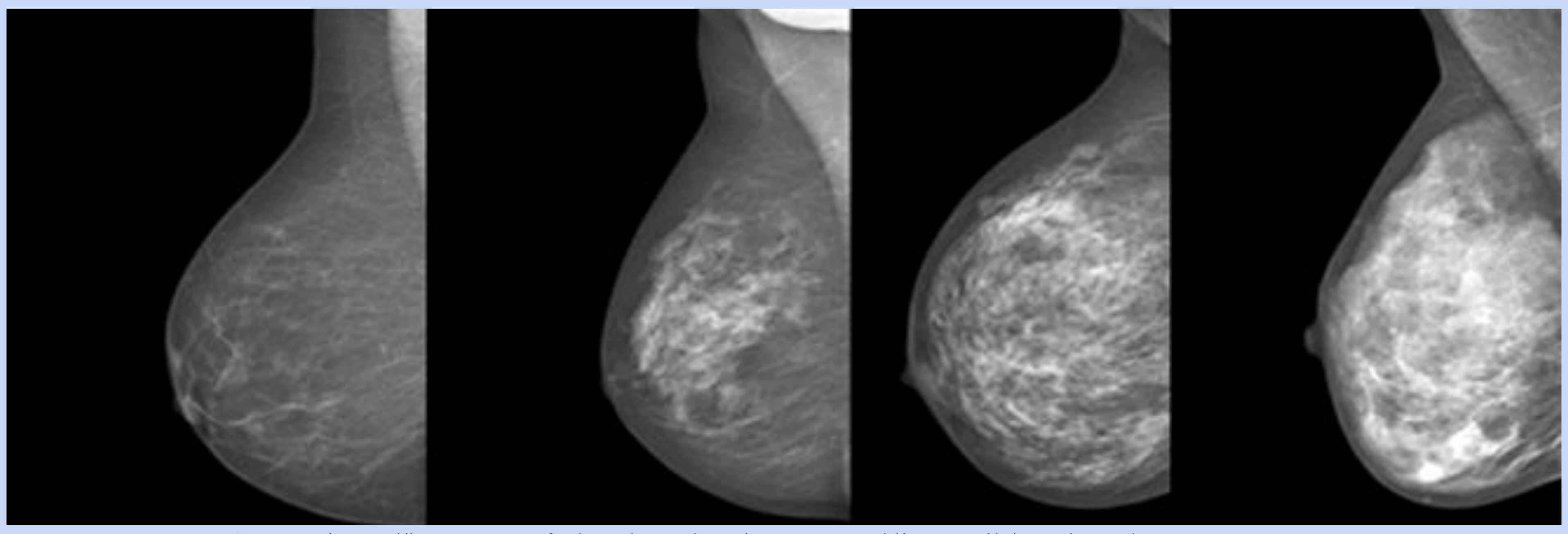
# Early Stage Breast Cancer Detection in the Age of Computers

A review

Dennis Amphan & Simon Jenner

## Introduction

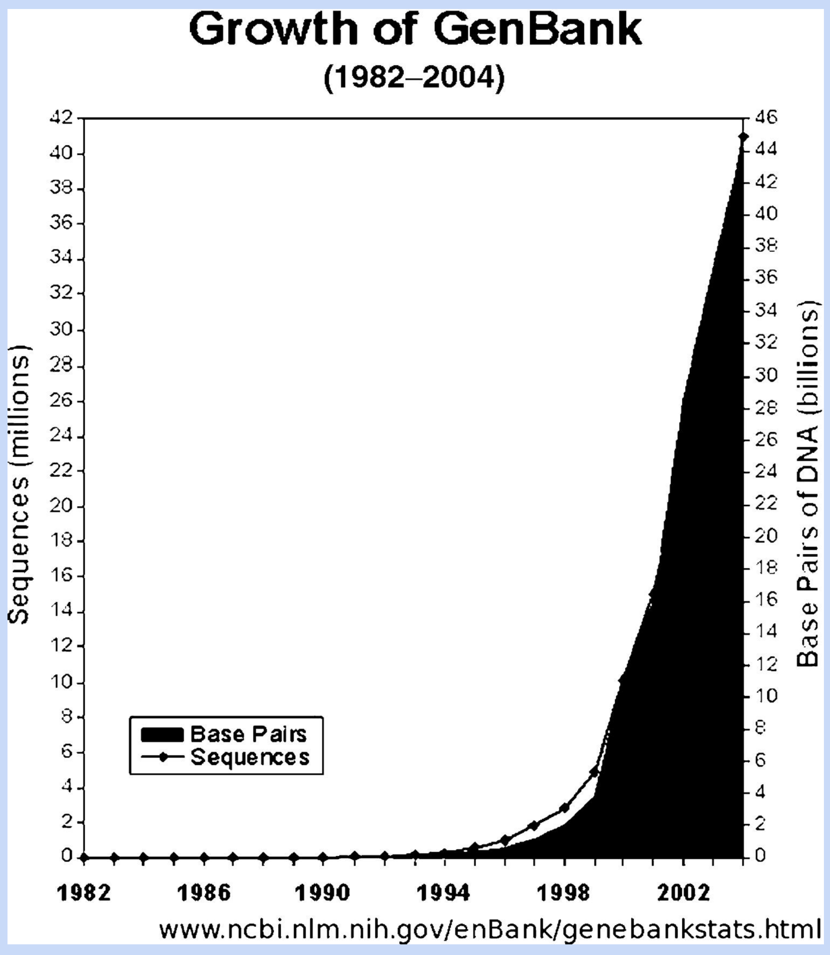
Breast cancer is the most common cancer type in the world and finding it in an early stage to get treatment is one of the most important strategies in order to prevent death. Today's methods for diagnosis (in the early stages) are heavily dependent on image analysis from image data, often X-ray images from mammograms. Recent studies have suggested flaws in this method of diagnosis, as the density of breast tissue can vary drastically between patients and smaller tumours can easily be missed in more dense breast tissue.



Source: https://brostcancerforbundet.se/om-brostcancer/diagnostik/tata-brost/

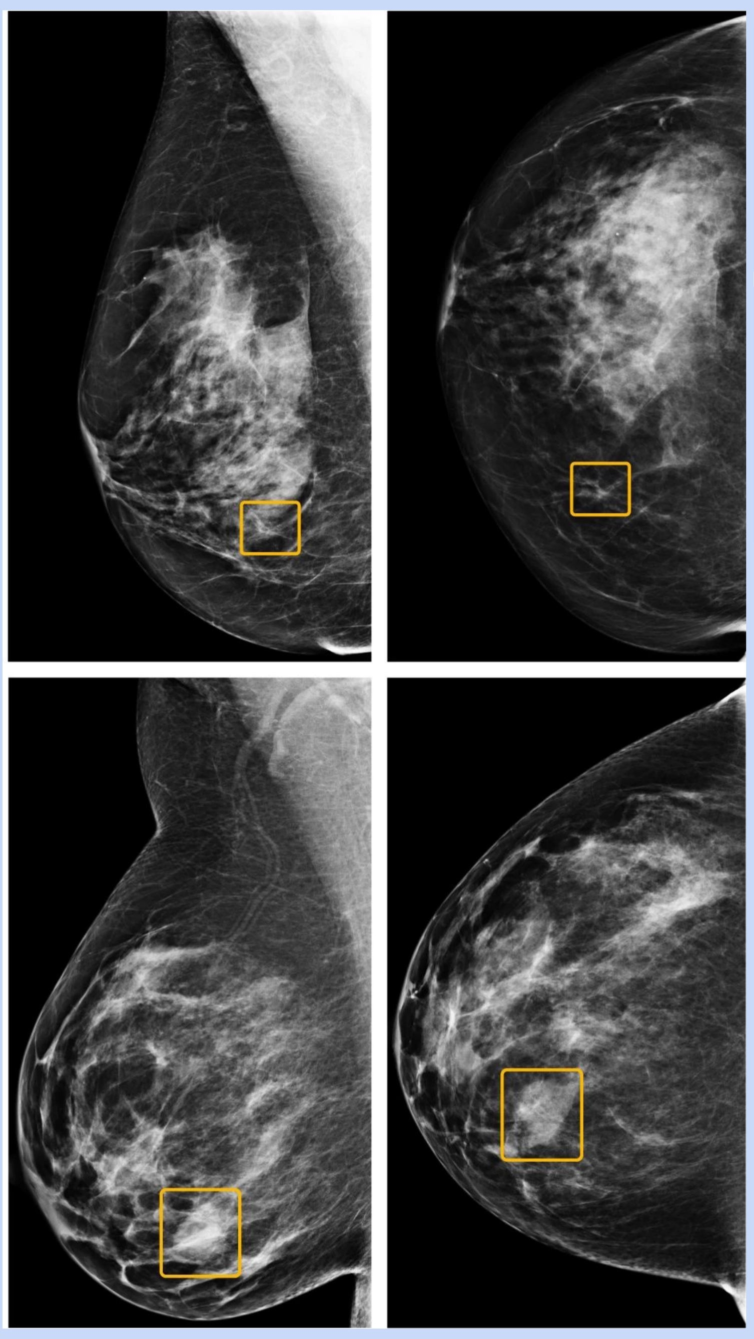
### Image Based Models (CNN)

