Surgical Artificial Intelligence

World Summit AI Americas
Montréal, Canada – April 20, 2023

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MASSACHUSETTS GENERAL HOSPITAL

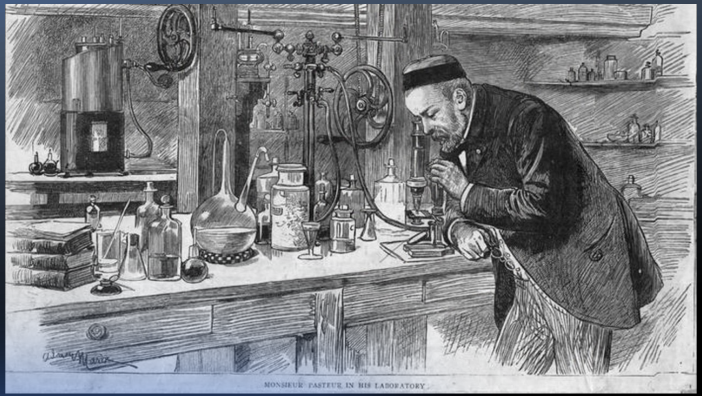
HARVARD MEDICAL SCHOOL

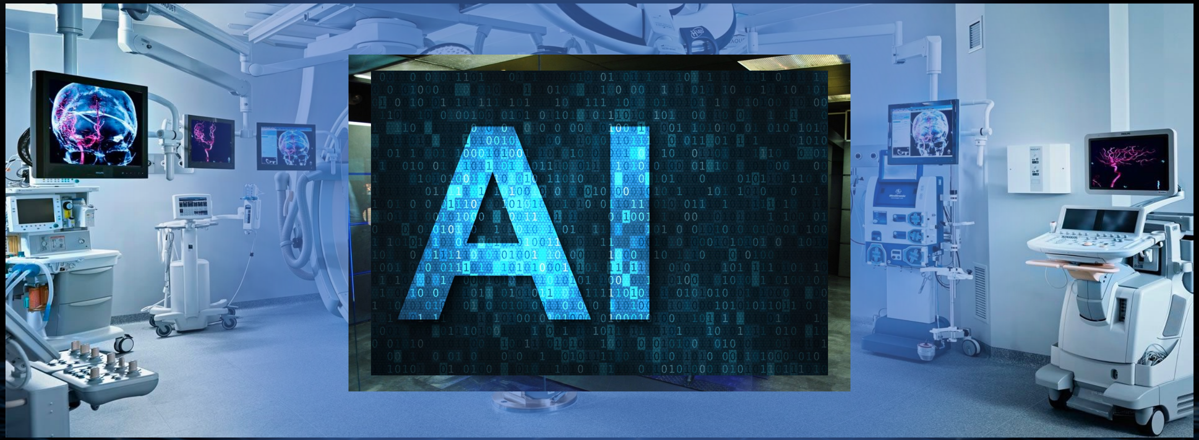
Key points

- Digital Surgical DATA generation
- Strategy for developing a new field
- The role that surgeons play

Surgical Revolutions (in the last 200 years)

- General Anesthesia – 1840s
- Antiseptic Surgery – 1860s
- Endoscopic Procedures – 1960s
- Cognitive Computing – 2010s





AI Definitions

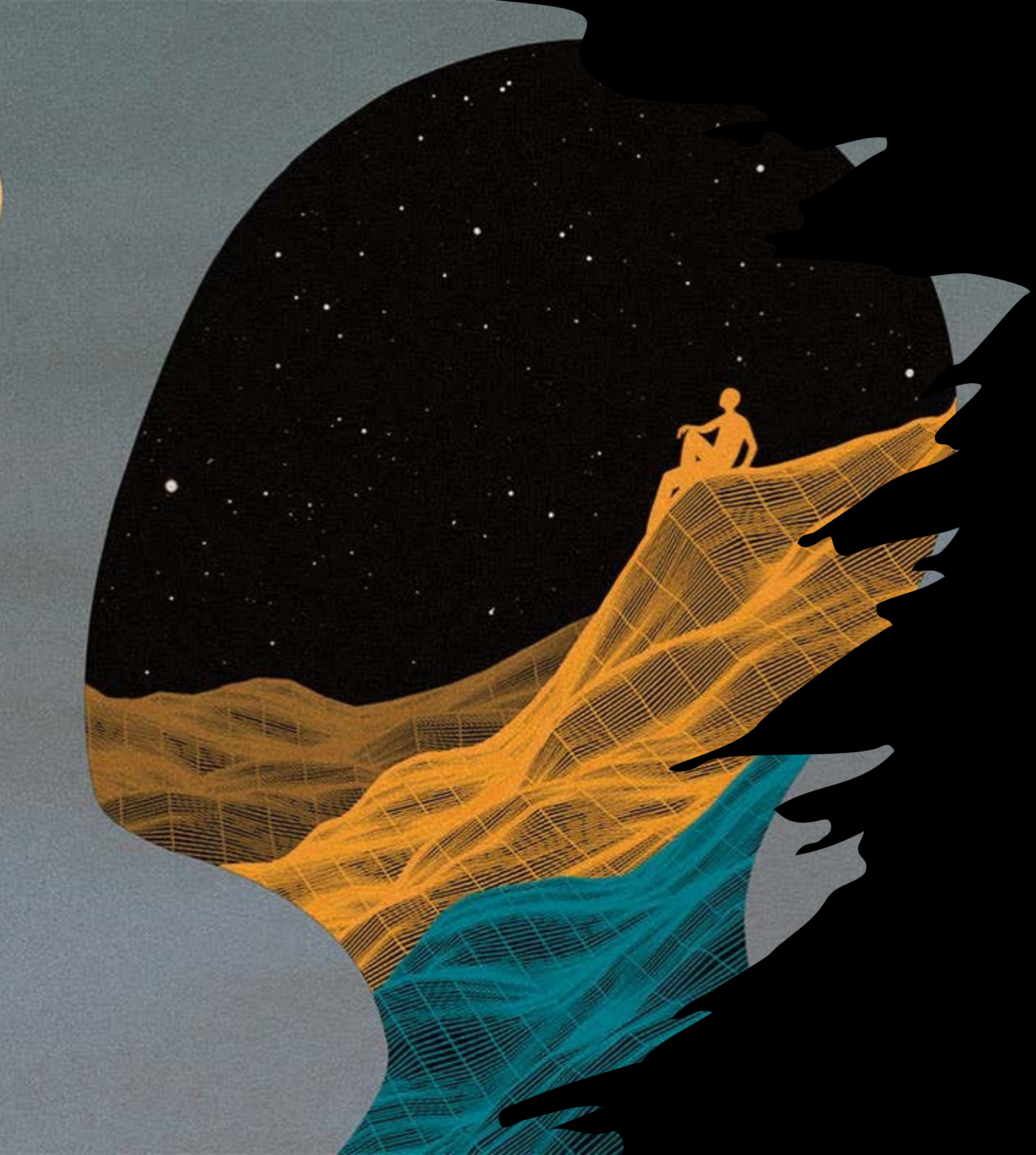
Artificial intelligence: The study of algorithms that give machines the ability to reason and perform cognitive functions - 1956

Machine Learning: Algorithms that improve automatically through data analysis and experience

Computer Vision: Machine understanding of images and videos

Source: KPMG

1. Bellman R. (1978).



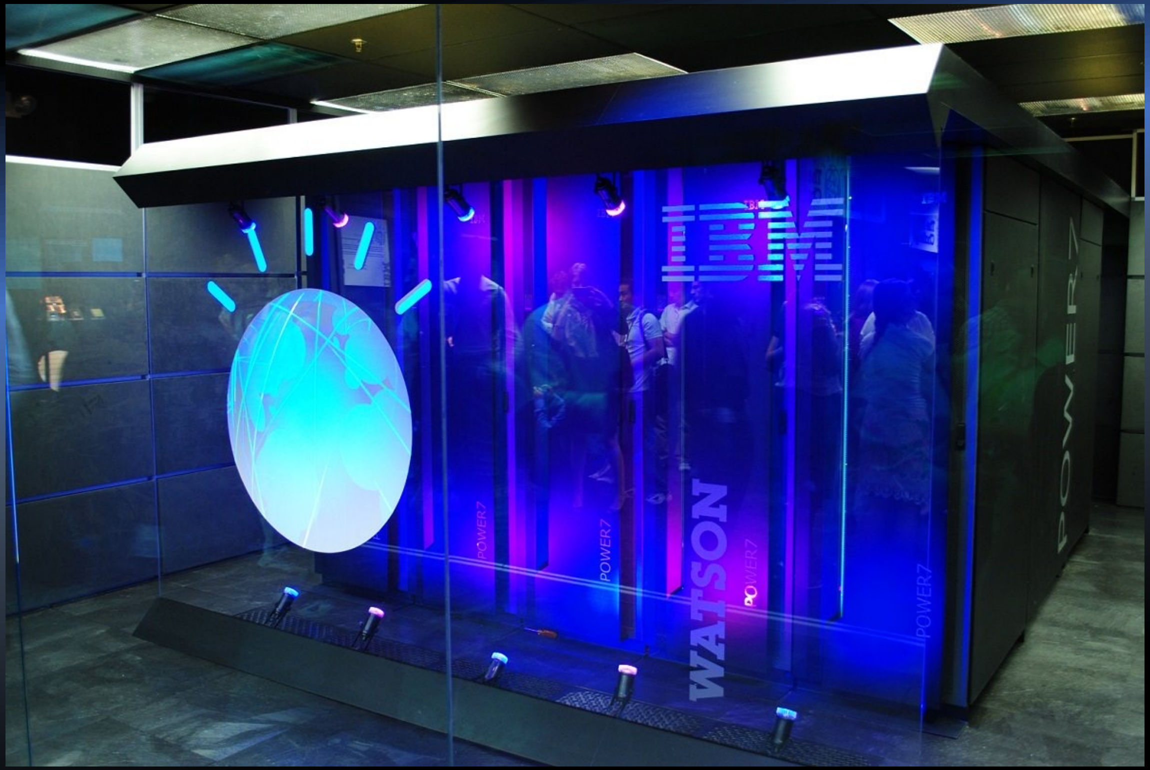
Consciousness: The awareness of internal and external existence.

The state of being aware of and responsive to one's surroundings.

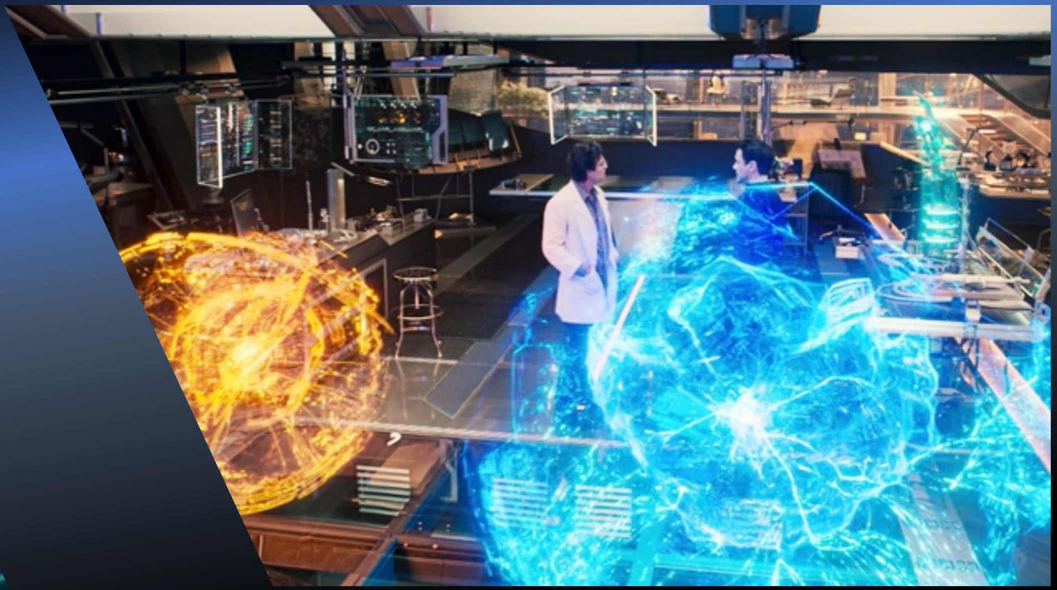
Collective Consciousness: The set of shared beliefs, ideas, and moral attitudes which operate as a unifying force within society. In general, it does not refer to the specifically moral conscience, but to a shared understanding of social norms and concepts.

Collins Dictionary of Sociology, p93.

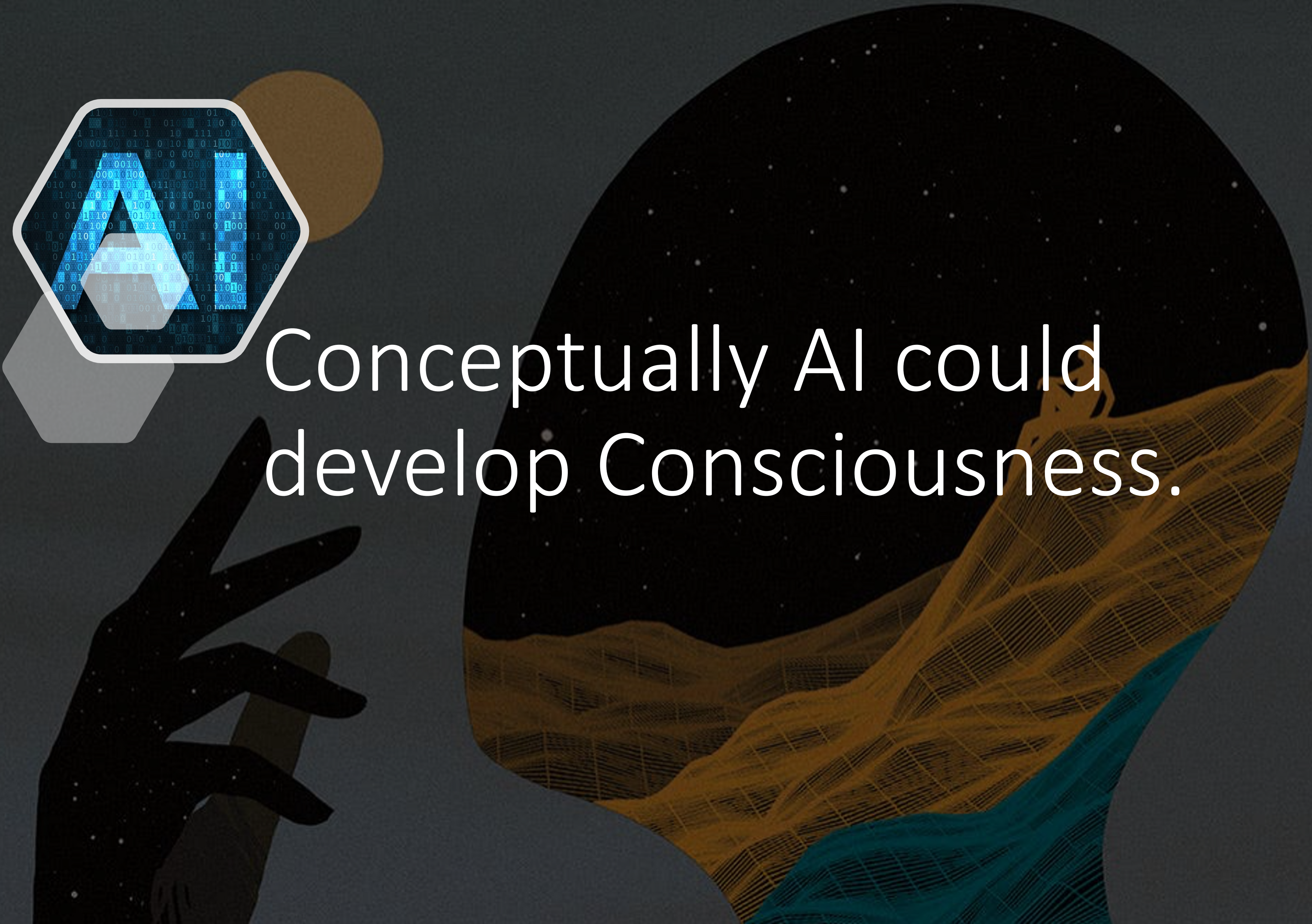
Reality - IBM and Tesla



General and Super AI



Conceptually AI could develop Consciousness.



