AI in Digital Health

Discussion Paper

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LIST OF ABBREVIATIONS

AI	Artificial intelligence
DL	Deep learning
FCAI	Forum for Cooperation on AI
GDP	Gross domestic product
ML	Machine learning
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMIS	Insurance Management Information System
ISO	International Organization for Standardization
LMIC	Low- and middle-income countries
OECD	Organisation for Economic Co-operation and Development

GLOSSARY

Artificial intelligence (AI): Artificial intelligence has been defined in many ways, but in general it can be described as a way of making a computer system "smart" – that is, able to understand complex tasks and carry out commands. This involves creating algorithms, or sets of rules, to sort and process data. The goal of AI research is to create systems that can learn and adapt on their own, without the need for human intervention. For example, a self-driving car would use AI to interpret traffic signals and other cues in order to navigate safely. Currently, AI is being used in a variety of fields such as medicine, finance, and manufacturing. As the technology continues to develop, it is expected to have an even greater impact on our world.

Machine learning (ML): Machine learning is a branch of artificial intelligence. ML uses known patterns learnt from training data to make predictions about new data. For example, a machine-learning system could be trained on historical weather data in order to predict weather patterns in the future. Machine learning is widely used in many applications, such as email filtering and computer vision. In general, any task that requires prediction or classification can benefit from machine learning.

Deep learning (DL): Deep learning is a subfield of machine learning that is concerned with algorithms inspired by the structure and function of the brain called artificial neural networks. Neural networks are interconnected networks of nodes, similar to the way neurons are interconnected in the brain. These networks are capable of learning to recognize patterns of input, which can then be used for classification or prediction. Deep learning architectures have been successful in a variety of tasks such as image recognition, natural language processing, and voice recognition. Deep learning models are difficult to interpret by humans and decision making of deep neural networks are similar to a black box.

EXECUTIVE SUMMARY

INTRODUCTION

Artificial intelligence (AI) will transform healthcare. It may enhance medical outcomes, patient satisfaction, and access to care. It has the potential to increase the productivity of healthcare professionals and allows organisations to proactively manage population health, direct resources where they will have the greatest impact, and encourage speedier treatment delivery, particularly by reducing diagnostic time. In recent years, concerns have been expressed regarding the influence of AI on practitioners, ethics, the terms of use of personal data, and other AI-related hazards.

With a focus on German Development Cooperation, this discussion paper presents current issues and trends of AI in healthcare with regard to low- and middle-income countries (LMIC). The main goals are to clarify the scope and effect of AI in healthcare, provide a framework for understanding AI systems, present selected initiatives and projects, identify regulatory and ethical issues and gaps, outline recommendations for German Development Cooperation, and inform cooperation with partners.

The paper is based on current publications on AI in healthcare with an emphasis on LMICs, interviews with selected stakeholders from the development cooperation sector and partner countries, as well as internal discussions and workshops of the GIZ Sector Initiative Global Health / Digital Health.

BACKGROUND

The term AI is broadly used and has numerous different application areas and technological foundations. This discussion paper focuses on narrow AI, more specifically machine learning (ML) and deep learning (DL) algorithms, which by far enable the most relevant use cases for practical AI applications today. ML is a broad phrase for the automated production of knowledge in the form of rules based on prior experience: An artificial system learns from example data and answers, and after the learning phase is complete, it can generalize them. ML means using known patterns learnt from training data to make predictions about new data. This means that it recognizes patterns and laws in the learning material rather than merely memorizing the examples. Therefore, an ML system might be able to identify cancer on an unknown medical image, because it was trained with many other images.

BUILDING BLOCKS

AI is the simulation of human cognitive abilities using technical aids. However, such a definition is ineffective in practice. What is required is a practical method for making the term AI suitable for use in organisations and to support policy experts who shape the framework conditions for AI usage. One attempt is the “periodic table of artificial intelligence,” which maps the concept of AI to business processes to build an understanding of the elements. In this sense, AI is viewed as a combination of fundamental elements, similar to different LEGO bricks. There are a total of 28 AI elements defined, which can be combined based on general criteria. Each AI element is classified into one of three categories:

- Assess (e.g., detect the traffic situation around a robot car in milliseconds),
- Infer (e.g., calculate the probability of a rear-end collision for the next 3 seconds), and
- Respond (e.g., initiate the braking or evasive manoeuvre of the robot car).

USE CASES

AI can be found in all areas of healthcare, including activities, facilities, people, processes and regulations that deal with health, health impairment, diseases, the restoration of health, as well as planetary health. From a practice-oriented point of view, the use of AI in health is mostly considered in the process of treating patients or in diagnosis.

Figure 1: Use of AI in the patient journey (example)

	Screening	Preventive Care	Diagnostics	Therapy	Monitoring	Aftercare
Goals	Prevent, detect and treat diseases, stop disease progression	Detect and eliminate health risks at an early stage	Identify a disease through questioning and evaluating findings	Help to enable or accelerate healing process of a disease	Improve treatment outcomes by identifying and correcting problems	Support patient after therapy and identify critical conditions
Typical AI use cases	AI to assist doctors by prioritizing, taking over standard tasks, monitoring screening and increasing overall process quality	AI to assist patients by early detection and making individual recommendations, as well as offering health status information	AI to help doctors make diagnoses, perform routine medical exams, and make better decisions based on large medical data sets	AI to predict patient response to a therapy, assist during therapy and assess whether medicines work with various treatment plans	AI to monitor critical situations, e.g., trigger an alarm to alert staff or continuously track vital functions and recommending actions	AI to help patients organize appointments and follow-up plans, remind to take medications, and organize reports and patient files

Source: Own presentation

Examples of AI applications in the broader healthcare sector with their position in the healthcare system are shown in the following figure:

Figure 2: Examples of AI applications in the broader healthcare sector

Inpatient and outpatient care	Production and supply	Management and research	Individual citizens
Hospitals ▶ Image analysis ▶ Surgical robots	**Pharmaceutical industry** ▶ Drug development ▶ Acceleration of studies	**Health insurance** ▶ Workflow automation ▶ Financial auditing	**Fitness and wellness** ▶ Health apps ▶ Activity tracker
Pharmacies ▶ Stock optimisation ▶ Patient screening	**Medical devices industry** ▶ Digital twins ▶ Precision medicine	**Ministries and administration** ▶ Expert systems ▶ Automation of applications	**Prevention** ▶ Symptom checks ▶ Wearables
Rehabilitation centres ▶ Exoskeleton ▶ Monitoring	**Logistics and supply chains** ▶ Autonomous driving ▶ Navigation systems	**Universities** ▶ AI writing bots ▶ Exams and assessments	**Health education** ▶ Virtual reality ▶ Augmented reality
Medical practices ▶ Virtual doctors ▶ Decision support	**Information technology** ▶ IT automation ▶ Cybersecurity	**Research and development** ▶ Behavioural predictions ▶ Data analytics	**Assistance systems** ▶ Smart home ▶ Monitoring
Care facilities ▶ Nursing robots ▶ Fall detection	**Specialised trade and retail** ▶ Dynamic pricing ▶ Inventory controls	**Education and training** ▶ Mobile learning ▶ Conversational interfaces	**Assisted living** ▶ Service robots ▶ Voice assistants

Source: Own presentation

STAKEHOLDERS

The landscape of stakeholders around AI-related topics in emerging economies is diverse, complex, and highly fragmented. When it comes to AI in general, different stakeholder groups can be differentiated, depending on their activities, strategies, and roles. The following table gives an overview of the most relevant stakeholder groups. Most of the use cases discussed previously fall into the group of "Using AI", i.e. healthcare organisations, healthcare facilities, healthcare companies, and patients.

Table 1: Stakeholder groups in AI

STAKEHOLDER GROUP	ACTIVITY	LEADING QUESTION	EXAMPLES
Leading AI	Innovating and improving AI	How can we create AI breakthroughs?	Big tech companies
Researching AI	Analysing and evaluating AI	What could AI do in the future?	Universities, institutes
Developing AI	Implementing AI systems	How should AI systems be designed?	Tech firms, developers
Using AI	Applying AI to solve business problems	How does AI aid decision-making?	Organisations of all kinds
Regulating AI	Setting policies for the use of AI	How can AI be used fairly and legally?	Policy makers, regulators
Funding AI	Supporting and investing in AI projects	What is the impact of an AI project?	Incubators, VCs, donors
Enabling AI	Providing the technological basis for AI	What technology does AI need?	Hardware manufacturers
Educating AI	Offering advice on the use of AI	How can we facilitate the use of AI?	Consultants, trainers

Source: Own presentation

REGULATIONS

At least 60 countries have adopted some form of AI policy since 2017, when Canada became the first to do so. Work on developing global AI standards has resulted in significant developments in various international bodies. Furthermore, there has been an increase in the number of declarations and frameworks issued by public and private organisations to guide the development of responsible AI. While many of these are focused on broad principles, the last years have seen an increase in efforts to put these principles into action through fully-fledged policy frameworks. Frontrunners in this regard have been Canada's directive on the use of AI in government, Singapore's Model AI Governance Framework, Japan's Social Principles of Human-Centric AI, and the United Kingdom's guidance on understanding AI ethics and safety; they were followed by the United States' guidance to federal agencies on AI regulation and an executive order on how these agencies should use AI. The most recent attempt to introduce a comprehensive legislative scheme governing AI was the EU proposal for adoption of regulation on AI.

DATASETS

When it comes to the use of AI in healthcare, the dominating issue across most LMIC stakeholder groups are usually issues and concerns around data quality and security, the interoperability of systems, and the governance and ownership of data.

Therefore, the main challenges are:

- **Digitisation of health data:** A lack of digital records and processes poses significant challenges for adopting AI solutions. Before launching AI efforts, it is critical to focus on the basic digitisation of systems and data, as well as the development of digital skills.
- **Data governance:** As more healthcare is delivered using new digital technologies, public concern about the use of healthcare data has grown. Healthcare organisations should have robust and compliant data-sharing policies in place that support the improvements in care that AI provides while also providing the necessary safeguards.
- **Data interoperability:** Healthcare data is notoriously difficult to manage. It is frequently collected using proprietary software and compiled in siloed databases that are part of largely incompatible systems. Healthcare systems and providers must develop policies to promote interoperability both within their own proprietary systems and those of external parties.

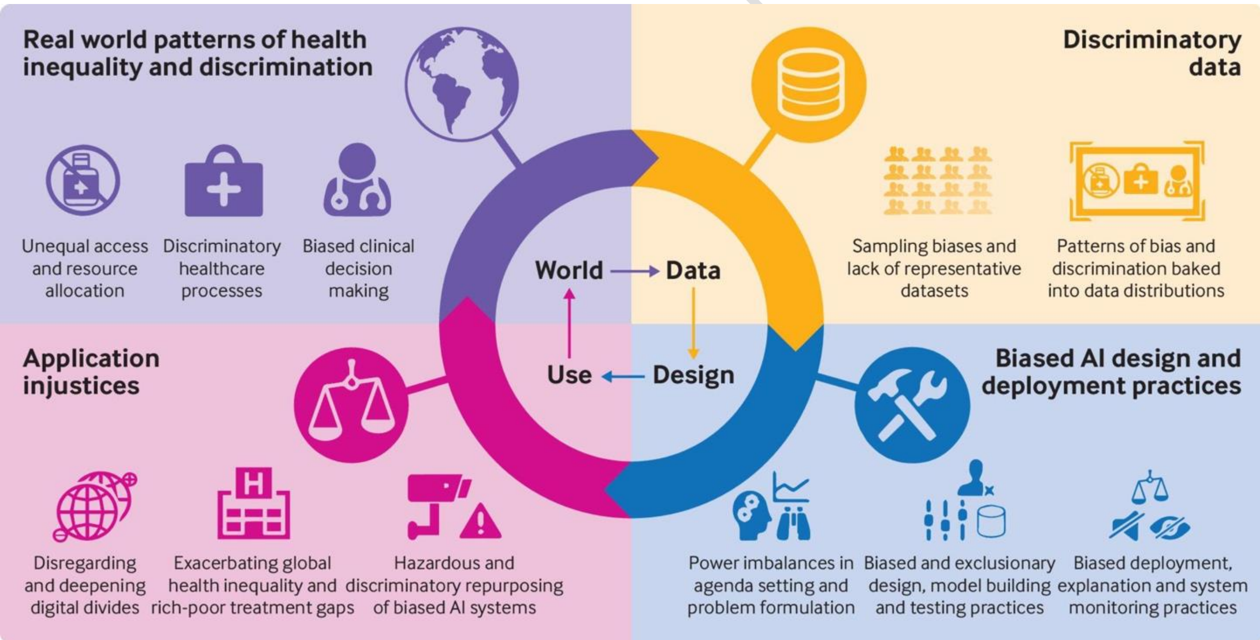
ETHICAL ISSUES

There are multiple ethical issues when it comes to using AI in general and even more so in relation to healthcare; among the most discussed ones are the following:[1]

- **Uncertainty and distrust of AI predictions**
  How was the recommendation made and is it really correct?
- **Regulation and governance of medical AI**
  Is the AI system trustworthy and who can ensure this?
- **Shifts in responsibility and liability introduced by using AI in practice**
  Who is responsible for decisions, and will my doctor follow the AI?
- **Concerns for data privacy and security**
  How can I be sure my data will only be used with my consent?
- **Biased results that hurt marginalized groups**
  Do the datasets and algorithms apply to my personal context?
- **Underlying business model and ownership**
  Who benefits from using a specific AI system and who owns the data?

