AI for better health

A report on the present situation for competitive Swedish AI in the life sciences sector

Marcus Österberg and Lars Lindsköld

AI for better health

A report on the present situation for competitive Swedish AI in the life sciences sector

A lot is happening in artificial intelligence (AI). So far, not much of it has found its way into health and medical services, but this doesn't mean there's a lack of interest in future issues, only that it's too early to evaluate a possible breakthrough for contemporary interest in AI.

AI for better health should be seen from several different parallel time perspectives.

- **Yesterday's AI** for medical imaging and other expert systems, which has been in use for quite some time.
- **Today's AI**, which is held back by regulatory uncertainties and legislation that hinders progress and which appears to put protection of an individual's privacy above the individual's health.
- **Tomorrow's more general AI**, which can behave like a human, understand and process human speech, and probably a lot more. Such an advance is probably not very far off if we can eliminate today's challenges.

Our clinical quality registers and personal ID numbers are often mentioned as being among our strengths, but if Sweden is not to lag behind it must get to grips with a number of things in addition to the rules and regulations. We need to work with digital sustainability issues, become even more digitally mature and not just focus on AI research, but rather make sure that AI gets implemented. We must also share our data, resources and outcomes. Not until then can Sweden find its niche in AI for better health.

Summary

A lot is going on in the field of AI, but almost all of it is a long way from being used to achieve better health.

> "The paradox: how can we claim on the one hand that AI is at least as good as human experts, while on the other it doesn't even seem to be useful today?"
>
> Claes Lundström during the seminar 'How can AI move from vision to real patient benefit?' (Almedalen 2019)

This is because although a lot of research is going on in AI, there is so far very little that can be applied in health and medical services, social care or pharmaceuticals. This does not mean things do not look hopeful, but only that it's too early to evaluate the true impact AI technology might have. If we take it to its logical extreme, AI is nothing other than digitalisation.

Fields that can be analysed visually can ride the current AI wave. This is in part due to AI deep learning technology and its already well-advanced image classification abilities. Perhaps we should look for projects in this field to reduce the risk of failed initiatives. At the same time, following practice means a greater risk of exposure to competition. How we choose also depends on where our organisation is on the road to greater digital maturity.

The use of AI to achieve better health must be seen from several parallel time perspectives: yesterday's AI (already done and dusted); the regulatory challenges that prevent implementation today, and if developments are favourable, the AI of the future a few years hence.

- **Yesterday's AI:** Image diagnostics, optical character recognition (OCR) and robot-assisted surgery are examples of older forms of AI already in production.
- **Today's regulatory challenges and uncertainties:** For example, the Swedish Patient Data Act (PDL) does not allow a general overview of the patient, the General Data Protection Regulation

(GDPR) prevents profiling and automatic decision making, while the Medical Device Regulations (MDR) effective from the summer of 2021 place strict demands on medical device software, i.e. AI in healthcare.

- **Tomorrow's AI:** What can we do moving forward given that today's concerns are dispelled? We can try to benefit from today's newer AI and what its hype consists of, i.e. deep learning, and processing natural language, unlike the AI expert systems that are already in production today.

Sweden's advantages

Sweden (and to some extent our neighbouring countries) has the following capabilities:

- Our personal ID numbers guarantee unique identities, enabling us to cross-reference our data sources and keep them better organised.
- Our long tradition of recording statistics gives us competitive advantages in a data-driven society. Typical examples are our clinical quality registers[1] and the fact that our health and medical services registries date back a very long time.
- Sweden is often recognised in international comparisons for its innovative approach and for having a population that is not afraid to use digital technology.

Sweden's disadvantages

The many regulations, widely accepted by the population, that protect and sometimes prohibit things, are a disadvantage. The report ***Förbjuden framtid? [Forbidden future]*** is perfectly clear about the problems municipalities have with digitisation. The same also applies to the regions. Among other things, the report states:

> "… that today, we're not allowed to use data to handle compound complex problems with methods that involve information transfer across privacy boundaries as the objectives development, decision support and prevention do not have any regulations to breach confidentiality.
> Of course, there are many digitising measures that can be implemented with great potential, but they generally only concern impersonal data or data in their respective privacy areas."

– Förbjuden framtid?[2] (Institute for Futures Studies, 2017)

The three largest regions of the country have also jointly raised this issue, including this contribution to the debate made in June 2019:

"Technological development offers great opportunities for us in the regions to create better, more coordinated care. We want to make use of such advances by introducing new health information systems. However, for this to be possible we need legislation that helps us develop healthcare."

– Johnny Magnusson, chairman of the VGR Regional Council, et al[3] (Dagens Samhälle [periodical], June 2019)

In other words, we're missing out on the great potential of **precision medicine (precision health)** or **hyper-personalisation** as it's sometimes called in AI, due to legislation that appears to protect the privacy of individuals more than it does their health.

Important actions

To take advantage of AI technology, there are a number of major challenges we must tackle, namely:

- **Rules and regulations.** How should GDPR be applied in practice? How can medical regulations be a help and not an obstacle? Should we have a national or European cloud infrastructure in support, and when may we use cloud services belonging to European companies?
- **Sustainability.** How can we apply AI responsibly and transparently? How reliable are AI solutions over time?
- **Digital maturity.** Are employees and citizens ready to let their lives be governed by algorithms they probably cannot understand? How do we bring specialists together with people who understand AI technology, or should domain experts learn more about AI?
- **Research -> innovation -> implementation.** How should we evaluate the results of AI research? The findings must be refined through an innovation process for the coming implementation. Today, things remain skewed in favour of research and there is very little implementation.
- **Sharing data, resources and results.** Sweden needs to share the resources we have, establish models that can be used by more people in more fields, and collaborate on data to a greater extent.

Table of Contents

Introduction

Artificial intelligence (AI) is a prerequisite for the health and medical services of the future. AI is a success factor, particularly in prevention and early detection. The strategic and systematic use of health data will help us stay healthy longer and detect and address risks earlier. All this may make healthcare and social care more effective, and hopefully also cheaper.

The amount of data on an individual's health status is growing rapidly. This may include the information that the patient provides during a healthcare visit, e.g. all the data provided by a routine blood sample, as well as data that the individual generates, e.g. through health apps and various sensors. All data about an individual that has a bearing on well-being can be called systematic health data.

Properly used, available systematic health data could offer health and medical services individually tailored to each of us. Unfortunately, the work of healthcare and regulatory authorities is lagging behind, which means we're unable to make full use of our systematic health data. This is something Swelife has worked with through the SWEPER project, in which we reviewed legal, regulatory and semantic obstacles to our making better use of data, and over the long term to better public health and a flourishing life science sector in Sweden.

Things are getting urgent. In Sweden, we can enjoy a competitive advantage if we quickly address the questions concerning AI technology and systematic health data associated with individual privacy and ethical issues regarding the use of data from different informational standpoints. The competitive advantage can be applied to create innovative companies, new jobs and better health and medical services in Sweden, etc. SEK 140 billion per year is a figure that clearly shows the economic potential of AI in Swedish public administration alone, according to the Agency for Digital Government's interim report[4] **Promoting the public administration's ability to use AI** (2020).

Compared to many other markets, we enjoy major advantages such as personal ID numbers and universal health and medical services.

But to leverage the full potential of future AI investments, we must invest in structural changes. The changes may not be as ingenious as chess-playing computers, or diagnoses performed by intelligent machines, but they are essential if we are to make the best use of the opportunities artificial intelligence has to offer. We must also think globally from the outset and create international links through which to work according to international standards, codes and regulations that enable us to share data and results across borders, and ensure that such data is readable, and also intelligible to machines.

It's not only important for Sweden to become a health data provider, but also for it to build up and retain the skills to process data. One way could be to pair up our health data with organisations and companies that can contribute with innovation. This would create value both for the individual and society as a whole.

About the report

Swelife seeks to strengthen its strategic AI efforts through a number of different initiatives. This will involve e.g. a situation analysis focusing on AI from a health perspective, including a gap analysis prior to future prioritisations and investments.

This data will be used internally by Swelife and contribute to the projects we support. However, the report is available to the public and can therefore form the basis for discussions on strategic initiatives in the field of AI with a focus on health, upon which other organisations and institutions can build. This report has a CC0 license that permits reuse[5], except for the borrowed images to which we do not own copyright.

Feverish activity in the field of AI, but…

There is a great deal of international AI activity aimed at achieving better health. However, much of this activity is a long way from implementation. If we measure this using technical yardsticks, we find a great deal of activity in the lower level of the TRL scale[6] **(Technical Readiness Level)**. This means a low degree of maturity and high technological risk.

On the other hand, if we look at the initiatives from an innovation standpoint, they are probably beneficial, but not yet useful. A Korean research report took stock of promising studies in radiology and found that not even the smallest fraction of them had been validated against

anything approaching clinical reality. This is discussed in more detail later in this report.

Alongside today's promising AI, there is an older generation of AI systems (expert systems) that has been in use a long time, at least in the healthcare sector.

Many people are busy doing things with AI to improve health. But what is being talked about, i.e. the news spreading around the world, differs from the things that change people's health in reality. It's easy to find lots of sensational, inspiring solutions. But not much is said about the things that make it all the way to implementation and actually benefit people. This is not due to a lack of good examples, but rather because AI seems to be regarded as something that belongs to tomorrow and not something to look at in the here and now. Or as John McCarthy, one of the pioneers in the field of AI, said explaining the so-called AI effect[7]:

> "As soon as it works, no one calls it AI any more."
> – John McCarthy

There's no lack of challenges. They differ and include access to appropriate data sources and regulations such as the US HIPAA, the EU General Data Protection Regulation (GDPR), and the medical device regulation that classifies software as medical devices. The latter highlights the challenge posed by transparency, reliability and ethics to achieving good health regardless of origin or individual characteristics.

There are signs that a so-called AI winter is imminent. A period of productivity during which there is no hype, which is how hype charts predict the development of all innovative technologies over time. At the same time, not a great many of the people who work with healthcare, health or medical treatment on a daily basis have truly taken on board what AI has to offer. Hopefully, these specialists, together with experts in AI technologies, will join forces to turn the ideas into viable solutions.

Definition of life sciences and AI in this report

Were we to be all-inclusive, then life sciences would be those that concern everything living. However, it would not be useful in this context even though the use of AI technology in reindeer husbandry and food processing naturally has an impact on human beings. These matters are omitted from this report.

Life sciences include a relatively long list of branches that do not really fall within the remit of this report. They include e.g. zoology and botany. Research!Sweden [Forska!Sverige] is a foundation that defines life sciences in a way that suits the purposes of this report [8]:

> "[…] primarily medical research and its applications aimed at generating medical progress, industrial development and better health."

Furthermore, Swelife has its origins in common endemic human diseases. So this report excludes:

- Livestock and food.
- General biology, zoology, botany, etc.
- Alternative medicine, complementary medicine.

At a minimum, the following is included:

- Genetics and other ***omics**[9].
- Drugs, their research and development.
- Medical technology, especially software that can be used in advanced decision support, medical imaging, and more.
- Social care, regardless of whether it's carried out by local authorities or other operators.
- Primary and inpatient care paid for and often carried out by regions and municipalities.
- Nationwide highly specialised care.
- Self-care. I.e., everything that supports people who work with their own healthcare or that of others.
- Other things that benefit the health of individuals.

In the context of this report, life sciences are restricted to things that promote human health; how people are kept healthy, their risk factors managed and attempts made to cure illnesses. This might be self-care, drugs, healthcare, medical treatment and social care, for example. In other words, there is a variety of operators that influence how AI can contribute to better health.

Definition of AI

Definitions of AI are usually linked to imitations in human intelligence, a person's abilities, drives or senses.

Unfortunately, AI does not have a single commonly accepted definition. This may be partly due to the hype cycle we are in. A report in Swedish by the National Board of Health and Welfare entitled ***Digital***

Health Services and Artificial Intelligence in Health and Medical Services,[10] (October 2019) defines AI. To be included, an AI system must perform a task relatively autonomously based on the information it receives, and/or which it learns over time to improve its ability to perform its task[a].

It would not make sense to adopt the most inclusive interpretation of AI as a concept, but in order for the reader to understand where the baseline is regarding AI in this particular report, it best to be clear. Excluded are things that others with research assignments in AI have sometimes chosen to include, such as:

- RPA[11] (**Robotised Process Automation**), ordinary software and more commonplace automation[12] or integration.
- Classic analytics tools.
- Big data, Business Intelligence[13], data mining[14] and ETL[15] (**Extract Transform Load**).

Included are:

- Advanced analytics tools using concepts from machine learning or other AI techniques.
- Expert systems, and other forms of GOFAI[16] (**Good Old-Fashioned AI**) from the 20th century.
- Machine-learning, deep learning and suchlike.
- Natural language, i.e. human languages (NLP - Natural Language Processing).
- Computer vision (or the form of visual diagnostics conducted in radiology, pathology, etc. in life sciences).
- Other techniques such as robotics, medical olfaction, digital twins, and more.

For the sake of simplicity, items included are referred to as "AI technologies" in this report. The abbreviation AI refers to the same thing.

In contrast to [an interpreted version of] the National Board of Health and Welfare's definition, lower standards could possibly be used concerning how autonomous, self learning or self improving an AI technology should be. The relatively sophisticated expert systems in healthcare are included. However, it's not easy to get sufficient details to truly know which components are used in each individual solution.

Precisely what is meant by autonomous, self-learning or self-improvement is a separate discussion. But in a nutshell, today's AI is:

---

a Page 45, the National Board of Health report

- **Autonomous** within very limited boundaries.
- **Self-learning** in that the machine learning algorithms have the ability to solve a task by extracting information in a (more or less) autonomous way. The outcome can be used e.g. to provide answers to specific questions.
- **Self-improvement** applies to certain AI systems to the extent that they refine their algorithms based on new data to which they are exposed, so called **online learning**[17]. Which is the whole point of AI exploring different possible solutions in **reinforcement learning**.

We should not expect an AI technology that successfully classifies skin diseases to begin excelling in psychiatry of its own accord. Then our expectations would probably be in vain. What's more, self-improvement is a process that needs to be checked, making it easier to release improvements only as and when their results are shown to be improvements.

"Healthcare is an information industry that continues to think it is a biological industry"
– Laurence McMahon[b] (2016)

Fields of application for AI

There is no self-evident consensus about which sub-technologies are included in AI. What one investigation regards as AI may be excluded by another. Unfortunately, differences make it difficult to fully benefit from each other's work.

If we group AI technologies according to how they compare with human intelligence, we arrive at e.g:

- The ability to learn by observing examples (machine learning).
- Seeing, hearing, and interpreting visual or audible impressions (computer vision, artificial hearing).
- Optimisation and improvement (artificial curiosity and reinforcement learning).
- The art of moving and doing things in the physical world (robotics, prostheses).
- Communicating, interpreting and interacting with the world (natural language - NLP, face recognition, interpreting bodily

b According to the book Artificial Intelligence in Medicine, ISBN: 9783030216429

expressions).

- Predicting the future and scenario planning (autonomous multi-agent systems).

However, the concept of intelligence is not as obvious as we might at first believe. Peter Gärdenfors, Professor of Cognitive Science in Lund, on intelligence and the measurement of intelligence in non-human beings, such as animals:

> "The only response is that intelligence is not a general concept. We should instead talk about problem-solving abilities. We humans can handle many practical problems; we're extremely flexible, and have succeeded in populating every corner of the planet. For me, this is a sign of intelligence. On the other hand, all animals have their ways of solving problems. Take orangutans, who are fantastic climbers, or bats with their spatial awareness; both have special abilities that we could never hope to achieve. So what does it take for a robot to be intelligent?"
> – Can we create intelligence?[18] (Forskning och Framsteg, 2015)

An ability to solve more or less well-defined problems and to find answers to specific questions is to some extent precisely what machines do have. Then it might try to win in a game with an unreasonable number of combinations of pieces. Or determine whether something on an image is a bone fracture.

But there are naturally critics of an inclusive approach to the concept of intelligence when it comes to machines. John Searle, professor of philosophy at Berkeley, believes that:

> "A machine cannot be intelligent, as intelligence presupposes awareness. And a computer is not aware. Siri, like all computers, does not understand the meaning of what you say, nor does she understand her own responses. A computer only manipulates symbols without understanding their meaning."
> – Can we create intelligence?[19] (Forskning och Framsteg, 2015)

However, this report is satisfied that AI technologies are capable of solving problems and answering to questions, the solutions to which are not entirely obvious, and which the AI technology succeeds in enhancing or complementing the user's intelligence.

Another way of breaking down AI has been suggested by analytics company **Cognilytica**[20]. It's an interesting way of grouping the use of AI technologies that seems to work pretty well, even though some

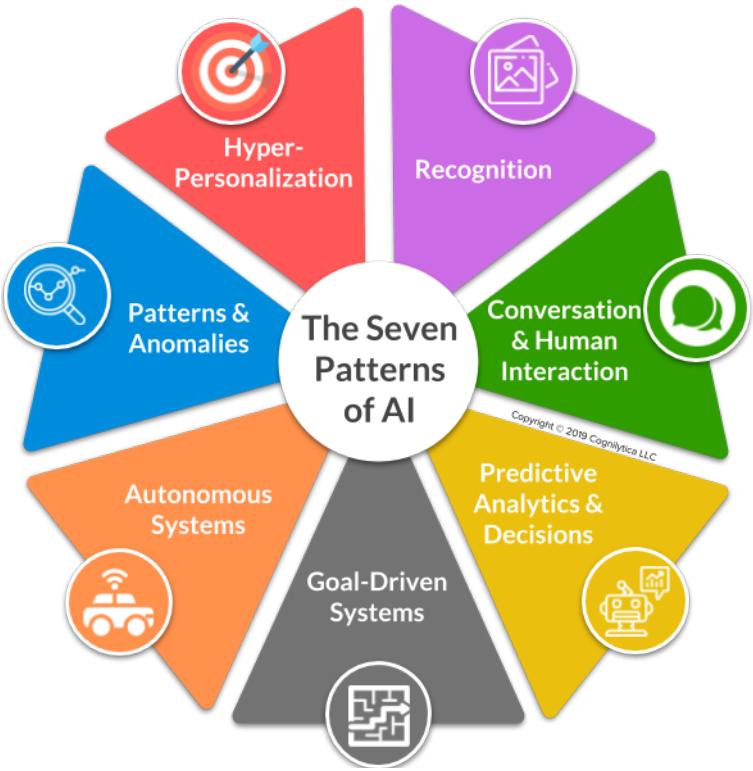

Figure 1: Seven common features for grouping AI (Cognilytica, April 2019)

solutions fall into more than one group:

1. **Hyper-personalisation**, which in life science is virtually equivalent to **precision medicine**. There is sufficient information to move from group level to adapting for individuals, perhaps "precision health" in the long-term, which is based on the individual's prospects for maintaining good health.
2. **Autonomous systems**, such as the relatively autonomous drones tested for the transport of e.g. samples. These have been tested in sparsely populated areas in Region Västerbotten and at Sahlgrenska University Hospital in Gothenburg. The term 'autonomous' is however complicated as many levels of independence apply to such things/systems.
3. **Predictive analytics and decisions**, e.g medical decision support, predicting the time needed for patient care, or the risk of

something. Then there is a wealth of solutions aimed directly at individuals, rather than through a caregiver.

4. **Conversation and human interaction**, like dental care in the Västerbotten receptionbot Aida[21] – but you are bound to have heard about chatbots in other contexts or spoken to such systems over the phone. All forms of interaction count, including text to speech, speech to text, various kinds of language translation and so on and so forth.

5. **Patterns and anomalies**, which includes the analysis of genes and medical digital twins for comparing individuals with each other, which can be incredibly useful for e.g. unusual diagnoses. But in general, perhaps the largest group here includes everything that machine learning can do using different datasets, such as different forms of groupings and time series analyses etc.

6. **Recognition**, as in identifying which pills to take with which meals on behalf of a visually impaired person. The general ability to identify and describe things such as various kinds of aids. Large overlap with group 4.

7. **Goal-driven systems**, in healthcare contexts they might concern motivating an individual to take his medication or carry out a physical activity, but in general it means influencing or controlling a system to e.g. win a game of chess.

There are a number of ways of grouping what is included under the term AI. AI and machine-learning are often referred to in the same breath. Probably because it's usually machine-learning we're referring to, sometimes more specifically deep learning, but we've already touched on examples of AI where machine-learning is not at all necessary, such as expert systems from an earlier wave of AI technology.

The definition of machine learning is **"the ability to learn without having been explicitly programmed"** which corresponds to most of the AI mentioned since 2012 when deep learning began its breakthrough[22]. Deep learning[23] is a sub-area of machine learning and takes advantage of **artificial neural network** (ANN) technology[24]. ANN seeks to mimic the function of a brain.

Part 1: National stock-take of what AI for life sciences entail

Method for gathering impressions

The stock-take took place during much of 2019. In order not to bog down in a specific location, we took samples from north to south, and we also reached out actively to different groups of people, with different roles. They included directors, academics, researchers, IT project managers, doctors, developers, and salespeople. The organisations they worked for were regions, small medical start-ups, science parks, innovation offices and some in the major IT companies, to give but a few examples.

The cities we made stops in were Umeå, Skövde, Stockholm, Malmö and Lund before finishing in Linköping in October. We interviewed more than 30 people in situ during the trips, with additional interviews by telephone.

The interviews were supplemented by internet surveys, where interviewees were able to respond themselves by filling in a form. Some dialogues were also held with e-patients or lead patients[a], representative self care patients and the disabled etc.

Most of those interviewed or who completed the internet questionnaire describe themselves as novices in the field of AI, but that they are becoming acquainted with it either through their expertise in healthcare, as business developers or earlier involvement in an adjacent technical area.

a A particularly knowledgeable individual with great insight and expertise about their own chronic disease

The respondents were fairly evenly distributed by gender and several have foreign backgrounds.