What is happening in the Operating Room now ?

OR Data Generation

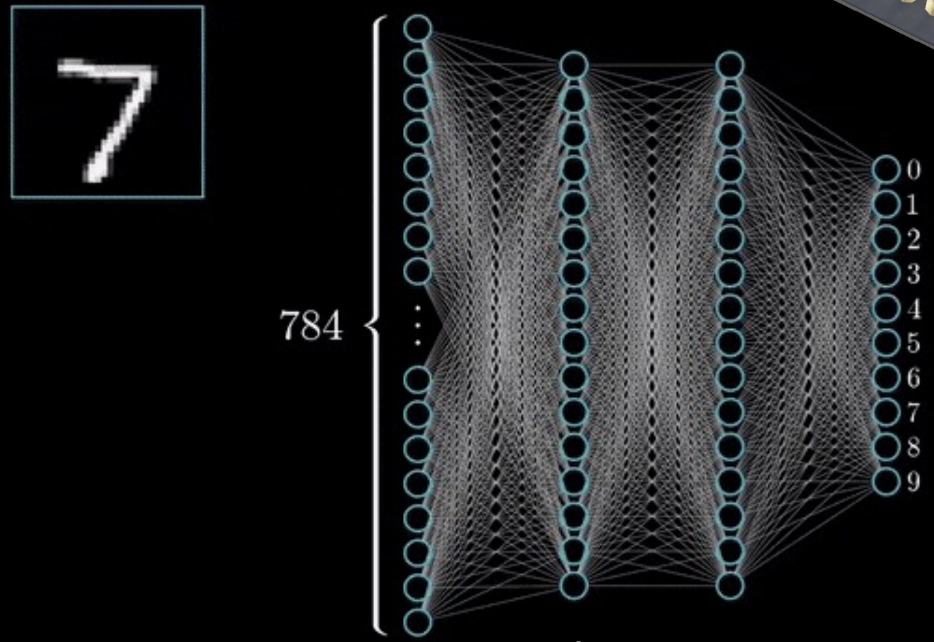
Hardware (instruments, Robotics)	Software (Data, Algorithms)	Human Operators (MD, RN, Biomed, IT,)	Telecom
Human (professional preparedness)	Economics (business plan)	Governance	Data ownership

Data sources and Analytics

- EHR
- Intra-operative data
- Outcome registries
- Scientific Research
- NLP
- ML Big DATA mining
- CV

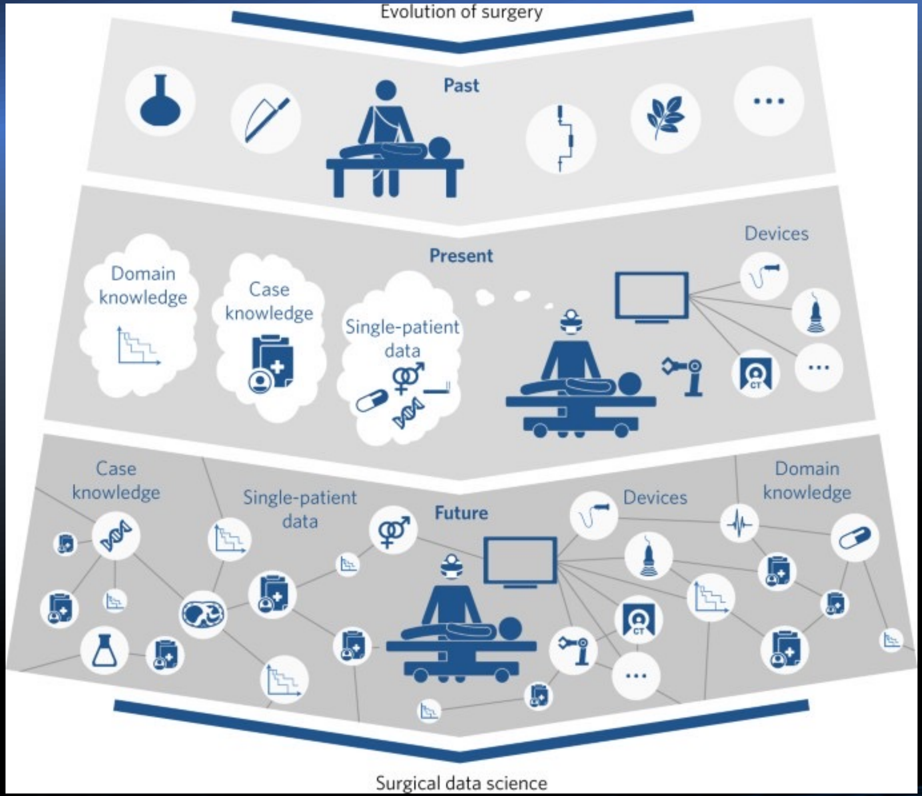
Video DATA

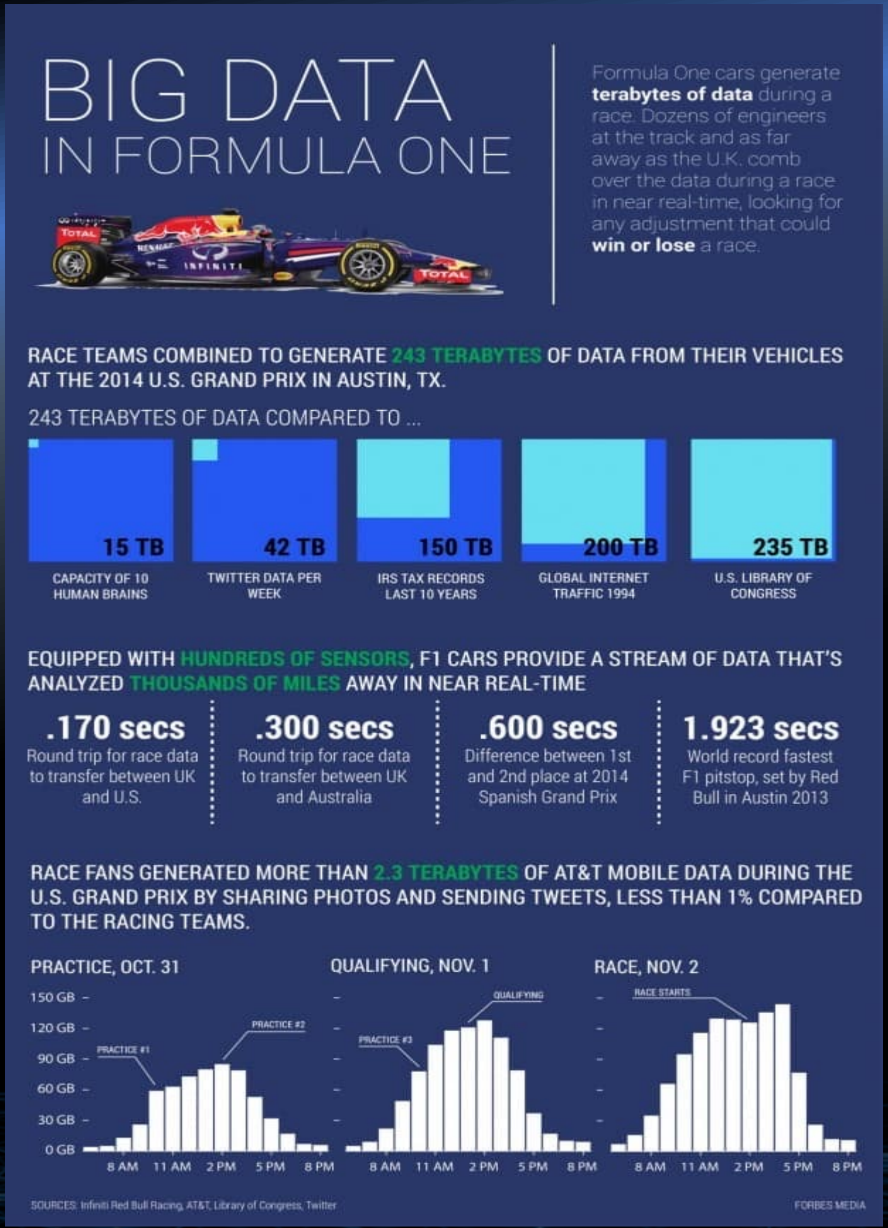
More computing power



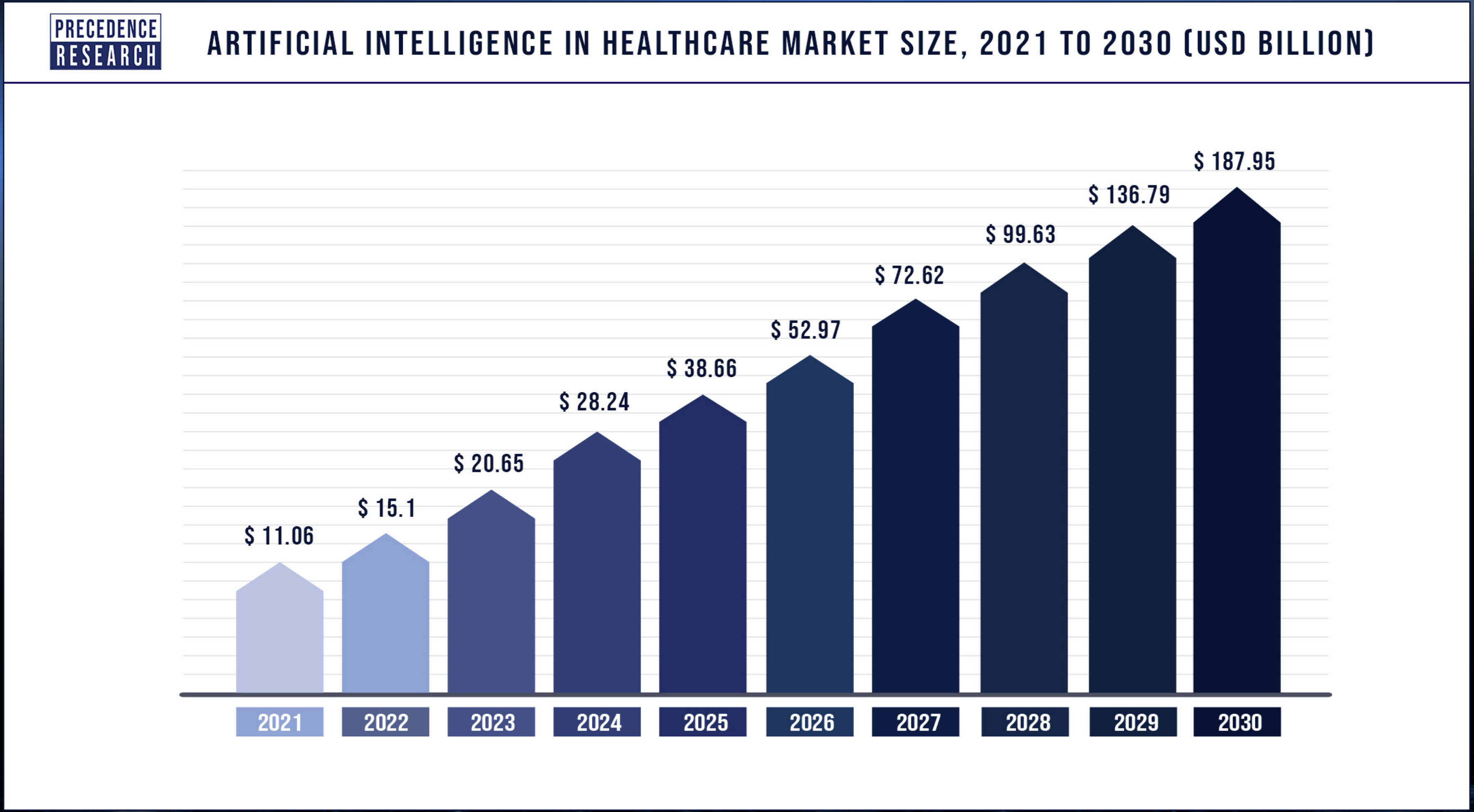
More powerful/efficient techniques

Large amount of DATA





The global market size of artificial intelligence in healthcare was estimated at US$ 11.06 billion in 2021 and is expected to surpass around US$ 187.95 billion by 2030, growing at a CAGR of 37% during the forecast period 2022 to 2030.



Precedence Research - Artificial Intelligence (AI) in Healthcare Market Size 2022-2030

Healthcare in 2065

Deloitte.

Patient centred healthcare: Everything from diagnosis, drugs to devices will be custom designed to seamlessly integrate into a patient's daily life.

