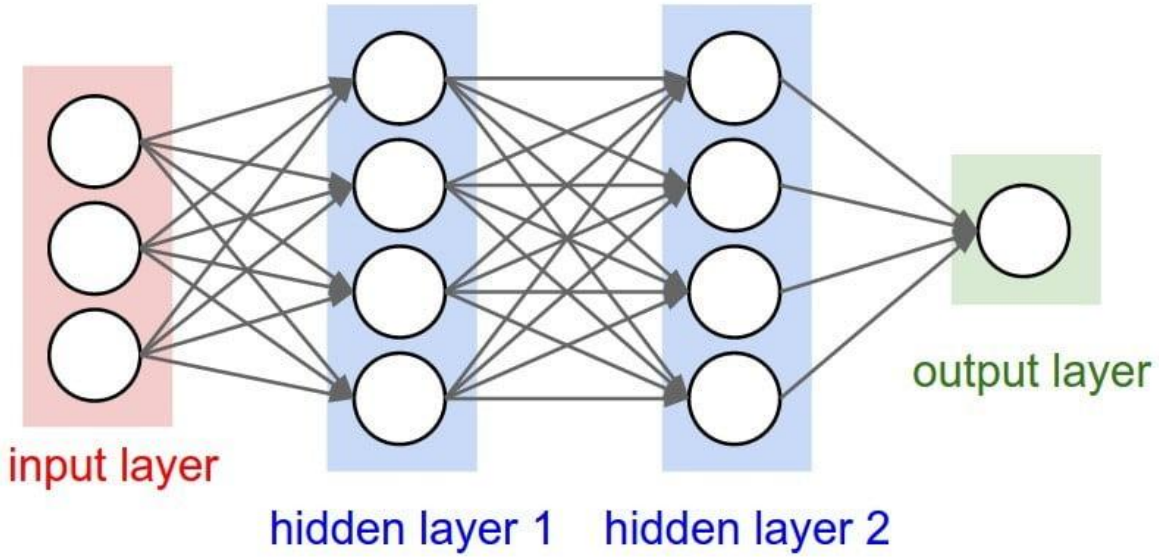
Deep Learning / Deep Neural Networks (DNN)

Deep learning: sub-discipline of machine learning

- Input layer
- Hidden layers of artificial neural networks ranging from 5 to 1,000, each responding to different features of e.g., an image (like shape or edges)
- output layer

