Emerging Avenue of Artificial Intelligence and Ethical Considerations

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Nepal Applied Mathematics and Informatics Institute for research (**NAAMII**)

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Symposium on Responsible Conduct of Research in Nepal:
Identifying and Addressing Gaps

Hotel Himalaya, Lalitpur, Nepal

18 July, 2023

Outline

Very Brief Intro to NAAMII

Brief Intro to AI

AI avenues in Nepal's Healthcare

Ethical Considerations

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NAAMII

Vision: A world class center of excellence to improve the lives of people through scientific research

A pioneering and leading research institute in Artificial Intelligence (AI) in Nepal

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Scientific Research

Research Groups at NAAMII

Autonomous Research Groups

Theoretical and Applied Research in Applied Maths, Informatics, AI

Diverse Application Domains: Healthcare, Agriculture, Finance, Education, AI-Society …

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Theoretical and Applied Research in Applied Maths, Informatics, AI

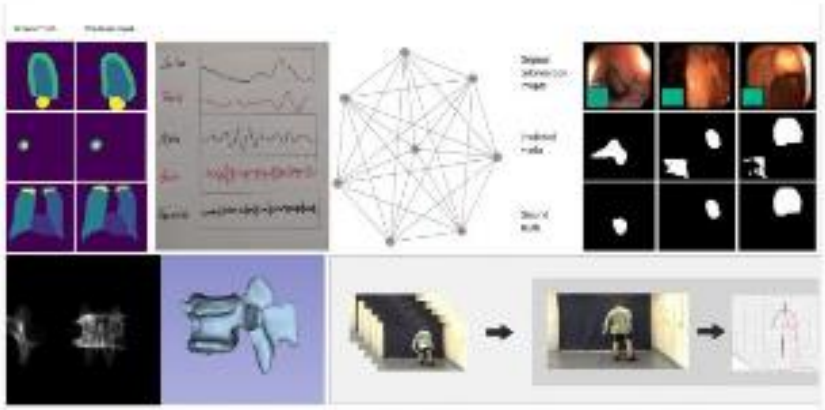
Diverse Application Domains: Healthcare, Agriculture, Finance, Education, AI-Society …

Published >30 research articles (MICCAI, CVPR, ICML/ICLR workshops, MeDIA, TMI, …)

Trained > 36 research staffs, supervised 5 Msc theses, 3 undergraduate final year projects, Full-time faculty co-supervising 2 PhD students in Korea and the USA

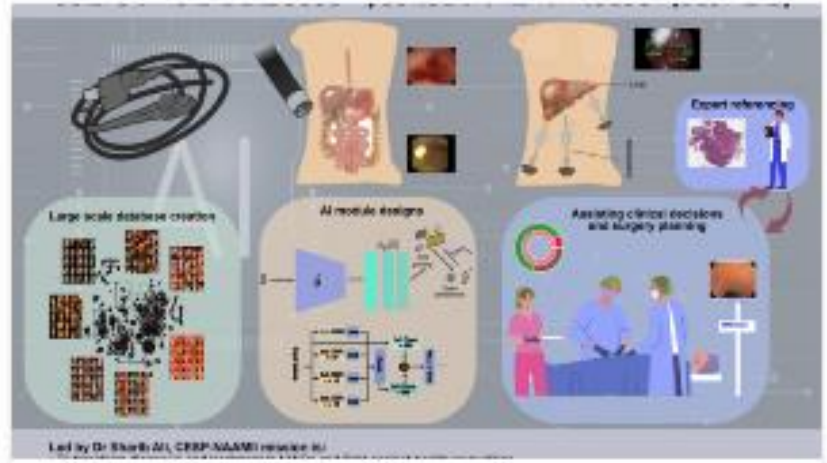
Scientific Research

Research Groups at NAAMII



Transforming Global health with AI (TOGAI)

B Bhattarai MultiModal Learning Lab (MMLL)



Computational Endoscopy, Surgery & Pathology (CESP)

Computational Genomics Lab (CGL)

Research using Artificial Intelligence in Neuroscience (RAIN)

AI & Society

Scientific Research

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Led by Dr. Bishesh Khanal,
Research Scientist at NAAMII

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Led by Dr. Binod Bhattarai,
Adj. Research Scientist at NAAMII
& Assitant Professor at University of Aberdeen

COMPUTATIONAL GENOMICS LAB

Led by Dr. Raunak Shrestha,
Adj. Research Scientist at NAAMII
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RESEARCH USING ARTIFICIAL INTELLIGENCE IN NEUROSCIENCE (RAIN)

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COMPUTATION ENDOSCOPY, SURGERY AND PATHOLOGY GROUP

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& Lecturer at University of Leeds

Other Adjunct Faculties

Dr. Ajad Chhatkuli,
Adj. Research Scientist at NAAMII
& Postdoc Researcher at ETH Zürich

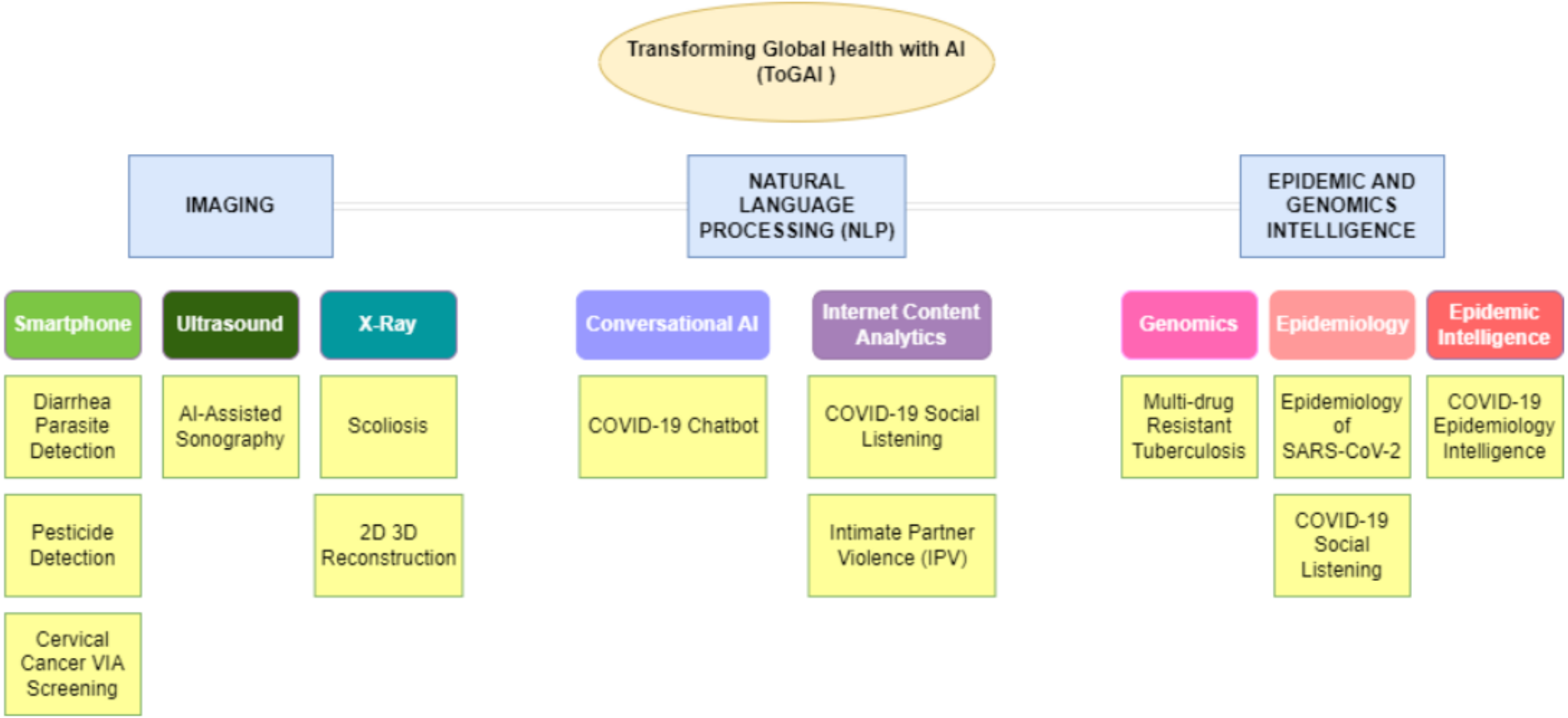
Shreyasha Paudel,
Research Fellow/Alumni at NAAMII
& PhD Scholar at University of Toronto