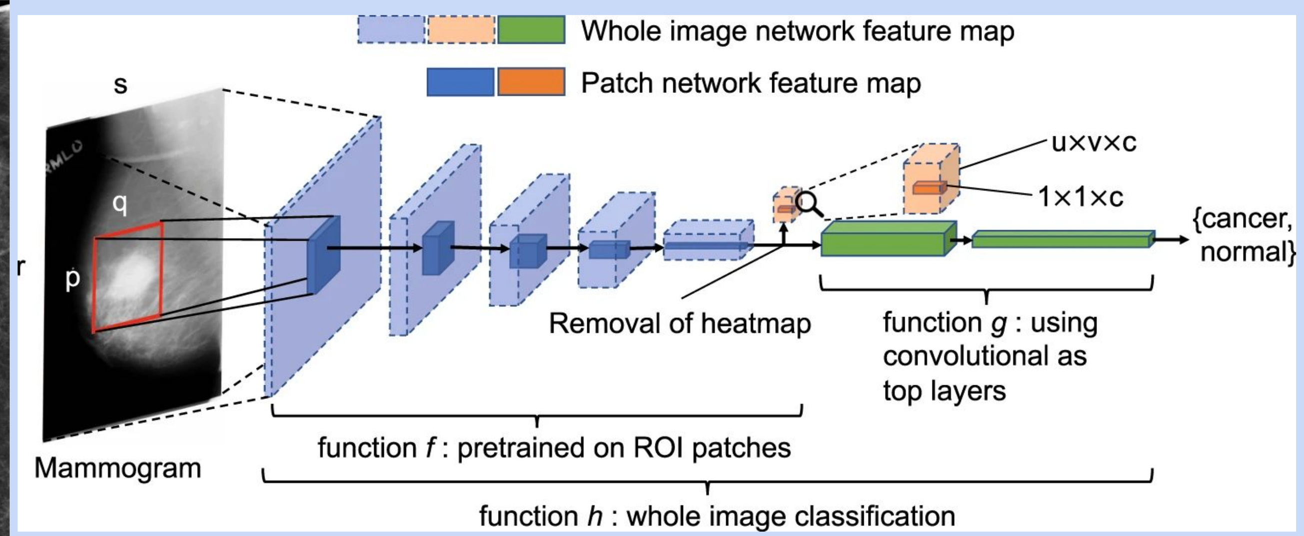
- Good results, similar performance as radiologist
- Easily built on existing methods
- Not reliable on dense tissue




In recent years the number of genes in the GenBank has increased drastically


Source: https://www.embopress.org/doi/full/10.15252/msb.20156651






Source: https://www.nature.com/articles/s41598-019-48995-4

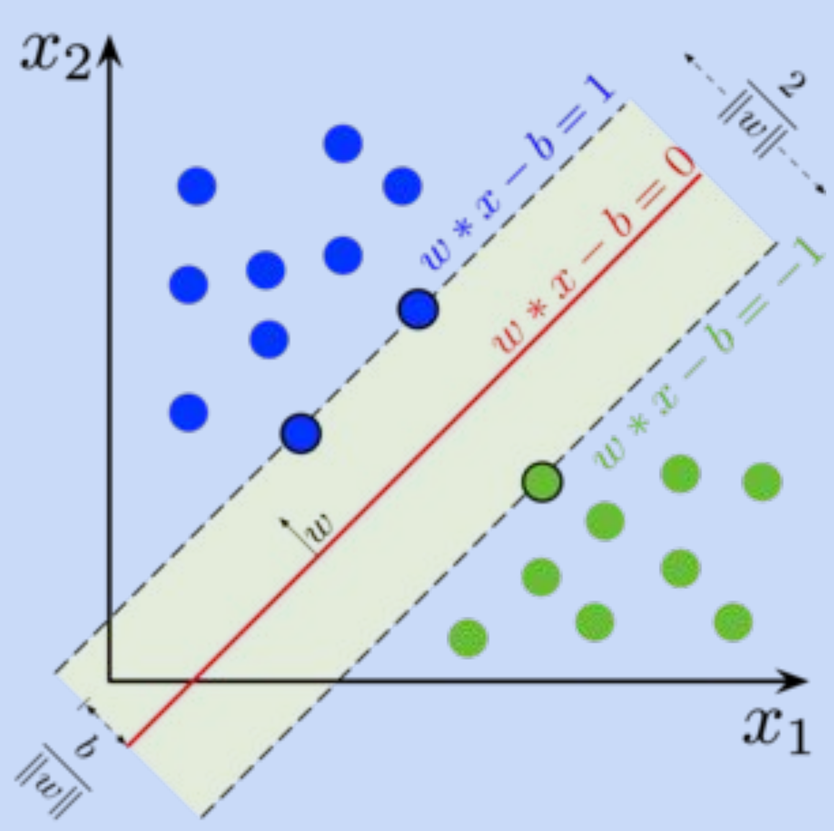
Top images were miss classified by 6 radiologists, but correctly classified by the model. The bottom two were the other way around.

Source: https://www.nature.com/articles/s41586-019-1799-6

## Results

| Method | Accuracy | Sensitivity | Specificity | AUC |
|---|---|---|---|---|
| Mammography | 89.3% | 97% | 64.5% | 0.75 |
| SVM - Biomarker | 98.82(±0.34)% | 97.69(±0.88)% | 83.80(±4.64)% | 0.96 |
| ANN - Biomarker | 97.36(±0.34)% | 98.32(±0.32)% | 89.59(±3.53)% | 0.99 |
| CNN - Mammography | — | 56.24% | 84.29% | 0.91 |

- Both methods using biomarkers provide better result
- Non ICT-method (standard mammography yields the lowest overall performance
- Double reading with AI yield same result as two radiologists.




Source:
https://upload.wikimedia.org/wikipedia/commons/thumb/7/72/SVM_margin.png/1024px-SVM_margin.png

Support vector machines could act as a suitable method for cancer diagnosis.

## Conclusion

- Black box nature makes it hard to fully integrate deep neural networks.
- More interpretable models for bioinformatic data, SVM.
- Combining neural networks with existing methods is a good way to keep transparency.
- Meanwhile a great potential for saving in on time and resources.
- More efficient workflow.
- Could remove the need for radiation exposure.

# Blockchain in Healthcare Applications

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Abstract & References

## 1. What is Blockchain?

Blockchain became recently popular through the cryptocurrency bitcoin[1]. It is used to **share information** on the Internet in a more **secure and transparent way** than traditional methods[2].

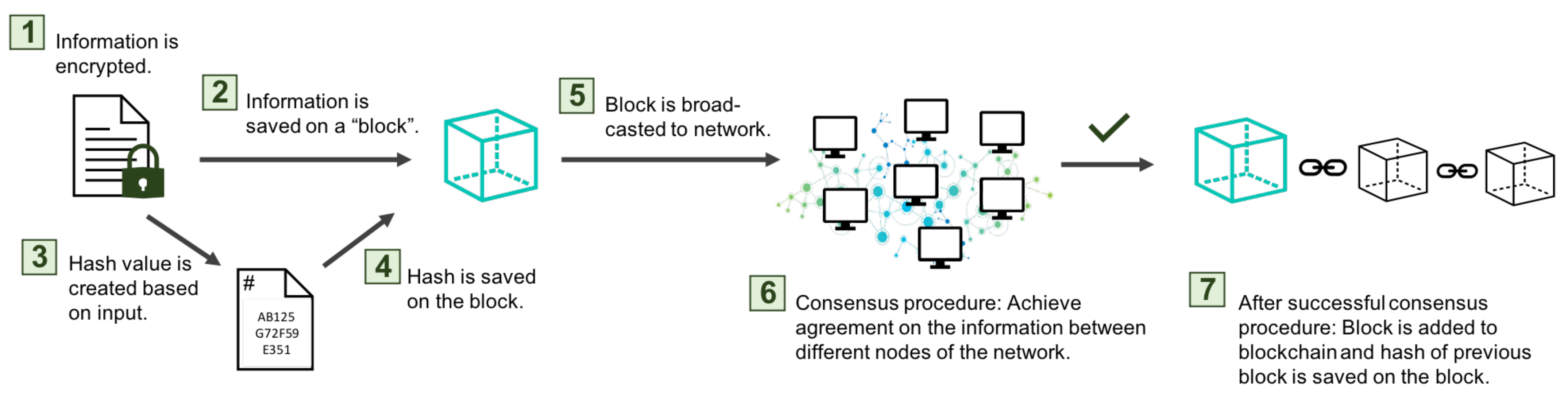



**Figure 1:** Basic Workflow of a Blockchain Transaction (Adapted from [1]).

### The 4 key characteristics[1,3]

1. **Decentralization:** The blockchain is distributed between several computers which makes it strong against attacks.
2. **Immutability:** The information on a block cannot be modified. Just new blocks can be added, and no information can be removed.
3. **Privacy:** The information on a block is encrypted with a private key. Just the holder of the key can access the information
4. **Trust:** It is possible for everyone in the network to calculate that the information they have is correct and unmodified.

## 2. Blockchain & Healthcare

The healthcare industry has unique requirements in terms of data protection. There are a lot of legal requirements to keep the data secure and private to protect the patient.[2]

### Blockchain Features that meet these requirements:

**(1) Security**
- Specific **access control**, while ensuring integrity and confidentiality[2]
- **Reliable over time** since data can't be modified[3]

**(2) Interoperability[2]**
- Difficult to share and transfer data since medical data is usually stored centrally at institutions
- Blockchain **simplifies interoperability** while **maintaining trust**

**(3) Data Access[2,3]**
- Blockchain enables more **flexible data access**
- can be adapted for **different stakeholders** involved (e.g., institutions and patients)

**(4) Mobility[2]**
- Patients become more mobile
- real-time sharing and access to data from anywhere

### Implementations:

There are several possibilities to design a blockchain network for different purposes (Table 1)[4]. Three Examples for platforms that fit the requirements for healthcare applications are Ethernum[5,6], Multichain[7,8] and Hyperledger[9,10].

**Table 1:** Relevant Features to design a blockchain for healthcare applications [4].

| Relevant Features | Options and implications | |
|---|---|---|
| Network permission (NP) | Permissioned (P) | Authorized participants |
| | Permissioned-les (PL) | Public participation |
| Consensus protocol (CP) | Prof of Work (PoW) | High intense demand algorithm suitable for PL |
| | Proof of Stake (PoS) | Low intense demand algorithm |
| | Mining Diversity | Low intense demand algorithm designed for P healthcare networks |
| | Kafka | Low energy consumption based on major voted. Requires higher time while the network grows |
| Special Hardware (SH) | Yes/No | If yes, hardware specifications should be specified before |
| Smart Contract Support (SC) | Yes/No | Required if the network contains autonomus operations like health insurance payments |

**Ethereum[4,5]**
- **NP:** Permissioned | Permissioned-less
- **CP:** PoW | PoS
- **SH:** No
- **SC:** Yes

**MultiChain[4,7]**
- **NP:** Permissioned
- **CP:** PoW | Mining Diversiy
- **SH:** No
- **SC:** Yes

**Hyperledger[4,9]**
- **NP:** Permissioned
- **CP:** Kafka
- **SH:** Yes
- **SC:** Yes

## 3. Applications

### Case 1: Health Records

Caro has moved from Germany to Sweden to study her masters.