AI systems have the potential to increase health inequities if they are not carefully built and implemented. There can even be a cascading impact of inequality and in the design and application of an AI system, as shown in the following figure:

Figure 3: Cascading AI bias in healthcare applications



Source: British Medical Journal[2]

Depending on the implementation setting, some biases are unavoidable while others can be mitigated. In any case, to effectively identify bias, the presence of bias throughout the whole AI pipeline needs to be mitigated.

[1] Topol, Eric: AI in health and medicine, Webinar, AI for Good, streamed live on 27 April 2022, https://www.youtube.com/watch?v=Z8A73pUr3aA (accessed 11 May 2022).
[2] British Medical Journal (2021): Does "AI" stand for augmenting inequality in the era of covid-19 healthcare?

GAP ANALYSIS

The following main issues for AI in healthcare have been identified with regards to LMIC:

- **Data availability and quality:** AI/ML applications require a training dataset with defined outcome variables. In LMIC, there is often a scarcity of locally generated usable data. Moreover, many AI applications are created in high-income countries with datasets that is often not directly applicable to population in LMIC (or there is a lack of appropriate medical evidence).
- **Regulation of AI:** Some LMICs lack a national digital health policy or plan to guide the implementation and monitoring of digital health strategies. Stakeholders from partner countries often feel that limited government policy participation has impeded adoption, and that greater engagement could stimulate early use of AI and other digital tools.
- **Costs of AI-based solutions:** The cost of assembling an AI/ML-based solution in healthcare is difficult to estimate but can be very high, depending on the setup and intended outcome. Data acquisition and preparation costs are typically the most critical and time-consuming aspect that fundamentally determines the quality of an AI application.
- **Inadequate infrastructure:** Another key barrier restricting the rate of growth of this technology in LMICs is insufficient infrastructure, e.g., low internet penetration and energy inaccessibility, making it difficult to implement and sustain digital technologies in all sectors of the economy, including healthcare.
- **Lack of skills on site:** One of the major challenges is the lack of local skills. In order to implement AI healthcare systems, trained personnel are needed to develop, operate and maintain the systems. However, there is a shortage of suitable experts in many LMICs, due to the lack of education and training opportunities in these countries.

CONCLUSIONS AND RECOMMENDATIONS

The potential of AI and ML to significantly improve healthcare should not be underestimated. In LMIC, the application of AI-driven tools can aid in the eradication of health disparities and alleviate the strain on health systems.

However, AI is empowered by data, knowledge and technology. The foundational elements for planning and implementing AI systems are therefore a vast amount of quality training data (big data), knowledge about the applicability and structure of data for AI (data science), and access to computing resources (cloud computing). While the latter is typically easy to solve (given sufficient internet access), the first two topics are often overlooked. Nonetheless, they are a basic prerequisite for the effective application of AI in any use case.

Overall, the following main enablers for AI adoption and implications for healthcare systems in LMICs should be taken into account:

Figure 4: AI-related recommendations for healthcare systems

Enablers for AI adoption	Implications for healthcare systems
Quality and suitability of solutions	Develop national AI strategy for healthcare
Education and training	Define use cases to support through funding and incentives
Data quality, governance, security, interoperability	Set standards for digitisation, data quality, data access, governance, security, interoperability
Change management	Redesign workforce planning and clinical education processes
Talent	Provide incentives and guidance for healthcare organisations
Regulation, policy making, liability	Address AI regulation, liability and funding issues
Funding	

Source: Own presentation

German Development Cooperation will need to go through a constant process to make sure that its policies and tools are appropriate. The BMZ jointly with its implementation partners must continue to increase their capacity, since the pace of change and potential for disruption brought on by AI cannot be understated. It will be crucial to give important decision-makers the knowledge they need to comprehend the fundamental operations of AI and ML, the issues that may be fixed, and the areas where expectations are incorrect. This covers not just technology elements but also the strategic and operational setups required to conduct AI initiatives successfully.

While finding AI-based application sectors is crucial, one function of German Development Cooperation efforts is to support regulatory systems in partner countries. Multinational collaboration will be essential in defining and creating standards and best practices in this context, and it will be a sphere in which German Development Cooperation may assist partner countries.

While many of the AI-related developments will take place in the upcoming years, other, more fundamental changes regarding the capability of AI applications will take longer to manifest. There is great potential for disruption through the use of AI in the healthcare sector over the medium to long term. Widespread usage of AI could radically alter current systems. This might also lead to significant hazards that have to be handled by stakeholders on all levels, especially when combined with the influence of other emerging technologies. The use of AI requires both international coordination and worldwide cooperation due to its global character.

1 INTRODUCTION

1.1 STARTING POINT AND GOALS

Advances in artificial intelligence (AI) and – more specifically – machine learning (ML) have led to the recent rise of intelligent systems with human-like cognitive abilities. These systems are being used in business and in people's personal lives, and they are changing the way people interact. For example, companies are using ML to improve decision-making for productivity, engagement, and employee retention. Trainable assistant systems are adapting to user preferences, and trading agents are challenging traditional investment strategies.

AI also has the potential to revolutionize other industries, for example the healthcare sector. It has the potential to enhance medical results, patient experience, and access to healthcare services. It can boost productivity and efficiency in care delivery, allowing healthcare providers to give more and better care to more people. Moreover, it can assist healthcare systems manage population health more proactively, directing resources to where they can have the greatest impact, and promote speedier delivery of care, primarily through expediting diagnostic time. In recent years, there has been substantial discussion about the ramifications of adopting and growing AI in healthcare. The entire potential of AI is still being contested, however concerns have been expressed regarding its possible influence on practitioners, as well as issues of ethics, personal data usage, and AI-related hazards. Simultaneously, healthcare investments in AI are increasing, creating or exacerbating disparities in healthcare innovation adoption. This raises questions about the role that health systems, public and private players, and individual healthcare practitioners can or should play in ensuring citizens fully reap the benefits of AI.

With a focus on German Development Cooperation, this discussion paper presents current issues and trends of AI in healthcare with regard to low- and middle-income countries (LMIC). The main goals are to

- clarify the scope and effect of AI in healthcare,
- provide a framework for understanding AI systems,
- present selected initiatives and projects,
- identify regulatory and ethical issues and gaps, and
- outline recommendations for German Development Cooperation and to inform cooperation with partners.

1.2 METHODOLOGY

The paper is based on current publications and presentations on AI in healthcare with an emphasis on LMIC, interviews with selected stakeholders from the development cooperation sector and partner countries, as well as internal discussions and workshops of the GIZ Sector Initiative Global Health / Digital Health.

The expert interviews were conducted through video conference in a semi-structured way. The participants were selected from the following thematic backgrounds:

- Emerging tech/AI sector
- Development cooperation sector
- Academia

All interview partners were selected in internal workshops and contacted directly through the GIZ network. The following research goals guided the interview:

- Participant assessment: Determine background and estimate experience level
- AI in digital health: Examine the relevance, prevalence and impact of AI in healthcare
- Promising use cases for LMIC: Determine the potential of AI applications in LMIC

- Major barriers for LMIC: Reveal factors that can hinder the success of healthcare AI in LMIC
- How to overcome the barriers: Identify drivers required to establish AI in LMIC
- Other topics: Own initiatives and other remarks from the interviewees

Based on this approach, we conducted 12 expert interviews between April and August 2022. Of the interviews, 8 were analysed for further use in the study. The other 4 interviews were not very relevant for our purpose (mostly missing the LMIC context) or the statements were too general and were therefore dismissed.

In parallel to the interviews, we conducted an extensive desk research process to collect additional insights on healthcare AI in LMIC. Information sources used included: The public internet, publications of organisations and other market participants, third-party studies and surveys, information from associations and authorities, legal documents, journals, and books.

In the course of the interviews and desk research, several interesting initiatives and flagship projects were identified. Selected projects are outlined in the appendix of this paper. The projects were selected on the basis of the workshops implemented in the team and the expert interviews conducted. The basis was the question of whether a project has a special AI component or whether there are future plans in this direction that could be relevant for the discussion paper. Also, some relevant initiatives were selected as examples, without any claim to being exhaustive.

2 BACKGROUND

The term artificial intelligence (AI) is broadly used and has numerous different application areas and technological foundations. As a result, there are many definitions for AI, for example:

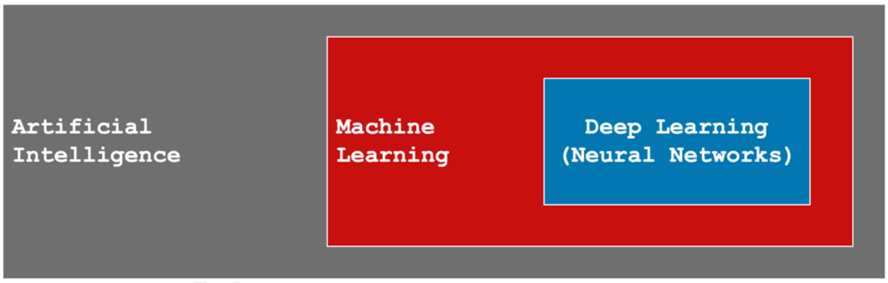
- “The capability of a machine to imitate intelligent human behavior.” (Merriam-Webster)
- “Artificial intelligence leverages computers and machines to mimic the problem-solving and decision-making capabilities of the human mind.” (IBM)
- “An AI system is a machine-based system that is capable of influencing the environment by producing an output (predictions, recommendations or decisions) for a given set of objectives.” (OECD)

First of all, there are two types of AI:

- **Narrow AI:** Narrow AI is the most common type of AI today. The name comes from the fact that some AI systems are specifically designed for a single mission. They are also referred to as “weak” AI due to their limited approach and inability to accomplish duties other than those assigned to them. This concentrates their intelligence on a single task or collection of tasks, allowing for additional optimization and customization.
- **General AI:** General AI is a type of AI that is supposed to think and function like humans. This encompasses perceptual processes like vision and language processing, as well as cognitive tasks, contextual understanding, and a more generalized approach to thinking. While narrow AI is designed to do a single purpose, general AI can be broad and adaptive.

This discussion paper focuses on narrow AI, more specifically machine learning (ML) and deep learning (DL) algorithms, which by far enable the most relevant use cases for practical AI applications today.

Figure 5: Relationship between artificial intelligence, machine learning and deep learning



Source: Own presentation

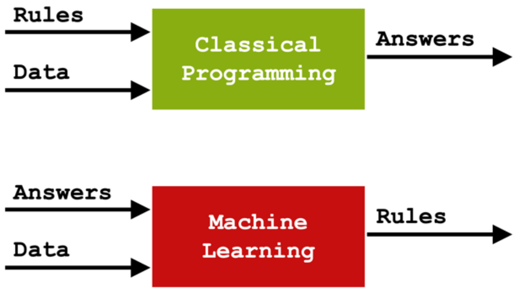
In classical computer programming, developing code usually means to define rules a software program has to apply to specific data structures. The output are answers, i.e., the solution that the software provides.

The first attempts at developing AI-like analytical models in fact depended on explicitly programming known correlations, methods, and decision logic into intelligent systems via handmade rules (e.g., expert systems for medical diagnoses). It turned out, however, that most problems are way too complex to solve with logic, i.e., humans cannot explicate all knowledge that is required to perform the necessary tasks.

ML, on the other hand, is a broad phrase for the automated production of knowledge in the form of rules based on prior experience: An artificial system learns from example data and answers, and after the learning phase is complete, it can generalize them. ML describes using known patterns learnt from training data to make predictions about new data. This means that it recognizes patterns and laws in the learning material rather than merely memorizing the examples. Therefore, an ML system might be able to identify cancer on an unknown medical image, because it was trained with many other images.