Dr. Danda Pani Paudel,
Adj. Research Scientist at NAAMII
& Researcher at Computer Vision Lab, ETH Zü

Dr. Suman Raj Bista,
Adj. Research Scientist at NAAMII

Dr. Taman Upadhaya,
Adj. Research Scientist at NAAMII
& Associate Researcher at UCSF

Prof. Sabita Maharjan,
Adj. Research Scientist at NAAMII
& Associate Professor at University of Oslo



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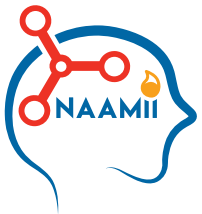
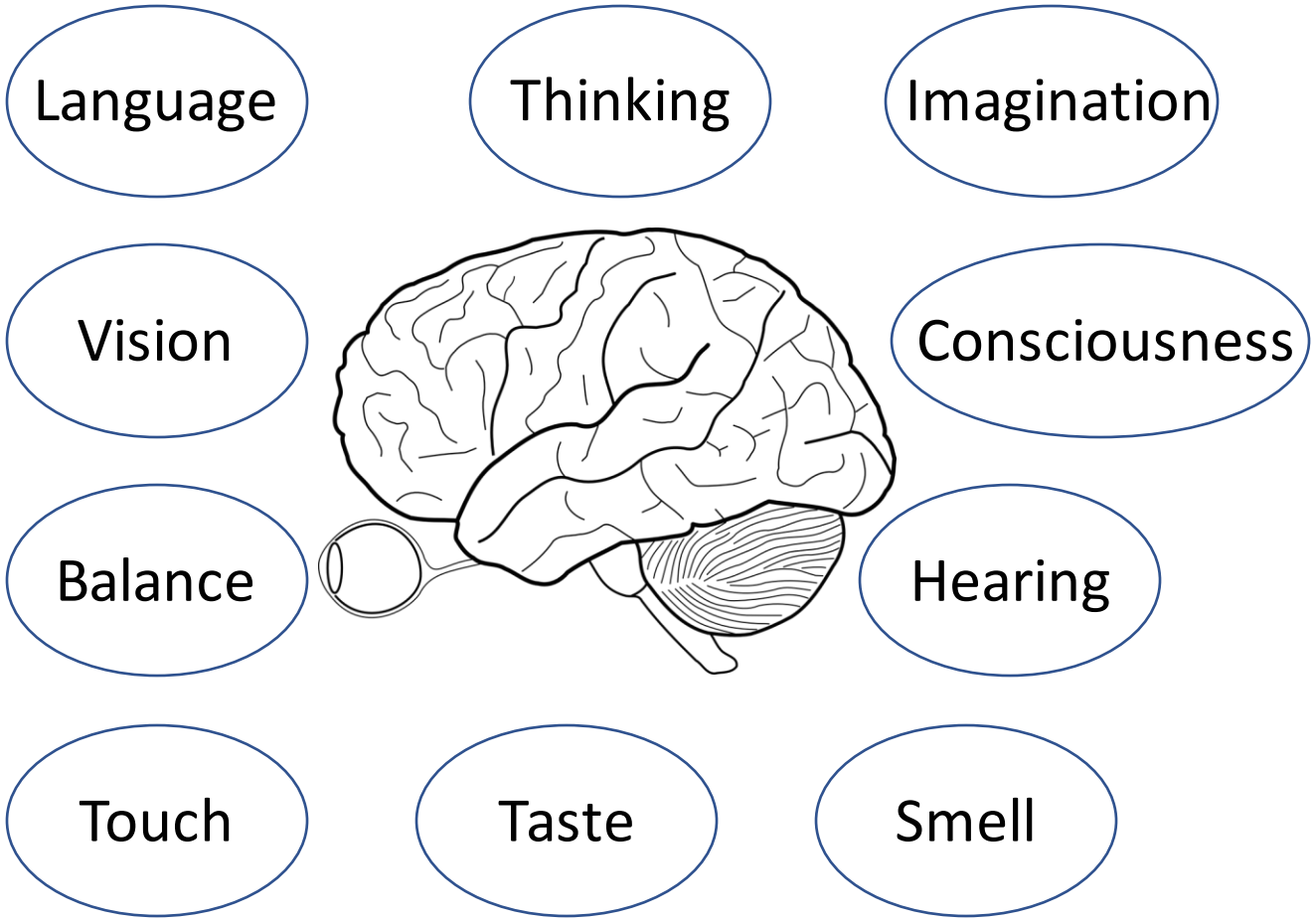


Artificial Intelligence (AI)

What is it?

Artificial Intelligence: From "Natural Intelligence"?