Last Friday she bumped her arm while cooking cinnamon buns.

She went to the doctor, and he asked her if she had some skin issue before.

She had an excema when she was 3 years old, but she was too young to remember.

→ **Problem:** Information spread over multiple centers
→ **Goal:** Transform patient data sharing and information interoperability
→ **Blockchain[11]:** **Patient data control, worldwide institutions EHR access, patient confidence, professional selective access**
→ **Example:** Akiri[12] (company), omniPHR[2] (architecture), MedRec[2,13] (architecture)

### Case 2: Counterfeit Drugs


Mario has sleeping problems. He goes to two doctors to get two prescriptions.

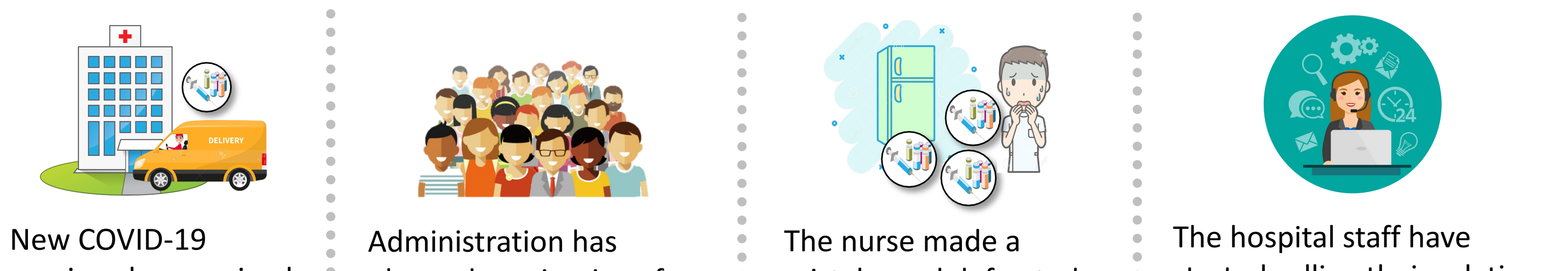
On Monday he goes to the pharmacy and asks for Dr. Smith's prescription.

After finishing the pills after a week, he goes again to the pharmacist and asks for Dr. Robin's prescription.

The pharmacists is surprised. That face is familiar to him.

→ **Problem:** Abuse of drug prescription because of an incomplete feedback between prescription writers and fillers
→ **Goal:** Close the loop between prescription writers and filler
→ **Blockchain[14,15]:** **Unique prescription identifier, patient prescription history, true information sharing, constant information checkup**
→ **Example:** BlockVerify[16] (Company)

### Case 3: Supply Chain



New COVID-19 vaccines have arrived at the Hospital.

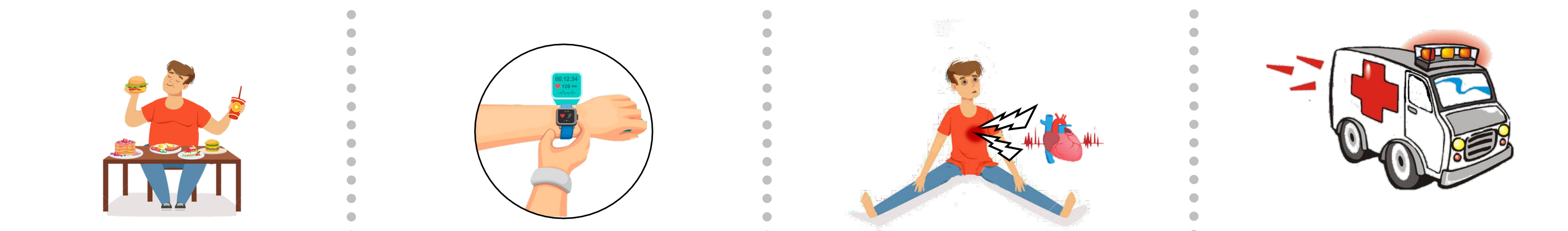
Administration has planned vaccinations for 23 people.

The nurse made a mistake and defrosted 30 vaccines.

The hospital staff have started calling their relatives to get vaccine the same day.

→ **Problem:** Problems in healthcare supply chain due to its complexity and global connectivity
→ **Goal:** Introduce supply chain transparency
→ **Blockchain[17]:** **Medicine trackability, Stock Register, Supply chain optimization, customer and professional confidence**
→ **Example:** IBM+ Sonoco[18] (company), FarmaTrust[19] (company)

### Case 4: IoT-Based Healthcare Monitoring



Tom has a very unhealthy lifestyle.

His doctor recommends him, to track his heart activity with a smartwatch for while.

The smartwatch collects a lot of data, which Tom wants to show his doctor the next visit.

Before Tom can visit the doctor, he has a heart attack and must go to the hospital.

→ **Problem:** Delays in patient treatment due to security and privacy issues of IoT-applications
→ **Goal:** Realtime IoT-Based Monitoring to be able to act in time
→ **Blockchain:** **Collecting and transferring data[20], ensuring IoT privacy and security[21], provide remote transparent and safe medical assistance[22]**
→ **Example:** eHealthChain (architecture)[23]

## 4. Challenges

Blockchain offers a lot of improvements and benefits, as explained above. However, the technology is still new and immature. Just a few pilot studies exist, but there is still a lot of research that must be conducted to solve the current existing challenges.[2,24]

**Security**
- Risk of unauthorized access of data[2,24]

**Privacy**
- Keeping track of data could reveal patient[1,24]

**Scalability**
- Large amount of patient data is collected with time
- processing large amount of data in real-time difficult[1]

**Costs**
- High implementation and electricity costs[24]
- Significant cost savings withing several years[24]

**Standardization**
- Technical challenges to standardize and transfer medical data to blockchain[2,25]

**Hardware**
- Computing power is limited[2]
- Risk of temporary outage[24]

**References:**
[1] Panda SK, Jena AK, Swain SK, Satapathy SC, editors. Blockchain Technology: Applications and Challenges. Springer; 2021. [2] McGhin T, Choo KK, Liu CZ, He D. Blockchain in healthcare applications: Research challenges and opportunities. Journal of Network and Computer Applications. 2019;135:62-75. [3] Engelhardt MA. Hitching healthcare to the chain: An introduction to blockchain technology in the healthcare sector. Technology Innovation Management Review. 2017;7(10). [4] Kuo TT, Zavaleta Rojas H, Ohno-Machado L. Comparison of blockchain platforms: a systematic review and healthcare examples. Journal of the American Medical Informatics Association. 2019; 26(5):462-78. [5] Mohan D, Alwin L, Neeraja P, Lawrence KD, Pathari V. A private Ethereum blockchain implementation for secure data handling in Internet of Medical Things. Journal of Reliable Intelligent Environments. 2021:1-8. [6] Buterin V. A next-generation smart contract and decentralized application platform. white paper. 2014;3(37). [7] Greenspan G. Multichain private blockchain-white paper. URl: http://www. multichain. com/download/MultiChain-White-Paper. pdf. 2015:57-60 (accessed 08 October 2021). [8] Nagori M, Patil A, Deshmukh S, Vaidya G, Rahangdale M, Kulkarni C, Kshirsagar V. Mutichain enabled EHR management system and predictive analytics. InSmart Trends in Computing and Communications. Springer, 2020: 179-187. [9] Aggarwal S, Kumar N. Hyperledger. In: Advances in Computers. Elsevier, 2021;121:323-343. [10] Seo J, Cho Y. Medical Image Sharing System using Hyperledger Fabric Blockchain. In: 2020 22nd International Conference on Advanced Communication Technology (ICACT) 2020 Feb 16 (pp. 62-64). IEEE. [11] Carter G, Shahriar H, Sneha S. Blockchain-based interoperable electronic health record sharing framework. In: 2019 IEEE 43rd Annual Computer Software and Applications Conference (COMPSAC) 2019 Jul 15 (Vol. 2, pp. 452-457). IEEE. [12] Akiri. https://akiri.com/ (accessed 08 October 2021). [13] MedRec. https://medrec.media.mit.edu/ (accessed 09 Octover 2021). [14] Sanghi A, Katakwar A, Arora A, Kaushik A. Detecting Fake Drugs using Blockchain. Int. J. Recent Technol. Eng. 2021; 10(1):100–109. [15] Uddin M. Blockchain Medledger: Hyperledger fabric enabled drug traceability system for counterfeit drugs in pharmaceutical industry. International Journal of Pharmaceutics. 2021;597:120235. [16] Blockverify. https://true.global/startups/blockverify/ (accesseed 08 October 2021). [17] Omar I, Debe M, Jayaraman R, Salah K, Omar M, Arshad J. Blockchain-based supply chain traceability for COVID-19 PPE. 2020. [18] IBM Blockchain Transparent Supply: Supply chain transparency solution. https://www.ibm.com/blockchain/solutions/transparent-supply (accessed 08 October 2021). [19] FarmaTrust. https://www.farmatrust.com/ (accessed 09 Octover 2021). [20] Ratta P, Kaur A, Sharma S, Shabaz M, Dhiman G. Application of blockchain and internet of things in healthcare and medical sector: applications, challenges, and future perspectives. Journal of Food Quality. 2021 May 25;2021. [21] Dwivedi AD, Srivastava G, Dhar S, Singh R. A decentralized privacy-preserving healthcare blockchain for IoT. Sensors. 2019 Jan;19(2):326. [22] Wang H. IoT based clinical sensor data management and transfer using blockchain technology. Journal of ISMAC. 2020;2(03):154-9. [23] Pawar P, Parolia N, Shinde S, Edoh TO, Singh M. eHealthChain—a blockchain-based personal health information management system. Annals of Telecommunications. 2021:1-3. [24] Radanović I, Likić R. Opportunities for use of blockchain technology in medicine. Applied health economics and health policy. 2018 Oct;16(5):583-90. [25] Namasudra S, Deka GC, editors. Applications of blockchain in healthcare. Singapore: Springer; 2021.

