

Smart Healthcare – An Overview

Faculty Development Program

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Outline

- Healthcare to Smart Healthcare
- Smart Healthcare - Characteristics
- Smart Healthcare - Components
- Smart Healthcare - Examples
- Smart Healthcare - Challenges
- Conclusions and Future Directions

Healthcare to Smart Healthcare

Smart Healthcare -- Prof./Dr. Saraju P. Mohanty



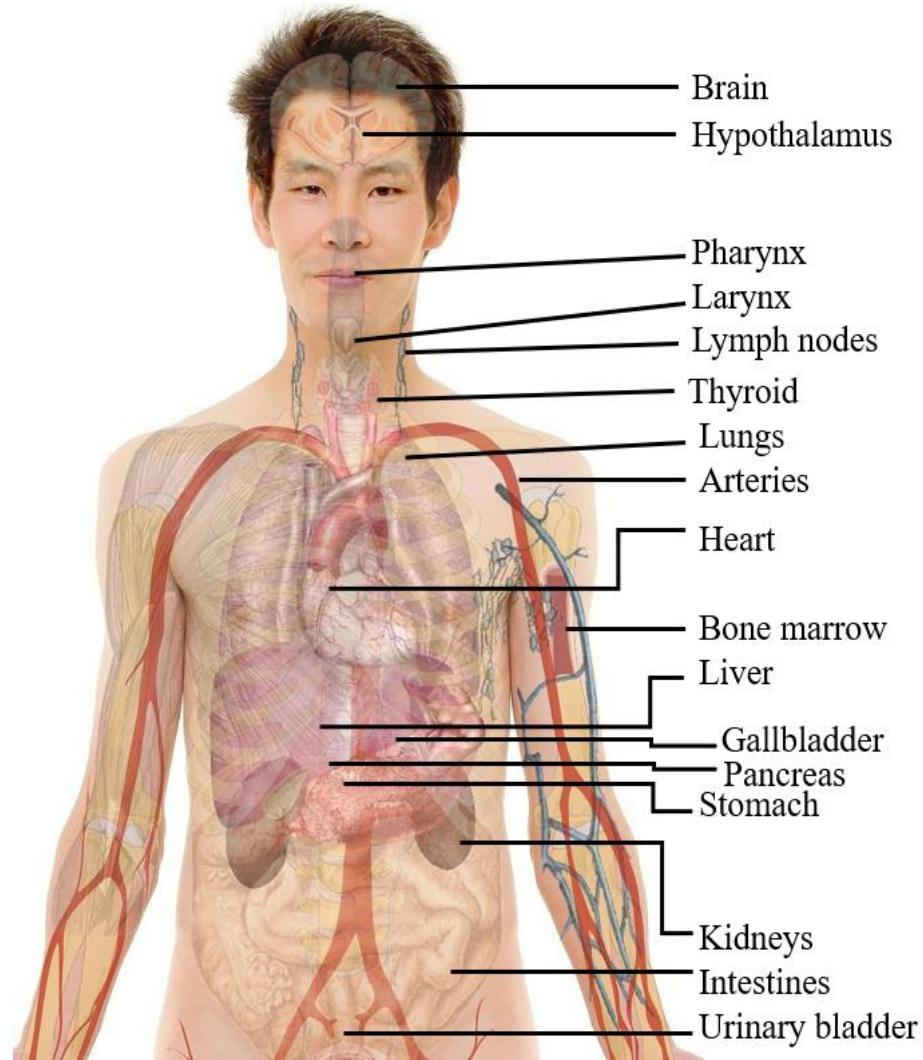
Human Body and Health

Human Body

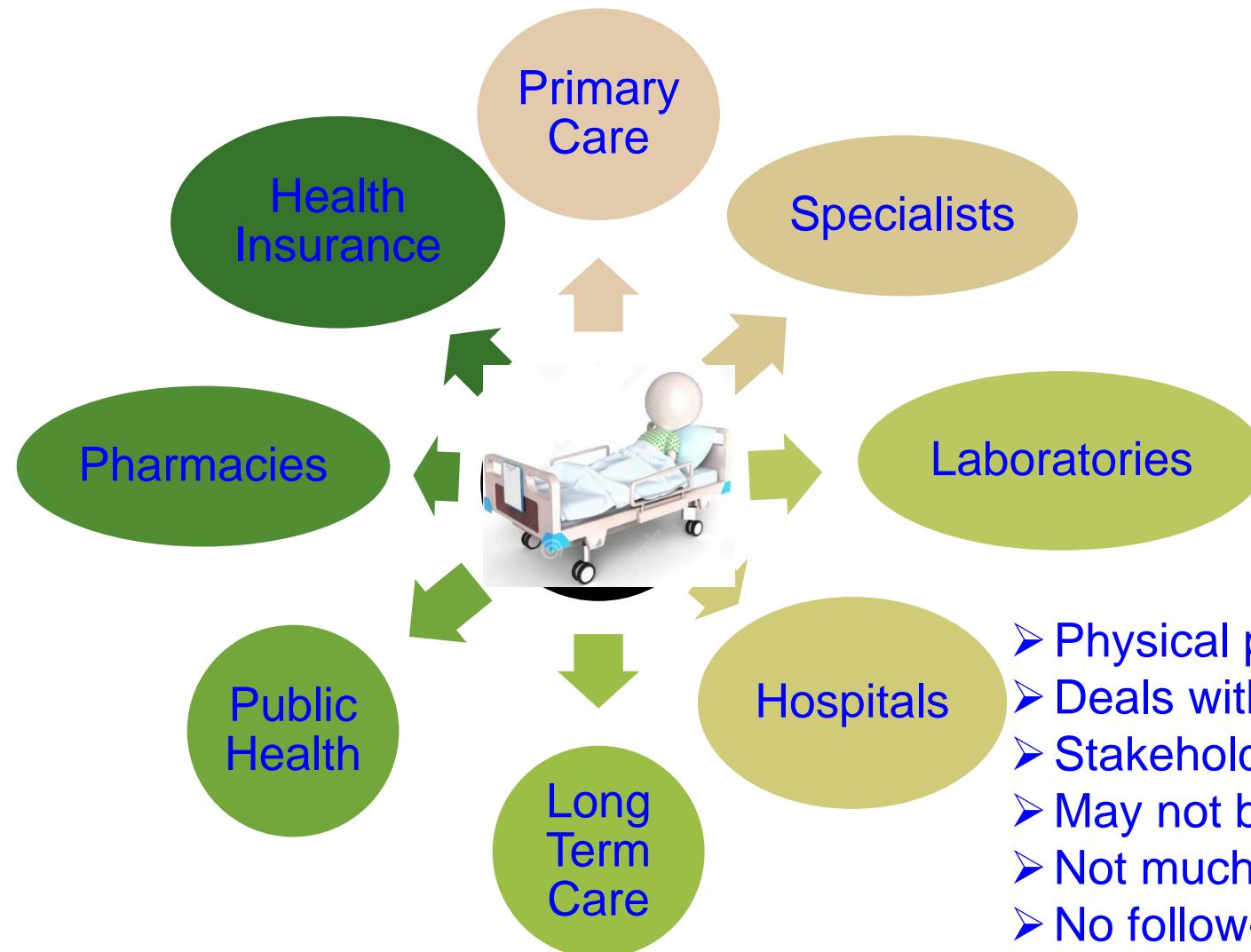
- From an engineering perspective, the human body can be defined as a combination of multi-disciplinary (electrical, mechanical, chemical ...).

Health

- Human health is a state of complete physical, mental and social well-being.



Traditional Healthcare



- Physical presence needed
- Deals with many stakeholders
- Stakeholders may not interact
- May not be personalized
- Not much active feedback
- No follow-up from physicians

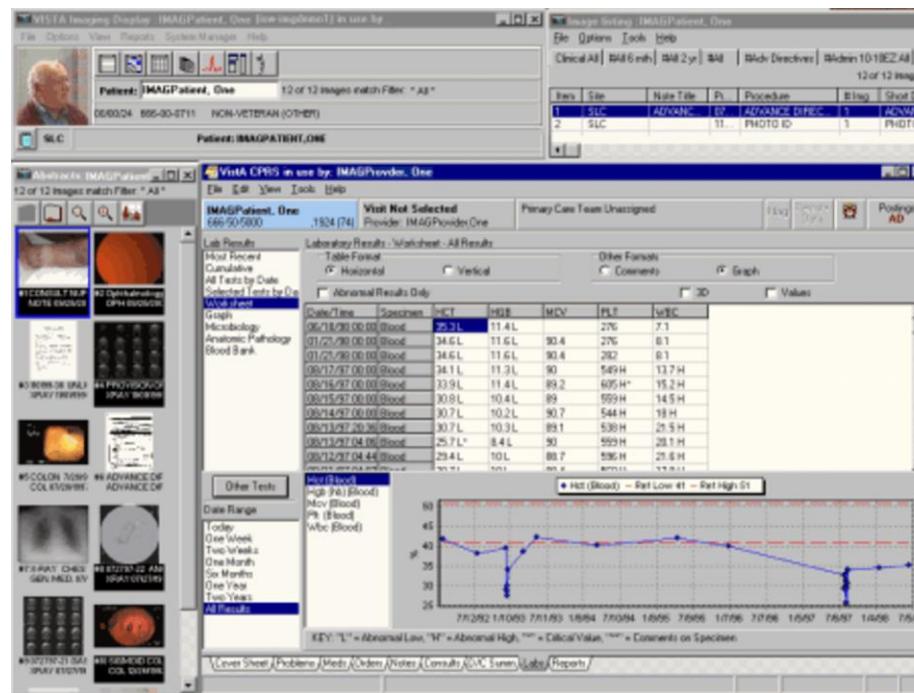
Telemedicine



Telemedicine is the use of telecommunication and information technology to provide clinical health care from a distance.

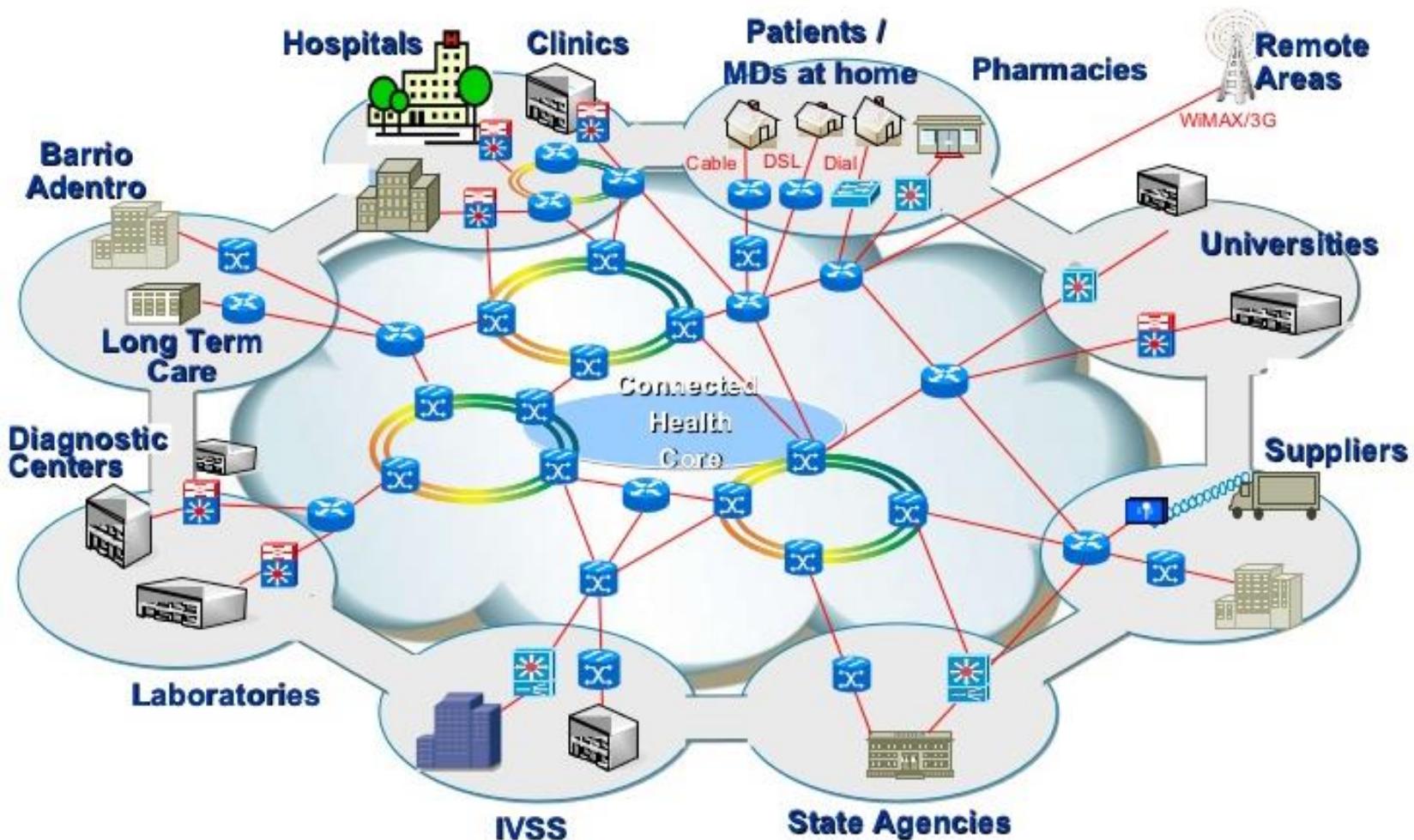
Electronic Health (eHealth)

- eHealth: The use of information and communication technologies (ICT) to improve healthcare services.



Source: W. O. Nijeweme-d'Hollosy, L. van Velsen, M. Huygens and H. Hermens, "Requirements for and Barriers towards Interoperable eHealth Technology in Primary Care," *IEEE Internet Computing*, vol. 19, no. 4, pp. 10-19, July-Aug. 2015.

Connected Health (cHealth)



Source: https://www.slideshare.net/tibisay_hernandez/connected-health-venfinal

Mobile Health (mHealth)

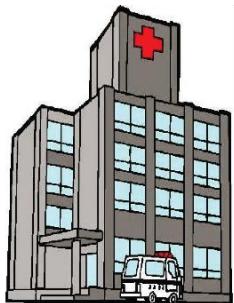
- mHealth: Healthcare supported by *mobile devices* that uses mobile telecommunications and multimedia technologies for the delivery of healthcare services and health information.



Source: H. Zhu, C. K. Wu, C. H. KOO, Y. T. Tsang, Y. Liu, H. R. Chi, and K. F. Tsang, "Smart Healthcare in the Era of Internet-of-Things", *IEEE Consumer Electronics Magazine*, vol. 8, no. 5, pp. 26-30, Sep 2019.

Smart Healthcare (sHealth)

Smart Hospital



Emergency Response



Smart Home



Nurse



IoMT

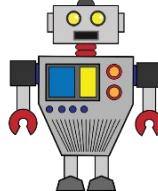
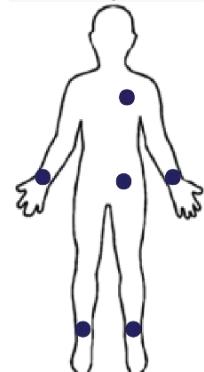


Doctor



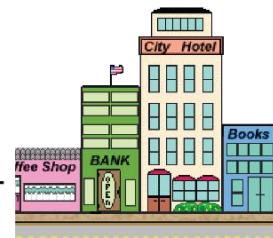
Technician

On-body Sensors



Robots

Smart Infrastructure



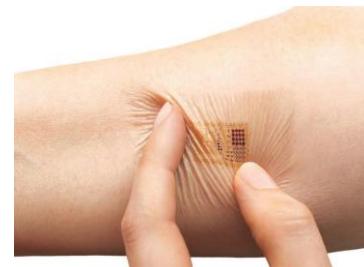
Smart Gadgets



Fitness
Trackers



Headband with Embedded
Neurosensors



Embedded
Skin Patches

Sethi 2017: JECE 2017

Quality and
sustainable healthcare
with limited resources.

Source: P. Sundaravadivel, E. Kougiános, S. P. Mohanty, and M. Ganapathiraju, "Everything You Wanted to Know about Smart Health Care", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 7, Issue 1, January 2018, pp. 18-28.

Smart Healthcare - Characteristics

Wearable Medical Devices (WMDs)

Fitness Trackers



Headband with Embedded Neurosensors



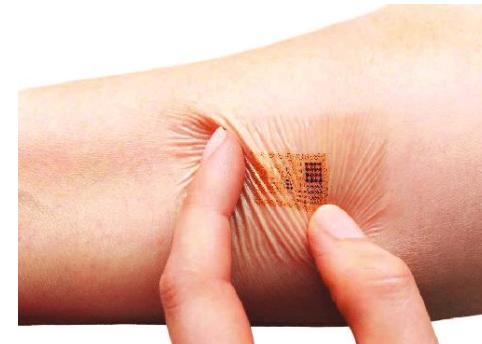
Source: <https://www.empatica.com/embrace2/>

Medical grade smart watch to detect seizure



Insulin Pump

Source: <https://www.webmd.com>

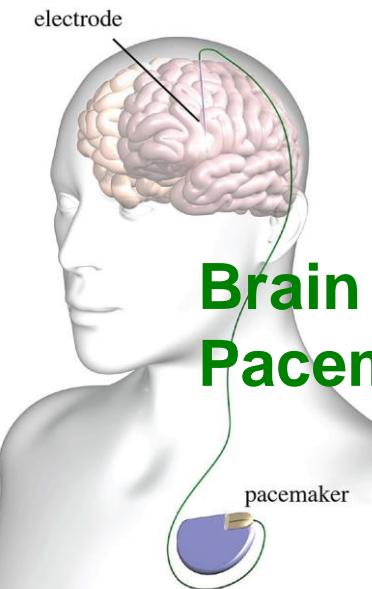
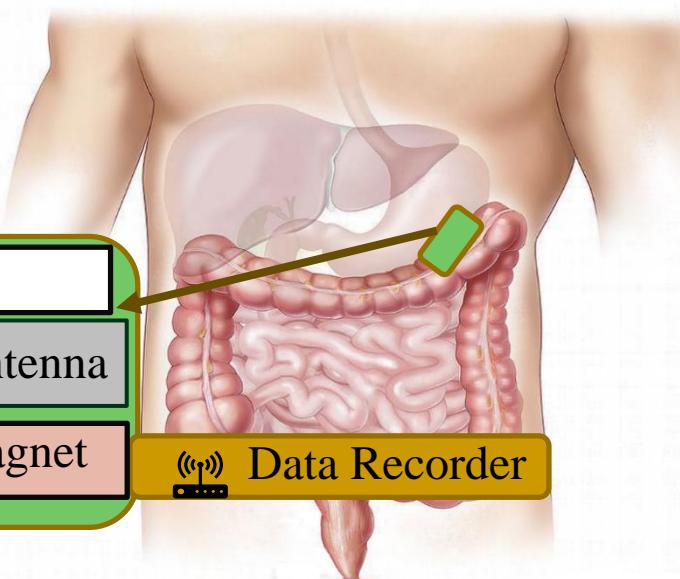
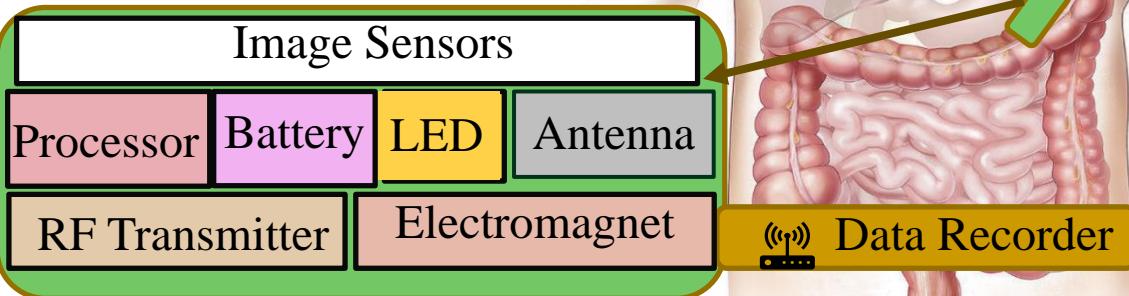


Embedded Skin Patches

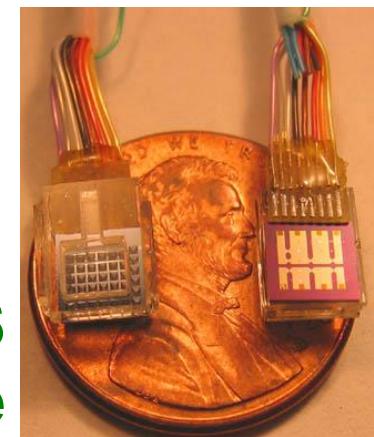
Implantable Medical Devices (IMDs)



Pill Camera



Brain Pacemaker



Source: P. Sundaravadiel, E. Kougianos, S. P. Mohanty, and M. Ganapathiraju, "Everything You Wanted to Know about Smart Health Care", IEEE Consumer Electronics Magazine (MCE), Volume 7, Issue 1, January 2018, pp. 18-28.

Collectively:
Implantable and Wearable
Medical Devices (IWMDs)

Implantable MEMS Device

Source: <http://web.mit.edu/cprl/www/research.shtml>

Smart Healthcare



Healthy Living

- Fitness Tracking
- Disease Prevention
- Food monitoring

Home Care

- Mobile health
- Telemedicine
- Self-management
- Assisted Living

Acute Care

- Hospital
- Specialty clinic
- Nursing Home
- Community Hospital

Internet of Medical Things (IoMT)

Frost and Sullivan predicts smart healthcare market value to reach US\$348.5 billion by 2025.

Source: P. Sundaravadivel, E. Kougianos, S. P. Mohanty, and M. Ganapathiraju, "Everything You Wanted to Know about Smart Health Care", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 7, Issue 1, January 2018, pp. 18-28.



What is Smart Healthcare?

Smart Healthcare ←
Conventional Healthcare
+ Body sensors
+ Smart Technologies
+ Information & Communication Technology (ICT)
+ AI/ML

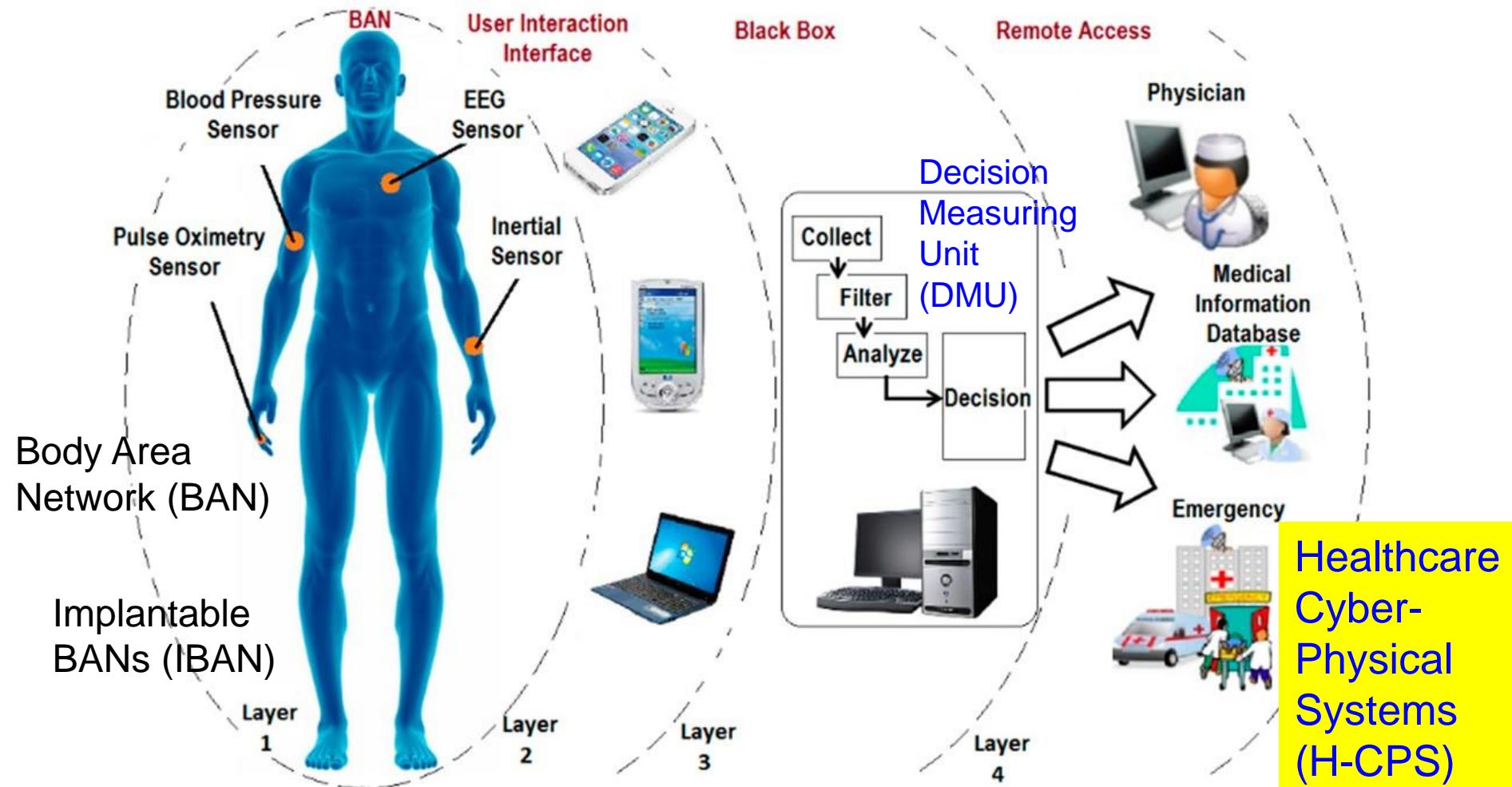
Internet of Medical Things (IoMT)

Internet of Health Things (IoHT)

Healthcare Cyber-Physical Systems (H-CPS)

Source: P. Sundaravadivel, E. Kougianos, S. P. Mohanty, and M. Ganapathiraju, "Everything You Wanted to Know about Smart Health Care", *IEEE Consumer Electronics Magazine (MCE)*, Volume 7, Issue 1, January 2018, pp. 18-28.

Smart Healthcare - 4-Layer Architecture



Source: M. Ghamari, B. Janko, R.S. Sherratt, W. Harwin, R. Piechockic, and C. Soltanpur, "A Survey on Wireless Body Area Networks for eHealthcare Systems in Residential Environments", Sensors, 2016. 16(6): p. 831.

IoMT based H-CPS

Patient-specific care with context and enabled through past health records.



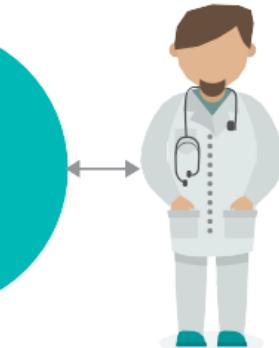
Patient

Improved inter-device connection and synchronization



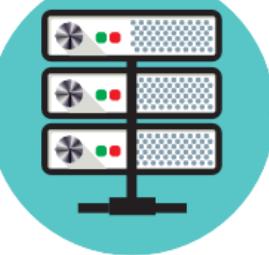
Development of evidence-based guidelines which can helpful to incorporate the local intelligence in future machine.

Real-time tracking and intervention



Healthcare Provider

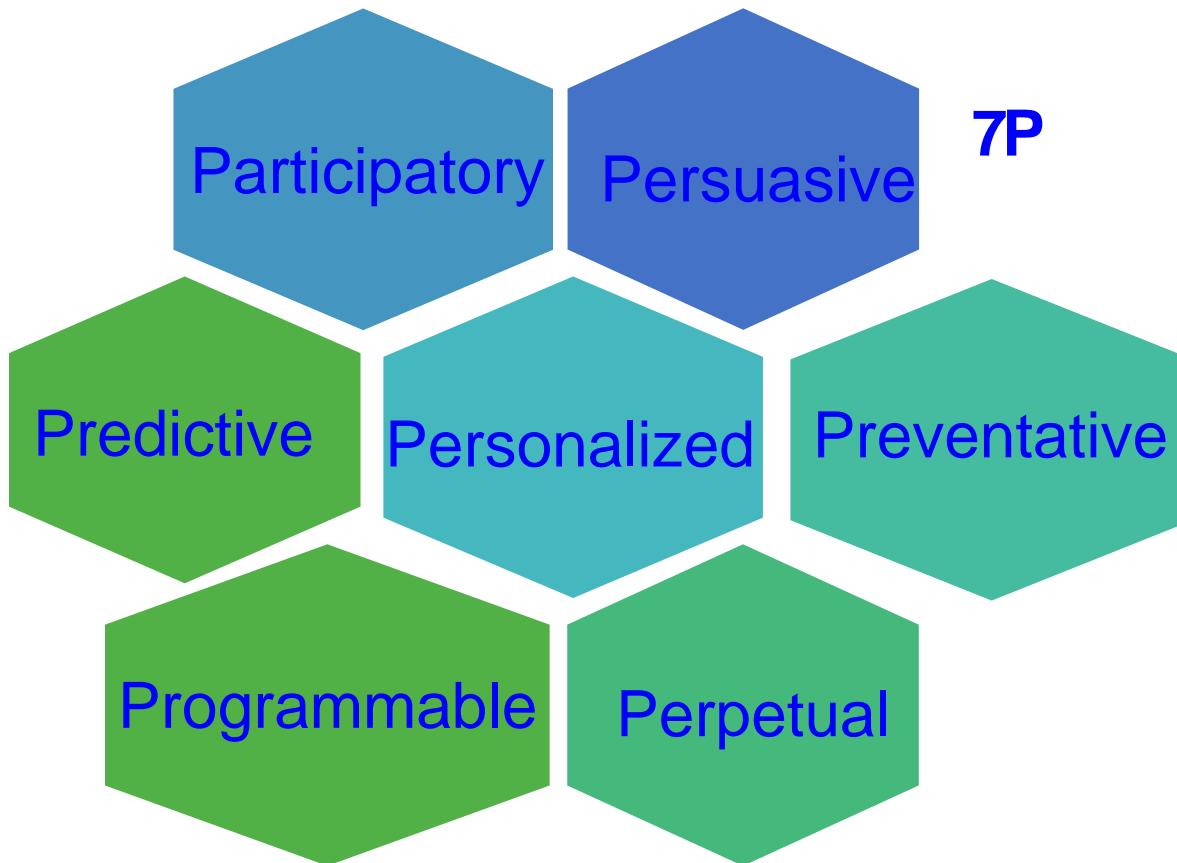
Data driven health prediction



Healthcare Cyber-Physical Systems (H-CPS)

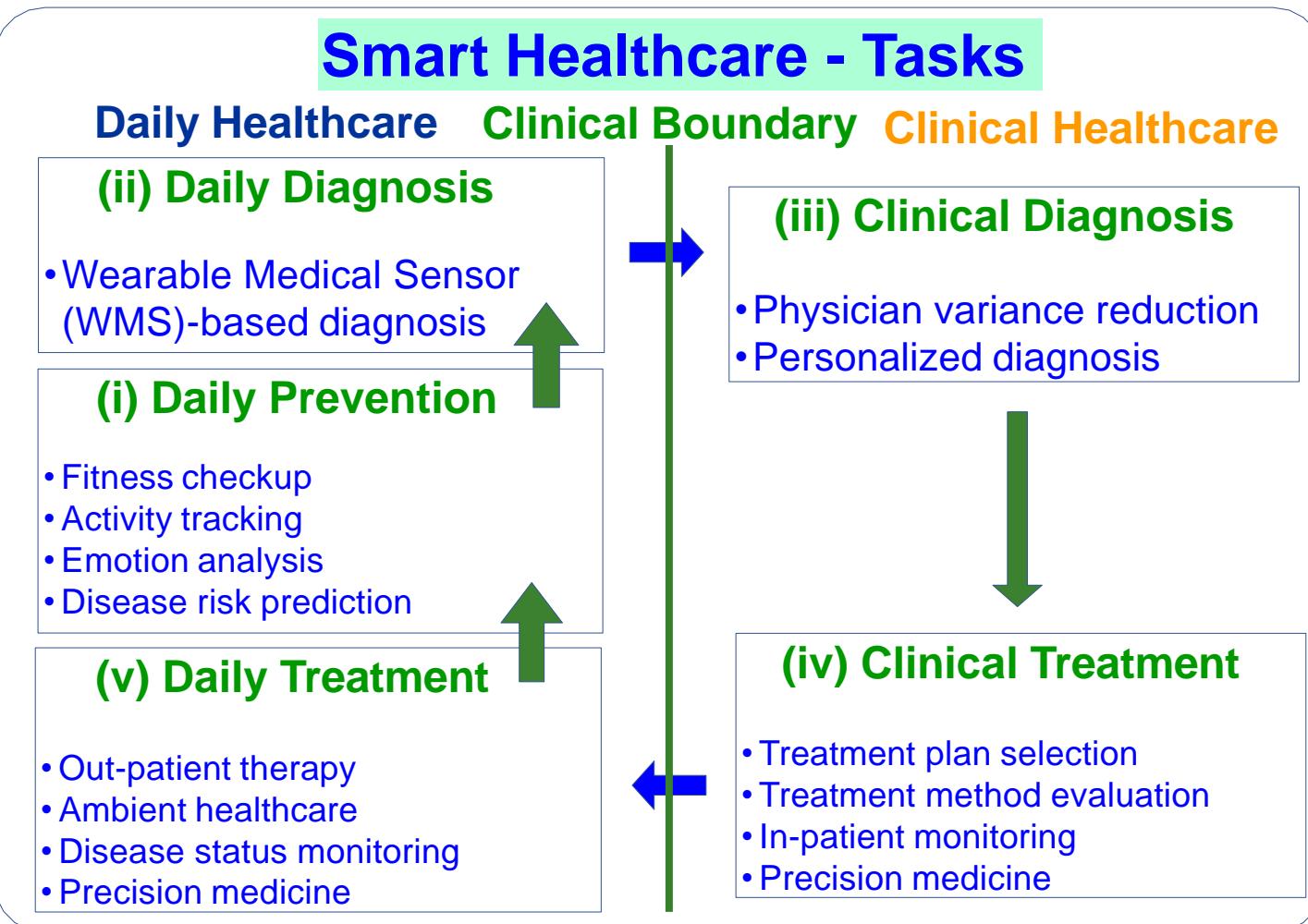
Source: Y. Shelke and A. Sharma, "Internet of Medical Things", 2016, Aranca, <https://www.aranca.com/knowledge-library/special-reports/ip-research/the-internet-of-medical-things-iomt>, Last Visited 10/18/2017.