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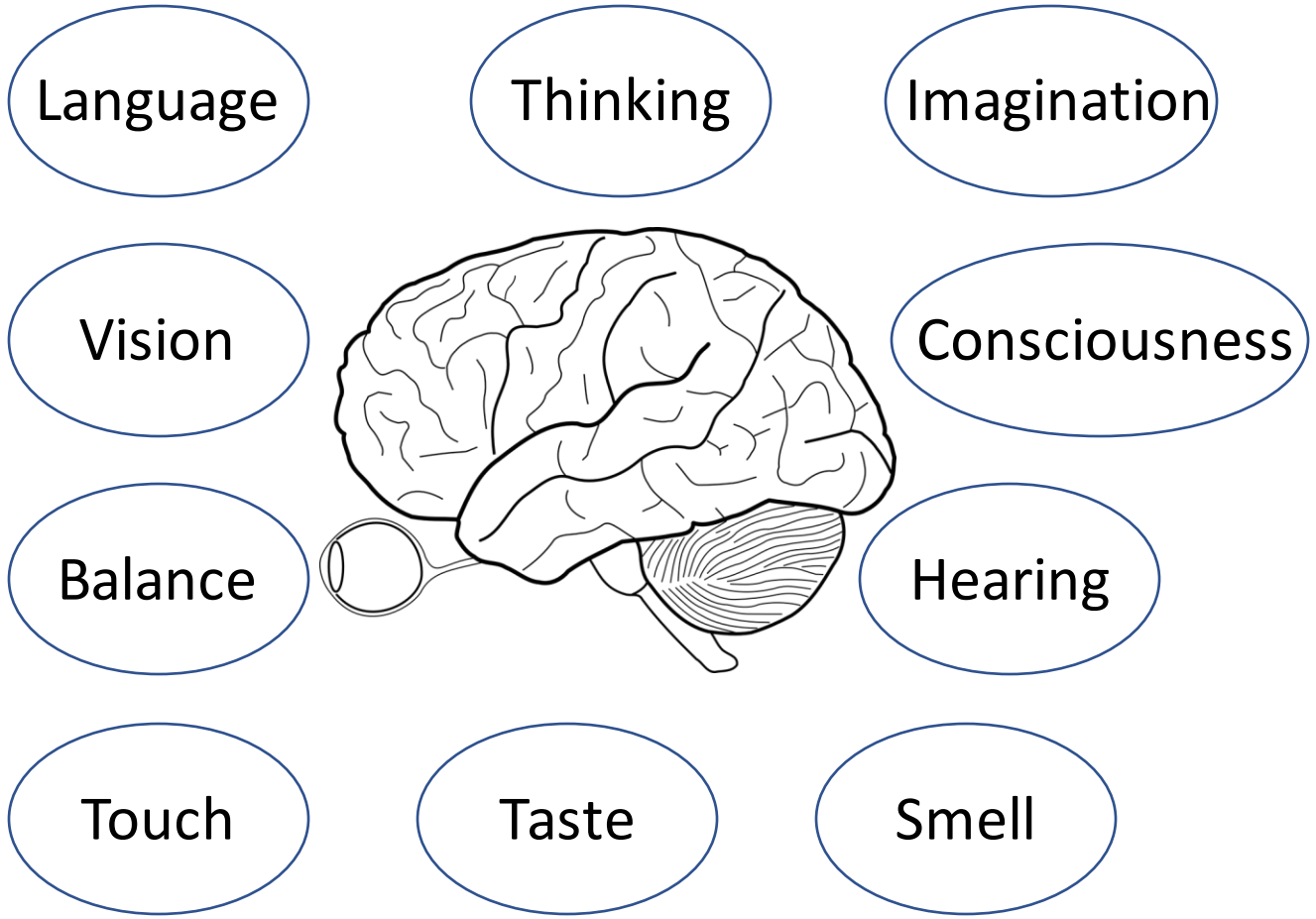


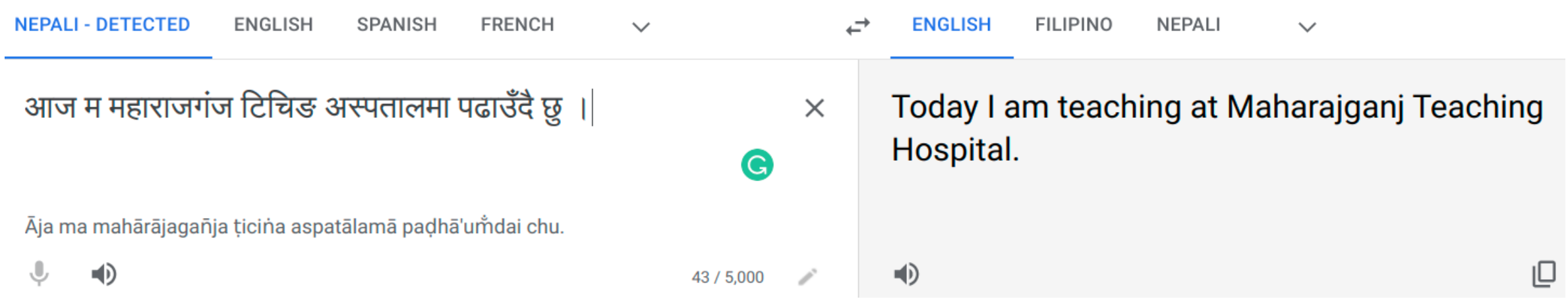
Emulating all these:
Artificial General Intelligence

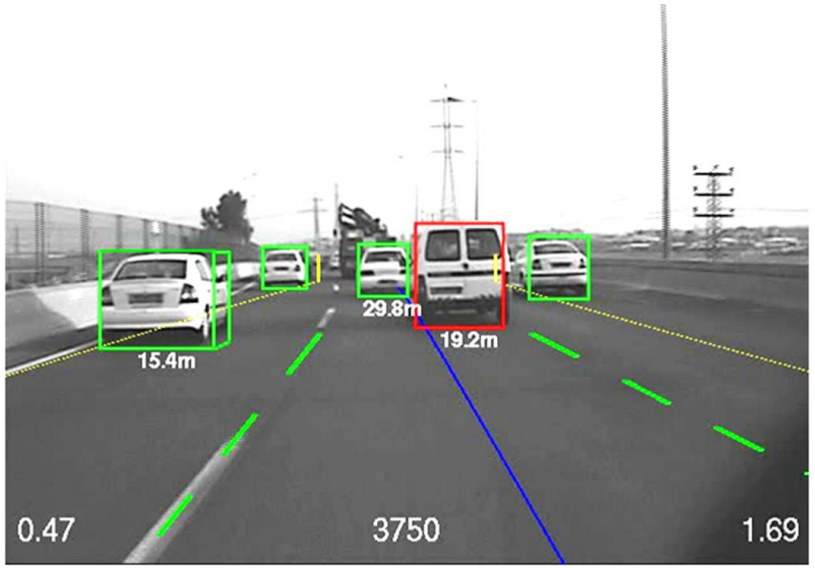
What's AI then?

Artificial Intelligence (AI)

Ability of man-made agents to do tasks traditionally attributed to "intelligence" of some level

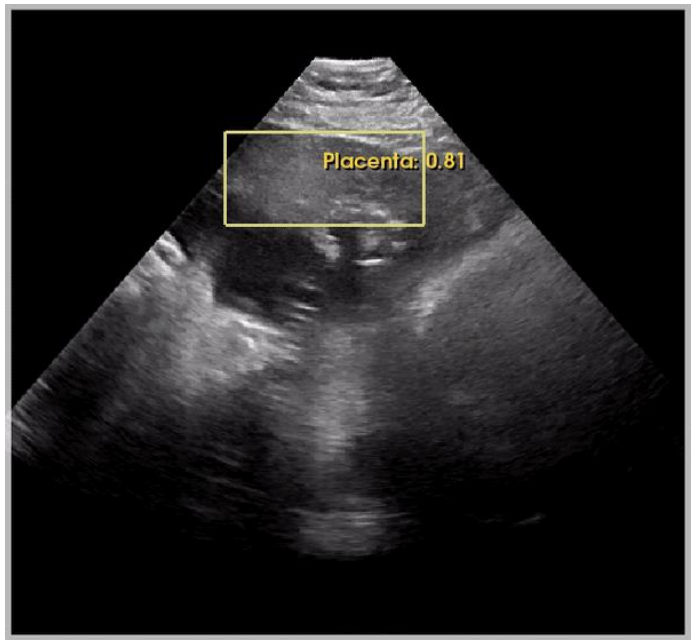
Artificial Intelligence (AI)