# How Dr. Pikachu Helps You to Get Healthy

Tim Flück and Zhaoyuan Wan

## Definition and Introduction

According to Deterning et al. „Gamification“ can be defined as „the use of game design elements in non-game contexts“. Gamification plays an ever growing role in the health care sector among other fields like business or engineering. Such tools are primarily used for prevention and training purposes but also support treatments for example in the area of mental health by motivating the user to keep up a workout routine or adhere to an overall healthier behaviour.

As technology gets better and almost every person has a smartphone nowadays, mobile health applications and its use of gaming elements are an easy and relatively cheap way to reach a lot of people and have an impact on public health interventions and healthy behaviour in general.

## Market Overview

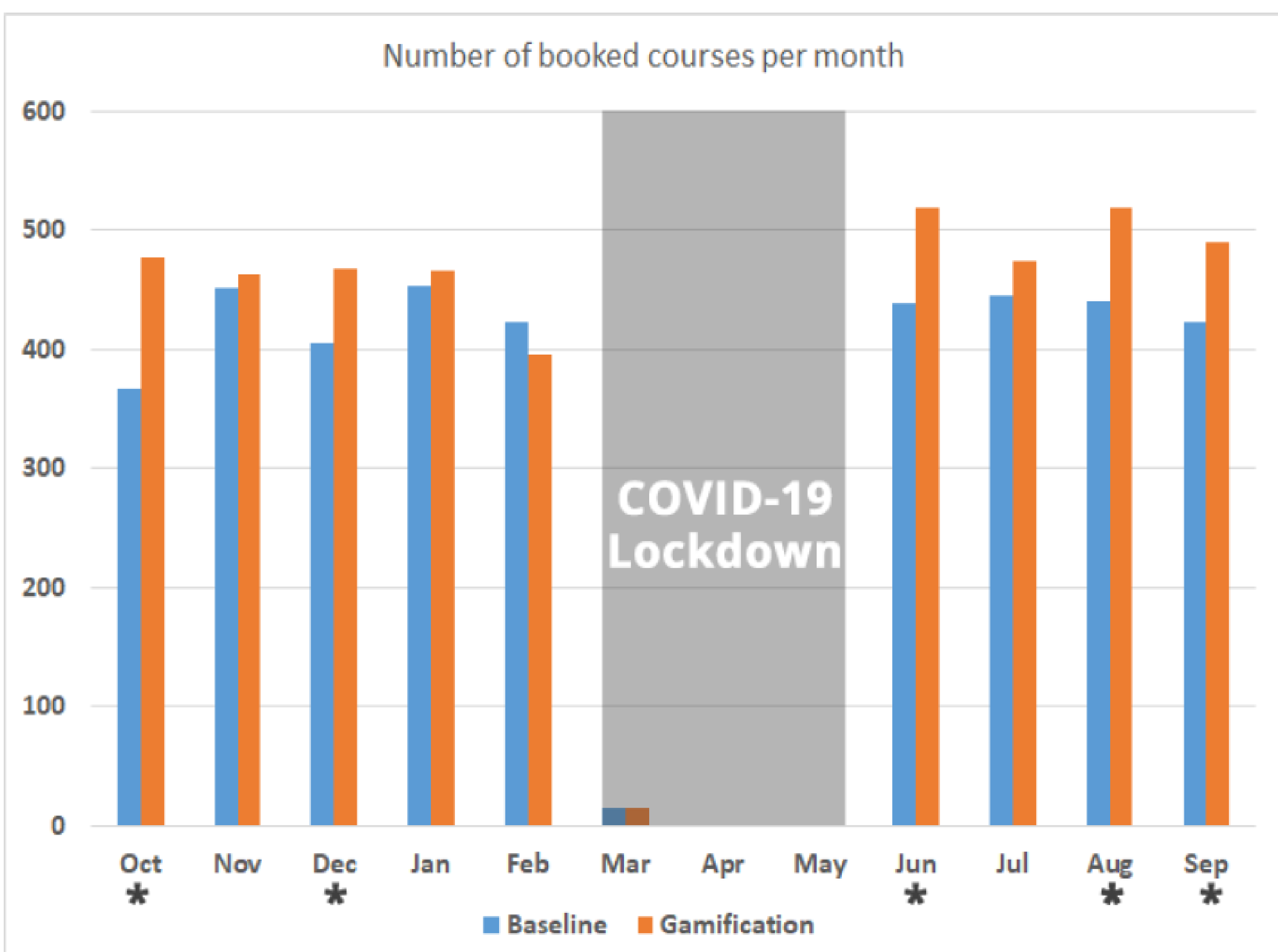
Before smartphones were widely available, most gamification of health was used in web-based applications like ayogo.com where children were rewarded when they entered information about their diabetes into an application.

In the beginning of the 2010s, almost everybody had a smartphone and the numbers of mobile health apps increased dramatically. One of those apps that included a high level of gamification was MyFitnessPal, which is still one of the most used Health Apps today.

With the development of AR technology, games like Ingress and Pokemon Go emerged. Although they were not initially designed for health purposes, their gameplay had inspired their players to take more physical activities, which in turn improved public health.

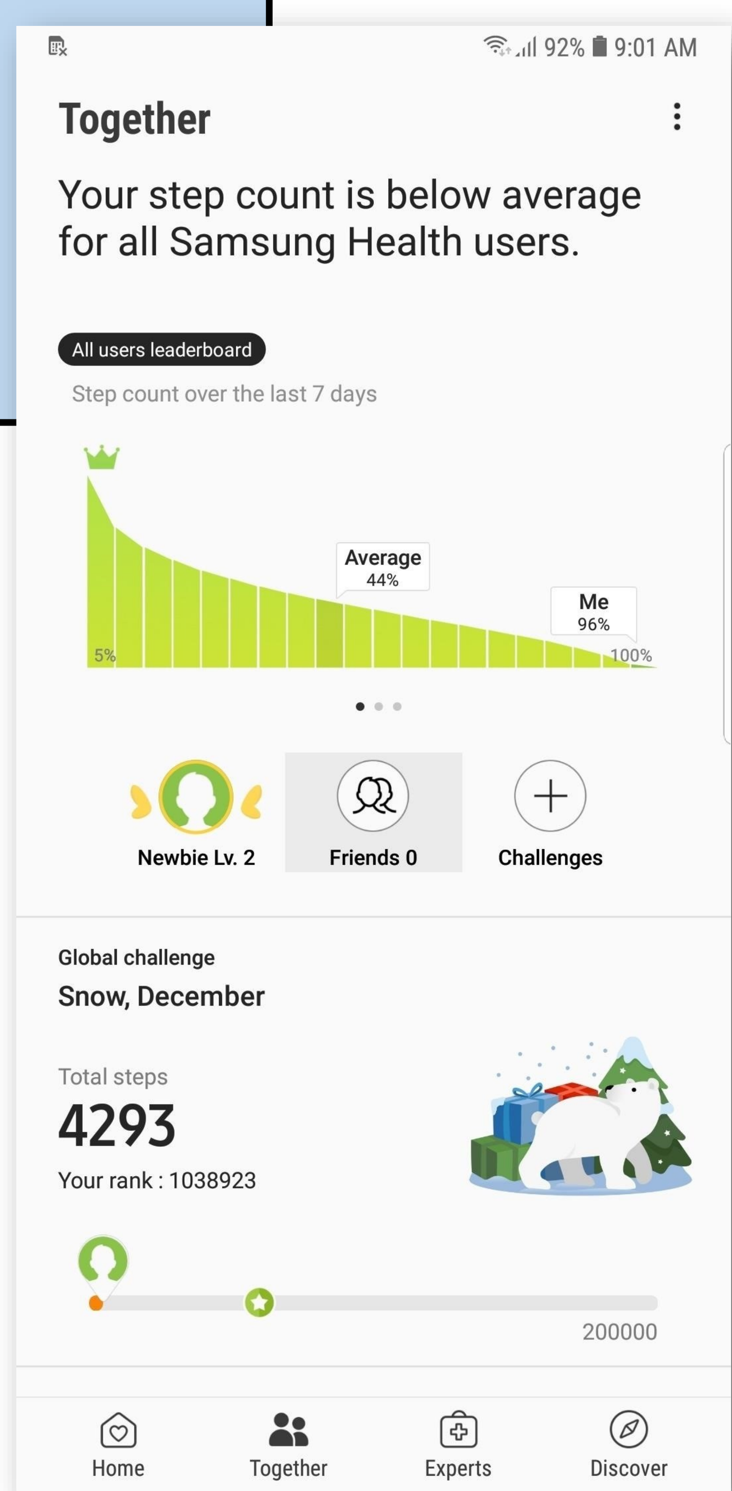
Pokemon GO logo

*Source: https://lofrev.net/pokemon-go-logo-pictures/ (11.10.2021)*




Comparison between the number of booked gym courses per month of people before (baseline) and after (Gamification) the use of Gamification in their workout.

*Source: „A long-term investigation on the effects of (personalized) gamification on course participation in a gym“ - Altmeyer et al.*




Samsung Health app

*Source: https://icohub.org/sa-har-starta-en-fitnesstavling-bland-vanner-med-samsung-health/*

## Features

Gamified apps and AR games are frequently developed on smartphones because of their technical features. With GPS and inbuilt accelerometers, the users' physical movements can be conveniently measured and monitored on their mobile phones.