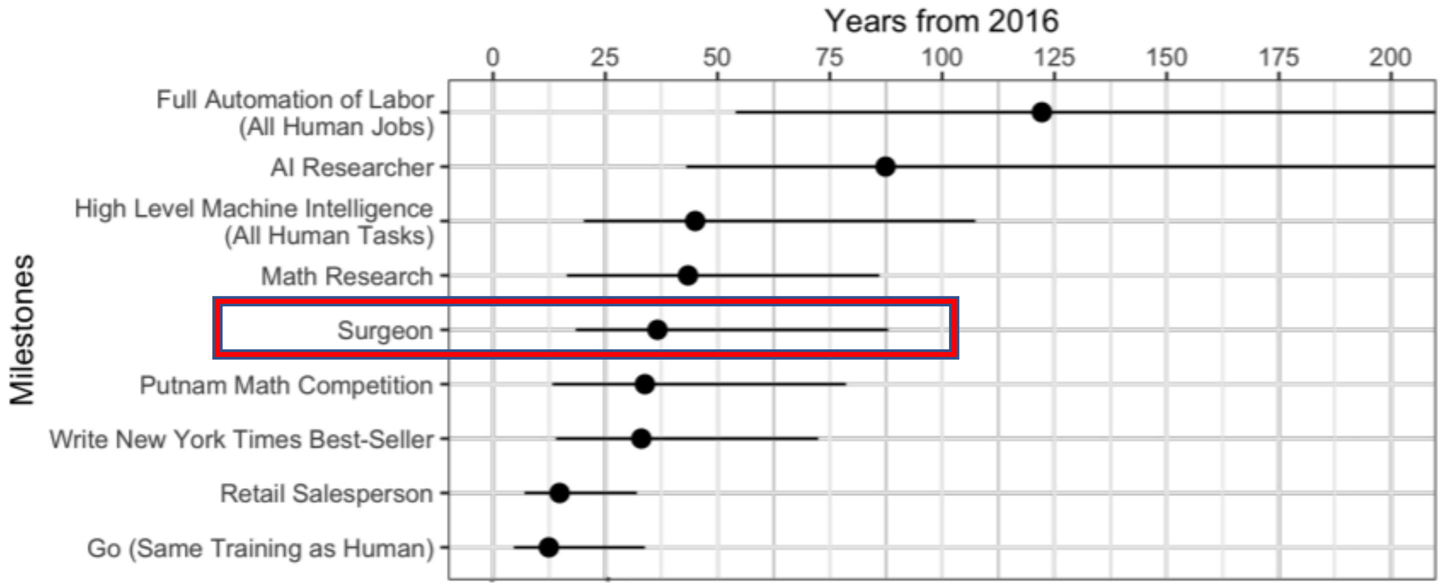
Wearables at the forefront: Always on and constantly collecting data, these peripherals are the basis of the medicalised quantified self.

Digitised and decentralised doctors: Improved connectivity and miniaturised diagnostic technology means accessibility and convenience for future medical consultations.

Rise of the machines: Medical robots and artificial intelligence create more efficient healthcare platforms that are powered by the insights of data analytics.

Evolved healthcare provision: Services will now be consumed continuously lending itself to a subscription based business model that focuses on high productivity and asset light strategies.

Researchers from Oxford University and Yale predict that all industries, including **healthcare**, could become significantly more reliant on machine intelligence by the middle of the century – and that machines may be able to automate all human jobs in less than 120 years



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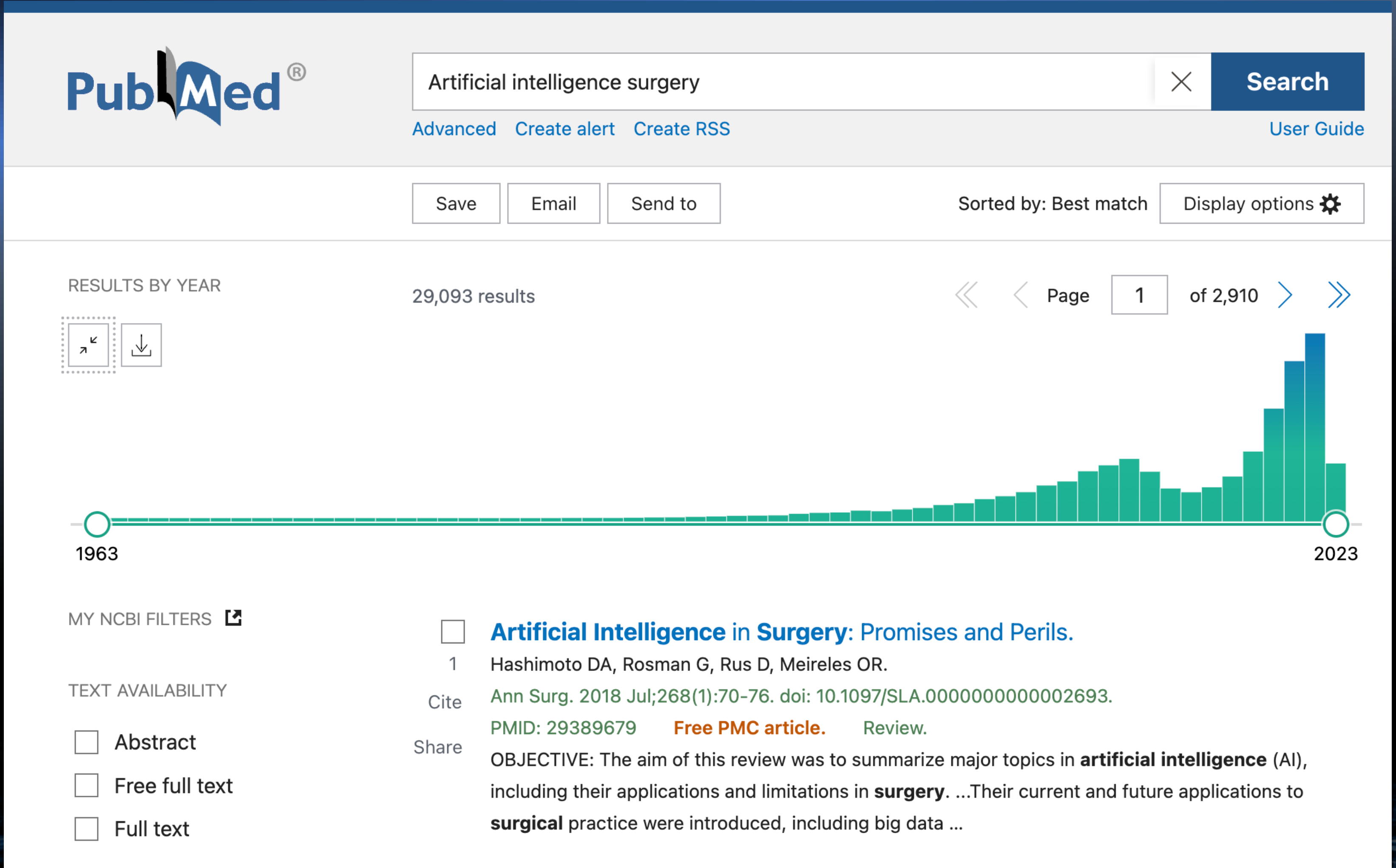
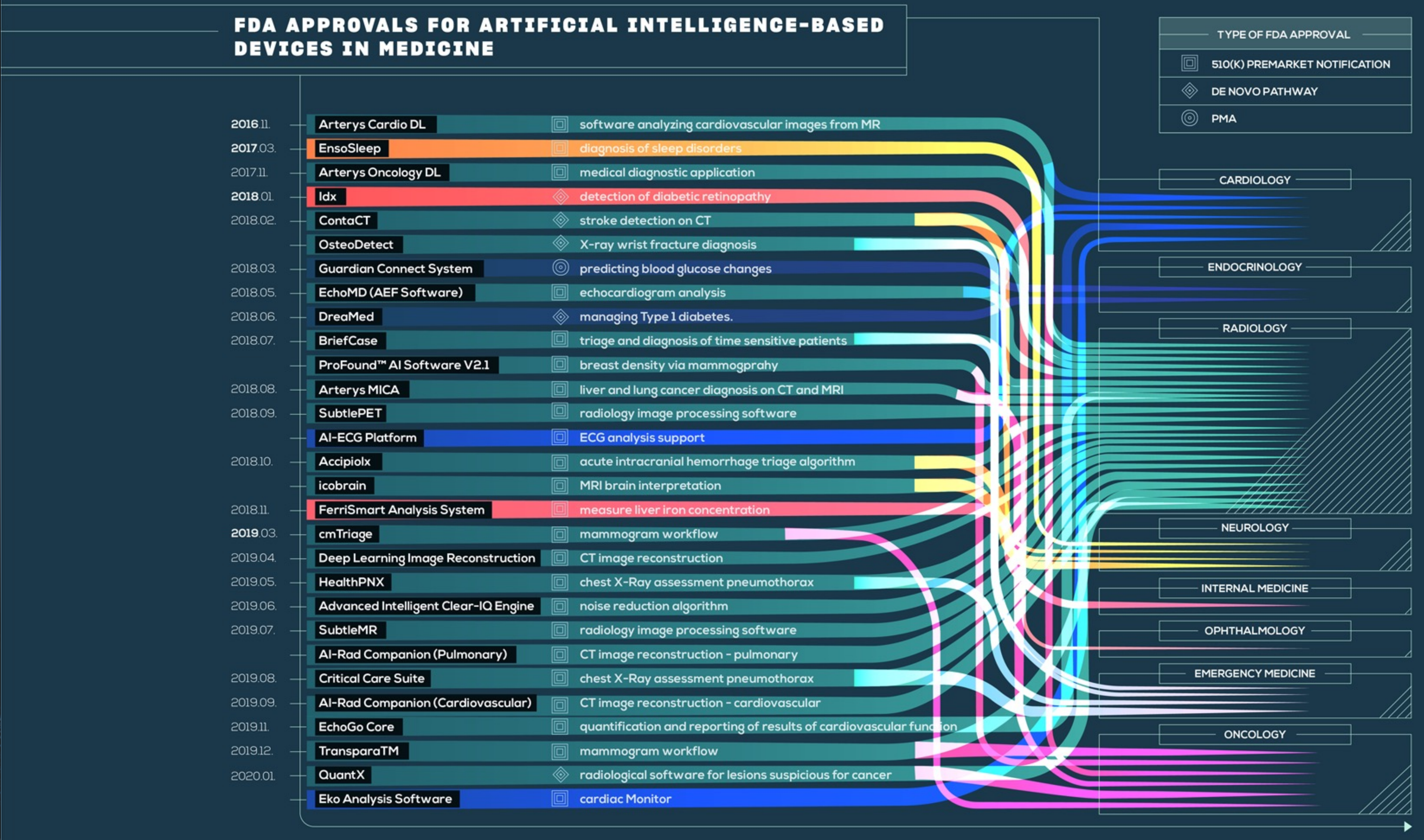
Scientific publications

Search performed on April 12, 2023

PubMed_Timeline_Results_by_Year

Search query: Artificial intelligence surgery	
Year	**Count**
2023	1627
2022	5496
2021	4671
2020	3259
2019	1982
2018	1239
2017	919
2016	770



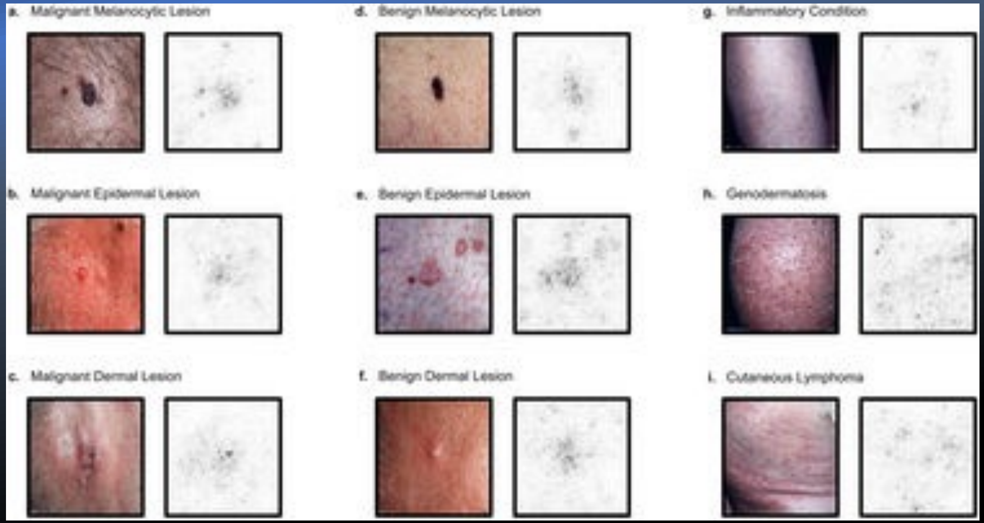

FDA APPROVALS FOR ARTIFICIAL INTELLIGENCE-BASED DEVICES IN MEDICINE
TYPE OF FDA APPROVAL
510(K) PREMARKET NOTIFICATION
DE NOVO PATHWAY
PMA
2016.11. Arterys Cardio DL software analyzing cardiovascular images from MR
2017.03. EnsoSleep diagnosis of sleep disorders
2017.11. Arterys Oncology DL medical diagnostic application
2018.01. Idx detection of diabetic retinopathy
2018.02. ContaCT stroke detection on CT
OsteoDetect X-ray wrist fracture diagnosis
2018.03. Guardian Connect System predicting blood glucose changes
2018.05. EchoMD (AEF Software) echocardiogram analysis
2018.06. DreaMed managing Type 1 diabetes.
2018.07. BriefCase triage and diagnosis of time sensitive patients
ProFound™ AI Software V2.1 breast density via mammogprahy
2018.08. Arterys MICA liver and lung cancer diagnosis on CT and MRI
2018.09. SubtlePET radiology image processing software
AI-ECG Platform ECG analysis support
2018.10. AccipioIx acute intracranial hemorrhage triage algorithm
icobrain MRI brain interpretation
2018.11. FerriSmart Analysis System measure liver iron concentration
2019.03. cmTriage mammogram workflow
2019.04. Deep Learning Image Reconstruction CT image reconstruction
2019.05. HealthPNX chest X-Ray assessment pneumothorax
2019.06. Advanced Intelligent Clear-IQ Engine noise reduction algorithm
2019.07. SubtleMR radiology image processing software
AI-Rad Companion (Pulmonary) CT image reconstruction - pulmonary
2019.08. Critical Care Suite chest X-Ray assessment pneumothorax
2019.09. AI-Rad Companion (Cardiovascular) CT image reconstruction - cardiovascular
2019.11. EchoGo Core quantification and reporting of results of cardiovascular function
2019.12. TransparaTM mammogram workflow
2020.01. QuantX radiological software for lesions suspicious for cancer
Eko Analysis Software cardiac Monitor
CARDIOLOGY
ENDOCRINOLOGY
RADIOLOGY
NEUROLOGY
INTERNAL MEDICINE
OPHTHALMOLOGY
EMERGENCY MEDICINE
ONCOLOGY

AI + Big DATA = Cognitive Augmentation

Information, Guidance, and Intervention


Application
Strg

CNN Clinical Application



129,450 clinical images

2,032 different diseases

Tested performance against 21 board-certified dermatologists on biopsy-proven clinical images.

The CNN achieves performance on par with all tested experts across both tasks, demonstrating an artificial intelligence capable of classifying skin cancer with a level of competence comparable to dermatologists

Esteva A, Kuprel B, Novoa RA, et al. Dermatologist-level classification of skin cancer with deep neural networks. *Nature* 2017; 542(7639):115-118.

Computer Vision and Endoscopy

AI4GI Video and copy rights

Experimental Phase

Research : Intraoperative decision support

- Shrinking data for surgical training
- Technique that reduces video files to one-tenth their initial size enables speedy analysis of laparoscopic procedures.