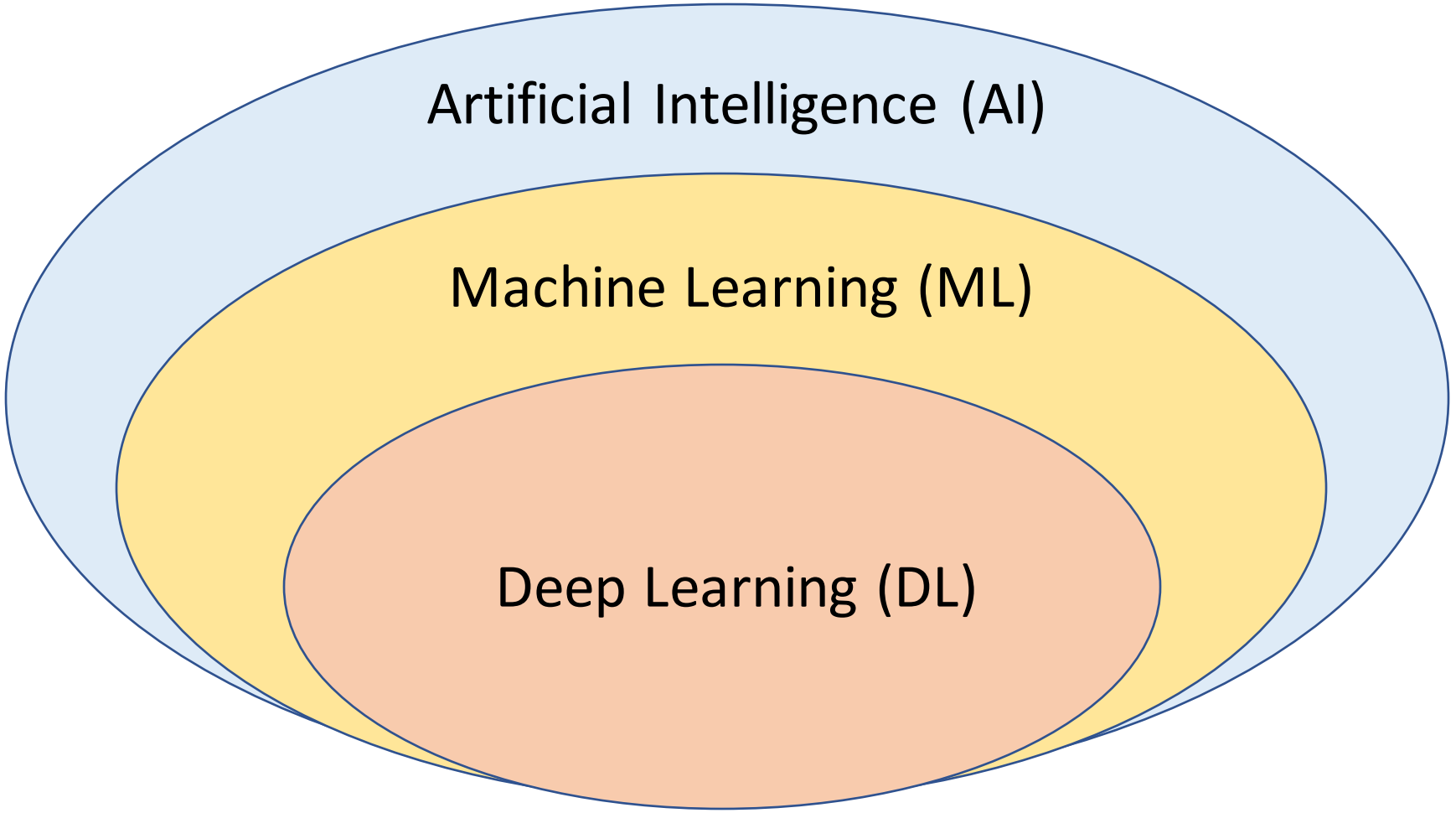


- Facebook Ads
- Facebook auto tagging
- Twitter Ads

- Netflix recommendation
- Amazon recommendation
- Youtube recommendation



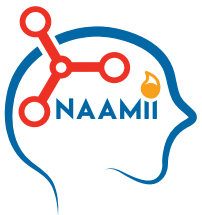
AI, Machine Learning and Deep Learning



Supervised Deep Learning

Collect a large number of "annotated data"

- E.g. 10 lakhs chest X-ray images with diagnosis on each image



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- Split 10 lakhs image into 9 lakhs training data & 1 lakh validation data
- Train AI model (DL model) to predict diagnosis from 9 lakhs images
- Validate (Evaluate) the performance of AI model on 1 lakh images

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Evaluation metrics

- Accuracy, Sensitivity, Specificity

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Generalization

Can we now use this AI model anywhere in the world?

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Improving quality of health service delivery in overburdened tertiary centers

Understanding biology and human body for better health care

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Pesticide Estimation from Low-Cost Paper Device & AI App

Pesticides in Vegetables & Fruits

- Big problem in Nepal

What if:

- we go to pharmacy & buy a kit
- Grind vegetables
- See results of kit on Smartphone

Khanal, B., Pokhrel, P., **Khanal, B.**, & Giri, B. (2021). *Machine-Learning-Assisted Analysis of Colorimetric Assays on Paper Analytical Devices*. ACS omega, 6(49), 33837-33845.

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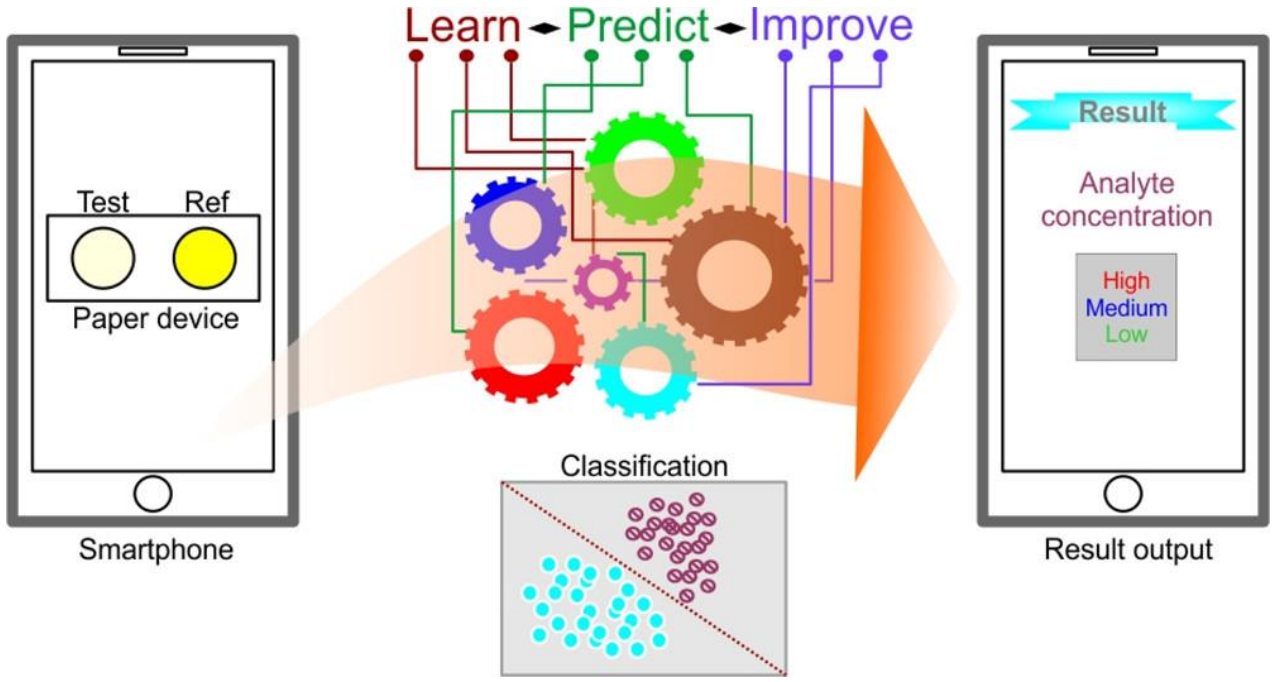