Smart Healthcare – 7Ps



Source: H. Zhu, C. K. Wu, C. H. KOO, Y. T. Tsang, Y. Liu, H. R. Chi, and K. F. Tsang, "Smart Healthcare in the Era of Internet-of-Things", *IEEE Consumer Electronics Magazine*, vol. 8, no. 5, pp. 26-30, Sep 2019.

Smart Healthcare - Tasks



Source: Hongxu Yin, Ayten Ozge Akmandor, Arsalan Mosenia and Niraj K. Jha (2018), "Smart Healthcare", *Foundations and Trends® in Electronic Design Automation*: Vol. 12: No. 4, pp 401-466. <http://dx.doi.org/10.1561/1000000054>

IoMT Advantages & Limitations

Advantages

Patients/Users

- Real-time interventions in emergency
- Cost reduction
- Reduced morbidity and financial burden due to less follow up visits

Healthcare Service Providers

- Optimal utilization of resources
- Reduced response time in emergency

Manufacturers

- Standardization/compatibility and uniformity of data available
- Capability to sense and communicate health related information to remote location

Limitations

Technical Challenges

- ❖ Security of IoT data - hacking and unauthorized use of IoT
- ❖ Lack of standards and communication protocols
- ❖ Errors in patient data handling
- ❖ Data integration
- ❖ Need for medical expertise
- ❖ Managing device diversity and interoperability
- ❖ Scale, data volume and performance

Market Challenges

- ❖ Physician compliance
- ❖ Data overload on healthcare facility
- ❖ Mobile hesitation
- ❖ Security policy compliance

Source: Y. Shelke and A. Sharma, "Internet of Medical Things", 2016, Aranca, <https://www.aranca.com/knowledge-library/special-reports/ip-research/the-internet-of-medical-things-iomt>, Last Visited 10/18/2017.

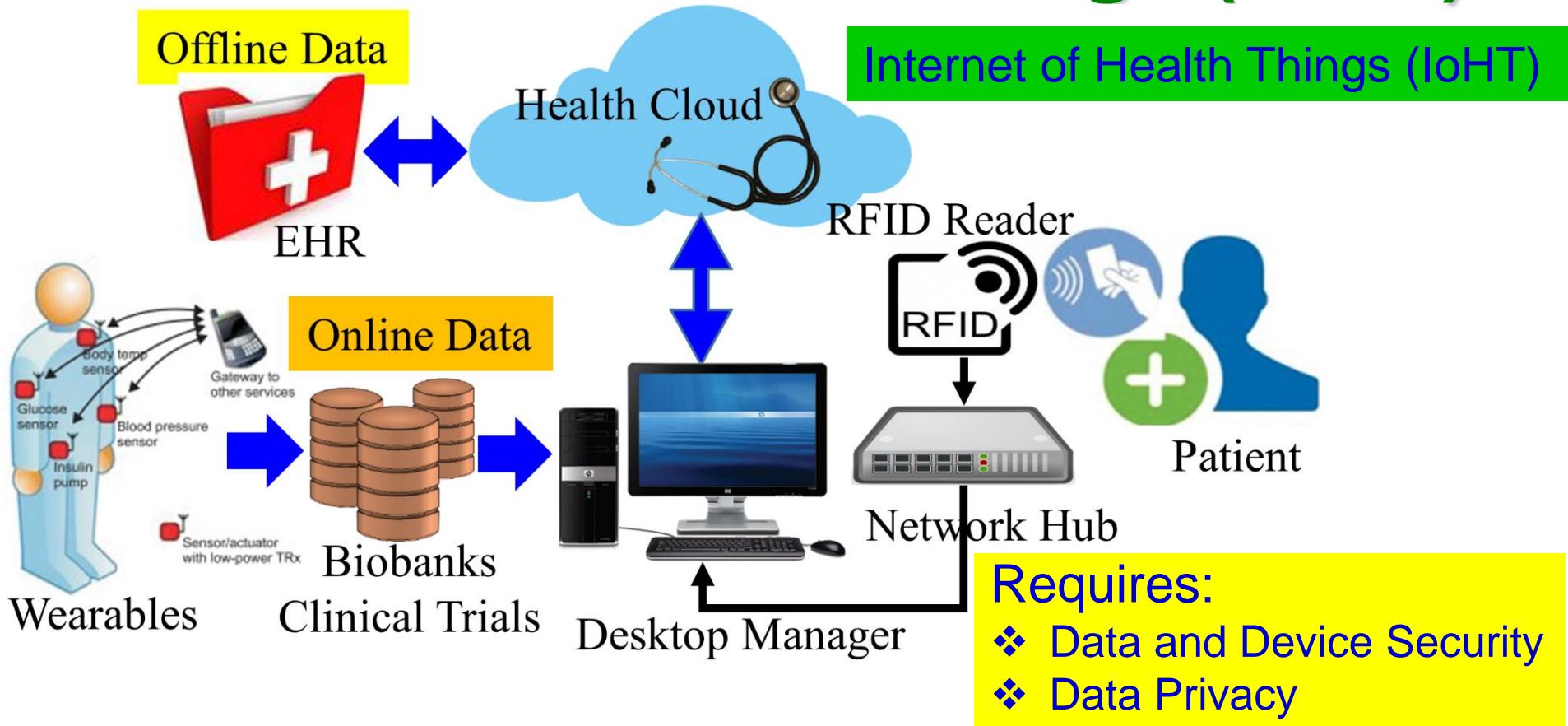


Smart Healthcare - Components

Smart Healthcare -- Prof./Dr. Saraju P. Mohanty



Internet of Medical Things (IoMT)

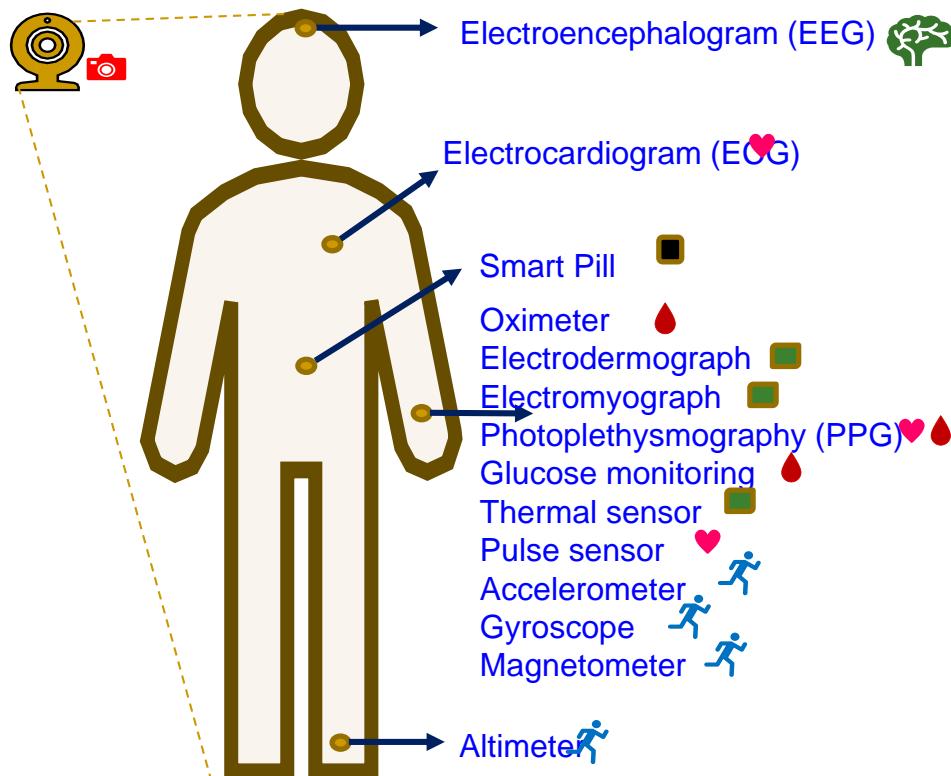


IoMT is a collection of medical sensors, devices, healthcare database, and applications that connected through Internet.

Source: <http://www.icemiller.com/ice-on-fire-insights/publications/the-internet-of-health-things-privacy-and-security/>

Source: <http://internetofthingsagenda.techtarget.com/definition/IoMT-Internet-of-Medical-Things>

Smart Healthcare Sensors



Types of Sensors	
	Brain related applications
	Imaging applications
	Heart related applications
	Skin related applications
	Blood related applications
	Ingestible sensors
	Motion Detection

Smart Healthcare Communication

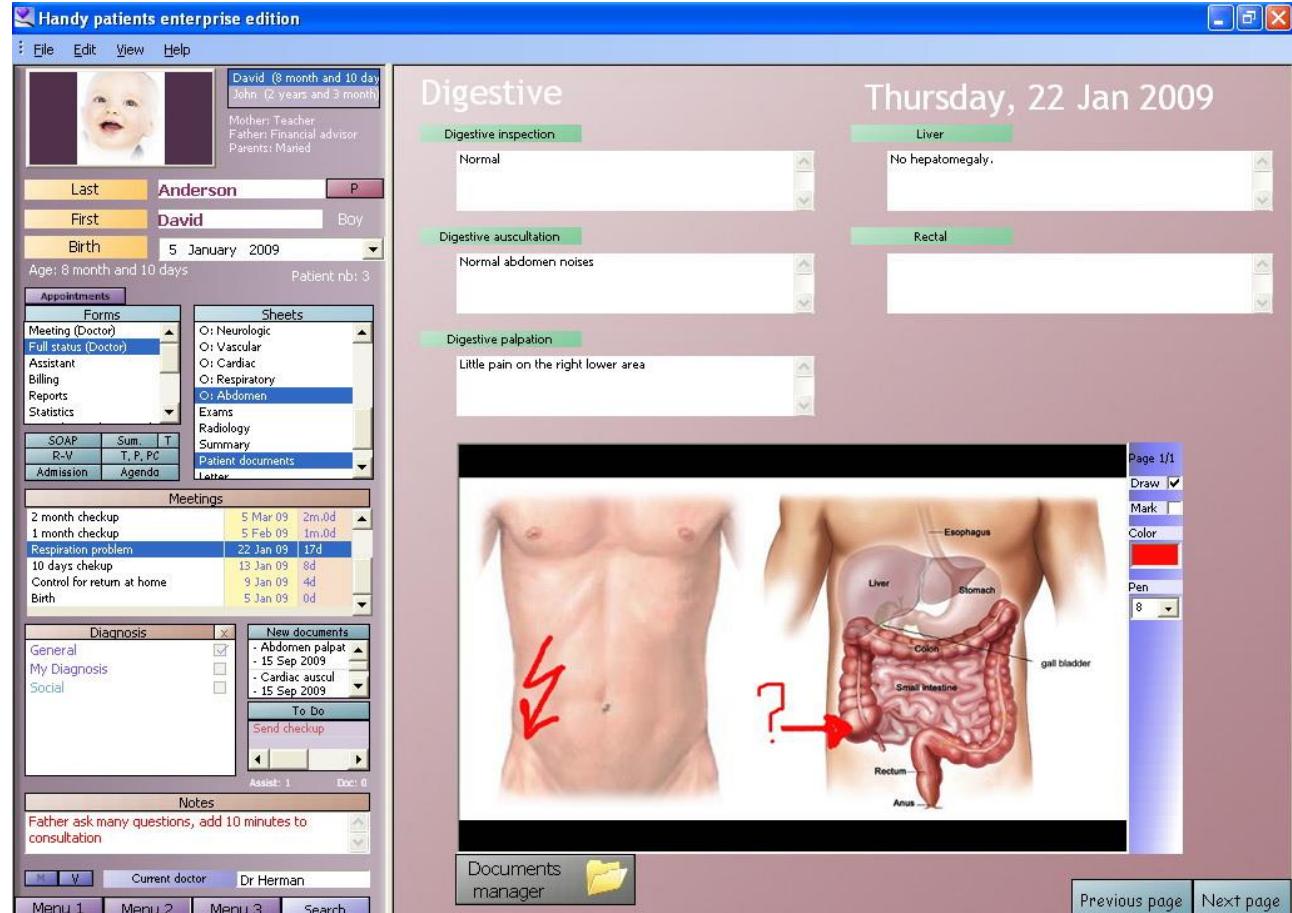
Technology	Frequency Band	Data Rate	Range	Transmission Power
Bluetooth 4.0 (LE)	2.4 GHz	50–200 Kbps	30 m	~10 mW
Zigbee	868 MHz/ 915 MHz/ 2.4 GHz	20–250 Kbps	30 m	30 mW
ANT	2400-2485 MHz	1 Mbps	Up to 10 m	0.01–1 mW
IEEE 802.15.6	2,360-2,400/ 2,400- 2,483.5 MHz UWB: 3–10 GHz HBC: 16/27 MHz	NB: 57.5– 485.7 Kbps UWB: 0.5– 10 Mbps	1.2 m	0.1 µW
Medical Implant Communications Service (MICS)	402-405 MHz	Up to 500 Kbps	2 m	25 µW

Source: V. Custodio, F.J. Herrera, G. López, and J. I. Moreno, "A Review on Architectures and Communications Technologies for Wearable Health-Monitoring Systems", Sensors, 2012. 12(10): p. 13907-13946.

Electronics Health Record (EHR)

Electronic Health Record (EHR) is the systematized collection of health information of individuals stored in a digital format.

Created by various health providers such as hospitals and clinics.



Electronic Medical Record (EMR)

Smart Healthcare - Framework

Smart Healthcare - System and Data Analytics : To Perform Tasks

Systems & Analytics

- Health cloud server
- Edge server
- Implantable Wearable Medical Devices (IWMDs)
- Machine Learning Engine

Systems & Analytics

- Clinical Decision Support Systems (CDSSs)
- Electronic Health Records (EHRs)

Machine Learning Engine



Data

- Physiological data
- Environmental data
- Genetic data
- Historical records
- Demographics

Data

- Physician observations
- Laboratory test results
- Genetic data
- Historical records
- Demographics

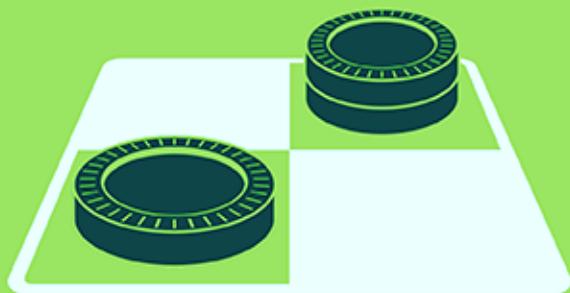


Source: Hongxu Yin, Ayten Ozge Akmandor, Arsalan Mosenia and Niraj K. Jha (2018), "Smart Healthcare", *Foundations and Trends® in Electronic Design Automation*, Vol. 12: No. 4, pp 401-466. <http://dx.doi.org/10.1561/1000000054>

AI, Machine Learning, and Deep Learning

ARTIFICIAL INTELLIGENCE

Early artificial intelligence stirs excitement.



MACHINE LEARNING

Machine learning begins to flourish.



DEEP LEARNING

Deep learning breakthroughs drive AI boom.

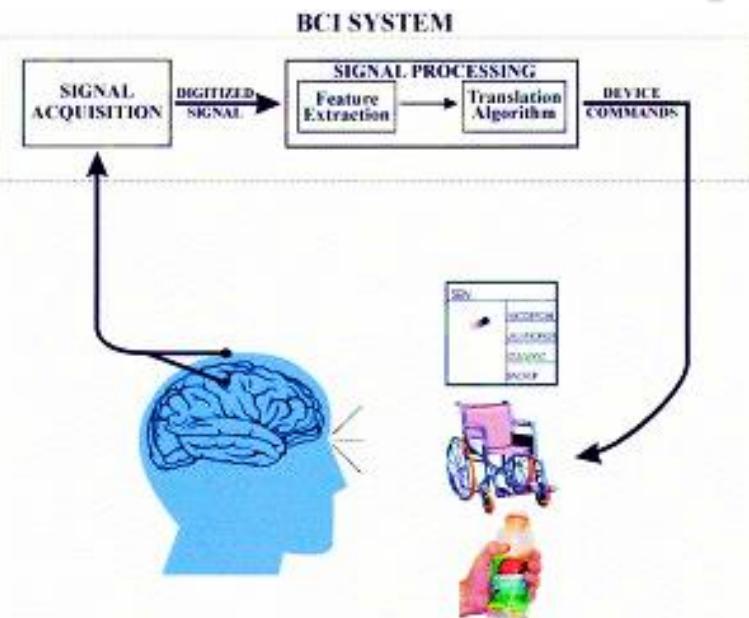


Timeline:

1950's 1960's 1970's 1980's 1990's 2000's 2010's

Source: <https://blogs.nvidia.com/blog/2016/07/29/whats-difference-artificial-intelligence-machine-learning-deep-learning-ai/>

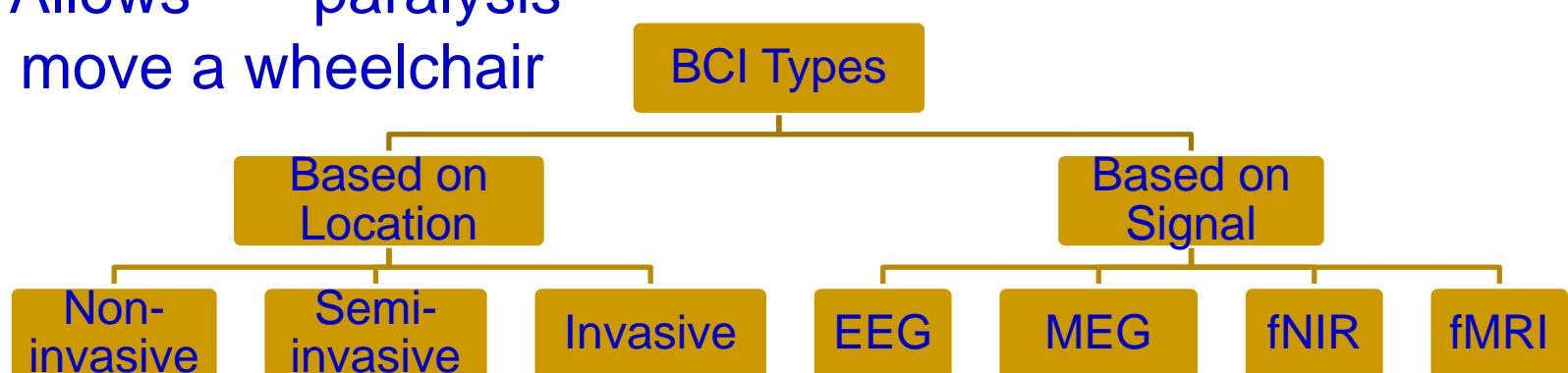
Brain Computer Interface (BCI)



Source: <http://brainpedia.org/brain-computer-interface-allows-paralysis-als-patients-type-much-faster/>

Source: <http://brainpedia.org/what-is-brain-computer-interface-bci/>
BCI Allows paralysis patients move a wheelchair

BCI Allows paralysis patients to Type



Virtual Reality in Healthcare



Source: <https://touchstoneresearch.com/tag/applied-vr/>

In Surgery

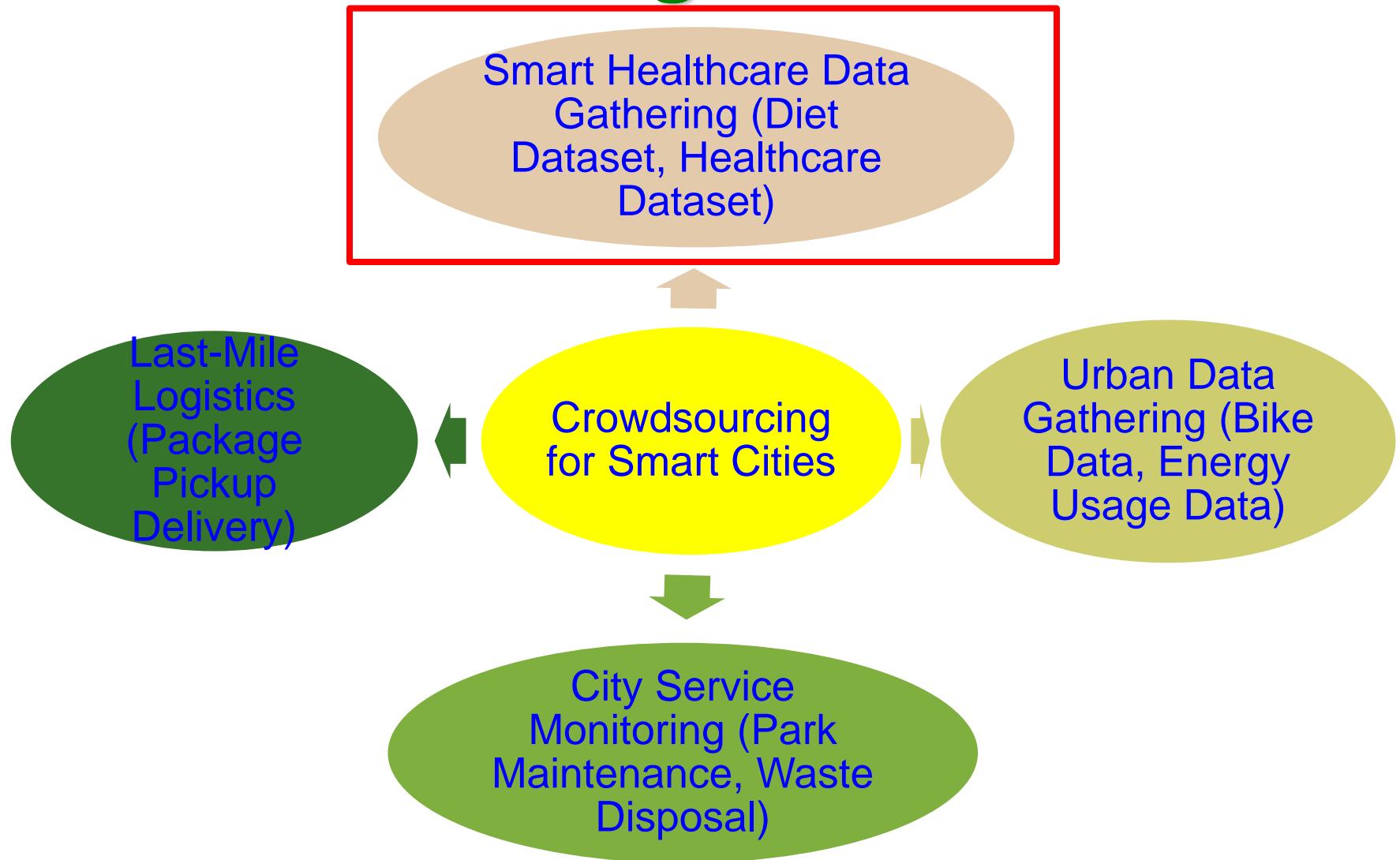


Source: <http://medicalfuturist.com/5-ways-medical-vr-is-changing-healthcare/>

For Therapy

- Help women get through labor pain
- Help post traumatic stress disorder (PTSD)

Crowdsourcing for Smart Cities



Smart Healthcare – Specific Examples

Stress is a Global Issue

- In major global economies - 6 in 10 workers experiencing increased workplace stress.
- In USA: 75% of adults reported experiencing moderate to high levels of stress. 1 out of 75 people may experience panic disorder.
- In Australia: 91% of adults feel stress in at least one important area of their lives.
- In UK: An estimated 442,000 individuals, who worked in 2007/08 believed that they were experiencing work-related stress
- Depression is among the leading causes of disability worldwide. 25% of those with depression world-wide have access to effective treatments → 75% don't have.

Source: <http://www.gostress.com/stress-facts/>

Why Stress Needs to be Resolved?

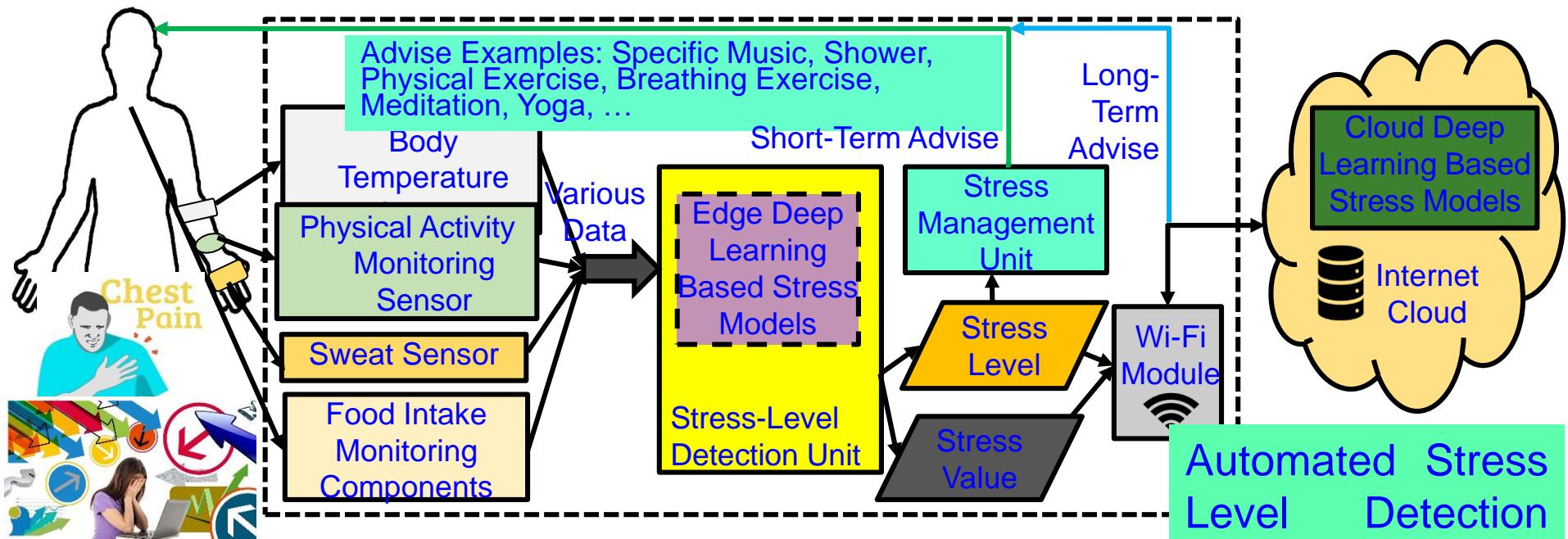
When there is an encounter with sudden **stress**, your brain floods your **body** with chemicals and hormones such as **adrenaline and cortisol**.

- Lack of Energy
- Type 2 Diabetes
- Osteoporosis
- Mental cloudiness (brain fog) and memory problems
- A weakened immune system, leading to more vulnerable to infections



Stress is the **body's reaction** to any change that requires an adjustment or response.

Smart Healthcare - Stress Monitoring & Control



Sensor	Low Stress	Normal Stress	High Stress
Accelerometer (steps/min)	0-75	75-100	101-200
Humidity (RH%)	27-65	66-91	91-120
Temperature F	98-100	90-97	80-90



Source: L. Rachakonda, S. P. Mohanty, E. Kougianos, and P. Sundaravadivel, "Stress-Lysis: A DNN-Integrated Edge Device for Stress Level Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol 65, No 4, Nov 2019, pp. 474--483.

Consumer Electronics Devices – Can Provide Data for Stress Detection

Brand	Device	Signals	RTI	Ambulant
Empatica	E4 wristband	PPG, GSR, HR, ACC, ST	Yes	Yes
Garmin	Vivosmart	HR, HRV, ACC	Yes	Yes
Zephyr	BioHarness 3.0	HR, HRV, GSR, ACC, ST	Yes	Yes
iMotions	Shimmer 3+ GSR	GSR, PPG	Yes	No
BIOPAC	Mobita Wearable	ECG, EEG, EGG, EMG, and EOG	Yes	No

GSR = Galvanic Skin Response, HR = Heart Rate, ACC = Acceleration, ST = Skin Temperature,
HRV = Heart Rate Variability, PPG = Photoplethysmograph, RTI = Real Time Implementation

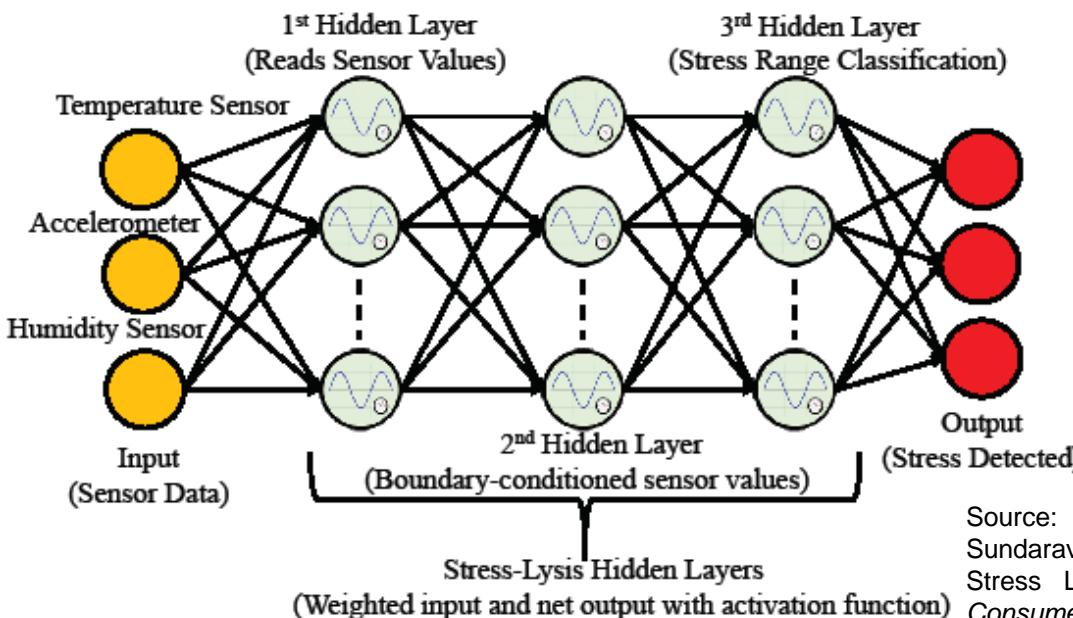
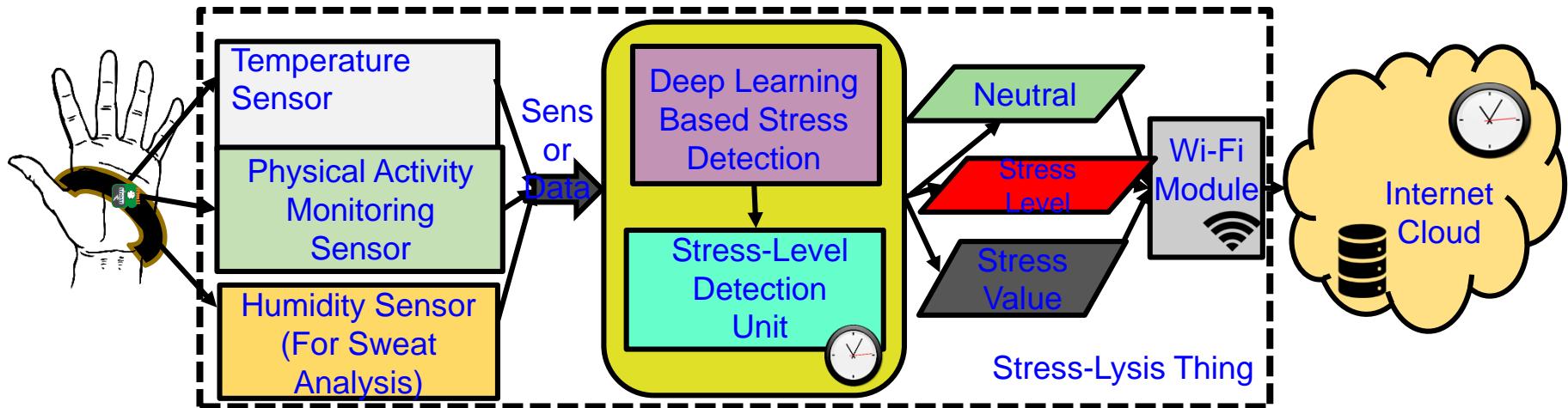
Source: R. K. Nath, H. Thapliyal, A. Caban-Holt, and S. P. Mohanty, "Machine Learning Based Solutions for Real-Time Stress Monitoring", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 9, XX, No. YY, ZZ 2020, DOI: 10.1109/MCE.2020.2993427.

Stress-Lysis: Research Question

- How to have an accurate and rapid Stress Level Detection system that *acquires and models sensor data, and detects stress level* at the user end (at *IoT-Edge*) and stores the data at the cloud end (at *IoT-Cloud*)?