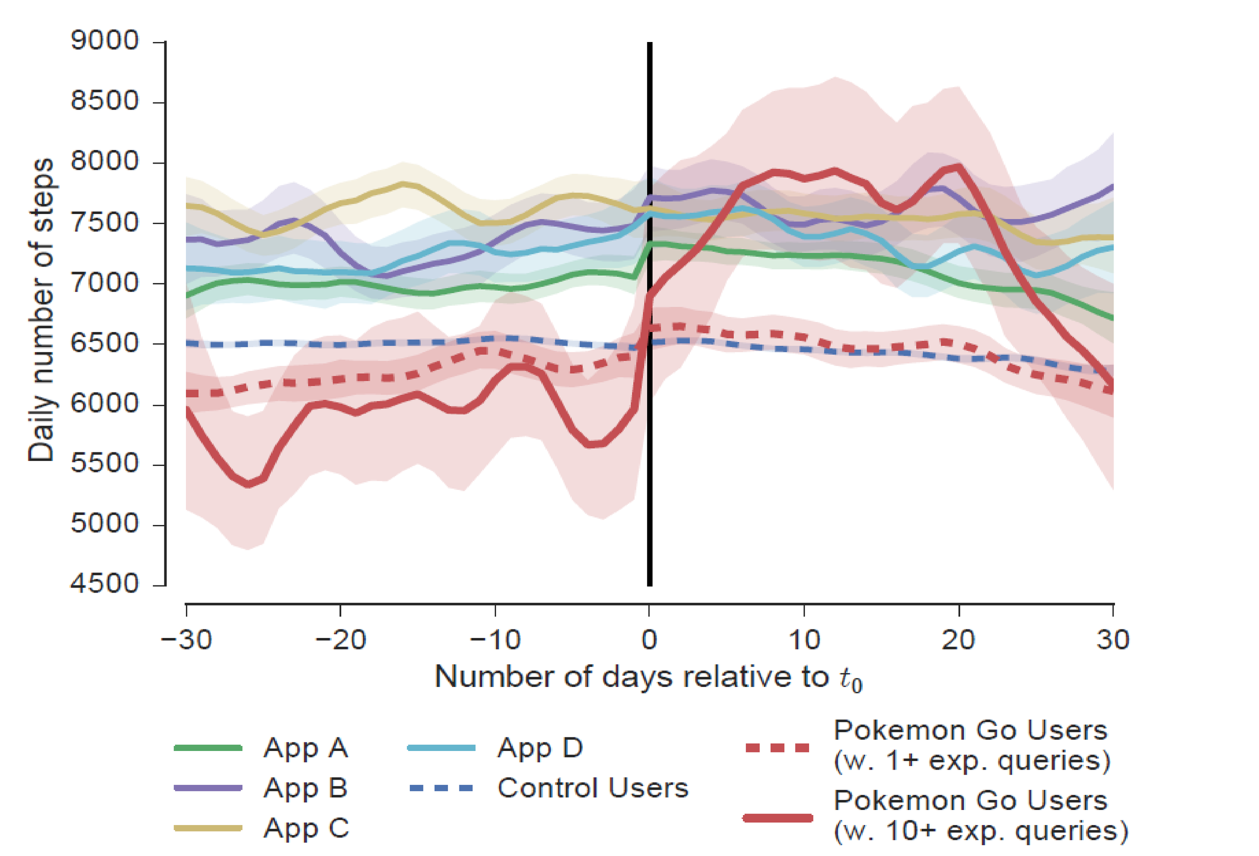
However, those sensing systems are nothing new. The 'game elements' should be the real focus. A typical feature of gamification is that many health apps have implemented achievement systems and ranking systems (leader boards) to motivate their users with senses of accomplishment and competition.

In AR games like Ingress and Pokémon GO, the players' real-world location directly decides their avatars' location in the game world. Hence it becomes natural for the players to take physical activities since it is the way to make progress in the game.

## Effectiveness

In the early 2010s there was no industry standard concerning gamification and the effectiveness of such mobile health interventions were not properly documented. In recent years, more and more studies with randomized control trials examined the impact of gamification on the user and how the user could profit. Though proper evaluation protocols are still lacking.

Promising results occurred primarily in of the field of fitness and mental health. While short-term studies showed that the higher the inclusion of game-like features the more popular the app is, long term studies also showed that the adherence to a workout regime is higher when gamification elements are involved. Increased adherence was also documented in studies with mental health apps, where adherence and easy access to treatment is especially important. These findings prove the potential of gamification in health care.




Comparison of the activity level of Pokemon Go users before and after they use the app and other consumer health apps

*Source: „Influence of Pokémon Go on Physical Activity: Study and Implications“ -Althoff et al.*

START

# GAMIFICATION TO TACKLE CHILD OBESITY

## 1 Gamification

**Gamification** = applying gaming principles, game design techniques, and game mechanics to non-game applications in order to improve clinical outcomes.

**Obesity**

= abnormal or excessive fat accumulation that presents a risk to health

BMI > 30

17,2% of children around the world have obesity

more deaths worldwide than underweight

## 2 Game Design Elements for Children Health Apps

**Narrative story** for game feeling.

**Rewards** for accomplishing tasks.

**Involvement** of family and hospital.

**Leaderboards** to compete with friends.

**Catchy name** applicable for children.


**Reminders** for user engagement.

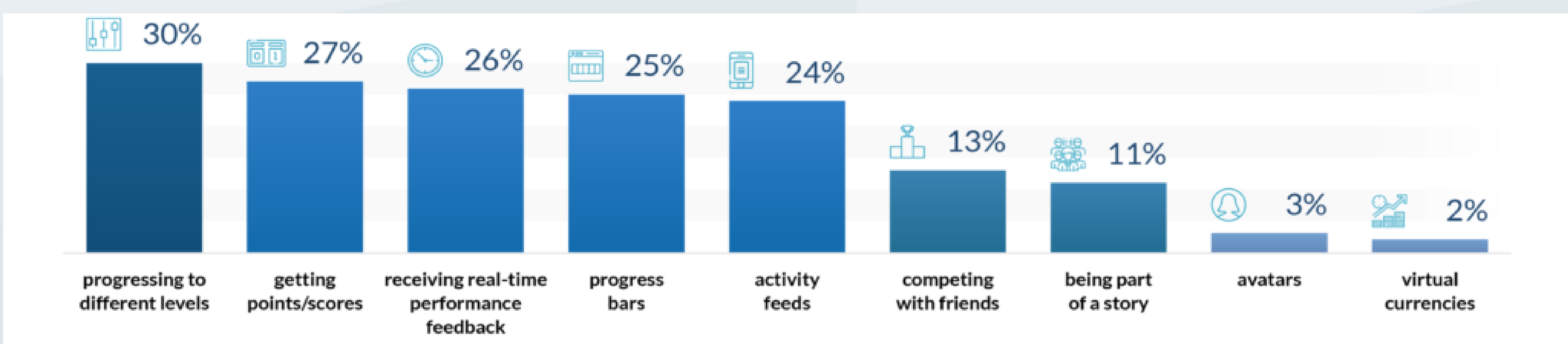
**Progress bars** for motivation.

**Challenges & Streaks** against friends and self.

**Social Networking** for a community feeling.

**Avatars** for personalisation.

### PREFERRED GAMIFICATION STRATEGIES




## 3 Other Gamification Techniques

Gamification is not necessarily the use of an app! There are other ways of turning 'annoying' tasks into something fun.

**Schools**
can implement games between children and classes to promote healhty eating and activity.
- healthy snack challenge
- step challenge
- healthy activity tracker
- complete missions in fictional world game
- ...

**Digital Watches**
like Fitbit or Apple watch can be used to track activity and motivate via challenges.

**Video Games**
like Wii or Playstation to play sports in a game related way.

## 4 Gamification Model

Game Elements

| Stage 1 | Stage 2 | Stage 3 |
|---|---|---|
| 1 - Story/ Theme<br>2 - Clear Goals<br>3 - Levels | 4 - Points<br>5 - Rewards<br>6 - Feedback | 7 - Achievements or Badges |

User Engagement

Enjoyment | Motivation

*Desired Psychological Outcomes*
New knowledge, mindset change

*Desired Behavioural Outcomes*
Weight loss and long-lasting changed habits

## 5 Game Aspects for Obesity

### HEALTHY EATING

**Traffic Light Labeling**
+ visual memory
+ often used in schools
- red was a too aggressive colour causing guilt when eating red foods

**Cartoon moods**
+ personalisation
+ emotion coupled learning
- learning to eat healthy for the avatar and not for themselves

**Pet-based**
+ good eating routines following that of the pet (i.e waking up for breakfast)
+ similarity design principle

**Tutorial-based**
+ family involvement
+ progress sent to nutritionist
+ real world situations

### PHYSICAL ACTIVITY

**Garmin Vivofit Jr. - Disney**
+ recognizable characters from movies
+ daily challenges adapted by parents
+ can't lie to sensor
- more expensive than an app

**Cartoon movements**
+ personalisation
+ emotion coupled learning
- no control mechanism

**Pet-based**
+ walk to take care of your dog
+ similarity design principle

**Story-based**
+ playing someone else helps to answer the 'why' questions
+ challenges easily incorporated
- no control mechanism

## 6 Role and Impact

### ON MEDICAL INFORMATION AND COMMUNICATION SYSTEMS AND THE HEALTH CARE SYSTEM

Improvements/in development

**EHR**
- continuous inflow of data
- better control
- more accurately decide if a check up is necessary

**Hardware Coupling**
- apps can be made compatible to connect with high quality sensors
- broader information

**Software Coupling**
- use algorithms to improve treatment control

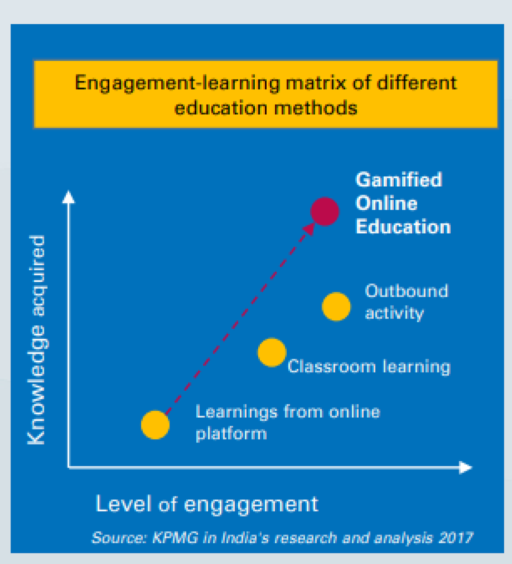
**Reduction of Child Obesity**
- increase child knowledge on food and exercise
- higher chance of action with gamification

**New Model for Health**
- lifelong interfaces

**Reduces hospitalization**
- remote feedback can lead to less necessary visits

## 7 Some Numbers

| +14% | +89% | +50% | 78% |
|---|---|---|---|
| Higher score on skill assessments | Are more eager to finish a gamified task | Improve productivity | Want some form of gamification in their treatment |




In general, research shows that most children want games and it improves the outcome of the healthcare.