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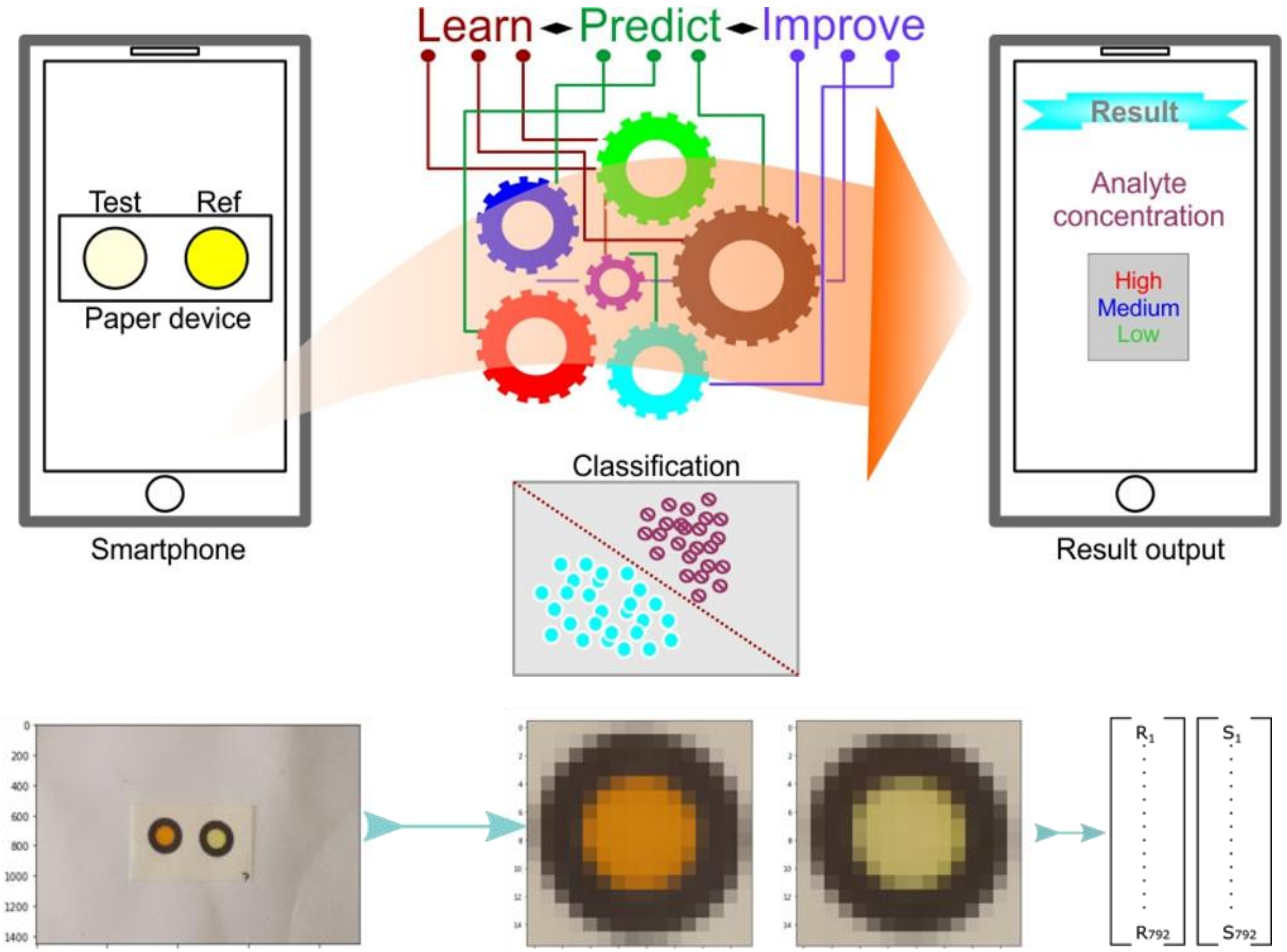
We showed that this could be possible for major pesticides.



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AI-assisted VIA for Cervical Cancer Screening

Cervical Cancer

- Major type of cancer for women in Nepal (& many LMICs)
- Preventable if identified in pre-cancerous stage
- Can be cured if in early stage
- Visual Inspection with Acetic acid (VIA) most common screening in low-resource

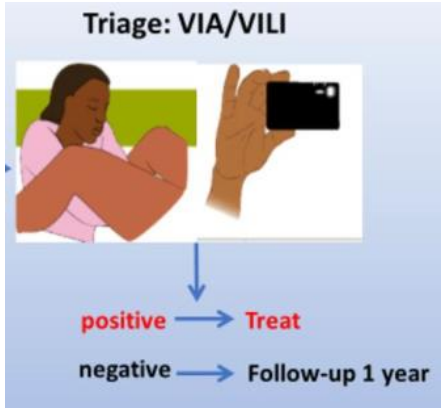

Image Source: Grohar D, et al. Scaling up community-based cervical cancer screening in Cameroon employing a single visit approach. IJGC 2020.

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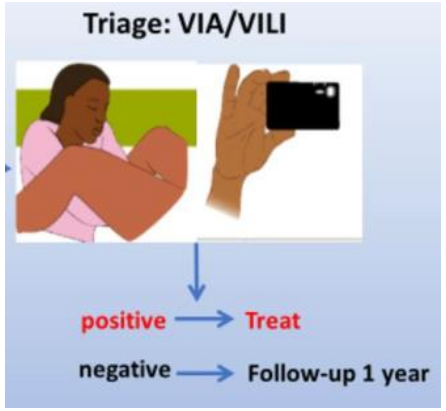

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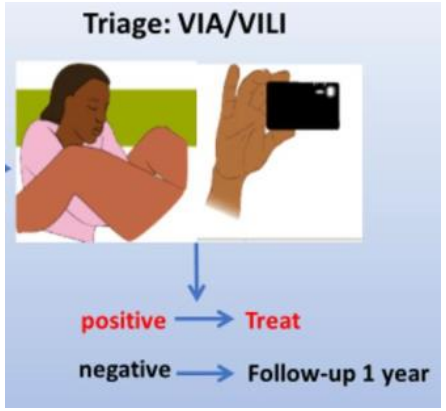

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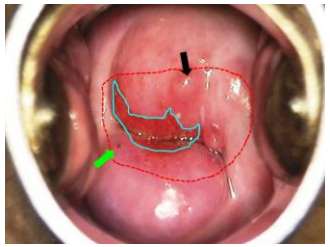


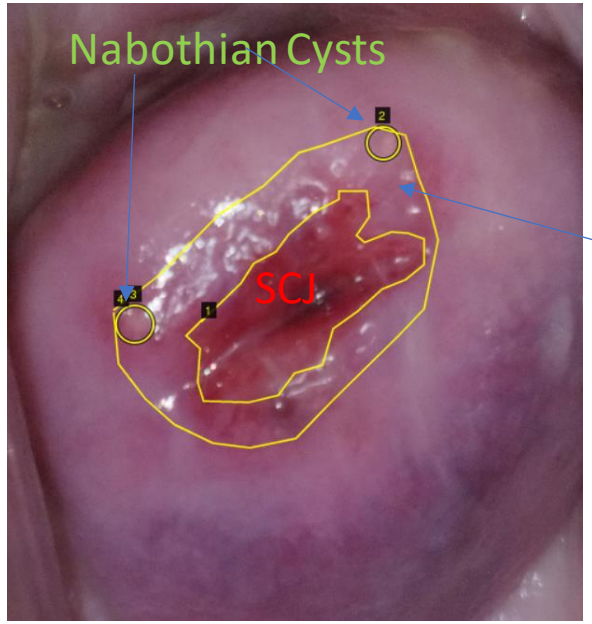
One Part of the Solution

- AI to assist non-experts (e.g. FCHVs, nurses) to do VIA more objectively & accurately