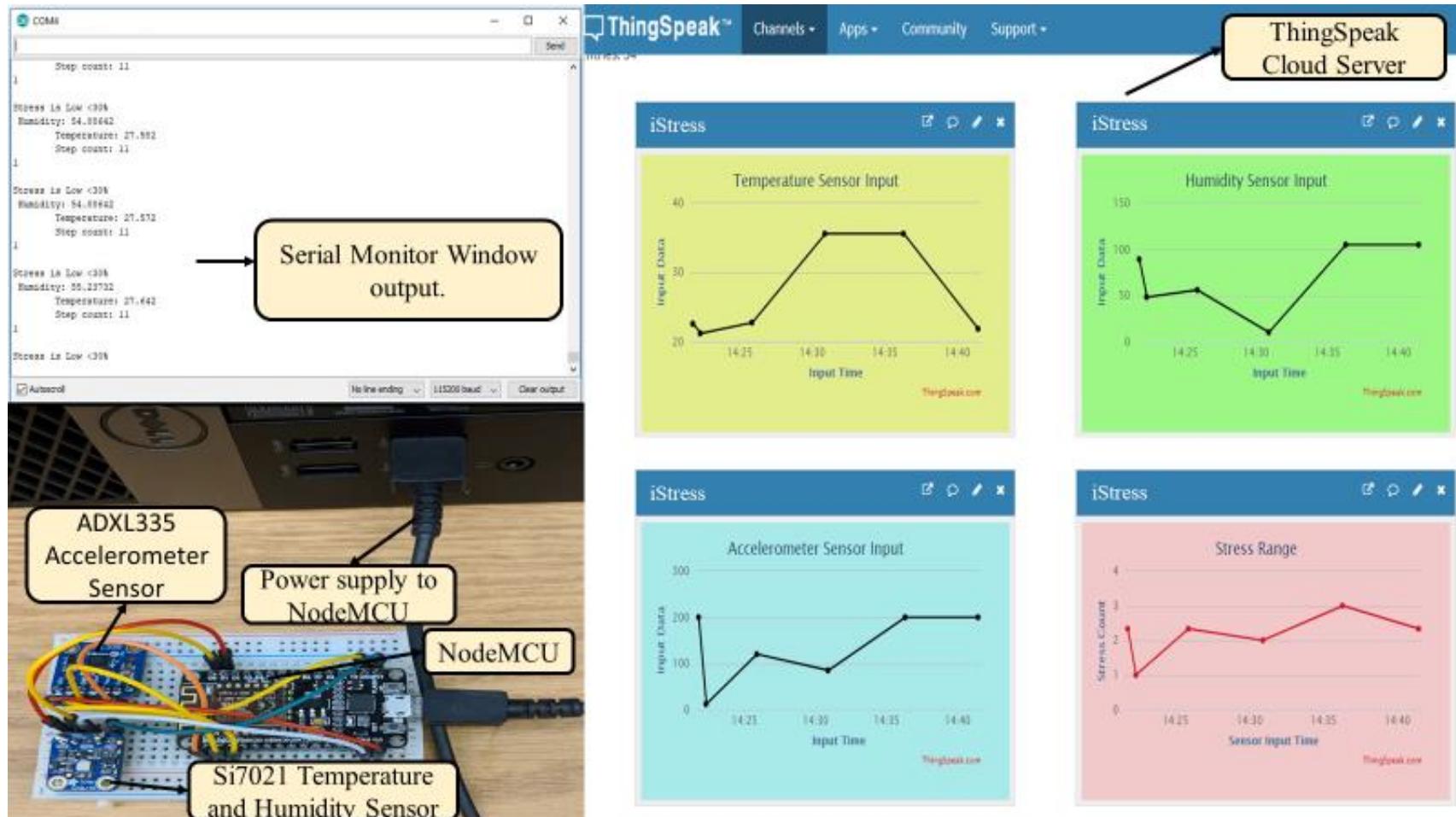
Source: L. Rachakonda, S. P. Mohanty, E. Kougianos, and P. Sundaravadivel, "Stress-Lysis: A DNN-Integrated Edge Device for Stress Level Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol 65, No 4, Nov 2019, pp. 474--483.

Stress-Lysis: From Physiological Signals



Source: L. Rachakonda, S. P. Mohanty, E. Kougianos, and P. Sundaravadivel, "Stress-Lysis: A DNN-Integrated Edge Device for Stress Level Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol 65, No 4, Nov 2019, pp. 474--483.

Stress-Lysis: Experiments



Source: L. Rachakonda, S. P. Mohanty, E. Kougianos, and P. Sundaravadivel, "Stress-Lysis: A DNN-Integrated Edge Device for Stress Level Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol 65, No 4, Nov 2019, pp. 474--483.

Smart-Pillow: Research Question

- How to have a non-invasive, optimized, IoT enabled system which detects the stress level variations based on the sleeping parameters, analyses the data at the user end (at *IoT-Edge*) and stores the data at the cloud end (at *IoT-Cloud*)?

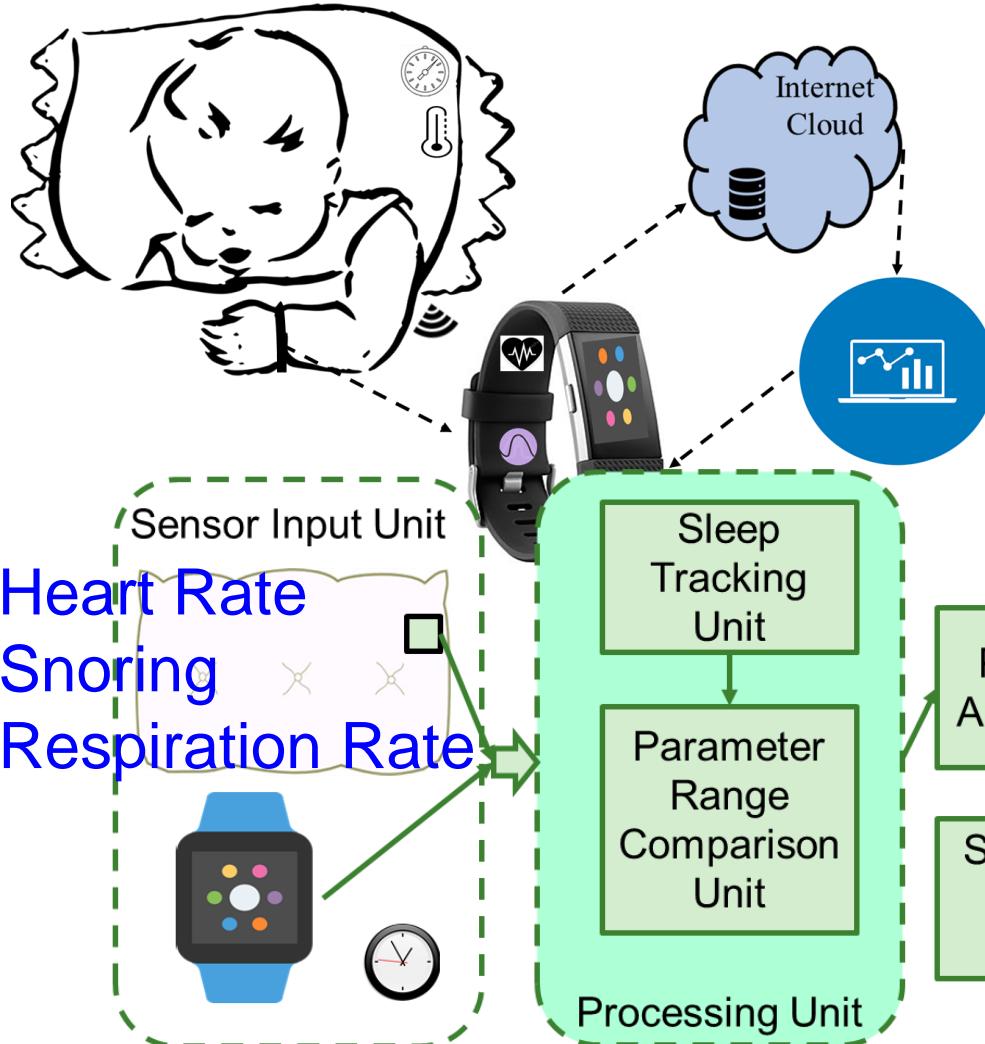
Source: Mohanty iSES 2018: "Smart-Pillow: An IoT based Device for Stress Detection Considering Sleeping Habits", in *Proc. of 4th IEEE International Symposium on Smart Electronic Systems (iSES) 2018.*

Consumer Electronics Sleep Trackers

Consumer Products	Approach	Features	Drawbacks
Fitbit [34]	Wearable	Heart rate monitor, sleep stages monitor. Has techniques to improve the sleep score.	Relationship between stress and sleep is not discussed.
SleepScore Max [36]	Non-wearable	Invisible radio wave sleep tracking	Does not manage stress with sleep.
Nokia Sleep [38]	Non-wearable	Uses Ballistocardiography sensor	Does not explain the relationship with stress with sleep.
Xiaomi Mi Band 3 [31]	Wearable	Pulse Monitor	No information on importance of quality sleep.
Eversleep [32]	wearable	Snoring and breathing interruptions	No explanation on the relationship between stress and sleep.
Beddit [35]	Non-wearable	Monitors snoring	Doesn't consider other possible features.
Eight [37]	Non-Wearable	Humidity, temperature, heartbeat, breathing rate	No data on how it is important to have a good sleep.
Dreem [33]	Wearable	Simulates slow brain waves	It doesn't consider other features; Does not manage stress with sleep.
Muse [26]	Wearable	Simulates brain waves	No understanding of the importance of quality sleep.

Source: L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "SaYoPillow: A Blockchain-Enabled, Privacy-Assured Framework for Stress Detection, Prediction and Control Considering Sleeping Habits in the IoMT", arXiv Computer Science, arXiv:2007.07377, July 2020, 38-pages.

Smart Healthcare – Smart-Pillow



Automatically monitors stress levels during the day and relates to sleeping behaviors at night.

Source: Mohanty iSES 2018: "Smart-Pillow: An IoT based Device for Stress Detection Considering Sleeping Habits", in Proc. of 4th IEEE International Symposium on Smart Electronic Systems (iSES) 2018.

Smart-Yoga Pillow (SaYoPillow) – Sleeping Pattern

Person On Pillow:

Physiological Sensor Data Monitoring Starts



Period 1. Lying on bed but not Sleeping



Period 3: Drift from Wakefulness to Sleep

Period 2: Trying to Sleep

Period 4: Deep Sleep

Person Off Pillow:

Physiological Sensor Data Monitoring Ends



Period 5: Awake Person

Transitions of a person drifting into non-rapid eye movement (NREM) followed by rapid eye movement (REM) to Awake State.



Secure Data Transfer



Secure Data Access



Data Processing

Secure Data Storage

User Applications

Source: L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Koulianou, "SaYoPillow: A Blockchain-Enabled, Privacy-Assured Framework for Stress Detection, Prediction and Control Considering Sleeping Habits in the IoMT", arXiv Computer Science, arXiv:2007.07377, July 2020, 38-pages.

Parameter Ranges

Snoring Range (dB)	Respiration Rate (bpm)	Heart Rate (bpm)	Stress State
50-60	17-19	54-57	LSS
60-70	19-21	57-60	MLSS
70-80	21-22	60-64	MSS
80-89	23-25	65-70	MHSS
90+	25+	70+	HSS

Smart-Pillow - simple fuzzy logic-based design finds classify stress to 5 levels

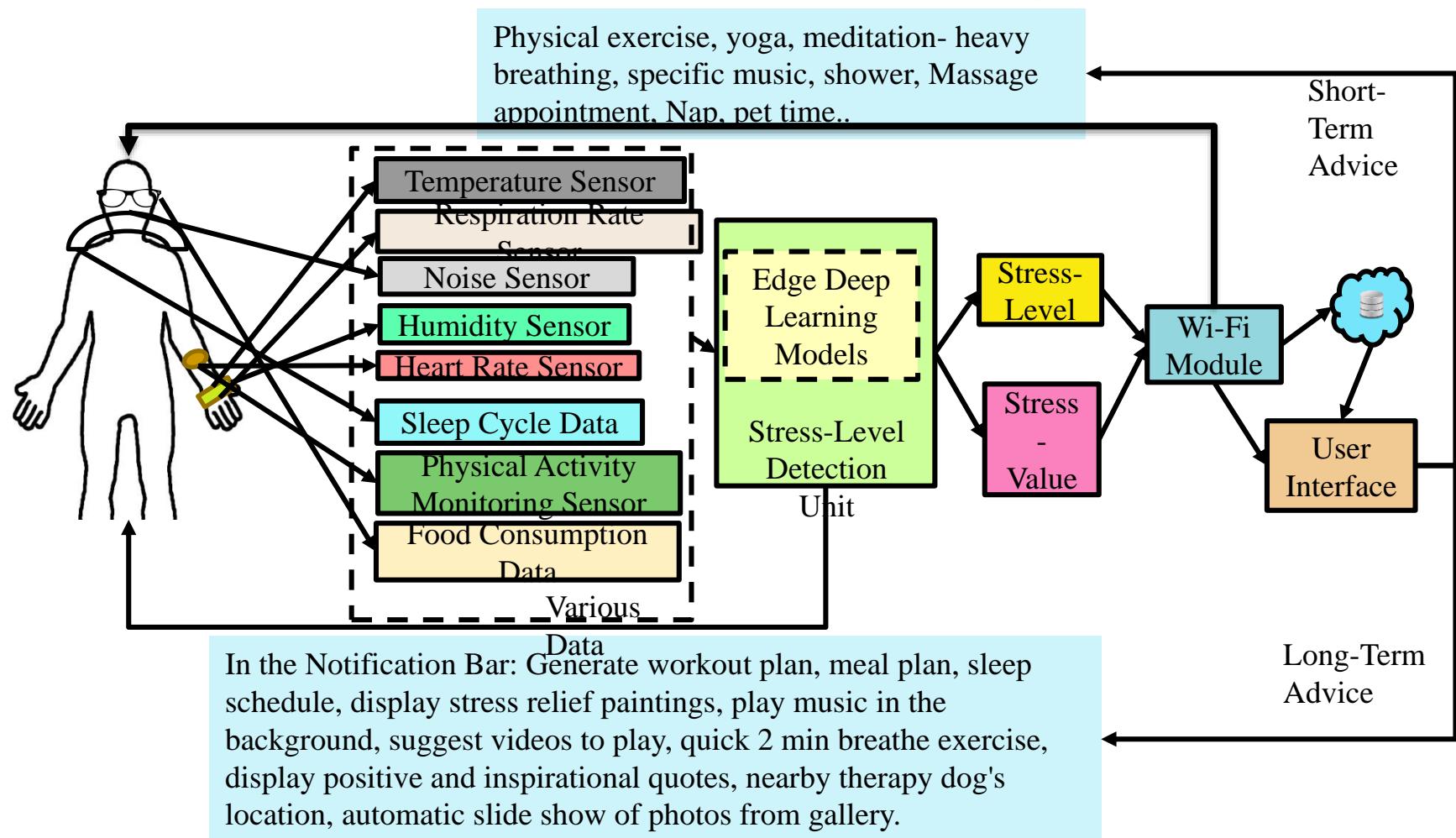
SaYoPillow – Uses deep learning for 96% accuracy with blockchain based security features

iFeliz: Research Question

- How to have an accurate and rapid **Stress Control** system at the user end (at ***IoT-Edge***) and stores the data at the cloud end (at ***IoT-Cloud***)?

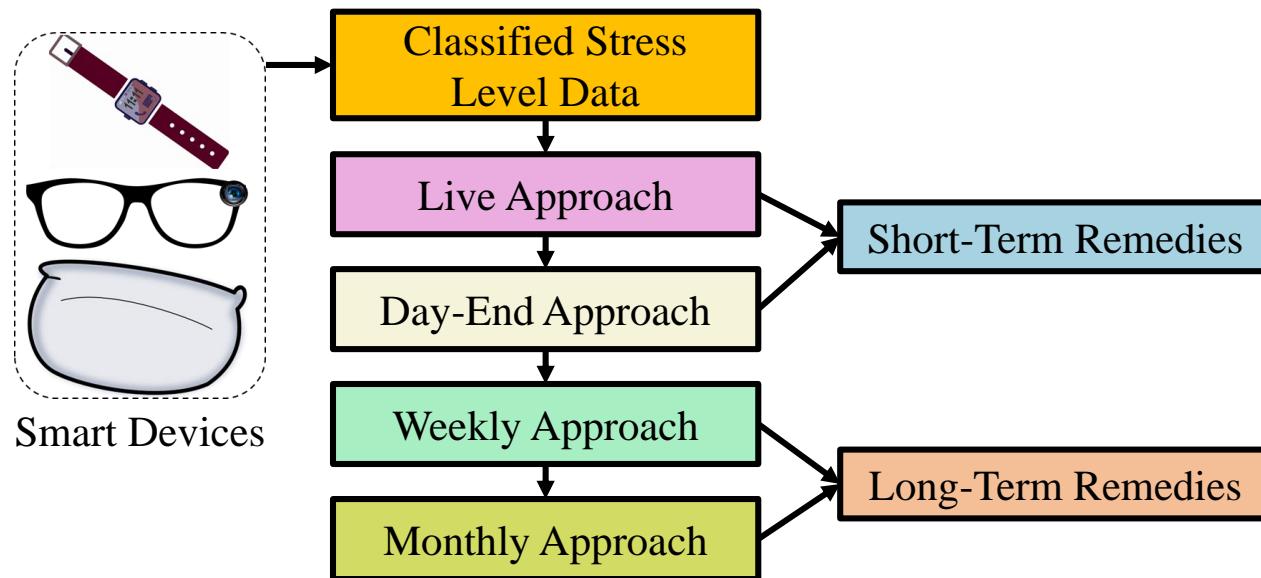
Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iFeliz: An Approach to Control Stress in the Midst of the Global Pandemic and Beyond for Smart Cities using the IoMT", in *Proc. of IEEE Smart Cities Conference*, 2020, pp. Accepted on 24 Aug 2020.

iFeliz: Proposed System



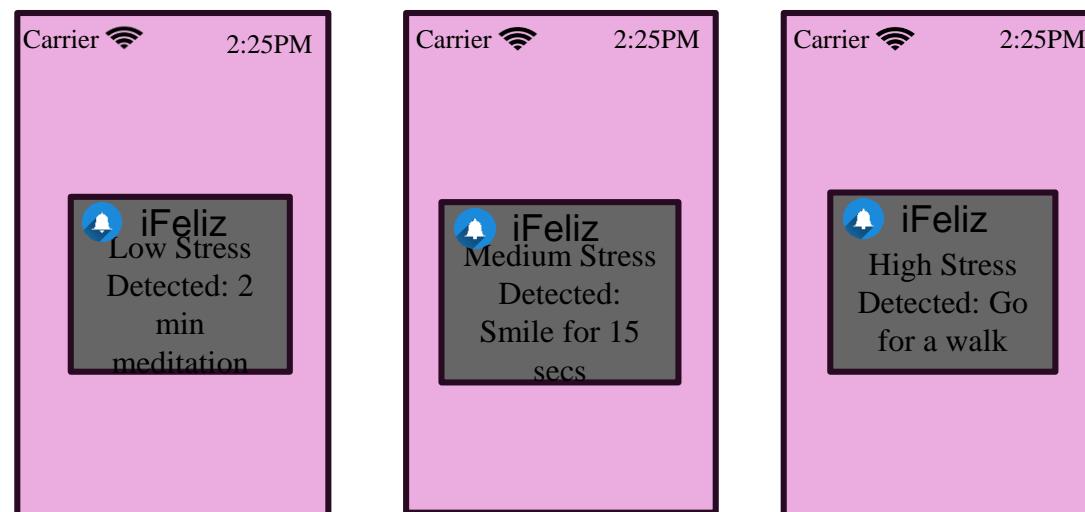
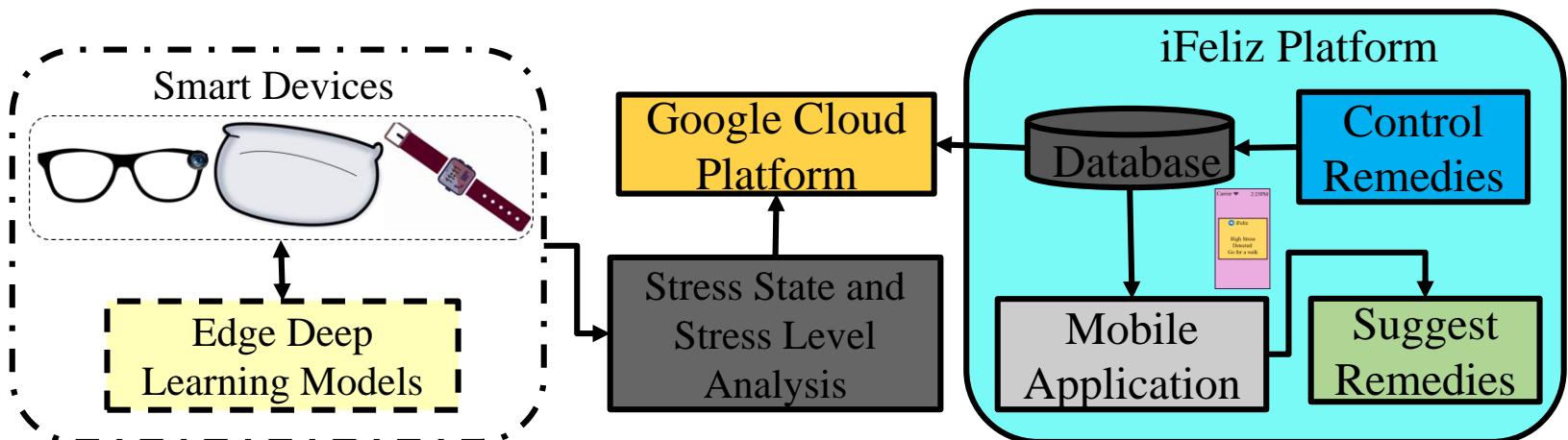
Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iFeliz: An Approach to Control Stress in the Midst of the Global Pandemic and Beyond for Smart Cities using the IoMT", in *Proc. of IEEE Smart Cities Conference*, 2020, pp. Accepted on 24 Aug 2020.

iFeliz: Stress Control Approaches



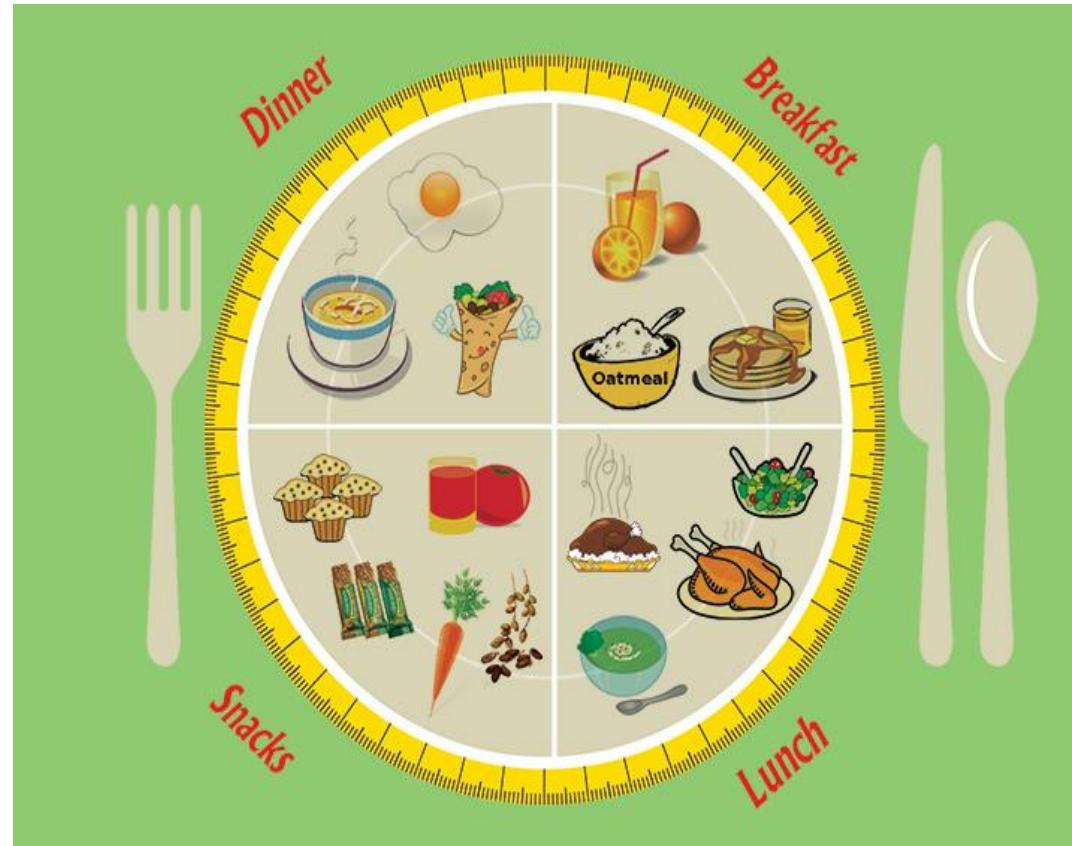
Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iFeliz: An Approach to Control Stress in the Midst of the Global Pandemic and Beyond for Smart Cities using the IoMT", in *Proc. of IEEE Smart Cities Conference*, 2020, pp. Accepted on 24 Aug 2020.

iFeliz: Prototyping



Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iFeliz: An Approach to Control Stress in the Midst of the Global Pandemic and Beyond for Smart Cities using the IoMT", in *Proc. of IEEE Smart Cities Conference*, 2020, pp. Accepted on 24 Aug 2020.

Automatic Food Intake Monitoring and Diet Management is Important



Imbalance Diet is a Global Issue

- Imbalanced diet can be either more or fewer of certain nutrients than the body needs.
- In 2017, 11 million deaths and 255 million disability-adjusted life-years (DALYs) were attributable to dietary risk factors.
- Eating wrong type of food is potential cause of a dietary imbalance:

- Psychiatric disorders
- Coronary heart disease
- High blood pressure

- Obesity
- Tooth decay
- Diabetes

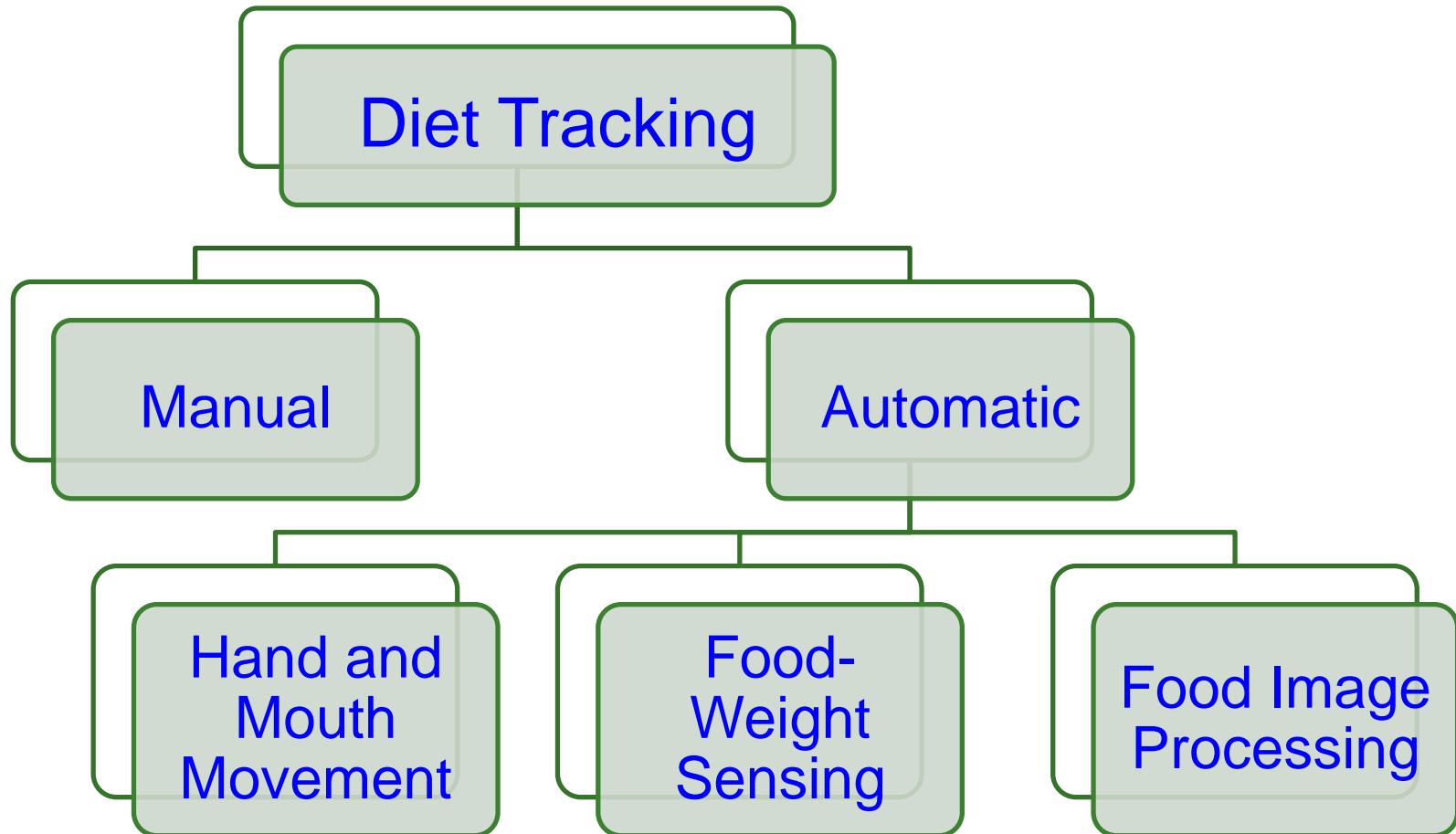
Source: <https://obesity-diet.nutritionalconference.com/events-list/imbalanced-diet-effects-and-causes>
[https://www.thelancet.com/article/S0140-6736\(19\)30041-8/fulltext](https://www.thelancet.com/article/S0140-6736(19)30041-8/fulltext)

Food Tracking Apps

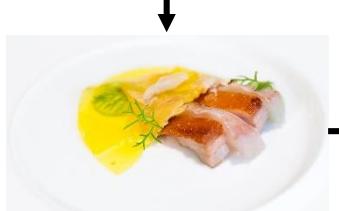
Table 1. Overview of popular food tracking approaches and their capabilities.

App Name	Downloads	Reviews	Rating	Image	Food-Label in Image			Manual	Scanning	Speech	Database search	Calories	Nutrition	
					Auto	Manual	Crowd Sourced	Input Method						
MyFitnessPal	50 M	2 M	4.6			X				X			X	
FatSecret	10 M	268 k	4.5			X				X			X	X
My Diet Coach	10 M	144 k	4.4					X					X	
Lose it	10 M	77 k	4.4	X				X		X			X	
MyPlate	1 M	31 k	4.6					X		X			X	X
mynetdiary	1 M	31 k	4.5					X					X	X
Macros	500 k	3 k	4.5					X		X			X	
Cron-o-meter	100 k	1 k	4.2					X						
Eating Habit	100 k	549	4	X		X							X	
21 day Fix	100 k	470	3.7						X				X	
Bite Snap	50 k	2k	4.7	X									X	X
MealLogger	50 k	225	3.5	X					X				X	X
EatRight	10 k	220	4.5						X				X	
Keto Meal Plan	10 k	19	2.6									X		
YouAte	10 k			X										
KudoLife	1 k	11	3.4									X	X	X
Calorific	19		3.2		X							X	?	?
Ate					X			?					?	?
Foodlog					X	X		X					X	

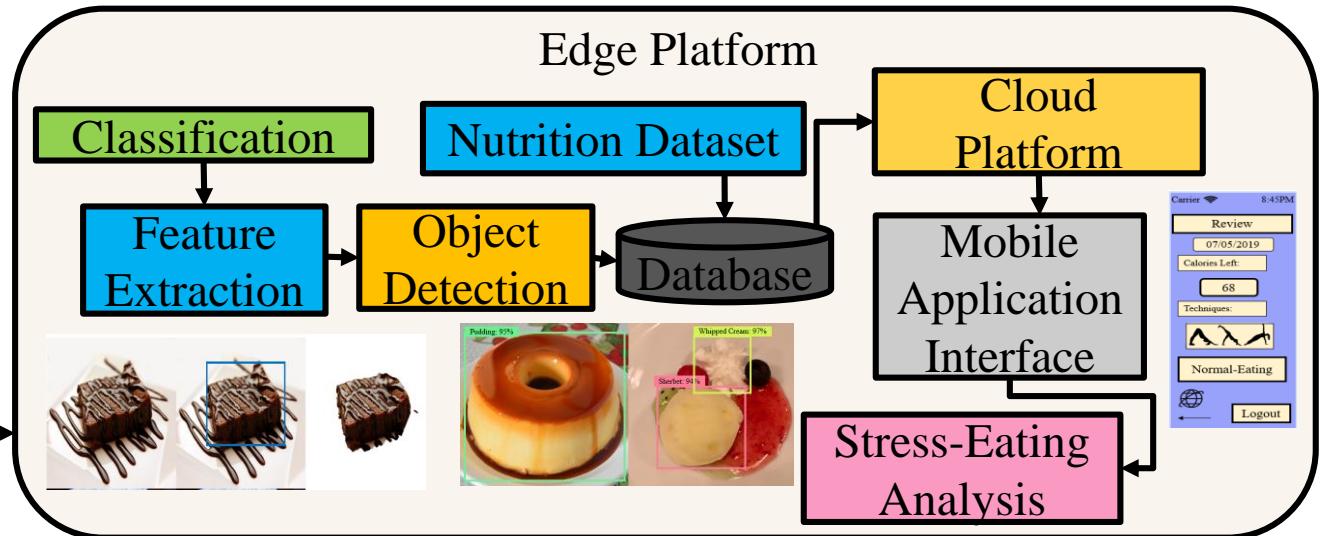
Diet Tracking Approaches



Smart Healthcare – iLog



Reference Image



iLog- Fully Automated Detection System with 98% accuracy.

Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iLog: An Intelligent Device for Automatic Food Intake Monitoring and Stress Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 66, No. 2, May 2020, pp. 115--124.