Questionnaire

The wording of the questions resulted from discussions on Twitter and internal social media for Region Västra Götaland. The following standard questions formed the basis of the calls; however, not all of them were relevant to every call:

- Tell us a little about the AI projects you're involved in or know about.
- Where did you get your inspiration?
- Which AI technologies did you use?
- What sort of tasks is AI trying to solve?
- In your opinion, what were, or are, the challenges?
- Do you lack any kind of support to help make things easier?
- Are you lacking the right skills?
- What data do you intend to use for your AI technology?
- What are your driving forces? (personal, own initiative, clients, efficiency, increased precision etc.)
- Which members of the community does the data represent, and how will you make sure that AI technology does not give preferential trealtmed to one social group and being unfavourable to another? If that is the point, why?
- How will AI technology strengthen democracy in society?
- What effects did you achieve; were metrics measured before and after?
- Any other thoughts?

Plus, time permitting:

- What will each AI application replace? I'm thinking (in simple terms) of a new solution in, an old solution out… Or?
- How will your business model work when you're (presumably) working more data driven?
- Are you reviewing any ethical problems that may arise from the outcomes?
- Would you consider sharing data, outcomes and findings as open-source information?
- Have you considered the environmental aspect of how to make your operations more efficient or which supplier(s) to use?

As previously mentioned, there was also an opportunity to respond to a questionnaire on the internet.

1. Tell us a little about the AI projects you're involved in or know about.

The just under 100 projects discussed were overwhelmingly about either machine learning for some form of decision support, or computer vision for diagnostics. Some make use of natural language, which not only included chatbots for the collection of patient records, but also diagnostics by analysing the content of communications.

Naturally, there is a great difference in how far various projects have progressed. Some are located under established arenas such as AIDA in Linköping, while others are start-ups. Some build on proven applications of AI technologies while others have a more research oriented approach.

Efforts also cover the entire span from the ambition to optimise personnel manning levels in hospitals by forecasting how long a patient can be expected to remain, to fixing major problems such as having far too few specialists in certain areas.

Sometimes the AI user is a patient, sometimes an employee, but it might also concern some form of continuous quality work.

2. Where did you get your inspiration?

There are a number of cultural influences regarding where their inspiration came from. It was a pretty safe bet that the Terminator films would get a mention, but documentary films about technology are also referred to.

However, the most usual answer was that respondents had observed everyday problems or challenges and had begun to be solution oriented. Their day-to-day world could be anything from the reception at a clinic, a specialist healthcare field or a group of people whose health the personnel were focusing on.

Examples of specific groups addressed are the hard-of-hearing, deaf and deaf blind with whom the goal was to hold discussions without a human go-between.

The fact that Sweden already lacks certain specialists and will in future also lack personnel, was mentioned a few times. One person said more or less that they already had the challenges up there in Norrland that other people in Sweden are worrying will soon happen to them. This had led them to look for innovative solutions to personnel shortfalls or to allow personnel to avoid things a machine can do instead.

3. Which AI technologies did you use?

Of course, discussing which AI technologies people have used can get a little complicated when there's no agreed, clear definition of AI. Before each interview, we made it clear that for the purposes of the conversation, AI could be interpreted very openly and broadly.

Bayesian networks[b], survival models, artificial neural networks through deep learning, natural language, computer vision and of course machine learning, were all mentioned.

Swedish examples of social robotics were absent. Surprisingly, none of the interviewees gave examples of borderline automation such as software robots like RPA, as this is sometimes included in AI as a concept.

4. What sort of tasks or problems is AI trying to solve?

Projects often concern relieving the workload for healthcare personnel so they can focus on the tasks where they are really needed. For example, calculating the probability of survival is unlikely to be a task that attracts people to work in healthcare; a machine can do that on behalf of humans.

Most of the initiatives are aimed at helping to make decisions based on data. This not only applies to both general machine learning and computer vision, but also to removing intermediaries for privacy reasons; interpreters in certain situations; modifying reception desk procedures or the ability to provide answers to simpler questions around the clock.

5. In your opinion, what were, or are, the challenges?

It was perhaps a little surprising that no one mentioned a lack of computing power or technical infrastructure. Rather, they talked about data-related difficulties, such as having too little of it or the quality of what they do have being too poor. Or that GDPR and the medical device regulations for software is challenging.

They also mention identifying the appropriate end-user needs and getting projects implemented. And that sometimes there is too little know-how and trust.

6. Do you lack any kind of support to help make things easier?

A recurring comment was 'just give us the time and money' and you'll get good returns. Also common were concerns about the exis-

b A model for calculating probability

ting IT infrastructure; that this makes implementation difficult, and that IT support personnel would rather act as obstacles than provide solutions or come up with suggestions.

On the subject of data, some people called for annotated datasets, which can be interpreted as someone else having already annotated the type of data they need.

One person called for a national resolution making AI work mandatory.

7. Are you lacking the right skills?

Someone wanted help with service design but could find none. Someone else felt that it was much too expensive to engage consultants and that the organisation should have its own in-house AI skills, or even more personal skills than they currently have.

There was more usually a lack of sufficient AI skills in the small organisations, but this is probably due to their size.

8. What data do you intend to use for your AI technology?

The groupings around the specific data of interest differ. When it comes to machine learning, clinical quality registers, local registers and medical records are often mentioned. Not all of this information necessarily includes personal data. Among other things, logistics data about visits to the health service is mentioned, as is information about how much care is produced broken down to a detailed level.

Computer vision often concerns lab sample diagnostics, radiology, pathology or skin conditions.

In the case of natural language technology, manuals, question-and-answer texts and open data are mentioned.

9. What are your driving forces? (personal, own initiative, clients, efficiency, increased precision etc.)

The responses to this question soon became very emotional and with clear empathy and great understanding for the frustration of patients, and an ambition to bring about change for the better. Or to improve opportunities for disabled people to participate in society.

One focus was on real needs – eliminating nonsense work, reducing missed appointments, improving access to healthcare, e.g. by virtually staying open round-the-clock.

10. Which members of the community does the data represent, and how will you make sure that AI technology does not disadvantage any group in society?

How to make sure that AI technology does not disadvantage any group was clearly an uncomfortable question to answer. That is surely due to the nature of the question. But most people have some kind of thoughts on how to get feedback, e.g. by budgeting to involve e-patients, as well as patients with unconventional points of view and ethnic diversity.

In some cases, the question was not such a burning issue according to the respondent. For example, because a solution only concerned a single sub-group such as people with a specific chronic diagnosis, they sometimes had to create balance by including both healthy volunteers and the sick in their collected data.

Some respondents replied straight out that they could not answer the question or that they would have preferred to work more with representation than they did.

11. In general, how will AI technology strengthen democracy in society?

A minority believed that AI technology would strengthen democracy. However, most people who answered in the negative or expressed doubt, gave very short answers. Some were confident that in the long term things will turn out well. For example, a very few privileged institutions and people control much of the data that is important to AI.

One person expressed it in this rather ominous fashion:

> ''To make matters worse, it's primarily countries that have dubious approaches to privacy and data security that are leading the ML/AI race. If anything, AI will (in the short term) lead to less democracy as surveillance using facial recognition will mean fewer people bold enough to protest for fear of retaliation. The same applies to freedom of expression as tracking plus ML is able to piece together information and identify people based on social media and apps. In the long term, when the technology is in the hands of the public and our grandchildren (30 years hence) are able to make counter demands of their data and control and develop AI, we will see a strengthened, more transparent democracy thanks to AI.''

The above is probably not an outlook that focuses primarily on Sweden, even though in some cases we've been ready to propose

more invasions of privacy than other EU countries. After all, Sweden's Data Retention Act[25] was struck down by the European Court of Justice. It has been a series of events in which the Swedish government considered the Swedish act to be correct, despite the European Court of Justice having ruled it invalid and incompatible with EU law. Sweden played a prominent part[26] in the drafting of the EU directive, which then became Swedish law.

Some of the positive respondents pointed out that AI, like other technologies, can work inclusively and improve opportunities for people to participate in society.

12. What effects did you achieve; were metrics measured before and after?

Most replied that they had not come far enough to evaluate things, that the work was more like a preliminary study and that there were still no solutions on the market, or similar.

The people who gave the clearest answers to the question did so from a more academic angle, as though they were releasing an article with their findings. What these respondents provided was more a form of knowledge rather than something to be implemented soon.

However, many clearly understood which metrics were of interest in measuring effects: length of sick leave, job satisfaction among doctors, productivity indicators and so forth.

13. What will the AI application replace; will you replace an old solution with a new one?

It's not always easy for a "system" consisting of AI to replace another system, as it's rather a kind of supplement. Such as supporting doctors in their assessments of high-risk patients, assisting with diagnoses, prescribing drugs, internal business planning and helping with decision-making in general.

However, AI will not supplement personnel in the few mentioned cases where it has the potential to completely replace manual work, or in contexts where it may be desirable for the patient not to have a human as an extra go-between.

14. How will your business model look when your (presumably) work is more data driven?

At this point, it's worth reminding you of the broad range of people interviewed. People on the front line in a hospital organisation and those further away from the reality of healthcare may have different

ideas about the 'business model' concept. The same goes for academics versus private start-ups versus the public sector.

Having said that, very few people gave especially exhaustive or good answers to this question. The clearest answers were from start-ups and companies already active in the health sector. Start-ups sometimes told a quick version of the headings from an apparently well-rehearsed **Business Model Canvas**[27]. The more established companies spoke in similar terms and sometimes mentioned an interest in spin-offs if the experiment succeeds commercially.

15. Are you reviewing any ethical problems that may arise from the outcomes?

Yet another question with a stigma. Many responded that they had been working with this. Sometimes there were examples of measures such as data anonymisation, constant monitoring or the existence of controls that prevent the occurrence of problems even though users contribute data.

16. Will you share data, outcomes and other findings as open-source?

Not everyone had this question worded in precisely the same way. The respondents interviewed in situ were sometimes asked whether the outcomes will be released and be free for others to use. It's unclear what this means precisely for each and everyone of the respondents.

Some intend to release outcomes in the form of various kinds of publication, others will release them completely free 'as it was developed by state operators.' A few answered no, but that findings and results are things they intend to disseminate. This was an excellent answer for those processing personal data.

17. Have you considered AI's environmental or sustainability impact?

The answers to this question seem to fall into two different groups – those who thought about the learning itself "in the light" of an article published during the year that addressed the sometimes huge energy consumption, and also those who talked about the environment and sustainability in more general terms.

In fact, only three replied that they had considered this; one of them stated that they chose an existing AI model instead of training a new one, another that their neural network takes one minute to train with new data.

18. Any other thoughts?

Many of the reflections and issues were about data sources and opportunities for collaboration.

There is a demand for access to annotated data sources, not just healthcare information, and that it needs to be easier to get hold of. There is a need for a catalogue of useful data sources, and is that what is meant by a data factory at AI Innovation of Sweden?

Questions about how we can work together more in Sweden, sharing the resources we are all short of. The law is given as an example of where resources are lacking and collaboration required. As the interviewer, I was often asked if I had tips on who to turn to, and usually the answer was about business developers as an entry to our Swedish science parks.

Taking stock of AI projects in Sweden

Problematising the stock-take

There are a number of problems when taking stock of everything that is lumped together as a technology under AI, the biggest being that there is no single established definition of AI, but in fact several.

The initiatives that are easy to find today are almost exclusively in the field of machine learning or natural language technology applied in the form of chatbots. Computer vision technologies such as AI medical imaging were mentioned a little less often. The same applies to robotics, more specifically social robotics, or artificial smell and touch.

Another complicating factor is not knowing precisely what AI contributes and the role it plays. The things we often encounter known as AI are usually some form of software as a service, e.g. an interactive decision tree for our own triage purposes. So perhaps using AI technology to create more static knowledge is not very exciting to communicate, when the only thing AI does is to create a result rather than ***be*** the result or the service.

Typical projects and AI technology centres

The attempt to put together a good list of national or major AI initiatives, really became a typical example of 'high and low' partly because almost everyone appears to have carried out tests projects and preliminary studies etc. to varying degrees. These can be anything

from having applied a boundary case between business intelligence technology[28] and machine-learning from a data source, and having learned something, to being a meeting place for computer vision in radiological AI technology. Another complicating dimension is where something is on the scale between basic research and already in use.

But it is still interesting to highlight some major examples and AI technology centres.

Linköping & Norrköping: AIDA (Analytic Imaging Diagnostic Arena), CMIV and Visual Sweden

Linköping University's AIDA is supported by, among others, Swelife's sister organisation Medtech4Health and Vinnova:

> "AIDA is a national arena for research and innovation in artificial intelligence, AI, for medical analytic imaging."
> – AIDA (Analytic Imaging Diagnostic Arena) at Linköping University[29]

Linköping is also home to CMIV (Centre for Medical Imaging and Visualisation), Visual Sweden in nearby Norrköping and the region's smart specialisation is simulation and visualisation. More about smart specialisation later.

Work is also being carried out on projects such as medical digital twin (MeDigIT):

> "[…] facilitating the use in healthcare of digital models specific to individuals for better diagnostics, more personalised treatment of disease, and simplified, improved training of healthcare professionals."
> – Medical Digital Twin (MeDigIT)[30]

Gothenburg: AI Innovation of Sweden, Scapis, PreSISe, language data lab and Chalmers AI Research Centre (CHAIR), etc.

The first node of AI Innovation of Sweden[31] opened in the spring of 2019 at Lindholmen in Gothenburg, followed by Stockholm, Malmö, Lund and other cities. In addition to shared office space, there are a number of goals, one of which is to build a data factory. And life sciences are represented in that the Scapis data set will be coming to the data factory. Scapis[32] is a globally unique study that has monitored and collected data from 30,000 people with the goal of preventing cardiovascular disease.

Work with PreSISe is carried out in PICTA (also at Lindholmen):

"PreSISe is a long-term project for the development and evaluation of AI-based decision support for assessing the risk of prehospital sepsis."
– PreSISe = Prehospital Decision Support for the Identification of Sepsis Risk[33]

The language data lab will be located in the aforementioned data factory, but it remains to be seen whether any of the domain-specific texts will be about health or healthcare. Nevertheless, the following purpose and goal were set out in the application to Vinnova:

"…develop a Swedish reference data sets and models for Natural Language Processing (NLP) and make them available via open access in AI Innovation of Sweden's data factory. The project will also include preliminary studies for further projects in domain-specific text and pre-trained models."
– Swedish Language Data lab[34]

The set-up states that **"the project also includes preliminary studies for the application of domain-specific text,"** so influence may be possible. The project coordinated by Sahlgrenska Science Park to establish a **Swedish medical language data lab**[35], is a similar initiative which enjoyed the support of Vinnova in December 2019. The University of Gothenburg's AI platform for medical data sets is another initiative from the same round of Vinnova support. The two initiatives will make access to training data and language models easier for AI R&D.

CHAIR[36] at Chalmers has an explicit focus on "**applied AI in life sciences and health**" as one of its five fields and has begun to deliver on that point. Chair will also collaborate with Sahlgrenska University Hospital:

"Chair and Sahlgrenska University Hospital have become strategic collaborative research on AI in healthcare. The hospital will be able to make use of the AI expertise possessed by Chalmers, while Chalmers can benefit from the University Hospital's medical expertise."
– Chalmers University Hospital and Sahlgrenska University Hospital in research collaboration on AI in healthcare[37] (September, 2019)

Also, the pharmaceutical company AstraZeneca has a local presence just south of Gothenburg. It's one of their R&D centres for drugs, with around 2,400 employees from over 50 countries. An interesting solution from Gothenburg by the company Appva, whereby healthcare professionals were relieved of an additional administrative burden

when complying with new regulations from the National Board of Health and Welfare, is typical of AI technology already implemented:

> "By using some of the 70 million digital e-signatures in MCSS, we trained an AI robot to identify and report healthcare quality classification codes to the National Board of Health and Welfare."
> – Appva[38] (December 2018)

Västerbotten: WASP-HS

WASP-HS is short for ***Wallenberg AI, Autonomous Systems and Software Program – Humanities & Society.***

Umeå University has recruited Virginia Dignum to strengthen its position in social AI, and in 2019, as host University, it was awarded money from the Wallenberg Foundation WASP to this end. Social/ethical AI is not necessarily related to the life sciences, but is guaranteed to be a valuable resource.

> "Among other things, we will be looking at methods and tools to make sure AI and autonomous systems are designed so as not to conflict with human values and ethical principles."
> – Virginia Dignum[39], conducts research into the societal, ethical and cultural consequences of AI

The benefits of AI technologies seen by interviewees in Umeå often revolved around the lack of people and resources for everything they wanted to do. Illustrative examples of what they were working on, such as a chatbot in the reception of the dental care test environment, were already in use in the real world. While in the southern half of Sweden we talk about a shortage of personnel and resources as future problems, they are already a reality in inland Norrland. In Umeå, there is also a need to optimise scheduling for the patient's sake, since journey times can be very long. Patients should not have to make one trip to give a blood sample and another one to get the result, and so forth.

In 'nearby' Skellefteå, they work with connected homes in collaboration with the strategic innovation programme IoT Sweden[40], for a more flexible home care.

Stockholm: I-AID, MedTechLabs and KTH

Karolinska University Hospital and Region Stockholm use I-AID as a tool for speeding up the introduction of AI into healthcare.

> "[…] to accelerate the development, and implementation, of AI in

healthcare based on healthcare and patient needs. The goal is safer, quicker diagnostics to make the best use of healthcare resources and to create more equal care."

– I-AID – regional joint effort to accelerate the introduction of AI in healthcare[41]

Another innovation in this context was Karolinska's open letter of referral for its AI procurement planned for the spring of 2019.

A list that mentioned every initiative with an AI component would of course be very long. But one of the more interesting is PATHFx[42], which is open source and of international interest as it's run against an international quality register for metastatic bone cancer. Another interesting initiative was conducted jointly with Region Dalarna, where Public Dental Care conducts screening for oral cancer[43]. It's similar to the method that has already proved successful for cervical cancer.

It will be an AI Innovation of Sweden node in Kista in 2020, but the H2 Health Hub[44] was already available for those seeking a meeting place for Nordic health technology.

MedTechLabs[45] is a new centre supported by e.g. the Royal Institute of Technology (KTH). KTH also has its own Life Science Technology platform.

"Life Science Technology is a multidisciplinary field, formed by the convergence of engineering, physics and mathematics. Several research groups at KTH are world leaders in their respective fields of expertise."

– KTH's Life Science Technology (LST)-platform[46]

Naturally, as the capital city and the place where a number of important agencies and key people are located, Stockholm enjoys many opportunities.

Summary of interviews in the Stockholm area

A small number of people were interviewed in the Stockholm area in the beginning of 2019. There included consultants, developers, product managers, project managers with a more or less large element of technical sales support. Features common to the assignments mentioned included the use of taxpayer money to finance the projects, and that solutions were aimed at raising the quality of health and medical services by becoming (yet) more data driven.

One of the participants spent a lot of time talking correlation[47] and causation[48] as there is a tendency also in the field of AI to act prema-

turely by applying something without actually understanding the cause (causality). The person concerned felt we should work more with causality, especially when something is important. The Stockholm AI Sustainability Center[49] was mentioned more than once.

Another of the interviewees worked with advanced analysis in the form of a product into which machine learning, natural language, computer vision and prediction functions had been integrated in recent years. One conclusion was that there actually is software that makes AI technology accessible to people who should not have to learn programming.

Skövde

Interestingly, the University of Skövde has a health education programme and experts in AI technology. It also possesses expertise on user experiences and games, which is relevant in a number of ways, especially in designing AI solutions to help them get put to use.

Examples of projects at the University of Skövde:

- **DMDPipe**[50] - Identifying and analysing pathogenic proteins.
- **Bio-mine** – diagnostic and prognostic methods to answer questions on e.g. how far a disease has progressed based on biomarkers.
- AI technique for analysing donated blood vessels, to avoid immune responses in recipients.

Joint projects with the automotive industry under way at the University may be of indirect benefit to health and medical services, such as the classification of gestures and attempts to interpret a person's intentions by his or her movements. They are also working with AstraZeneca to develop new drugs, using deep learning. The underlying theme of the discussions was to bring things a little closer to real-world application compared to other universities.

Skåne: HealthTech Nordic and AI-center

Medicon Village[51] is a life sciences park, where work also naturally concerns various AI technologies. It also has the **Smile**[52] incubator and the **HealthTech Nordic**[53] project that helps start-ups in health technology, even outside Skåne, e.g:

- **aiten**[54] - personal algorithms for people with hypertension.
- **Aweria**[55] - Decision support for pre-hospital and emergency care.
- **Boneprox**[56] - assesses risk of osteoporosis via dental X-rays.

Just to name three at the top of the alphabetical list.

If you were impressed by Google's Duplex solution during the i/0 developer conference in the spring of 2019, there are similar initiatives in Skåne. Tmeeting-TERA enables hearing impaired people to make regular phone calls and meet without going through a third party, such as an interpreter. The built-in AI interpreter uses speech-to-text and text-to-speech technology both in phone calls and in regular calls when the conversing parties are in the same place.

They also have at least one AI centre in progress. There will be at least one southern node in the AI Innovation of Sweden national initiative, and they told us shortly before Christmas 2019 that Sony will be the first major company to join[57]. Also, the City of Helsingborg presented[58] **Get AI** jointly with Lund University, an AI centre whose ambition is to join the government's AI Innovation of Sweden initiative.

Impressions from the interviews in Malmö and Lund

A number of doctors showed up at the meetings in southern Sweden. Other attendees were start-ups or established organisations with AI projects as prospective spin-offs. Many were in medical technology, others worked in combinations of health care and the academy. Some did machine learning from scratch while others used the frameworks on offer.

Also, an interesting side discussion cropped up in southern Sweden, namely that "AI is really only a more advanced form of analysis" and that the subject was broached with a dash of irritation concerning the concept, but also that very few say they are good at AI.

Halmstad University and Region Halland

Aiway[59] at the **Health Technology Centre in Halland** is an exciting mix between Region Halland and Halmstad University. During the spring interviews, the University was mentioned as a pioneering thinker in IT security, which is of course pertinent in this context. Due to their collaboration with American organisations, they are also studying distributed machine learning in order to comply with anticipated privacy protection.