AI-assisted VIA for Cervical Cancer Screening

Anatomy of Cervical Cancer

- Most cancers and precancers originate from the squamous epithelium in the Transformation Zone(TZ) of the cervix



Transformation Zone (TZ)

AI-assisted VIA for Cervical Cancer Screening

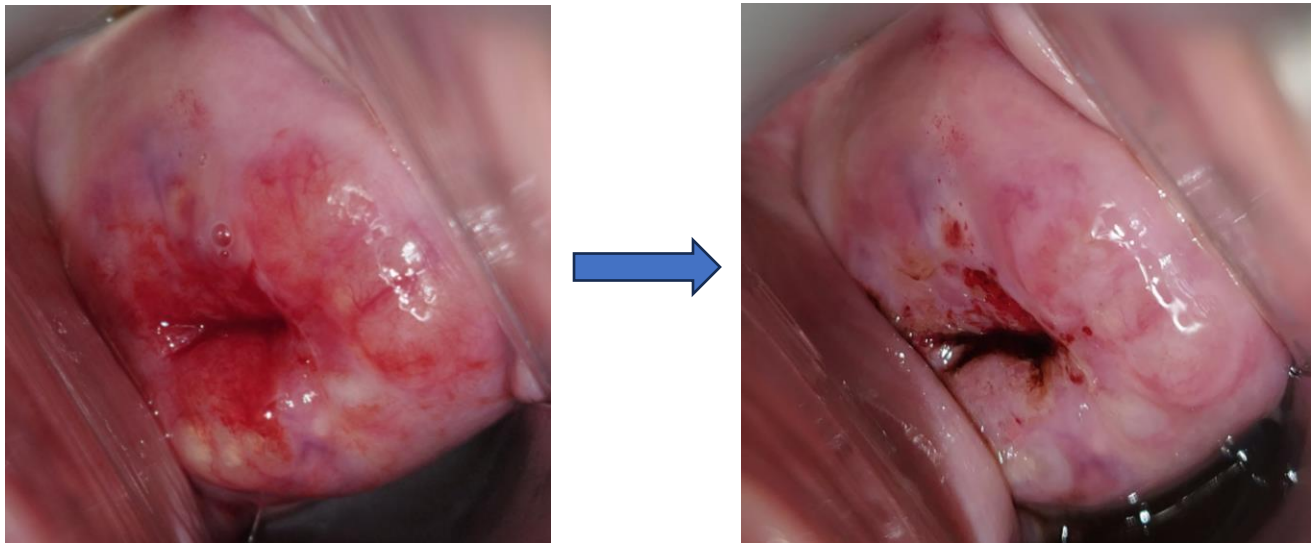
Anatomy of Cervical Cancer

- But very difficult to locate these landmarks in most of the cases!

AI-assisted VIA for Cervical Cancer Screening

Morphology of Cervical Cancer

- Precancerous lesions take whitish color on application of acetic acid



Positive case from our camp verified as precancer by biopsy

AI-assisted VIA for Cervical Cancer Screening

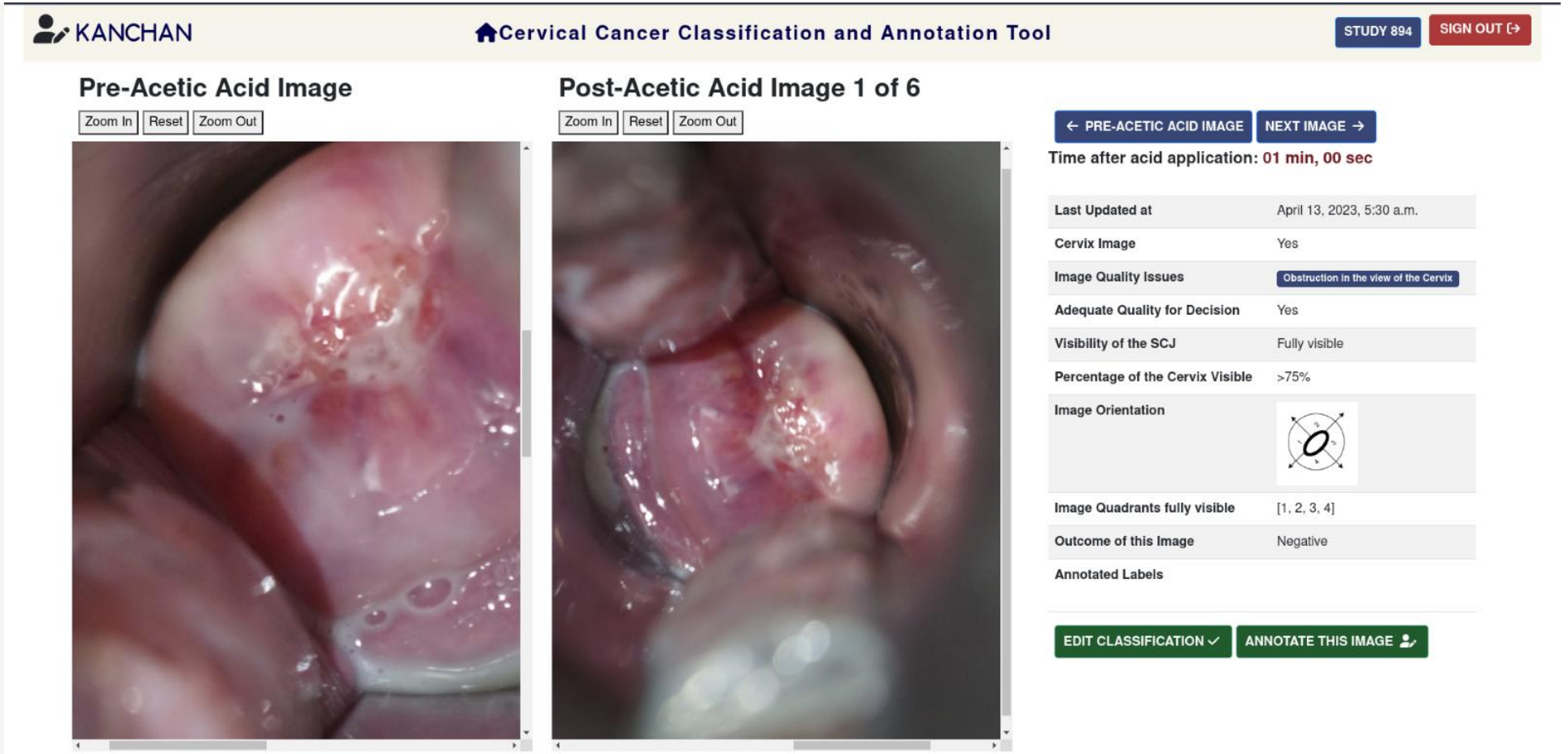
Morphology of Cervical Cancer

- Precancerous lesions take whitish color on application of acetic acid

- But, not every acetowhite change in cervix is a precancer or a cancer!