## 8 Conclusion

If implemented in an interactive way, gamification of health care apps can be an effective way to treat child obesity. Certain elements are very important to keep the children engaged, like a story, progress bars and real-time feedback. This can lead to psychological and behavioural outcomes, which in the case of obesity is changed food and exercise habits and eventually weight loss. Implementing these new habits can be achieved in different ways. For food, some tested methods are traffic light labeling and cartoon moods. For exercise, pets and stories are often used. If the real-life control can be improved, these apps can have life changing effects for many children around the world.

STOP

# The biggest breakthrough in the medicine history

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## Introduction

| | |
|---|---|
| 1956 | · The term 'Artificial Intelligence' firstly used<br>· The first program including AI launched |
| | Not achieved good result with Machine Learning |
| 2000 | · Deep learning performs good enough<br>· Tried to be used in medicine |
| 2017 | · Deep learning network deployed in many clinical practices<br>(detect lesions, diagnosis, medical reports) |

- ***Definition of AI, ML and DL***

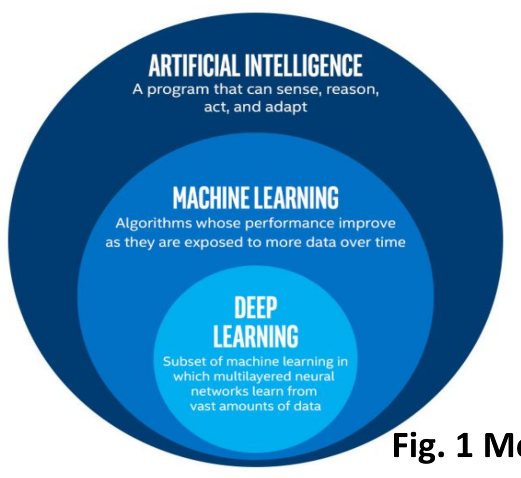



**Fig. 1 Meaningful definition of AI[2]**

## Biomarker discovery

- ***Biomarker?***
  A measurable indicator of a normal or abnormal biological process or response
- ***Omic biomarker***
  e.g.) Trisomy 21 (Down's syndrome)
  : Genetic signature to predict the status of disease
  → It is impossible for researchers to manually analyse and interpret a vast amount of data

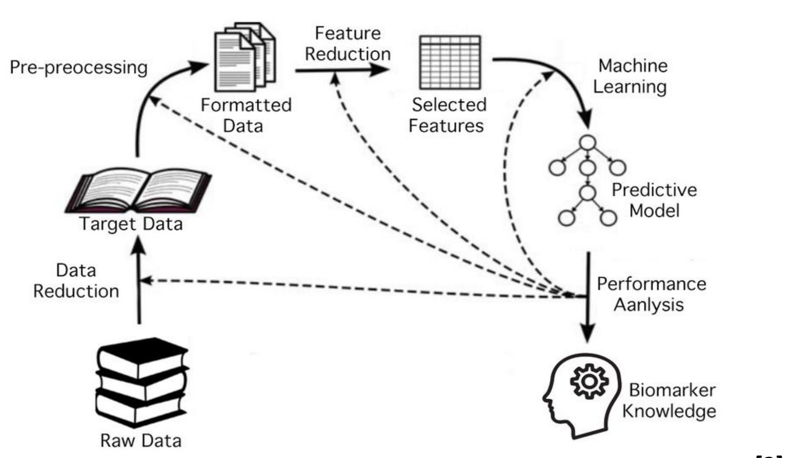



**Fig. 4 ML for Biomarker Discovery[3]**

- ***Non-omic biomarker***
  e.g.) Neural excitement signal
  : Can facilitate the development of interface for prosthetic control

## Concept of main networks

- <u>**Convolutional Neural Network (CNN)**</u>
- ***Purpose:***
  Classification task
- ***Components:***
  <u>Input layer :</u> images
  <u>First inner layers :</u> Convolutional layers
  <u>Last inner layers :</u> neural layers
  <u>output layer:</u> neural layer with number of neurons equals to the number of class.

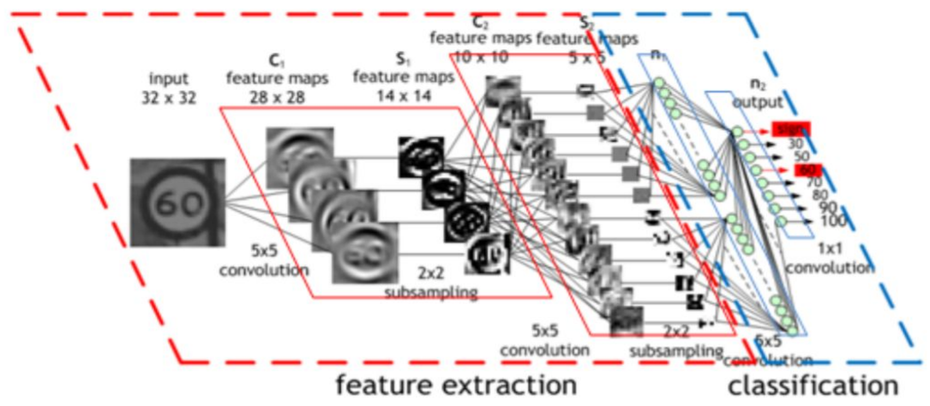



**Fig. 2 CNN structure[6]**

1. Weights of the neurons and of the convolutional masks are set randomly.
2. During training step, the outputs are compared with the grountruth and all the weights are adjusted.
3. The validation step aims at assessing the model, but the weights are not changed anymore.

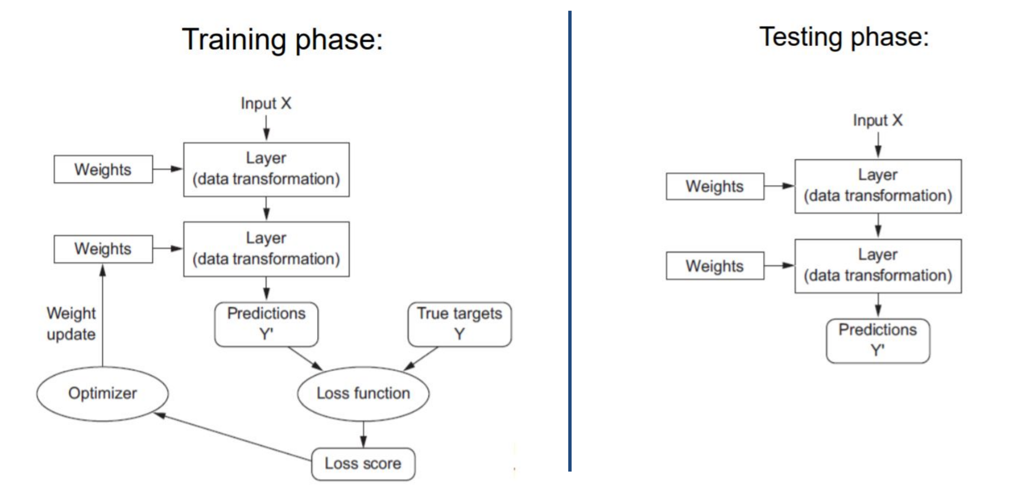



**Fig. 3 Training and Testing phase[6]**

- <u>**Fully Convolutional Network (FCN)**</u>
- ***Purpose:***
  Segmentation task
- ***Components:***
  <u>Input layer :</u> images
  <u>Inner layers :</u> Convolutional layers
  <u>output layer:</u> images

The convolutional layers are used to extract features from images, whereas neural layers try to mimic the human brain with sort of neurons all connected on each other.

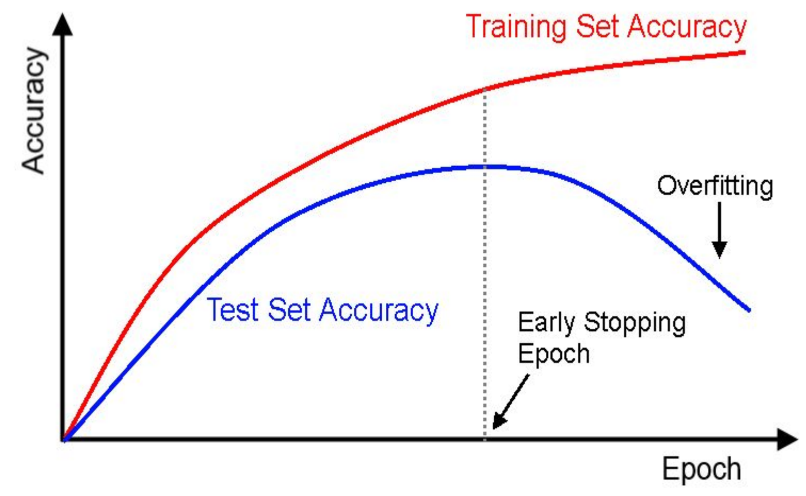



Chart 5. The overfitting problem.[2]

## Image Based Diagnosis

The most widely used technologies : X-ray, MRI, CT, PET

- ***Radiology***
  Detection of lung nodules
  Diagnosis of pulmonary tuberculosis & lung disease
  Breast-mass identification
  → Employed '<u>transfer learning</u>'