AI technology centres and investments without a specific focus on life sciences

During the summer of 2019, Vinnova released a report concerning research and innovation environments that:

> "[…] have taken on the burden of leadership and which gather and coordinate the forces of development and skills necessary for the development of artificial intelligence. The environments differ in nature and consist of research and education, test beds, incubators, hubs, arenas and networks."
> – AI environments in Sweden[60] (Vinnova, July 2019)

There are a number of stand-outs in academia, research and education. Some have already been mentioned, such as KTH, Umeå University and Chalmers, but there are others such as the national organisations **AI Competence for Sweden**[61], which works nationwide with education and skills development within AI, and SAIS, **the Swedish AI Society**[62].

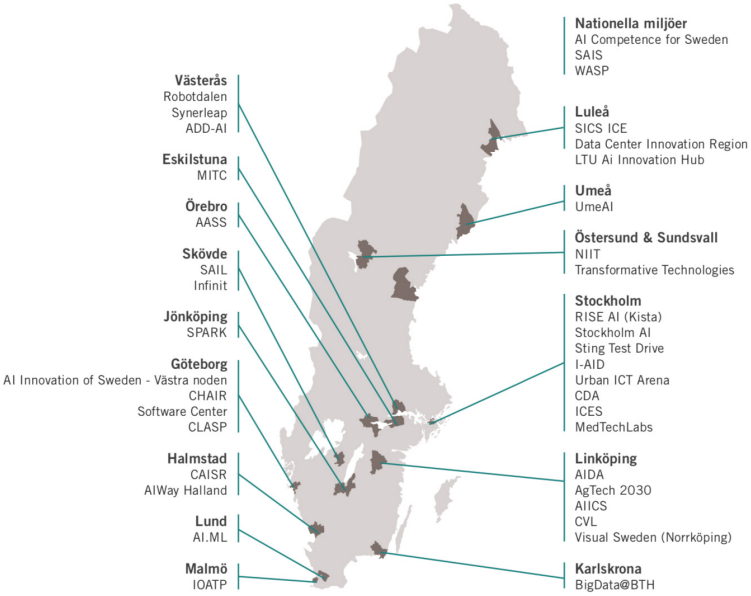

Figure 2: This map showing where AI is taking place in Sweden can be found in the above mentioned report from Vinnova.

The Wallenberg Foundation, WASP (**Wallenberg AI, Autonomous Systems and Software Program**), will invest SEK billions in AI in the years ahead, including humanistic and social science research in AI and autonomous systems - WASP-HS[63]. WASP-HS runs a post-graduate school with up to 70 PhD students. A major proportion of the money is awarded to Umeå University, which is also investing SEK 100 million in AI[64].

The Vinnova Innovation agency has of course held several tenders, e.g. for setting out companies and organisations on their AI journey and the use of natural language as a technique, etc.

The Vinnova report, AI environments in Sweden, has more details about each AI environment.

Part 2: International outlook

Introduction, purpose and method

Among other things, this section is based on the international outlook presented by the National Board of Health and Welfare in its report, **Digital Services and Artificial Intelligence in Health and Medical Services**, released in the autumn of 2019[65]. In view of the differences in the objectives of the reports, there are additional perspectives worth mentioning in this report. Also, because there are several existing studies and reports dealing with different parts of the subject, this section will make frequent references rather than present complete lists. There is more focus on nuances, current discourses and updates since each reference was written.

AI is described as the fourth industrial revolution and something we must soon, or perhaps already, seriously consider if we are to remain relevant. It's interesting to study the current situation in the light of our great expectations of this new phenomenon, and whether it can also be applied in life science as an industry to achieve better health.

The purpose of an international outlook is to note what others are doing and see which niche could make Sweden competitive internationally. Few people believe Sweden is able to dominate the field of AI. There is also a fear that small countries risk becoming data exporters and will not find their place a little higher up in the value chain.

Of course, it's difficult to know all the answers to the challenge of making Sweden competitive in the field of AI for better health. Among other things, the ambition is to provide an outlook and to problematise certain recurrent 'truths' about the state of things.

Method for gathering information

It's a big world, and travelling it to interview people would be a huge undertaking. However, it's naturally important to try to break out of our own filter bubble. Accordingly, we have:

- Studied a wide range of media (in particular MIT Tech Review)
- Read books
- Studied reports and letters from the UK **National Health Service** (NHS) and the US **Federal Drug Administration** (FDA).
- Listened to a number of podcasts.
- Noted information obtained through interviews with Swedish expertise during trips from one end of our country to the other.

International AI Centres

Not everything addressed below is specific to AI for better health. What's more, it's difficult to avoid comparing apples with pears, given everything that is currently characterised as AI. It should be taken with a large pinch of scepticism. What has been included is there because in many cases available AI/IT expertise can be supplemented with specialist expertise from local healthcare. For further perspectives, the National Board of Health and Welfare has an international outlook[66] that summarises the Vinnova report from 2018 entitled **Artificial Intelligence in Swedish Commerce and Society**, and the more general report, **Artificial Intelligence: A European Perspective**, released by the EU Science Hub[67] at the end of 2019.

Alternatively, you can check out Crunchbase[68]; they have identified more than 200 hubs within AI in general and 7,000 start-ups in machine learning. However, they mix nations, regions and cities, so it requires some geography skills.

Nations at the forefront

The United States and China are often mentioned, so too Canada, and the EU countries as a group. Common methods of comparison at the national level include referring to the size of investments in financial terms or how many recognised companies exist. Profit/loss is rarely discussed at the national level. This is natural considering financial performance is usually reported lower down in the structure, e.g. by individual companies and universities, or at a supranational level among the technology giants.

One country that stands out a little is Canada, with its CIFAR[69]. They release reports annually[70] on how their national AI strategy is progressing. According to CIFAR, Canada was first to develop a national AI strategy.

Naturally, the EU wants to keep up and is investing relatively heavily. When the European Investment Fund (EIF) in November[71] 2019 committed EUR 100 million to AI (and block-chain technology), it stressed the need not only to finance research, as:

> ''[...] much of the funding is directed at the research and proof-of-concept stage. When it comes to funding development on a larger scale, we just don't do so much of it in Europe.''
> – Why do we need to support blockchain and AI in Europe? (EIF, November 2019)

The EIF points out that those who succeed in moving from research to market have to a large extent been dependent on support from the United States or the US market. This may lead to a brain drain in Europe, whereby people with good solutions move or are in some other way tied to extra-European interests.

Concerning actual results, the EU's **High-level experts Group (HLEG) on AI**[72] has perhaps made the most tangible contribution in recent times through its **Ethical Guidelines for Reliable AI**[73]. The ethical use of AI was widely discussed in 2018 and 2019. A nose or two have been bloodied regarding what the targets and fields of application are for AI under development in China. However, AI technology in American companies has come under fire and doubts raised about whether they align with privacy, the individual's right to a private life and protection from automated decision-making as regulated e.g. by the EU General Data Protection Regulation.

The American market (and FDA) appear innovative

For people with the US market in their thoughts, many of these issues are regulated by the FDA, which is similar to the Swedish Medical Products Agency. The key law is called the **Health Insurance Portability and Accountability Act** (HIPAA[74]).

The FDA has an action plan called the **Digital Health Innovation Action Plan**, announced in January 2019[75]. It has the ambition of "**aiming to make the agency more efficient, while promoting safety**

throughout a product's lifecycle" according to their representative Scott Gottlieb.

The FDA released a clarifying[76] outline on clinical decision support software in the autumn of 2019. It concerns regulating software products that have a medium to high risk of directly affecting health. The FDA's press release[77] in conjunction with the clarification, stated that regulation must strike a balance and encourage innovation without compromising patient safety. The FDA had previously launched ideas in the field such as a simplified process for certifying AI solutions under the **Digital Health Precertification (Pre-Cert) Program**[78], which allows the creators of AI solutions to work on the approval of the process until a solution is found, rather than attempting to have it certified retroactively once the AI solution is finally finished.

Eric Topol, an expert at Scripps Research Institute and author of the book **Deep Medicine**[79], commented the FDA's work by e-mail with STAT. Topol declares the wisdom of not basing certification on the past by freezing the solution at the moment of certification.

> "[Eric Topol] added that the eventual regulatory framework should support the ability of adaptive AI systems to learn and improve over time. "It is important to come up with a means of not shortchanging the auto-didactic power of deep learning nets that will continue to improve, not 'freeze' at the time of approval"
> – FDA developing new rules for artificial intelligence in medicine[80] (STAT, April 2019)

Gartner released a report[81] in July 2019, admittedly not specific to life sciences, in which 59% of the companies interviewed had already launched at least one AI or machine learning project. They had on average four projects in progress and a further six planned for 2020. The study's respondents estimate they will have an average of 35 project in progress by 2022.

Interestingly, the study found that the most common driving force mentioned behind AI initiatives was the desire to improve the customer experience. No less than 40% hope to achieve this. This study is not specific to those who work with AI for better health, but describes trains of thought in general.

Another international study was published by the **MIT Sloan Management Review** at the end of 2019, entitled **Winning With AI**[82]. They interviewed 2,500 business leaders, of whom seven out of ten declared that they had had no, or very limited, use of AI hitherto. But this

does not mean they lack hope; no fewer than nine out of ten believe AI to be a business opportunity for their organisations.

Exploring possibilities

It's difficult to know what exactly is meant by all these papers and press releases. Is everyone talking about the same AI?

It's easy to believe that the established health sector operators are not using AI technology to innovate as they seldom enjoy big headlines. If you're bold enough to speculate, the established operators may be further to the right on the hype cycle [83]. They are more mature, they are on the productive plateau. This presupposes that AI technology did not come as a total surprise to them, but that they had worked in a methodical, data-driven manner before, and that today's AI technology in their world is only an ongoing improvement on what they already did expertly.

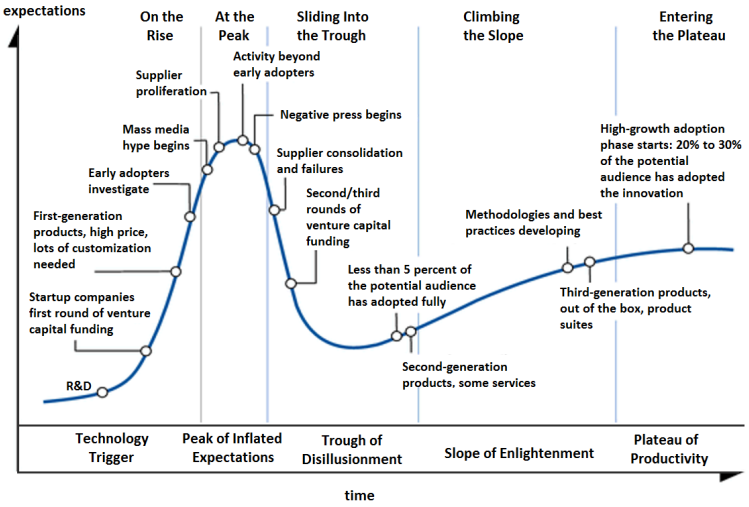

Figure 3: Hype chart with different stages of technology maturity.

And if we speculate a little around those sensational headlines, remember they're often from a start-up or someone with a powerful IT giant behind them. Communication is essential for start-ups, as is taking advantage of a hype cycle, which helps them find financiers to support the development of their companies. During the start-up

phase, the hype cycle's **peak of inflated expectations** is condition normal; after all, one is trying to find out how to convert a **technology trigger** into something profitable. AI is without doubt a technology trigger and enabler. A start-up can benefit from using this in ways that established operators have not realised are beneficial. And of course a start-up is quicker to adapt its exploration of possibilities.

Examples of interesting companies

With all due respect for the work of established operators, some examples of more revolutionary solutions are listed below. All that then remains to be seen is whether what they do will work well enough for implementation.

Insilico Medicine, in what was depicted as the AlphaGo moment[84] of the pharmaceutical industry , has shown examples of how successful drug candidates[85] have been created in a few days. This is purportedly 15 times faster than usual.

> "The drug discovery process consists of many phases and often takes decades. In preclinical phases the failure rates are over 99%. Our AI can be used in all phases and in some cases lead to superhuman results. Our AI is exceptionally good at finding the molecular targets in specific diseases and inventing new chemistry. We intend to use this in a big way."
>
> – Alex Zhavoronkov PhD, Founder & CEO, Insilico Medicine[86]

Accelerating the development of drugs is essential for the switch to treating smaller groups, and for reaching a development that can begin balancing the supply of drugs to less prosperous parts of the world.

The company **Verily**[87] (owned by Alphabet, i.e. Google's parent company) works at the interface between technology, data science and healthcare to create benefit from all the health data available. This is not only done through precision medicine such as personalised treatment of Parkinson's disease, but also in the NHS's early intervention test bed, among many examples[88].

One company that many of us realise still has some way to go before reaching a mass market is **Neuralink**[89], which has Elon Musk as its colourful ambassador. Neurallink's approach is to build an interface between brain biology and technical equipment – a **brain-machine interface**[a] (BMI). This kind of technology can be used for brain-machi-

a In other contexts called Brain Computer Interface (BCI)

ne communication in general, but research[b] on various therapies is available. Among other things, treatment for non-congenital blindness, prosthesis control, and the hope of treating brains affected by stroke, trauma and aging.

> "Brain-machine interfaces (BMIs) hold promise for the restoration of sensory and motor function and the treatment of neurological disorders, but clinical BMIs have not yet been widely adopted, in part because modest channel counts have limited their potential.
>
> [...]
>
> We have also built a neurosurgical robot capable of inserting six threads (192 electrodes) per minute. Each thread can be individually inserted into the brain with micron precision for avoidance of surface vasculature and targeting specific brain regions. The electrode array is packaged into a small implantable device"
> – An integrated brain-machine interface platform with thousands of channels[90] (Elon Musk, Neuralink, July 2019)

b Artificial Intelligence in Behavioral and Mental Health Care (2015), ISBN: 9780124 202481

Part 3: Gap analysis – what is Sweden's competitive situation?

There is a very clear ulterior motive to this gap analysis, namely to find answers to questions such as what sub-areas can Sweden excel in to make its companies competitive?

Think future tax revenues, skills development, creating pioneering thinkers, switching from reactive healthcare to preventive healthcare and ultimately contributing to better health for everyone who lives in Sweden.

Impressions from the gap analysis are both qualitative and quantitative. Structured surveys, regular interviews and discussions took place, and a great deal of reading was done across a range of different materials on the subject.

Sweden has certain characteristics in common with its neighbouring countries. For example, we often have legislation in common, or at least in harmony, with most countries in Europe, and we rarely differ too much from our Nordic neighbours culturally. This may mean fewer competitors in a given niche, or that we have a European home market in which we only compete with other countries who are also subject to the EU data protection regulation or our medical device regulations.

Strengths – what speaks in favour of Swedish AI

Our tradition of maintaining good order is often mentioned when our strengths are discussed. Sweden's system of unique identities for all residents in the form of personal ID numbers (and coordination num-

bers) and healthcare's interest in quality through our clinical quality registers.

It's difficult to overlook the fact that the Wallenberg Foundation WASP invests billions in Sweden, and that these investments will bear fruit within a few years. The Swedish Innovation Agency, Vinnova, also invests money in various AI-focused initiatives across a broad spectrum, including minor sums to help companies set out on an AI journey, as well as for specific things such as supporting AI 's natural language technology.

Swedes are often described as technical mature in comparison with other populations, and as a nation we (and our neighbours) score highly in practically every innovation ranking available, including the **Bloomberg Innovation Index**[91]. Some of the questionnaire's respondents as well as interviewees emphasise that Sweden's size can be a strength in that coordination should be easier here than elsewhere.

Data centres like Nordic cool

If we read the IT industry's publications, it's easy to believe that Sweden enjoys a unique position for running data centres thanks to our cool climate, good access to cooling water and our proximity to a somewhat warmer Europe. For example:

> "– the cool Nordic region is Europe's hottest data centre market. A company establishing a 100 megawatt installation can save around USD 2 billion over 20 years by locating its data centre in Sweden or Norway rather than the UK."
>
> – Byrne Murphy[92], Chairman of Digitplex (May 2019, Computer Sweden)

Can life sciences succeed if legal problems like the US legislation's CLOUD Act[93] get solved, or because more local cloud providers get an upswing precisely because of the law? Cerner and Epic probably do not have much to gain from building additional cloud infrastructure in Sweden for their medical record systems. The CLOUD Act means that US companies may not deliver cloud services to organisations for data that is subject to Swedish security and privacy laws. This is because US legislation requires US companies to hand over data even if it's stored in e.g. Sweden. In November 2018, eSAM stated the following:

> "eSam's legal expert group believes that it cannot exclude the possibility of a provider of a cloud service, that is subject to foreign legislation, participating in the disclosure of confidential information."

– eSAM sees cloud computing risks in public sector[94]

However, eSAM's interpretation encountered a number of objections from the outset, and since the spring of 2019 there have been a number of clarifications on what is required for the CLOUD Act not to be a problem, at least not legally. Another way would be a state-owned cloud, and in September 2019 the government set up an inquiry[95] to define and shed light on the subject, including what government agencies may store in private clouds – something which should also clarify matters for the private sector.

Weaknesses – identified shortcomings

Our clinical quality registers may well be good, but they exist in their own silos. Variables that refer to the same thing have completely different names, while things with different meanings may be called the same thing. However, **the RUT project**[96], which the **Swedish Research Council** has done work on, provides good metadata transparency for people researching the registers. It's at least something in consolation.

Respondents and interviewees highlighted the weakness inherent in not using existing information and data to a greater extent. For example, patients have a lot of information that neither AI nor doctors ever see. Nor is there any simple or established means for sharing the collected data possessed by patients/citizens. Since medical records are not under their control, citizens as patients are unable to help one doctor review another doctor's notes, when the latter is not in the same system. The ability of health and medical services to at least share patient information internally is something almost all regions will be working on in 2020 and the years ahead. We will hopefully reach this goal, but it may take many years. But this will not necessarily solve the whole problem, despite initiatives such as patient portals and promises about APIs. Not until the new health information environments are in place may residents actually have their own copy of their medical records and not be restricted to the health and medical services provided in Sweden.

The digital heritage[a] inherent in everything we have already invested in is a clear weakness in terms of being especially innovative, at least for the Swedish public sector.

"Major parts of the Swedish public sector are burdened with high technical debt. This means previous digital investments and purchases that

a Sometimes called Technical Debt.

remain inside an organisation act as a brake, costing money and human resources."

– Johan Magnusson, associate professor at the University of Gothenburg, commenting[97] on the report Digital Maturity in Public Administration 2019[98]

One respondent replied with a question: "**Scattered initiatives of AI experiments exist, but will they make a difference?**" Anecdotally, this is partially confirmed by all the AI initiatives already undertaken, together with the difficulty of confirming their outcomes, but more objectively, **Digital Maturity in Public Administration in 2019**, identified shortcomings in benefits realisation concerning innovation in general.

In this context, it often comes up that Sweden only invests small change in AI. However, it may seem unfair to count money at the national level, given that our population is equivalent to that of an ordinary metropolis in many other countries. Perhaps we should instead compare money invested per capita.

There also seems to be a consensus on how difficult it is to get around in the realm of healthcare specialists. It's sometimes described as the need for Sweden to be bold and get pilot projects into the healthcare line organisation. Sometimes the people in the front line of health and medical services are too busy to bother with innovation or even to put solutions already validated into practice.

Naïve use of technology

When investigating hyped technology, it easily happens that we apply that new whatsit to things that are not the most appropriate or optimal choice. Initiatives that are intended to benefit from AI technology may well end up using a more established and simpler technological solution. Of course, the problem is not unique to AI, or any of its sub-technologies. Compare it to the parallel hype concerning block chains or digital technology in general.

Bringing together the extremes of people's opinions about AI can be tricky. This can be everything from the technology optimist's view that if only they could get hold of more data they could solve more or less everything, to medical device engineers who dismiss the entire field with "if AI really is intelligent, its use must surely be illegal". There are also extremes within healthcare. From Eric Topol's thoughts in the book Deep Medicine where AI can bring out the humane in care again, to those who fear that this only means more of the IT they believe takes focus away from face-to-face meetings.

Common misconceptions about medical AI

In his chapter in the book **Artificial Intelligence in Medicine**[b], Anthony Chang summarises some of what he considers the more common misconceptions relating to the application of AI in medicine. Under the descriptive chapter heading **Common Misconceptions and Future Directions for AI in Medicine: A Physician-Data Scientist Perspective**, Chang argues against the following 11 misconceptions.

Everyone engaged in clinical work will be replaced by AI

There seems to be a fundamental lack of understanding about what a clinician actually does. Even though AI is able to **perceive** better than humans in an increasing number of cases, it doesn't come anywhere close to a human in tasks that involve **cognition** or anything else in an **activity** involving human versatility.

AI can be applied and add value to all parts of health and medical services

While AI can certainly contribute to workflows and diagnostic accuracy (as does other medical technology), it does not excel in all areas. For example, Chang suggests **auscultation**[99], listening to the patient's body, and proposes that innovators in AI begin by clarifying the problem first by taking advantage of **design thinking**[100].

Because AI was successful in playing the game Go, it can also be successful in the medical and health sector

A clear difference between Go and medical practice is in the way the strategy game is applied. In intensive care and A&E, the management of chronic patients and public health are more like a real-time strategy game such as **Starcraft**. Even though DeepMind did manage to play the game **AlphaStar**[101] per se in the beginning of 2019, every patient comes with his or her own conditions that change the "game". It's not just about the ability to play hundreds of games in parallel since not all the rules of the game can be written beforehand, and this may prove more difficult than originally thought.

Deep learning, in particular CNN[102], will be our long-term AI tool preference

There's no reason to deny that deep learning is effective in computer vision, and especially in healthcare for interpreting medical imaging.

b Released in 2019, ISBN: 9783030216429

Deep learning is also excellent for medical decision support.

> "Widespread application of artificial intelligence in health care has been anticipated for half a century. For most of that time, the dominant approach to artificial intelligence was inspired by logic: researchers assumed that the essence of intelligence was manipulating symbolic expressions, using rules of inference."
> – Deep Learning — A Technology with the Potential to Transform Health Care[103] (JAMA, 2018)

But even deep-learning gurus such as Geoffrey Hinton, who wrote the article quoted above, believes that in the future, deep learning needs to be more sophisticated if it is to transform health and medical services. This will require technologies such as **recursive cortical networks** and **transfer learning**[104] to handle the perfectly natural limitations of training data. Transfer learning is a means whereby one limited field of application can learn from another.