Positive cases from our camps, diagnosed as Infections and negative for cancer/pre-cancer

AI-assisted VIA for Cervical Cancer Screening



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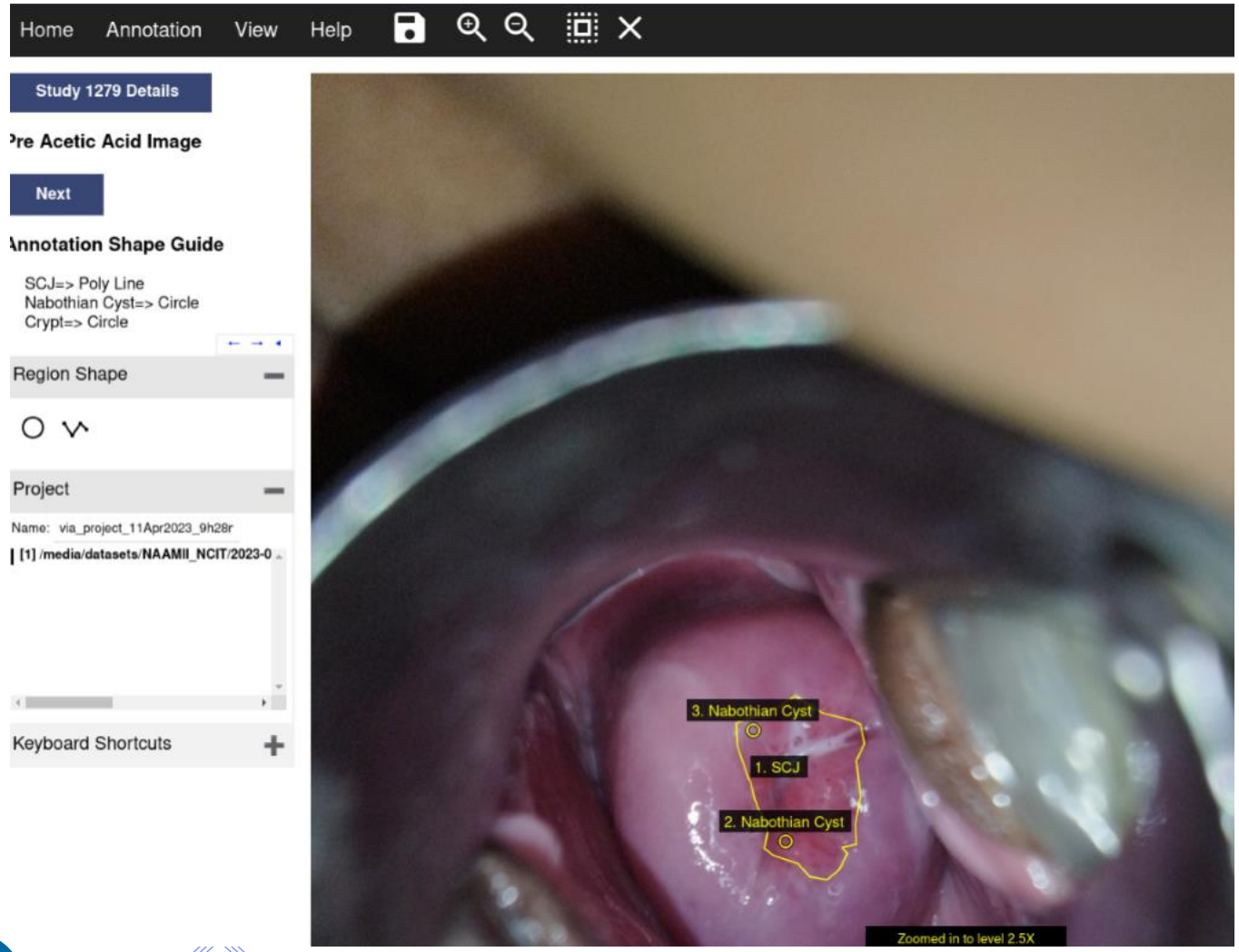

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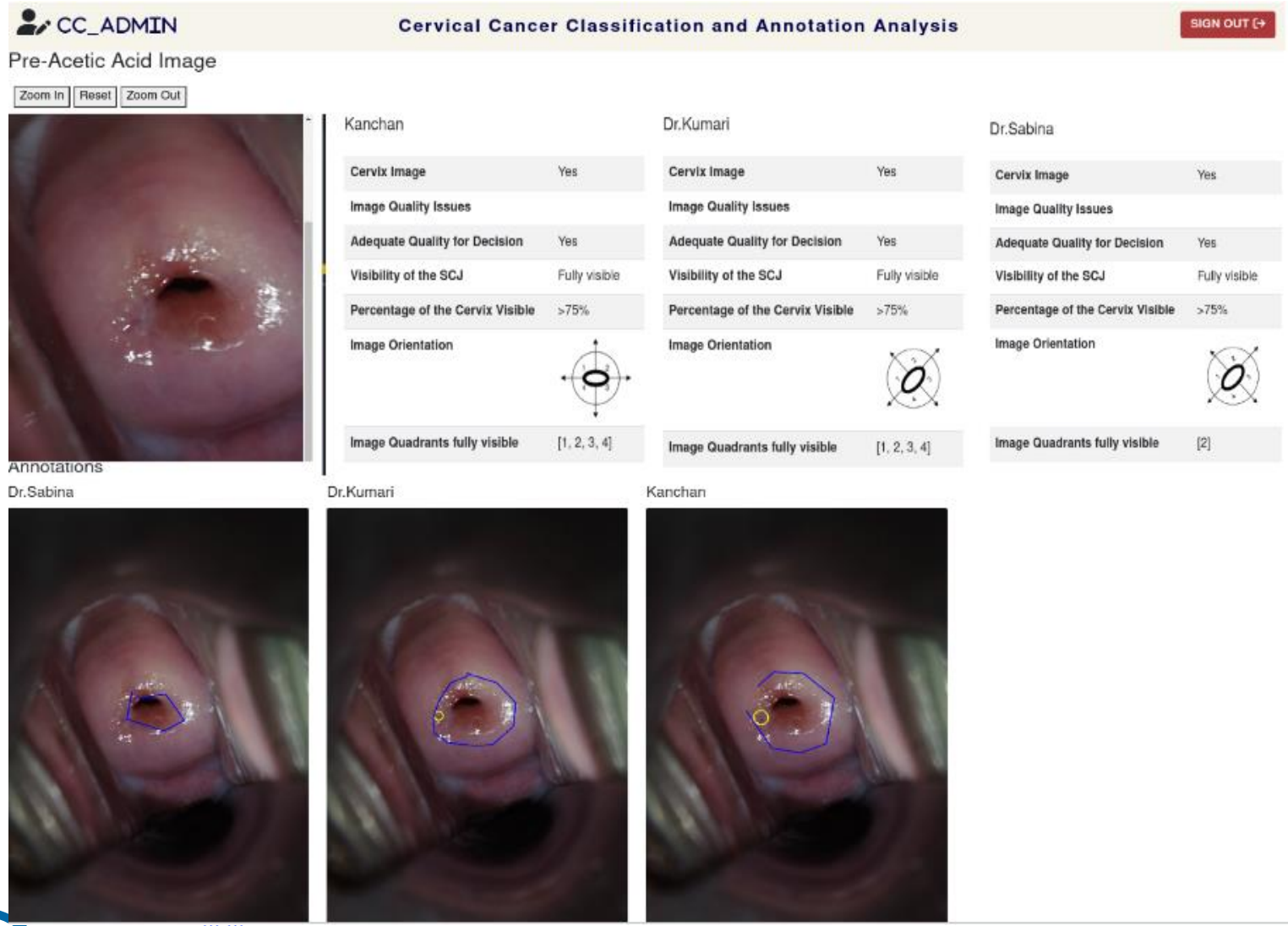