Smart Healthcare – iLog

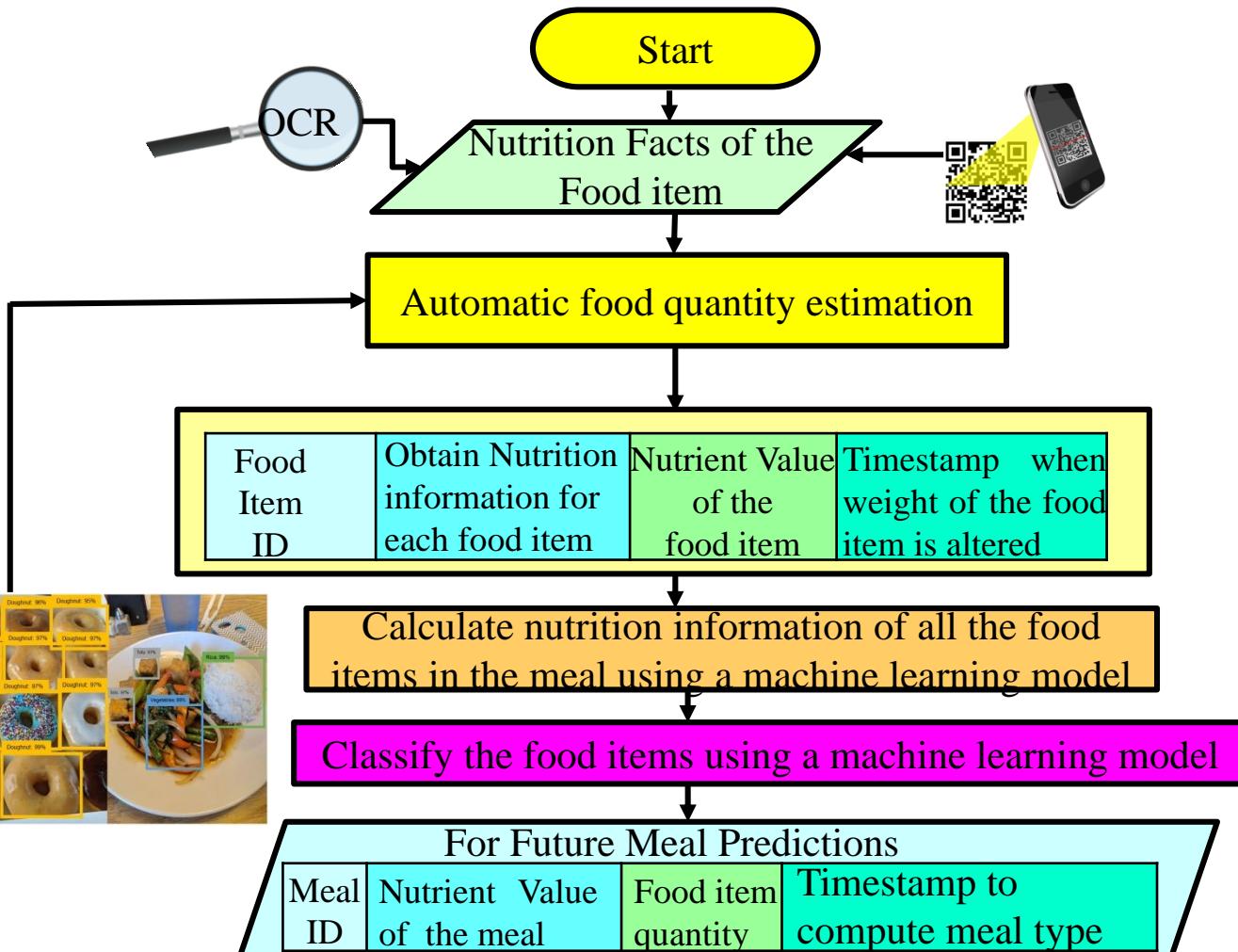


The data collected is sent to the Firebase Database in which the calorie count is generated by using a dataset with calories and sugars count of individual items from data.gov.

Source: L. Rachakonda, S. P. Mohanty, and E. Kougianos, "iLog: An Intelligent Device for Automatic Food Intake Monitoring and Stress Detection in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol. 66, No. 2, May 2020, pp. 115--124.

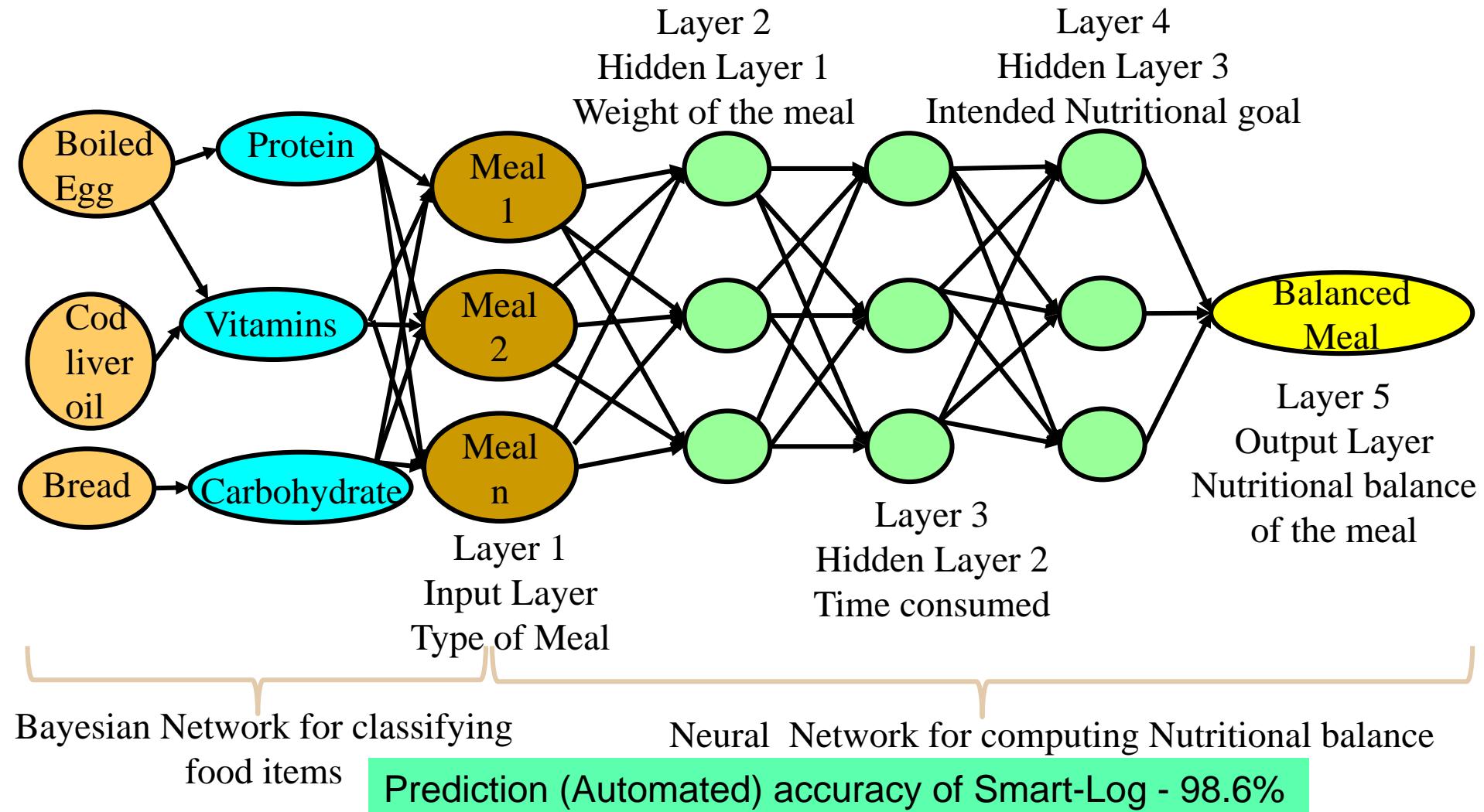
Smart Healthcare – Diet Prediction

Computer Vision
Methods using
Machine Learning
Models



Source: P. Sundaravadivel, K. Kesavan, L. Kesavan, **S. P. Mohanty**, and E. Kougianos, "Smart-Log: A Deep-Learning based Automated Nutrition Monitoring System in the IoT", *IEEE Transactions on Consumer Electronics*, Vol 64, Issue 3, Aug 2018, pp. 390-398.

Smart Healthcare – Diet Prediction



Source: P. Sundaravadiel, K. Kesavan, L. Kesavan, S. P. Mohanty, and E. Koulianou, "Smart-Log: A Deep-Learning based Automated Nutrition Monitoring System in the IoT", *IEEE Transactions on Consumer Electronics (TCE)*, Volume 64, Issue 3, August 2018, pp. 390-398.

Epileptic Seizure

- A seizure is an abnormal activity in the nervous system which causes its sufferers to lose consciousness and control.

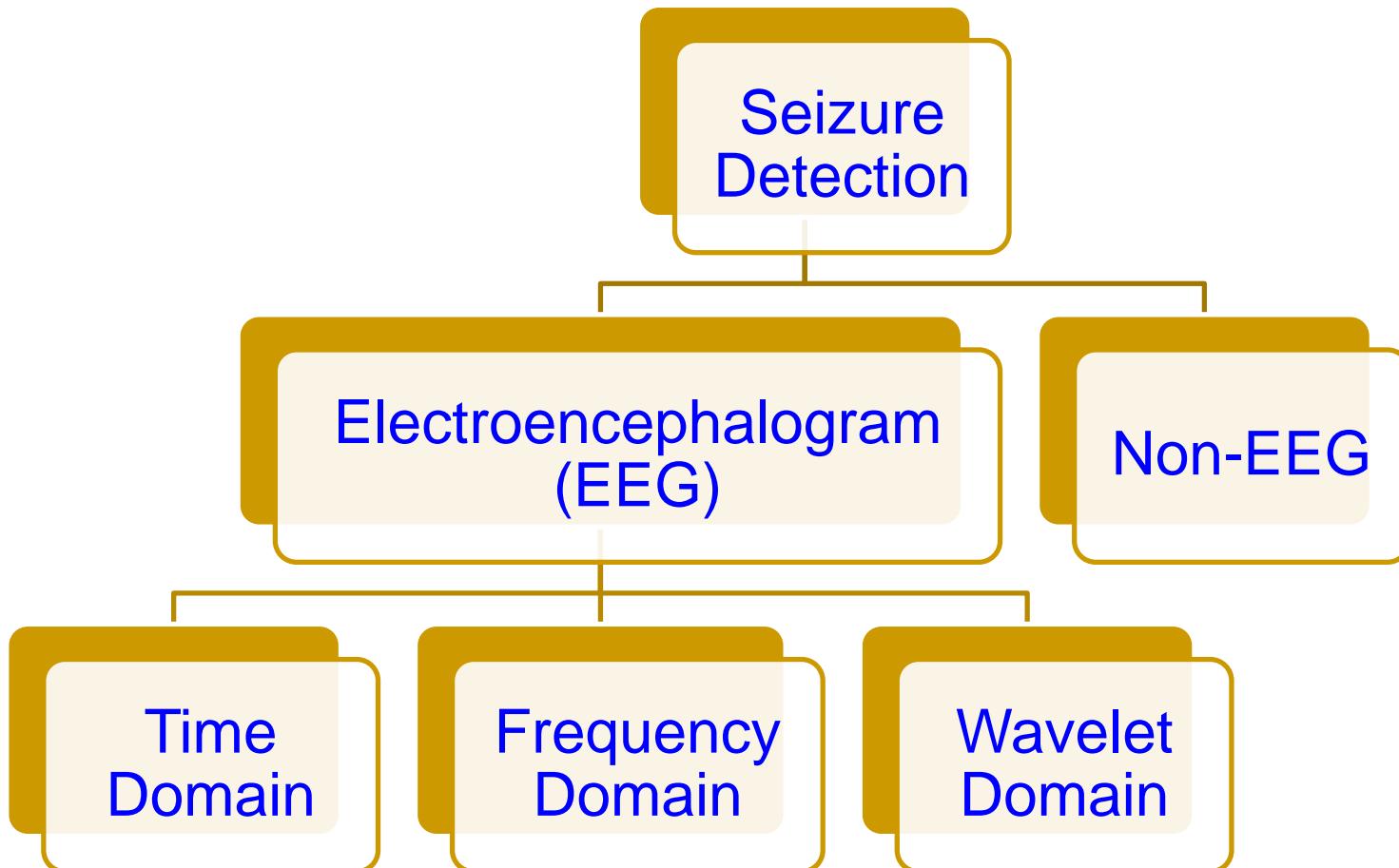


Epileptic Seizure Has Global Impact

- Up to 1% of the world's population suffers from epilepsy.
- Epilepsy is the fourth most common neurological disease after migraine, stroke, and Alzheimer's.
- Individuals can suffer a seizure at any time with potentially disastrous outcomes including a fatal complication called "Sudden Unexpected Death in Epilepsy" (SUDEP).

Source: <https://www.epilepsy.com/learn/about-epilepsy-basics/epilepsy-statistics>

Seizure Detection Methods



Consumer Electronics for Seizure Detection



Source: <https://spectrum.ieee.org/the-human-os/biomedical/diagnostics/this-seizuredetecting-smartwatch-could-save-your-life>

- Embrace2: Smart-band which uses machine learning to detect convulsive Seizures and notifies caregivers.

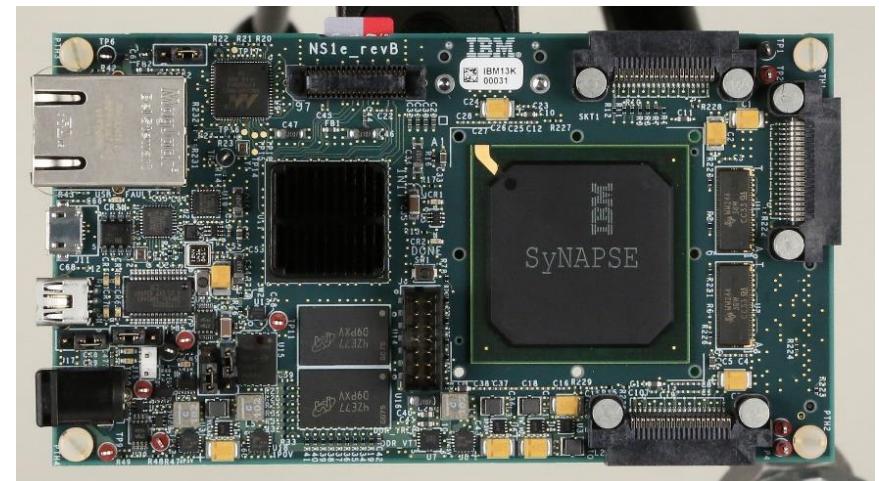


Source: <https://www.empatica.com/embrace2/>

- Medical grade smart watch: It detects generalized clonic-tonic Seizures and notifies physicians.

IBM's Implantable Seizure Detector

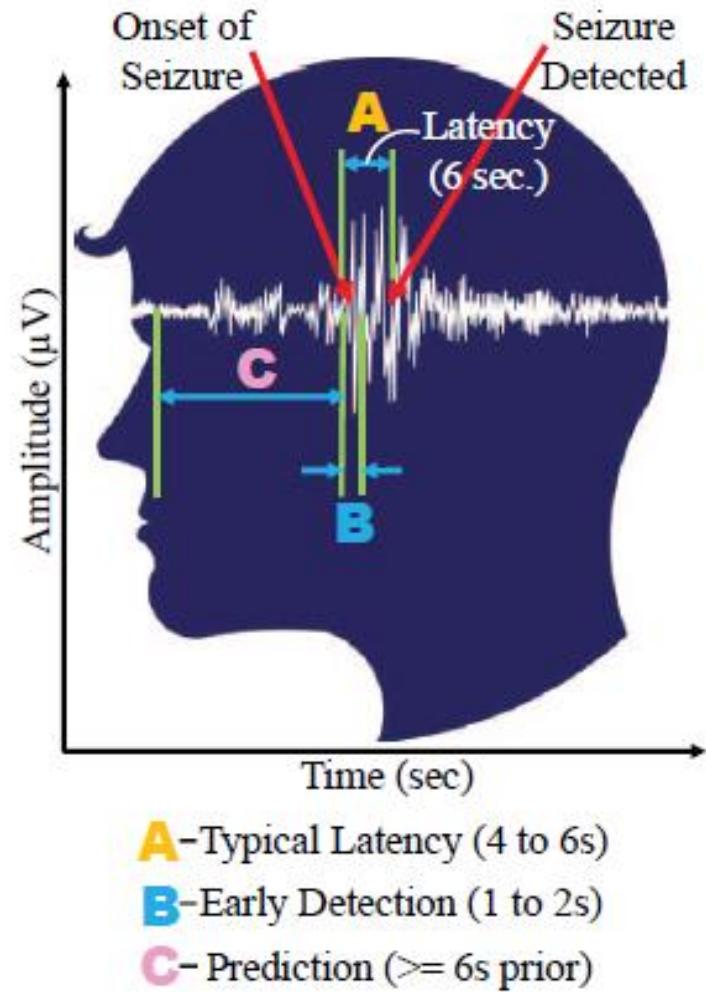
- The TrueNorth chip is postage stamp-sized and consumes over 1,000 times less power than a conventional processor of similar size.



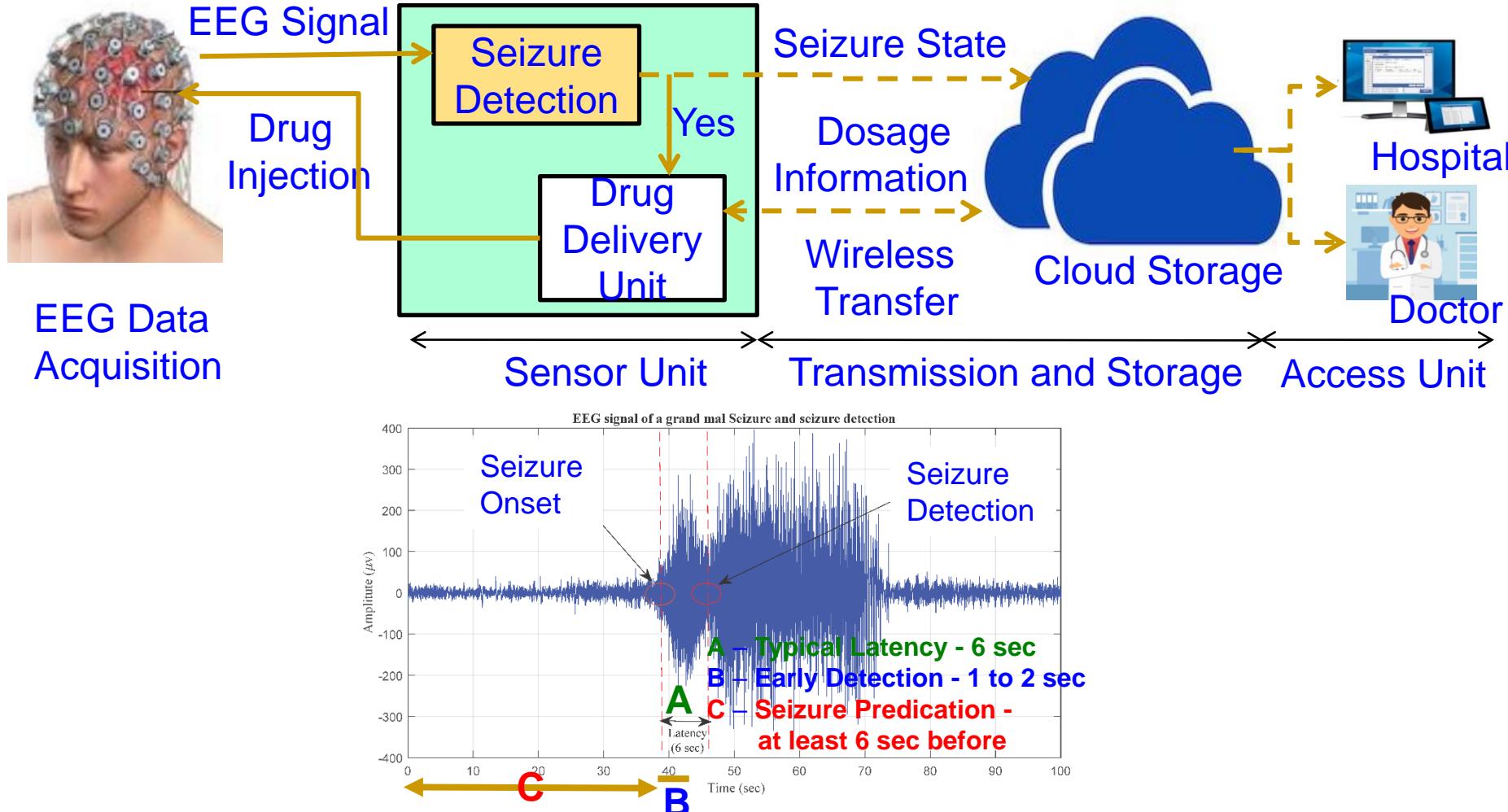
Source: http://uberveillance.squarespace.com/?category=health_care

Drawbacks of Existing Works?

- High seizure detection latency.
- Not suitable for real time IoMT deployment.
- Intervention mechanism after detection is lacking.

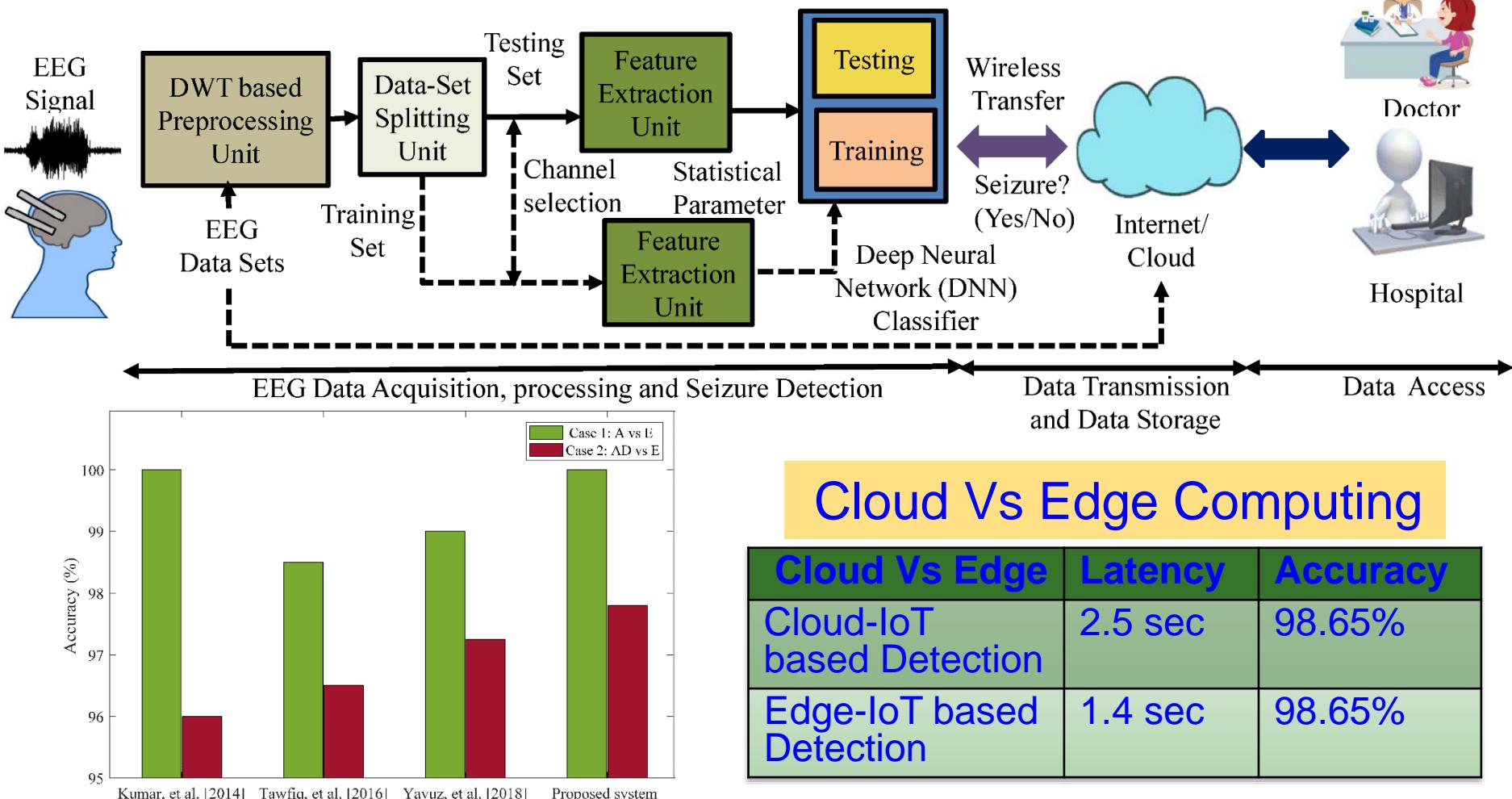


Smart Healthcare - Seizure Detection & Control



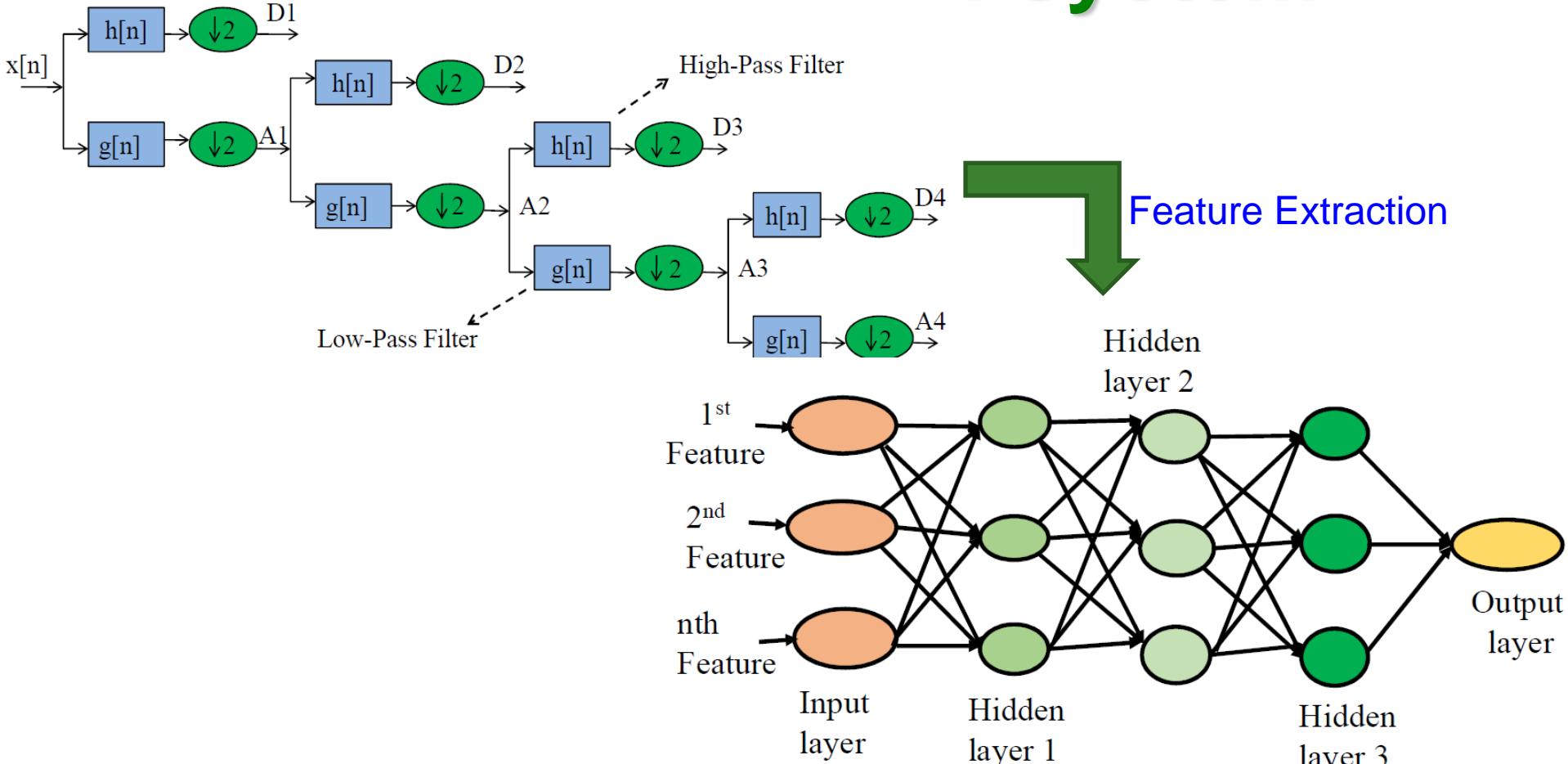
Source: M. A. Sayeed, S. P. Mohanty, E. Kougianos, and H. Zaveri, "eSeiz: An Edge-Device for Accurate Seizure Detection for Smart Healthcare", *IEEE Transactions on Consumer Electronics (TCE)*, Volume 65, Issue 3, August 2019, pp. 379--387.

Seizure Detection Approaches



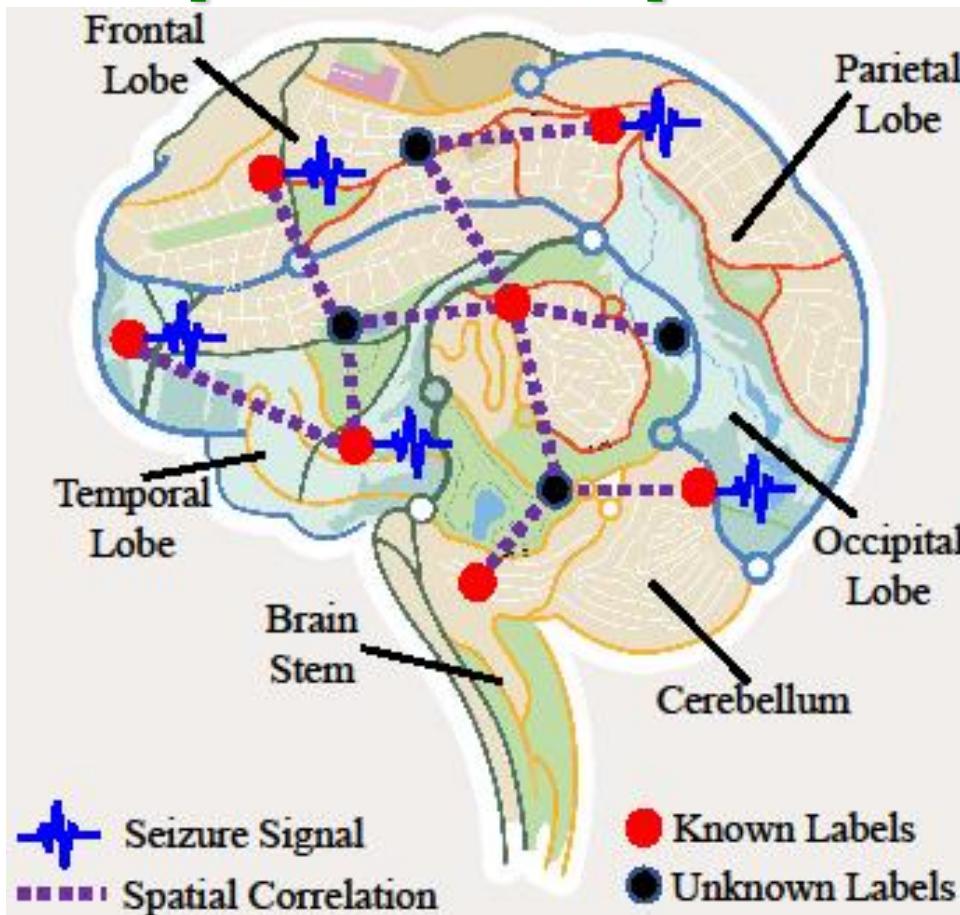
Source: M. A. Sayeed, S. P. Mohanty, E. Kouglanos, and H. Zaveri, "Neuro-Detect: A Machine Learning Based Fast and Accurate Seizure Detection System in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol 65, No 3, Aug 2019, pp. 359--368.

Our Neuro-Detect : A ML Based Seizure Detection System

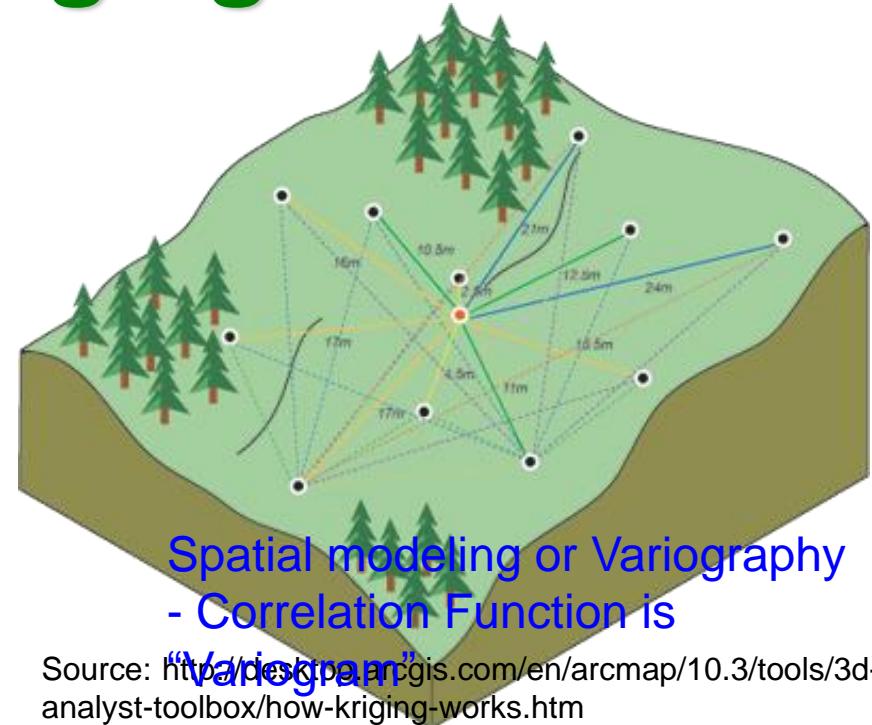


Source: M. A. Sayeed, S. P. Mohanty, E. Kouglanos, and H. Zaveri , "Neuro-Detect: A Machine Learning Based Fast and Accurate Seizure Detection System in the IoMT", *IEEE Transactions on Consumer Electronics (TCE)*, Vol 65, Issue 3, Aug 2019, pp. 359-368.

Smart Healthcare – Brain as a Spatial Map → Kriging Methods



Source: I. L. Olokodana, S. P. Mohanty, and E. Koulianou, "Ordinary-Kriging Based Real-Time Seizure Detection in an Edge Computing Paradigm", in *Proceedings of the 38th IEEE International Conference on Consumer Electronics (ICCE)*, 2020, Accepted.