Surgery & AI | Projects | Work with us | Team | SAIIL-Net | SAIIL-MGH | Sponsorship | Get Involved

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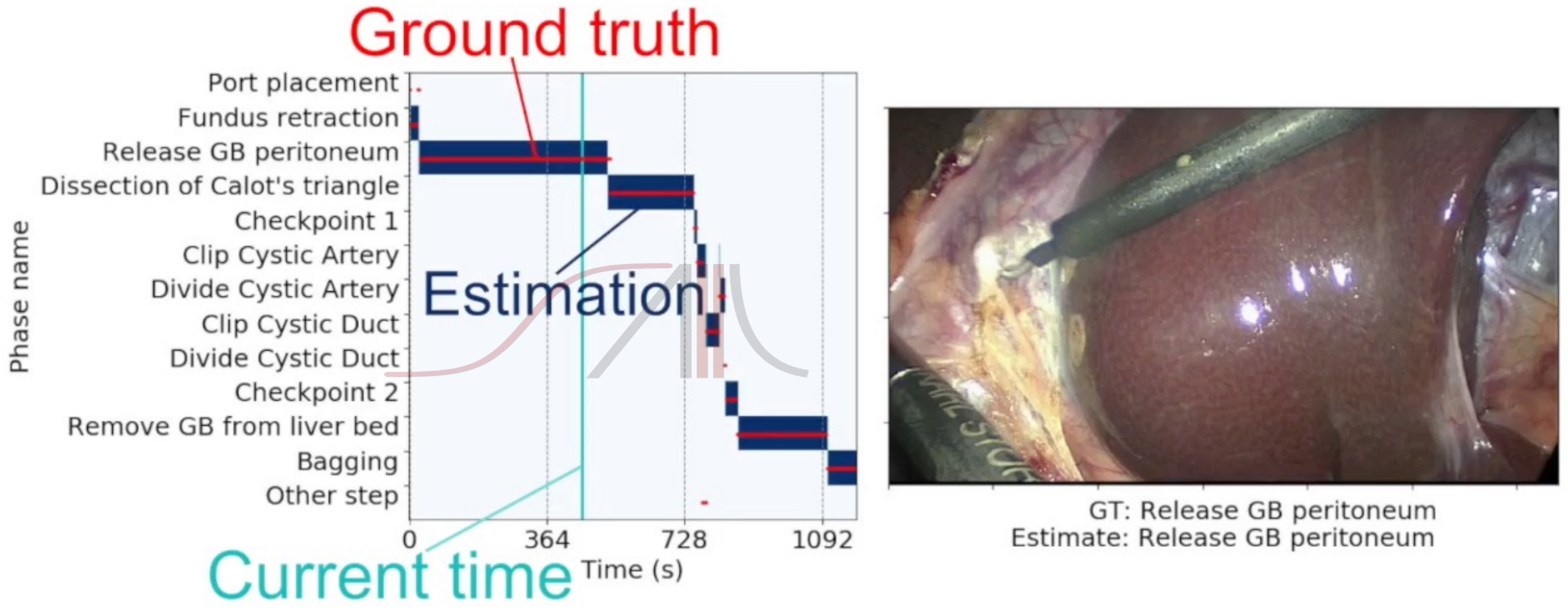
Surgical Artificial Intelligence and Innovation Laboratory

Established in 2017, Boston, USA

Real Time Phase Detection



Surgical Artificial Intelligence & Innovation Laboratory - Massachusetts General Hospital

Experimental Phase

Artificial intelligence prediction of cholecystectomy operative course from automated identification of gallbladder inflammation

Thomas M. Ward[1] · Daniel A. Hashimoto[1] · Yutong Ban[1,2] · Guy Rosman[1,2] · Ozanan R. Meireles[1]

What explains intra-operative variability in cholecystectomy?

Surgeon + Inflammation

Bayesian Multilevel Models

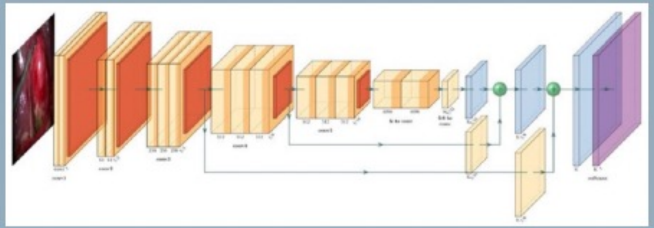
Gallbladder Injury
Increased injury probability by 11%, and up to 28%, per case

Duration
Average 17, and up to 31.3, minutes added

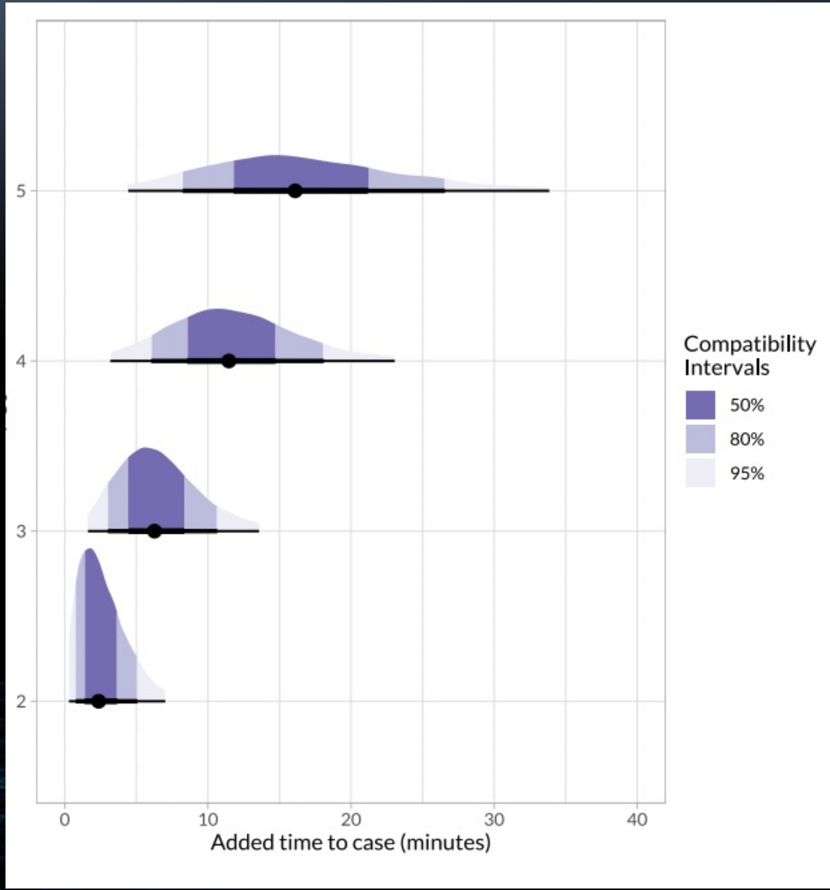
Critical View of Safety
No effect

Can computers reliably classify inflammation?