In other words, ML tries to automatically discover meaningful relationships and patterns from examples and observations rather than codifying knowledge into computers:

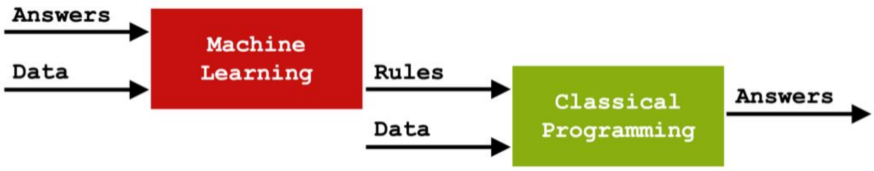
Figure 6: Classical programming vs. machine learning



Source: Own presentation

The rules identified by the ML algorithm can then be used to feed software products that are still developed through classical programming processes:

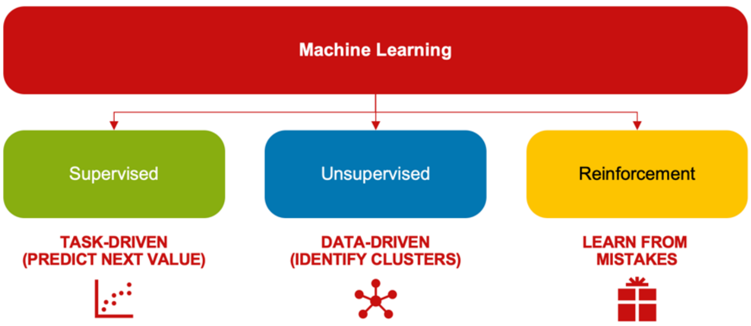
Figure 7: Machine learning to empower software programs



Source: Own presentation

There are three forms of ML based on the presented problem and the accessible data: supervised learning, unsupervised learning, and reinforcement learning. While the majority of AI applications use supervised learning, there are implementations of all types.

Figure 8: Types of machine learning algorithms



Source: Own presentation

3 SUMMARY OF FINDINGS

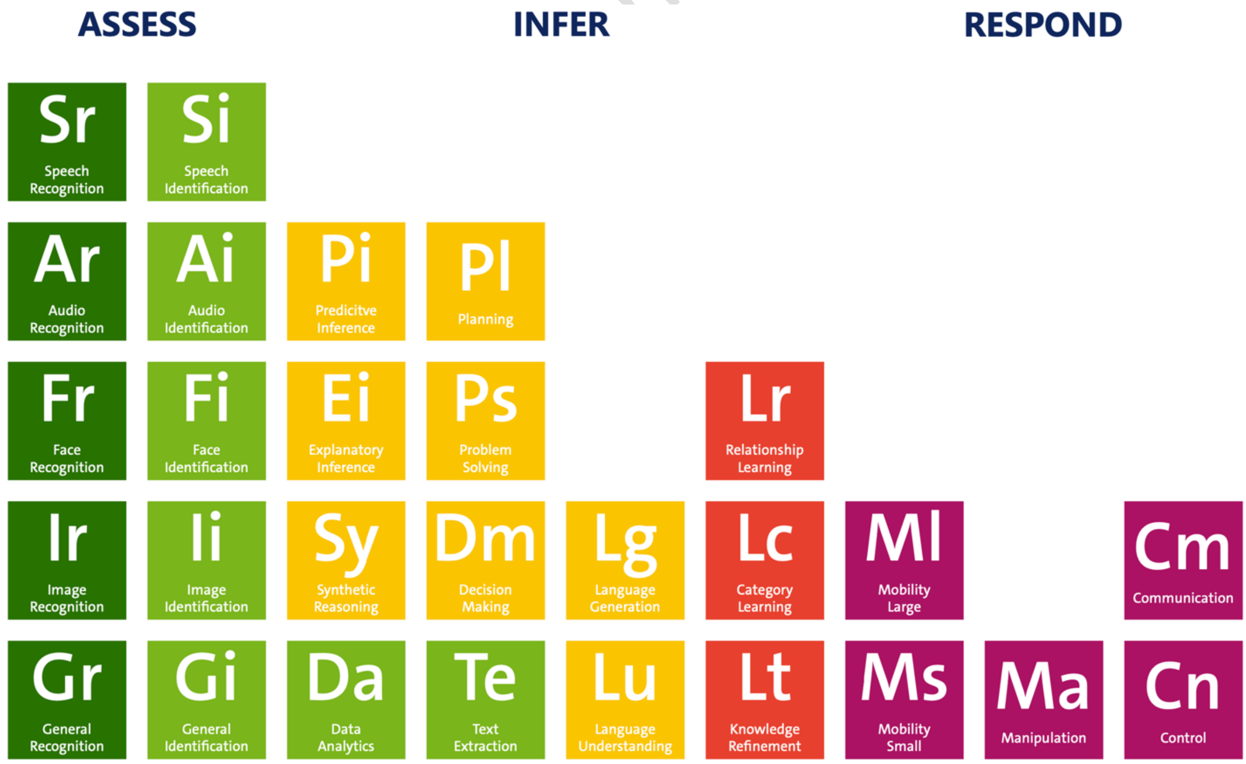
3.1 BUILDING BLOCKS

Many attempts have been made to define AI. When the definitions are compared, there is one common denominator: AI is the simulation of cognitive abilities using technical aids that were previously reserved for humans. However, such a definition is ineffective in practice. It is written too broadly and necessitates knowledge of cognitive sciences in order to apply it operationally. What is required is a practical method for making the term AI suitable for use in organisations and to support policy experts who shape the framework conditions for AI usage.

Kristian Hammond, an American computer scientist, has attempted to develop a lingua franca for artificial intelligence. He refers to it as the “periodic table of artificial intelligence,” borrowing a term from chemistry.[3] Similar to the Periodic Table of Chemical Elements, the Periodic Table of Artificial Intelligence helps map the concept of AI to business processes and build an understanding of the elements. The method aids in understanding and estimating market readiness, effort, required machine training, knowledge and experience.

In this sense, artificial intelligence is viewed as a combination of fundamental elements, similar to different LEGO bricks. Each AI element represents a sub-function that has traditionally been established as an encapsulated functionality of varying complexity and power. There are a total of 28 AI elements defined, which can be combined based on general criteria.

Figure 9: The Periodic Table of AI



Source: Bitkom (2018)

[3] Hammond, Christian (2017): The Periodic Table of AI, http://danielschristian.com/learning-ecosystems/2017/01/23/the-periodic-table-of-ai-hammond/ (accessed 3 May 2022).

Each AI element is classified into one of three categories. As an “AI element triple,” the selection of at least one AI element from each group represents the typical processing step of an AI-driven use case, namely:

- Assess (e.g., detect the traffic situation around a robot car in milliseconds),
- Infer (e.g., calculate the probability of a rear-end collision for the next 3 seconds), and
- Respond (e.g., initiate the braking or evasive manoeuvre of the robot car).

The following table presents all AI elements with their group, a brief description[4] and an indicator on each element’s relevance for healthcare applications.

Table 2: Brief descriptions of the AI elements

GROUP	ELEMENT	SYMBOL	DESCRIPTION	RELEVANCE IN HEALTH
ASSESS	**Speech Recognition**	[Sr]	The recognition of spoken language and/or emotional states in general in an audio signal.	medium
	Audio Recognition	[Ar]	The detection of certain types of sounds (alarms, equipment stress, car engine) in an audio signal.	low
	Face Recognition	[Fr]	The recognition of faces and emotional states in images or video signals.	medium
	Image Recognition	[Ir]	The recognition of certain types of objects in images or video signals.	high
	General Recognition	[Gr]	Analysing sensor data to recognise object types and/or situations from the signal alone.	high
	Speech Identification	[Si]	The recognition of an individual voice in an audio signal.	low
	Audio Identification	[Ai]	The recognition of audio signatures (a particular motor or doorbell) from audio signals.	low
	Face Identification	[Fi]	The recognition of concrete persons in pictures or video signals.	low
	Image Identification	[Ii]	The recognition of a concrete object in an image or video.	low
	General Identification	[Gi]	Analysing sensor data to recognise objects and/or situations from the signal alone.	low
	Data Analytics	[Da]	Analysing data to identify specific facts and/or events that the data represents.	high
	Text Extraction	[Te]	Analysing texts to extract information about entities, time, places and facts that are exclusively contained in the text.	high
INFER	**Predictive Inference**	[Pi]	The prediction of events or conditions in the future based on an understanding of a current state of the world and how the world works.	high
	Explanatory Inference	[Ei]	Explaining events or conditions in the real world based on an understanding of previous conditions.	high
	Synthetic Reasoning	[Sy]	The use of evidence to support inferences about the real state of the world, a prediction or an explanation.	high

[4] Based on Bitkom e.V. (2018): Digitalisierung gestalten mit dem Periodensystem der Künstlichen Intelligenz, https://www.bitkom.org/sites/default/files/2018-12/181204_LF_Periodensystem_online_0.pdf (accessed 2 May 2021).

GROUP	ELEMENT	SYMBOL	DESCRIPTION	RELEVANCE IN HEALTH
	Planning	[Pl]	The creation of an action plan based on a set of goals, an understanding of the real state of the world and knowledge about actions and their consequences.	low
	Problem Solving	[Ps]	The creation of a solution to a problem, which may or may not involve the use of actions (see Planning [Pl]).	medium
	Decision Making	[Dm]	Selecting a particular plan or solution based on available evidence, alternative solutions and a set of objectives.	high
	Language Generation	[Lg]	Creating natural language texts and/or explanations based on some understanding of the world.	medium
	Language Understanding	[Lu]	Creating a semantic representation of the meaning of a text that shows context and some understanding of how the world works.	medium
	Relationship Learning	[Lr]	Identifying relationships between features that can be used to predict the presence of a set of hidden features when others are visible.	high
	Category Learning	[Lc]	The recognition of new categories of semantic values based on memory collections.	high
	Knowledge Refinement	[Lt]	Revising knowledge or rules that already exist in response to using them to support actions or conclusions.	high
RESPOND	**Mobility Large**	[Ml]	Controlling autonomous vehicles that interact with other vehicles first and foremost.	low
	Mobility Small	[Ms]	Controlling robots that move through indoor spaces, work and interact with people.	low
	Manipulation	[Ma]	Manipulating the same objects that people work with on a regular basis.	low
	Communication	[Cm]	Mechanisms that support the execution of various forms of communication between humans and machines.	high
	Control	[Cn]	The intelligent control of other machines when no manipulation or action in the physical world is required (e.g. automated trading).	high

Source: Own presentation

RECOMMENDED READING | *Bitkom (2018): Digitalisierung gestalten mit dem Periodensystem der Künstlichen Intelligenz* – The German digital association Bitkom has published a guide to using the periodic table of AI. It briefly outlines the 28 AI components and describes what each individual element does, how it can be used in organisations, and what economic significance it currently has and will have in the future. https://www.bitkom.org/sites/default/files/2018-12/181204_LF_Periodensystem_online_0.pdf

3.2 USE CASES

AI can be found in all areas of healthcare, including, for example, activities, facilities, people, processes and regulations that deal with health, health impairment, disease, the restoration of health as well as planetary health.

3.2.1 USE OF AI IN GLOBAL HEALTH

There are six main areas that are affected by AI in the global healthcare sector. The areas listed are not to be regarded as distinct from each other; rather, they complement each other and are partially interdependent:[5]

HEALTHCARE SUPPLY AND LOGISTICS

Healthcare is dependent on various sectors of the economy, such as the pharmaceutical industry, medical technology, and biotechnology, all of which contribute to ensuring future medical care for citizens through innovation and progress. The products, services, and technologies used in healthcare must be patient-centered. Before they are deployed and access is enabled in patients, medical innovations supported by AI must be safe, tested, and technologically necessary. Ethical, legal, and societal questions must be addressed in order to improve patient care quality. The healthcare system's defined framework conditions must lead to the responsible use of AI.

HEALTHCARE FACILITIES

AI projects in healthcare institutions are typically managed by top executives. They decide whether to buy applications or develop them themselves. They also decide in which area an application should be used and where AI can be used in collaboration with actors from various institutions. To use AI in healthcare facilities, the necessary requirements must be identified and clarified. AI-powered applications, for example, necessitate a thorough understanding of the benefits and drawbacks that may arise during use. Applications for primary care practices provide "artificial employees" in the form of digital assistants (e.g., chatbots) that answer questions due to a shortage of specialists. AI applications are also used in interviews and surveys, as well as in disease diagnosis.

HEALTHCARE MARKET

The healthcare market is divided into two parts: The first healthcare market contains traditional healthcare services that are regulated by the state and provided by healthcare institutions, whereas the second healthcare market contains individual healthcare services that must be paid for privately. In addition to a domestic healthcare market, there is an international healthcare market where AI is increasingly being used to show treatment information and services, as well as to improve treatment methods in healthcare. AI in the healthcare market influences market growth and competition, company strategies, and market participants' options for action.