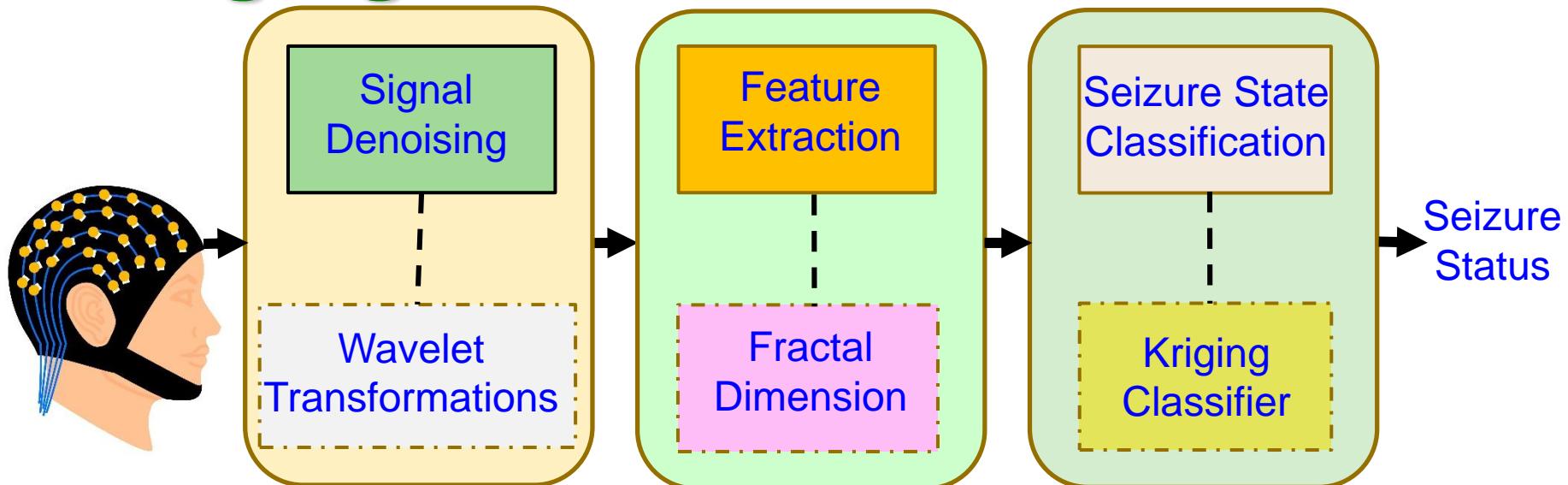


Spatial modeling or Variography
- Correlation Function is

"[Variogram](#)"

Spatial autocorrelation principle
- things that are closer are more alike than things farther

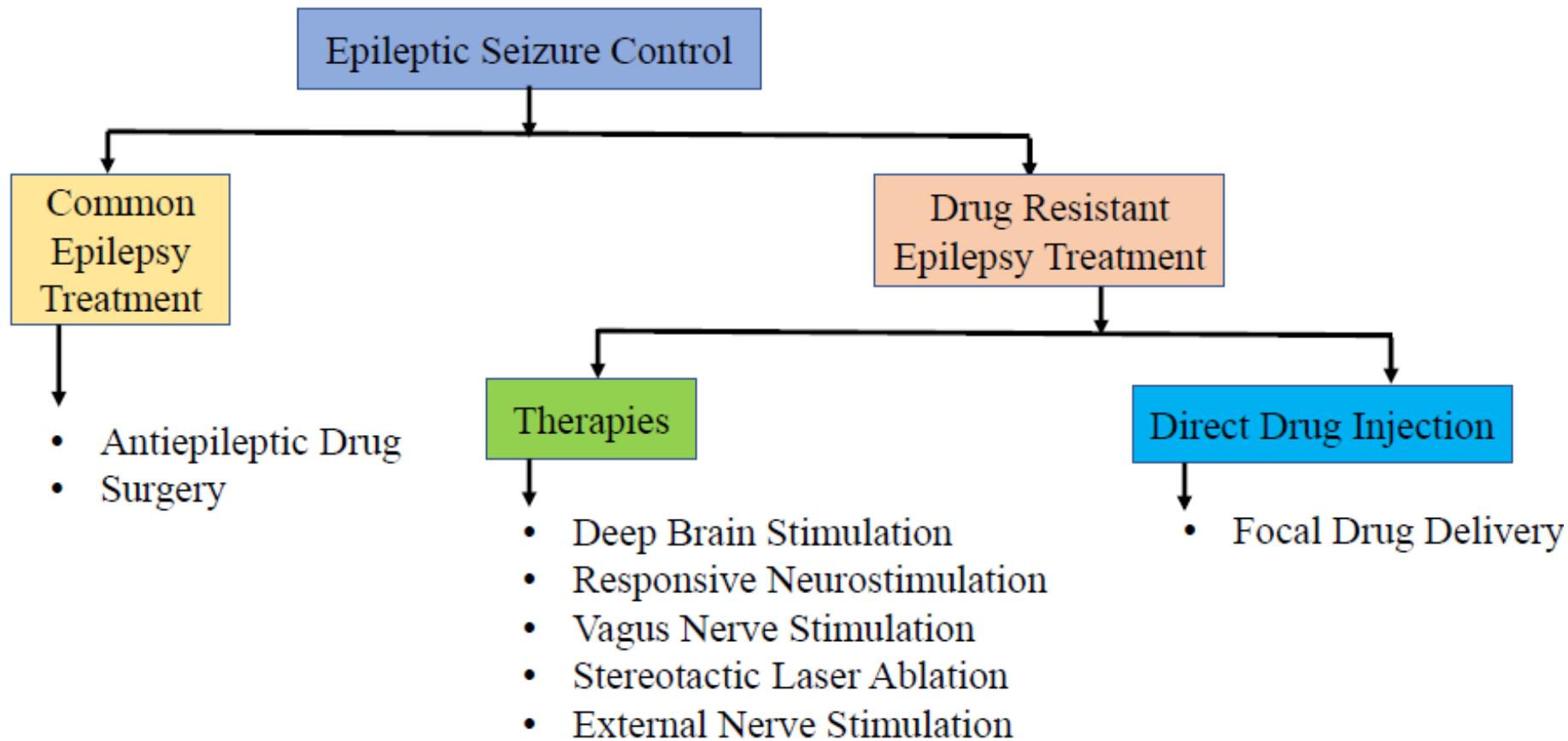
Kriging based Seizure Detection



Works	Extracted Features	Classification Algorithm	Sensitivity	Latency
Zandi, et al. 2012 [23]	Regularity, energy & combined seizure indices	Cumulative Sum thresholding	91.00%	9 sec.
Altaf, et al. 2015 [24]	Digital hysteresis	Support Vector Machine	95.70%	1 sec
Vidyaratne, et al. 2017 [25]	Fractal dimension, spatial/temporal features	Relevance Vector Machine (RVM)	96.00%	1.89 sec
Our Proposed	Petrosian fractal dimension	Kriging Classifier	100.0%	0.85 s

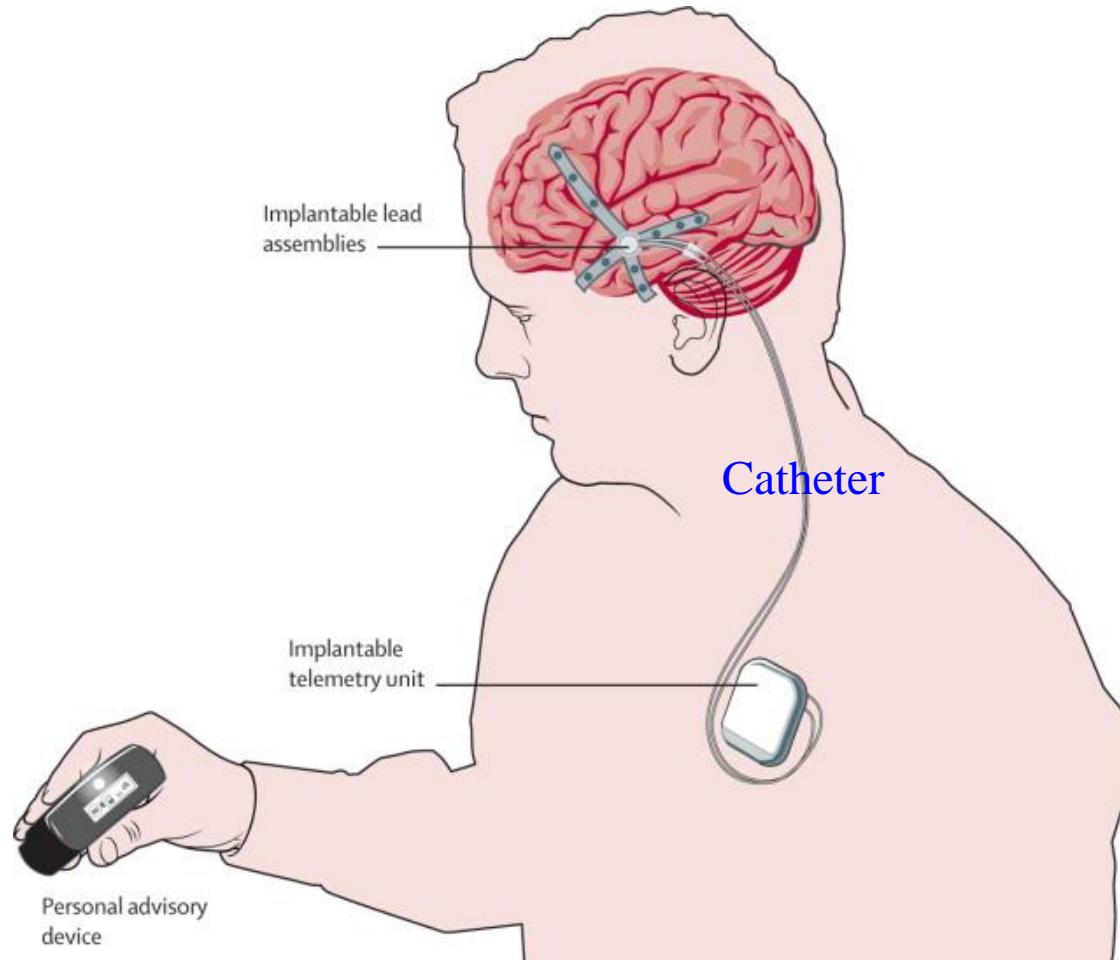
Source: I. L. Olokodana, S. P. Mohanty, and E. Koulianou, "Ordinary-Kriging Based Real-Time Seizure Detection in an Edge Computing Paradigm", in *Proceedings of the 38th IEEE International Conference on Consumer Electronics (ICCE)*, 2020, Accepted.

Seizure Control Methods



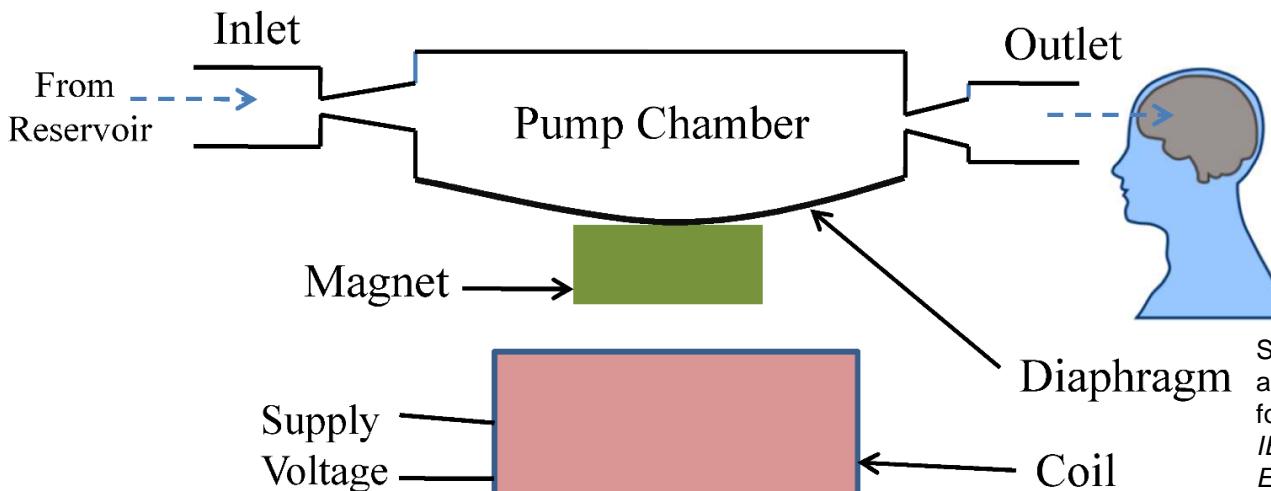
Source: M. A. Sayeed, S. P. Mohanty, E. Kougianos, and H. Zaveri, "iDDS: An Edge-Device in IoMT for Automatic Seizure Control using On-Time Drug Delivery", in *Proceedings of the 38th IEEE International Conference on Consumer Electronics (ICCE)*, 2020.

Implantable for Seizure Detection and Control



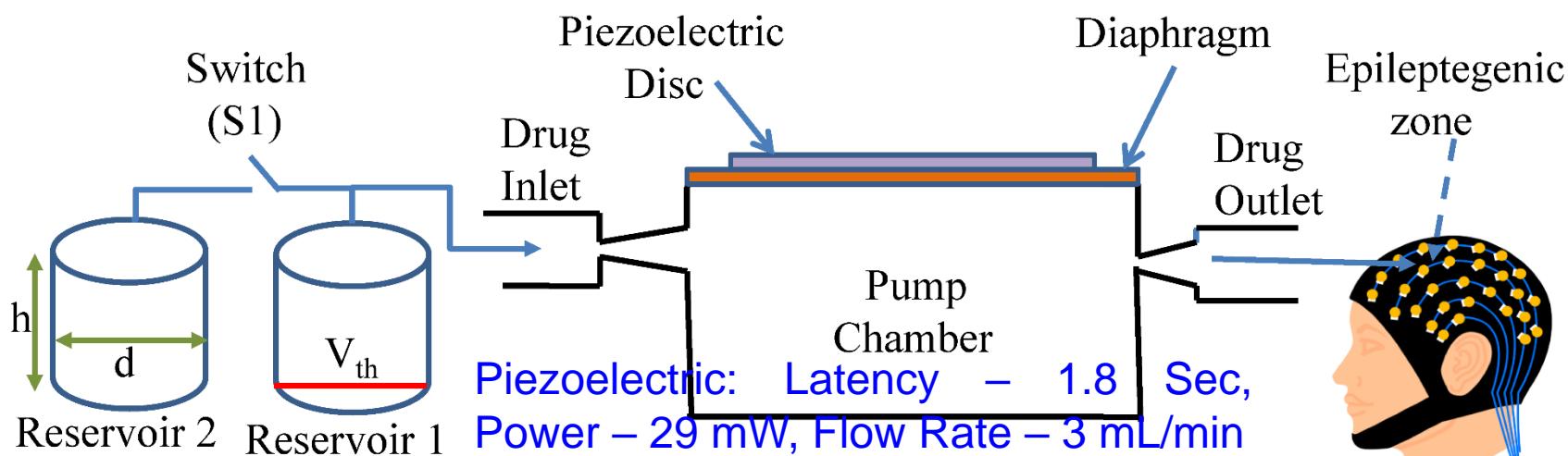
Source: <https://www.kurzweilai.net/brain-implant-gives-early-warning-of-epileptic-seizure>

Seizure Control Methods



Electromagnetic: Latency – 1.8 Sec, Power – 12.81 mW, Flow Rate – 0.34 mL/min

Source: M. A. Sayeed, S. P. Mohanty, E. Kougianos, and H. Zaveri, "An IoT-based Drug Delivery System for Refractory Epilepsy", in *Proceedings of the 37th IEEE International Conference on Consumer Electronics (ICCE)*, 2019.



Source: M. A. Sayeed, S. P. Mohanty, E. Kougianos, and H. Zaveri, "iDDS: An Edge-Device in IoMT for Automatic Seizure Control using On-Time Drug Delivery", in *Proceedings of the 38th IEEE International Conference on Consumer Electronics (ICCE)*, 2020.

Elderly Fall Automatic Detection is Needed to Improve Quality of Life

- Elderly Fall: Approximately a third of elderly people 65 years or older fall each year.
- Fall Caused: Over 800,000 hospital admissions, 2.8 million injuries and 27,000 deaths have occurred in the last few years.

Source: L. Rachakonda, A. Sharma, S. P. Mohanty, and E. Kougianos, "Good-Eye: A Combined Computer-Vision and Physiological-Sensor based Device for Full-Proof Prediction and Detection of Fall of Adults", in *Proceedings of the 2nd IFIP International Internet of Things (IoT) Conference (IFIP-IoT)*, 2019, pp. 273--288.

Consumer Electronics for Fall Detection

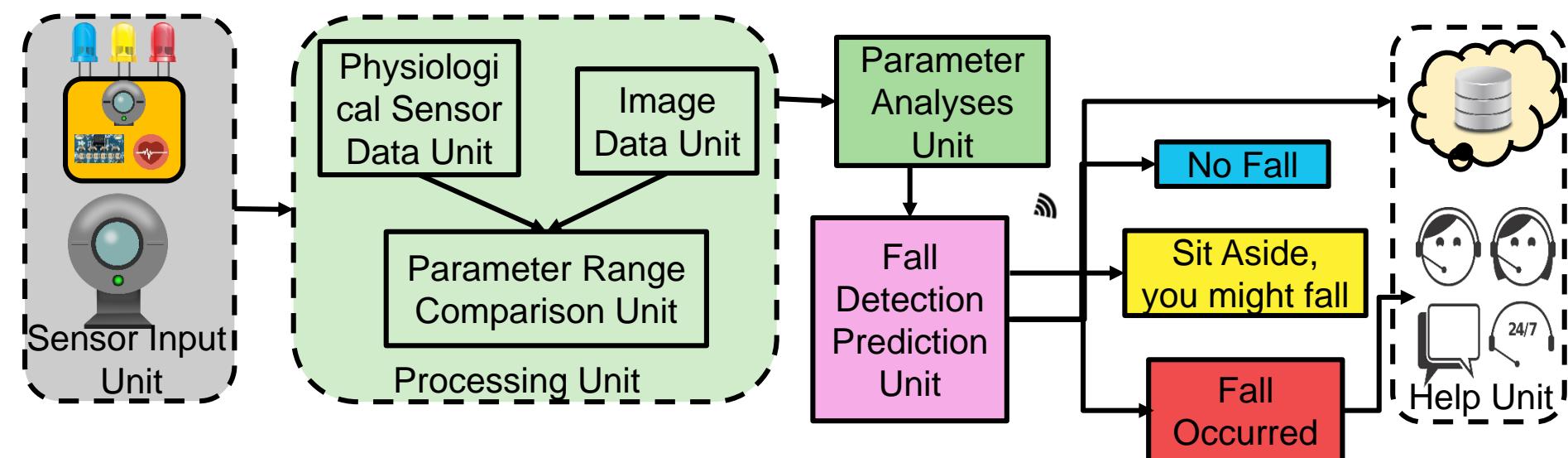
Wearables	Drawbacks
	Apple watch: uses only accelerometers, doesn't work on low thresholds like double carpet, bathroom, hardwood floors. The user must manually select the option SOS and as a reason it fails if the person is unconscious. Users may remain on the floor with no help for large hours.
	Philips Lifeline: Uses only accelerometers and barometric sensors for pressure changes. After the fall, the system waits for 30 sec and directly connects to help.
	Lively Mobile by greatcall and Sense4Care Angel4: Monitors fluctuations using only accelerometers.
	Bay Alarm Medical and Medical Guardian: Use only accelerometers. Have huge base stations limiting the usage and location access.

Good-Eye: Research Question

- How to have a non-invasive, optimized, IoT enabled system which detects and predicts the falls in elderly based on the physiological and vision signal data, analyses the data at the user end (at IoT-Edge) and stores the data at the cloud end (at IoT-Cloud)?

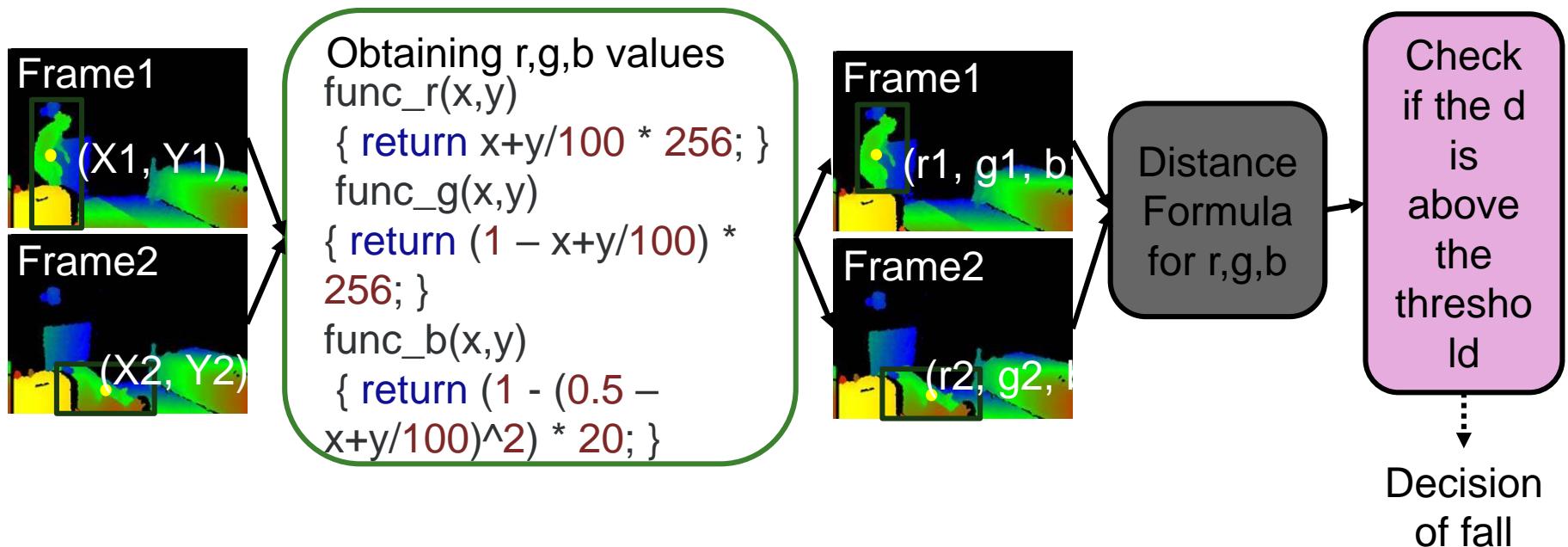
Source: L. Rachakonda, A. Sharma, S. P. Mohanty, and E. Kougianos, "Good-Eye: A Combined Computer-Vision and Physiological-Sensor based Device for Full-Proof Prediction and Detection of Fall of Adults", in *Proceedings of the 2nd IFIP International Internet of Things (IoT) Conference (IFIP-IoT)*, 2019, pp. 273--288.

Good-Eye: Our Multimodal Sensor System for Elderly Fall Prediction and Detection



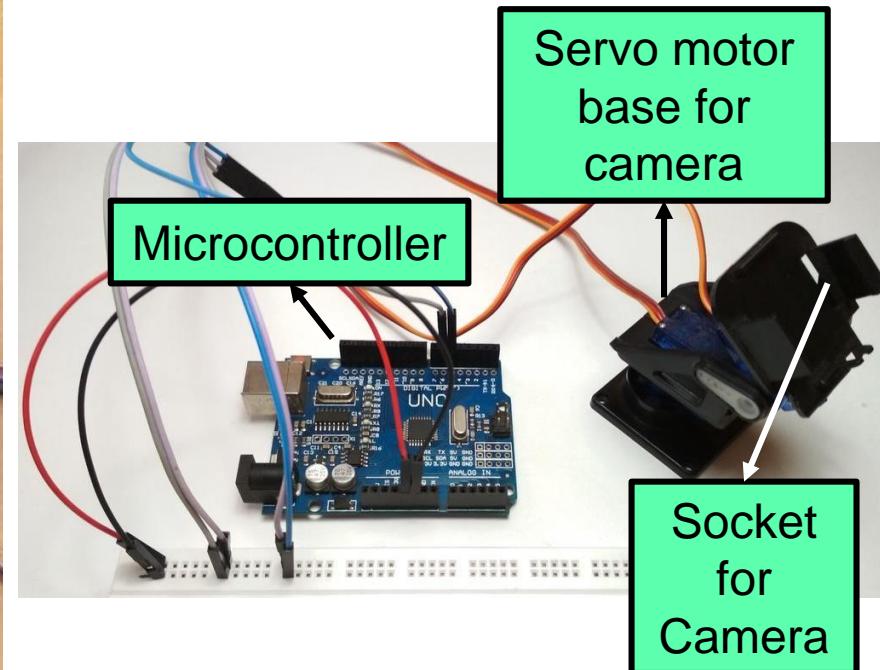
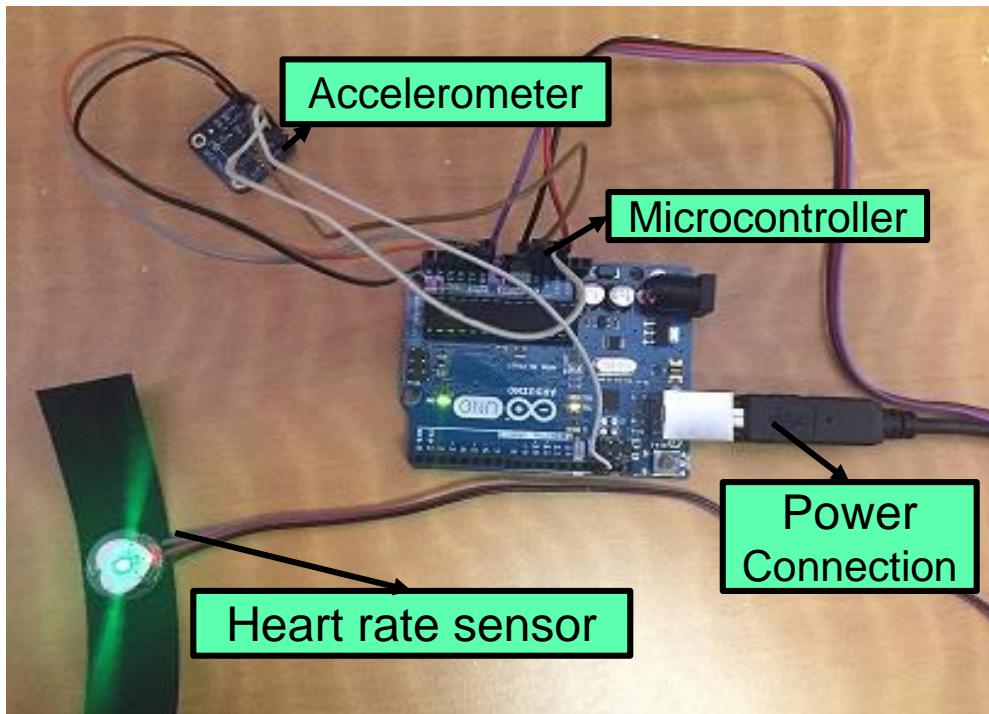
Source: L. Rachakonda, A. Sharma, S. P. Mohanty, and E. Kougianos, "Good-Eye: A Combined Computer-Vision and Physiological-Sensor based Device for Full-Proof Prediction and Detection of Fall of Adults", in *Proceedings of the 2nd IFIP International Internet of Things (IoT) Conference (IFIP-IoT)*, 2019, pp. 273--288.

Good-Eye: Elderly Fall Detection



Source: L. Rachakonda, A. Sharma, S. P. Mohanty, and E. Kougianos, "Good-Eye: A Combined Computer-Vision and Physiological-Sensor based Device for Full-Proof Prediction and Detection of Fall of Adults", in *Proceedings of the 2nd IFIP International Internet of Things (IoT) Conference (IFIP-IoT)*, 2019, pp. 273--288.

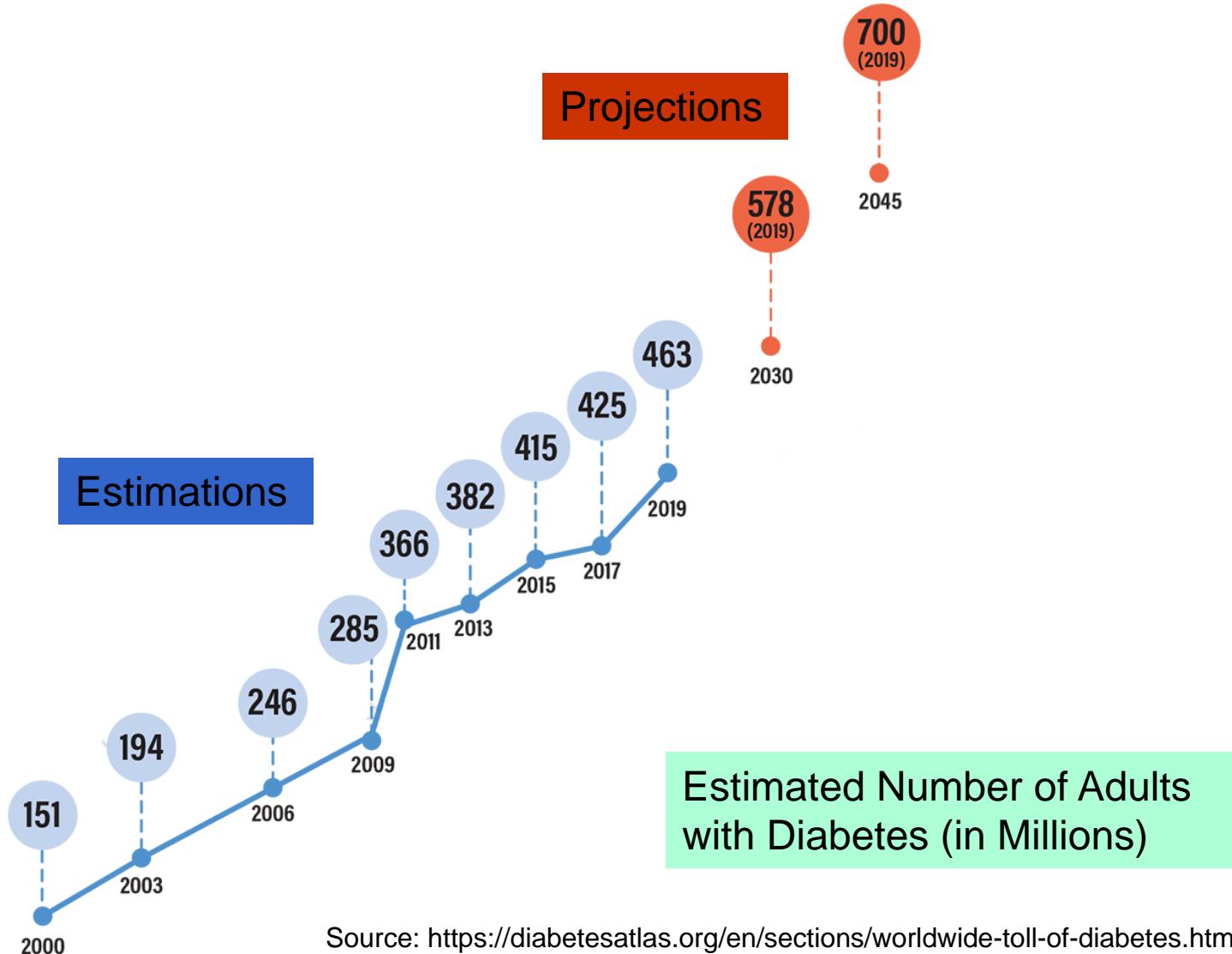
Good-Eye: Prototyping



Good-Eye: Fall detection and prediction Accuracy - 95%.

Source: L. Rachakonda, A. Sharma, S. P. Mohanty, and E. Kougianos, "Good-Eye: A Combined Computer-Vision and Physiological-Sensor based Device for Full-Proof Prediction and Detection of Fall of Adults", in *Proceedings of the 2nd IFIP International Internet of Things (IoT) Conference (IFIP-IoT)*, 2019, pp. 273--288.