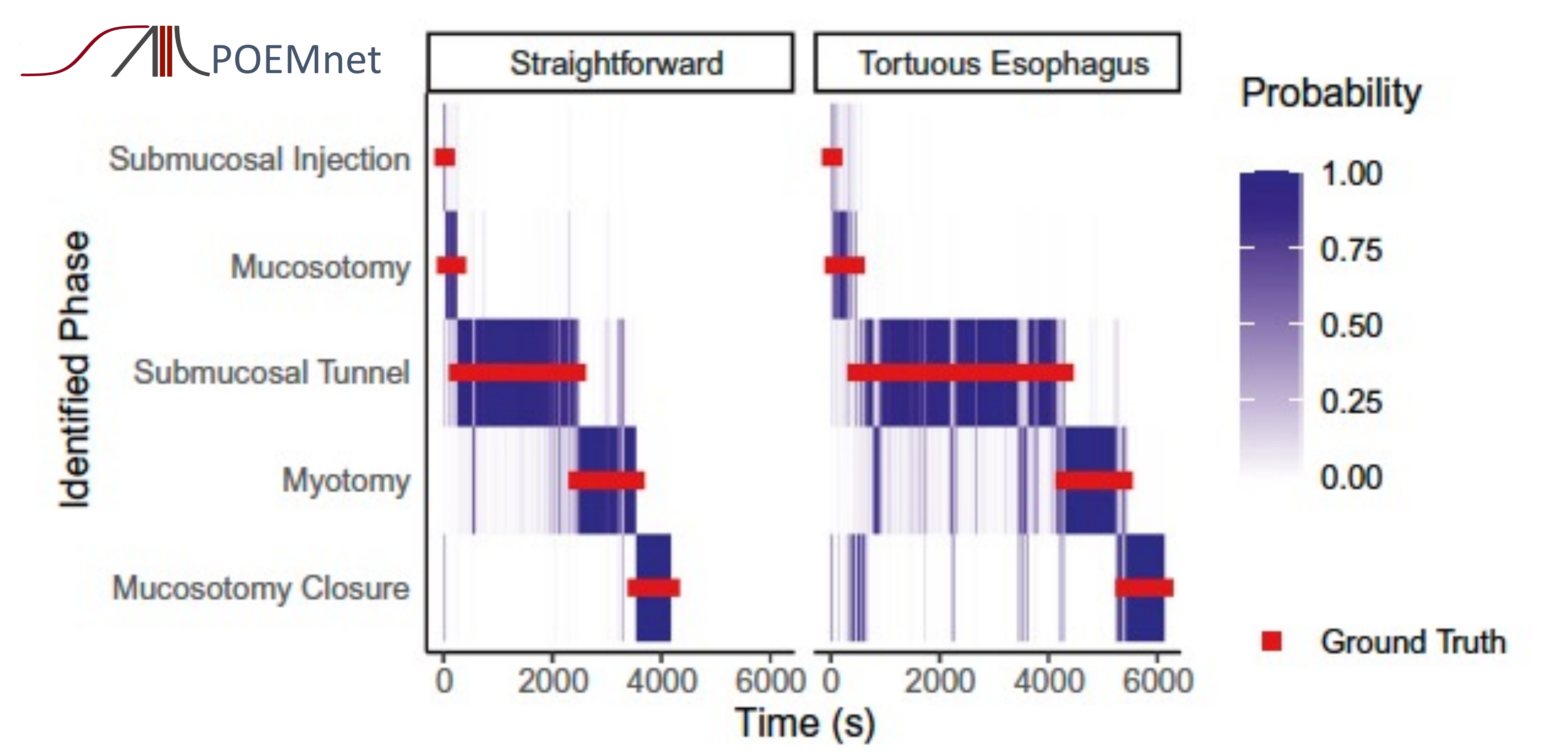
Convolutional Neural Network



	Krippendoff's α	95% CI
AI Model	0.71	0.65-0.77
2nd Surgeon	0.82	0.75-0.87



Surgical Fingerprint – POEM



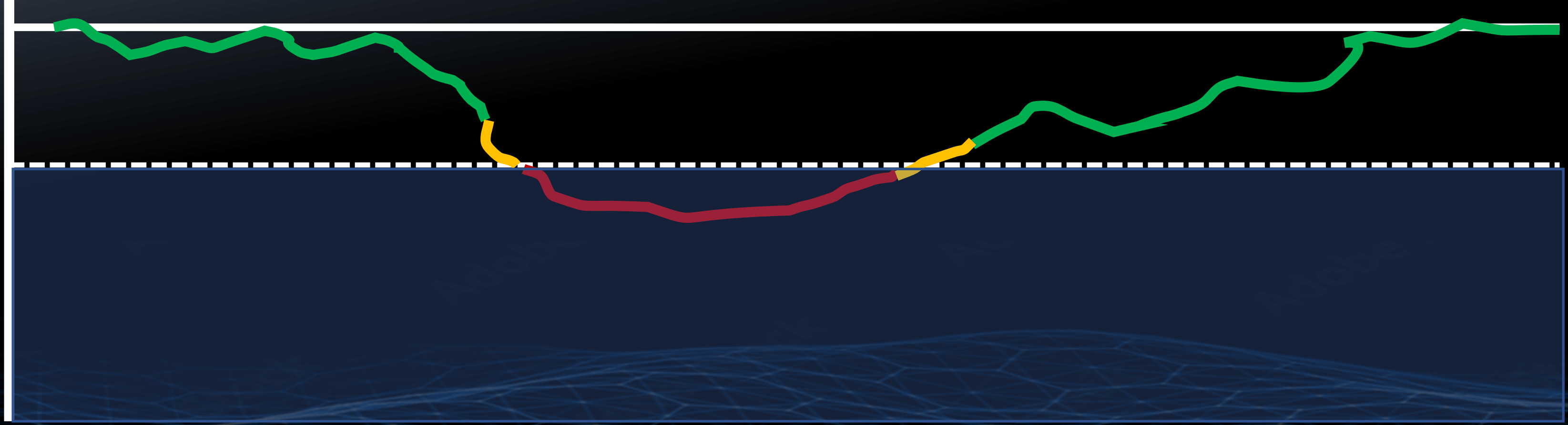
Analysis of intraoperative video

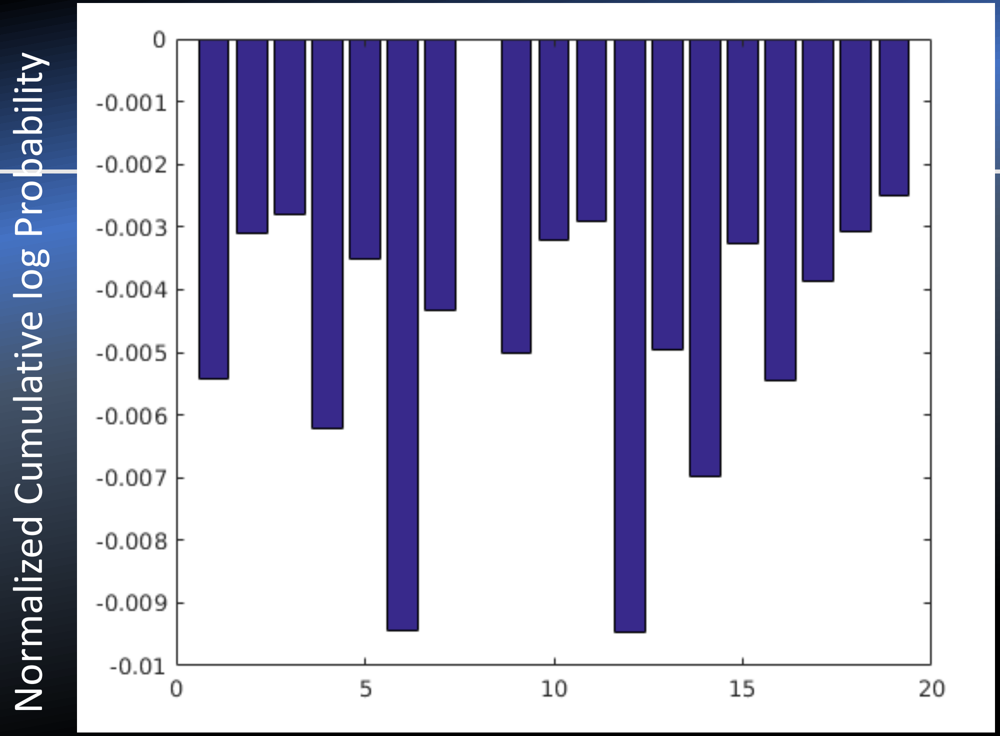
Experimental Phase

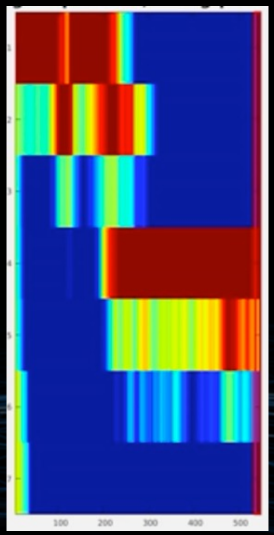
Detecting Deviations

Normal range

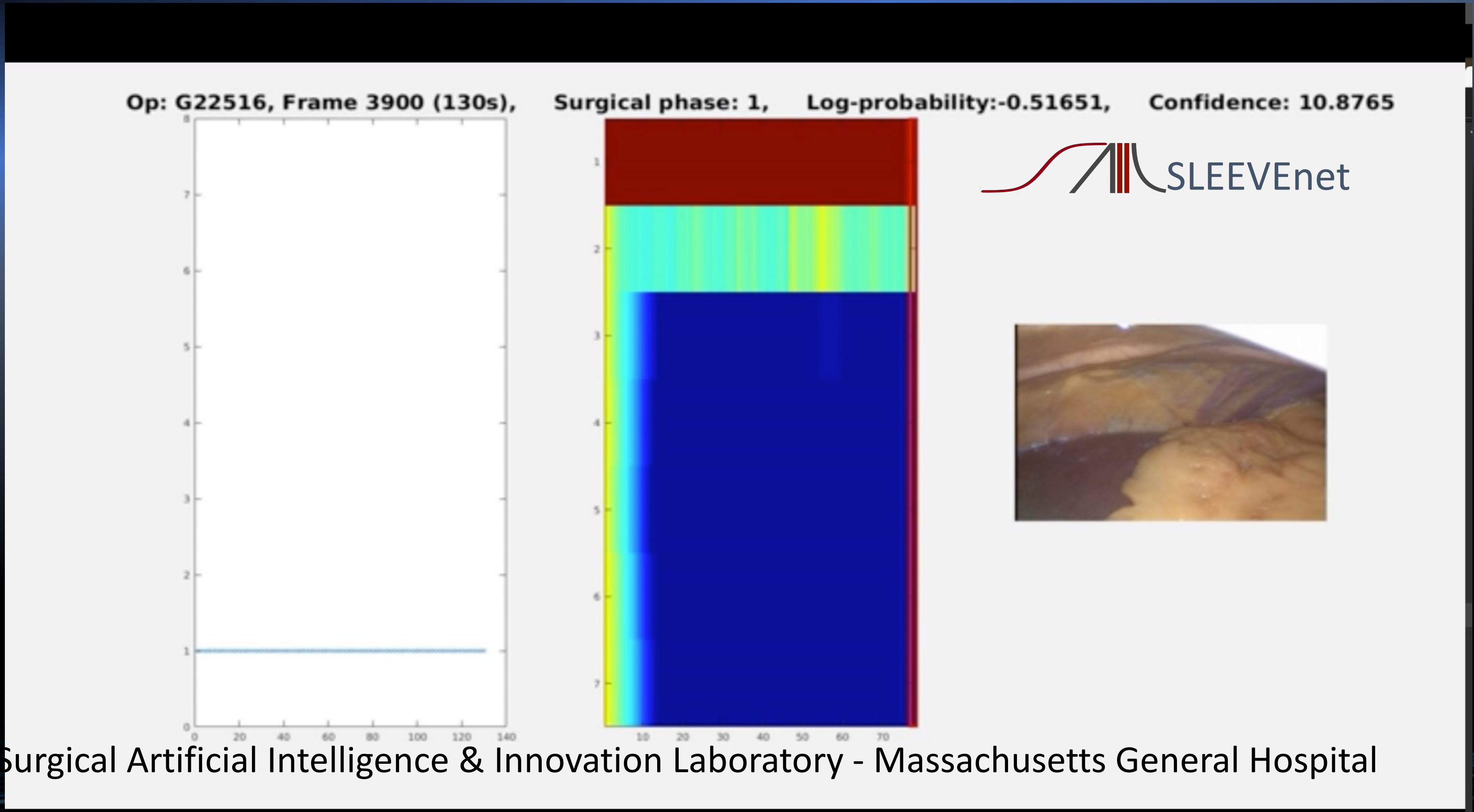
Deviation







Deviation Analysis and Detection

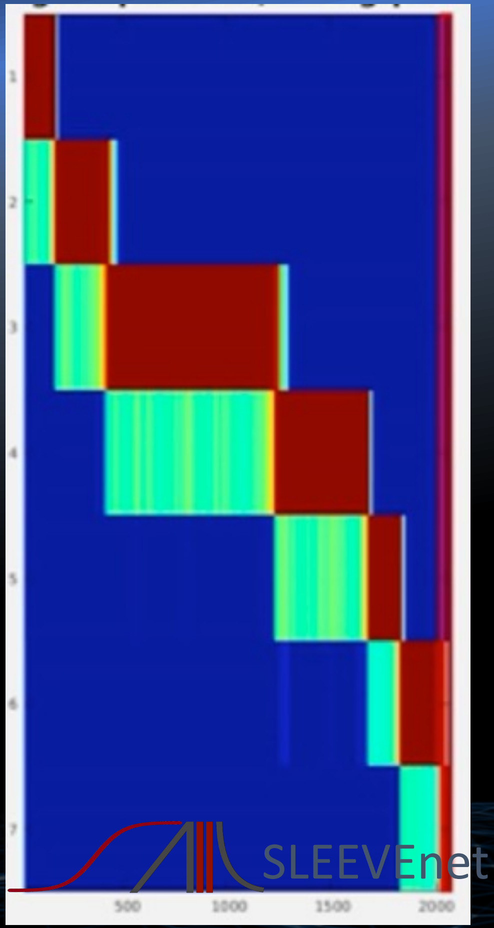


MGH 1811

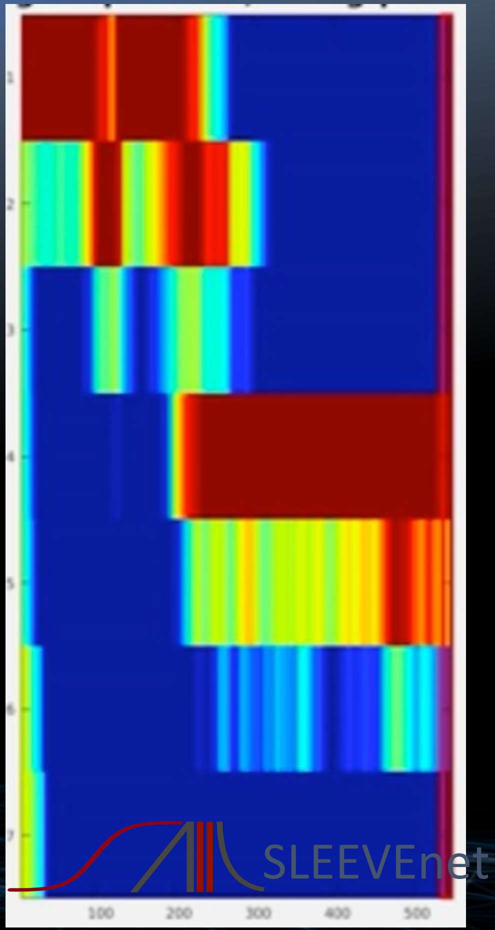
SLEEVEnet

Surgical Fingerprint – Sleeve Gastrectomy

Case A



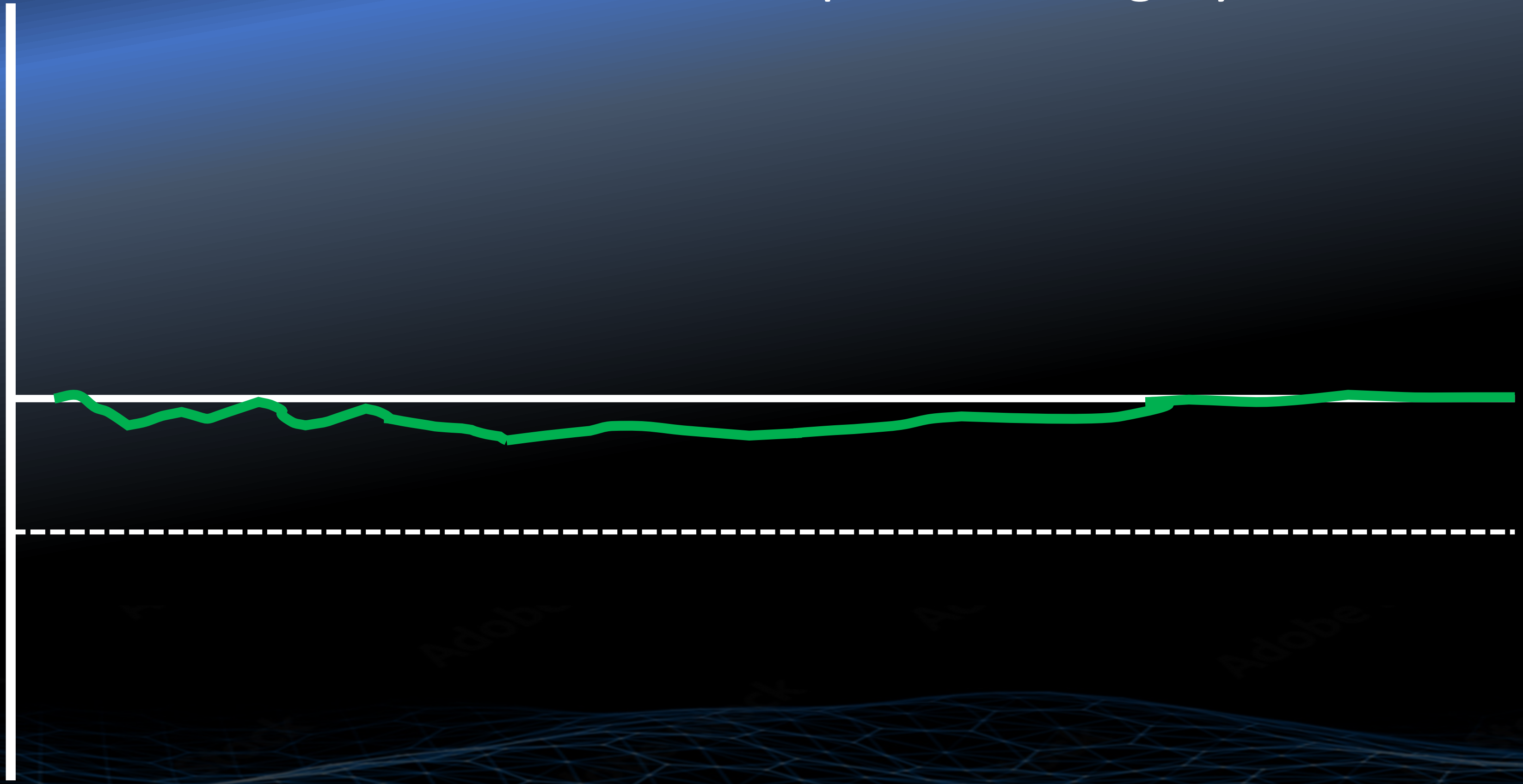
Case B

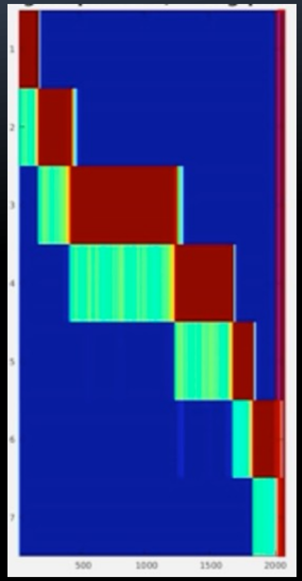


Analysis of intraoperative video

Experimental Phase

Case 1 – Uncomplicated Surgery

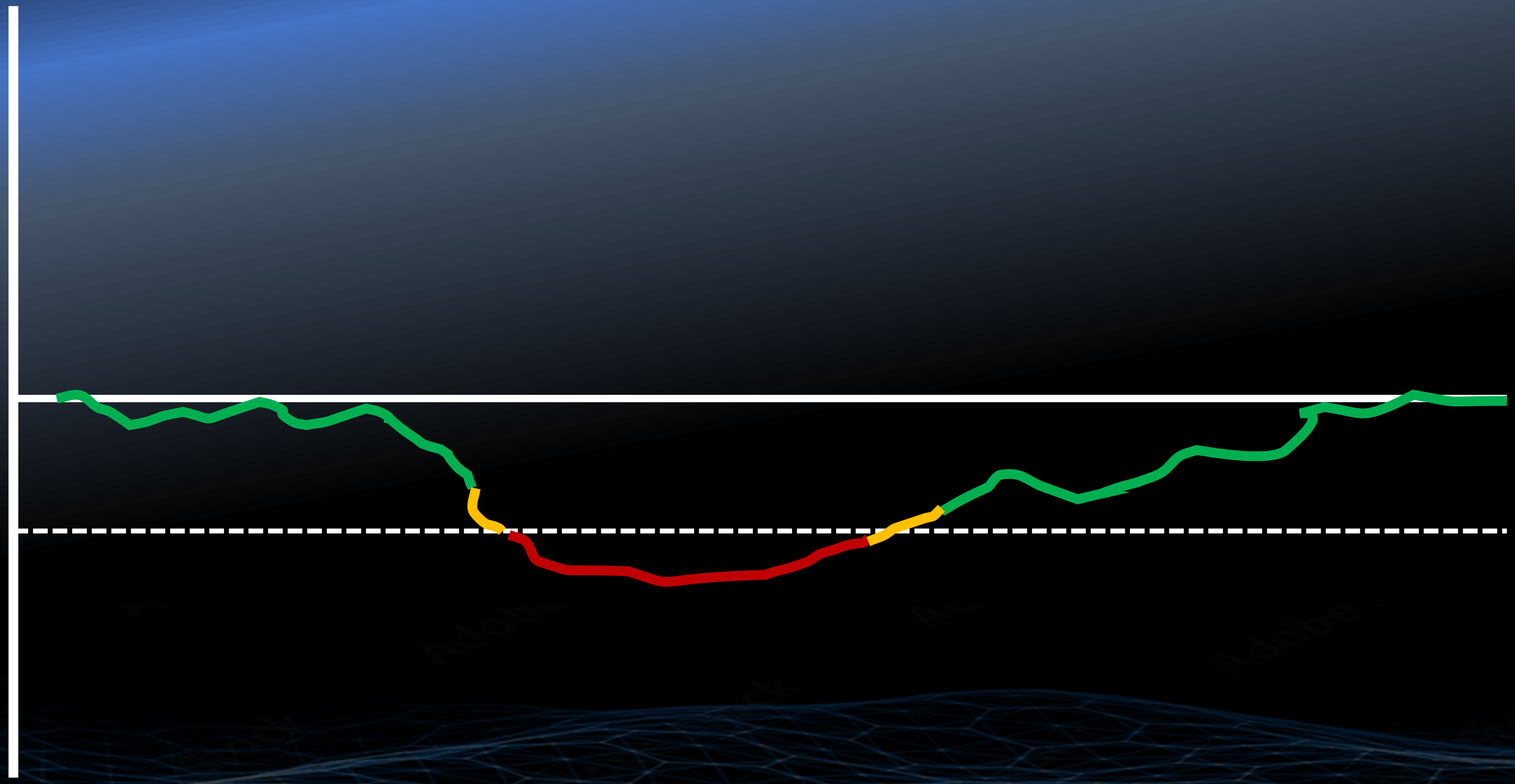


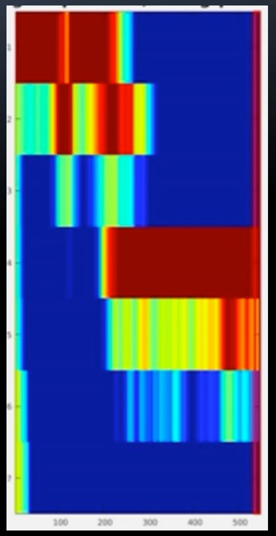


Analysis of intraoperative video

Experimental Phase

Case 2 – Detecting Complication





Potential applications

- **Attending notification system**
  - Notify attendings if the trainees are nearing critical portions of the operation.
- **Peer Review**
  - Augmented Morbidity and Mortality meetings
  - Board certification
  - Hospital credentialing and recredentialing
- **Tele-mentoring**
  - Establish automated communication link to human mentor when error is predicted or identified.
  - Battlefield and Rural Areas support, to medical staff who may not have the necessary specialty specific knowledge

Automation

AI and Mechanical Automation

Experimental Phase

Berkeley UNIVERSITY OF CALIFORNIA

Ken Goldberg
Professor, Industrial Engineering and Operations Research
William S. Floyd Jr. Distinguished Chair in Engineering, UC Berkeley

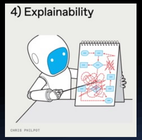
A.I.