More biomedical data is needed for deep learning

There are a number of fields where big data is not a reasonable solution, such as in rare diagnoses where there is a very limited number of relevant patients to compare with. Further examples naturally involve other unusual features such as extremely sophisticated or invasive tests, or extremely risky or costly procedures. While big data is no guarantee for creativity, **Generative Adversarial Networks** (GANs[105]) and **One-shot learning**[106] can balance that image.

The area beneath the curve (AUC[107]) is a good indicator of algorithm performance

To begin with, Anthony Chang highlights the very human trait whereby parents often have higher expectations of their children than they do of themselves. In the same way, clinicians and data scientists can have greater (and possibly unreasonable) expectations of AI.

Chang argues that it's not uncommon for clinicians themselves to attain an accuracy of just over 50% in certain diagnoses. in other words, not much better than chance. Then the question is how high should the bar be set for an AI application.

Anyone who wants to contribute to medical AI must be able to program

There are many ways other than programming where we can help

develop AI. The biggest shortcoming in medical AI is not in the various technical tools, but rather in the quality and processing of the biomedical data that has to be collected.

AI is primarily for specialists like radiologists and pathologists

AI has certainly begun to challenge these specialists in making diagnoses and contributing to the work process. There's nothing new in that. The previous wave of AI from the 20th century could also do that, known as expert systems, and have already been implemented for a long time.

What remains for AI in these specialist fields is instead to be good in other AI technologies, such as natural language. So if we now include automation, like RPA bots, to automate the administrative tasks that do not require medical competence, then there's a lot to gain.

AI will make everyone engaged in clinical work less human

No, the converse is true. By taking advantage of **Natural Language Understanding**[108] (NLU), clinical staff can spend more time on human needs and less on distracting technology. Rather, think of a healthcare meeting where no form of tech is visible and where the focus is the interpersonal aspects of the meeting.

AI products will be difficult to understand and regulate

There is definitely a risk of self-fulfilling prophecy if no one tries to understand or explain AI. Chang suggests that it may not be the technology per se that should be regulated, but rather the individuals and groups within organisations that work with AI, by introducing personal responsibility even for the creators of AI.

Another proposal regarding regulation is to leave it to machines to monitor other machines continuously, with the regular involvement of people to perform manual reviews.

Medical AI is only a thing of the future

> "The future is already here — it's just not very evenly distributed"
> – William Gibson

Precisely! The same applies to AI in medicine. Medical AI is already here but is not used everywhere it should.

> "The advent of AI is a precious gift from our technological colleagues, and while AI is not necessarily going to replace clinicians, it should be

part of every medical student's educational curriculum as well as every physician's clinical portfolio from this point forward."
– Anthony Chang

The more Chang gets right about what he calls common misconceptions, the more resources will be wasted on work that does not lead to results.

How much is actually about AI technology?

"Only a small fraction of real-world ML systems is composed of the ML code, as shown by the small black box in the middle. The required surrounding infrastructure is vast and complex."

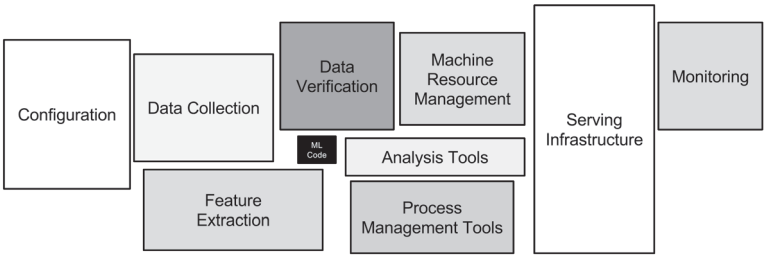

Figure 4: Components of machine-learning. ML (machine learning) is the little black box in the centre. (Sculley et. al. 2015)

– Hidden technical debt in machine learning systems[109], Sculley et. al. (2015)

There's a great deal of focus on the little machine-learning part of the puzzle, and a great deal less on the other crucial pieces. The collection and verification of data is pretty much self-explanatory, but requires greater effort than we might think. These other parts are sometimes described as the boring bits of AI, but that does not make them any less important. Each part requires great attention; they do not look after themselves.

Do we resolve any real problems, or the biggest problems, by exploring the hype? It's a bit like the conundrum that asks which technology would be most helpful to a nurse travelling between needy people in a bunch of villages out in the African bush. Would the nurse benefit most from advanced forecasting, route planning, or maybe medical decision support? Or perhaps a torch to look out for snakes, as street lighting is not something you can bank on? The most important solution is not always the most attractive.

Difficult to keep skills in Sweden

> "Today, giants like Google, Facebook and Apple are buying up all the top scientists in artificial intelligence, and in terms of resources, academia has difficulty competing."
> – Michael Felsberg[110], professor at Linköping University

We receive alarming news at regular intervals on how difficult it is to attract or retain AI researchers in Sweden. This is of course a legitimate concern. But is it a problem mainly for the little part of the puzzle specific to machine learning and other AI technologies? Is it also a problem when the national approach is more about applications and drawing benefit from AI? The government answers these questions as follows:

> "Sweden must be a leader in taking advantage of the opportunities that the use of AI has to offer, with the aim of strengthening both Swedish welfare and Swedish competitiveness."
> – National Approach to Artificial Intelligence[111] (Ministry of Enterprise and Innovation, May 2018)

Or does it mean AI research into applications that are close to implementation?

Naïve approach to problems others have long given thought to

During the Swedish Agency for Economic and Regional Growth's AI network[112] seminar in December 2019, Daniel Gillblad from the RISE research institute remarked that there are things about AI we will probably still be talking about several years hence. They are by no means new challenges, and we can look at them as fundamental limitations for many of the AI technologies where there are no simple or obvious solutions, namely:

- Explainability
- Scalability
- Handling uncertainty
- Causality (i.e. causal relationships and not just settling for correlations)
- Ethics
- Robustness

Naivety about ethics is probably the riskiest and most unpleasant of them. And ethical AI is by no means a new field of research, as

Virginia Dignum, professor and scientific director of the WASP-HS (Humanities and Society), explained to participants during a full day of ethical AI at the University of Gothenburg in December 2019.

> "I've been working with this since 1986. For most of my life; no one cared."
> – Virginia Dignum[113]

Digital dazzle?

This is naturally not just about things that are specific to AI. Will we have the conditions to succeed if we come up with new, shiny tools and want to take time away from healthcare specialists? Almost every profession seems to have the same mantra: "It would've been good if you'd involved us a little earlier in the process".

Today's AI concerns the health of individuals and for obvious reasons focuses on episodes (as in healthcare), and on things that can be isolated relatively easily (i.e., rarely co-morbidities). In every study and article, we read about AI being better than a dermatologists at making a handful of diagnoses, or finding brain tumours faster than a radiologist, and so on.

Does this mean there are no systemic opportunities to resolve? Or are we trying to resolve the small details, e.g. a single diagnosis at a time? Can we piece all this back together into a meaningful whole afterwards?

Sweden is poor at sharing – even harmless data

A number of interviewees or respondents returned to our need to collaborate better in Sweden – we need to share. It might be easier to find what is ready for implementation and to make sure it's useful.

Instead, we get a whole load of theory that's never put to use. One measurable way of looking at Sweden's position on this matter is to study open data. Admittedly, it's not even close to patient data (the corresponding term would be linked data[114], in other words not open). However, open data can provide information on demographics, health and medical system productivity, health trends, health guidelines and recommendations, and much more.

So how good is Sweden at open data? The undersigned wrote a recommendation for Region Västra Götaland specifically about open data in 2010, so to say that the subject is something new on the Swedish digital map is just plain wrong.

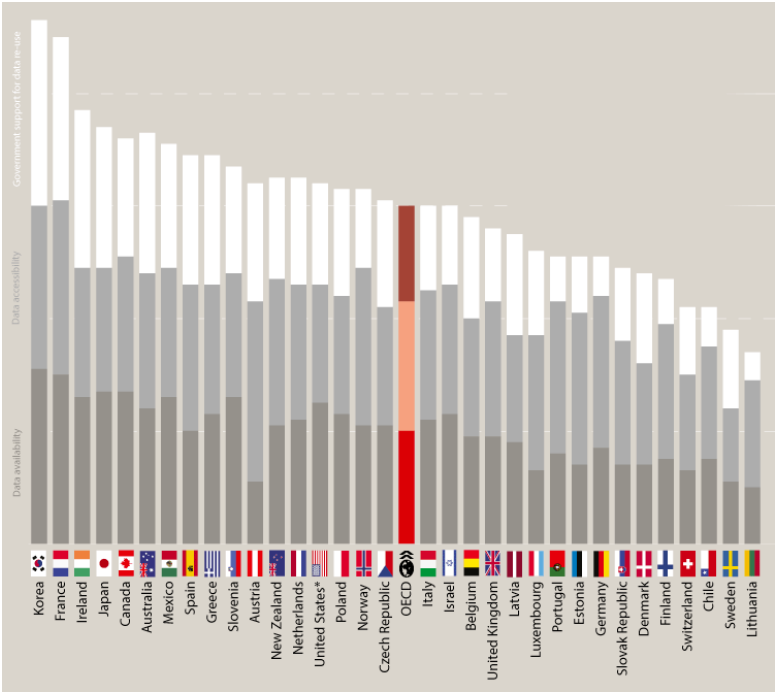

Figure 5: OECD report for 2019 looking into data availability (dark grey), data accessibility (grey), and government support for data re-use (white). Sweden is second from last.

Sweden's position in terms of open data is truly, truly awful. The OECD examines this every year and in 2019 Sweden came second from last[115]. This is not due to some sudden dive; Sweden is always in a poor position in this ranking. If we look at it from a competitive standpoint, there is little consolation in Sweden having improved so much in recent years when we continue to lag so far behind.

Consider developer experience (DX)

Open data alone cannot solve specific AI problems concerning health. Data is available on demographics, healthcare productivity and much more, however this will only be useful for AI as long as we gain and offer access to people who may also find it useful. This data must be machine-readable, i.e. able to be processed by a machine; maybe even various data source directories themselves must be machine-readable. Such catalogues are managed by DIGG, the Agency for Digital Government, and can be found at dataportal.se

Releasing a list of scanned documentation PDFs will probably not do the trick, even though it could be technically classified as open data. It would be better to follow best practice in designing APIs and hold discussions with prospective data re-users—the developers.

Our own data, or someone else's, becomes de facto standard as it spreads

If AI solutions are created on Swedish data and resources, just as several of the digital assistants have been trained on Wikipedia (which behind the scenes follow the concept of linked open data), the solutions will suit Sweden better. This is surely the reason why major technical organisations, which otherwise like to keep their secrets closely guarded, actually release crucial technical frameworks and functions quite openly. Google has its framework **TensorFlow**[116] among other things for machine learning, while Facebook has released **Prophet**[117] openly to enable others to make forecasts, to name initiatives by two major organisations.

So it's very unfortunate that we're so bad in Sweden at sharing the results we've already achieved among ourselves, even within the country.

Disseminating results paid for by the taxpayer?

A fascinating example is Swelife's own AI project, which seem to have run into apparently unnecessary obstacles to the use of data. This was at Inera when we tried to use the texts published on 1177.se for use with natural language AI technology. Do not regard this as criticism aimed at Inera, but rather as the type of friction we can expect where Inera's months of dealing with the issue can be seen as a graphic example that must surely apply to many more organisations unprepared for this type of issue.

An API for the articles on 1177.se has been available for a long time, and the content is subject to the legislation on public documentation, as everyone seems to be aware.

However, we were not allowed to disseminate these texts even in workshops for general education on AI. Nor were we allowed to give away a data starter pack and sample code to people who want to start learning about AI in health and medical services.

We're talking about data, quality-reviewed by specialists, paid for by the taxpayer. Shouldn't it be openly available? Or at least be available for use freely in other tax-funded activities such as in the regions or the Swelife innovation programme financed by the Vinnova

innovation agency?

The 1177 Healthcare Guide website, 1177.se, is operated by Inera, which is owned by SKR[118], which in turn is owned by our municipalities and regions. I.e., by extension, the people. It's a highly democratic organisation that exists for the public good.

Open by default

Everything produced by SKR and Inera should be automatically offered as open data unless there are compelling reasons not to. If not even the articles on 1177.se may be released openly, we might wonder how we can become best in eHealth by 2025. At present, users are required to sign agreements and not pass on information. These snags do not restrict e.g. Google, which by dint of its size is able to download all the material directly from the website. Google already has an infrastructure in place for such, in contrast to Bjurholm's municipality with little more than 2,000 inhabitants, which probably doesn't even have its own IT manager.

It's a little strange when something that has been paid for by Swedish taxpayers is easier for Google to use than our own entrepreneurs, or indeed health and social care themselves.

Open data

Open data has a definition, which makes it easy to use when qualifying suppliers and comprehensible for re-use of the data. The definition is generally accepted. The fact that Tim Berners-Lee, the founder of the web, is its author made it easier to reach consensus.

It has been a topical issue for at least 10 years, among others with the E-delegation, then the National Archives and these days at DIGG. However, it's time for organisations that produce important data sets to open them up automatically and to ensure that any limitations are well-motivated and quite rare.

Of course, there are a number of data sources that it would be interesting to mix with the things Inera produces, including:

- **Kolada**[119] – municipalities and regions report comparison data nationally, but are they allowed to reuse each other's raw data for their own analyses, e.g. between two metropolitan areas' hospitals?
- **Clinical quality registers**[120] – anything harmless from the registers. Maybe at the group level, municipal level and diagnostic groups etc. Karolinska University Hospital has previously carried out a project regarding how much abstraction is necessary to conceal a person in a group when it concerns healthcare data.

Data is considered to be our new natural resource, but unless it's open and easy to find, it will not get used.

Information processing

There are also challenges in the mix between law and information processing, as recognised in the summer of 2019 by the US company Cerner when it announced that its Millennium product, in its existing condition, was not able to comply with the Patient Data Act[121]. Which, at least in the case of Region Västra Götaland did not even involve the use of any American cloud services.

Another challenge is the overall nature of the data collected. Is it comparable to data from another activity with seemingly identical tasks? The author of the book **All Data Are Local: Thinking Critically in a Data-Driven Society**[c] has pointed out that collected data is often very local:

> "[…] data are cultural artefacts, created by people, and their dutiful machines, at a time, in a place, and with the instruments at hand for audiences that are conditioned to receive them."
> – Yanni Alexander Loukissas

Loukissas points out that concepts such as **data** and **data sets** can easily mislead us. We can easily believe that the content is complete, portable and separable from its context. Loukissas suggests we think more about **data settings**, i.e. the location and context where the data was collected.

> "Aspiring to the ideology of big data means seeking to collect everything on a subject, downplaying the importance of data's origins, and assuming that data alone can entirely supplant other ways of knowing."
> – Yanni Alexander Loukissas[d]

And just because we have big data sets, popularly known as **big data**, it doesn't mean our data quality challenges are resolved. Big Data is usually described as having characteristics that start with the letter V:

- **Volume** – actual size or amount that is difficult to process
- **Velocity** – a high velocity or fast throughput
- **Variety** – large variation where it's difficult to know what precisely is meant

c MIT Press (2019), ISBN: 9780262039666
d Page 16, the book All data are local

Big data is sometimes humorously dismissed as anything that is too big for Excel. But big data, and its use, has also been described as an emotion, i.e. data that for various reasons causes anxiety[122], both for the person who will process it and for the person who understands the full extent of having his or her personal data in it.

It's risky to assume that collected data is universal and comparable across various boundaries. This insight reduces the utility of data. If this local training data is nevertheless used for a solution, it will not be quite as accurate elsewhere or in some other context. Or as anthropologist Clifford Geertz has put it:

> "Who knows the river better, the hydrologist or the swimmer? Put that way, it clearly depends on what you mean by 'knows'."
> – Clifford Geertz[e]

Data processing is not a particularly new issue. The same type of question has been around in epidemiology for a long time. Epidemiologists do not get rid of collected data after its first use as the same data may prove useful later on. There are examples of data sets from the 1940s that are still in use, with the consent of parents of the **data subjects**[f] concerned. Many of these parents are now dead, but the same data is still being used.

To some extent, AI for better health is merely epidemiology in a scaled-up version. The difference is that today we use big data as mental abstraction.

International collaboration is not straightforward – it's easier inside the EU

If we look at legislation internationally, it's not wholly compatible between different countries. There has been an occasionally polarised debate on how, if at all, European organisations can use cloud infrastructures belonging to American companies, even if they have data centres in the EU. This will be a problem for AI when successful, non-European organisations succeed in offering a cloud infrastructure, and they have partner organisations that depend on those clouds. To a degree, the discussion is proof of the successful development of useful AI cloud services by Amazon, Google, Microsoft and others, and that it's easier and cheaper to rely on their infrastructure rather than owning one.

---

e The book Available Light, page 140, by Clifford Geertz, ISBN: 9780691089560

f Individual that can be directly or indirectly identified, through names or factors that are unique to the individual

However, it becomes a problem when legislation seems to demand a high degree of caution and such cloud services are difficult to avoid even through the country's local consultancy organisations. So how can we begin implementation quickly when many seem to assume they may use services that do not comply with data protection, confidentiality and national digital sovereignty?

During the autumn of 2019 SKR released the **Guide to cloud services**[123] from a Swedish perspective (quickly met with disappointment[124] [125] from certain quarters). It's worth remembering that SKR is a membership organisation in which the cloud not only concerns sensitive patient data, but also whether students are able to use office applications in the cloud and even completely harmless tasks e.g. public documents subject to open data legislation such as the EU PSI Directive[126] or the Swedish principle of public access. Shortly after the SKR Guide, eSam released an update to its guide[127], **Outsourcing 2.0**, which SKR quickly declared[128] it was not approving.

Not just a debate in Sweden

However, this is not a discussion in Sweden alone. The Netherlands has concluded that it's obliged to have second agreements with suppliers whose legal domicile is controlled outside the EU. Parts of Germany have come to the conclusion that they cannot even use standard applications, like Microsoft's Office, that make use of the cloud[129].

> "In one or two previous investigations[130], so-called Data Protection impact assessments, (DPIA), Privacy Company has concluded that the Dutch authorities may not use Microsoft Office, in either its desktop, cloud or mobile versions"
>
> Microsoft is changing Office to get GDPR approval[131] (Computer Sweden, August 2019)

Much is attributable to the CLOUD Act and FISA[132]. The CLOUD Act[133] deals with the exchange of data for criminal investigations when such data is not stored on servers located geographically in the United States, which is why the discussion is about whether the US authorities can legally demand access to data stored on servers located in the EU, when the server is controlled by a US company. The US Department of Justice, DOJ, has described the purpose of the CLOUD Act as follows:

> "The CLOUD Act authorises executive agreements between the United States and trusted foreign partners that will make both nations'

citizens safer, while at the same time ensuring a high level of protection of those citizens' rights."

– The Purpose and Impact of the CLOUD Act[134], U.S. Department of Justice (April 2019)

The CLOUD Act is a collaboration concerning data between the United States and other countries, but requires an agreement between the United States and each respective country, such as Sweden, to be in force, and only then should the United States comply with the relevant country's laws. In defence of the CLOUD Act, both the EU and the United States have signed the so-called **Budapest Convention**[135] which regulates how we cooperate internationally to investigate cyber crime. Critics would certainly refer here to the risk of a shift in purpose and that not all interested parties have taken due notice of whether their operations have complied with the law historically.

In defence of the United States, we should also mention that it's not alone in having this type of legislation, something which Försäkringskassan's (Swedish Social Insurance Agency) White Paper[136] on Cloud Services addresses:

"Several countries, among them the United States, China and India, now have legislation that allows their authorities to access, under certain conditions, data and information stored with service providers under their own jurisdiction, even if the storage takes place outside the territory of their own state. Against this background, a debate has arisen on whether the use of cloud services available on the market is compatible with Swedish law and EU law."

– White Paper: Cloud services in social underpinning activities – risks, suitability and the way ahead (Försäkringskassan, November 2019)

Försäkringskassan's Director-General's appearance, in connection with the White Paper, in the Swedish daily Dagens Nyheter[137] under the headline **Sweden's digital sovereignty is threatened by IT cloud services** perfectly describes the current discussion.

FISA stands for Foreign Intelligence Surveillance Act (USA). The essence of Edward Snowden's revelations in 2013[138] was that the US intelligence agency, NSA, deliberately chose not to follow FISA[139].

"The European economy urgently needs an infrastructure that ensures data sovereignty."

– Peter Altmaier[140], Finance Minister, Germany

Germany and France are planning to set up an EU cloud to avoid

altogether the problem[141] of cloud services under extra-European control. The project, known as Gaia-x, seeks to achieve European independence in the field of cloud service providers.

> "Behind it is the same discussion going on in Sweden about how the services of American cloud giants can be considered for use by the public sector given all its confidential information. There is concern that US suppliers may be forced to disclose data to the US authorities, under domestic legislation such as the CLOUD act and FISA."
> – We've taken the first step toward an EU cloud – what happens next? (ComputerSweden, November 2019)

Perhaps the solution will be not to use international IT giants, but to choose segmentation in the different jurisdictions instead. The EU has its own IT giants, so too the United States, Russia, and China (behind the **Great Firewall of China**[142]) etc. Among other things, the development of cloud cyber security certification[143] is in progress in the EU, which could make the choice of cloud providers easier in the future.

All this takes a lot of time and energy away from actually achieving something.

Perhaps it would be easier to move directly to the US market with its large population in a single jurisdiction where already successful IT giants offer interesting applications and the FDA is active in the issue. Depending on what we're looking for, Sweden's inability to offer a domestic market for validation could be seen as a weakness, but for people seeking an opening, the US market presents an interesting possibility. Let's hope for some clarity in Europe very soon.

Aligning with the global goals

The global goals[144] are a list of goals for promoting sustainability. The UN development programme (UNDP) has drawn up the list "**in order to end poverty, reduce inequalities and promote peaceful societies"**[145].