✓ Exponential increase in the amount of data required to train



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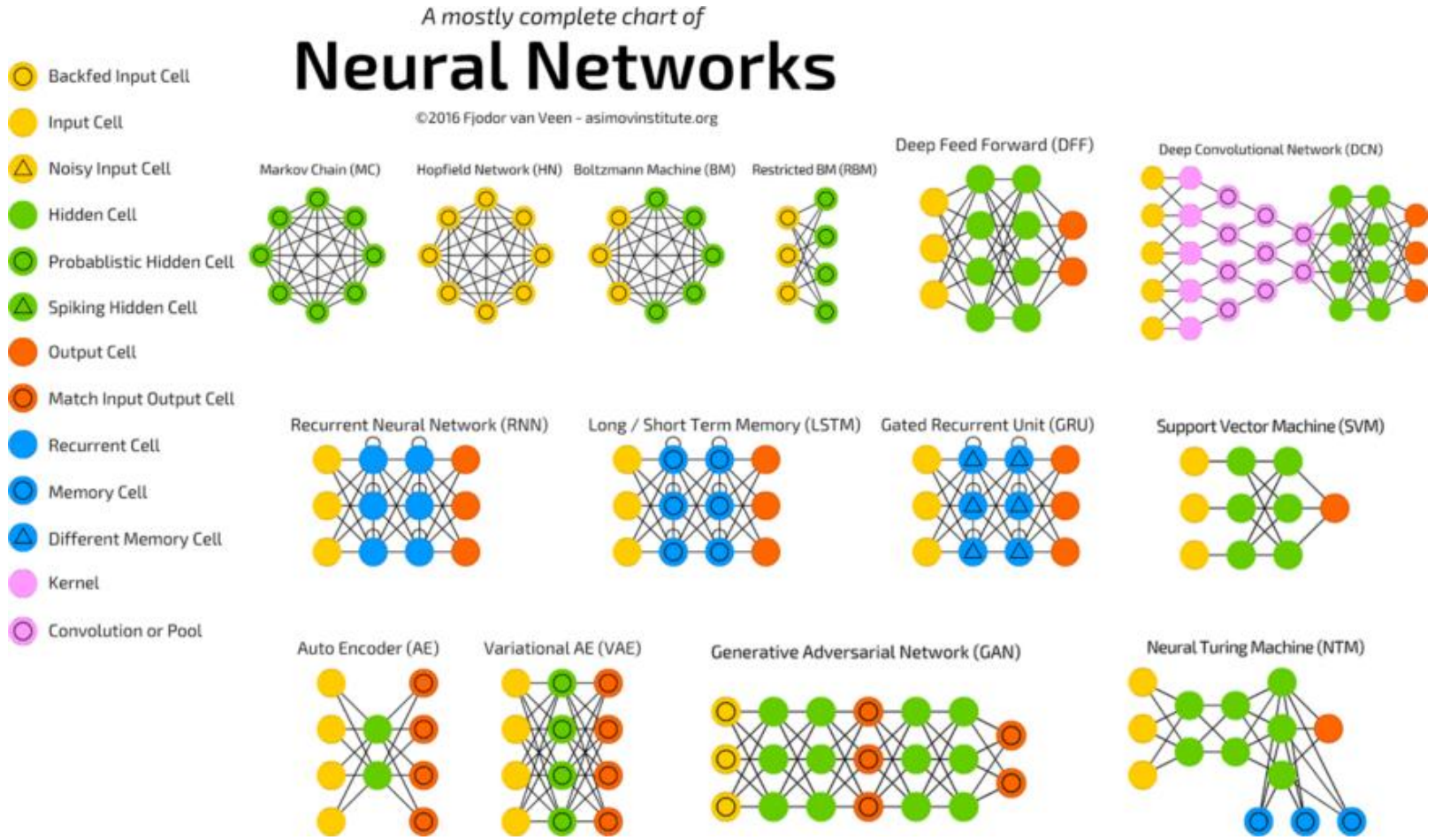
Types of Neural Networks



https://towardsdatascience.com/graph-theory-and-deep-learning-know-hows-6556b0e9891b

Towards a Global Operating System: Digital World 5.0

- **We experience the metamorphosis from the stand-alone computer to the global operating system of our world: The Digital World 5.0 (networking Industry 4.0; Health 4.0; …) will digitize everything and automate work and thinking**
- **This Digital World 5.0 OS links, integrates, and permeates everything: work, leisure, politics, the personal, the professional, and the private**

Adapted from Vienna Workshop on Digital Humanism, 2019

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Quantum 2.0 – The Future?

- **Quantum technology transitions some of the properties of quantum mechanics, especially quantum entanglement, quantum superposition and quantum tunnelling, into practical applications**
- **Main applications:**
  - ✓ **(Cloud) Computing**
  - ✓ **(5G) Communications; Internet of things (IoT)**
  - ✓ **Sensing/measuring**
  - ✓ **Cryptography**
- **Quantum computers may be "rolled out" by 2025 (broad commercialization from 2030?), but only for tackling very specific problems**
- **Quantum technologies will indeed become "disruptive" and will "open up new markets"**

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Applications in Health

Applications for medical professionals: Prediction, prevention, diagnosis, treatment (I)

Radiology

- More than 2 billion chest X-ray images worldwide p.a.
- Accuracy (121-layer convolutional neural network) in detecting pneumonia in 112,000 images was AUC of 0.76
- Outperformed four radiologists
- Interpretation of scans 150 x faster by AI
- Accuracy: sometimes better, sometimes worse; big help for less experienced MDs
- IBM Watson – Cancer decision support

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Applications for medical professionals (II)

Pathology

- **Inconsistency among pathologists' interpretations of slides**
- **Deep learning of digitized pathology slides can improve accuracy and speed of interpretation (few retrospective studies)**
- **Results affected by the length of time the pathologists had to review slides**

Cardiology

- **Electrocardiograms (ECG) and echocardiograms (EVD)**
- **In a small retrospective dataset of 549 ECGs, a sensitivity of 93% and specificity of 90% were reported**
- **Accuracy comparable with cardiologists**

- Adapted from Eric J. Topol, 2019

Applications for medical professionals (III)