Moravec's Paradox

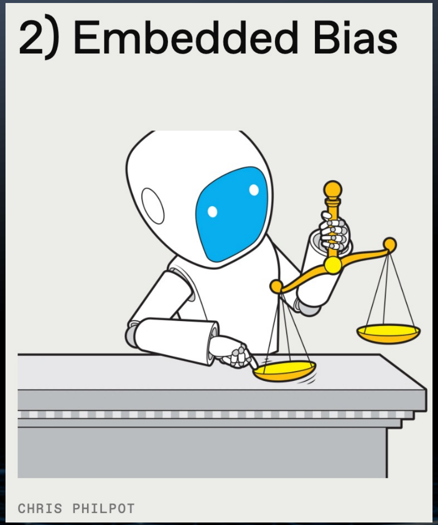
- *"Robots find the difficult things easy and the easy things difficult"*
- "Contrary to traditional assumptions, high-level reasoning requires relatively little computation power, whereas low-level sensorimotor skills require enormous computational resources"

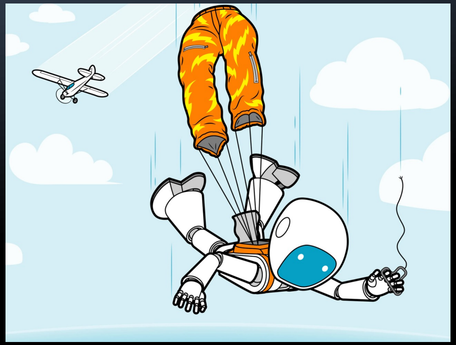
Potential Failures

7 REVEALING WAYS AI FAIL



IEEE Spectrum





- Brittleness
- Embedded Bias
- Catastrophic Forgetting
- Explainability
- Quantifying Uncertainty
- Common Sense
- Math

- https://spectrum.ieee.org/ai-failures

Real life examples of AI Failures

HANDS ON THE WHEEL —

Another Tesla with Autopilot crashed into a stationary object—the driver is suing

Fail: Microsoft's AI Chatbot Corrupted by Twitter Trolls

Google Home outage hits users, '100 percent failure rate' reported

Apple's Face ID Defeated by a 3D Mask

IBM's Watson supercomputer recommended 'unsafe and incorrect' cancer treatments, internal documents show

Obstacles and Limitations

Data
- Limited access
- Limited annotation
- Regulation
- Systemic biases

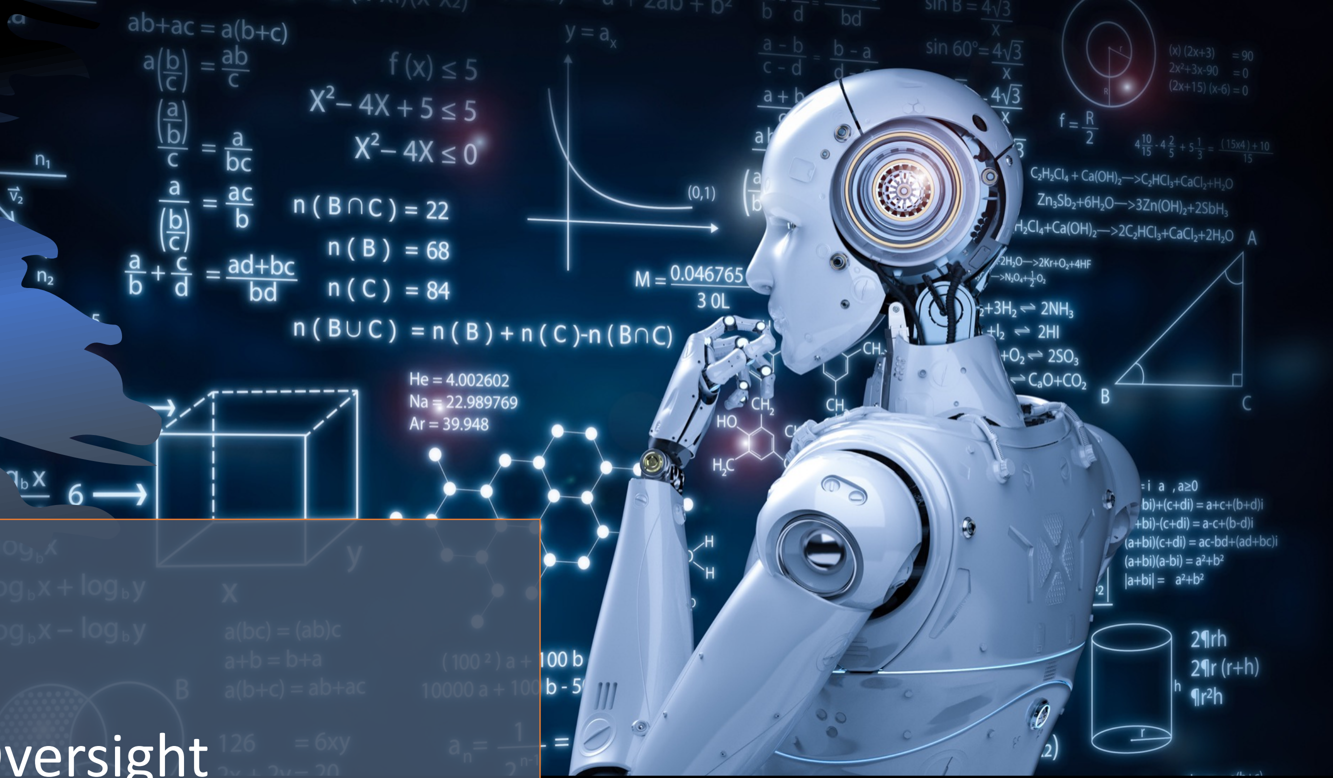
Clinician
- Limited time
- Productivity pressure
- Culture

Researcher
- Limited exposure
- Innovation pressure

Industry
- Market pressure
- Culture

Patient
- Privacy
- Healthcare pressure
- Clinician relationship

Solution



Foundational work

- Annotation ✅
- Data Structure and Use ✅
- Governance Policies, Regulations, and Oversight

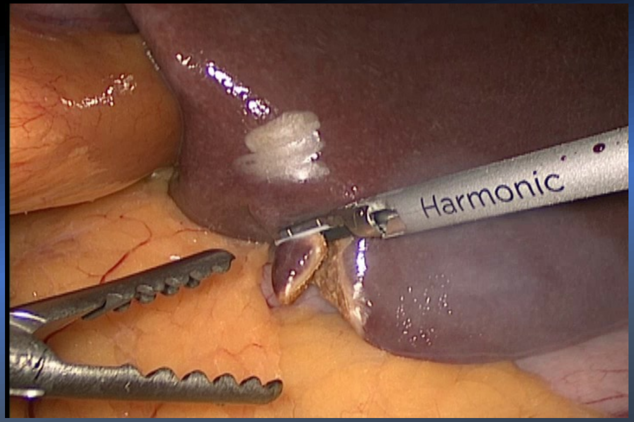
Structural needs

- Video Data Acquisition Framework ✅
- Management through data lifecycle

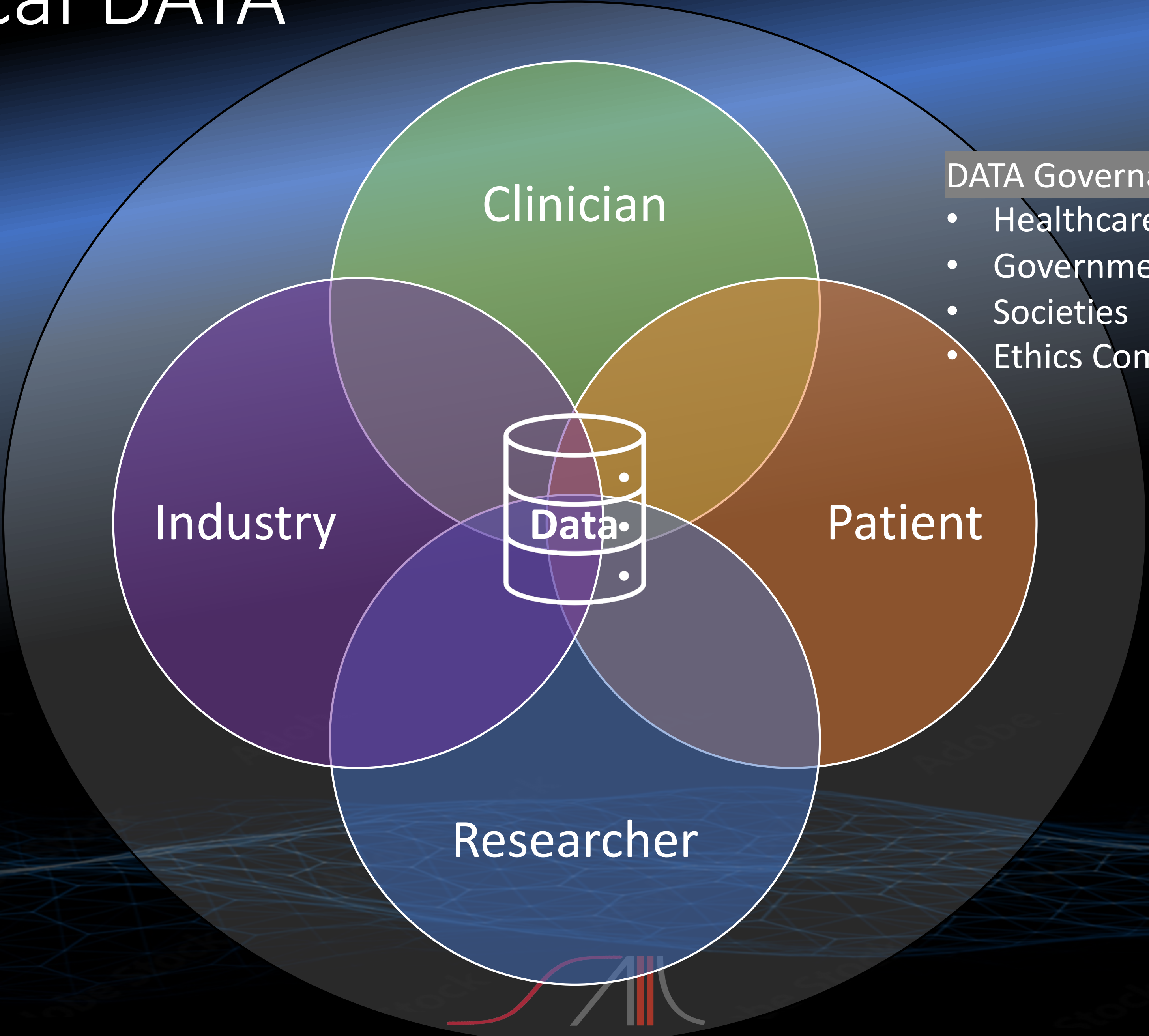
Knowledge creation and dissemination

- Scientific Research ✅
- Education ✅
- Cultural Transformation

DATA collection



Surgical DATA



DATA Governance, Policies and Oversight

- Healthcare Systems
- Governments
- Societies
- Ethics Committees

Consensus Recommendations on an Annotation Framework for Surgical Video

Surgical Endoscopy (2021) 35:4918–4929
https://doi.org/10.1007/s00464-021-08578-9

CONSENSUS STATEMENT

SAGES consensus recommendations on an annotation framework for surgical video

Ozanan R. Meireles[1] · Guy Rosman[1,2] · Maria S. Altieri[3] · Lawrence Carin[4] · Gregory Hager[5] · Amin Madani[6] · Nicolas Padoy[7,8] · Carla M. Pugh[9] · Patricia Sylla[10] · Thomas M. Ward[1] · Daniel A. Hashimoto[1] · the SAGES Video Annotation for AI Working Groups

Received: 25 April 2021 / Accepted: 26 May 2021 / Published online: 6 July 2021

Abstract

Background The growing interest in analysis of surgical video through machine learning has led to increased research efforts; however, common methods of annotating video data are lacking. There is a need to establish recommendations on the annotation of surgical video data to enable assessment of algorithms and multi-institutional collaboration.

Methods Four working groups were formed from a pool of participants that included clinicians, engineers, and data scientists. The working groups were focused on four themes: (1) temporal models, (2) actions and tasks, (3) tissue characteristics and general anatomy, and (4) software and data structure. A modified Delphi process was utilized to create a consensus survey based on suggested recommendations from each of the working groups.

Results After three Delphi rounds, consensus was reached on recommendations for annotation within each of these domains. A hierarchy for annotation of temporal events in surgery was established.

Conclusions While additional work remains to achieve accepted standards for video annotation in surgery, the consensus recommendations on a general framework for annotation presented here lay the foundation for standardization. This type of framework is critical to enabling diverse datasets, performance benchmarks, and collaboration.