We don't have to look further than the fairly obvious challenges, such as equality, that everything from AI research to applications encounters major problems here and there. In April 2019, AINow highlighted this in its report **Discriminating Systems: Gender, Race, and Power in AI**[146]:

> "There is a diversity crisis in the AI sector across gender and race. Recent studies found only 18% of authors at leading AI conferences are women, and more than 80% of AI professors are men. This disparity is

extreme in the AI industry: women comprise only 15% of AI research staff at Facebook and 10% at Google."

And nor did they find any data on trans people or other gender minorities. However, they warn that the ambition to promote women in the technology sector will go awry and benefit white women. Diversity is multifaceted!

> "The emergence of artificial intelligence (AI) and its progressively wider impact on many sectors requires an assessment of its effect on the achievement of the Sustainable Development Goals. Using a consensus-based expert elicitation process, we find that AI can enable the accomplishment of 134 targets across all the goals, but it may also inhibit 59 targets."
>
> – The role of artificial intelligence in achieving the Sustainable Development Goals[147] (Nature, January 2020)

Many organisations are launching various groupings within AI to concentrate their resources. One revealing example was Stanford University, which in the spring of 2019 announced its new **Institute for Human-Centered Artificial Intelligence**. Of the 121 faculty members presented on their website, not one was non-white[148]. There are organisations trying to make a difference, e.g. **Black in AI**[149] and **Women in AI**[150] for diversified skin colour and gender. But it's worth remembering that these are but two of many kinds of bias.

Energy consumption (not headed in only the wrong direction)

Training AI takes more than a little energy. Karen Hao wrote an article in MIT Technology Review[151] whose subtitle summarises the problem perfectly, in that: **"Deep learning has a terrible carbon footprint"**. Deep learning happens to be the version of AI that is most popular in this latest wave. It's precisely deep learning that capitalises on the huge amounts of data often referred to as to AI essential, and there is a risk that people following the AI trend will get on that particular bandwagon. Not only is there a lot of carbon dioxide, it's pushing up prices on the energy market, which at best has a positive side effect in that there is money to develop cleaner energy.

There is hope in the fact that the cost of training AI models in some cases has fallen, sometimes significantly. One example is an image classification model that in 2017 would have cost $2,300 to train, but which in September 2018, only cost $12. The cost halves every 3

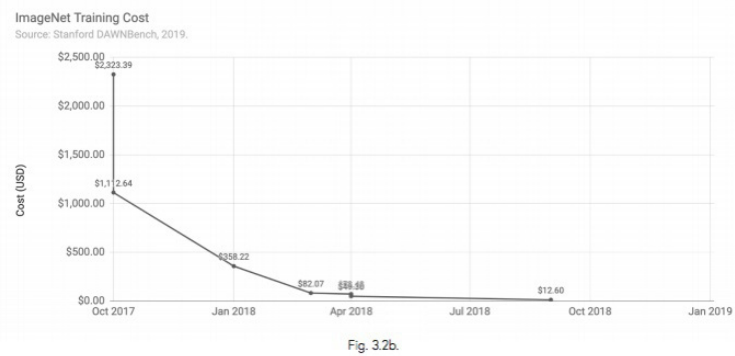

Fig. 3.2b.

Figure 6: Training cost for image classification through ImageNet (source Stanford DAWNBench)

to 4 months, unlike the 24 months Moore's law[152] takes, which is the boost AI can count on thanks to development of the hardware we use for training.

Of course, it's not possible to equate cost and the change in sustainability, but at least it's due to some extent to efficiency in the form of less computational power being used for certain tasks, which leads to lower hardware and energy requirements. This does not necessarily mean it will become more sustainable from every standpoint, but perhaps we can earn more from our investment in AI in the form of e.g. more trained AI models.

Opportunities

For readers who skipped the section on strengths, here's a repeat of our relatively extensive registers. We not only have clinical quality registers, but also registers collected more widely and which may perhaps be disseminated a little more openly if put through information classification. Perhaps we need a more comprehensive list of registers, with instructions on precisely what is necessary for access even to confidential data, whether or not the registers are open.

One problem with confidential information occurs when innovators and developers do not even know that it exists or what the data looks like. So how will they know how to design their concept to make use of this unknown?

One possibility asked about by people in the private sector during the nationwide interviews is how to get hold of annotated data, or

data in general. The nature of the problem is not entirely clear. What must start-ups do to be allowed to reuse sensitive health data in the same way as academia or quality and business developers in health and medical services already do? Is it an educational challenge or a legal obstacle course? But more interestingly, how should they proceed in order to help achieve better health?

The trepidatious who still defend openness can always fall back on synthetic data[153], i.e., representative data that does not reveal anything sensitive but which contributes to understanding, or can actually be used in major volumes for machine learning.

Sweden is in agreement – we have to change!

There seems to be a broad understanding that health and medical services cannot continue as it is today for many more years without there being major problems and lots of friction. However, this is still positive as change would seem to be inevitable.

One respondent put it as follows: **"We're facing a crisis and we have to find a way out of it, so perhaps now is the right time for AI to show its potential."** The respondent mentioned that we can save both time and money by digitising our way out of **"boring, slow, manual processes in healthcare".**

95% would consider sharing their health data

By means of coherent medical record keeping, a caregiver can read information about patients in another caregiver's system. However, this requires consent[154] and a legitimate reason. Today, a caregiver is not allowed to use all of this information to pro actively train an AI application. For example, if a region includes everything a municipality knows about a given individual. This is problematic and not in line with either the individuals' health needs or cost-effective care. However, in an opinion poll commissioned by Research!Sweden it emerged that the population/respondents are overwhelmingly positive to sharing, summarised thus:

> "95% of the public are in favour of sharing their health data for research and health promotion purposes."
> – Research!Sweden's opinion poll 2019[155]

Conversely, reading the survey shows that one in twenty (5%) did not agree with any of the four answer options regarding the kind of sharing they were prepared to do, and instead chose: **Doubtful / Don't know / None of the above.** But how many people must like the idea

for a change in legislation to be justified? Sweden probably has many laws with popular support far lower than 95%, and the widespread willingness to share is only one amendment in law away from becoming a major force.

Self-financing AI initiatives?

In Region Västra Götaland (VGR) alone, there were more than 150,000 hospital appointments where patients failed to turn up in 2019[156]. This not only leads to neglected care, but also to a lot of extra administration for rescheduling and, of course, longer healthcare waiting lists. While VGR may have other even bigger problems, it would surely be exciting to begin trying to make a difference where a single region alone has the potential to save SEK 500 million annually, or to provide 150,000 appointments that patients actually turn up for.

Regarding costs, 1% of the existing cost would provide SEK 5 million for investment in an innovative solution. Would this be enough to save at least SEK 5 million in terms of the missed appointments we're already living with? What other problems in healthcare are there where AI technology has such a great potential to provide a solution?

9% of healthcare admissions reviewed led to avoidable iatrogenesis

It's extraordinary and serious that almost one in ten of the Västra Götaland healthcare admissions reviewed by SKR (2017) led to iatrogenesis (an injury or illness that occurs because of medical care) that could have been avoided, but it's certainly not unique to that region.

> "Patients, caregivers, researchers and companies must have better opportunities to help with the collection, use and sharing of data. This would significantly reduce iatrogenesis cases in Västra Götaland, while enhancing care quality and equality."
>
> Health data crucial for better care and fewer iatrogenesis cases in Västra Götaland[157] (Lerums Tidning, July 2019)

For Sweden as a whole, it concerns 110,000 individuals every year at an annual cost of almost SEK 9 billion. Assuming legislation is updated, imagine what could be achieved if health services had a holistic picture not only of the patient, but also of other relevant, anonymised individuals for comparison. And what would happen if we reinvested the SEK 9 billion in preventive medicine and health care development by e.g. implementing AI that has already proved itself?

What can Sweden be best at?

Speculation alert; where it concerns arguments about Sweden's small size and that our entire population is tiny compared to those of other countries, the issue is by no means settled. One reason is that not everything in life sciences requires the level of precision necessary for the records of several hundred million individuals, and another is the assumption that the answer to an individual's health resides in data at group level. Of course, it helps to have huge amounts of data to find an individual with the corresponding gene expression, but given the energy required to make a specialised AI model, it may be an issue for the future when AI can be trained much more efficiently. MIT Technology Review[158] showed that the emissions from training a single AI model can correspond to those of five cars throughout their entire lifetimes. It will not be sustainable for any operator to train AI models on an individual basis, and this levels the playing field to our advantage.

In the case of specialised AI, does not the fact that by comparison we have a partly homogeneous population make us relevant in certain contexts? At least in some of the medical digital twins of Swedish descendants. For example, in the United States, a nation with great purchasing power, there are 4.5–8 million Swedish descendants[159], depending on how you count.

And how much can China export in healthcare AI? Do they have an solution for **Skelleftesjukan**[160], which in addition to its presence in Västerbotten and Norrbotten, is also present in Japan, northern Portugal and Brazil? Time will tell.

Sweden may not be able to dominate a major niche in tomorrow's AI, but we can do quite well in a number of smaller niches where our strengths are hard to beat. Like the AI products we create from our clinical quality registers, the dominant gene pool here, a technology-friendly and innovative home market, and so forth.

Established specialisations

One way of considering what is worth investing in is to start with the Swedish Agency for Economic and Regional Growth's work on smart specialisation[161] and the determination each of the nation's regions has concerning their own focus:

> "Smart specialisation is all about investing in what we can be best at in order to strengthen our future competitiveness."
> – Smart specialisation (Swedish Agency for Economic and Regional Growth)

If we filter out only the things associated with life science-like approaches, or where the use of AI technologies should be able to cross-fertilise with life sciences, we arrive at the following list. We can gain a sense of what else there is in the surrounding environment that can strengthen a cross-sectoral perspective and exchange of experience.

BLEKINGE

- ICT (Information and Communication Technologies)
- Digitisation

DALARNA

- Health & Welfare

HALLAND

- Health
- IT

SKÅNE

- Personal health

STOCKHOLM

- Health, healthcare, social care

UPPSALA

- Life sciences
- Tech industry

VÄSTERBOTTEN

- Digital services
- Health and medical care
- Life Sciences

VÄSTMANLAND

- Welfare and health

VÄSTRA GÖTALAND

- Life sciences

ÖREBRO

- Autonomous digitised intelligent systems
- Foodstuffs in the intersection between sustainability, health, the environment & mealtimes

- Simulation & visualisation

Östergötland is a good example of a region which, although not specialised in any of the life sciences, is still truly active in the sector. They are working on AI **computer vision** through their specialisation in simulation and visualisation. In visual, they can be seen e.g. in AIDA, and projects in Visual Sweden, which is part of the life sciences sector.

Västra Götaland's specialisation in textiles may appear too far-fetched to be relevant in this context, but there are cross-border projects concerning smart textiles[162] that can diagnose the wearer's health. Nor do we probably imagine that sustainable transport will get people working on autonomous ambulance drones. So while not revealing the whole truth, the filtered list above will hopefully give us some clues. Check out the Swedish Agency for Economic and Regional Growth website[163] for a complete list of specialisations.

Pharmaceuticals and advanced therapeutic drugs

Depending on what we include under drugs, much is already being done using AI technology, but there remains of course potential. One example we ran across during the nationwide interviews was the collaboration between researchers at the University of Skövde and AstraZeneca. Researchers at the university describe AI, and especially deep learning, as having great potential in anything that ends with *omics, e.g. genomics, among other things.

In the field of **Advanced Therapy Medicinal Products** (ATMP) there are of course more, including the **Karolinska Cell Therapy Centre** (KCC)[164], which also offers services within Europe.

Another aspect concerning drugs is the issue of compliance. Do patients take their medication on time, in the right way, or at all? This is something for goal-seeking systems (e.g., **reinforcement learning** in which AI tries to help the patient do the right thing and where the AI is rewarded when things go well and punished when things go wrong), in combination with gamification at the patient end, where a human and a machine are both players who must try to achieve certain goals together. For example, the best chess has proven to be played not by man or machine, but by a combination of both. Sweden's strong gaming sector cannot have escaped the attention of anyone given the presence of Mojang, King and many others.

Monitoring drug regimen compliance via the internet has been around in various forms for several years. One of the operators we encountered is Mevia[165] and at Vitalis in 2018, there was a demonstration of a more general dosing robot that could speak and alert if necessary. Here, advances in hyper-personalisation can make machines more helpful and adapted to suit the individual, so that it doesn't yell at the patient in the middle of the night about something that can wait till morning.

Protein folding

We can also include **protein folding**[166]. A protein has different functions depending on its three-dimensional shape. A mix of enormous computing power and machine learning will allow new shapes to be developed and automatically tested in silico[167], i.e. in a computer. We give the machines the task to develop potential candidates for further evaluation.

Is this where we should take advantage of our cool climate and build data centres next to our northern rivers?

There is ongoing collaboration via the internet where laymen in the field can also help in projects such as **Folding@home**[168], to which computational power can be donated.

There is an established route to market in the field of drugs, and this makes international competition tough. We could argue that this is not AI, as AI technology is sometimes used to make the actual discovery rather than be its outcome. But if we regard AI as a digital tool, it can do a great deal of good for the health of both the individual and the population as a whole.

Self-care and prevention

Sweden (especially the south and Stockholm) has many engineers skilled in mobile technology which, in combination with our medical technology industry, means we should have the basic conditions for creating solutions that support healthy everyday lives in citizens and patients.

Activity recognition[169], and in the particular case of this paper, **Human Activity recognition**[170] (HAR) is of interest. The aim is to make machines 'understand' context by means of a series of observations using various sensors. For example, in the healthcare field, wristbands using time series analysis try to figure out whether a hard knock was due to a person falling or to bumping their wrist against something. Is the wristband motionless because the person has gone to bed, or has collapsed on the floor and needs help?

Such solutions look for patterns in both the individual and group levels that can improve precision also at the individual level.

The Swedish population is often identified as being technical minded, and this is not only essential if everyday technology is to be developed locally, but also for its validation, productisation and use. The field is sometimes referred to as welfare technology and can be found in many parts of the country, including **AllAgeHub**[171], which works with accessible living environments for people of all ages. A tech-savvy population also provides the conditions for patient-driven innovation in self-care.

Threats – obstacles and challenges in finding a Swedish niche in AI for better health

A relatively common criticism is that the healthcare sector lacks coordination or sufficient skills in AI technology in general, or in specific areas such as machine learning. There is a risk that Sweden will become a follower rather than a leader. A similar response asserts that it appears difficult for organisations to collaborate, share and protect data.

Another respondent found that "all problems and threats appear to be organisational and not technical. We're not good at setting regulatory or national guidelines that must be complied with." We have various strategies that nobody reads or follows. Unless something is mandatory, nothing happens all that quickly, and that's down to organisational problems.

Another respondent is alarmed that the United States and China are investing so much more than Sweden. Sweden, together with the EU, needs to invest much more in order to have a chance.

One person blamed leaders and the healthcare profession for being partially responsible for the lack of progress. He felt that decision-makers do not understand the complexity of developing AI, and that the healthcare profession feels threatened by AI instead of getting a grip and developing their skills.

Perhaps not everything that's called AI is AI

Being in a hype cycle causes problems. There are unreasonable expectations from certain quarters, while some people trying to ride the wave are not always equipped to succeed. In 2019, disheartening studies were published on how small a proportion of what is marketed as AI even contains such a thing.

"According to the survey from London venture capital firm MMC, 40 percent of European start-ups that are classified as AI companies don't actually use artificial intelligence in a way that is "material" to their businesses. MMC studied some 2,830 AI start-ups in 13 EU countries to come to its conclusion, reviewing the "activities, focus, and funding" of each firm."

– Forty percent of 'AI start-ups' in Europe don't actually use AI, claims report[172] (The Verge, March 2019)

How far will deep learning take us?

There's also talk of the limitations of deep learning, which is the main technology behind the recent interest in AI. MIT Technology Review wrote about it in 2017 as follows:

"Just about every AI advance you've heard of depends on a breakthrough that's three decades old. Keeping up the pace of progress will require confronting AI's serious limitations."

– Is AI Riding a One-Trick Pony?[173] (MIT Technology Review, 2017)

Two years later, Blaise Aguera y Arcas expressed the challenge as follows, with a comment by Wired:

""We're kind of like the dog who caught the car," Aguera y Arcas said. Deep learning has rapidly knocked down some longstanding challenges in AI—but it doesn't immediately seem well suited to many that remain. Problems that involve reasoning or social intelligence, such as weighing up a potential hire in the way a human would, are still out of reach."

– A sobering message about the future at AI's biggest party[174] (Wired, December 2019)

Arcas argues that there are problems we need to solve that are not at all similar to what we've been able to use deep learning for so far. Or as Yoshua Bengio, one of the people identified as deep-learning's Godfather, put it at the same conference:

"[AI] need much more data to learn a task than human examples of intelligence, and they still make stupid mistakes."

– Yoshua Bengio, during NeuroIPS 2019

In November 2019, a seminar was held at AI Innovation of Sweden in Gothenburg. Claes Strannegård[175], Assistant Professor at the Department of Data Science and AI at Chalmers, spoke in his lecture entitled **Deep learning: Advantages and drawbacks**, about the challenges

facing deep learning in the way it's used today. Deep learning can be summarised as follows:

- **Cannot be fully automated** – it requires experts working manually to design the architecture.
- **Unable to describe itself** – in other words, cannot be used for decisions in medicine, finance, traffic (and certainly other regulated industries).
- **Is sometimes very expensive.**
- **Requires a great many examples to learn** – in other words, not one-shot learning[176].
- **Not at all versatile** – the principle is to have one custom network per solvable problem, which is a hassle if we switch to another data set.
- **Often requires a great deal of energy.**

In an additional perspective, one interviewed medical device engineer submitted that if what our AI is doing truly is intelligent, then its use is probably illegal, at least in the EU. This is because AI, often referred to as a **black box**, that is unable to explain itself should be close to impossible to CE-mark, and also because the data protection regulation demands the preservation of the privacy of individuals and protection from automated decision-making.

It's not necessarily a problem that deep learning in certain cases is coming to the end of the road. That complaint is not directed against life science but is rather more general in nature. Sometimes AI, and science in general, focuses on so-called **toy problems**[177]; these are more trivial and isolated than the focus required for the future implementation of an initial finding. If we believe the authors of the book **Deep Learning for the Life Sciences**[g], there are a number of areas with particular potential for deep learning. These include microscopy, biophysics, biochemistry as in predicting toxicity, genomics as mentioned earlier etc., besides the more general deep learning of health data from medical records.

Far from implementation

Other, not exactly positive, results concern how close published academic findings in AI are to the real-world problems that require AI solutions. The Korean Journal of Radiology published an article that studied several hundred other articles in medical imaging diagnostics. Unfortunately, only a wretchedly small percentage had been validated

g By Bharath Ramsundar et al (2019), ISBN: 97814920339839

and could also be used for something:

> "Of 516 eligible published studies, only 6% (31 studies) performed external validation. None of the 31 studies adopted all three design features: diagnostic cohort design, the inclusion of multiple institutions, and prospective data collection for external validation."
> – Dong Wook Kim, et al.[178] (Korean Journal of Radiology, February 2019)

The vast majority of the studies were test projects that could not be applied in the real world. The conclusion drawn was that:

> "Nearly all of the studies published in the study period that evaluated the performance of AI algorithms for diagnostic analysis of medical images were designed as proof-of-concept technical feasibility studies and did not have the design features that are recommended for robust validation of the real-world clinical performance of AI algorithms."
> – Dong Wook Kim, et al. (Korean Journal of Radiology, February 2019)

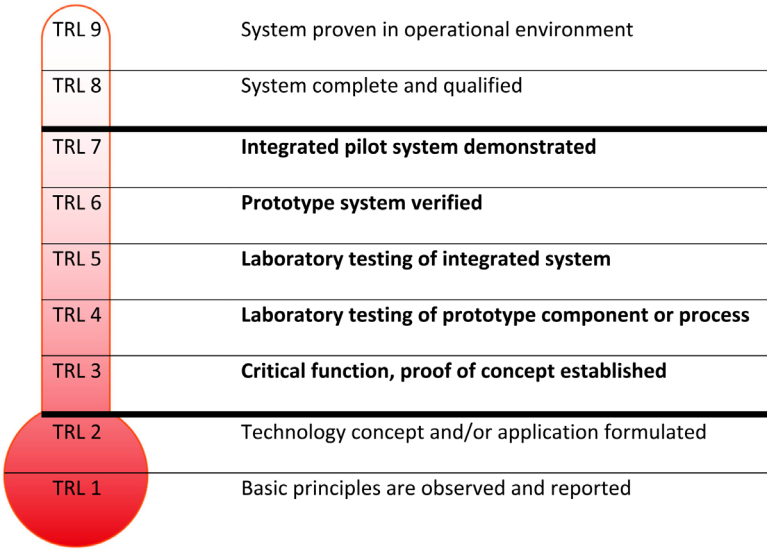

Figure 7: The TRL scale, a method for assessing the degree of technological maturity.

A generous way of looking at the AI hype cycle is where a large part of what becomes AI headlines is at a fairly low level on the TRL scale. The **Technology Readiness Level (TRL)**[179] is a way of measuring how mature something is. A low degree of maturity entails a higher technological risk. The scale was developed by NASA in the 1970s to provide a uniform manner in which to talk about technical maturity, and which would work across different kinds of technologies.

> "A technology's TRL is determined during a Technology Readiness Assessment (TRA) that examines program concepts, technology requirements, and demonstrated technology capabilities."
> – Technology readiness level (Wikipedia)

Naturally, if a technology does not have the right capabilities, it should not be implemented. On the other hand, if we look at the AI initiatives from an innovation standpoint, they are probably beneficial, but often not yet useful. Using TRL, or rather TRA meetings, it's possible to assess how ready they are for implementation.

Often, implementation is quite a long way off in the real world. Nothing wrong with that per se, but it does not always show how far there is to go before a successful solution can be ready for use.