HEALTH PERSONNEL

In most countries, qualified professionals are desperately needed in the healthcare sector, but the demand cannot always be met. AI has been shown to improve productivity, safety, and error reduction. AI can assist processes, making work easier and saving time. Before using AI, it must be investigated how it can be made more personal, how human and artificial intelligence can be combined, and how algorithms can be tested, compared, and evaluated before they are used. Professionals, on the other hand, must be guided, trained, and supported in their use of AI.

[5] Pfannstiel, Mario (2022): Künstliche Intelligenz im Gesundheitswesen, Kapitel 1.

HEALTH ECONOMY

The health economy is concerned with the development and marketing of health-related products, services, and technologies. The goals include maintaining population health and performance. Advances in patient care, digitalization of healthcare, and treatment of common diseases can all be made through research and development. Because innovations contribute to better healthcare, collaboration between businesses, science, and clinical institutions should be encouraged. Approval procedures for innovative developments must be improved further so that AI innovations can be implemented quickly. Well-trained specialists and managers are required for a long-term culture of innovation in patient care in the healthcare system.

HEALTH REGULATION

AI should be investigated and continuously improved in its respective field of application. AI that is harmful to humans should be prohibited, while peaceful applications should be encouraged. At the national level, comprehensible regulations (e.g., a risk-adaptive regulatory system) that create transparency and deregulate the health system are required. AI regulation and control are increasingly being promoted at transnational levels; here, too, over-regulation and misregulation must be reduced. When it comes to issues of equality, integration, and liability, or when supplied data contains racist, discriminatory, or sexist content, the establishment of basic rules and approval procedures for the application of AI is required. It should also be noted that regulations can lead to cost increases, whereas deregulation, for example, promotes competition and innovation.

3.2.2 USE OF AI IN THE PATIENT JOURNEY

From a practice-oriented point of view, the use of AI in health is mostly considered in the process of treating patients or in diagnosis. Six stages can be distinguished here:

SCREENING

Health screenings are required to prevent, detect, and treat diseases. The prevention of disease outbreaks is just as important as stopping disease progression or managing chronic diseases. Examinations benefit children, adolescents, adults, and the elderly. Doctors will not only advise patients during examinations, but will also record health risk factors and perform stress tests in the future. AI will assist doctors during examinations by prioritising, taking over standard tasks, and monitoring the entire examination to ensure that no details are overlooked and patients receive the best possible care. AI aids in the improvement of patient screenings.

PREVENTIVE CARE

Prevention and early detection services allow health risks to be detected and eliminated at an early stage. Physical examinations, health check-ups, vaccinations, and prenatal care are among the services provided. AI is already being used to assist patients and make individual recommendations in the early detection of breast, skin, and colon cancer. The earlier a serious disease is detected, the more time there is to treat it and avoid long-term consequences. Doctors must accurately record patients' health status for them to live a long and healthy life.

DIAGNOSTICS

Diagnostics is the process of identifying a disease through questioning and evaluating findings. Patients can be physically examined during anamnesis using various devices in addition to basic diagnostics by a doctor. AI can help doctors make diagnoses, perform routine medical exams, and perform apparatus-based diagnostics. Improved image quality or automated detection of abnormal findings can provide information about a patient’s health. Tissue structures, in addition to image data, can be analysed and evaluated in radiology. In recent years, the speed with which data can be evaluated and compared to existing data has greatly increased. AI, particularly with large data sets, can be used to quickly build a foundation for decision-making.

THERAPY

A therapy can have a positive impact on a disease or its progression. Through specific measures, a therapy can help to enable or accelerate the healing process of a disease. Furthermore, a therapy can reduce or eliminate the symptoms of a patient's illness. AI can be used prior to, during, and after therapy. It is possible to predict whether a patient will respond to a therapy prior to beginning treatment (systems medicine). Diseases should be identified earlier and treated with more specific active substances. Surgical and nursing robots can be used during therapy. AI can also be used to assess whether medicines work with various treatment plans and therapy approaches. The goal is to provide a therapy that is tailored to each individual patient. Following therapy, AI can be used to predict the likelihood of relapse.

MONITORING

Monitoring patients can help to improve treatment outcomes by identifying and correcting treatment problems, such as medication issues. In the field of body activity monitoring, AI can trigger an alarm in certain situations, alerting medical or nursing staff before a difficult situation arises. Through activity recognition in the patient, medical and nursing needs can be assessed, planned, adapted, extended, or changed. All vital functions in intensive care and emergency medicine can be monitored and immediate action taken using tracking and continuous monitoring. Patients' lifestyles, physical and mental functions can also be documented and monitored outside of healthcare facilities.

AFTERCARE

Data collected during therapy can be used to simulate specific scenarios after therapy. A virtual image of a patient can be used to identify potentially dangerous situations. Services that use AI (e.g., apps) can help patients organise appointments, create a follow-up plan, remind them to take their medication, organise doctor's reports and findings, and manage their own patient file. What is relevant at this point is how AI interacts with hospital doctors, specialists, patients, health insurance companies, and other actors involved in aftercare processes, such as general practitioners and pharmacies.

Figure 10: Use of AI in the patient journey (examples)

	Screening	Preventive Care	Diagnostics	Therapy	Monitoring	Aftercare
Goals	Prevent, detect and treat diseases, stop disease progression	Detect and eliminate health risks at an early stage	Identify a disease through questioning and evaluating findings	Help to enable or accelerate healing process of a disease	Improve treatment outcomes by identifying and correcting problems	Support patient after therapy and identify critical conditions
Typical AI use cases	AI to assist doctors by prioritizing, taking over standard tasks, monitoring screening and increasing overall process quality	AI to assist patients by early detection and making individual recommendations, as well as offering health status information	AI to help doctors make diagnoses, perform routine medical exams, and make better decisions based on large medical data sets	AI to predict patient response to a therapy, assist during therapy and assess whether medicines work with various treatment plans	AI to monitor critical situations, e.g., trigger an alarm to alert staff or continuously track vital functions and recommending actions	AI to help patients organize appointments and follow-up plans, remind to take medications, and organize reports and patient files

Source: Own presentation

When it comes to the use of AI in healthcare, one of the major problems is algorithmic bias within AI systems. Biases occur when there is a lack of fairness or favouritism towards one group because of a specific categorical distinction, such as ethnicity, age, gender, qualifications, disabilities, and geographic location. This issue and other ethical considerations will be analysed in chapter 3.6.

3.2.3 APPLICATION LANDSCAPE OF AI IN HEALTHCARE

The health economy can be used to represent the healthcare system as a layer model. There are four layers to the model:[6]

- Inpatient and outpatient care
- Production and supply
- Management and research
- Individual citizens

Examples of AI applications with their position in the healthcare system are shown in the following figure.

Figure 11: Examples of AI applications in the broader healthcare sector

Inpatient and outpatient care	Production and supply	Management and research	Individual citizens
Hospitals ▶ Image analysis ▶ Surgical robots	**Pharmaceutical industry** ▶ Drug development ▶ Acceleration of studies	**Health insurance** ▶ Workflow automation ▶ Financial auditing	**Fitness and wellness** ▶ Health apps ▶ Activity tracker
Pharmacies ▶ Stock optimisation ▶ Patient screening	**Medical devices industry** ▶ Digital twins ▶ Precision medicine	**Ministries and administration** ▶ Expert systems ▶ Automation of applications	**Prevention** ▶ Symptom checks ▶ Wearables
Rehabilitation centres ▶ Exoskeleton ▶ Monitoring	**Logistics and supply chains** ▶ Autonomous driving ▶ Navigation systems	**Universities** ▶ AI writing bots ▶ Exams and assessments	**Health education** ▶ Virtual reality ▶ Augmented reality
Medical practices ▶ Virtual doctors ▶ Decision support	**Information technology** ▶ IT automation ▶ Cybersecurity	**Research and development** ▶ Behavioural predictions ▶ Data analytics	**Assistance systems** ▶ Smart home ▶ Monitoring
Care facilities ▶ Nursing robots ▶ Fall detection	**Specialised trade and retail** ▶ Dynamic pricing ▶ Inventory controls	**Education and training** ▶ Mobile learning ▶ Conversational interfaces	**Assisted living** ▶ Service robots ▶ Voice assistants

Source: Own presentation

3.2.4 SELECTED FOCUS AREAS OF AI IN HEALTHCARE

AI has many potential applications in healthcare. One of the most important is image analysis, e.g. the ability to automatically interpret medical images such as x-rays and ultrasounds. This could potentially help to speed up diagnosis and treatment. In addition, AI could help in many ways to support pandemic preparedness and pandemic prevention. For example, it could be used to analyse large data sets to identify patterns and trends that might indicate the early stages of a pandemic. This section gives a brief overview of these selected use cases.

AI AND PANDEMIC PREVENTION

Given the current rate of globalisation, future pandemics are anticipated to follow the COVID-19 illness, while their frequency is unknown. Despite having a substantially lower mortality rate than SARS, COVID-19 has caused exponentially more devastation. The virus spread quickly and widely over the world, with asymptomatic and mild infections resulting in undetected transmission and a larger total mortality toll.

To successfully manage pandemics, policymakers, physicians, and other stakeholders must have near-real-time access to data and suggestions, including models that balance the relative risks and benefits of various actions. Notably, there have been multiple competing projection models for COVID-19, but only a handful have been found to be correct for this unique virus.

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[6] Pfannstiel, Mario (2022): Künstliche Intelligenz im Gesundheitswesen, Kapitel 1.

Policymakers and governments have a wide range of options for population-level health interventions, which are crucial for controlling spread early on. Implementing travel limits, closing companies, closing schools, mandating masks, and distributing scarce supplies such as personal protective equipment (PPE) and testing are examples of non-pharmaceutical solutions. Implementation, timing, enforcement, and termination are all options. Many of these judgments still rely on expert advice rather than data-driven algorithms.

To respond successfully at each stage of a pandemic, quick feedback cycles of data-driven learning are required. Data has always been crucial in healthcare and public health decision-making; however, data has been especially useful in global efforts to combat COVID-19. Unprecedented levels of world-wide collaboration have sparked data-sharing activities from both traditional and non-traditional sources, such as transit records and personal data from cell phones. These early data-sharing advances are crucial for AI, where performance increases with huge, inclusive, historical, and real-time datasets.

A scoping review study published by Nature's npj Journal on Digital Medicine identified six key use cases where ML was applied for pandemic preparedness and response, as well as related areas.[7] They are presented in the following table, together with commonly used data sources and types of ML.

Table 3: Use case overview for AI in pandemic preparedness and response

KEY USE CASE	COMMONLY USED DATA SOURCES	SUITABLE TYPES OF ML
Forecasting infectious disease dynamics and effects of interventions	Publicly available counts, media reports, commercial publications, web searches, social media, census data, population-level comorbidity statistics, data on outbreaks of similar pathogens	• Augmenting traditional models: neural networks • Data-driven ML: recurrent neural networks
Surveillance and outbreak detection	Social media (e.g., Twitter), web searches, news reports, medical record data (structured and unstructured fields)	• Text mining: natural language processing • Classification: support vector machines, transformer neural networks
Real-time monitoring of adherence to public health recommendations	Cameras in public spaces, GIS data, trajectory data (e.g., GPS)	• Compliance with mandated quarantine: proprietary facial recognition • Adherence to mask wearing, social distancing, and sanitation: proprietary computer vision • Monitoring movements of pandemic disease patients: supervised ML algorithms
Real-time detection of influenza-like illness	Cameras and sensors in public spaces	• Interpretation of thermal imaging: neural networks, computer vision
Triage and timely diagnosis of infections	Exposure history, medical record data (structured and unstructured fields, laboratory results, chest imaging)	• Interpretation of chest imaging: convolutional neural networks • Triage based on routinely collected medical record data: no standout ML • Interpretation of unstructured clinical notes: transformer neural networks
Prognosis of illness and response to treatment	Medical record data (structured and unstructured fields, laboratory results, chest imaging)	• Based on chest imaging: combination of convolutional and recurrent neural networks • Based on routinely collected medical record data: no standout ML • Interpretation of unstructured clinical notes: natural language processing, neural networks

Source: Own presentation, based on npj Digital Medicine (2021).

[7] npj Digital Medicine (2021): Leveraging artificial intelligence for pandemic preparedness and response: a scoping review to identify key use cases.