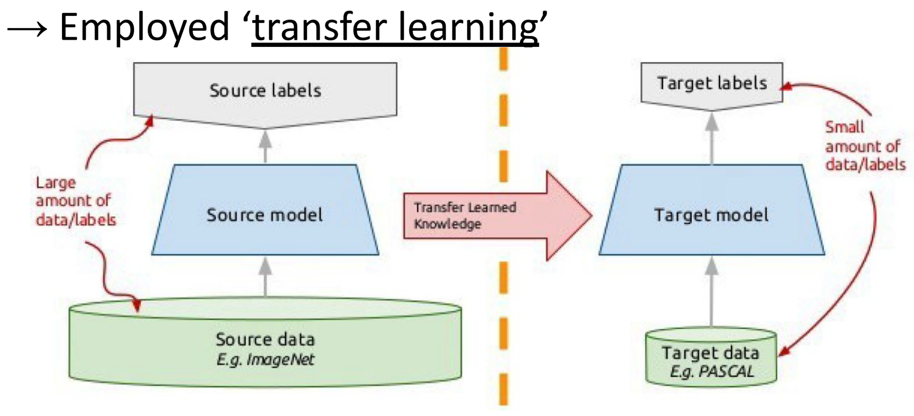
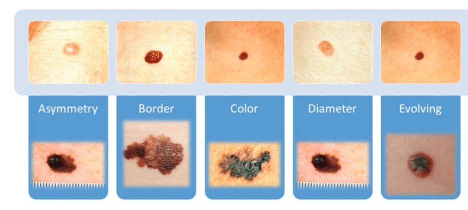



**Fig. 6 Transfer Learning concept[6]**

- ***Dermatology***
  ABCDE's of Melanoma : criteria of skin cancer



Recently, finalized diagnostic model can be deployed on <u>mobile devices</u>

**Fig. 7 ABCDE's rule[7]**

- ***Ophthalmology***
  Detection of DR(Diabetic Retinopathy), glaucoma
  → Capture the image of retina with Fundus photography

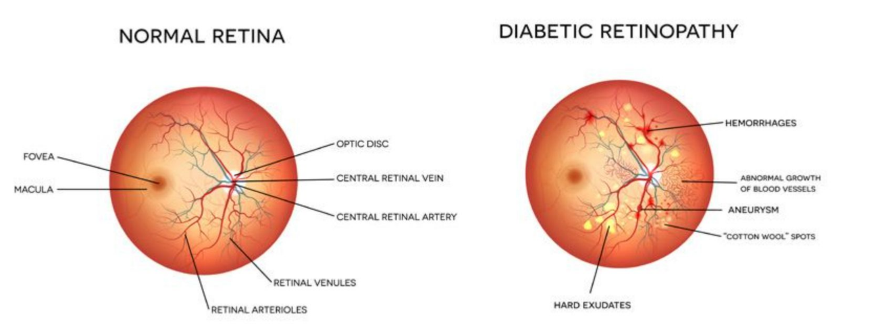



**Fig. 8 Normal vs DR retina image[8]**

- ***Pathology***
  Detection of many different cancers (prostate, breast)
  → Interpreting the slides under a microscope

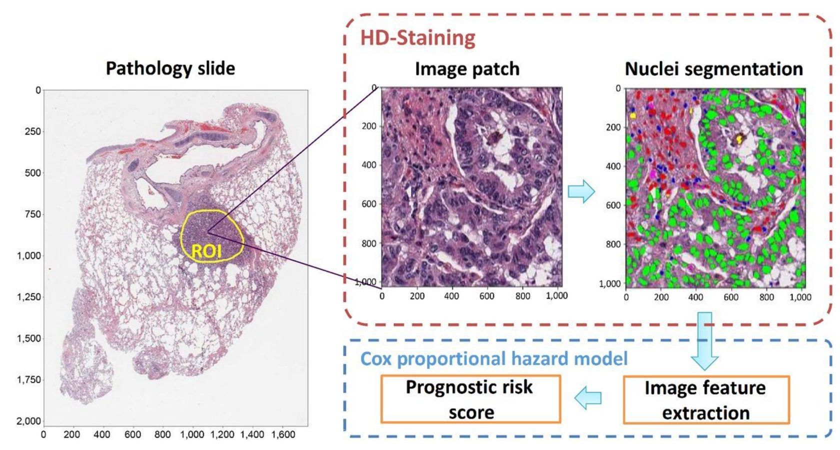
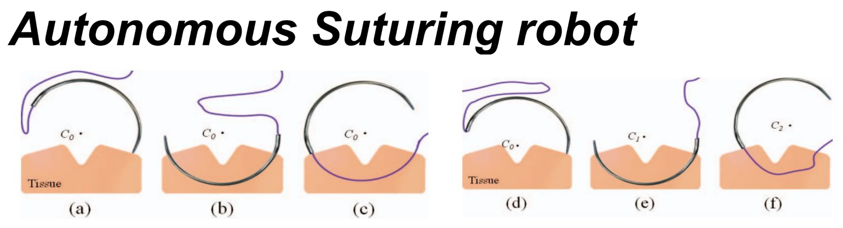


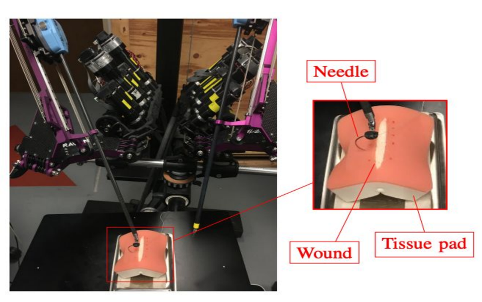

**Fig. 9 Flow chart of pathology image analysis[9]**

## Autonomous Robotic Surgery

- ***Robotic systems controlled by AI***
  <u>Industry</u> : Commonly used
  <u>Medical surgery</u> : Robotically '**assisted**' → But started to change
- ***Autonomous Suturing robot***



◁ **Fig. 10-1 Motion control concept[4]**
▷ **Fig. 10-2 Autonomous suturing workstation[4]**
→ Have better consistency




- ***Autonomous Cochleostomy***
  Cochlear implantation drilling robot

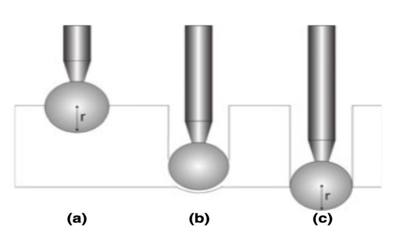


**Fig. 6 States of drilling process[5]**

→ Have better consistency
→ Minimize the damage

## Challenges

- **Ethical problem**

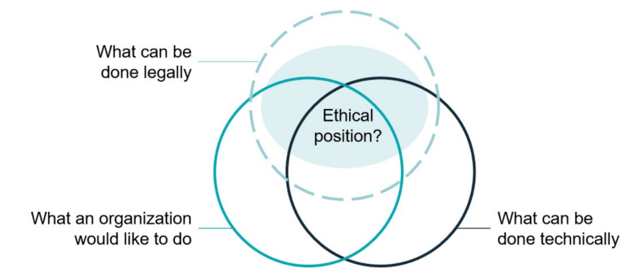



**Fig. 11 An ethical position[1]**

- **Environmental problem**
  e.g.) Higher demand for semiconductors

## Contact

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# Biometric Authentication for Wireless Body Area Networks


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## Introduction

Wireless sensor networks play an important role in designing effective mobile healthcare (mHealth) systems to manage healthcare. Body sensor network (BSN), also known as body area sensor network (BASN), is a sensor network whose nodes are biosensors either implanted in, worn on, or close to human bodies. BASN can facilitate self-monitoring, allowing patients to avoid hospitalisation. and improving the healthcare sector. It can provide long-term health monitoring without disrupting a patient's privacy and is used in vital signs monitoring, home care monitoring, clinical monitoring and sports health.

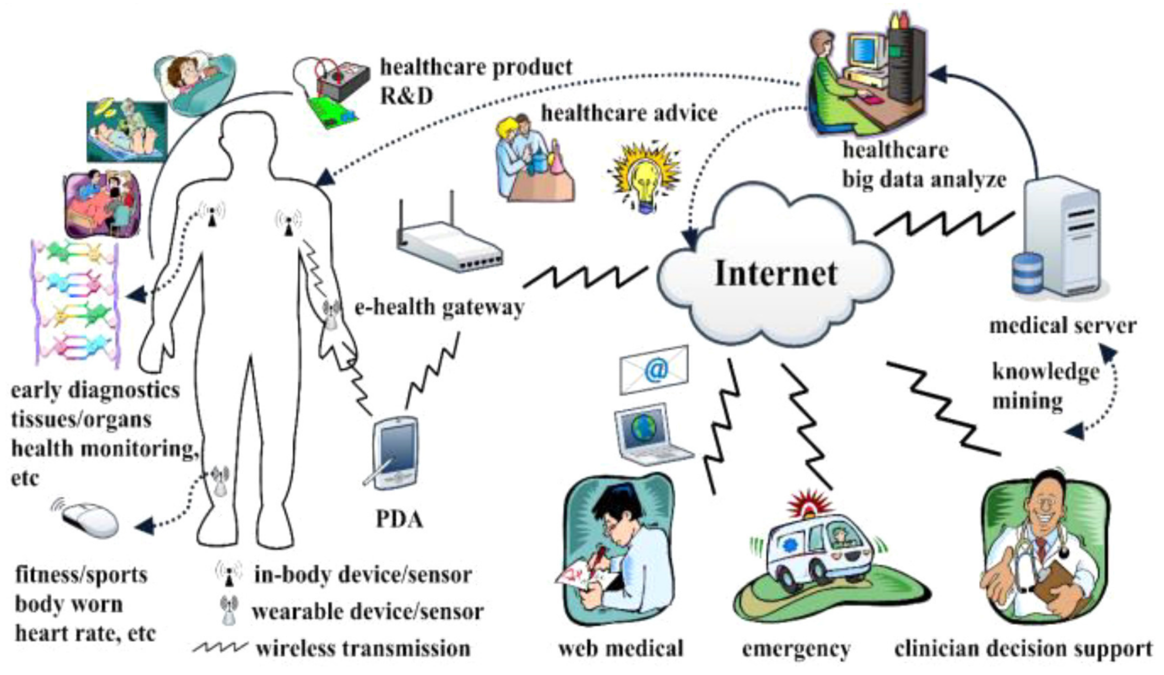


Fig. 1: Representative examples of wearable biosensors [7]