Annotation Framework
Hierarchical Structure with Expandable Granularity

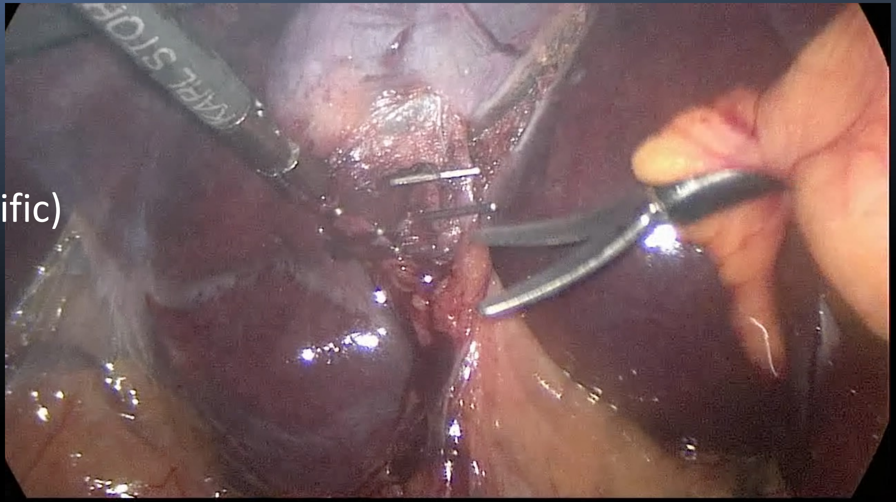
Temporal Events

Phase (generic)

Step (procedure- specific)

Task (generic)

Action (generic)



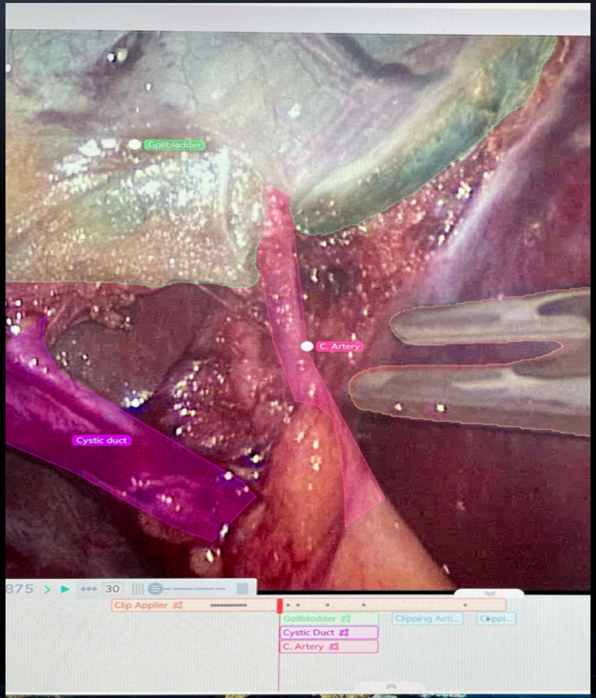
Spatial Events

Anatomic region

Specific anatomy

General anatomy

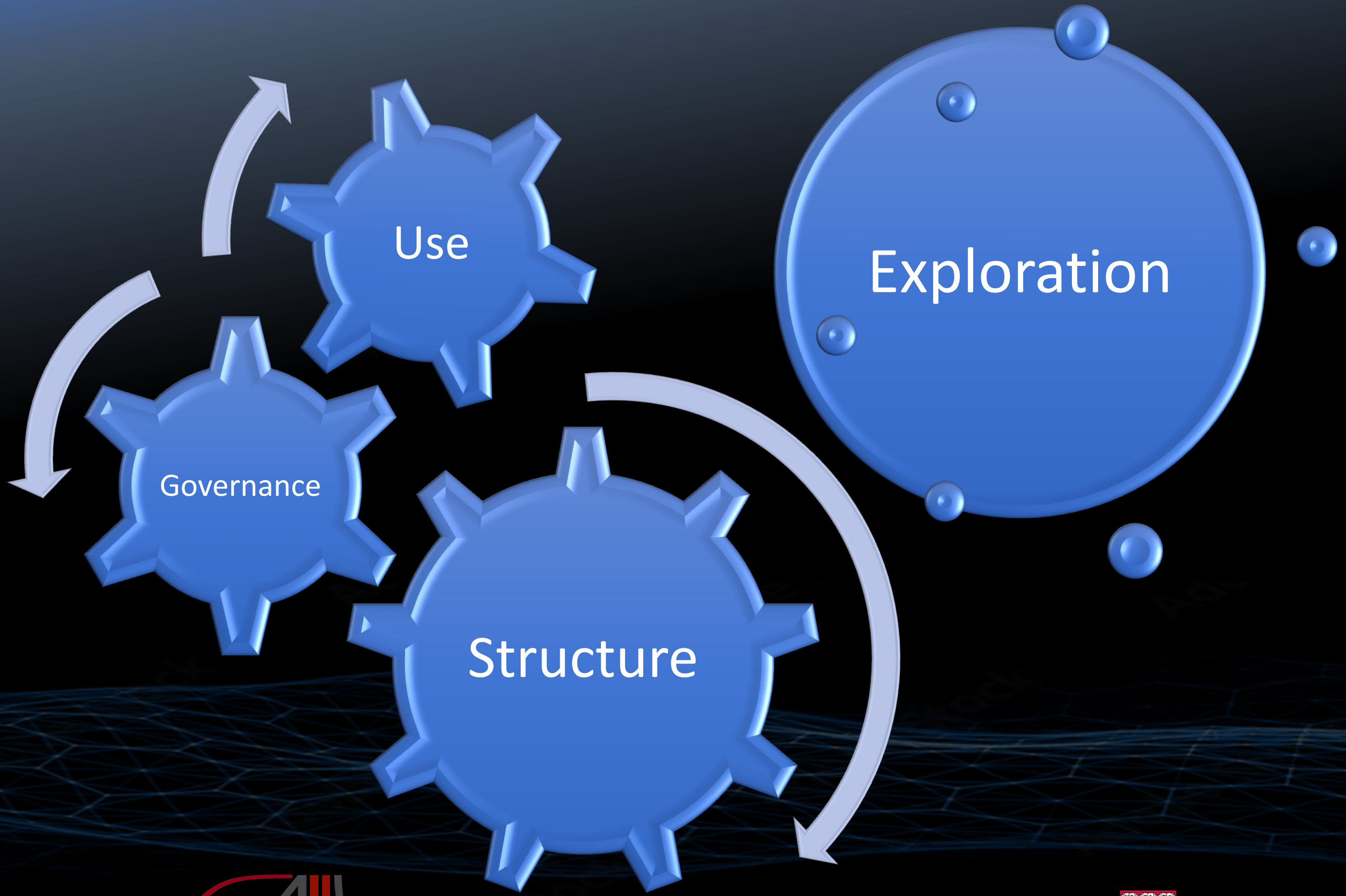
Tissue characteristics



DATA Use and Structure

Objective: Establish a framework for video data use in surgery to improve collaboration and proposed methods to structure the use of surgical video for clinical use, education, and research applications.

SAGES Surgical Video Data Summit 2021



Surgical Operating System Framework

- Open Access Model to Promote Collaboration
- Standardization
  - Annotation
  - Data Structure
- Clear Policies and Regulations
- Transparency and Oversight
- Address Ownership Issues

Scientific efforts

Clinical Trials

Computer Vison Challenges

Multi-institutional collaborations

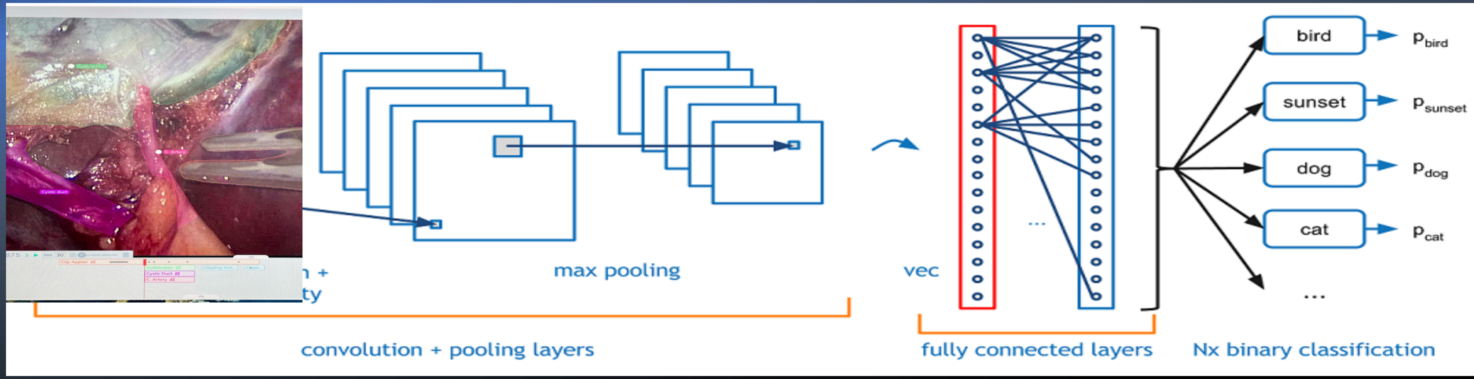
Academia and Industry partnership

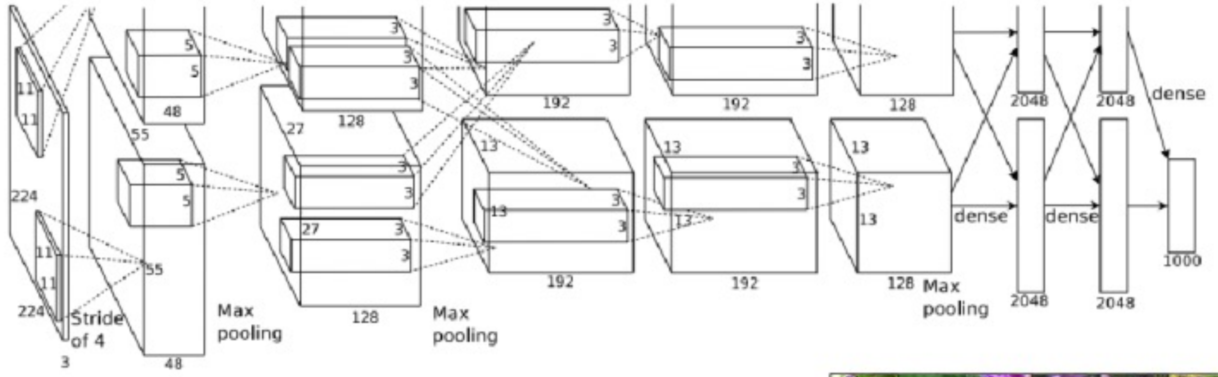
Standards for Publications

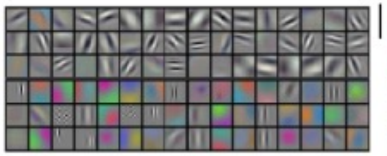
Validation Studies

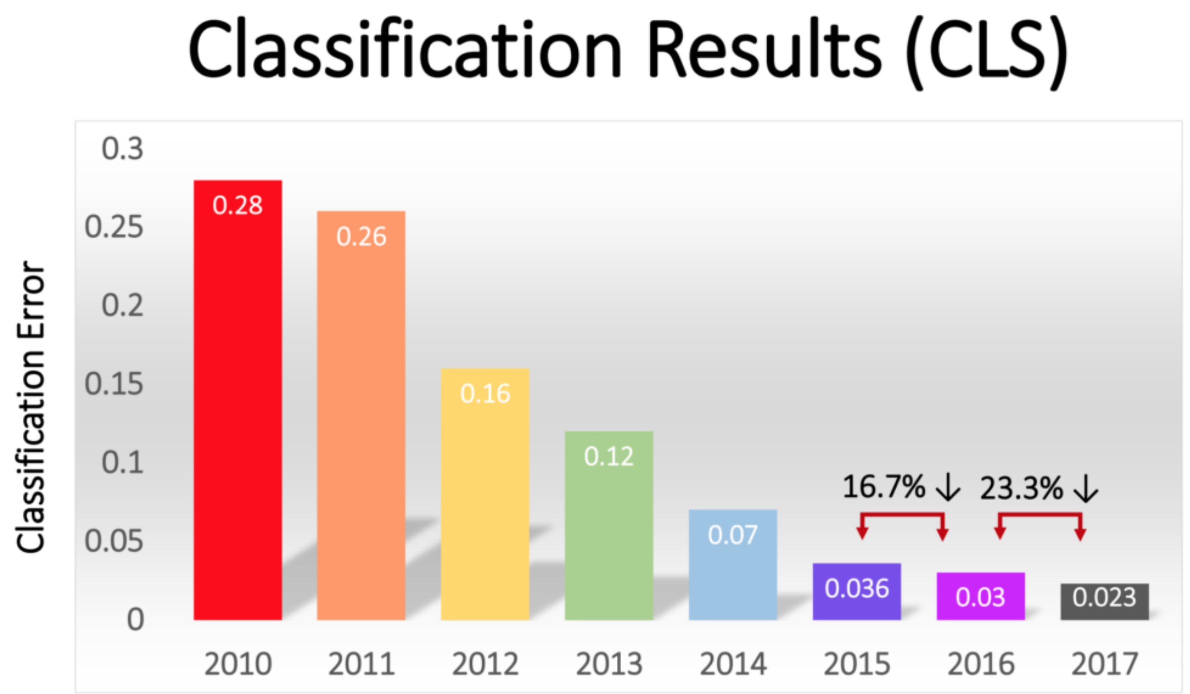
Promote Diversity

What is Computer Vision Challenge ?