RECOMMENDED READING | *npj Digital Medicine (2021): Leveraging artificial intelligence for pandemic preparedness and response: a scoping review to identify key use cases* – The paper investigates key use cases for involving AI for pandemic preparedness and response from the peer-reviewed, preprint, and grey literature. https://www.nature.com/articles/s41746-021-00459-8.pdf

RECOMMENDED READING | *Wireless Networks (2022): A framework for monitoring movements of pandemic disease patients based on GPS trajectory datasets* – The study provides a framework for monitoring Movements of Pandemic Disease Patients and predicting their next geographical locations given the recent trend of infected COVID-19 patients absconding from isolation centres as evidenced in the Nigerian case. The methodology for this study proposes a system architecture incorporating GPS (Global Positioning System) and Assisted-GPS technologies for monitoring the geographical movements of COVID-19 patients and recording of their movement Trajectory Datasets on the assumption that they are assigned with GPS-enabled devices such as smartphones. https://www.nature.com/articles/s41746-021-00459-8.pdf

AI AND IMAGE DIAGNOSTICS

It can be difficult to interpret data that arrives in the shape of an image or a video. Experts in the field must train for several years to be able to distinguish medical phenomena, and they must also actively learn new content when new research and information becomes available. However, demand is rising, and there is a severe scarcity of expertise, especially in LMICs. AI appears to be a tool that could be used to fill this gap.

The following table summarises some of the most discussed use cases for AI in image diagnostics.[8]

Table 4: Use case overview for AI in image diagnostics

KEY USE CASE	DESCRIPTION
Identifying cardiovascular abnormalities	Measuring the various parts of the heart might show an individual's risk for cardiovascular disease or detect issues that may require surgical or pharmaceutical intervention. Automation of abnormality identification in regularly requested imaging procedures, such as chest x-rays, could result in faster decision-making and fewer diagnostic errors.
Detecting fractures and other musculoskeletal injuries	Fractures and musculoskeletal injuries, if not treated promptly and effectively, can lead to long-term, chronic discomfort. Hip fractures in the elderly are also associated with poor overall results due to decreased mobility and subsequent hospitalizations. Using AI to detect difficult-to-see fractures, dislocations, or soft tissue injuries could give surgeons and specialists more confidence in their treatment decisions.
Aiding in diagnosing neurological diseases	Degenerative neurological illnesses like amyotrophic lateral sclerosis (ALS) can be catastrophic for patients. While there is presently no cure for ALS and many other neurological illnesses, correct diagnosis could help people understand their chances of survival and plan for long-term care or end-of-life wishes. Algorithms may be able to support the diagnosis by detecting photos with suspicious results and provide risk ratios for the presence of ALS or PLS.
Flagging thoracic complications and conditions	Pneumonia and pneumothorax are two illnesses that require clinicians to act quickly. Radiology scans are frequently used to detect pneumonia and differentiate it from other lung disorders such as bronchitis. However, radiologists are not always accessible to read images, and they may have difficulties detecting pneumonia if the patient has pre-existing lung disorders such as malignancies or cystic fibrosis. When a pneumothorax is suspected, AI can also assist in identifying high-risk individuals, especially when radiologists are not present.
Screening for common cancers	Medical imaging is frequently utilised in routine, preventive cancer screenings, such as breast cancer and colon cancer. By providing risk scores for areas of concern, physicians and patients may be able to make more informed decisions about how to continue with testing or treatment.

Source: Own presentation, based on Health IT Analytics (2022).

8 Health IT Analytics: Top 5 Use Cases for Artificial Intelligence in Medical Imaging, https://healthitanalytics.com/news/top-5-use-cases-for-artificial-intelligence-in-medical-imaging (accessed 10 May 2022).

3.3 STAKEHOLDERS

When it comes to AI in general, various stakeholder groups can be differentiated, depending on their activities, strategies, and roles. The following table gives an overview of the most relevant stakeholder groups. Most of the use cases discussed previously fall into the group of “Using AI”, i.e. healthcare organisations, healthcare facilities, healthcare companies, and patients.

Table 5: Stakeholder groups in AI

STAKEHOLDER GROUP	ACTIVITY	LEADING QUESTION	EXAMPLES
Leading AI	Innovating and improving AI	How can we create AI breakthroughs?	Big tech companies
Researching AI	Analysing and evaluating AI	What could AI do in the future?	Universities, institutes
Developing AI	Implementing AI systems	How should AI systems be designed?	Tech firms, developers
Using AI	Applying AI to solve business problems	How does AI aid decision-making?	Organisations of all kinds
Regulating AI	Setting policies for the use of AI	How can AI be used fairly and legally?	Policy makers, regulators
Funding AI	Supporting and investing in AI projects	What is the impact of an AI project?	Incubators, VCs, donors
Enabling AI	Providing the technological basis for AI	What technology does AI need?	Hardware manufacturers
Educating AI	Offering advice on the use of AI	How can we facilitate the use of AI?	Consultants, trainers

Source: Own presentation

In the healthcare sector, digital data collection and processing are growing at an exponential rate, and digital developments and technologies are increasingly converging. It is not surprising, given the importance of the healthcare sector to the economy, that the biggest tech companies are increasingly driving the digital transformation in health as well. In 2019, Apple’s CEO Tim Cook even claimed that his company will one day look back and realize that its greatest contribution to humanity has been in healthcare.[9]

A wide range of activities can already be observed worldwide, for example in medical care (including the construction of hospitals), in the financing of health services (including health insurance) and in the digital networking of different actors, devices and structures. Big tech companies will continue to position themselves as an integral part of healthcare systems in the long term.

Big tech companies have advanced digital technology competencies and massive financial resources. In most cases, they base their economic success and market position on other business areas, and by entering the healthcare market, they aim to pursue not only economic interests but also, according to their own statements, the goal of using digital innovations to improve people's health. Fifteen of the world's most important tech companies are listed below. In 2021, thirteen of these companies were among the top 100 most valuable corporations in the world based on stock market value.[10]

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[9] Forbes (2019): Why Big Tech Companies Won’t Solve Healthcare’s Biggest Challenges, https://www.forbes.com/sites/robertpearl/2019/12/16/big-tech/?sh=714b20a16d28 (accessed 8 April 2022).

[10] Handelsblatt (2021): Die wertvollsten Konzerne der Welt: Wie Apple, Microsoft und Alphabet Europa abhängen, https://www.handelsblatt.com/finanzen/anlagestrategie/trends/top-100-nach-boersenwert-die-wertvollsten-konzerne-der-welt-wie-apple-microsoft-und-alphabet-europa-abhaengen/27916288.html (accessed 8 April 2022).

Table 6: Overview of big tech companies with major AI activities

COMPANY	MAIN BUSINESS	REVENUE 2020/21 (BN)	COUNTRY
Amazon	E-commerce, cloud hosting, computing	$470	USA
Apple	Consumer electronics	$366	USA
Google/Alphabet	Online search and advertising	$257	USA
Samsung	Consumer electronics	$234	South Korea
Microsoft	Computer software and hardware	$168	USA
Huawei	Telecommunication and consumer electronics	$140	China
Meta (formerly Facebook)	Social media and advertising	$118	USA
Alibaba	E-commerce, online retail	$113	China
Intel	Semiconductors, network equipment	$79	USA
Tencent	Social media, entertainment	$76	China
Siemens	Industry automation and digitalization	$71	Germany
IBM	Software, hardware, consulting	$57	USA
SAP	Enterprise software	$32	Germany
Philips	Health technology and household appliances	$22	Netherlands
Nvidia	Graphics processors and chipsets	$17	USA

Source: Own presentation, based on Handelsblatt (2021)

RECOMMENDED READING | *Bertelsmann Stiftung (2022): Tech-Giganten im Gesundheitswesen (German language)* – Global technology firms are progressively infiltrating the healthcare sector. Their activities and business areas are extremely diverse. Some firms, particularly in the United States and China, are establishing themselves as health-care providers. These “tech titans” represent a huge opportunity for the digital transformation of health systems due to their inventive power. On the other hand, the digital firms' partly monopoly-like market dominance poses significant problems, such as in data evaluation or equal access to medical services. Politics and society must reach an agreement on how to best integrate digital firms into existing health organisations while upholding the notion of solidarity. The report suggests possible solutions. https://www.bertelsmann-stiftung.de/fileadmin/files/user_upload/VV_Tech-Giganten_im_Gesundheitswesen1.pdf

Big tech companies are investing heavily in AI research and the development of AI-based systems and applications in healthcare. Selected activities are presented below as examples.

Table 7: Selected health-related AI activities of big tech companies

COMPANY	PROJECT EXAMPLES	DESCRIPTION
Amazon	Amazon Rekognition Video	Amazon Rekognition Video is a deep-learning function for video analysis that can recognise, track and extract objects, faces and content from videos. In healthcare, this may be particularly relevant in the field of medical imaging in the future.
	Amazon Transcribe Medical	Amazon Transcribe Medical is an Automatic Speech Recognition (ASR) service that provides speech-to-text capabilities. The service is used in various medical fields – for example conversations between doctors and patients can be transcribed.
	Amazon Comprehend Medical	Amazon Comprehend Medical is an ML-based natural language processing (NLP) service that extracts health data and information from medical texts.
Apple	Apple Machine Learning Research	Apple is dedicated to AI research through its Apple Machine Learning Research division.
Google/Alphabet	Google Health	Research on applications for everyday clinical practice in cooperation with medical care providers as well as governmental and academic partners. One focus of Google Health is computer vision, which is used in medical imaging and diagnostics.
	Google Brain	Deep learning algorithms, including in healthcare. The researchers at Google Brain, for example, developed the world's leading open source platform for machine learning: TensorFlow.
	DeepMind Health	Development of applications in the health sector (e.g., the medical smartphone app Streams). DeepMind achieved a breakthrough in November 2020 as part of AlphaFold (CASP), when it succeeded for the first time in determining the 3D shape of proteins based on their amino acid sequences using deep learning
Microsoft	Microsoft Healthcare NeXT	The Microsoft Healthcare NExT initiative aims to transform healthcare by leveraging AI and the Microsoft Azure Cloud.
	Microsoft AI for Good Initiative	Microsoft's AI for Good initiative is the umbrella for various programmes such as AI for Earth, AI for Humanitarian Action and also AI for Health, which aim to tackle major crises and pursue UN sustainability goals in collaboration with non-governmental organisations (NGOs) and other humanitarian organisations.
	Project EmpowerMD	Microsoft is collaborating with Nuance Communications, Inc. on Project EmpowerMD, which processes conversations between doctors and patients, integrates the content into Electronic Health Records (EHRs) and automatically provides a medical summary.
Huawei	Huawei Cloud	Huawei provides various AI-based services with its Huawei Cloud to combat Covid-19, among others.
Meta (formerly Facebook)	AI-based fact checking	Meta uses AI to reduce the sharing of misinformation on its platforms, such as on Covid-19.
	fastMRI	fastMRI is an AI-based medical imaging research project involving Facebook AI Research (FAIR) and New York University (NYU) Langone Health.

Source: Own presentation, based on Bertelsmann Stiftung (2022)

3.4 REGULATIONS

At least 60 countries have adopted some form of AI policy since 2017, when Canada became the first to do so. Work on developing global AI standards has resulted in significant developments in various international bodies. These include both technical aspects of AI (in organisations such as the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), and the Institute of Electrical and Electronics Engineers (IEEE), among others) and ethical and policy dimensions of responsible AI. In addition, the G-7 agreed in 2018 to form the Global Partnership on AI, a multistakeholder initiative that will work on projects to investigate regulatory issues and opportunities for AI development. To support and inform AI policy development, the Organization for Economic Co-operation and Development (OECD) established the AI Policy Observatory. Several other international organisations have begun to work on proposed frameworks for responsible AI development.

Furthermore, there has been an increase in the number of declarations and frameworks issued by public and private organisations to guide the development of responsible AI. While many of these are focused on broad principles, the last years have seen an increase in efforts to put these principles into action through fully-fledged policy frameworks. Frontrunners in this regard have been Canada's directive on the use of AI in government, Singapore's Model AI Governance Framework, Japan's Social Principles of Human-Centric AI, and the United Kingdom's guidance on understanding AI ethics and safety; they were followed by the United States' guidance to federal agencies on AI regulation and an executive order on how these agencies should use AI. The most recent attempt to introduce a comprehensive legislative scheme governing AI was the EU proposal for adoption of regulation on AI.