## Architecture of mHealth system

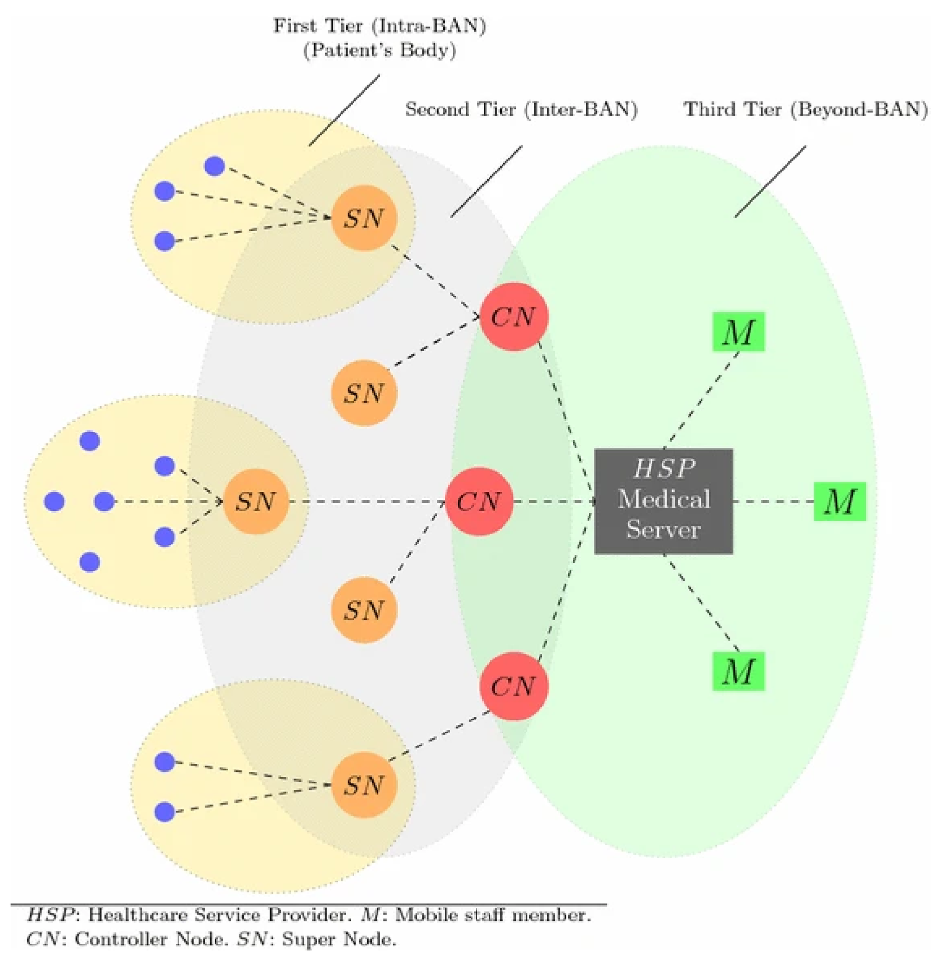


Fig. 2: Architecture of an mHealth system [2]

Data from various sensor nodes is transmitted to a special node called super sensor node, with more storage capabilities. The data collected by the super sensor nodes is sent to a local controller node. The controller node is responsible for collecting all patients' data and sends them to the healthcare provider's medical server through public networks. Two main biometric authenticatio approaches for intra-BAN communication have been compared here - ECG fiducial point based and IPI based. Both methods use heart rate variability as a shared source of entropy for cryptographic key generation.

## Key Requirements

| | |
|---|---|
| **Mutual authentication:** | A secure process where both entities verify the identity of each other before communication. |
| **Anonymity:** | The identity of the node / user needs to be anonymous to maintain patient privacy. |
| **Unlinkability:** | Consecutive transactions / sessions should not be linkable by an adversary. |
| **Reliability:** | Proposed systems need quality of service and fault tolerance. |
| **Secure management:** | A console is needed for a coordinator to add and remove nodes securely. |
| **Integrity:** | Check if the data received has been altered. |
| **Freshness:** | Ensure the newness of data (timestamp). |

* Anonymity and unlinkability are applicable mainly to Tier 2 and 3 communication

## Working Principle

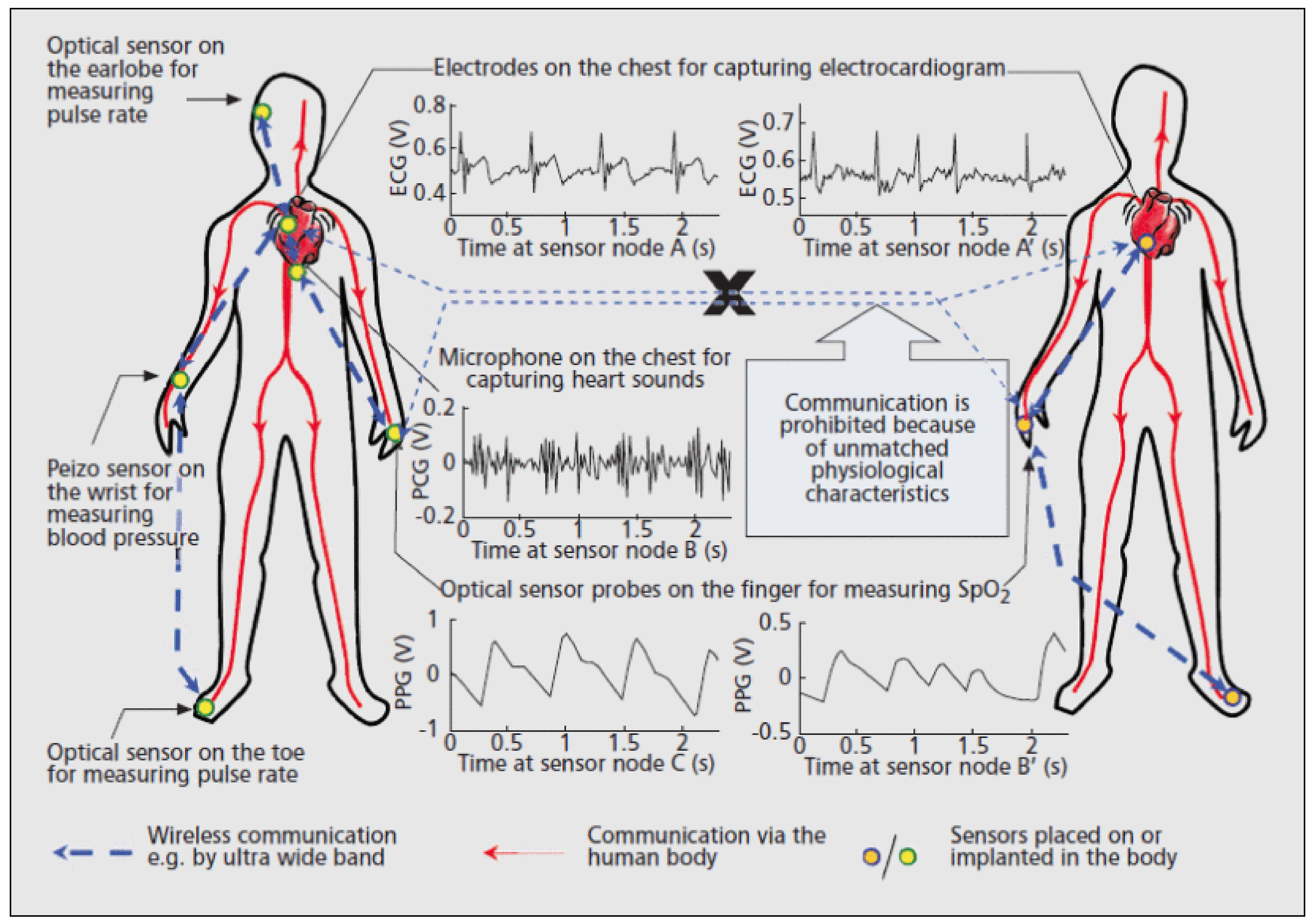


Fig. 3: Biometric authentication in intra-BAN communication [5]

The process begins with both the sensor node and super sensor node measuring their respective parameters of the heart. The algorithm then extracts HRV parameters (mentioned in the table) and uses it a entropy source to generate the shared key. Standard cryptographic methods can be implemented for key exchange and initial secure communication. The sequence similarity is quantified as a distance measure to authenticate the device and evaluate the method. The table below summarises some works from literature.

| Ref. | Parameters | Modeling |
|---|---|---|
| [6] | NN interval, SDNN, RMSSD, pNN50 | Hash function with message |
| [1], [9] | RR, RQ, RS, RP, RT interval | Multiple fiducial point binary sequence generation |
| [8] | QRS axis, QT-interval, ST-level, and T-wave abnormalities | Wavelet domain Hidden Markov Model |
| [3] | Inter pulse interval | $\mu$ and $\sigma$ of IPI array |
| [4] | Inter pulse interval | Finite monotonic increasing sequences generation, cyclic block encoding |
| [5] | IPI from ECG and PPG | Hamming distance of generated binary sequence |

## Comparison of Methods

| Metric | Inter Pulse Interval based | ECG Fiducial based |
|---|---|---|
| Computation cost | Lower | Higher |
| Energy cost | Lower | Higher |
| Data duration | $\sim$30 sec | $\sim$30 sec |
| Randomness of source | Lower | Higher |
| Synchronisation errors | Higher | Lower |

**Key Challenges:**

**Synchronisation in measurement -** The pulse wave has a slightly different timing based on the location of measurement, leading to synchronisation difficulties.

**Requirement of circulatory sensing in every node -** Since every node needs to measure the heart rhythm in some way, it may lead to redundant sensors increasing the cost, size and complexity.

## Implications for Medical Information Systems

The increased adoption of wearable devices in consumer electronics and healthcare has created scope for continuous long term monitoring. By aggregating and synchronising multi-modal sources of data from the body, there is great potential to improve the quality of data recorded by automatically filtering noisy values or annotating mismatch timestamps, etc. This information could prove useful to better sensor design as well analytics. Due the privacy concerns with medical data, it is instrumental to have a secure communication interface - although classical cryptographic methods exist using hardware random number generation algorithms, biometric authentication techniques offer an alternative approach that utilizes the shared pool of information in the heart beat. It also offers the added benefit that it cannot be "sniffed" remotely, requiring physical contact with the subject to access the information.

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