- ✓ **Dermatology**
- ✓ **Gastroenterology**
- ✓ **Genetics**
- ✓ **Predicting suicide**
- ✓ **Predicting bouts of psychosis in schizophrenics**
- ✓ **Many other clinical settings, like diagnosis of stroke, autism, stroke or heart attack *by paramedics* etc.**
- ✓ **Robotics**

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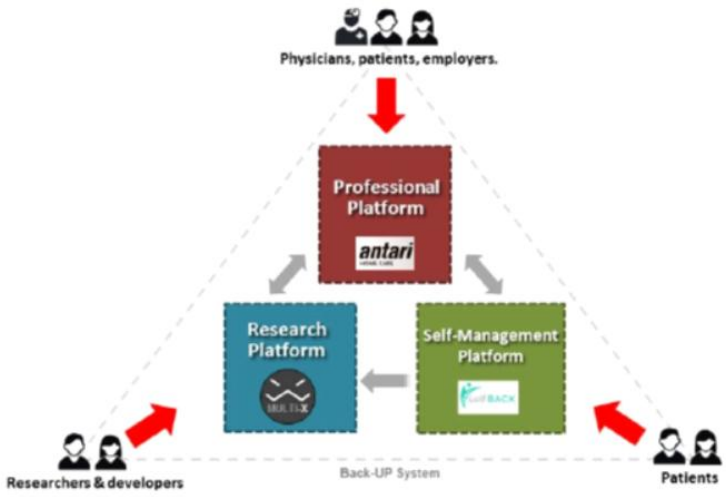
Other application fields in medicine

- **Health systems**: Improve workflow and potential for reducing medical errors
- **Patients**: process their own data to promote health
- **Management** of workforce: select, direct, control, promote, fire

Exemplar: Back-UP Patient DSS "SELFBACK"

- **Project "Personalised prognostic model to support efficient management of neck and low back pain" – 2018 to 2020**
- **AI-based decision support system**
- **Complex integrated AI system consisting of**
  - **Research Platform**
  - **Clinical Professionals Platform**
  - **Patient Self-Management Platform**
- **Models: Machine Learning using neural network techniques, statistical models**