RECOMMENDED READING | *Brookings (2021): Strengthening International Cooperation on AI* – The report presents a compelling argument for worldwide AI collaboration. It outlines both the negative effects of an international landscape devoid of cooperation and the benefits of expanded partnership. It also underlines the potential benefits of AI in addressing global concerns such as climate change and pandemic preparedness. The research contends that "no country can go it alone," and explains how a coordinated worldwide framework might significantly impact the favourable trajectory of AI development and deployment. https://www.brookings.edu/wp-content/uploads/2021/10/Strengthening-International-Cooperation-AI_Oct21.pdf

The following table presents an overview of AI activities from selected countries and regions.[11]

Table 8: Regulatory AI frameworks from selected countries and regions

ADMINISTRATION	AI ETHICS FRAMEWORK	EXISTING AI REGULATION	AI STANDARDS
Australia	Australia's AI Ethics Framework	Review of existing regulations per the AI Action Plan	Standards Australia focuses on by-design and standards testing; AI Standards Roadmap
Canada	CIFAR Pan-Canadian AI Strategy 2017; Digital Charter 2017/2021; Montreal Declaration for Responsible Development of AI	Directive on Automated Decision Making; Algorithmic Impact Assessment	CIO Strategy Council develops AI Standards and is accredited by Standards Council of Canada, focusing on ethical design and ADM audits; $8.6 million over five years, starting in 2021–22, to advance the development and adoption of AI standards
EU	Ethics Guidelines for Trustworthy AI; White Paper on AI; Proposal for a regulation on AI; National ethics guidelines	Coordinated Plan on AI; Proposal for a regulation on AI; Digital Decade package	CEN-CENELC Joint Technical Committee 21 'Artificial Intelligence'; national standards focus on EU interoperability, ethics, fundamental rights, and safety

[11] Brookings (2021): Strengthening International Cooperation on AI.

Japan	R&D Guidelines 2018; Social Principles of Human-Centric AI 2019; AI Utilization Guidelines 2019; Society 5.0 framework	Draft AI Utilization Principles Guidelines 2019; AI Technology Strategy 2017	Ministry of Economy, Trade and Industry (METI), Japanese Industrial Standards Committee and Information Technology Standards Commission focus on developing sector-specific standards in transportation, safety, and patents
Singapore	Model AI Governance Framework, 2nd Edition, 2020; Implementation and Self-Assessment Guide for Organizations; Principles to Promote Fairness, Ethics, Accountability and Transparency	National AI Strategy	Voluntary Horizontal Model Framework contributes to global standards for AI-related policies and guidelines
UK	Guidance on Ethics, Transparency Accountability for ADM	National AI Strategy	British Standard Institute (BSI) focuses on international cooperation and healthcare standards
US	Principles in Executive Order 13859 and Executive Order 13960; Agency specific frameworks, state-specific guidelines	Government agencies assessing where AI regulation is needed, where existing regulation applies, and roles for selfassessment, codes, etc.	National Institute of Standards and Technology (NIST) and American National Standards Institute (ANSI) focus on maintaining U.S. leadership/ priority, international engagement, foundational AI standards

Source: Own presentation, based on Brookings (2021)

International regulatory cooperation could reduce regulatory burdens and trade barriers, encourage the development and use of AI, and make global markets more competitive. However, countries differ in terms of legal tradition, economic structure, comparative advantage in AI, and balancing civil and fundamental rights. Despite these differences, all countries' AI policy development is in its early stages, so timely and focused international cooperation can help align AI policies and regulations.

According to FCAI, the following areas for cooperation emerged from their dialogues and analyses:

- Building international cooperation into AI policies
- A common, technology-neutral definition of AI for regulatory purposes
- Building on a risk-based approach to AI regulation
- Sharing experiences and developing common criteria and standards for auditing AI system
- A joint platform for regulatory sandboxes
- Cooperation on AI use in government (procurement and accountability)
- Sectoral cooperation on AI use cases

Several LMIC have also started creating national AI policies with the goal of expanding investment, talent development, and financial aid, acknowledging that AI has the ability to increase GDP and provide competitive advantages to countries. One of the first nations in Africa to release its 70-page AI national strategy was Mauritius.[12]

Although AI technologies from high-income countries predominate worldwide, they may not offer technology goods and solutions that are in line with regional development aspirations of LMIC. Policy responses to AI should build on national digital agendas and prioritize inclusive digital, data, and computing infrastructure and skills development in order to foster local AI capacity that benefits local economies and ecosystems.

[12] Mauritius Artificial Intelligence Strategy, 2018, https://ncb.govmu.org/ncb/strategicplans/MauritiusAIStrategy2018.pdf.

3.5 DATASETS

In a survey among healthcare professionals, healthcare investors and executives across Europe, conducted in January 2020, McKinsey asked the participants: “What are the major barriers for introducing or scaling AI in healthcare organisations?”. The dominating answers across all participant groups were issues and concerns around data quality and security, the interoperability of systems and the governance and ownership of data.

Therefore, when it comes to health data, the following main challenges should be explored:

DIGITISATION OF HEALTH DATA

Adopting digitised and automated processes is a critical first step toward the effective implementation of AI in healthcare. Healthcare providers in some high-income countries have made progress in using EHRs, but – especially in LMICs – there are still many examples of frontline staff manually recording data and independent clinical systems that cannot communicate with one another or fully integrate all of a patient’s information. As new digital solutions are introduced, data fragmentation grows. Interfaces that seem obvious, such as digital data on patients’ vital signs integrating with EHRs, are frequently not standard, and interoperability levels within and across hospital systems and other care providers are variable at best.

Many EU countries are still developing electronic data collection and automation of operational and clinical tasks, which will necessitate significant changes in workflow practises and a shift in workforce skills. Healthcare is one of Europe’s least digitised sectors, trailing others in terms of digital business processes, digital spend per worker, digital capital depth, and digitisation of work and processes. Most LMICs face similar problems.

This lack of digital records and processes poses significant challenges for adopting AI solutions, not only because data are required to feed the algorithms, but also because staff frustration with existing digital system inadequacies can lead to a reluctance to adopt more innovative AI solutions. In any case, before launching AI efforts, it is critical to complete the basic digitisation of systems and data, as well as the development of digital skills. Systematizing digital data collection, connecting datasets across systems, and ensuring data cleansing is performed on a regular basis are all prerequisites for implementing AI solutions. However, there is frequently a mismatch between the ideal of completely clean data and the reality that most healthcare organisations face.

DATA GOVERNANCE

Healthcare providers should be accustomed to dealing with massive amounts of clinical data, much of which is highly sensitive and confidential, and they should have well-tested policies for managing data security, such as asking patients to consent to their data being shared, including for clinical research purposes. However, as more healthcare is delivered using new digital technologies, public concern about the use of healthcare data has grown.

Patients in Europe, the United States, Canada, and other parts of the world could be reassured about their data security because they have well-developed data security laws. Despite this, there have been high-profile cases in which AI companies and healthcare providers were found to have failed to communicate clearly with patients about how their data would be used, or to have accessed data without the required consents. In the United Kingdom, for example, the Information Commissioner declared in 2017 that the Royal Free NHS Foundation Trust’s sharing of 1.6 million patient records with Google DeepMind violated the UK Data Protection Act because “patients would not have reasonably expected their information to be used in this way, and the Trust could and should have been far more transparent with patients about what was going on.”

Healthcare organisations should have robust and compliant data-sharing policies in place that support the improvements in care that AI provides while also providing the necessary safeguards. In terms of data governance, Europe as a region could serve as a model for LMICs: healthcare organisations and health systems are accustomed to handling sensitive data via well-structured data governance and risk-management processes.

DATA INTEROPERABILITY

One of the most significant barriers to AI in healthcare is that, while sufficient data is often available across a national system, it is not connected or interoperable. Policymakers, funding bodies, and non-profit organisations must support efforts to sufficiently anonymize or link data and, where appropriate, build federated networks of interoperable datasets that can be queried as needed (with the appropriate security and governance protocols), or assist in the creation of scaled-up databases that can be accessed only by stakeholders with the necessary safeguards.

The European Nucleotide Archive, for example, provides free, unrestricted access to genomic data associated with academic life science research. More sensitive data, such as that generated by the Danish Reference Genome Project or Genomics England's 100,000 Genomes Project, are also available for research purposes, but they are de-identified and subject to strict access policies. The Genomics England dataset, for example, is hosted in a secure environment within the datacentre, and analytical tools are available within this environment, but data cannot be moved outside or downloaded. Another example of centralised efforts to spearhead and support the development of national datasets for healthcare, including for AI applications, is the Israeli government's recent initiative to combine national digital medical records in a unified system.

However, it should be acknowledged that healthcare data is notoriously difficult to manage. They are frequently collected using proprietary software and compiled in siloed databases that are part of largely incompatible systems – sometimes even within the same hospital. This renders a large portion of the existing data virtually useless in its current state. This is an important consideration for healthcare providers, who must develop policies to promote interoperability both within their own proprietary systems and those of external suppliers and other providers. To make the most of the rich data available, healthcare systems require an interconnected data infrastructure, as well as data format standards, whether they are Fast Interoperability Resources or open EHRs, data exchange, and semantic interoperability of medical terminologies to reduce noise in the data. Such efforts have previously been successful, such as gene and protein naming conventions, data-format standards for next-generation DNA sequencing data, and International Classification of Diseases codes. They have frequently evolved organically, proposed by groups of researchers or international committees of larger organisations, and could serve as a model for similar AI efforts.

3.6 ETHICAL CONSIDERATIONS AND BIASES

There are multiple ethical issues when it comes to using AI in general and even more so in relation to healthcare; among the most discussed ones are the following:[13]

- Uncertainty and distrust of AI predictions
- Regulation and governance of medical AI
- Shifts in responsibility and liability introduced by using AI in practice
- Concerns for data privacy and security
- Biased results that hurt marginalized group
- Underlying business model and ownership

The following paragraphs look at some of the most relevant ethical issues and discussion points.

DATA BIAS

Assuming the digitisation challenge discussed in the previous section has been solved – i.e., there is enough data available to work with AI algorithms – there is still the problem of algorithmic bias within AI systems. Biases occur when there is a lack of fairness or favouritism towards one group as a result

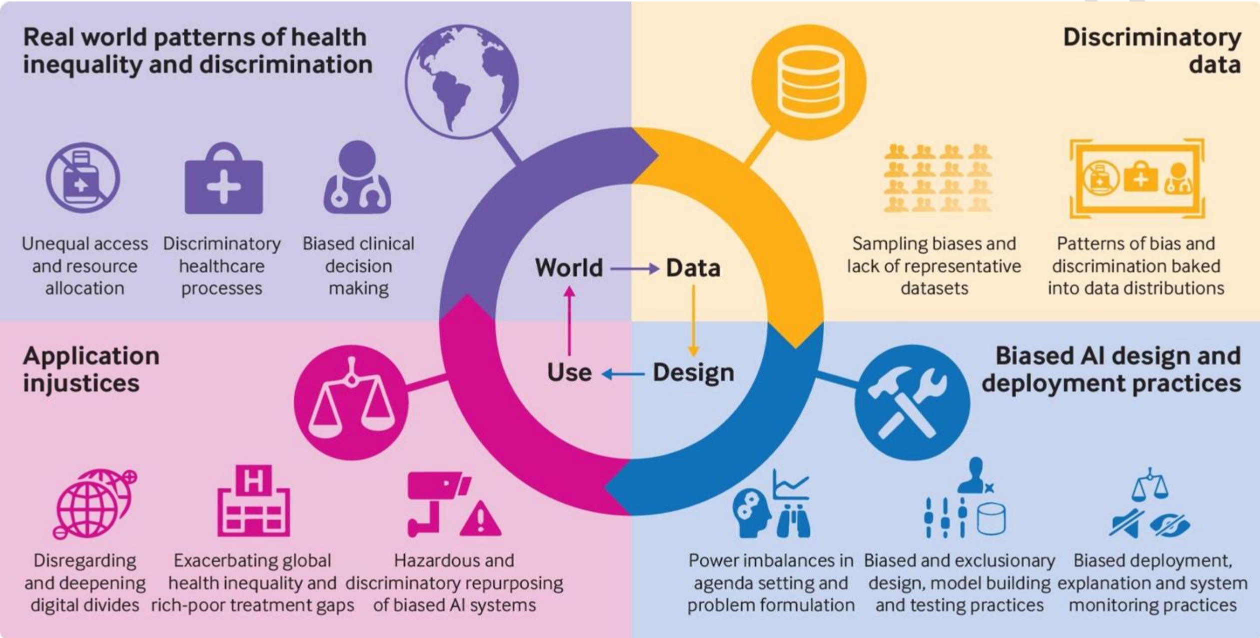
[13] Topol, Eric: AI in health and medicine, Webinar, AI for Good, streamed live on 27 April 2022, https://www.youtube.com/watch?v=Z8A73pUr3aA (accessed 11 May 2022).

of a specific categorical distinction, such as ethnicity, age, gender, qualifications, disabilities, and geographic location.

Those incorrect assumptions about the dataset or model output are made during the machine learning process, resulting in flawed results. Bias can occur during the project's design or during the data collection process, resulting in output that unfairly represents the population.

As a result, AI systems have the potential to increase health inequities if they are not carefully built and implemented. There can even be a cascading impact of inequality and in the design and application of an AI system, as shown in the following figure[14].