Diabetes is a Global Crisis

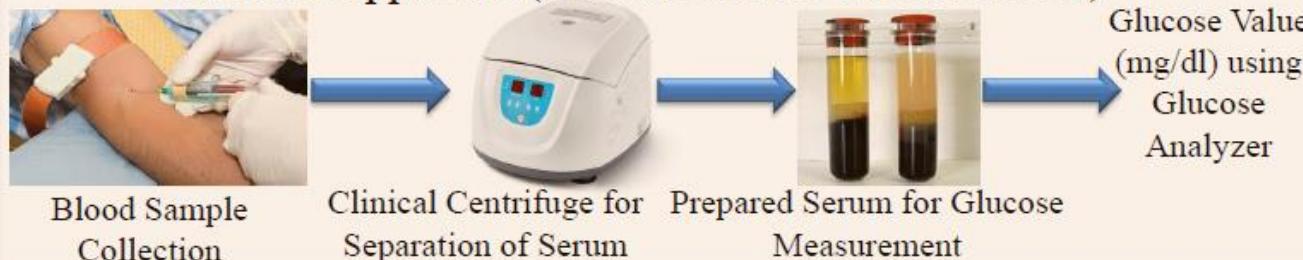


Blood Glucose Monitoring – Invasive Vs Noninvasive

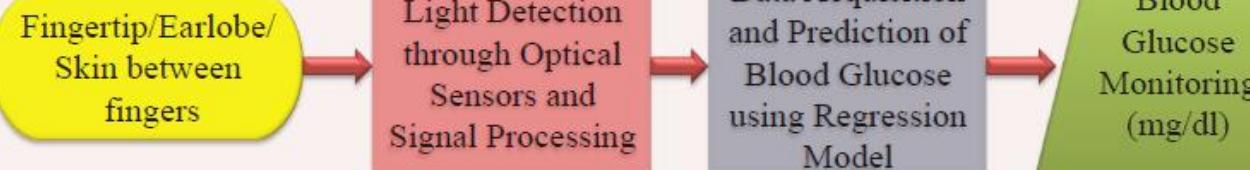
Invasive Approach (Capillary Glucose Measurement)



Invasive Approach (Serum Glucose Measurement)



Non Invasive Approach

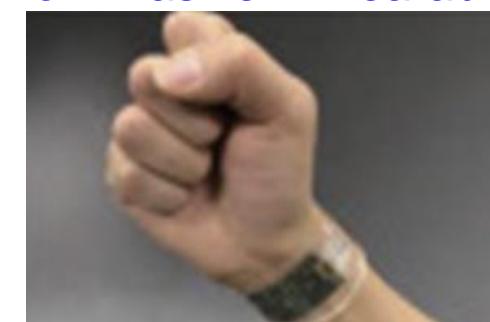


Traditional – Finger Pricking



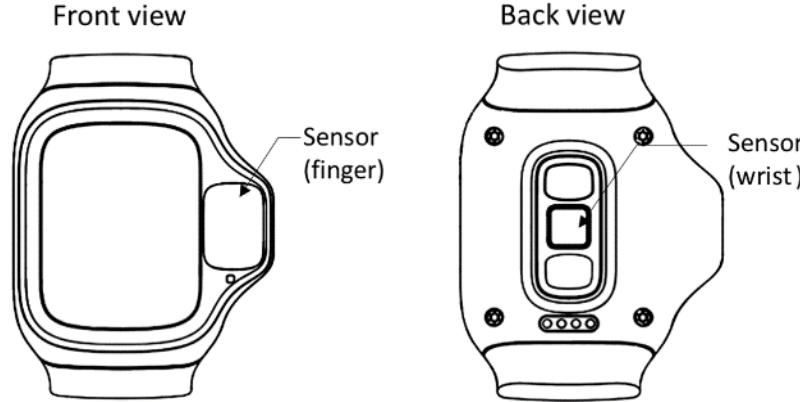
Invasive Approach – Processing Blood/Serum

Noninvasive – Wearable

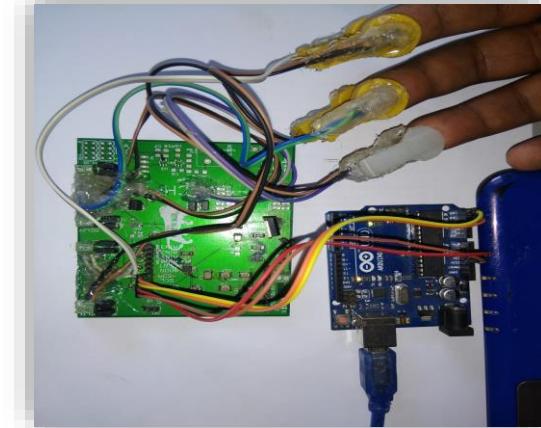


Noninvasive Approach – Processing Light

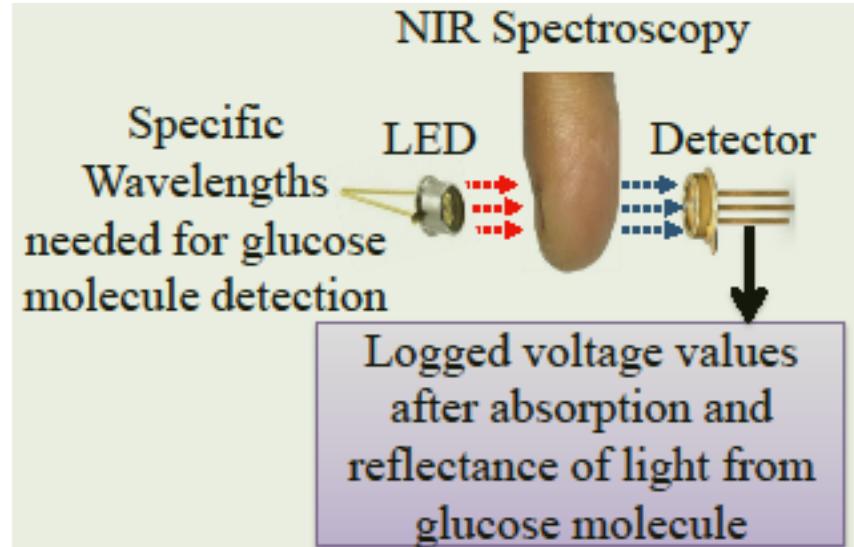
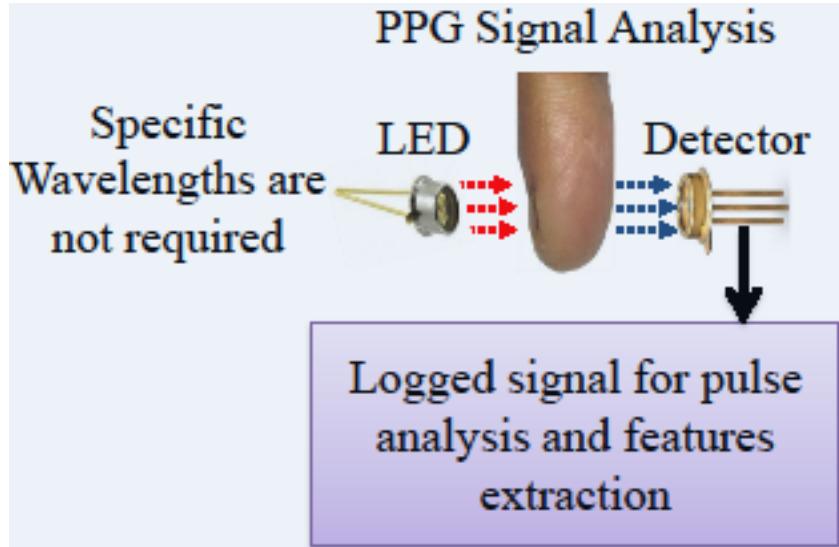
Noninvasive Glucose-Level Monitoring



Photoplethysmogram (PPG)

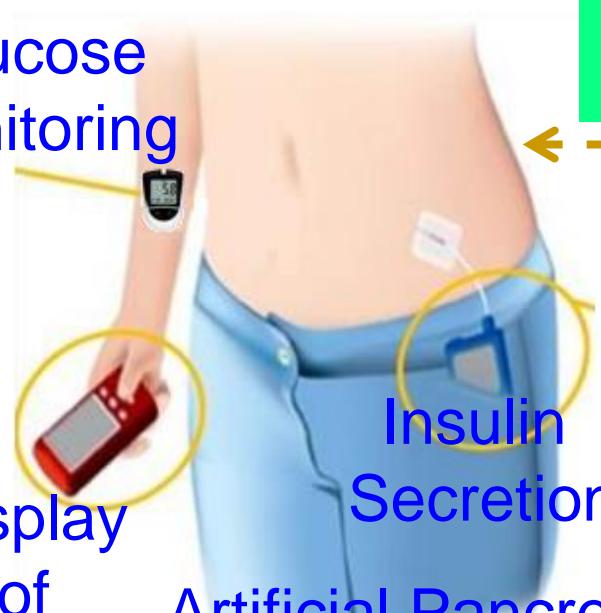


Near Infrared (NIR)

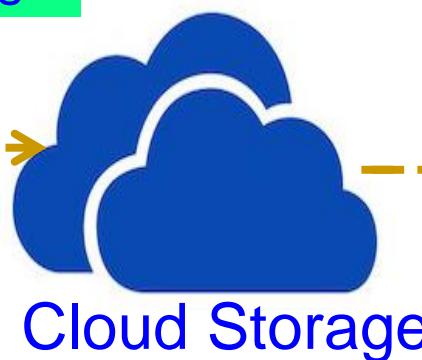
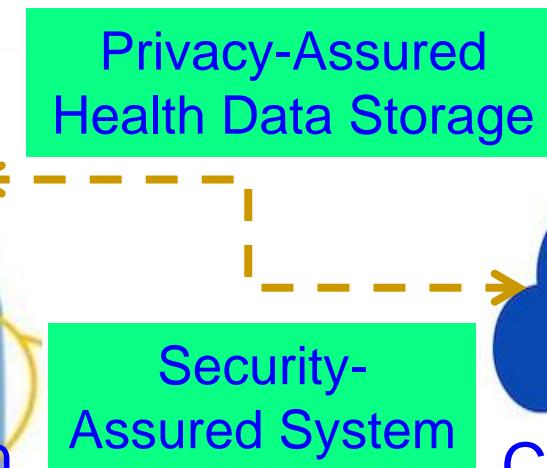


Our Vision – iGLU (Intelligent Noninvasive Monitoring and Control)

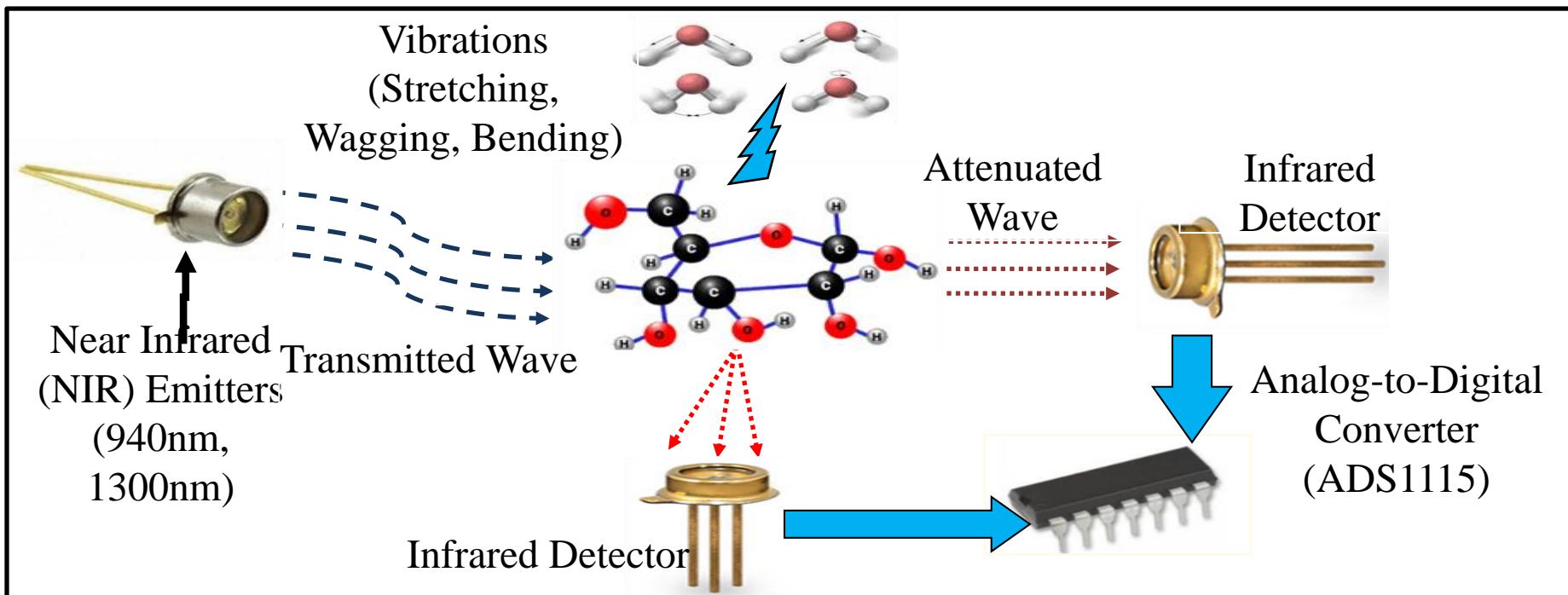
Continuous
Glucose
Monitoring



Display
of
Artificial Pancreases
Parameters
System (APS)



iGLU 1.0: Capillary Glucose

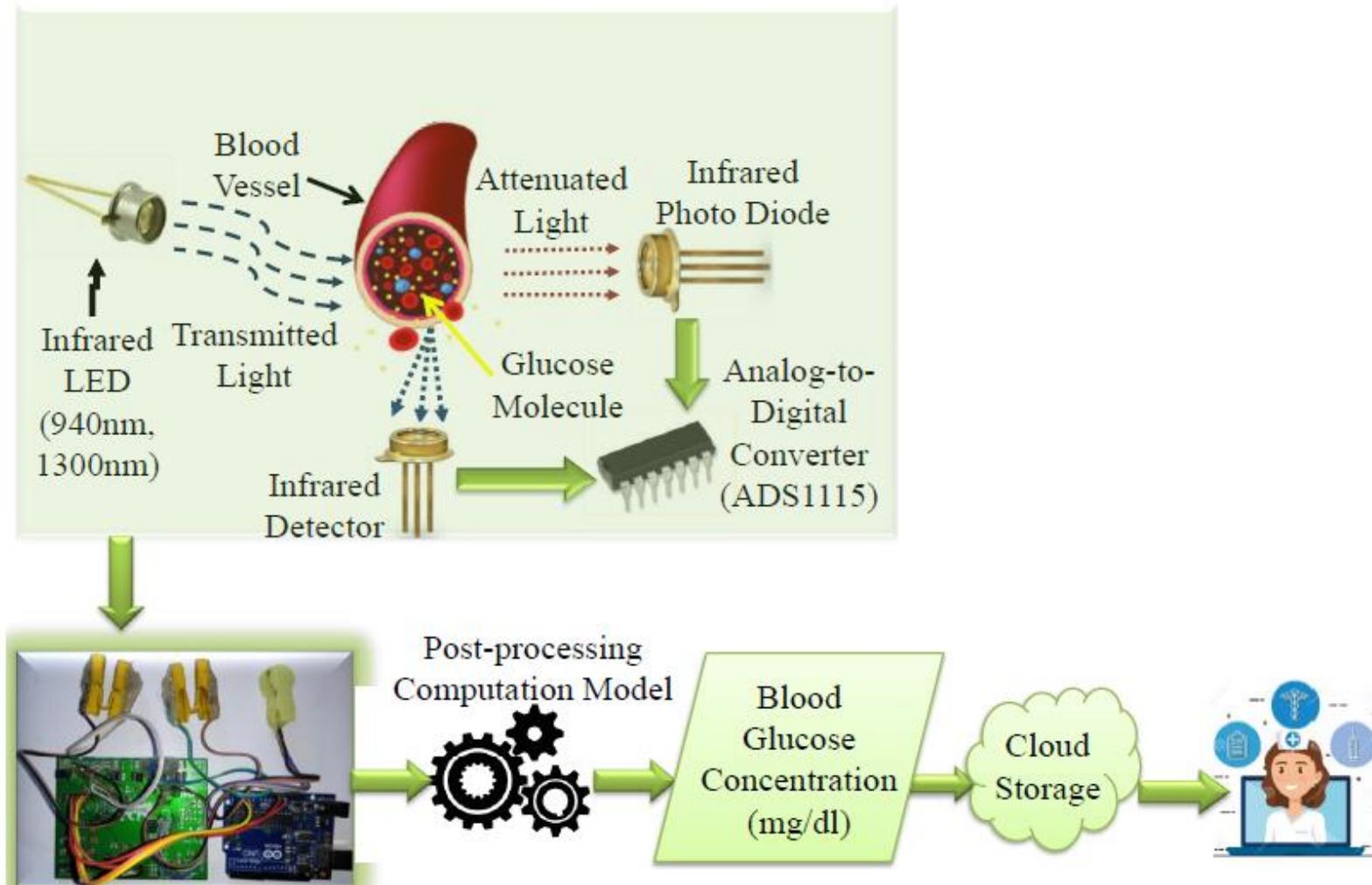


Clinically tested in an hospital.

Cost - US\$ 20
Accuracy - 100%

Source: P. Jain, A. M. Joshi, and S. P. Mohanty, "iGLU: An Intelligent Device for Accurate Non-Invasive Blood Glucose-Level Monitoring in Smart Healthcare", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 9, No. 1, January 2020, pp. 35-42.

iGLU 2.0: Serum Glucose



Source: P. Jain, A. M. Joshi, N. Agrawal, and S. P. Mohanty, "iGLU 2.0: A New Non-invasive, Accurate Serum Glucometer for Smart Healthcare", *arXiv Electrical Engineering and Systems Science*, arXiv:2001.09182, January 2020, 19-pages.

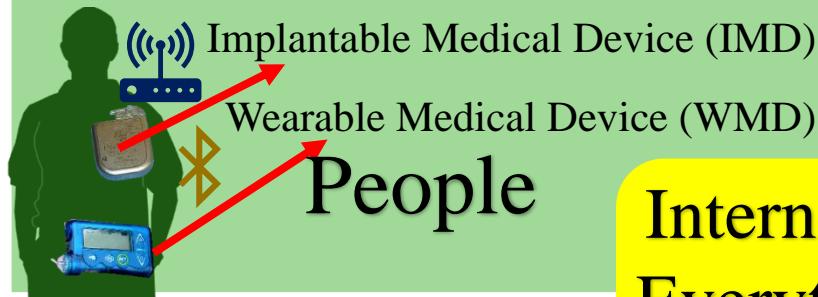
Smart Healthcare – Some Challenges

Smart Healthcare -- Prof./Dr. Saraju P. Mohanty



Users are Integral Part: For Them and By Them

Connecting people to the Internet
for more valuable communications



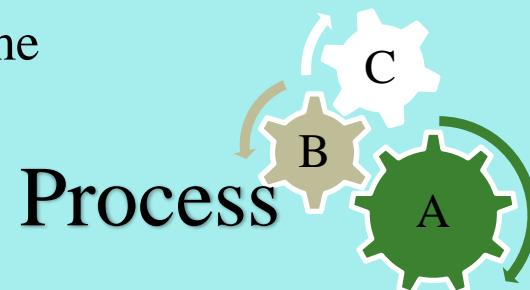
Data

Collecting data and leverage it
for decision making



Crowdsourcing

Deliver right information to right
place, person or machine at the
right time



Internet of
Everything
(IoE)

Things

Devices connected to each
other and the internet
(Internet of Things (IoT)).

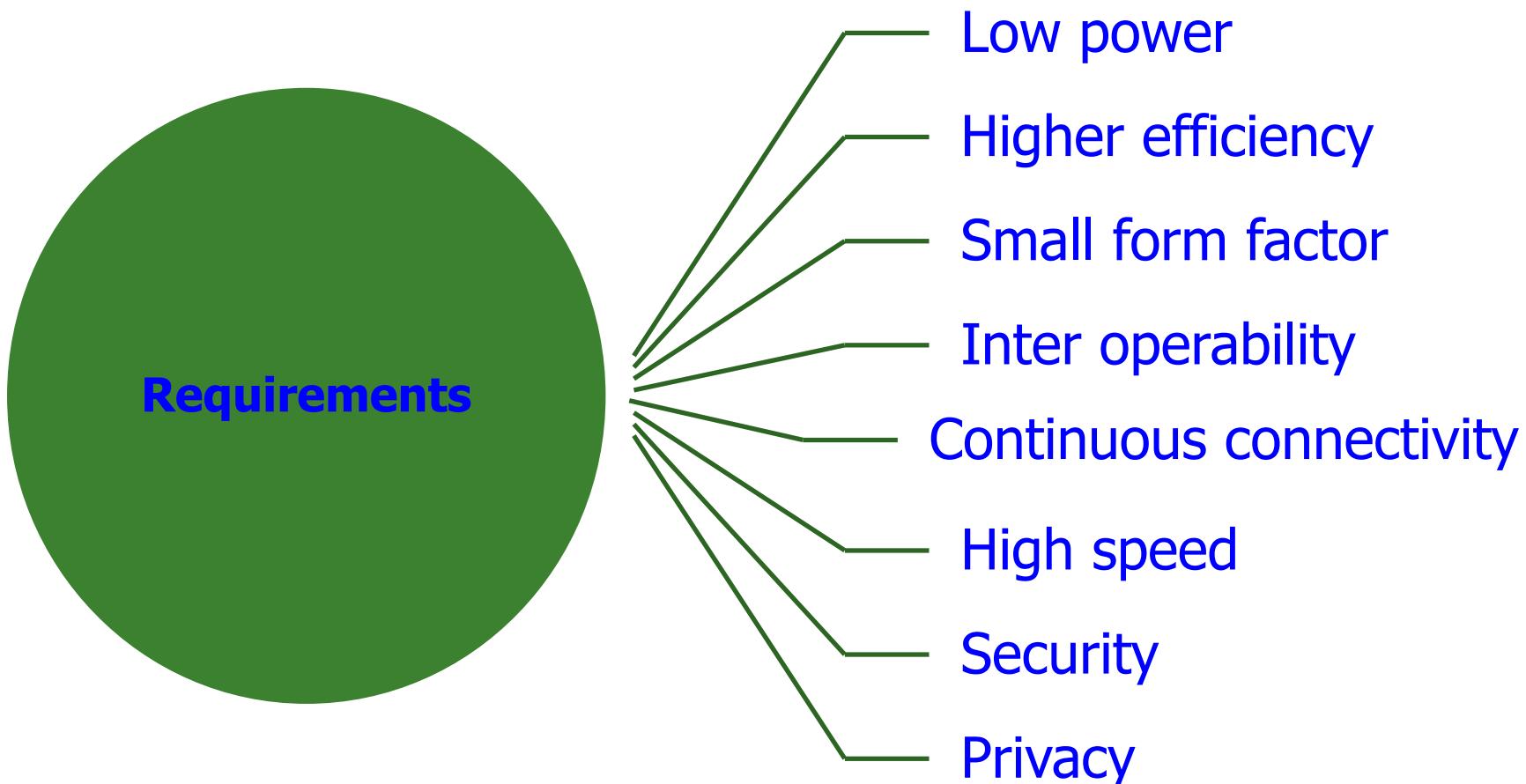


Perform decision making
whenever necessary.



Source: S. P. Mohanty, V. P. Yanambaka, E. Kougianos, and D. Puthal, "PUFchain: Hardware-Assisted Blockchain for Sustainable Simultaneous Device and Data Security in Internet of Everything (IoE)", *IEEE Consumer Electronics Magazine (MCE)*, Vol. 9, No. 2, March 2020, pp. 8--16.

Smart Healthcare Architecture – Requirements



Smart Healthcare – Data Quality



Source: H. Zhu, C. K. Wu, C. H. KOO, Y. T. Tsang, Y. Liu, H. R. Chi, and K. F. Tsang, "Smart Healthcare in the Era of Internet-of-Things", *IEEE Consumer Electronics Magazine*, vol. 8, no. 5, pp. 26-30, Sep 2019.

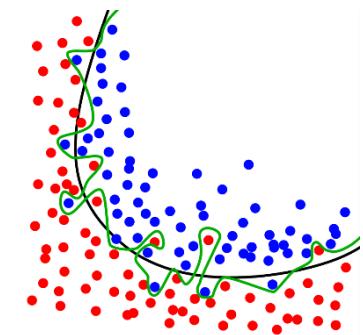
Machine Learning Challenges



Machine
Learning Issues



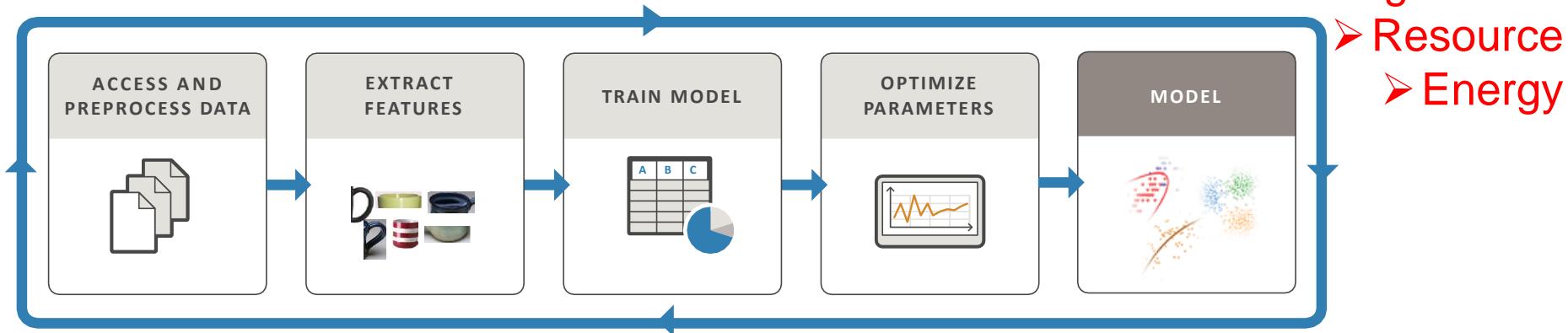
- High Energy Requirements
- High Computational Resource Requirements
- Large Amount of Data Requirements
- Underfitting/Overfitting Issue
- Class Imbalance Issue
- Fake Data Issue



Source: Mohanty ISCT Keynote 2019

Deep Neural Network (DNN) - Resource and Energy Costs

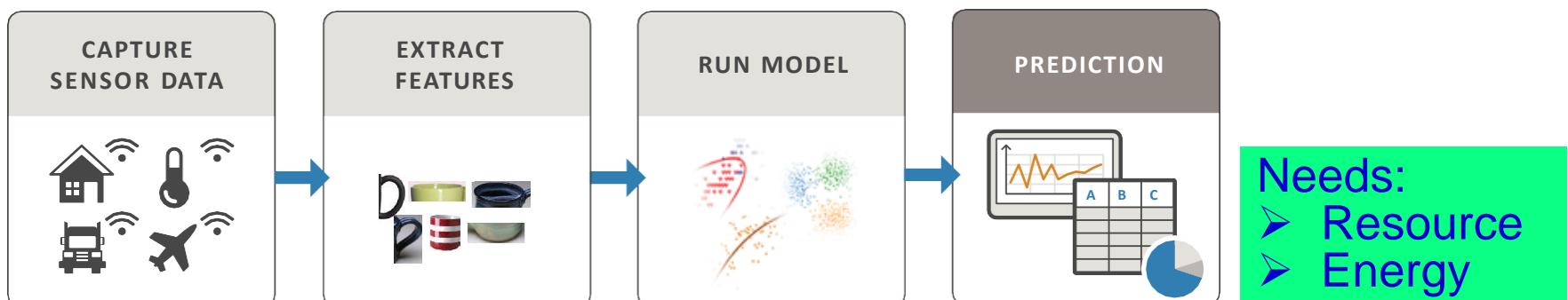
TRAIN: Iterate until you achieve satisfactory performance.



Needs Significant:

- Resource
- Energy

PREDICT: Integrate trained models into applications.

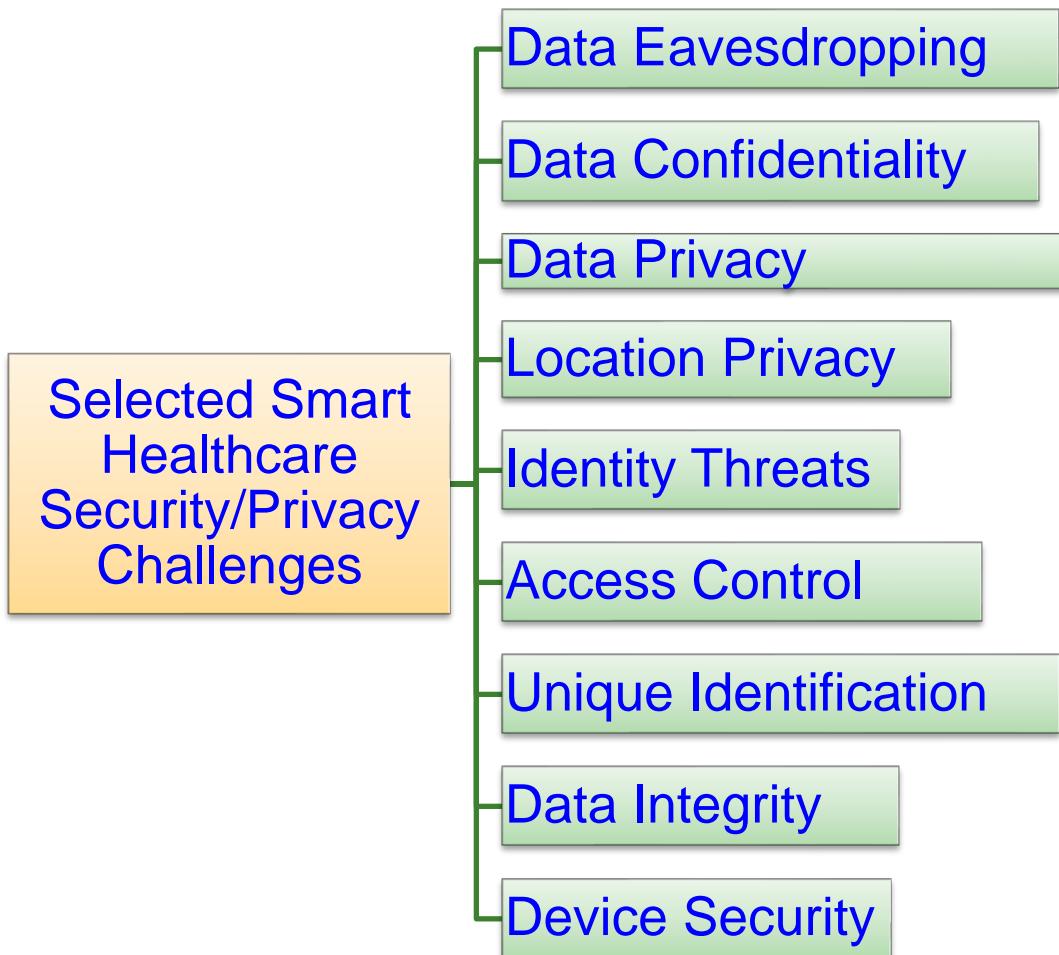


Needs:

- Resource
- Energy

Source: <https://www.mathworks.com/campaigns/offers/mastering-machine-learning-with-matlab.html>

Smart Healthcare - Security Challenges



Source: P. Sundaravadivel, E. Kougianos, S. P. Mohanty, and M. Ganapathiraju, "Everything You Wanted to Know about Smart Health Care", *IEEE Consumer Electronics Magazine (CEM)*, Volume 7, Issue 1, January 2018, pp. 18-28.

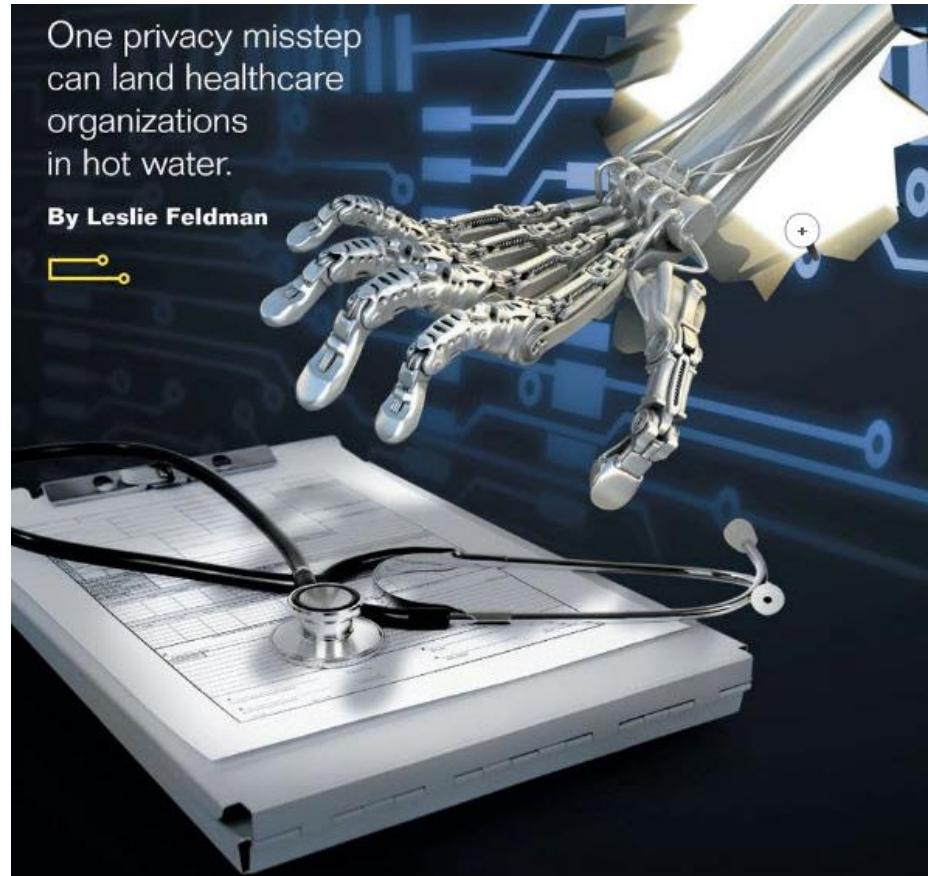
Information Privacy



Source: <http://ciphercloud.com/three-ways-pursue-cloud-data-privacy-medical-records/>

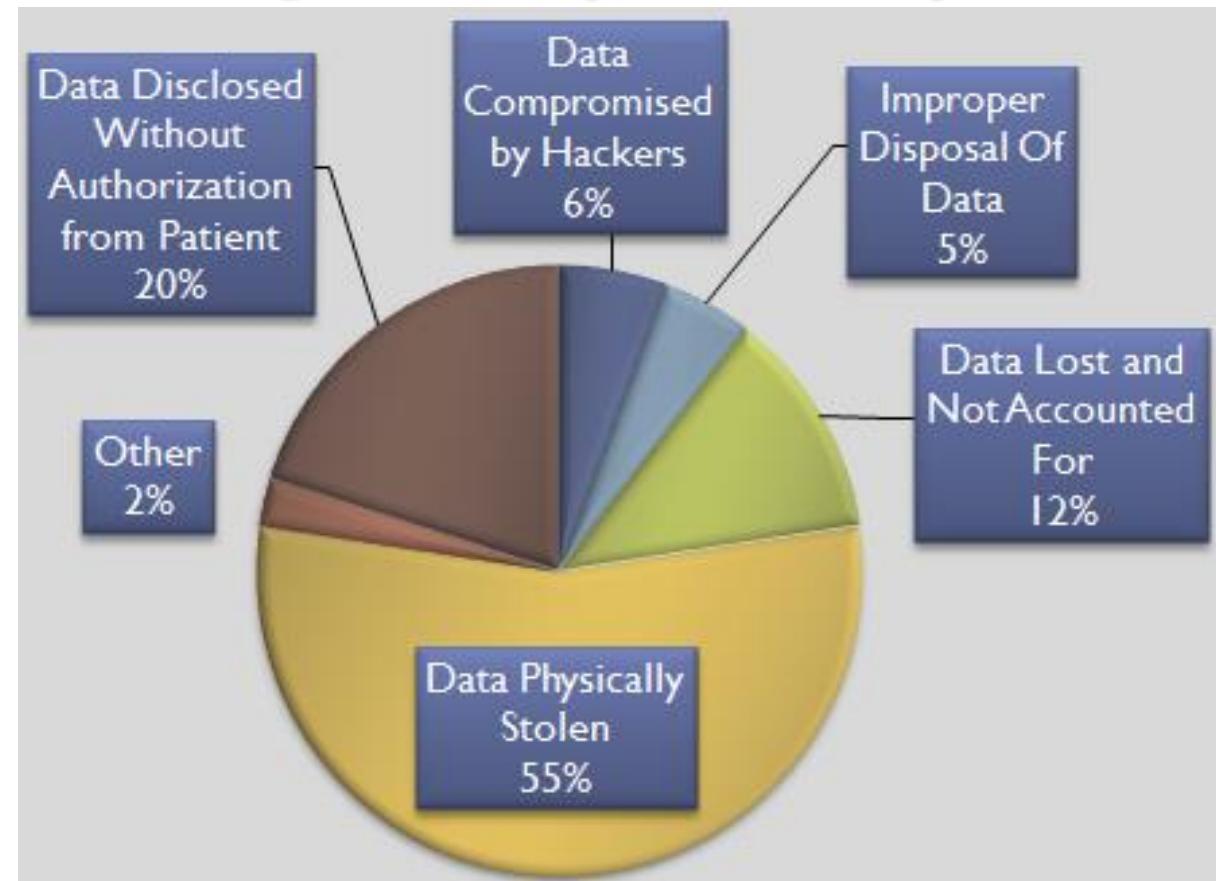
One privacy misstep
can land healthcare
organizations
in hot water.