The CVS Challenge | News | Data Donation | Annotation | Compete | Sponsorship | The Team
2023 Summit (NEW) | SAGES

The Critical View of Safety Challenge

A SAGES Initiative

MASSACHUSETTS GENERAL HOSPITAL

#SAGESAI

HARVARD MEDICAL SCHOOL

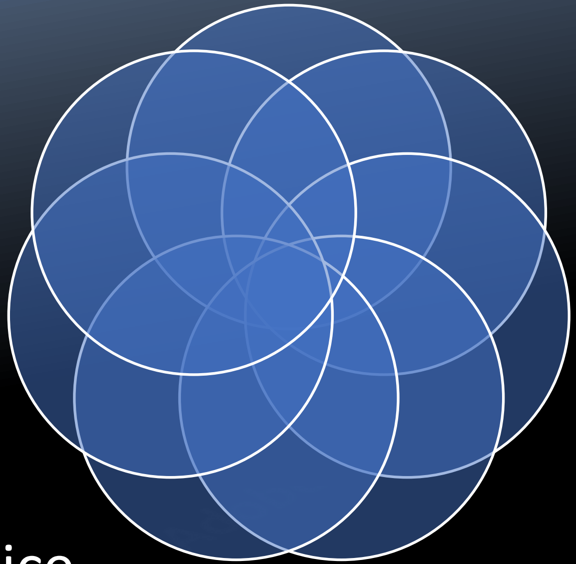
Surgical AI Governance

Regulations, Policies and Oversight

Surgeons

Patients

Government officials



Industry

Hospitals

Malpractice Insurance companies

Payers

2023

Education and Training

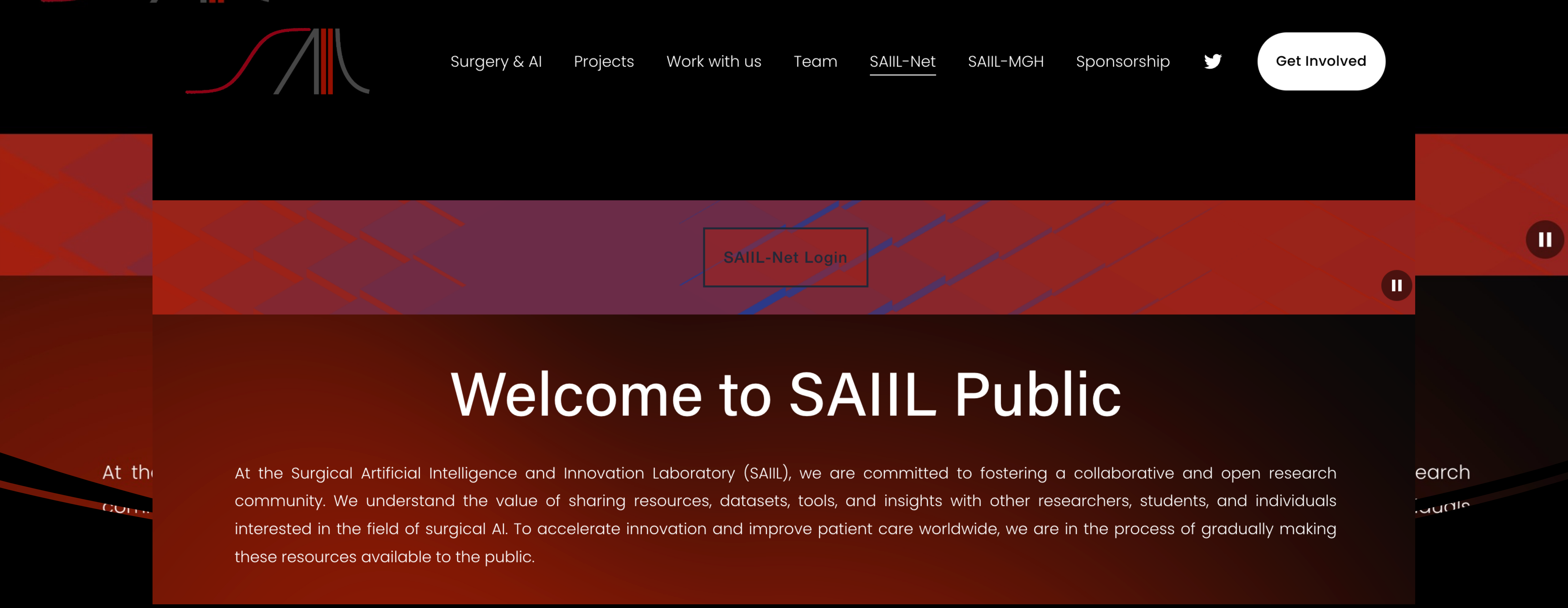
Scientific Meetings

Dedicated Fellowships

e.g. SAIIL

Medical School Curriculum

Publications



Education and Training

- Scientific Meetings
- Dedicated Fellowships e.g. SAIIL
- Medical School Curriculum
- Publications

Professional Preparation

Computer science

Ethics

Programing

Work force

Training

Credentialing

Simulations

(36)

Cultural Transformation

SHARING DATA

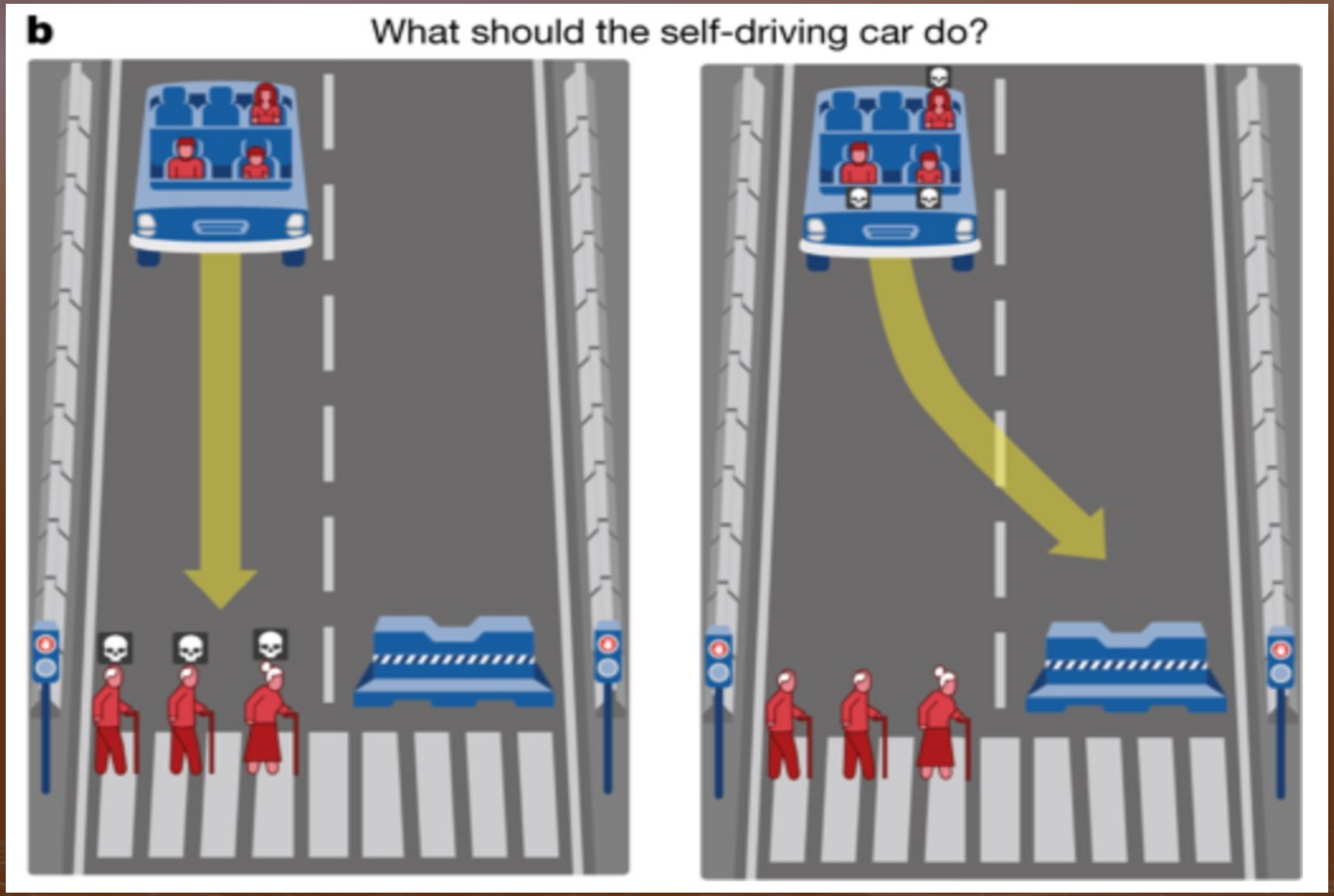
SHARING KNOWLEDGE

CULTURAL DIFFERENCES

Ethical considerations

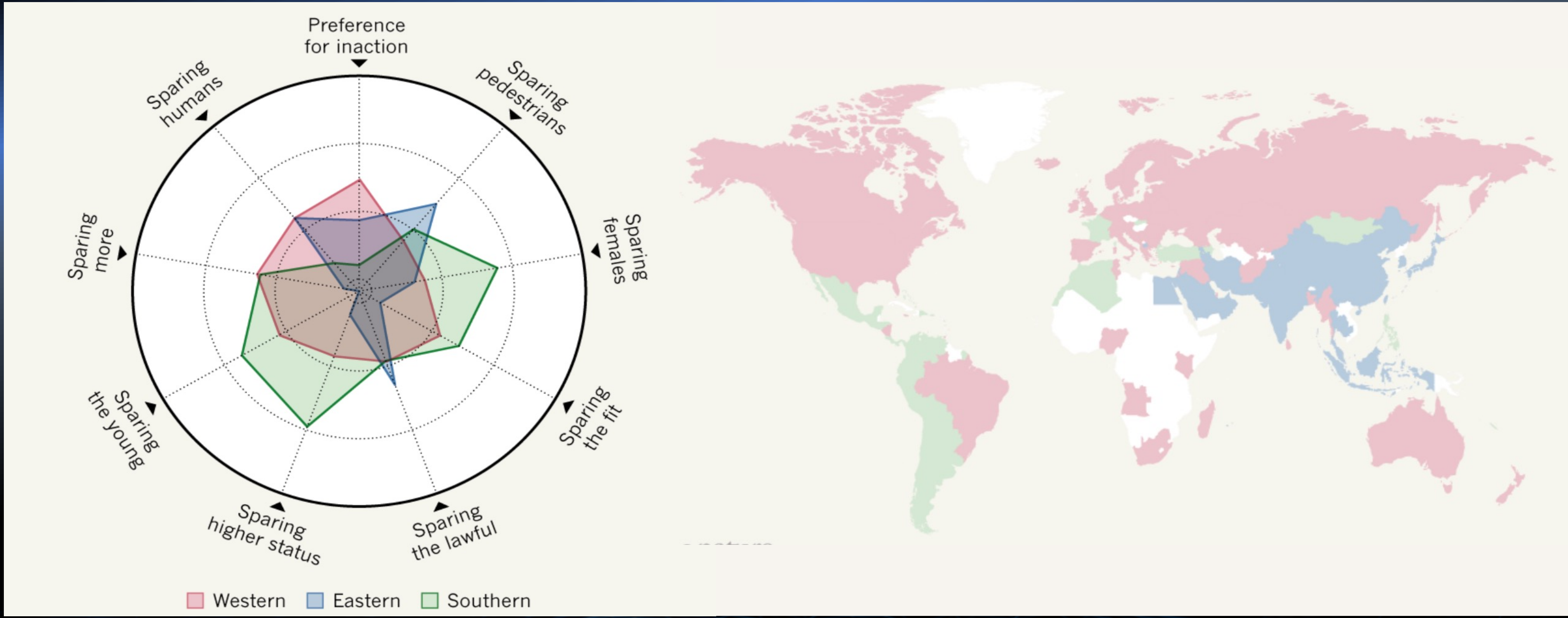
The Moral Machine

http://moralmachine.mit.edu



Awad et al. 2018. *Nature*

Ethical according to whom?



http://moralmachine.mit.edu

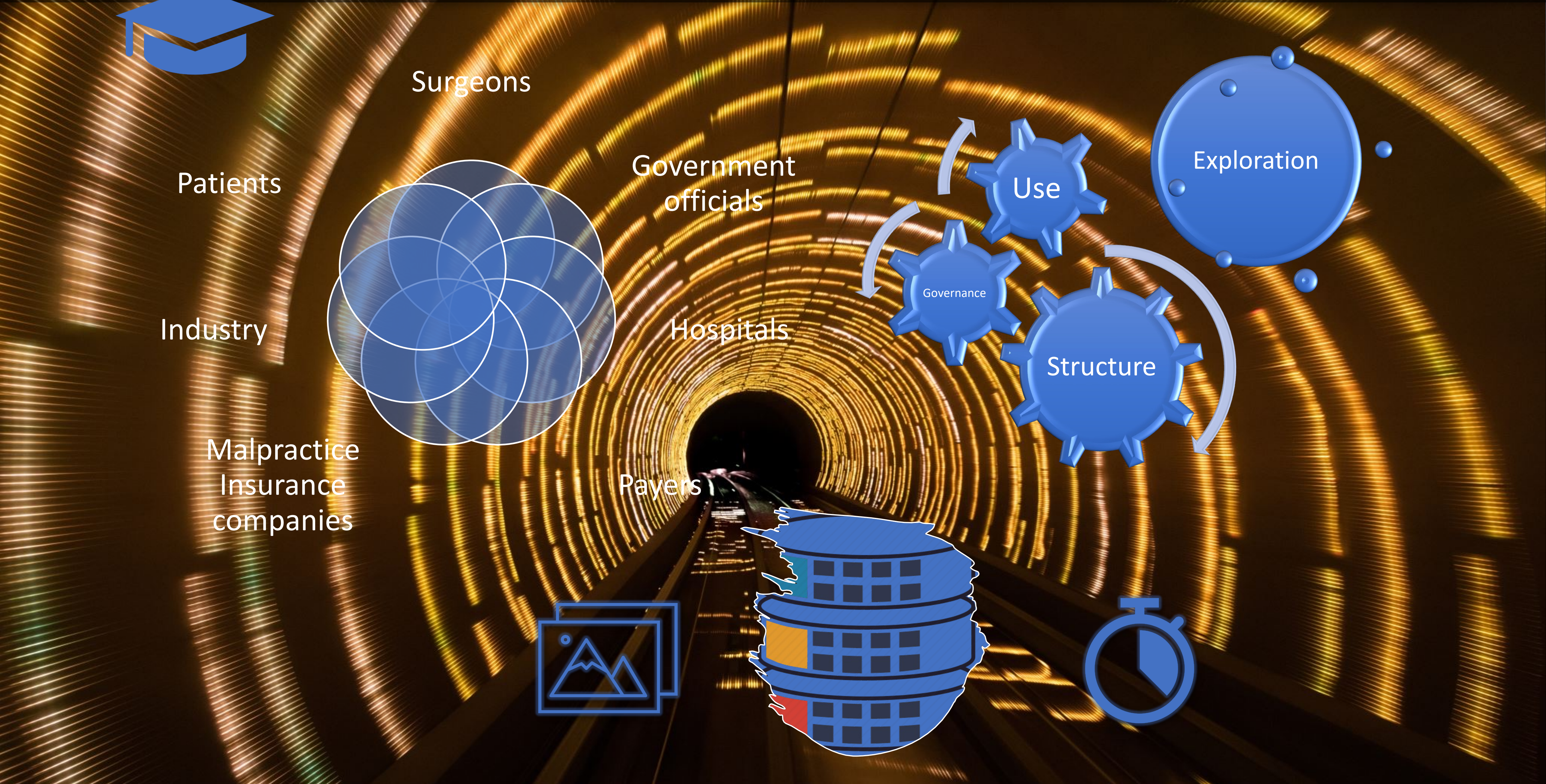
Other Considerations

Who owns the data?	Patient, Provider, Hospital, Payor
Who gets the credit?	Who gets the blame?

How do you explain AI-driven decisions to patients?

Can you challenge the decision ?

Surgical AI


Surgeons
Patients
Government officials
Industry
Hospitals
Malpractice Insurance companies
Payers
Use
Exploration
Governance
Structure

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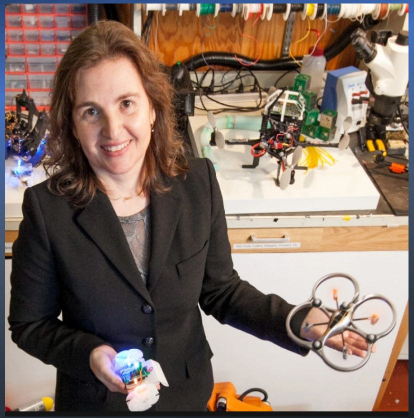

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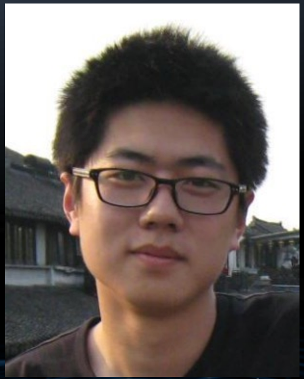

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Thank you!

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