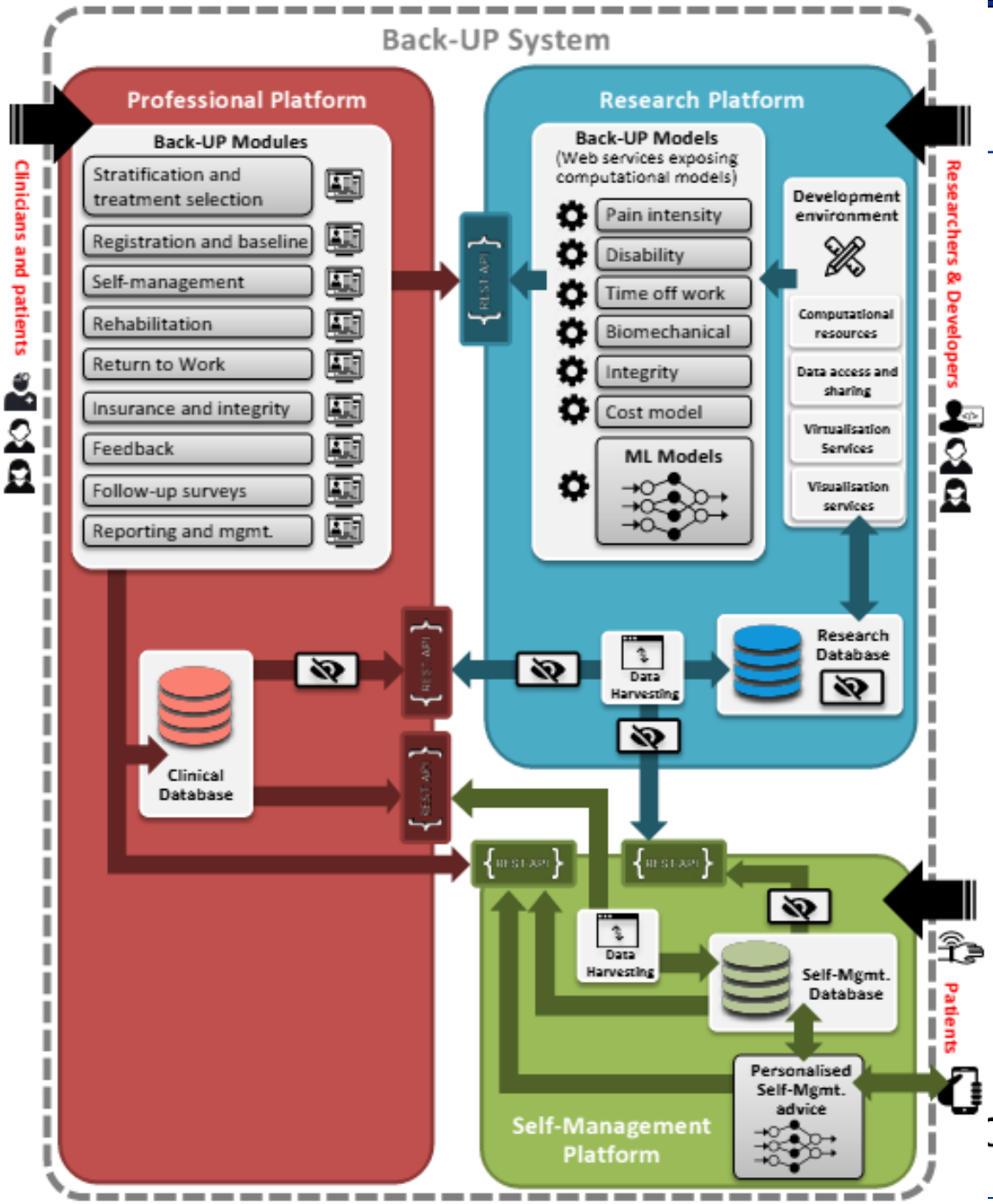


Source: Back-UP project

Conceptual diagram of

- Platforms
- Modules
- Models
- Databases
- App/Patient service

Source: Back-UP project



Challenges

AI Chasms in Health

- **Validation of the performance of an algorithm is not equivalent to demonstrating clinical efficacy**
- **Needs proof to indeed improve clinical outcomes**
- **Prediction of risk for adverse outcomes, but no therapy available?**

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From AI algorithm to changing medical practice



Validate a DNN in silico

Clinical validation in real-world medicine

Implementation in healthcare

Debbie Maizels/Springer Nature

The Ethical Dilemma

- ***Health AI applications must be driven by human values and needs***
- **Ethics: "The discipline dealing with what is good and bad and with moral duty and obligation"**
- **Values are culturally determined, by tradition, by religious believes**
- **Ethical medical rules may differ by country, ethnicity, etc.**
- **AI systems may contain such rules, but on which basis (machines with ethically-significant behaviours)?**
- **Who decides / controls witch values are reflected by the algorithms?**

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Missing Business Models

- **Business Model for investment in tools and applications: Who will ensure continuous update of**
  - ✓ **Input data & images**
  - ✓ **Data quality**
  - ✓ **New regulations**
  - ✓ **New medical drugs and devices**
  - ✓ **New medical knowledge and medical interventions**
  - ✓ **Continuous tuning of “algorithms”**

Input Data

- **Bias of input data**
  - ✓ **Behavioural and cultural differences across health systems, countries, people**
  - ✓ **White versus coloured people**
  - ✓ **Social class related recognition of pictures**
  - ✓ **Medical expert opinions on best treatment**
  - ✓ **…**

Further Challenges

- **Quality, reliability and safety of components of AI systems (interplay of input devices, algorithms, output devices)**
- **“Virtual Crash-Test“ – Boeing 737 Max accidents**
- **Regulation & control of AI systems and applications**
- **Data protection of patient data**
- **Cybersecurity of connected systems**
- **Legal issues**
- **Growing complexity and dependencies: AI systems inform or even direct other AI systems**





Summary & Outlook

- **Great potential towards**
  - **Safer, better and more efficient healthcare**
  - **Extension of evidence-based medicine into explanation-based medicine**
  - **A "learning" health system with continuous feedback based on input from process and outcome data generating knowledge**
- **Collaborative effort to accelerate the development and uptake of Health AI for the benefit of all**
- **Explore the policies, challenges, consequences of AI for Health**
- **Create a European „AI for Health" collaborative programme and platform to compete globally**

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