By Leslie Feldman



Source: <http://blog.veriphyr.com/2012/06/electronic-medical-records-security-and.html>

Health Insurance Portability and Accountability Act (HIPPA)



HIPPA Privacy Violation by Types

IoMT Device Security Issue is Scary

- Insulin pumps are vulnerable to hacking, FDA warns amid recall:

<https://www.washingtonpost.com/health/2019/06/28/insulin-pumps-are-vulnerable-hacking-fda-warns-amid-recall/>

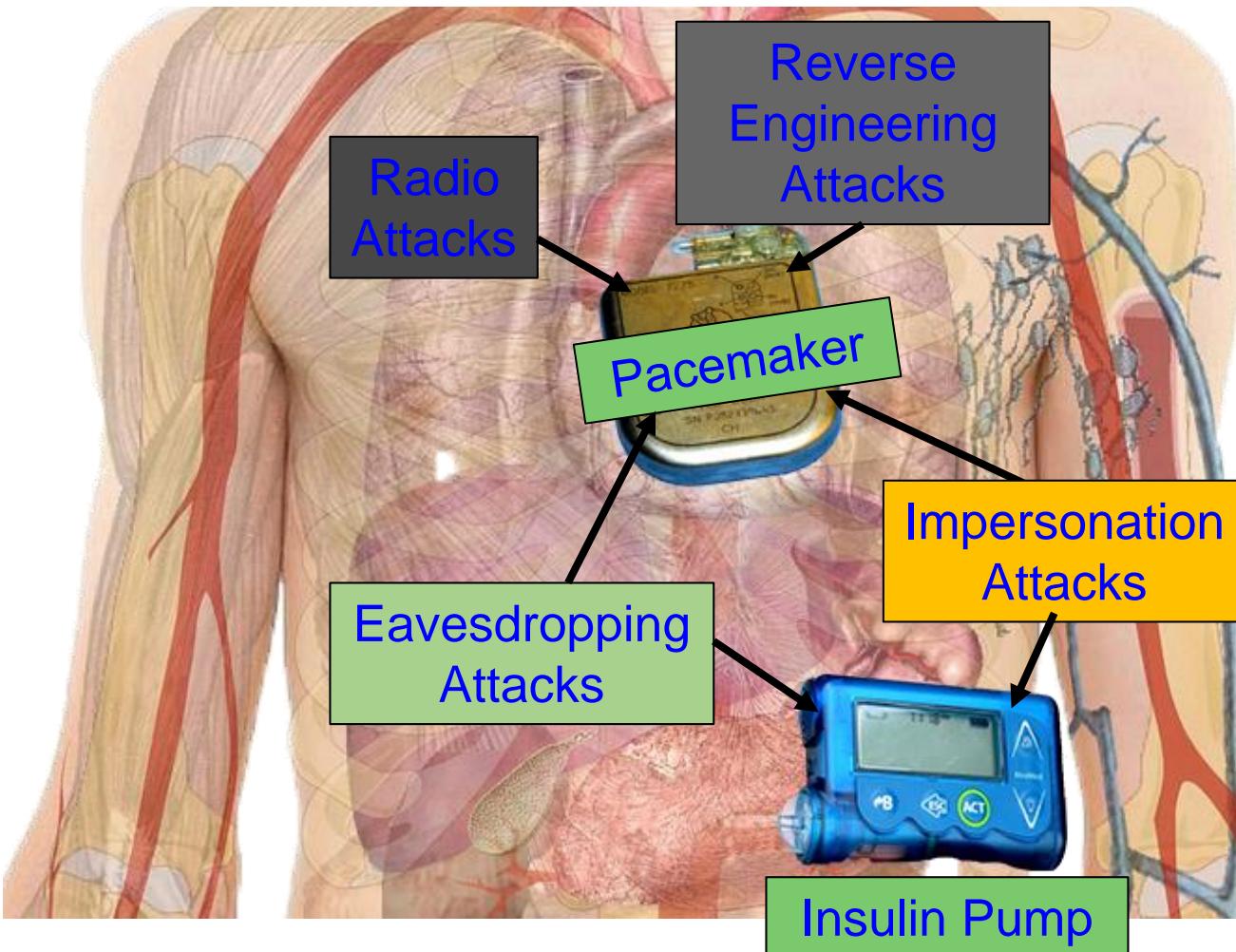
- Software vulnerabilities in some medical devices could leave them susceptible to hackers, FDA warns:

<https://www.cnn.com/2019/10/02/health/fda-medical-devices-hackers-trnd/index.html>

- FDA Issues Recall For Medtronic mHealth Devices Over Hacking Concerns:

<https://mhealthintelligence.com/news/fda-issues-recall-for-medtronic-mhealth-devices-over-hacking-concerns>

IoMT Security Measures is Hard



Collectively
(WMD+IMD):
Implantable and
Wearable Medical
Devices (IWMDs)

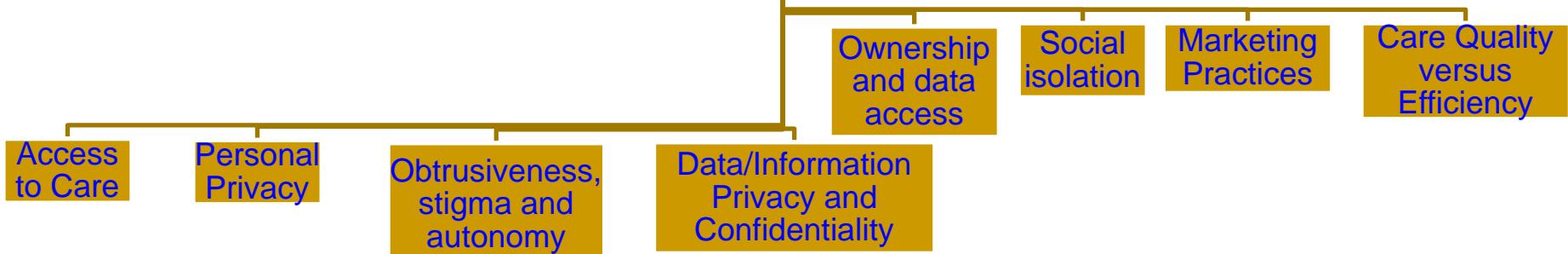
Implantable and
Wearable Medical
Devices (IWMDs) --
Battery Characteristics:
→ Longer life
→ Safer
→ Smaller size
→ Smaller weight

Smart Healthcare - Ethics



Source: <https://online.alvernia.edu/articles/ethical-issues-in-healthcare/>

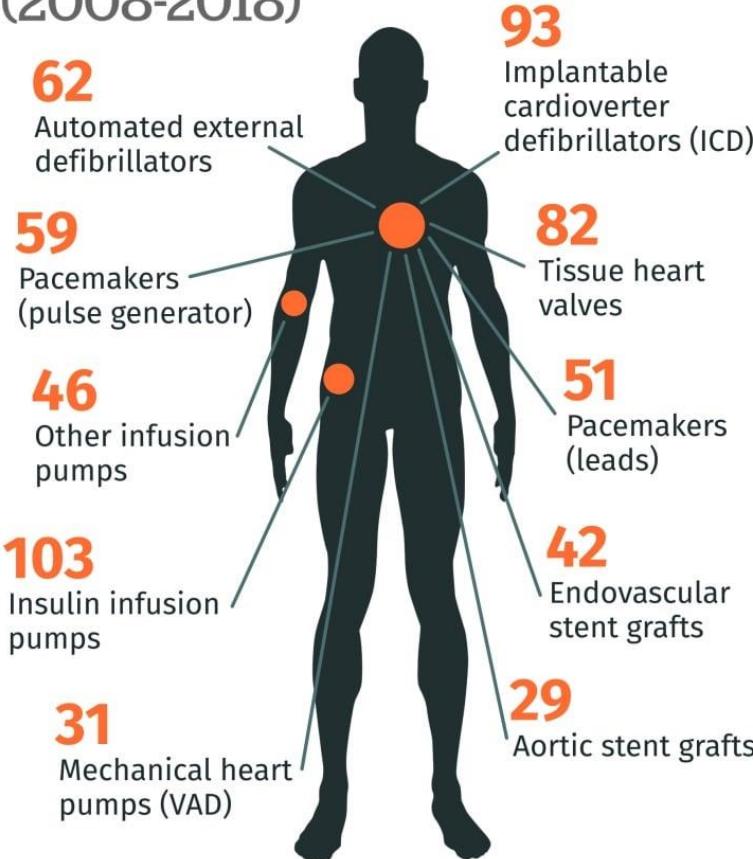
Ethical Issues Include



Source: B. Mittelstadt, "Ethics of the health-related internet of things: a narrative review", *Ethics Inf Technol* **19**, 157–175 (2017), DOI: <https://doi.org/10.1007/s10676-017-9426-4>.

Smart Healthcare - Safety

10 devices tied to the most reports involving death (2008-2018)



CBC NEWS

Source <https://planet-report.com/canadian-advocates-call-for-all-medical-implants-to-be-registered-cbc-news/>

Source: Health Canada & ICIJ

CENTRAL ILLUSTRATION: Cardiac-Implantable Electronic Devices: Technical and Safety Considerations

FACTORS INFLUENCING SAFETY	SMALL POTENTIAL RISKS
MR magnet: <ul style="list-style-type: none">Magnet strengthRadiofrequency powerMagnet position	Heating effects: Tissue injury (Mainly theoretical) Strategy to minimize risk: Lead designed to limit current induction
Cardiac implantable device: <ul style="list-style-type: none">Ferromagnetic materialPresence of reed switchDevice programming	Mechanical effects: Device movement (Mainly theoretical) Strategy to minimize risk: Limitation of ferromagnetic materials
Leads: <ul style="list-style-type: none">Ferromagnetic materialLead stability	Electromagnetic effects: <ul style="list-style-type: none">Altered sensing/captureInhibited therapiesInappropriate therapies (No significant adverse patient outcomes) Strategy to minimize risk: Lead designed to limit current induction, replacement of reed switch with Hall sensor, temporary device reprogramming
Patient: <ul style="list-style-type: none">Patient positionPatient size	Indication to scan: If the benefits outweigh the very small potential risks, MRI is acceptable

Miller, J.D. et al. *J Am Coll Cardiol.* 2016;68(14):1590-8.

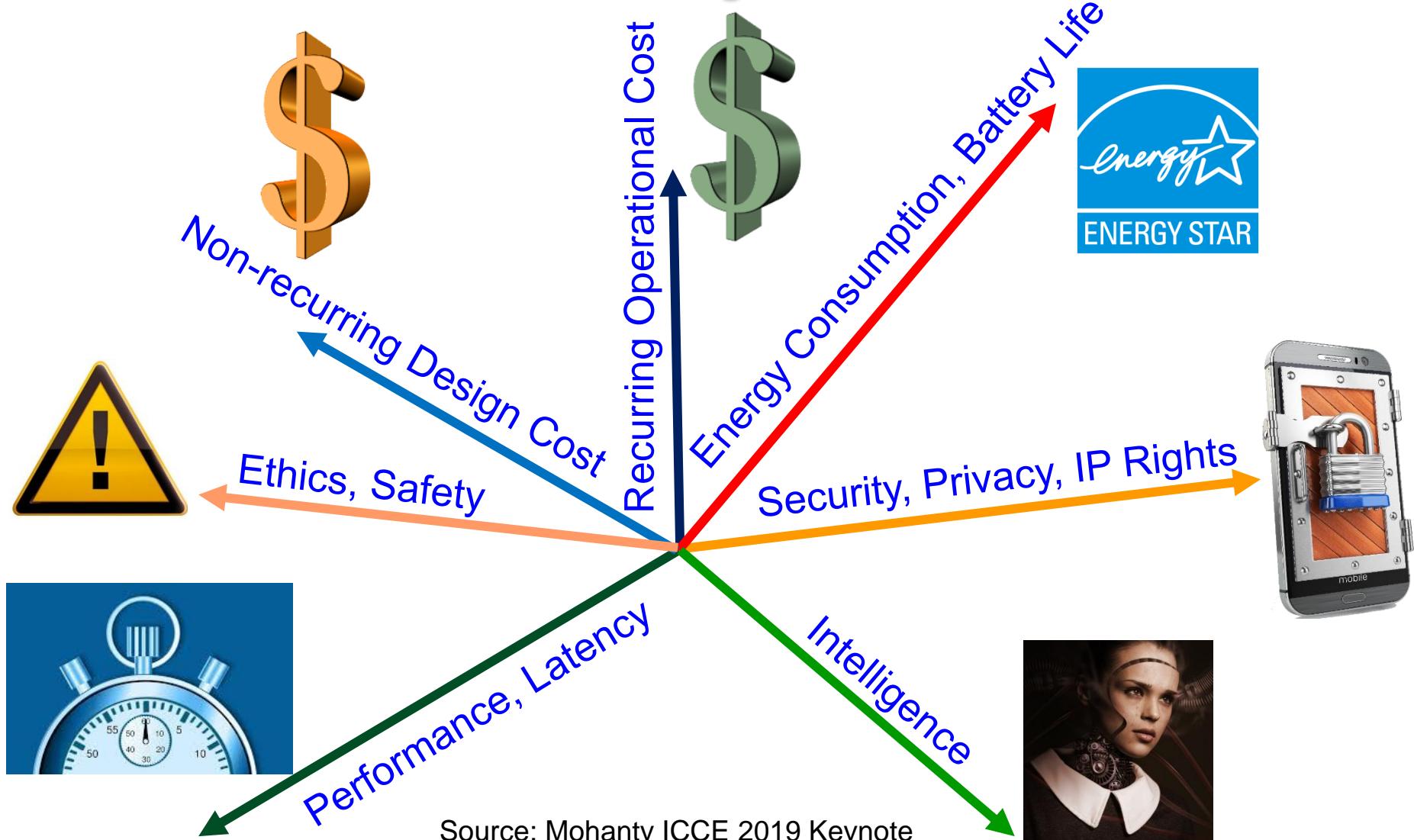
Source: J. D. Miller, S. Nazarian, H. R. Halperin, "Implantable Electronic Cardiac Devices and Compatibility With Magnetic Resonance Imaging", *J Am Coll Cardiol.* 2016 Oct, 68 (14), pp. 1590-1598.

Smart Healthcare – Some Solutions

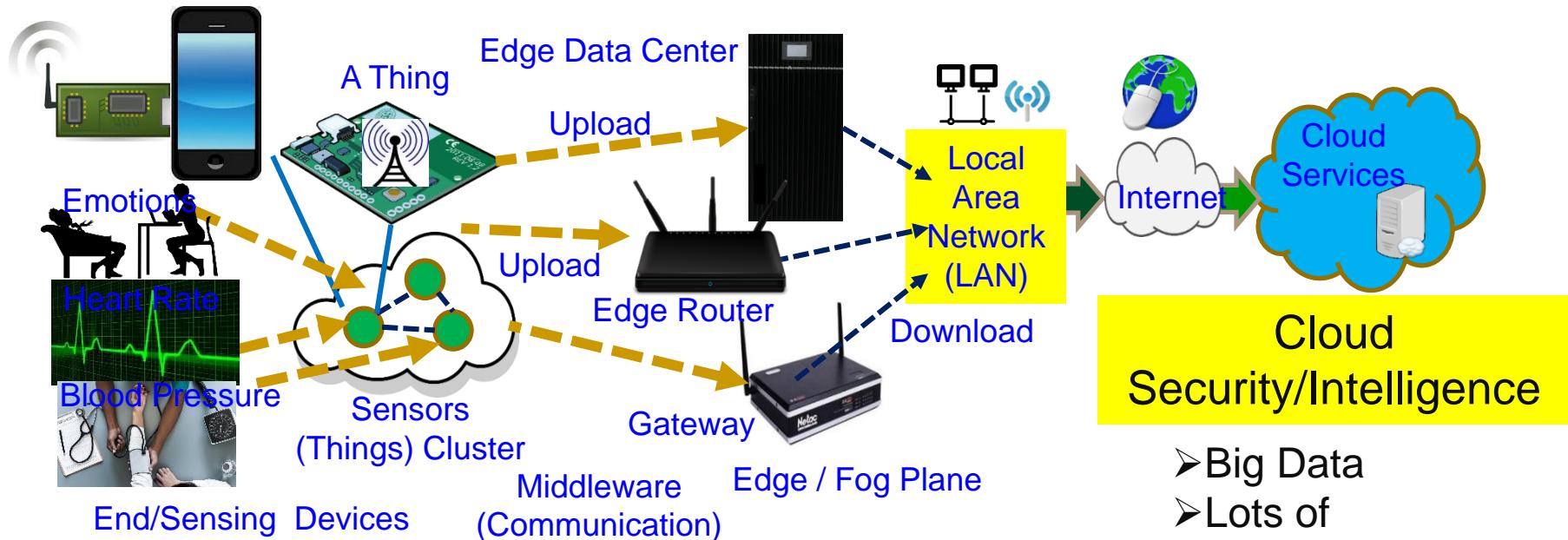
Smart Healthcare -- Prof./Dr. Saraju P. Mohanty



H-CPS - Multi-Objective Tradeoffs



Smart Healthcare – Edge Vs Cloud



End Security/Intelligence

- Minimal Data
- Minimal Computational Resource
- Least Accurate Data Analytics
- Very Rapid Response

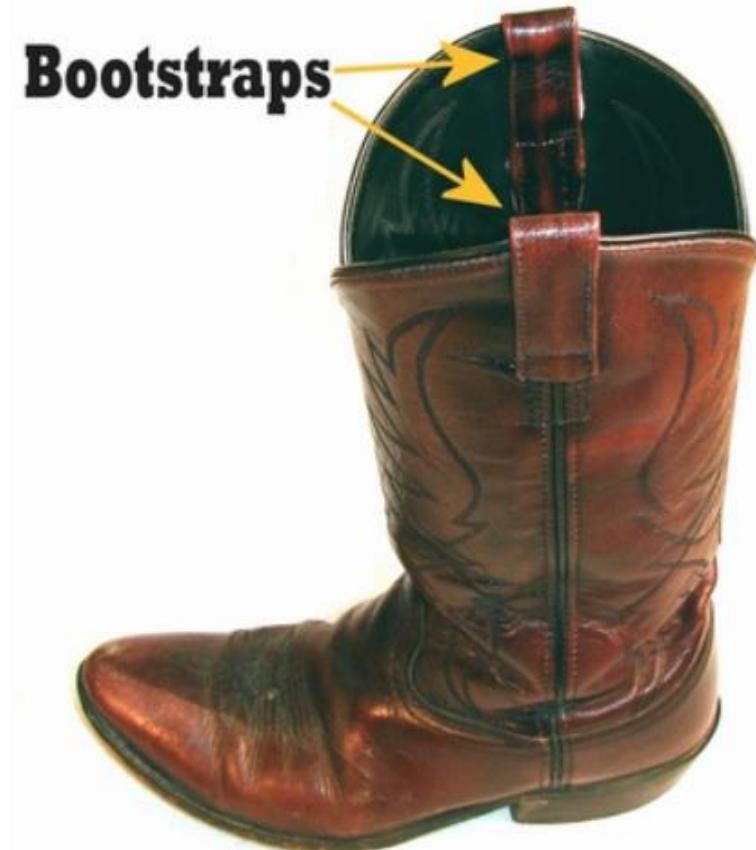
Edge Security/Intelligence

- Less Data
- Less Computational Resource
- Less Accurate Data Analytics
- Rapid Response

- Big Data
- Lots of Computational Resource
- Accurate Data Analytics
- Latency in Network
- Energy overhead in Communications

Hierarchical ML to Reduce Training Time - Bootstrapping

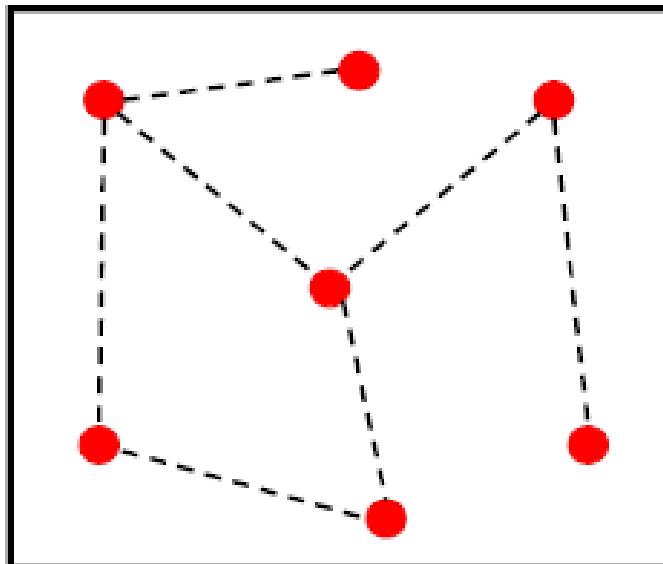
- A Bootstrap helps in pulling on a boot.
- It means solving a problem without external resources



Source: <http://www.lemen.com/dictionary-b.html#bootstrap>

Bootstrapped Kriging

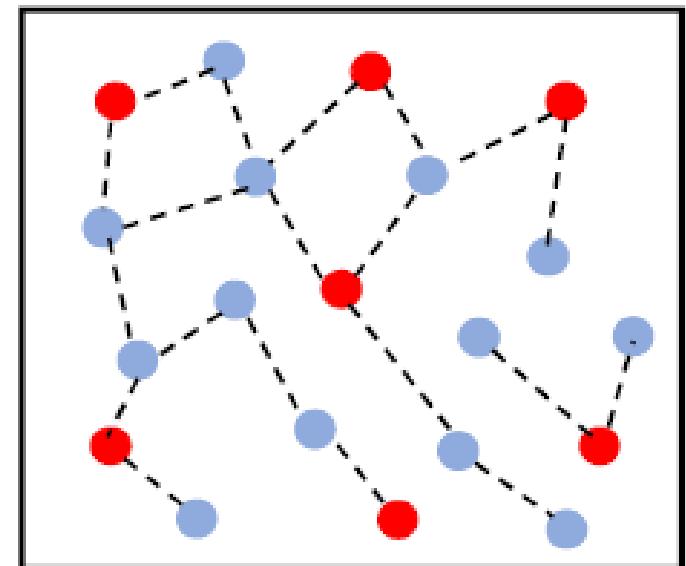
Initial Sample Field



Sample Size = 7

Bootstrapping
by Kriging

New Sample Field

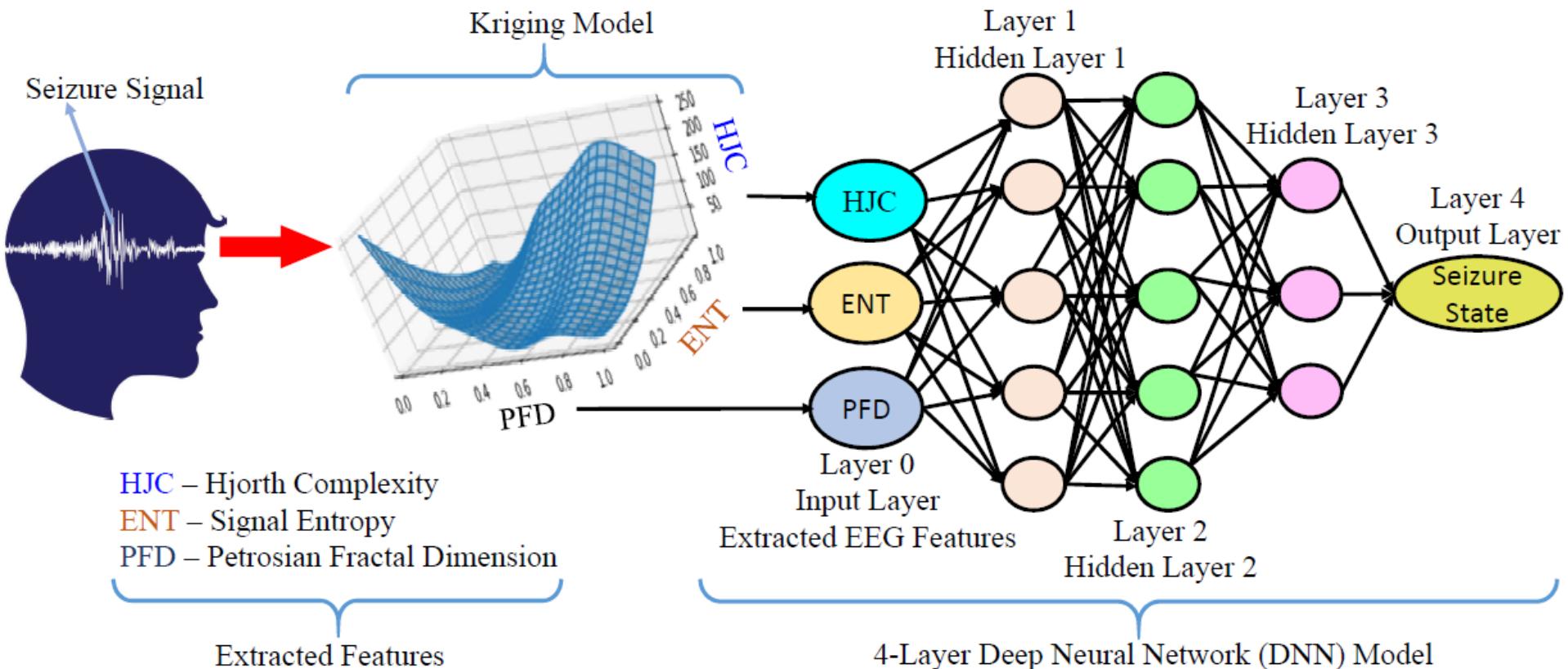


Bootstrap Size = 20

13

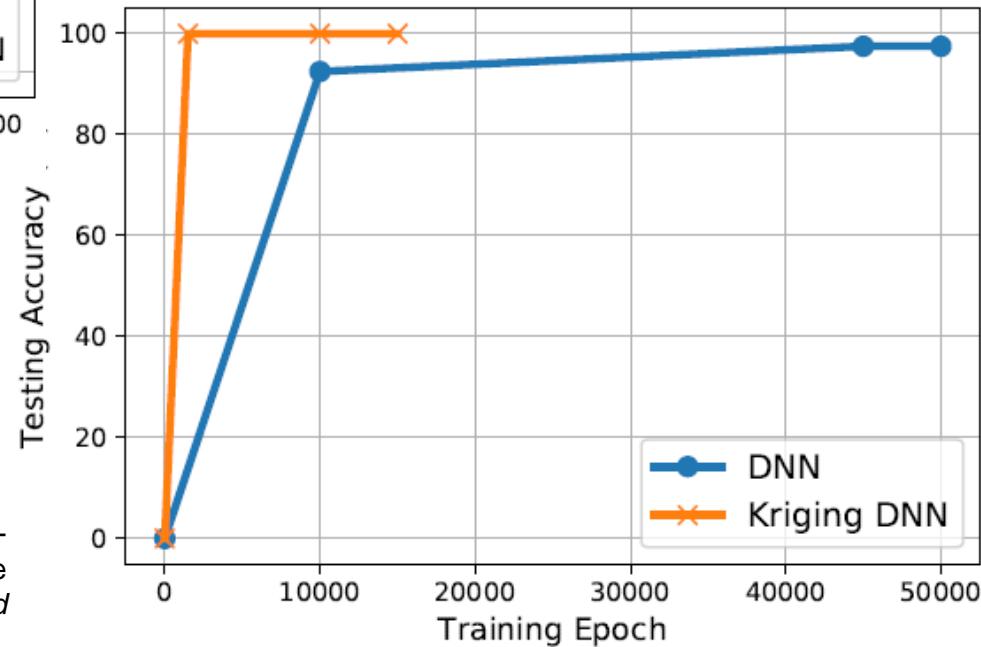
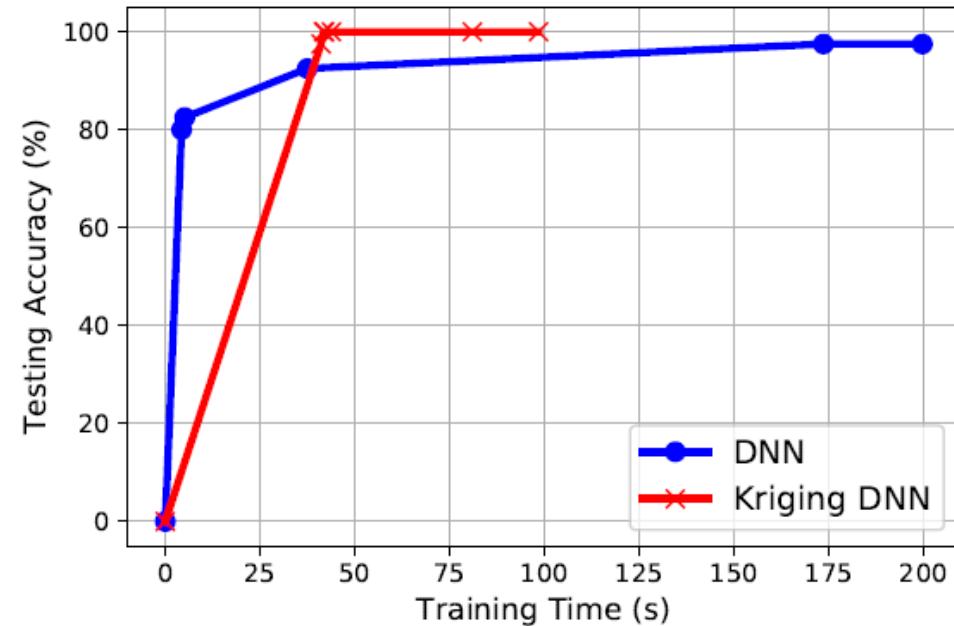
Source: I. L. Olokodana, S. P. Mohanty, and E. Kougianos, "Kriging-Bootstrapped DNN Hierarchical Model for Real-Time Seizure Detection from EEG Signals", in *Proceedings of the 6th IEEE World Forum on Internet of Things (WF-IoT)*, 2020

Proposed Kriging-Bootstrapped DNN Model



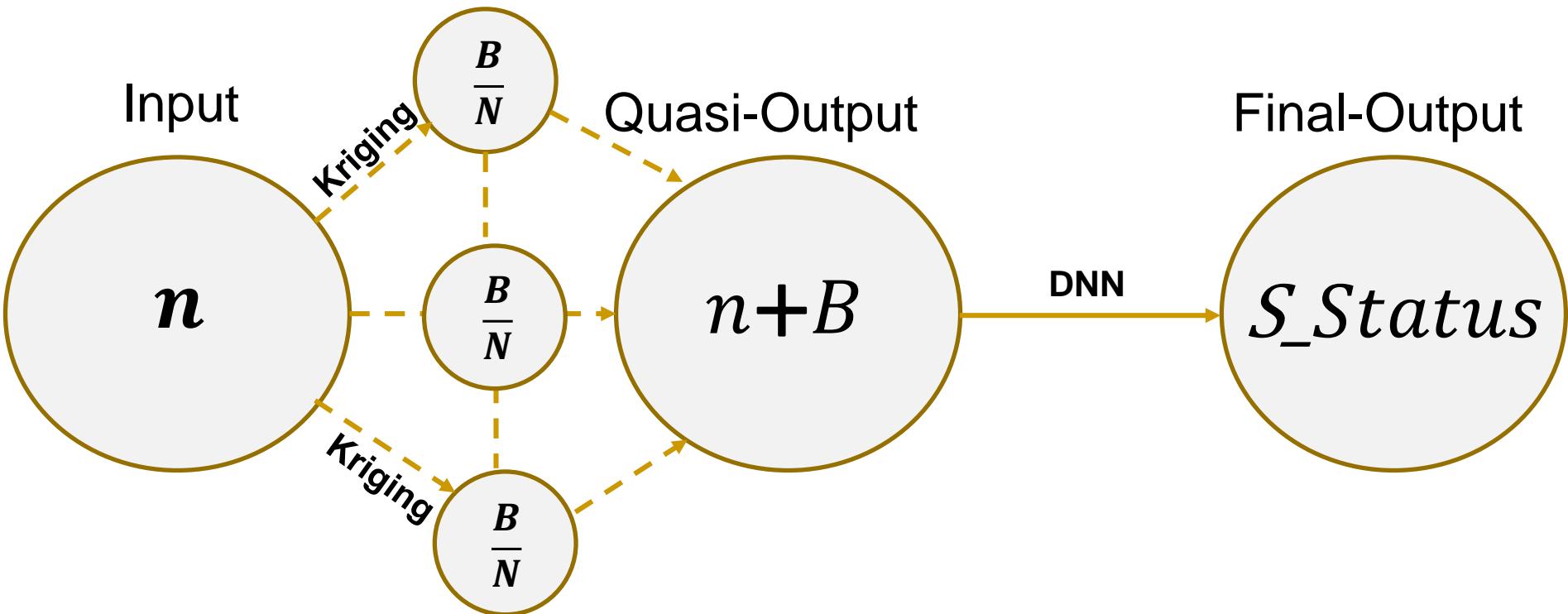
Source: I. L. Olokodana, S. P. Mohanty, and E. Kougiannos, "Kriging-Bootstrapped DNN Hierarchical Model for Real-Time Seizure Detection from EEG Signals", in *Proceedings of the 6th IEEE World Forum on Internet of Things (WF-IoT)*, 2020

Experimental Results



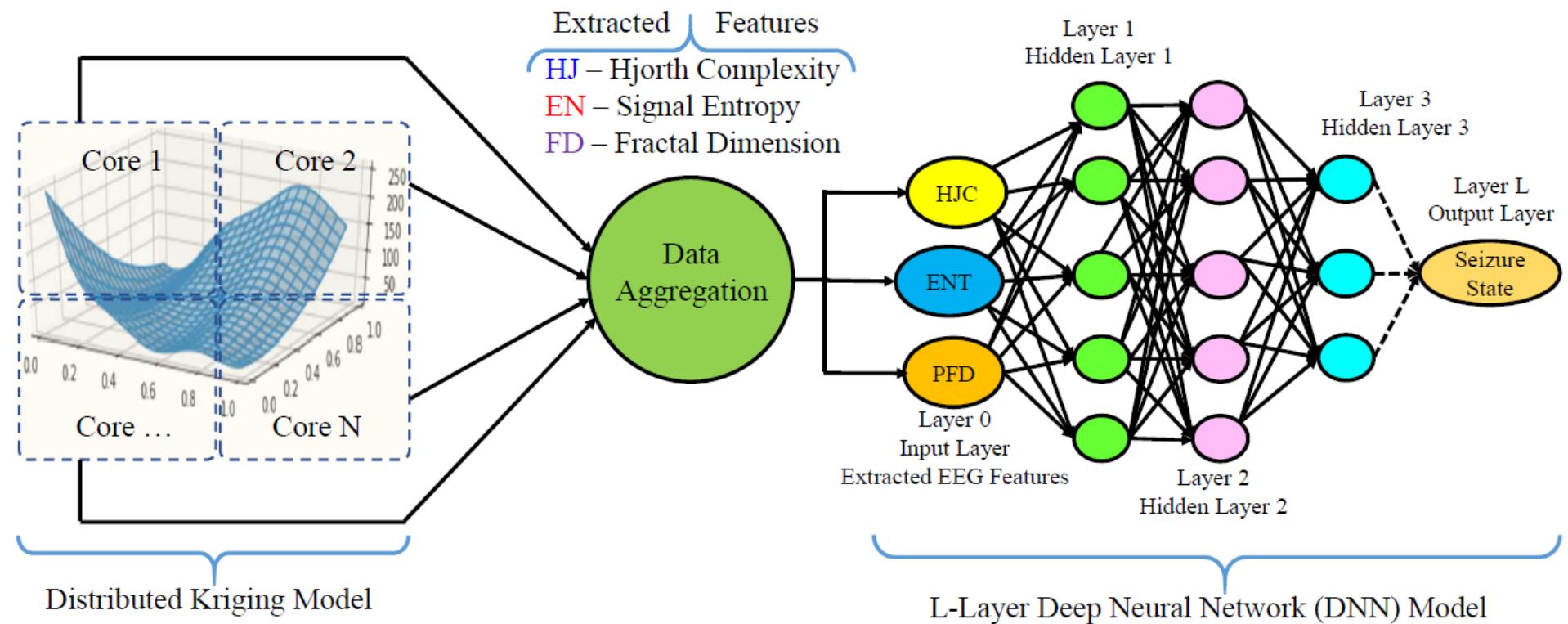
Source: I. L. Olokodana, S. P. Mohanty, and E. Kougianos, "Kriging-Bootstrapped DNN Hierarchical Model for Real-Time Seizure Detection from EEG Signals", in *Proceedings of the 6th IEEE World Forum on Internet of Things (WF-IoT)*, 2020

Model Training or Learning Process



Source: I. L. Olokodana, S. P. Mohanty, and E. Kougianos, "Distributed Kriging-Bootstrapped DNN Model for Fast, Accurate Seizure Detection from EEG Signals", *Proceedings of the 19th IEEE Computer Society Annual Symposium on VLSI (ISVLSI)*, 2020.