Figure 12: Cascading AI bias in healthcare applications



Source: British Medical Journal (2021)

Depending on the project setting, some biases are unavoidable while others can be mitigated. In any case, to effectively identify bias, the presence of bias throughout the whole AI pipeline needs to be mitigated.

Some of the most common biases are described in the following table:

Table 9: Typical biases throughout the AI pipeline

BIAS	DESCRIPTION
Implicit bias	Implicit bias is discrimination or prejudice against a person or group that is unconsciously held by the individual with the bias. It is harmful because the person is unaware of the bias – whether it be based on gender, ethnicity, disability, sexuality, or class.
Sampling bias	This is a statistical problem in which random data drawn from the population do not accurately reflect the distribution of the population. The sample data may be biased toward a subgroup of the group.
Temporal bias	This is dependent on our perception of time. We can create a ML model that performs well now but fails in the future because we did not account for potential future modifications when developing the model.

[14] British Medical Journal (2021): Does "AI" stand for augmenting inequality in the era of covid-19 healthcare?

Over-fitting to training data	This occurs when the AI model can reliably predict values from the training dataset but cannot predict fresh data accurately. The model is very dependent on the training dataset and does not generalise to a bigger population.
Edge cases and outliers	These are records that are outside the boundaries of the training dataset. Outliers are data points that fall outside of the normal distribution of the data Edge cases are errors and noise: Errors are missing or inaccurate values in the dataset; noise is data that has a detrimental impact on the ML process.

Source: Own presentation

RECOMMENDED READING | *British Medical Journal (2021): Does "AI" stand for augmenting inequality in the era of covid-19 healthcare?* – The paper analyses how bias and discrimination in AI design and deployment risk exacerbating existing health inequity. https://www.bmj.com/content/bmj/372/bmj.n304.full.pdf

RESPONSIBLE AI

Australia, the EU, Japan, and Singapore have created extensive sets of guidelines for the responsible development of AI. The OECD has echoed these (particularly the EU ones) by establishing a list that broadens the scope of responsible AI development toward a multistakeholder approach, while also arguing that governments must implement safeguards to support responsible AI development and deployment. The following table summarizes the key values of these international frameworks.[15]

Table 10: OECD framework for the development of responsible AI

VALUES	DEFINITIONS
Human centred	AI systems should be designed to be inclusive, accommodating the needs of the individuals that interact with it, and used in a manner that is aligned with the values of the community in which it is deployed.
Mitigate risks and promote benefits	AI systems should be designed and deployed for the benefit of end users and avoid unintended negative impacts on third parties.
Fairness	Governance and technical safeguards are important to identify and mitigate risks of unfair biases, particularly in circumstances where an AI system could have a consequential impact on people.
Explainability	AI systems should be understandable; context will dictate the appropriate mechanisms for providing transparency about a particular system's decisionmaking processes.
Privacy and security	AI systems should be secure and enable users to make informed choices regarding use of personal information.
Safety and reliability	AI systems should be designed to mitigate foreseeable safety risks and adequately tested to ensure that they operate as intended.
Accountability	A lifecycle approach to AI accountability, including appropriate governance structures for the design phase and redress mechanisms following deployment is important.
Risk-based and proportionate	Risks are context-specific and encourage stakeholders to deploy risk management techniques that are tailored to specific use cases.
Multiple stakeholders	Multiple stakeholders have important roles to play in mitigating risks involved in the development, deployment, and use of AI.
Promotes innovation	Government is a key enabler of AI innovation, and promotes a policy environment that is conducive to crossborder data flows, value-added data services, access to non-sensitive government data, R&D, and workforce development initiatives.

Source: Own presentation, based on Brookings (2021)

15 Brookings (2021): Strengthening International Cooperation on AI.

CHALLENGES IN INTERNATIONAL COOPERATION

As AI increasingly permeates our everyday lives, it is important to consider the ethical implications of this technology on an international level. In particular, AI presents a number of challenges to human dignity and autonomy, as well as individual rights to free expression and nondiscrimination. For example, facial recognition technology can be used to track and monitor individuals without their consent or knowledge. This raises serious concerns about privacy and security, as well as the potential for misuse by government and other institutions.

The ethical implications of AI are still being debated in many countries around the world. While some nations have restricted certain uses of AI, such as facial recognition, others have embraced the technology and are using it extensively. This divergence in opinion makes it difficult to establish common ground for international cooperation on AI. However, it is essential that different nations find a way to work together on this issue, in order to define common values and boundaries. Otherwise, the potential for abuse of AI will only continue to grow.

4 GAP ANALYSIS

This section gives a brief overview of the main problems that LMIC typically face when considering the introduction of AI-based solutions in the healthcare sector.

4.1 DATA AVAILABILITY AND QUALITY

AI/ML applications require a training dataset with defined outcome variables. The absence of big clinical datasets for training AI models is a significant problem in applying AI to health and medicine. This is especially true for labelled datasets, which necessitate doctor/medical expert annotation and are hence costly and time-consuming to obtain. Because of a typically low degree of digitalization and electronic medical record adoption in LMICs, there is a scarcity of locally generated usable data that is critical for constructing AI systems.

The concept of algorithmic bias, which argues that AI is only as good as the data it is trained on, is a significant consideration in the creation of AI products and services. This aspect, while not unique to LMICs, has a greater impact when AI technologies are introduced into the LMIC context. Because most AI applications are created in high-income countries, the majority of datasets accessible are from people who differ physiologically from many LMICs. While this may not be a major concern in some cases, it may have a detrimental effect on sensitivity in others. AI systems may potentially have algorithms that are based on the developers' preconceptions and unique ideas. This opens the door to unintended bias, which can lead to discrimination and incorrect outcomes when applied to others in low-resource contexts without their developmental involvement and data.

4.2 REGULATION OF AI

Many governments throughout the world are still building a governance policy or legal framework for the adoption of AI in many industries, including healthcare. Some LMICs lack a national digital health policy or plan to guide the implementation and monitoring of digital health strategies. Stakeholders from partner countries often feel that limited government policy participation has impeded adoption, and that greater engagement could stimulate early use of AI and other digital tools.

There are no clear regulations in LMICs or around the world that govern who bears responsibility for negative outcomes that may result from the use of AI in healthcare, which is highly possible given how and where AI may be used in healthcare. The most likely solutions involve the application of current rules, while some issues and scenarios are not foreseen or covered by existing laws.

4.3 COSTS OF AI-BASED SOLUTIONS

The cost of assembling an AI/ML-based solution in healthcare is difficult to estimate, although it might range from a few thousand euro for simple chatbots to millions of euros for complex systems. The following are the costs connected with the application or adoption of AI:

- **Data acquisition and preparation costs:** Typically, this is the most critical and time-consuming phase that fundamentally determines the quality of an AI application.
- **Hardware and computing resources:** In most of today's AI applications, the accuracy of an ML model can be predicted based on the magnitude and quality of the available dataset, and the available computing power. Hence, a project can incur high costs for accessing cloud-based computing and database services.
- **System maintenance and upgrading:** Typically, AI/ML models need to be constantly updated and changed in significant ways to fulfil their purpose and keep working as expected. This aspect is often overlooked or underestimated.

4.4 INADEQUATE INFRASTRUCTURE

Another key barrier restricting the rate of growth of this technology in LMICs is insufficient infrastructure, e.g., low Internet penetration, as well as social concerns impeding acceptance. There is also widespread energy inaccessibility across LMICs; for example, almost half of Africans lack access to electricity, making it difficult to implement and sustain digital technologies in all sectors of the economy, including healthcare.[16]

4.5 LACK OF SKILLS ON SITE

One of the major challenges is the lack of local skills. In order to implement AI healthcare systems, trained personnel are needed to develop, operate and maintain the systems. However, there is a shortage of suitable experts in many LMICs, due to the lack of education and training opportunities in these countries.

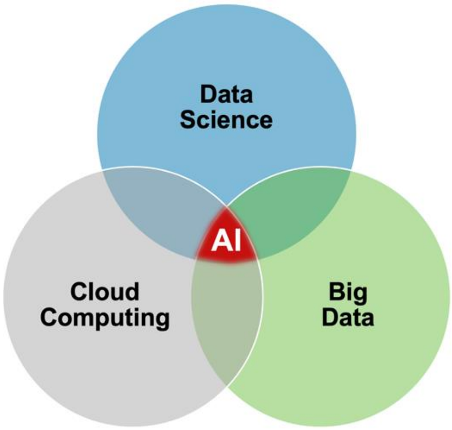
[16] The Economist (2019): More than half of sub-Saharan Africans lack access to electricity, https://www.economist.com/graphic-detail/2019/11/13/more-than-half-of-sub-saharan-africans-lack-access-to-electricity, 13 November 2019 (accessed 11 August 2022).

5 CONCLUSIONS AND RECOMMENDATIONS

The potential of AI and ML to significantly improve healthcare should not be underestimated. In LMIC, the application of AI-driven tools can aid in the eradication of health disparities and alleviate the strain on health systems.

However, AI is empowered by data, knowledge and technology. The foundational elements for planning and implementing AI systems are therefore a vast amount of quality training data (big data), knowledge about the applicability and structure of data for AI (data science), and access to computing resources (cloud computing). While the latter is typically easy to solve (given sufficient internet access), the first two topics are often overlooked. Nonetheless, they are a basic prerequisite for the effective application of AI in any use case.

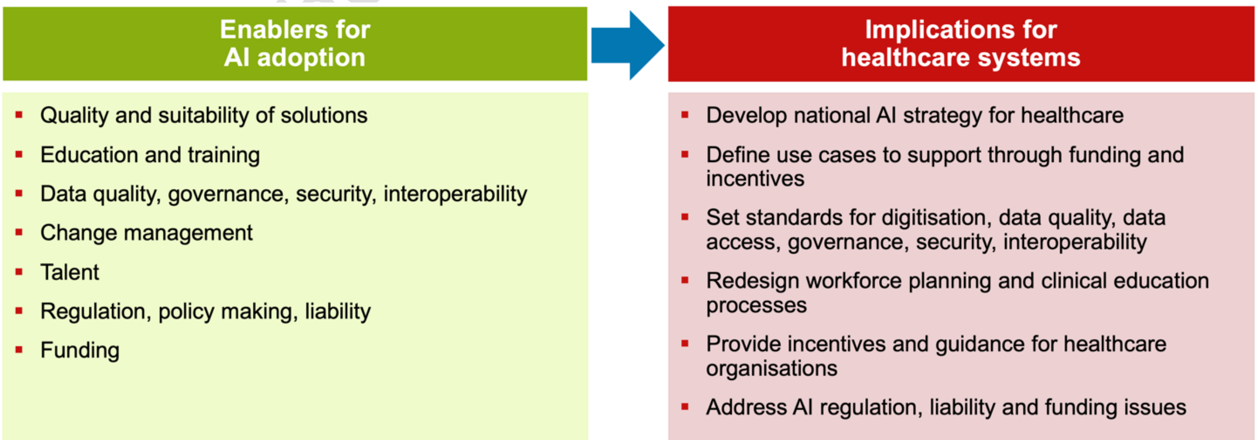
Figure 13: Foundational elements for implementing AI



Source: Own presentation

Overall, the following main enablers for AI adoption and their implications for healthcare systems in LMIC should be taken into consideration:

Figure 14: AI-related recommendations for healthcare systems in partner countries



Source: Own presentation

German Development Cooperation will need to go through a constant process to make sure that its policies and tools are appropriate. The BMZ jointly with its implementation partners must continue to increase their capacity, since the pace of change and potential for disruption brought on by AI cannot be understated. It will be crucial to give important decision-makers the knowledge they need to comprehend the fundamental operations of AI and ML, the issues that may be fixed, and the areas where expectations are incorrect. This covers not just technology elements but also the strategic and operational setups required to conduct AI initiatives successfully. To lessen reluctance or prevent unsatisfactory project implementation results, it is important to address significant technical misconceptions with all stakeholders. It will be crucial to prevent fragmentation and coordinate knowledge management among German development cooperation implementers in the public and commercial sectors. A high level of international coordination and cooperation will be required to create standards, identify best practices, and deal with global entities due to the transnational nature of the technology. Within the parameters of their individual responsibilities, numerous multinational organizations work on this issue. To create and distribute expertise among implementers, this must be tightly interwoven with the current German development cooperation.

Public-private partnerships such as the recently announced United AI Alliance – an initiative of the technology company Nvidia and the United Nations Economic Commission for Africa (UNECA) – can also be a way to work on reducing the Digital Divide in underserved communities by improving data science and supporting more informed policy-making.