Legal concerns about working preventively

In 2019, Swelife focused on discussing the short-term thinking whereby Sweden devotes so many resources to people who are ill, when more energy should be put into prevention. Swelife talks about this as the stages of health people may be in at different times of their lives: **HEALTHY – RISK – ILL.**

But even if there's a willingness to work preventively, to protect health instead of trying to cure the already ill, then legislation does not accommodate this.

In the summer of 2019, the three regional chairpersons for Region Västra Götaland, Skåne and Stockholm, wrote a contribution to the debate in the SKR weekly Dagens Samhälle – **Modern care requires modern legislation**[180]:

> "The conditions for the collection of patient data should be changed to enable the development of preventive health, medical services and decision support to a greater extent. This would help healthcare professionals treat patients more safely using systems that alert for specific risk factors to a patient, based on previous care visits."

and

> "The Patient Data Act requires explicit consent from the patient to process data from other caregivers. Even with regard to privacy aspects, the consent requirement is not ideally suited to the obligation of health care providers to provide good, safe patient care."

This is something that also some regions' chief legal officers supported in their article "Chief lawyers demand modern legislation on patient data" in June 2019, published behind Insiktsmedicin's pay wall.

Legal: AI for better health

The report by the National Board of Health and Welfare[181] takes up the issue of laws and regulations from a Swedish perspective and summarises it quite well. What can be regarded as news or topical in the transition to the 2020s is probably the European regulatory framework for CE labelling of medical devices. One of the news items talked about a lot in this context is how software is regulated, which includes AI technologies such as machine learning, computer vision, and more. The regulatory framework will apply from May 2021 and involve greater demands and more work for all manufacturers, importers and distributors of medical device software and information systems.

It's sometimes postulated that Sweden is determined to be best in class in the EU in interpreting GDPR in the strictest way possible, which causes us problems and lowers Sweden's competitiveness in other fields that use data.

> "In Sweden, development in the use of health data is hampered by current regulations. Legislation concerning health data is complex and difficult to appraise, which makes collaboration between health, medical services and academia difficult."
> – Camilla Waltersson Grönvall, Marie Morell, Nicklas Sandström[182] (Dagens Medicin, October 2019)

The authors of the above opinion piece suggest that Sweden should learn from Finland, which adopted new rules[183] in March 2019. These allow the secondary use of social care and healthcare data in research, development and innovation. In this way, Finland gained a clear competitive advantage internationally and a head start compared to Sweden.

The fact that regulatory frameworks may need to be duly adapted,

is also highlighted in the National Strategy for Life Sciences released at the end of 2019.

> "As precision medicine and AI are introduced into healthcare, the need for policy development increases. It's about adapting regulations, approaches and working methods to take advantage of technological developments and innovations."
> – A National Strategy for Life Sciences[184] (Government Offices of Sweden, December 2019)

It's worth mentioning here that the government has a policy development committee known as KOMET (**Committee for Technological Innovation and Ethics**), tasked with continuously providing information in such fields as precision medicine.

Part 4: Problematisation and summary

As can be expected, when something is as sought after as the things AI promises, there arises a matter for concern and sometimes anxiety about many issues. Who is able to change health and medical services, social care and help people with self-care? Is it reasonable that a start-up can become a health technology giant and impose a completely different ecosystem in the same way social media have done, or the way the advertising company Google benefits from the internet?

New companies, especially those inexperienced in the health sector, are naturally in danger of lacking the sort of experience that established companies regard as being so self-evident that they do not necessarily remember to specify it as a requirement in procurements or collaborations. The British NHSx, working on the digitisation of the NHS, in its report **Artificial Intelligence, draws attention to: How to get it right – Putting policy into practice for safe data-driven innovation in health and care**[185], to the need for a framework for controlling AI. Among other things, it mentions the need for a code of conduct, the advantage of using open standards, that algorithms must be explicable, and much more.

Many of the interviewees and questionnaire respondents quite legitimately questioned whether AI is what we really need. One of many examples concerned a patient's insulin pump that is unable to cease alerting in the middle of the night that the insulin will run out within 24 hours, a message that would be more useful when the patient is awake. Many things only require better programming, better insight into the user experience and greater involvement of relatives. We should start with the need and not be too quick to believe we're fully proficient and offer a solution that perhaps no one wants.

Are American and Chinese IT giants stepping in and taking control of healthtech?

A relatively common idea of things to come is that the AI giants in the United States and China will soon catch up with healthcare; that with their profound skills in technology and everything to do with AI, they will solve the challenges of health and medical services, just as long as they have sufficient data.

But neither the United States nor China have the same social systems as us, which can play to Sweden's advantage in offering AI to the rest of Europe and other compatible countries or organisations. The great expectations of AI at the national level are redolent of cold war competition, and seem to be both hyperbolic and counter-productive, something we encounter pretty quickly in critical reading and reviews of Kai-Fu Lee's book **AI Superpowers - China, Silicon Valley, and the New World Order**[a]. The thinking is not necessarily strange, but its focus is directed largely at the national level, when initiatives in other contexts have more to do with regions, or clusters of industries.

Attempts at subtle distinction

It's not enough that data contains evidence in the form of more or less hidden patterns, or that AI is so much more effective than people at finding these patterns. It's true that AI can already teach itself things right now, and some people believe development to be taking place exponentially; it's already happening apace and the rate of development is increasing every day. So why would it take more than just a short while for AI to outclass humans in everything related to health and healthcare? It's all to do with what our goals are. AI, being the latest wave of digitisation, nevertheless remains a technology that needs questions to answer, and unless we ask interesting questions, we'll find nothing of interest.

This is partly answered under the gap analysis heading concerning the fundamental weaknesses behind deep learning, but here are a few more attempts at subtle distinction. Is AI for better health even a technology problem? We're certainly led to believe that when we read what major technology companies are expected to achieve. However, if we assign these technology companies to an industry other than IT, it often becomes marketing, media or e-commerce. This applies to both the American and Chinese IT giants.

a AI Superpowers, ISBN: 9781328546395

They're successful at using technology to manipulate people's attention, display advertisements, suggest products and suchlike. These characteristics are important for the ability to create better health, but it's not exactly that expertise that's lacking if AI is to make its big breakthrough in the field of health.

One criticism levelled at the American IT giants is that they are at best beginners in the field of health. A number of them have previously tried and failed in their health initiatives. The Chinese giants are also minnows in health. We can direct criticism at the Chinese system in general, and how they invest in AI; that although they spend a lot of money, things are so badly organised that there is no correlation between the investment and returns[186] at all.

Neither of the two countries would deny under oath that they are anything but great AI powers. They have nothing to gain from that. However, everyone else has a lot to lose by failing to see a more subtle distinction.

Italy has more influential AI researchers than China...

In August 2019, the **Center for Data Innovation** think tank[187] published a highly quantified comparison between the United States, China and the EU. In some cases the EU is in the same class as the United States (which often leads in comparisons), and sometimes it's the last of the three. This naturally also depends on how we count and what we think will make a difference to the economy and society as a whole. For example, how great is the chance that an AI researcher's insights will inspire the population's remaining innovative ability. For example, there were 23.2 leading AI researchers per million workers in the EU in 2017, while only 1.2 in China[188].

The Center for Data Innovation also discusses the quality of AI research. One way of measuring this is the **h-index** which values productivity and the impact someone have. If we take the group that is in the top ten per cent in international ratings, we find that:

> "Through 2017, the European Union led with an estimated 5,787 researchers, ahead of the United States (5,158) and China (977). The United Kingdom (1,177), Germany (1,119), France (1,056), Italy (987), and Spain (772) combined for 5,111 such individuals."
> – Who Is Winning the AI Race: China, the EU or the United States? (Center for Data Innovations, August 2019)

Thus Italy has more influential AI researchers than all of China. Neither this nor the lead the European Union has over the United States, at least in this way of measuring, is something we hear about often.

Is it an arms race like the Cold War?

If we listen to the Swedish AI Council, then it definitely resembles an arms race. They are not alone in this view; it's also often used to explain why we need to invest.

> "When it comes to AI, Sweden is currently in the middle of an arms race with the rest of the world. The recently published AI report by Vinnova and the survey taking place in conjunction with the major AI initiative from WASP, highlight many of the obstacles that currently stand in the way of Sweden becoming a prominent, leading AI contender. It's clear that Sweden and Europe lag far behind other regions."
> – Swedish AI Council[189]

But there's also criticism of the melodramatic suggestion that there's an arms race or a race between nations. Certainly, in China the state has rigged the system[190] around the money being distributed – it all becomes a competition between communist party big shots in the various Chinese regions. On the other hand, the arms race between states is more a media narrative than something that is easy to confirm.

Not even between China and the United States, often identified as the great AI powers, does there seem to be an arms race worth talking about. Otherwise, why would Baidu, China's leading search engine, be part of a consortium[191] created by US companies exploring technological risk?

Those who excel at AI do not necessarily swear a lifelong loyalty to a nation. This becomes clear if we look at e.g. all visiting researchers on the subject who do not seem to be restricted by national borders. One reason for the talk of AI development as being a struggle between nations can be an assumption that it has great potential in autonomous warfare. What's more, Vladimir Putin is purported to have said:

> "It comes with colossal opportunities, but also threats that are difficult to predict. Whoever becomes the leader in this sphere will become the ruler of the world."
> – Vladimir Putin (Russia Today[192], 2017)

This is something that prominent people in the technology industry have taken on board, including Elon Musk[193]. However, if we get bogged down in the above quote, we've missed the point as Putin also said that Russia does not intend to monopolise the technology if it reaches a crucial level first.

> "If we become leaders in this area, we will share this know-how with the entire world, the same way we share our nuclear technologies today."
> – Vladimir Putin (The Verge[194], 2017)

If these statements had been made by the Prime Minister of Norway, no one would have reacted all that strongly.

AI professor Virginia Dignum is one well-informed person who demolishes all talk of there being a competition:

> "Press and policy makers are obsessed with the so-called AI race, and with Europe's position in it. Just this week at Davos, US executives warned that China may be winning this supposed race. In another recent article, Bloomberg pointed out that countries are rushing to not be left behind.
>
> [...]
>
> Firstly, there is no race and secondly, if there is, it's the wrong race to run.
>
> [...]
>
> There is no race because of the very definition of a race: a competition of speed, against an objective criterion, usually a clock or to a specific point. In AI developments, we don't have an end point! Nor do we have a specific time to stop. There is therefore no way to determine when and where someone will win this so-called race."
> – Virginia Dignum[195], co-founder ALLAI

Sometimes the arms race discussion is about which organisation recruits most people from desirable professions. Nor in the case of employers is it reasonable for them to tie down the labour force over time. Where people want to work changes. And if the trend in the report entitled **Best places to work 2020**[196] continues, hiring may become more difficult for e.g. Google and Facebook, who both fell in the rankings when employees rated their employers.

Exponential development? An AI revolution?

Another popular narrative is the rapid rate of development within AI. It can certainly seem fast sometimes, but is the pace really exponential? The market value of AI start-ups has of course risen exponentially during periods of huge advances. The question is whether this is a revolution, or evolution?

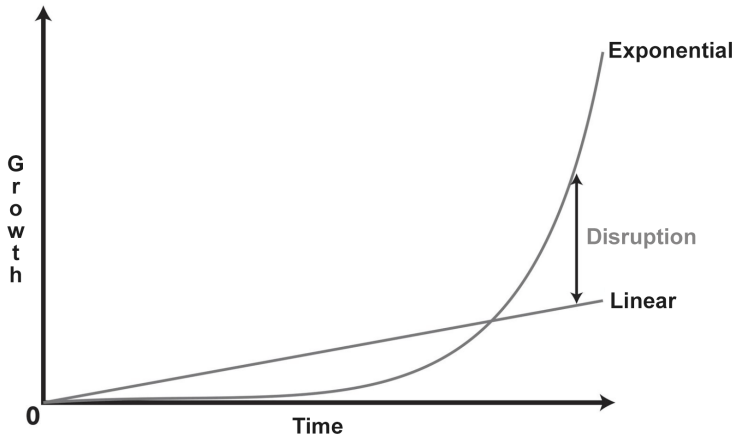

Figure 8: Difference between the rates of linear and exponential development.

Technology tends to get inflated valuations. When the IT bubble burst in 2002, there were unreasonable expectations of things that did not begin to work until fifteen years later, such as the home delivery of groceries.

> "Despite the hype, artificial intelligence will take years to significantly boost economic productivity"
> – AI and Economic Productivity: Expect Evolution, Not Revolution[197] (Jeffrey Funk at IEEE Spectrum, December 2019)

Having inflated expectations of what we can achieve with AI technology is nothing new. It's actually happened several times before. NLP AI technology has its roots in the first half of the 1950s, from what is known as the **Georgetown experiment**[198]. It was a demonstra-

tion aimed at attracting interest and funding from the US public and the authorities. The demonstrator translated 60 sentences in Russian into English by following only six grammatical rules, and it only knew a rather limited number of words.

There was huge optimism! People thought that within five years machines would be able to translate between all the languages of the world, i.e. 1960. However, this was not the case. In fact, it's only in recent years that we've begun to see it work quite well.

> "The general reliability of expert judgement in AI time line predictions is shown to be poor, a result that fits in with previous studies of expert competence."
> – The errors, insights and lessons of famous AI predictions – and what they mean for the future[199] (Stuart Armstrong et al, 2014)

Another prediction, surrounded with controversy, came from Marvin Minsky, reproduced in the magazine Life in 1970:

> "In from three to eight years we will have a machine with the general intelligence of an average human being. I mean a machine that will be able to read Shakespeare, grease a car, play office politics, tell a joke, have a fight. At that point the machine will be able to educate itself with fantastic speed. In a few months it will be at genius level and a few months after that its powers will be incalculable."
> – Marvin Minsky, according to the article Meet Shaky, the first electronic person[200] (Life, 1970)

The author of the article, Brad Darrach together with other people active in the AI field, investigated the prediction of whether a machine could achieve general intelligence within three to eight years. According to Darrach, many thought that Minsky was just a tad optimistic and many others countered that it would probably take 15 years.

> "When I checked Minsky's prophecy with other people working on Artificial Intelligence, however, many of them said that Minsky's timetable might be somewhat wishful — "give us 15 years," was a common remark — but all agreed that there would be such a machine and that it could precipitate the third Industrial Revolution, wipe out war and poverty and roll up centuries of growth in science, education and the arts…"
> – Marvin Minsky, author of the article Meet Shaky, the first electronic person (Life, 1970)

Nor did we have **artificial general intelligence** (AGI)[201] by 1985.

No matter whether these predictions are understood correctly, they reoccur regularly in the media, books or presentations at conferences. It's fanning the flames of an unsustainable hype that must be balanced sooner or later. This is what the recurrent so-called AI winter's do.

There has been criticism of the over-optimism surrounding AI almost from the beginning. One such critic was Hubert Dreyfus[202], who published ridiculing comparisons with alchemy, together with an analysis of what machines could not be expected to do, in the 1960s and 70s.

How far has AI for health advanced?

So the question is whether this over-optimism also exists in AI for better health. The headlines we read are clear. Time and time again, machines are better at something than people, often better than the best of experts. So what's the problem? Why hasn't this exponential AI development already reached e.g. healthcare?

One reason is that when, in a comparative test with e.g. a dermatologist, AI turns out to be better at something, it does not mean that the dermatologist can be replaced by AI. What AI is better at

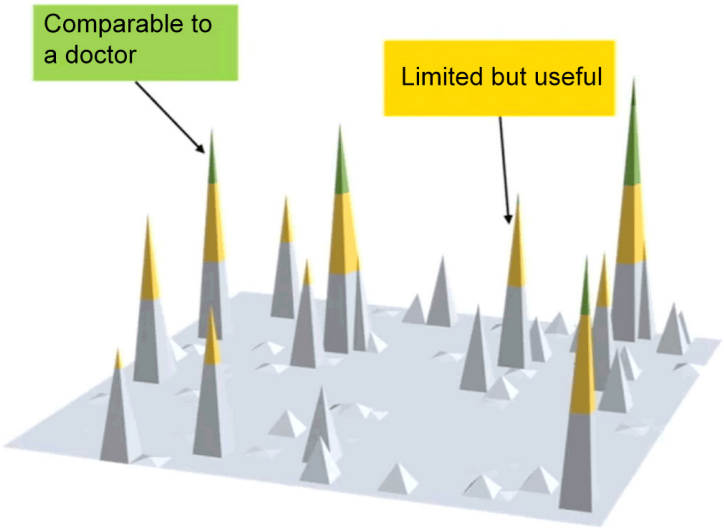

Figure 9: AI viewed as a landscape where the heights represent what AI can do today. (Image borrowed from Linköping University).

is quite a small part of the whole, even though absolutely crucial in certain cases. But AI that is great at determining a certain type of skin cancer cannot take care of everything else on its own, such as booking appointments, meeting the patient, examining the patient's vital signs, managing medical devices to take images of the skin, etc.

> ''The paradox: how can we claim on the one hand that AI is at least as good as human experts, while on the other it doesn't even seem to be useful today?''
> – Claes Lundström, Almedalen 2019

Claes Lundström[203], Professor at Linköping University and leader at the Analytic Imaging Diagnostic Arena (AIDA), talked about this during the Almedalen 2019 gathering as the sharp peaks of the AI landscape during a seminar on **How can AI move from vision to real patient benefit?**[204] Taking AI from the sheltered research workshop to the clinical wilderness is one giant, difficult step.

Because the AI landscape has peaks where AI is in the same class as human experts, but the landscape is also very expansive and contains lots of things that AI cannot help with at all, it's difficult to jump directly from an impressive research study to something that can be implemented. It's not enough to work on raising the peaks, it must also end up in a clinical, everyday context.

Where is healthcare AI performed; in the citizen's own gadgets or in healthcare's closed systems?

Most care provided is self-care, carried out by individuals themselves or their relatives. However, there is no sharp dividing line between care and self-care. Healthcare already does things to support self-care, but sometimes also offers tools where people can monitor their health in everyday life using AI technology to prevent or at least mitigate consequences.

A typical example, in the form of a mobile phone app, is MoodMapper.

> "It clearly shows that changes in everyday behaviour in particular reflect how we feel. For example, if we're getting depressed, we're more likely to make fewer calls and maybe move around less. On the other hand, if

we're manic, we're more likely to have more contacts."
– Ulla Karilampi[205], in the article Mobile app to help the bipolar (Göteborgs-Posten, July 2019)

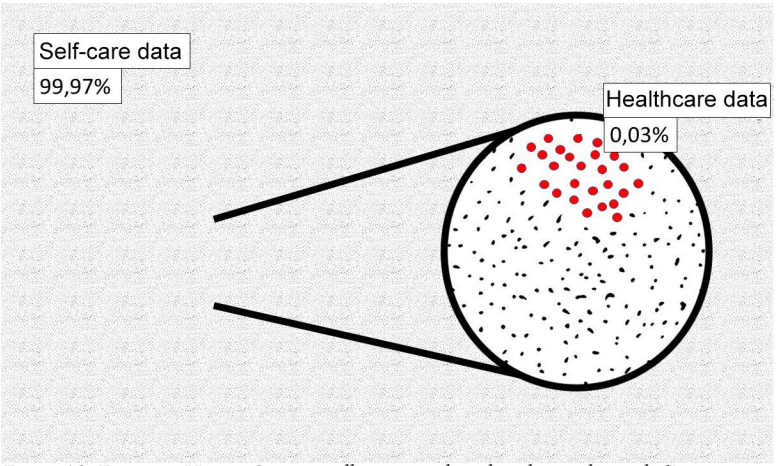

Figure 10: E-patient Hanna Svensson illustrates where her data is located. (Image on loan from H Svensson).

"Did you know that healthcare saves only 0.03% of my health data; often they don't get to see 99.97% of it, and it's not in the medical data, only in self-care."
Hanna Svensson[206] (Twitter, June 2019)

If we assume Hanna's example to be the norm, we might wonder if medical data is always where the magic of AI happens. Do we need to collaborate on the patient's data, or is the patient doing just fine without any healthcare data when it comes to AI?

The sales pitch for healthcare data says that it's calibrated and controlled equipment managed by professional users. But for the patient, it's in an abnormal environment and not under everyday conditions. What's more, it risks being somewhat misleading as its information is collected sporadically and, at least in certain contexts, is not exactly big data (which modern AI often requires).

Another way to group information concerning someone's health is to ask who controls it or has access to it. Here there are many operators. Foreign technology giants, companies manufacturing sensors or mobile phones, niche health teams such as **PatientsLikeMe,** consumer-friendly genetics companies like **23andMe**, insurance companies,

training shoe companies, and enthusiasts like e-patients and those in the quantified self movement[207].

The devil's advocate would often categorise most of these AI solutions as applied statistics or mathematics, which is probably perfectly justified criticism. At the same time, everything a machine does is a mathematical calculation, after all, it's the only way a computer can do anything at all.

Encryption, de-identification and pseudonymisation

We often talk about techniques such as encryption, de-identification or pseudonymisation. People who see risks associated with this usually point out that encryption can have flaws, or back doors[208], that are not discovered until later and which cause all content to be decrypted. Then there are quantum computers in the offing that are expected to crack at least some crypto much more easily than is possible today. But there seems to be consensus on how to design encryption to keep it out of reach of what quantum computers do better than ordinary computers. Efforts to create quantum-secure encryption are being made by the **Open Quantum Safe project**[209], among others.

One criticism of this is that it might at least be worth hoarding information about certain people who may prove to be particularly important in the future, even if it's impossible to crack it at the time of collection. It remains to be seen if this kind of interest from e.g. intelligence organisations will affect common man in the same way as world leaders such as Angela Merkel[210].

One aggravating factor lies in the assertion that 'the internet never forgets'. Getting hold of old data when the encryption can be broken might become a reality in the future that will affect many more people than the most powerful.

Breaking encryption is nothing new. Perhaps the most famous code breaker was the genius grandfather of AI, Alan Turing, who helped crack the German radio encryption codes during the Second World War.