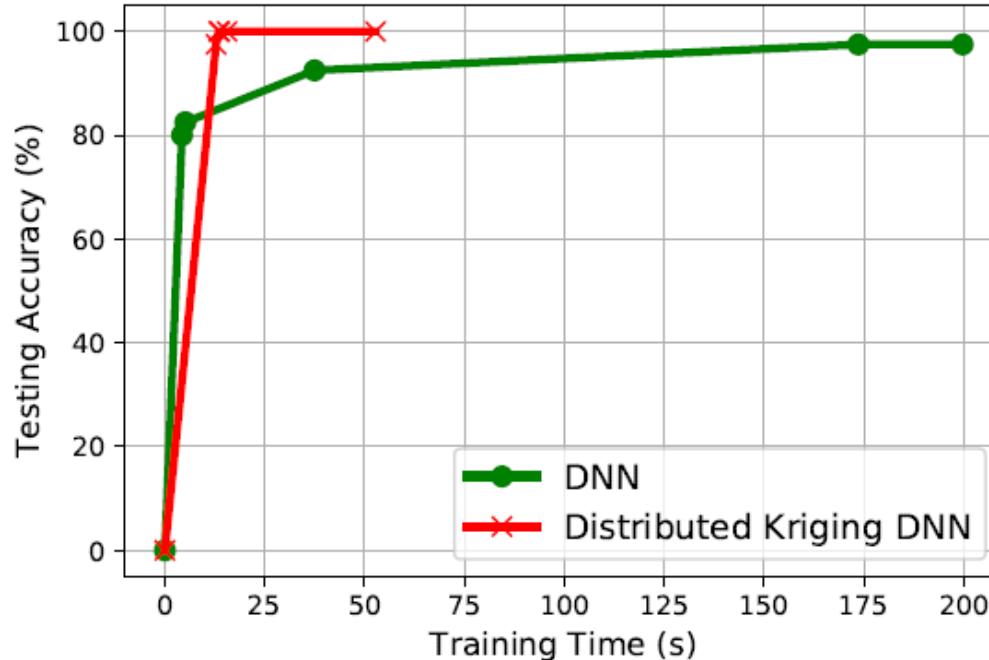
Our Distributed Kriging-Bootstrapped DNN Model



Source: I. L. Olokodana, S. P. Mohanty, and E. Kougianos, "Distributed Kriging-Bootstrapped DNN Model for Fast, Accurate Seizure Detection from EEG Signals", *Proceedings of the 19th IEEE Computer Society Annual Symposium on VLSI (ISVLSI)*, 2020.

Experimental Results: Dataset A

Models	DNN	Ordinary Kriging	Kriging DNN	Distributed Kriging DNN
Tr. Data Size	10000	2000	10000	10000
Tr. Epochs	45000	NA	1500	1500
Learning Rate	0.00001	NA	0.001	0.001
Training Acc.	99.99%	100.00%	99.92%	99.92%
Testing Acc.	97.50%	99.78%	100.00%	100.00%
Training Time	173.57s	72.24s	43.83s	15.56s

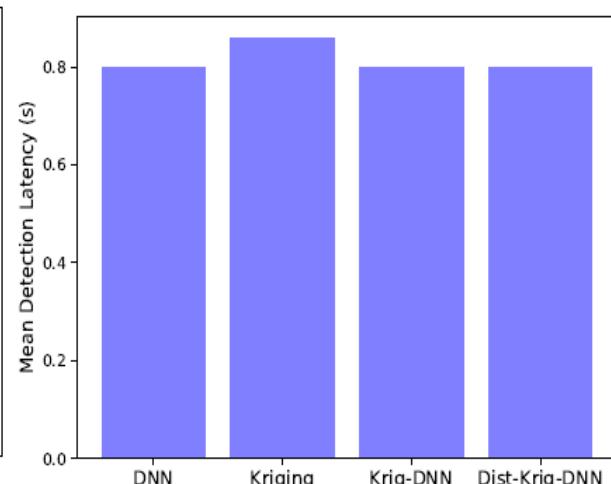
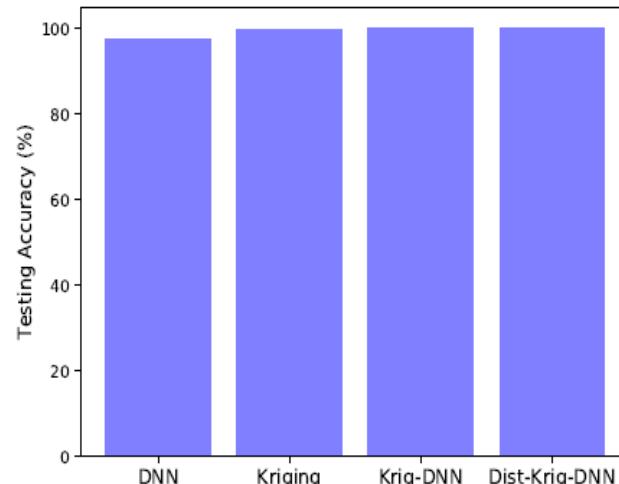
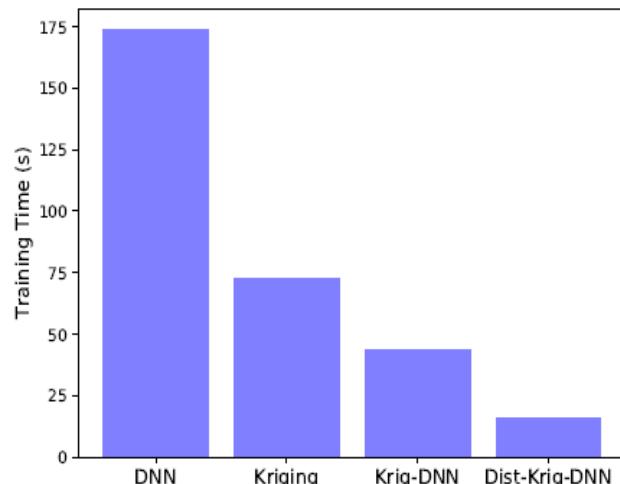


■ Training Time reduced by 91%

Source: I. L. Olokodana, S. P. Mohanty, and E. Kougiannos, "Distributed Kriging-Bootstrapped DNN Model for Fast, Accurate Seizure Detection from EEG Signals", *Proceedings of the 19th IEEE Computer Society Annual Symposium on VLSI (ISVLSI)*, 2020.

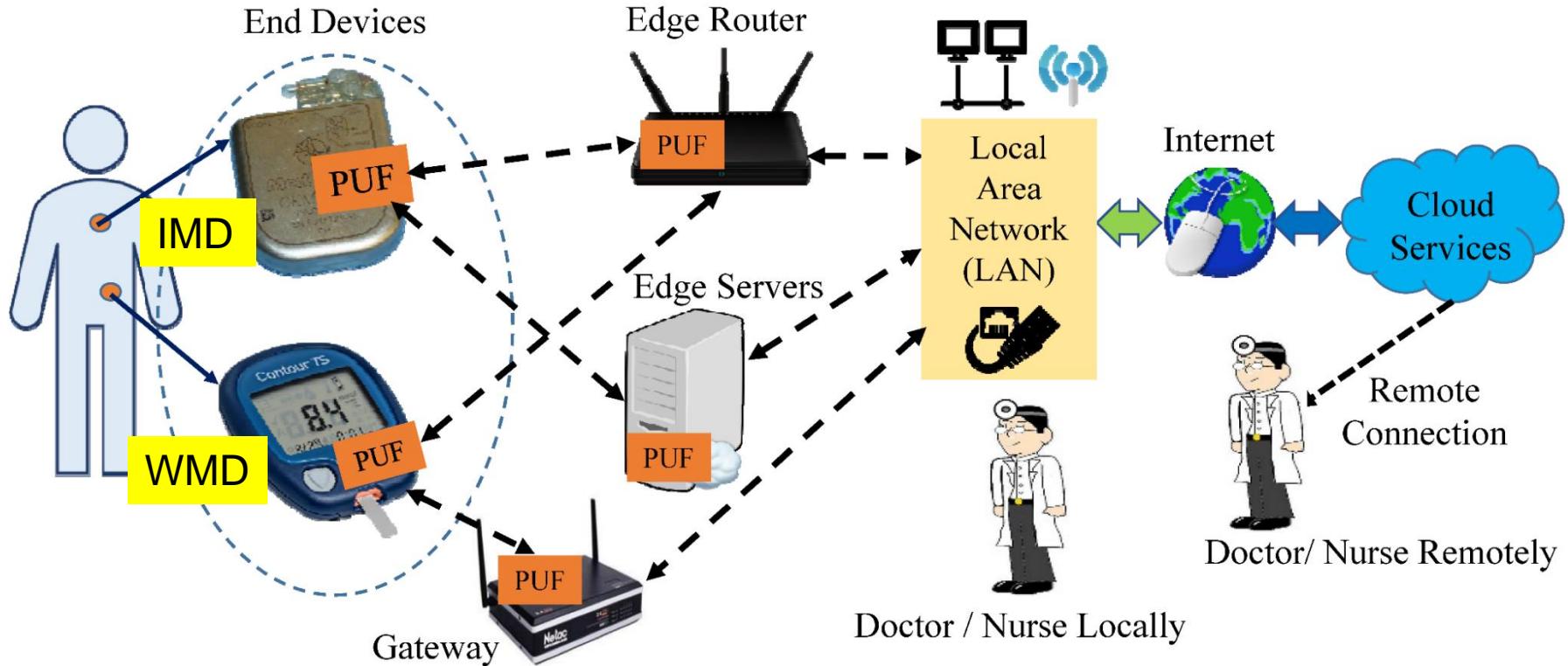
Experimental Results: Dataset A

Models	Detection Latency
DNN	0.80s
Ordinary Kriging	0.86s
Krig-DNN	0.80s
Dist-Krig-DNN	0.80s



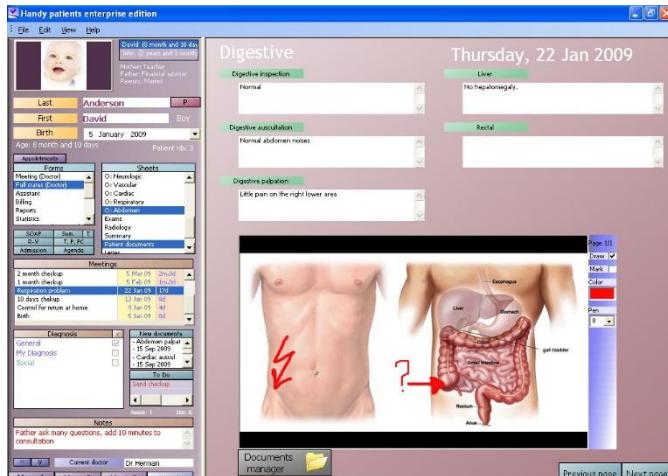
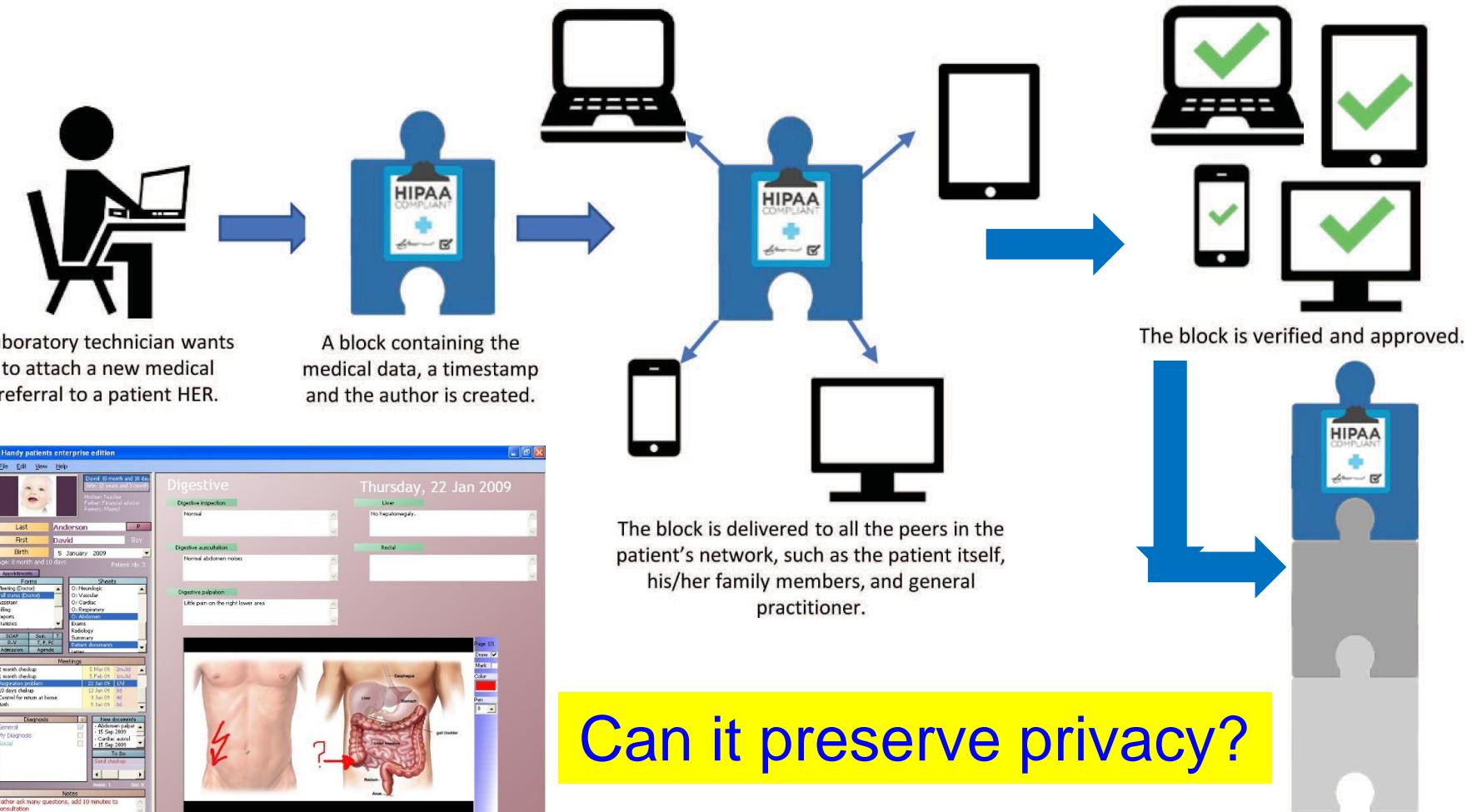
Source: I. L. Olokodana, S. P. Mohanty, and E. Kougiannos, "Distributed Kriging-Bootstrapped DNN Model for Fast, Accurate Seizure Detection from EEG Signals", *Proceedings of the 19th IEEE Computer Society Annual Symposium on VLSI (ISVLSI)*, 2020.

Our Secure by Design Approach for Robust Security in Healthcare CPS



Source: V. P. Yanambaka, S. P. Mohanty, E. Kougianos, and D. Puthal, "PMsec: Physical Unclonable Function-Based Robust and Lightweight Authentication in the Internet of Medical Things", *IEEE Transactions on Consumer Electronics (TCE)*, Volume 65, Issue 3, August 2019, pp. 388--397.

Blockchain in Smart Healthcare



Source: C. Esposito, A. De Santis, G. Tortora, H. Chang and K. R. Choo, "Blockchain: A Panacea for Healthcare Cloud-Based Data Security and Privacy?", IEEE Cloud Computing, vol. 5, no. 1, pp. 31-37, Jan./Feb. 2018.

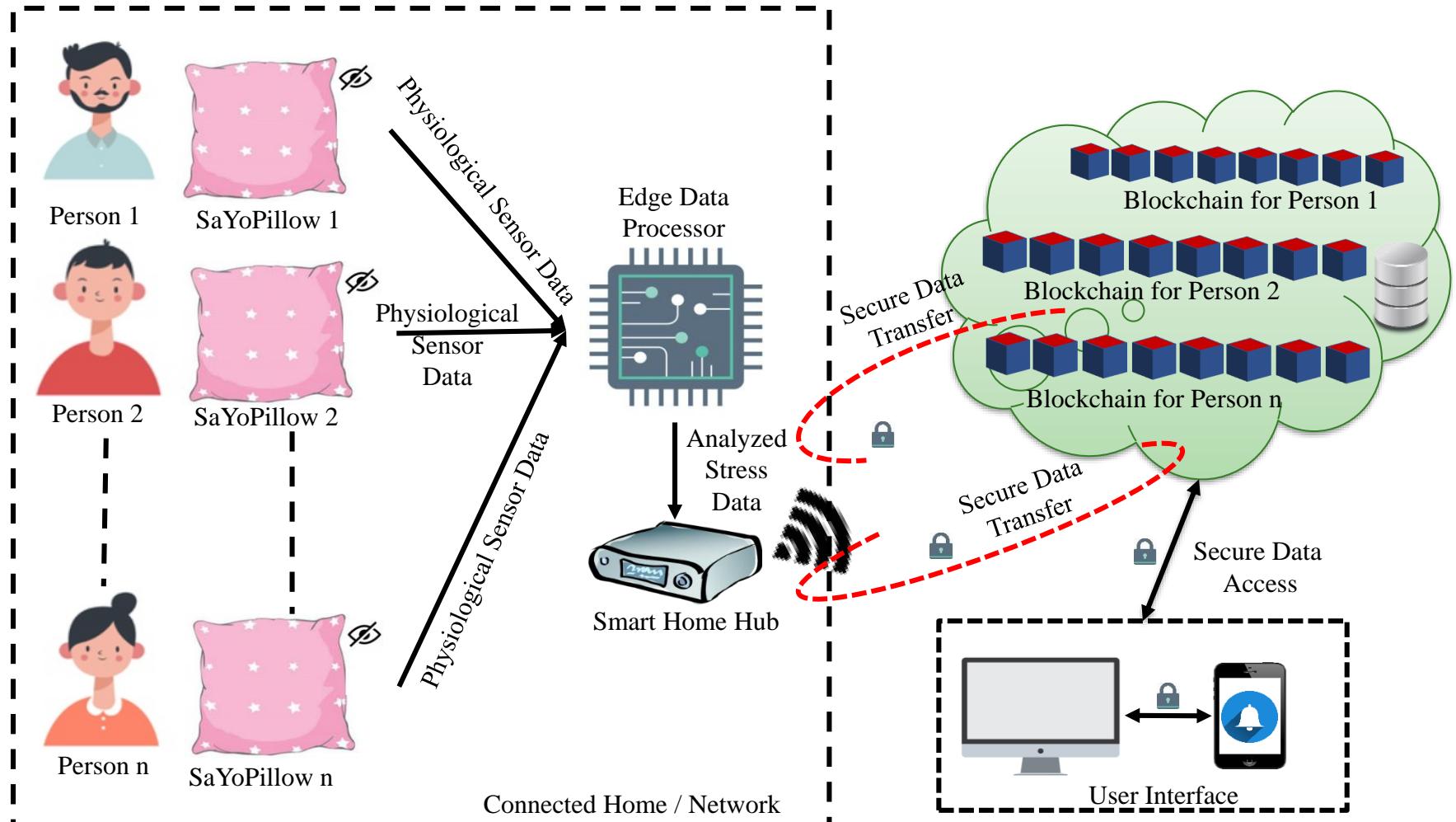
The block is inserted in the chain and linked with the previous blocks.

Traditional Versus Blockchain EHR

Health Information Exchange (HIE) Pain Points		Blockchain Opportunities
	Establishing a Trust Network depends on the HIE as an intermediary to establish point-to-point sharing and “book-keeping” of what data was exchanged.	Disintermediation of Trust likely would not require an HIE operator because all participants would have access to the distributed ledger to maintain a secure exchange without complex brokered trust.
	Cost Per Transaction , given low transaction volumes, reduces the business case for central systems or new edge networks for participating groups.	Reduced Transaction Costs due to disintermediation, as well as near-real time processing, would make the system more efficient.
	Master Patient Index (MPI) challenges arise from the need to synchronize multiple patient identifiers between systems while securing patient privacy.	Distributed framework for patient digital identities , which uses private and public identifiers secured through cryptography, creates a singular, more secure method of protecting patient identity.
	Varying Data Standards reduce interoperability because records are not compatible between systems.	Shared data enables near real-time updates across the network to all parties.
	Limited Access to Population Health Data , as HIE is one of the few sources of integrated records.	Distributed, secure access to patient longitudinal health data across the distributed ledger.
	Inconsistent Rules and Permissions inhibit the right health organization from accessing the right patient data at the right time.	Smart Contracts create a consistent, rule-based method for accessing patient data that can be permissioned to selected health organizations.

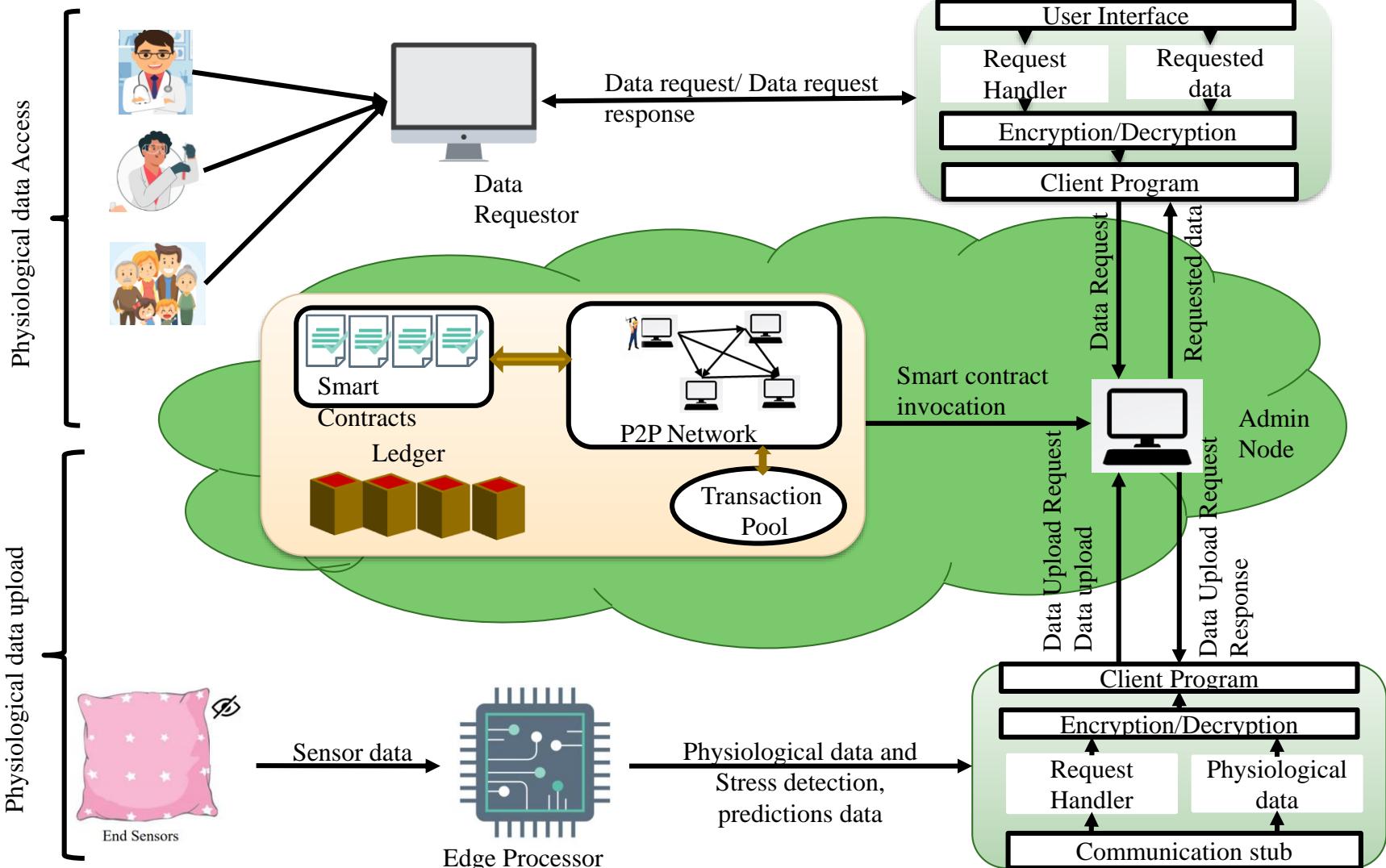
Source: Exploring the Use of Blockchain for EHRs, Healthcare Big Data, <https://healthitanalytics.com/features/exploring-the-use-of-blockchain-for-ehrs-healthcare-big-data>

Smart-Yoga Pillow (SaYoPillow) - Idea



Source: L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "SaYoPillow: A Blockchain-Enabled, Privacy-Assured Framework for Stress Detection, Prediction and Control Considering Sleeping Habits in the IoMT", arXiv Computer Science, arXiv:2007.07377, July 2020, 38-pages.

SaYoPillow: Blockchain Details



Source: L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "SaYoPillow: A Blockchain-Enabled, Privacy-Assured Framework for Stress Detection, Prediction and Control Considering Sleeping Habits in the IoMT", arXiv Computer Science, arXiv:2007.07377, July 2020, 38-pages.

SaYoPillow: Prototyping

Transaction View information about an Ethereum transaction

0x8629d9ee638a181b1454771666bc579ba8189bdb2f78665b739214184587d3b9

0x0adfc4a4b2a1132f82488546aca086d7e24ea324

0x212c30420fce0f7ed1192b6e01de238f295f8505

0 ETH

15297 Confirmations

0 ETH

Summary

Block Hash

0x44214514875cdcb9d8e27ed1290716ce7a1d52bd0c1575771a8ec4298c9aed0b

Received Time

Jul 2, 2020 8:49:19 AM

Included In Block

23663

Gas Used

241,526 m/s

Gas Price

0.0000000010 ETH

Transaction Confirmations

15297

Number of transactions made by the sender prior to this one

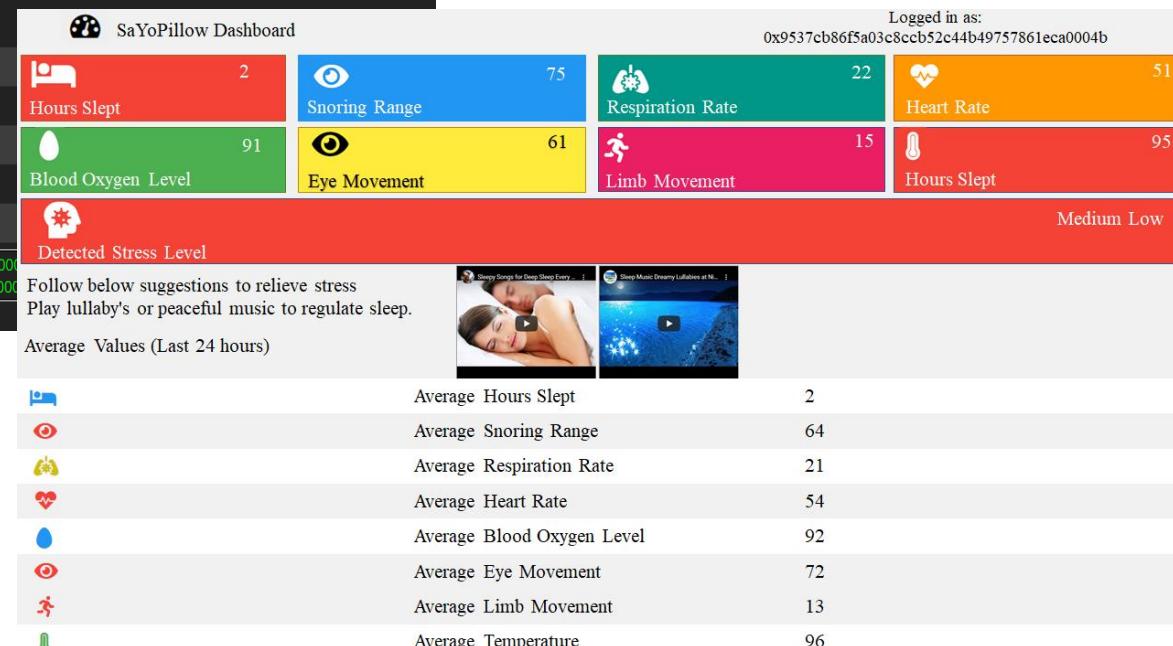
53

Transaction price

0.000241526 ETH

Data

0x8e9cf29c000000000000000000000000
00200000000000000000000000000000



Source: L. Rachakonda, A. K. Bapatla, S. P. Mohanty, and E. Kougianos, "SaYoPillow: A Blockchain-Enabled, Privacy-Assured Framework for Stress Detection, Prediction and Control Considering Sleeping Habits in the IoMT", arXiv Computer Science, arXiv:2007.07377, July 2020, 38-pages.

Conclusions and Future Research



Conclusions

- Healthcare has been evolving to Healthcare-Cyber-Physical-System (H-CPS) i.e. smart healthcare.
- Internet of Medical Things (IoMT) plays a key role in smart healthcare.
- Smart healthcare can reduce cost of healthcare and give more personalized experience to the individual.
- IoMT provides advantages but also has limitations in terms of security, and privacy.
- Smart Healthcare can be effective during stay-at-home scenario during pandemic.

Future Research

- Machine learning (ML) models for smart healthcare needs research.
- Internet-of-Everything (IoE) with Human as active part as crowdsourcing need research.
- IoE will need robust data, device, and H-CPS security need more research.
- Security of IWMDs needs to have extremely minimal energy overhead to be useful and hence needs research.
- Integration of blockchain for smart healthcare need research due to energy and computational overheads associated with it.