While finding AI-based application sectors is crucial, one function of German Development Cooperation efforts is to strengthen regulatory competence in an with partner countries. Multinational collaboration will be essential in defining and creating standards and best practices in this context, and it will be a sphere in which German Development Cooperation may assist partner countries. They can take part in value creation through AI applications by promoting economic growth through a detailed legal framework, financial incentives, and technical help. The partner countries' potential and hazards are not distributed equally, therefore a thorough analysis will be required to pinpoint country-specifics in terms of technology literacy and market structure so that they can position themselves.

While many of the AI-related developments will take place in the upcoming years, other, more fundamental changes regarding the capability of AI applications will take longer to manifest. There is great potential for disruption through the use of AI in the healthcare sector over the medium to long term. Widespread usage of AI could radically alter current systems. This might also lead to significant hazards that have to be handled by stakeholders on all levels, especially when combined with the influence of other new technologies. The use of AI requires both international coordination and worldwide cooperation due to its global character.

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APPENDIX: INITIATIVES AND FLAGSHIP PROJECTS

This chapter outlines some interesting initiatives, projects, and products around AI in digital health. The projects were selected on the basis of the workshops implemented in the team and the expert interviews conducted. The basis was the question of whether a project has a special AI component or whether there are future plans in this direction that could be relevant for the discussion paper. Also, some relevant initiatives were selected as examples, without any claim to being exhaustive.

EUROPEAN HEALTH DATA SPACE AND AI REGULATION

The European Commission is proposing a legislation to establish the European Health Data Space in order to maximize the potential of health data. With the help of this proposal, individuals should be able to take control of their own health data and use it to improve healthcare delivery, research, innovation, and policymaking. Additionally, the EU should be able to fully capitalize on the opportunities presented by a safe and secure exchange, use, and reuse of health data.[17]

The European Health Data Space is an ecosystem focused on health that consists of regulations, common standards and practices, infrastructures, and a governance framework. Its goals are to empower individuals by enhancing digital access to and control over their electronic personal health data at the national and EU-wide levels, supporting their freedom of movement, and fostering a true single market for electronic health record systems, pertinent medical devices, and high-risk AI. The provision of a standardized, reliable, and effective framework for the use of health data in research, innovation, policymaking, and regulatory activities is another objective.

A resilient Europe for the Digital Decade, where people and businesses can benefit from AI, is supposed to be created with the support of the European approach to AI.[18] It concentrates on two things: excellence in AI and trustworthy AI. The European approach to AI wants to make sure that any advancements are based on regulations that protect the operation of the public sector, markets, and people's fundamental rights.

The European Commission created an AI strategy to support the European approach to AI in order to assist further articulate its vision for AI. The AI strategy suggested ways to speed up research as well as potential regulatory choices, which influenced the development of the AI package. In April 2021, the Commission released its proposal for an AI regulation, recommending new laws and initiatives to make Europe the world center for reliable AI.[19]

FAIR FORWARD

AI opens up new avenues for underdeveloped and rising countries to overcome difficulties and accomplish the global Sustainable Development Goals: For example, AI-powered apps are already assisting local farmers in Tunisia and India in detecting agricultural diseases in real time. AI also provides new tools for digital entrepreneurs to create novel goods.

However, there is frequently a shortage of frameworks, capacities, and methods for responsible and locally relevant AI application development. Today, just 25 of 54 African countries have data privacy legislation, and only a few pioneering countries, such as Kenya and India, have started AI use and promotion initiatives.

As a result, developing and emerging countries risk falling behind in the use and development of AI, or becoming dependent on leading AI nations. At the same time, there is a risk that new technology will worsen inequities, discrimination, and human rights breaches.

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17 European Commission: European Health Data Space, May 2022, https://health.ec.europa.eu/ehealth-digital-health-and-care/european-health-data-space_en.

18 European Commission: A European approach to artificial intelligence, June 2022, https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence.

19 European Commission: Proposal for an AI regulation, April 2021, https://digital-strategy.ec.europa.eu/news-redirect/709090.

The German Development Cooperation initiative “FAIR Forward – Artificial Intelligence for All” aims to promote a more open, inclusive, and long-term approach to AI on a global scale. The initiative is currently collaborating with six partner countries: Ghana, Rwanda, Kenya, South Africa, Uganda, and India.

The initiative pursues three major objectives:

- Access to training data and AI technologies for local innovation
- Strengthen local technical know-how on AI
- Develop policy frameworks for ethical AI, data protection and privacy

The project is part of the “Digital Transformation for Sustainable Development” program of the BMZ and implemented by GIZ.[20]

FCAI

Governments, business, and other international stakeholders have begun to adopt distinct plans to capitalise on opportunities and manage difficulties as the strategic, economic, and social relevance of artificial intelligence has become widely acknowledged in recent years.

Since 2017, when Canada became the first government to adopt a national AI policy, at least 60 countries have enacted artificial intelligence policies in some form—declarations, guidelines, industry recommendations, or principles. Similar measures have been made by industry leaders in the tech sector to formalise their approaches to AI, with the goal of achieving responsible, trustworthy, and ethical use and consequences.

As these efforts among stakeholders became more global – and their results more strong – Brookings and the Center for European Policy Studies (CEPS) collaborated on a deeper examination of future harmonisation mechanisms, resulting in the formation of the Forum for Cooperation on Artificial Intelligence (FCAI) in early 2020. The FCAI is a multi-stakeholder dialogue that brings together high-level government officials as well as specialists from industry, civil society, and academia. They recently published a paper that assesses the current state of worldwide AI cooperation and makes recommendations for future advancement.

Since then the FCAI has hosted nine AI Dialogues, bringing together hundreds of participants for high-level, multistakeholder roundtables with government officials from the United Kingdom, the United States, the European Union, Canada, the United Kingdom, Japan, Australia, and Singapore, as well as leading experts from academia, the private sector, and civil society.

The FCAI presents a compelling argument for worldwide AI collaboration, also when it comes to addressing global concerns such as climate change and pandemic preparedness. A coordinated worldwide framework might significantly impact the favourable trajectory of AI development and deployment. The increasingly global AI research and development scene exemplifies the requirement and benefits of a collaborative approach, suggesting that collaboration across worldwide teams has the ability to facilitate resource-intensive research and enable developers to scale projects.[21]

I-DAIR

The International Digital Health & AI Research Collaborative (I-DAIR) (https://www.i-dair.org/) is a Geneva-based global platform focusing on access to inclusive, impactful, and responsible research into digital health and Artificial Intelligence (AI) for health. The incubation effort based at a WHO Collaborating Centre was initially convened by Fondation Botnar in 2019 and is, since 2020, also supported by the Wellcome Trust.

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[20] More information on the FAIR Forward initiative can be found here: https://toolkit-digitalisierung.de/en/fair-forward/.

[21] More information on the FCAI can be found here: https://www.brookings.edu/blog/techtank/2021/11/30/why-international-cooperation-matters-in-the-development-of-artificial-intelligence-strategies/.

I-DAIR has established seven hubs around the world (in Geneva, Johannesburg, Nairobi, New Delhi, Santiago de Chile, Singapore and Tunis), with plans to open additional affiliate research centers in other locations. This will create a global network of research and innovation hubs.

IDRC

IDRC (International Development Research Centre, https://idrc.ca/en) is a Canadian federal agency that funds research and innovation in and alongside developing regions as part of Canada's foreign and development policy. The heead office located in Ottawa, Canada, while five regional offices are located in Montevideo, Uruguay; Nairobi, Kenya; Dakar Senegal; Amman Jordan; New Delhi, India.

ONE HEALTH

Health is not only a prerequisite for a self-determined life, but also essential for social and sustainable economic development worldwide. The current COVID-19 pandemic shows the dangers posed by infectious diseases. The pathogen causing the pandemic, SARS-CoV-2, also gives an indication of the importance of zoonotic diseases, i.e. diseases that can be transmitted between animals and humans. It is to be expected that this type of pathogen will occur even more frequently in the future. In order to contain these health risks, new approaches are needed in development cooperation.

One Health stands for a holistic, interdisciplinary approach that encompasses the complex interrelationships between humans, animals and the environment and is intended to lead to an improvement in global health.[22] It is based on the idea that human and animal health is directly linked to an intact environment. One Health addresses the interface between human, animal and environmental health.

One of the major fields of action in One Health is digitalisation to improve the data situation and early detection of potential outbreak scenarios. The aim is to link human and veterinary data with climate and satellite data and to build capacities and use digital technologies for risk analyses. Data science and machine learning are playing an increasingly important role in this area. Overall, AI and big data applications offer the chance to address complex data challenges in the One Health approach, such as various data types and systems as well as multiple interactions and diverse networks.

OPENIMIS

More and more countries are establishing measures to increase their citizens' access to Universal Health Coverage (UHC) and Universal Social Protection (USP). Efficient management of the process required for these remain a challenge to most; a challenge that digitalization can help overcome.

openIMIS is a digital public good that facilitates the digitalization and effective management of various of social protection and health financing workflows.. As a global good, openIMIS evolves and improves based on the experiences and contributions of existing implementations, as well as the knowledge of professionals throughout the world. This vibrant community of practice consisting of users from over 8 countries, software developers, health and social protection experts, and various development cooperation agencies contribute to the continuous development of openIMIS.

Responding to the request from one of their users, the Health Insurance Board of Nepal, the openIMIS initiative has developed new functionality based on AI that allows for the faster medical review of claims before reimbursement. This supports the medical review team to quickly identify potential issues with claims and find solutions – ultimately resulting in faster reimbursement payments to health facilities. This showcases how AI can help in improving process efficiencies that strengthen health systems.

[22] The Berlin principles on one health – Bridging global health and conservation: https://www.giz.de/en/downloads/2020-the-berlin-principles-on-one-health.pdf.

OSCAR

In health crises, good information utilisation is critical in order to respond promptly and appropriately, as well as to use limited resources efficiently and effectively. Nonetheless, this responsibility frequently falls short. OSCAR, a digital decision support platform initiated by KfW and funded by BMZ, enables the study of huge datasets for emergency preparedness and response. When faced with an emergency, OSCAR offers better coordinated and more effective assistance. Furthermore, it has significant promise for routine health planning activities.

OSCAR has been deployed in Nepal. The platform gives the administration an up-to-date snapshot of case counts and, shortly, available health capacities. How many free beds are there, and where? Is there a sufficient number of doctors in the area where a COVID-19 cluster has just formed? Is there an issue with ventilators? The platform will eventually offer forecasting capabilities based on mathematical models and AI/ML. This allows Nepal to make the best use of its limited personnel and financial resources in the health sector.

Moreover, the initiative is investigating a model-based warning system for outbreaks: If there is an abnormal number of cases, the ministry should be automatically notified and get an estimation where and what to be expected in the coming weeks, so that it can prepare and execute a proper response.

The OSCAR initiative is creating a digital global public good. As a result, it will also launch an open source community to assist it continuously enhancing the platform. The prototype is not restricted to COVID-19, but can potentially provide beneficial services for other health crises and normal planning in the health sector with suitable changes. As a result, the platform may be integrated as a digital component into comprehensive KfW projects on pandemic prevention, which the BMZ is emphasising in its new BMZ 2030 plan.

PATH

PATH (formerly known as the Program for Appropriate Technology in Health, https://path.org/) is an international, nonprofit global health organization based in Seattle, with 1,600 employees in more than 70 countries around the world. PATH focuses on six platforms—vaccines, drugs, diagnostics, devices, system, and service innovations—to develop innovations and implement solutions that save lives and improve health.

Since 2000, PATH expanded from about 300 employees and an annual budget of $60 million to, in 2020, a payroll of 1,600 people working in 70+ countries and a budget of $323 million. PATH is one of the largest nonprofit organizations in global health today.

PATH is best known for developing and adapting technologies, such as improved vaccination devices and new tools to prevent cervical cancer, to address the health needs in low- and middle-income countries. It specializes in developing, introducing, and scaling up solutions to the world's most pressing health challenges, in collaboration with funders, partner nonprofits, and the private sector.

UNITED AI ALLIANCE

The United AI Alliance is a public-private partnership that aims to reduce the Digital Divide in underserved communities and enhance data research and reporting for key initiatives, such as Census Data, Climate Science, and Healthcare.

The alliance is led by the United Nations (UN) Economic Commission for Africa, the Global Partnership for Sustainable Development Data, and NVIDIA, the company that invented the GPU in 1999 and is pioneering today's most significant advancements in the fields of Artificial Intelligence (AI), Data Science, Gaming, and High-Performance Computing (HPC).

The goal of this project is to empower national statistical offices in developing nations by providing them with access to AI technology, data science training programs, and ecosystem support. By strengthening these organizations, the quality and accuracy of data collected on important topics such as population censuses, economic policymaking, healthcare delivery, and more can be improved.

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