Nor is de-identification a magic solution to the problem, as Andy Coravos of biomarker specialists **Elektra Labs** notes (bold type added):

> "How many people here think you could de-identify your genome?" "Probably not, because your genome is unique to you. It's the same with most of the biospecimens coming off a lot of wearables and sen-

sors — **I am uniquely identifiable with 30 seconds of walk data**."
– What if AI in health care is the next asbestos?[211] (STAT)

Information security is a difficult topic and one that needs to be discussed by more sections of society than just IT security experts. What do we think is acceptable risk?

In the case of data that has no protection value at all, it may be possible to take advantage of the investments in storage and computing capacity by other organisations' data centres. At the same time, none of the respondents expressed this as an urgent need. They say rather that when the need arises, they already have capacity and they know who to turn to in-house. It's not easy to see whether all the talk about the need for public clouds bandied about by third parties or extra-European IT giants is based on any actual demand when it comes to AI for better health.

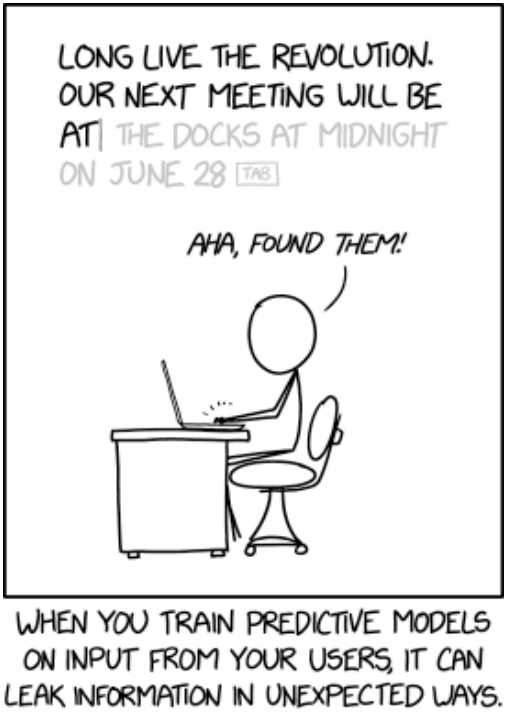

Figure 11: As usual, the xkcd website is joking about technology.

"Anonymity is a shield from the tyranny of the majority"
– John Paul Stevens, U.S. Supreme Court

In the well-known data leaks of recent years, it has sometimes been possible to link what in a single system appears to be anonymous data to individuals by adding more data sources. As Claudia Diaz[212] pointed out during a lecture at a Chalmers seminar on digitisation in 2018, this is made even easier by the existence of the internet as data now flows more easily than ever before.

In the lecture, Diaz cited the book Frankenstein as an example; it was originally published anonymously, as in the 19th century the fact that the author was a woman could be bad publicity. Talk about the tyranny of the majority. Once it was revealed that the author was Mary Shelley, her anonymity was blown for good. And today, with more than half the world's population having access to the internet, information about a broken anonymity spreads more quickly and easily than ever.

Of course, we must remember that all information processing involves risks, whether we use third-country cloud companies, have our own server hall in a bombproof shelter or fax patient records.

Or as Anna Troberg, party leader for the single-issue Pirate Party, wrote in 2013:

"First of all, history is yet more proof that all databases leak. Sometimes it happens via deliberate leaks, sometimes because of carelessness, sometimes because they are hacked from outside; the only thing we can be certain of is that they will leak sooner or later. If it hasn't happened already, it's just a matter of time before a database that contains information about you will also leak. This is something we should all keep in the back of our minds."
– Media pilloried[213] (SvD, December 2013)

Since the above was written, 2.7 million telephone calls to the 1177 Healthcare Guide service got exposed, unprotected, to the Internet. Hopefully, no one other than the journalists at Computer Sweden have downloaded any recordings.

"[…] one of the biggest failures of all time when it comes to Swedish patient safety and privacy. We have come across 2.7 million recorded telephone calls to the 1177 guide service number on an open web server, utterly without password protection or other security. The calls date back to 2013 and concern 170,000 hours of sensitive calls that anyone can download or listen to."

– 2.7 million recorded calls to the 1177 healthcare guide utterly unprotected on the internet[214] (Computer Sweden, February 2019)

Unfortunately, this is far from the only example where healthcare data has been disseminated. There's often a lot of attention when a healthcare professional is convicted of the unauthorised reading of someone's medical records.

Naturally, offences like those committed by individuals must be prosecuted. But there is a huge difference in scale when an individual is found to abuse his or her authority in health and social care; it affects but one or a few individuals. Compare this to the fact that sensitive data belonging to a great many people is available as a commodity on the dark web[215] or is made publicly available as happened in 2014[216] when the private images of a great number of celebrities were leaked online.

The centralisation of healthcare and social care data brings with it huge responsibility. AI techniques like federated learning[217] may help each of us keep our data. But in this case, all the operators that want to promote health must truly collaborate – for real!

There a great deal of focus on the legal challenges of AI in general, but naturally also when it will be applied to health and medical services, given the particularly sensitive personal data involved. In some cases, it may not be challenges, but rather a lack of consensus or precedent that is of concern. With regard to healthcare law, Swelife's report **Person-centred data and the law**[218] from 2018 is a good read for an overview. AI law is not only about the use of foreign cloud services, even though we sometimes think so, but also about patient safety, patient data, transparency and medical device regulations, among other things.

Broadly speaking, there was unanimity concerning the things mentioned in the interviews from around the country. The message was "help us work in peace". Sometimes this means money, other times the need for support with the medical device regulations for software, in both the domestic and US markets.

The big question is whether the value of AI for better health will live up to expectations. This is not entirely self-evident. However, it's clear that all the energy now invested in AI will be of benefit in health and medical services, which are facing major challenges, partly because of demographic change.

In conclusion…

The general theme of this report is the huge hopes for the things AI technology can contribute; that there certainly are challenges, and that the new AI variants are conspicuous by their absence in the clinician's everyday world.

Things are this way for a number of reasons, including the fact that the existing regulations are not fully adapted or established in the form of clear precedents. Another reason is that AI technology is better at some things than human experts, but not versatile enough to take part in the daily life of a clinician, or even a citizen in self-care.

Nor is it easy to compare what one organisation considers to be AI with another since there is no established, unambiguous definition. People who have worked with AI for better health for decades have been talking about a different generation of AI, so-called expert systems, while the new wave of AI, which began in 2012, is based on deep learning. In other words, it's extremely rare for someone to have any extensive experience of "today's AI".

But of course that depends on our definition of AI. Those who include different forms of automation, e.g. **Robotic Process Automation**, can trace their experiences a little way back into the 20th century. Were I to use such an inclusive definition, then I've been working with AI since 1997, although I would rather openly admit to it being software agents I built in Lotus Notes. I for one don't think it's AI.

January, 2020
Marcus Österberg, for the Swelife AI project

Appendices

The following is a list of the resources discovered and created during the course of the work.

- **Appendix 1:** Data sources, competitions and more that are relevant to AI for better health

Competitions

It's possible to compete in data science by providing the best solution to a problem based on open-source data. Below are some competitions and organisers:

- **The ISIC Challenge**[219] – detecting skin diseases
- **BraTS**[220] – multi-modal brain tumour segmentation
- **The Turing test / the Loebner Prize**[221] – getting a person to believe he or she is talking to a person (even though it's a machine at the other end)
- **Kaggle**[222] – organiser of many different competitions, often on health

Data sources

There are loads of different data sources. Some have open licenses that allow you to do what you want with the content, others are open but not for re-use commercially. Some data sources are more well known, sometimes called reference data sources, as they are used as references.

Appendix 2 provides a longer list which is interesting if you want to see data sources about demographics or things that can be used for sentiment analysis, etc.

Reference data sources:

- **HAM10000**[223] – images in dermatology
- **ASAN dataset**[224] – Clinical diagnosis based on images
- **CAMLYON**[225] – Images to detect metastases in breast tissue

Other data sources:

- **International Skin Imaging Collaboration (ISIC)**[226] – projects for detecting skin cancer
- **CheXNet**[227] – Stanford's data set for identifying pneumonia through thorax images
- **Healthdata.gov**[228] – Collection of data sources from US government agencies
- **MIMIC Critical Care Database**[229] – Collection of health data sets from 40,000 patients. Including demographics, vital parameters and drugs.
- **STRIDES**[230] – Biomedical data

- **NIH Data Sharing Repositories**[231] – Health data sources funded by the US National Institute of Health (NIH).

Appendix 1

Data sources, competitions and more that are relevant to AI for better health

Miscellaneous, with more or less strong links to AI or life sciences

Alliance on Artificial Intelligence
Founded by three Dutchmen who are members of the EU HLEG on AI. Among others, Virginia Dignum.
Internet: http://allai.nl

EurAI (European Association for Artificial Intelligence)
Internet: https://www.eurai.org

HealthTech Nordic
Internet: http://healthtechnordic.com

OpenAI – California, USA
"OpenAI's mission is to ensure that artificial general intelligence benefits all of humanity. We're a team of a hundred people based in San Francisco, California."
Internet: https://openai.com

Future of Life Institute
Inter alia AI. Founded by Max Tegmark and others.
Internet: https://futureoflife.org

CIFAR, Canada
Internet: https://www.cifar.ca/ai
Ethics, sustainability, etc.

Center for Humane Technology
"Our primary goal was to move public discourse in Silicon Valley from a cacophony of disconnected grievances and scandals ("they took our data!") to a meaningful humane agenda of actions that address the vast surface area of problems arising from technology's race for attention.
In last week's presentation, we explained how seemingly separate problems – tech addiction, teen depression, shortening attention spans, political polarisation, the breakdown of truth, outrage-ification of culture, and the rise of vanity/micro-celebrity culture – are actually not separate issues. They are all symptoms of one underlying problem: the race between tech giants to capture human attention, which becomes a race to overwhelm human weaknesses. Put together, that race creates "human downgrading.""
Internet: https://humanetech.com

AI for Good Foundation
Internet: https://ai4good.org

Human-Centered AI
Internet: https://hai.stanford.edu

High-Level Expert Group on Artificial Intelligence – EU
Report released in the spring of 2019.
Internet: https://ec.europa.eu/digital-single-market/en/artificial-intelligence
Internet: https://ec.europa.eu/digital-single-market/en/high-level-expert-group-artificial-intelligence

The Nightingale Initiative (USA)
Data platform in the mix between medicine and data science, for the benefit of the public good.
Internet: http://www.nighvision.net

Conferences
Where can we find examples of leading-edge organisations?

HealthConf (Portugal)
Internet: https://websummit.com/healthconf

World Congress on Healthcare & Technologies (UK)
Internet: https://europe.healthconferences.org

Intelligent Health AI (Switzerland)
In Basel 2019, in London February 2020, and also in September 2020 in a location to be determined.
Internet: https://intelligenthealth.ai

Vitalis (Sweden)
Internet: https://vitalis.nu

InnoHEALTH (India)
Internet: http://innohealth.in

HIMMS Europe (Finland 2020)
Internet: https://www.himsseuropeconference.eu

HIMMS (USA)
Internet: https://www.himssconference.org

AMIA Informatics Summit (USA)
Had a data science track in 2019.
Internet: https://www.amia.org/summit2019

Bio-IT World Conference (USA)
Inter alia block chains, AI, machine learning, deep learning.
Internet: http://www.giiconference.com/chi653337/

AI Healthcare Innovation Summit (USA)
Internet: https://www.theinnovationenterprise.com/summits/ai-healthcare-san-francisco

Big Data & Analytics in Healthcare Summit (USA)
Inter alia on AI and machine-learning.
Internet: https://10times.com/big-data-analytics-in-healthcare

HLTH (USA)
Has a track dedicated to AI.
Internet: https://hlth.com

SXSW Health & Medtech (USA)
Internet: https://www.sxsw.com/conference/health-and-medtech/

SCOPE (USA)
Had "AI in Clinical Research" as one of the tracks in 2019.
Internet: https://www.scopesummit.com

Connected Health (USA)
Has AI, machine learning and analytics on the schedule.
Internet: https://www.connectedhealthconf.org/boston/2019

Exponential Medicine (USA)
AI, quantum engineering, etc. on the schedule.
Internet: https://exponential.singularityu.org/medicine/

Healthcare Innovation Summit (US, multiple venues)
Inter alia on AI and data analytics.
Internet: https://www.hcinnovationgroup.com/summits

RSNA Annual Meeting (USA)
Major radiology conference.
Internet: https://www.rsna.org/annual-meeting

AI Applications in Biopharma Summit (USA)
"A new kind of collaborative experience where the industry's top science minds, AI technology experts and strategy leaders share detailed use cases to help each other build out the adoption of AI technology to improve patients' lives.
The Summit is a 'who's who' of AI in biopharma and is your chance to engage in deep coverage of AI in drug discovery, clinical development and real-world evidence from an elite speaker line up including Sanofi, Novartis Institutes for Biomedical Research, Pfizer, Biogen, AstraZeneca, Boehringer Ingelheim Pharmaceuticals, Janssen, GSK and more who are pioneers in the movement."
Internet: https://www.aiapplicationssummit.com/biopharma/

AI-ML Clinical Development (USA)
Internet: https://ai-clinicaldevelopment.com

MedInfo (France)
Some AI and analytics on the programme in 2019.
Internet: https://medinfo-lyon.org/en/

Unsorted

Crunchbase - list of start-ups
There were 8000 start-ups in machine learning in June 2019.
Internet: https://www.crunchbase.com

International investigations and assignments

AI WATCH – EU
"Monitor the development, uptake and impact of Artificial Intelligence for Europe"
Internet: https://ec.europa.eu/knowledge4policy/ai-watch_en

Collaborations

Declaration on AI in the Nordic-Baltic Region
"Declaration on AI in the Nordic-Baltic Region" prepared in May 2018 by ministers responsible for digital development in Denmark, Estonia, Finland, the Faroe Isles, Iceland, Latvia, Lithuania, Norway and Sweden. The collaboration seeks to develop and promote the use of artificial intelligence as an aid to humanity. Through collaboration, the countries aim to focus more specifically on:

- Improving opportunities for skills development
- Promoting access to data
- Developing ethical, transparent guidelines, principals, standards and values
- Developing hardware and software standards that engender integrity, security, and trust
- Make sure AI has a prominent role in European discussions on the Digital Single Market.
- Avoiding unnecessary regulation
- Using the Nordic Council of Ministers to promote collaboration."

https://www.regeringen.se/49a602/globalassets/regeringen/dokument/naringsdepartementet/20180514_nmr_deklaration-slutlig-webb.pdf

Nordic Five Tech
Chalmers, KTH, Aalto from Finland, DTU from Denmark and NTNU from Norway are all involved.
Internet: http://www.nordicfivetech.org

"App Stores" and developer packs

Nvidia Clara Platform
"NVIDIA Clara™ is a computational platform that makes it easy to build, manage,

and deploy intelligent medical imaging workflows and instruments. Developers use Clara to increase diagnostic accuracy and the quality of scans to enhance patient outcomes and reduce the cost of care."
Internet: https://www.nvidia.com/en-us/healthcare/

Nuance AI Marketplace
Internet:
https://aimarketplace.portal.azure-api.net/ och https://www.nuance.com/healthcare/diagnostics-solutions/ai-marketplace.html

Data sources

Google Dataset Search
Internet: https://datasetsearch.research.google.com

NLP

WIKIPEDIA LINKS DATA
https://code.google.com/archive/p/wiki-links/downloads

SENTIMENT ANALYSIS – STANFORD SENTIMENT TREEBANK
https://nlp.stanford.edu/sentiment/code.html

TWITTER US AIRLINE SENTIMENT
https://www.kaggle.com/crowdflower/twitter-airline-sentiment

Demographics

WORLD BANK OPEN DATA
https://data.worldbank.org

IMF DATA
https://www.imf.org/en/Data

Computer vision

GOOGLE'S OPEN IMAGES
Nine million categorised images, in more than 6,000 categories. The images are licensed under Creative Commons.
Internet: https://ai.googleblog.com/2016/09/introducing-open-images-dataset.html

Health

HEALTHDATA.GOV
"a resource from the US federal government providing data to improve health outcomes for the US population."
Internet: https://healthdata.gov/search/type/dataset

MIMC CRITICAL CARE DATABASE
"Datasets for Computational Physiology with unidentified health data from 40,000 critical care patients (demographics, vital signs, medications, etc.)"
Internet: https://mimic.physionet.org

DATA USA
Has data from "industries" such as hospitals, among other things.
Internet: https://datausa.io

NATIONAL INSTITUTE OF HEALTH (USA)
Their data science office can be found here:
https://datascience.nih.gov
They also have Common Data Elements (CDE), which is data common to multiple data sources, i.e. references that bridge the gaps between different data sources.
https://www.nlm.nih.gov/cde/index.html

STRIDES – BIOMEDICAL DATA
Internet: https://datascience.nih.gov/strides
NIH Data Sharing Repositories
A long list of different types of data sources supported by NIH.
Internet: https://www.nlm.nih.gov/NIHbmic/nih_data_sharing_repositories.html

EU OPEN DATA PORTAL
Has a category for Health, and it may conceal interesting things under the other categories.
Internet: https://data.europa.eu/euodp/data/

EUROPEAN DATA PORTAL
Has category for Health. They harvest data sets from open data sets in different countries.
Internet:
https://www.europeandataportal.eu/data/datasets?categories=heal&page=1&locale=en

ISIC
Internet: https://www.isic-archive.com

STANFORD CHEXNET
Internet: https://stanfordmlgroup.github.io/projects/chexnet/

Speech

FLICKR AUDIO CAPTION CORPUS
"40,000 spoken captions from 8,000 images in a manageable size. It was initially designed for unsupervised speech pattern discovery."
Internet: https://groups.csail.mit.edu/sls/downloads/flickraudio/

SPEECH COMMANDS DATASET
"A continuously evolving collection of one-second-long utterances from thousands of different people. It's still receiving contributions and is useful for building basic voice interfaces."
Internet: https://ai.googleblog.com/2017/08/launching-speech-commands-dataset.html

Sound

FSD (FREESOUND)
"A collection of everyday sounds collected by contribution under an open source license."

Internet: https://annotator.freesound.org/fsd/

ENVIRONMENTAL AUDIO DATASETS
"It does contain some proprietary information, but a large portion is open source. It contains sound events tables and acoustic scenes tables."
Internet: http://www.cs.tut.fi/~heittolt/datasets

Miscellaneous

OPENDATASOFT
"2600 data portals arranged in an interactive map formation or by country list. If you're looking for it, chances are, it's here."
Internet: https://www.opendatasoft.com/a-comprehensive-list-of-all-open-data-portals-around-the-world/

KAGGLE
"an online community of data scientists where users can work with and upload datasets. It's a community and a resource in one."
Internet: http://www.kaggle.com

UCI MACHINE LEARNING REPOSITORY
"User contributed datasets in various levels of cleanliness. It's one of the originals, and you can download datasets without having to register anything."
Internet: http://mlr.cs.umass.edu/ml/

STOCK-TAKE: PERSONAL HEALTH TRAIN
Dutch initiative to link the various sources of personal health data.
Internet: https://www.dtls.nl/fair-data/personal-health-train/

Competitions

Pure competitions and also reference data sets with which to complete while learning to master them.

THE ISIC CHALLENGE – DETECTING SKIN DISEASES
Internet: https://www.isic-archive.com

KAGGLE - COMPETITIONS IN SEVERAL CATEGORIES
Has both competitions and open data sources.
Internet: https://www.kaggle.com

THE TURING TEST / LOEBNER PRIZE – UNMASK A COMPUTER IN CONVERSATION
Internet: http://www.aisb.org.uk/events/loebner-prize

BRATS (MULTIMODAL BRAIN TUMOR SEGMENTATION CHALLENGE)
Where in an image is the brain tumor?
Internet: http://braintumorsegmentation.org

Reference data sources

There is a list available here: https://benchmarks.ai

- MNIST - handwritten text
- CIFAR-10/100 - classifying images
- SVHN - street numbers
- STL-10 - image recognition
- MPI Sintel - optical flow
- PASCAL VOC Object - detection/segmentation
- COCO Object Detection. Panoptic Segmentation
- KITTI Optical Flow
- NIST 2000 Switchboard - speech, telephone conversation
- WMT English ->? - machine translation, inter alia to Finnish

IMAGENET - IMAGE DATABASE

"Dataset containing over 14 million images available for download in different formats. It also includes API integration and is organised according to the WordNet hierarchy."
Internet: http://www.image-net.org

WordNet

Word Database.
Internet: https://wordnet.princeton.edu/download

ASAN Dataset - clinical diagnosis based on images

Internet: https://api.medicalphoto.org/datasets.html

HAM10000- images for dermatology

Internet: https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/DBW86T

CAMLYON - Images for detecting metastases in breast tissue

Web: http://gigadb.org/dataset/100439

Rules and regulations

EU GDPR: Article 22 - Automated individual decision-making, including profiling

"The data subject shall have the right not to be subject to a decision based solely on automated processing, including profiling, which produces legal effects concerning him or her or similarly significantly affects him or her. "
However, does not apply if there is explicit consent:
"of the data subject means any freely given, specific, informed and unambiguous indication of the data subject's wishes by which he or she, by a statement or by a clear affirmative action, signifies agreement to the processing of personal data relating to him or her;"
Internet: http://www.privacy-regulation.eu/en/article-22-automated-individual-decision-making-including-profiling-GDPR.htm

EU MDR Classification: Rule 11, Medical Device Software

"Software intended to provide information which is used to take decisions with diagnosis or therapeutic purposes is classified as class IIa, except if such decisions have an impact that may cause:

- Death or an irreversible deterioration of a person's state of health, in which case it's in class III; or
- Serious deterioration of a person's state of health or a surgical intervention, in which case it's classified as class IIb.

Software intended to monitor physiological processes is classified as class IIa, except if it's intended for monitoring of vital physiological parameters, where the nature of variations of those parameters is such that it could result in immediate danger to the patient, in which case it's classified as class IIb.
All other software are classified as class I."
Internet: https://www.johner-institute.com/articles/regulatory-affairs/and-more/mdr-rule-11-software/

EU Open data & PSI directive (2019)

"All public sector content that can be accessed under national access to documents rules is in principle freely available for re-use."
Internet: http://europa.eu/rapid/press-release_IP-19-525_en.htm
Finland: Secondary use of health and social data
Internet: https://stm.fi/en/secondary-use-of-health-and-social-data
US HIPAA - Health insurance portability and accountability act
Info: https://en.wikipedia.org/wiki/Health_Insurance_Portability_and_Accountability_Act

Thank you to:

Proofreaders, sounding boards and others for their help. Especially:

- Almira Osmanovic Thunström
- Anders Frick
- Gino Almondo
- Hanna Svensson
- Jessica Ylvén
- Lars Lindsköld
- Magnus Kjellberg
- Margreth Jonson Lekare
- Maria Lidholm
- Marie Wedlin
- Mia Isacson
- Niklas Angmyr
- Pål Jacobsen
- Sonja Aits

Intellectual property references

Figure 1: Cognilytica – https://www.cognilytica.com/2019/04/04/the-seven-patterns-of-ai/
Figure 2: Vinnova – https://www.vinnova.se/globalassets/mikrosajter/ai/rapport-om-ai-miljoer-i-sverige.pdf
Figure 3: Wikipedia – https://sv.wikipedia.org/wiki/Hajpkurva#/media/Fil:Hype-Cycle-General.png
Figure 4: Sculley et al 2015
Figure 5: OECD
Figure 6: Stanford DAWNBench
Figure 7: TRL by Fasterholdt et al 2018, license CC-BY 2.0 https://www.researchgate.net/figure/Defining-early-with-Technology-Readiness-Levels-TRL-based-on-early-NASA-model_fig1_328777621
Figure 9: Linköpings Universitet & Claes Lundström
Figure 10: Hanna Svensson – https://twitter.com/svenssonhannase/status/1145299251028779009
Figure 11: xkcd – https://xkcd.com/2169/
Cover illustration: pikisuperstar / Freepik

Other images are CC0.

Endnotes

1 https://www.registerforskning.se
2 http://www.sou.gov.se/wp-content/uploads/2017/05/F%C3%B6rbjuden-framtid-Den-digitala-kommunen-slutrapport-2018-12-07.pd
3 https://www.dagenssamhalle.se/debatt/en-modern-vard-kraver-en-moderna-re-lagstiftning-28416
4 https://www.digg.se/globalassets/slutrapport---framja-den-offentliga-forvaltningens-formaga-att-anvanda-ai.pdf
5 https://creativecommons.org/publicdomain/zero/1.0/deed.sv
6 https://sv.wikipedia.org/wiki/Technology_Readiness_Level
7 https://en.wikipedia.org/wiki/AI_effect
8 http://www.forskasverige.se
9 https://en.wikipedia.org/wiki/Omics
10 https://www.socialstyrelsen.se/globalassets/sharepoint-dokument/artikelkatalog/ovrigt/2019-10-6431.pdf
11 https://en.wikipedia.org/wiki/Robotic_process_automation
12 https://marcusosterberg.se/rpa.html
13 https://sv.wikipedia.org/wiki/Business_intelligence
14 https://sv.wikipedia.org/wiki/Datautvinning
15 https://en.wikipedia.org/wiki/Extract,_transform,_load
16 https://en.wikipedia.org/wiki/Symbolic_artificial_intelligence
17 https://en.wikipedia.org/wiki/Online_machine_learning
18 https://fof.se/tidning/2015/7/artikel/kan-vi-skapa-intelligens
19 https://fof.se/tidning/2015/7/artikel/kan-vi-skapa-intelligens
20 https://www.cognilytica.com/2019/04/04/the-seven-patterns-of-ai/
21 https://www.vk.se/2019-03-29/har-halsar-roboten-aida-dig-valkommen-till-tandlakaren
22 https://en.wikipedia.org/wiki/Deep_learning#Deep_learning_revolution
23 https://sv.wikipedia.org/wiki/Djupinl%C3%A4rning
24 https://sv.wikipedia.org/wiki/Artificiellt_neuronn%C3%A4t
25 https://sverigesradio.se/sida/artikel.aspx?programid=83&artikel=7212558
26 https://sv.wikipedia.org/wiki/Datalagringsdirektivet
27 https://en.wikipedia.org/wiki/Business_Model_Canvas
28 https://en.wikipedia.org/wiki/Business_intelligence
29 https://liu.se/forskning/aida
30 https://www.visualsweden.se/aktuella-projekt/medicinsk-digital-tvilling-medigit/
31 https://www.ai.se
32 http://scapis.se

33 https://picta.lindholmen.se/projekt-1/presise-prehospitalt-beslutsstod-identifiering-av-sepsisrisk
34 https://www.vinnova.se/p/svenskt-sprakdatalabb/
35 https://www.vinnova.se/nyheter/2019/12/nya-datalabb-ska-snabba-pa-utvecklingen-inom-ai/
36 https://www.chalmers.se/en/centres/chair/Pages/default.aspx
37 https://www.sahlgrenska.se/nyheter/nyheter/chalmers-och-sahlgrenska-universitetssjukhuset-i-forskningssamarbete-kring-ai-i-sjukvarden/
38 https://appva.com/sv/2018/12/appva-lanserar-ai-for-kva-rapportering/
39 https://news.cision.com/se/marianne-och-marcus-wallenbergs-stiftelse/r/wallenbergstiftelserna-satsar-pa-humanistisk--och-samhallsvetenskaplig-forskning-inom-ai-och-autonom,c2831620
40 https://iotsverige.se/skelleftea-kommun/
41 https://www.karolinska.se/iaid
42 https://www.pathfx.org
43 https://www.svt.se/nyheter/lokalt/dalarna/ny-metod-for-att-upptacka-mun-cancer-testas-i-dalarna
44 https://www.h2healthhub.com
45 https://www.medtechlabs.se
46 https://www.kth.se/forskning/forskningsplattformar/lst
47 https://sv.wikipedia.org/wiki/Korrelation
48 https://sv.wikipedia.org/wiki/Kausalitet
49 https://www.aisustainability.org
50 http://www.his.se/Forskning/Systembiologi/Translationell-Bioinformatik/DMDPipe/
51 https://www.mediconvillage.se
52 https://www.smileincubator.life
53 http://healthtechnordic.com
54 https://www.aiten.se
55 https://www.aweria.com
56 https://boneprox.com
57 http://www.rapidus.se/mobile-heights-leder-ai-satsning-med-sony/
58 http://www.mynewsdesk.com/se/helsingborg/pressreleases/ai-centret-get-punkt-ai-etableras-i-helsingborg-2938698
59 https://halsoteknikcentrum.hh.se/aiway/
60 https://www.vinnova.se/globalassets/mikrosajter/ai/rapport-om-ai-miljoer-i-sverige.pdf
61 https://ai-competence.se
62 https://www.sais.se
63 https://news.cision.com/se/marianne-och-marcus-wallenbergs-stiftelse/r/wallenbergstiftelserna-satsar-pa-humanistisk--och-samhallsvetenskaplig-forskning-inom-ai-och-autonom,c2831620
64 https://www.umu.se/nyheter/hundra-miljoner-over-tio-ar-i-ai-satsning_8013383/
65 https://www.socialstyrelsen.se/om-socialstyrelsen/pressrum/press/mycket-forskning-men-begransad-anvandning-av-ai-i-halso--och-sjukvarden/
66 (page 47) https://www.socialstyrelsen.se/globalassets/sharepoint-dokument/artikelkatalog/ovrigt/2019-10-6431.pdf
67 https://ec.europa.eu/jrc/en/publication/artificial-intelligence-european-per-

spective
68 https://www.crunchbase.com/search/hubs/field/hubs/category_groups/artificial-intelligence-e551hj.
69 https://www.cifar.ca/ai
70 https://www.cifar.ca/docs/default-source/ai-reports/ai_annualreport2019_web.pdf?sfvrsn=244ded44_17
71 https://medium.com/@eif4smes/why-do-we-need-to-support-blockchain-and-ai-in-europe-30a122383f33
72 https://ec.europa.eu/digital-single-market/en/high-level-expert-group-artificial-intelligence
73 https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=60441
74 https://en.wikipedia.org/wiki/Health_Insurance_Portability_and_Accountability_Act
75 https://www.fda.gov/downloads/medicaldevices/digitalhealth/ucm568735.pdf
76 https://www.fda.gov/regulatory-information/search-fda-guidance-documents/clinical-decision-support-software samt själva utkastet https://www.fda.gov/media/109618/download
77 https://www.fda.gov/news-events/press-announcements/statement-new-steps-advance-digital-health-policies-encourage-innovation-and-enable-efficient-and
78 https://www.fda.gov/news-events/press-announcements/statement-fda-commissioner-scott-gottlieb-md-agencys-new-actions-under-pre-cert-pilot-program
79 ISBN: 9781541644632
80 https://www.statnews.com/2019/04/02/fda-new-rules-for-artificial-intelligence-in-medicine/
81 Survey Analysis: AI and ML Development Strategies, Motivators and Adoption Challenges
82 https://sloanreview.mit.edu/projects/winning-with-ai/
83 https://sv.wikipedia.org/wiki/Hajpkurva
84 https://dka.global/new-drugs-in-days/
85 https://www.nature.com/articles/s41587-019-0224-x
86 https://www.linkedin.com/pulse/pharmas-alphago-moment-first-time-ai-has-designed-new-colangelo/
87 https://verily.com
88 https://verily.com/projects/
89 https://neuralink.com
90 https://www.biorxiv.org/content/10.1101/703801v2
91 https://www.bloomberg.com/news/articles/2019-01-22/germany-nearly-catches-korea-as-innovation-champ-u-s-rebounds
92 https://computersweden.idg.se/2.2683/1.718332/digiplex-datacenterbolag
93 https://en.wikipedia.org/wiki/CLOUD_Act
94 http://www.esamverka.se/nyheter/nyheter/2018-11-12-esam-ser-risker-med-molntjanster-i-offentlig-sektor.html
95 https://computersweden.idg.se/2.2683/1.724249/regeringen-sverige-statligt-moln
96 https://www.registerforskning.se/sv/register-i-sverige/metadataverktyget-rut/
97 https://news.cision.com/se/goteborgs-universitet/r/offentlig-sektor-behover-bli-battre-pa-att-nyttja-digitaliseringen,c2813509
98 https://www.digitalforvaltning.se/wp-content/uploads/2019/05/Statusrapport-Digital-Mognad2019.pdf

99 https://sv.wikipedia.org/wiki/Auskultation_(medicin)
100 https://en.wikipedia.org/wiki/Design_thinking
101 https://deepmind.com/blog/article/alphastar-mastering-real-time-strategy-game-starcraft-ii
102 https://en.wikipedia.org/wiki/Convolutional_neural_network
103 https://jamanetwork.com/journals/jama/article-abstract/2701666
104 https://en.wikipedia.org/wiki/Transfer_learning
105 https://en.wikipedia.org/wiki/Generative_adversarial_network
106 https://en.wikipedia.org/wiki/One-shot_learning
107 https://en.wikipedia.org/wiki/Receiver_operating_characteristic#Area_under_the_curve
108 https://en.wikipedia.org/wiki/Natural-language_understanding
109 https://papers.nips.cc/paper/5656-hidden-technical-debt-in-machine-learning-systems.pdf
110 https://liu.se/nyhet/ai-forskning-i-konkurrens-med-giganterna
111 https://www.regeringen.se/informationsmaterial/2018/05/nationell-inriktning-for-artificiell-intelligens/
112 https://youtu.be/T5K9Rw5tufU?t=312
113 https://marcusosterberg.se/virginia-dignum-2019.html
114 https://sv.wikipedia.org/wiki/L%C3%A4nkade_data
115 https://oppnadata.se/2019/11/26/sa-far-sverige-en-battre-plats-i-ourdata-index/
116 https://sv.wikipedia.org/wiki/TensorFlow
117 https://facebook.github.io/prophet/
118 https://www.inera.se/om-inera/breddat-agande-i-inera/
119 https://www.kolada.se
120 http://kvalitetsregister.se
121 https://computersweden.idg.se/2.2683/1.725805/forsenat-projekt-varden-skadestand
122 https://thenewinquiry.com/the-anxieties-of-big-data/
123 https://skl.se/4.27efeeb616e088819f6c7cf8.html
124 https://www.peterhedenskog.com/blog/2019/11/drommen-om-molnet/
125 https://www.linkedin.com/pulse/skls-vilseledning-f%25C3%25B6r-molntj%25C3%25A4nster-magnus-kolsj%25C3%25B6/
126 https://sv.wikipedia.org/wiki/PSI-lagen
127 http://www.esamverka.se/nyheter/nyheter/2019-12-13-uppdaterad-vagledning-om-outsourcing-och-sekretess.html
128 https://skr.se/naringslivarbetedigitalisering/digitalisering/nyhetsarkivdigitalisering/arkivdigitalisering/skrstarintebakomesamsnyavagledningommolntjanster.31199.html
129 https://edri.org/microsoft-office-365-banned-from-german-schools-over-privacy-concerns/
130 https://www.privacycompany.eu/blogpost-en/new-dpia-on-microsoft-office-and-windows-software-still-privacy-risks-remaining-short-blog
131 https://computersweden.idg.se/2.2683/1.722011/office-365-gdpr-godkant
132 https://sv.wikipedia.org/wiki/Foreign_Intelligence_Surveillance_Act
133 https://en.wikipedia.org/wiki/CLOUD_Act
134 https://www.justice.gov/opa/press-release/file/1153446/download
135 https://en.wikipedia.org/wiki/Convention_on_Cybercrime

136 https://www.forsakringskassan.se/wps/wcm/connect/30cc57bd-b5cd-4e04-94cd-1f7a02a9ae1a/vitbok.pdf?MOD=AJPERES&CVID=
137 https://www.dn.se/debatt/sveriges-digitala-suveranitet-hotas-av-it-tjanster-i-molnet/
138 https://www.bbc.com/news/world-us-canada-23721818
139 https://sv.wikipedia.org/wiki/Foreign_Intelligence_Surveillance_Act#Brott_mot_lagen
140 https://fortune.com/2019/10/30/europe-cloud-independence-gaia-x-germany-france/
141 https://computersweden.idg.se/2.2683/1.726130/forsta-steget-eu-moln
142 https://en.wikipedia.org/wiki/Great_Firewall
143 https://ec.europa.eu/digital-single-market/en/news/towards-more-secure-and-trusted-cloud-europe
144 https://www.globalamalen.se
145 https://www.globalamalen.se/om-undp/
146 https://ainowinstitute.org/discriminatingsystems.pdf
147 https://www.nature.com/articles/s41467-019-14108-y
148 https://axbom.blog/representation-ai-sweden/
149 https://blackinai.github.io
150 https://www.womeninai.co
151 https://www.technologyreview.com/s/613630/training-a-single-ai-model-can-emit-as-much-carbon-as-five-cars-in-their-lifetimes/
152 https://sv.wikipedia.org/wiki/Moores_lag
153 https://en.wikipedia.org/wiki/Synthetic_data
154 https://www.1177.se/Vastra-Gotaland/sa-fungerar-varden/sa-skyddas-och-hanteras-dina-uppgifter/sammanhallen-journalforing/
155 http://www.forskasverige.se/wp-content/uploads/Opinionsunders%C3%B6kning-2019-ForskaSverige.pdf
156 https://vgrfokus.se/2019/12/154-000-patienter-uteblev-fran-bokade-sjukhusbesok/
157 https://www.lerumstidning.se/2019/07/halsodata-avgorande-for-battre-vard-och-farre-vardskador-i-vastra-gotaland/
158 https://www.technologyreview.com/s/613630/training-a-single-ai-model-can-emit-as-much-carbon-as-five-cars-in-their-lifetimes/
159 https://sv.wikipedia.org/wiki/Svenskamerikan
160 https://sv.wikipedia.org/wiki/Familj%C3%A4r_amyloidos_med_polyneuropati
161 https://tillvaxtverket.se/amnesomraden/regional-kapacitet/smart-specialisering.html
162 https://smarttextiles.se
163 https://tillvaxtverket.se/amnesomraden/regional-kapacitet/smart-specialisering.html
164 https://www.karolinska.se/om-oss/forskning-och-utbildning/forskning/core-faciliteter/kcc/
165 https://www.mevia.se
166 https://sv.wikipedia.org/wiki/Proteinveckning
167 https://en.wikipedia.org/wiki/In_silico
168 https://foldingathome.org
169 https://en.wikipedia.org/wiki/Activity_recognition

170 https://machinelearningmastery.com/deep-learning-models-for-human-activity-recognition/
171 https://allagehub.se
172 https://www.theverge.com/2019/3/5/18251326/ai-startups-europe-fake-40-percent-mmc-report
173 https://www.technologyreview.com/s/608911/is-ai-riding-a-one-trick-pony/
174 https://www.wired.com/story/sobering-message-future-ai-party/
175 https://www.chalmers.se/sv/personal/Sidor/claes-strannegard.aspx
176 https://en.wikipedia.org/wiki/One-shot_learning
177 https://en.wikipedia.org/wiki/Toy_problem
178 https://www.kjronline.org/search.php?where=aview&id=10.3348/kjr.2019.0025&code=0068KJR&vmode=FULL
179 https://en.wikipedia.org/wiki/Technology_readiness_level
180 https://www.dagenssamhalle.se/debatt/en-modern-vard-kraver-en-moderna-re-lagstiftning-28416
181 Page 39, https://www.socialstyrelsen.se/globalassets/sharepoint-dokument/artikelkatalog/ovrigt/2019-10-6431.pdf
182 https://www.dagensmedicin.se/artiklar/2019/10/23/viljan-att-vara-bast-i-klassen-kan-ge-farre-forskningsframsteg/
183 https://stm.fi/en/secondary-use-of-health-and-social-data
184 https://www.regeringen.se/informationsmaterial/2019/12/en-nationell-strategi-for-life-science/
185 https://www.nhsx.nhs.uk/assets/NHSX_AI_report.pdf
186 https://www.datahubbs.com/ai-and-super-powered-economic-errors/
187 https://www.datainnovation.org/2019/08/who-is-winning-the-ai-race-china-the-eu-or-the-united-states/
188 Table 8, Center for Data Innovations report Who Is Winning the AI Race: China, the EU or the United States?
189 https://swedishaicouncil.com/swedish
190 AI Superpowers: China, Silicon Valley, and the New World Order, by Kai-Fu Lee, ISBN: 9781328546395
191 https://www.technologyreview.com/f/612316/baidu-just-showed-that-china-and-the-us-can-collaborate-on-ai/
192 https://www.rt.com/news/401731-ai-rule-world-putin/
193 https://twitter.com/elonmusk/status/904633084309422080
194 https://www.theverge.com/2017/9/4/16251226/russia-ai-putin-rule-the-world
195 http://allai.nl/there-is-no-ai-race/
196 https://www.glassdoor.com/employers/blog/best-places-to-work-2020/
197 https://spectrum.ieee.org/computing/software/ai-and-economic-productivity-expect-evolution-not-revolution.amp.html
198 https://en.wikipedia.org/wiki/Georgetown%E2%80%93IBM_experiment
199 https://www.fhi.ox.ac.uk/wp-content/uploads/FAIC.pdf
200 https://books.google.se/books?id=2FMEAAAAMBAJ&pg=PA57&lpg=-PA57&dq=life+Meet+Shaky,+the+first+electronic+person.&source=bl&ots=v_7Kn-MpctZ&sig=ACfU3U0AH5kUvI0Qu4YKnLMMwCnipyeqUQ&hl=sv&sa=X-&ved=2ahUKEwi8kvbjuvbmAhW4zMQBHUUhDaIQ6AEwDXoECAcQAQ#v=onepage&q=life%20Meet%20Shaky%2C%20the%20first%20electronic%20person.&f=false

201 https://sv.wikipedia.org/wiki/Artificiell_intelligens#Artificiell_generell_intelligens
202 https://en.wikipedia.org/wiki/Hubert_Dreyfus%27s_views_on_artificial_intelligence
203 https://liu.se/medarbetare/clalu03
204 https://youtu.be/hV8sqnvEL4c?t=353
205 https://www.gp.se/nyheter/mobilapp-ska-hj%C3%A4lpa-bipol%C3%A4ra-1.16204396
206 https://twitter.com/svenssonhannase/status/1145299251028779009
207 https://en.wikipedia.org/wiki/Quantified_self
208 https://www.nytimes.com/2019/07/23/us/politics/william-barr-encryption-security.html
209 https://en.wikipedia.org/wiki/Post-quantum_cryptography#Open_Quantum_Safe_project
210 https://www.theguardian.com/us-news/2015/jul/08/nsa-tapped-german-chancellery-decades-wikileaks-claims-merkel
211 https://www-new.statnews.com/2019/06/19/what-if-ai-in-health-care-is-next-asbestos/
212 https://www.youtube.com/watch?v=SYo_PvCqgnw
213 https://www.svd.se/medierna-blir-till-offentlig-skampale
214 https://computersweden.idg.se/2.2683/1.714787/inspelade-samtal-1177-vardguiden-oskyddade-internet
215 https://en.wikipedia.org/wiki/Dark_web
216 https://en.wikipedia.org/wiki/ICloud_leaks_of_celebrity_photos
217 https://towardsdatascience.com/the-new-dawn-of-ai-federated-learning-8ccd9ed7fc3a
218 https://swelife.se/2018/11/09/ny-rapport-om-personcentrerad-data-och-juridik-i-varden/
219 https://www.isic-archive.com
220 http://braintumorsegmentation.org
221 http://www.aisb.org.uk/events/loebner-prize
222 https://www.kaggle.com
223 https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/DBW86T
224 https://api.medicalphoto.org/datasets.html
225 http://gigadb.org/dataset/100439
226 https://www.isic-archive.com
227 https://stanfordmlgroup.github.io/projects/chexnet/
228 https://healthdata.gov/search/type/dataset
229 https://mimic.physionet.org
230 https://datascience.nih.gov/strides
231 https://www.nlm.nih.gov/NIHbmic/nih_data_sharing_repositories.html

30/01/2020

Author: Marcus Österberg
Editor: Lars Lindsköld
Translation: Semantix AB

Swelife is a strategic innovation programme funded by the Vinnova Innovation Agency and the project's partners. This report was prepared as part of the SWEPER project within Swelife.