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Empowering general-public for prevention and early detection

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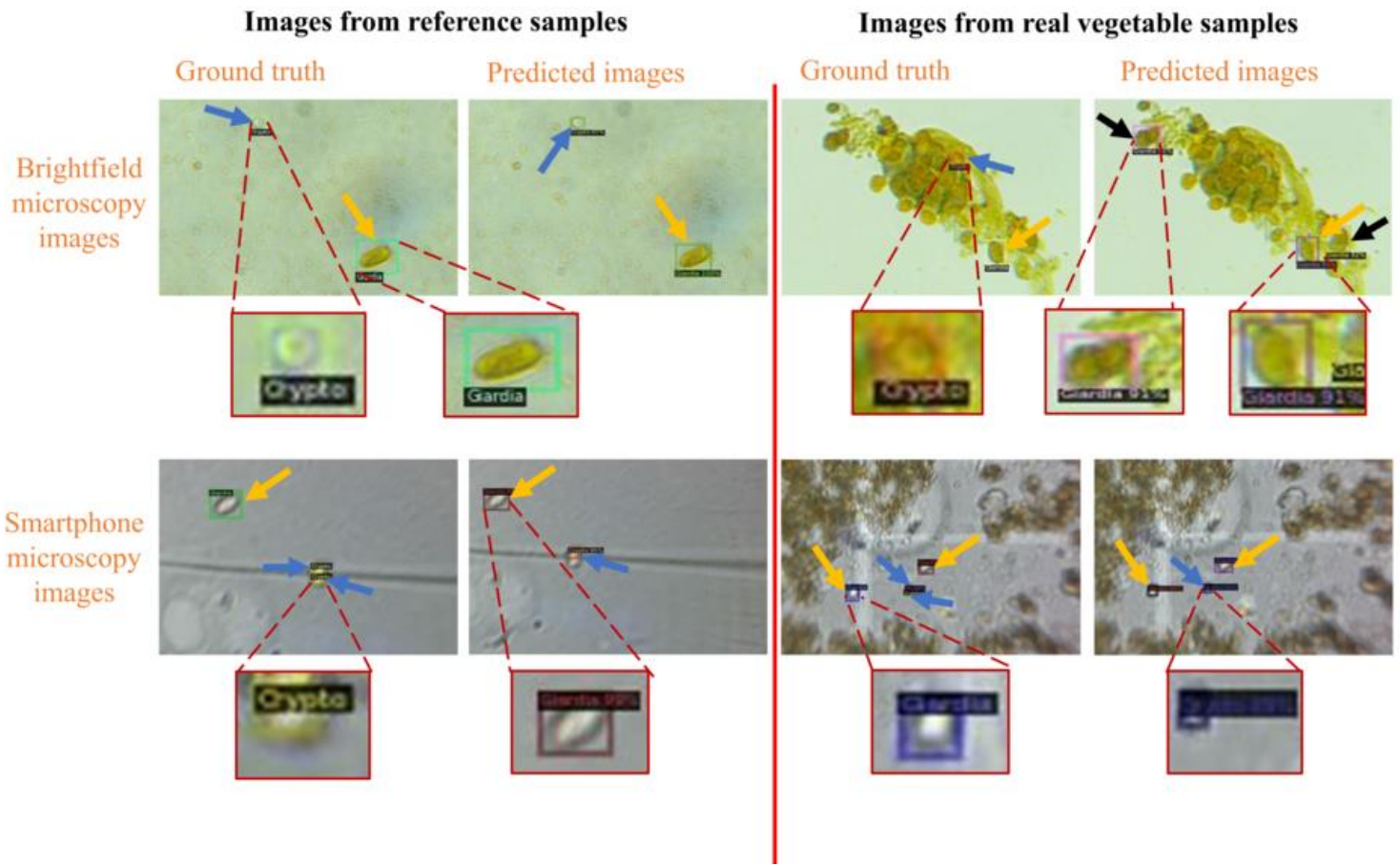
AI-Assisted Smartphone Microscopy



Diarrhea causing parasites

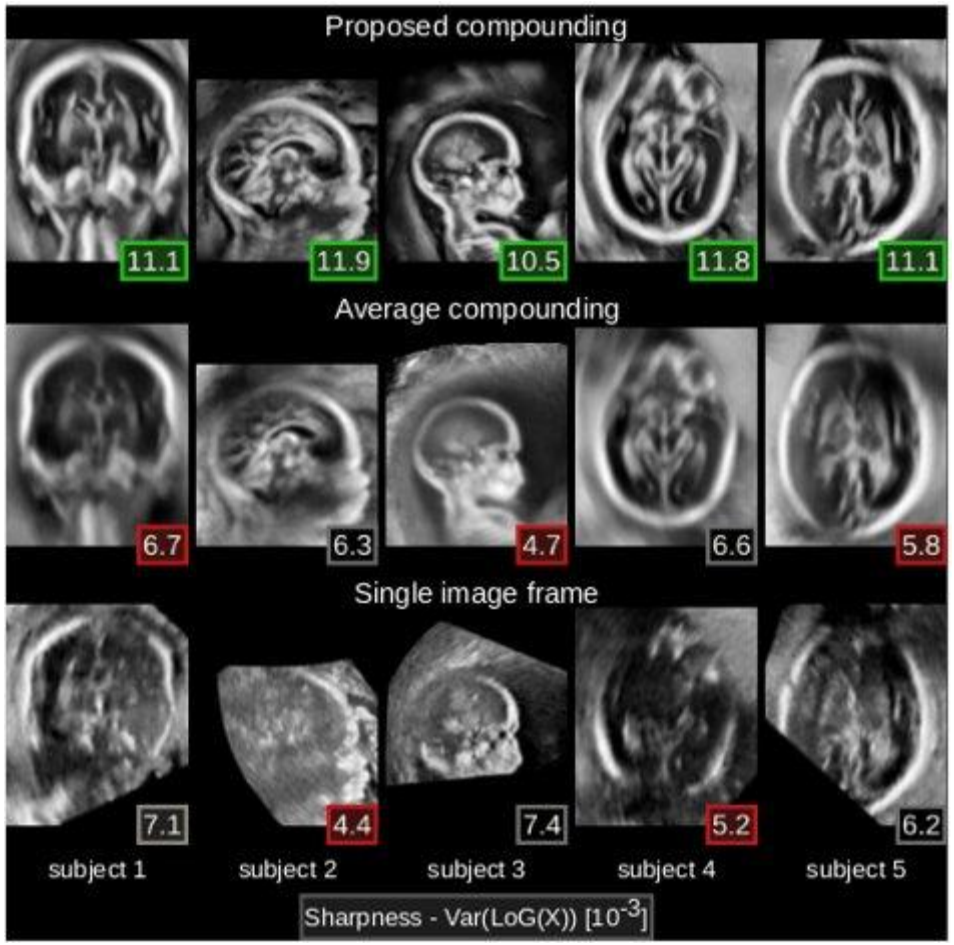
Rapid easy test in

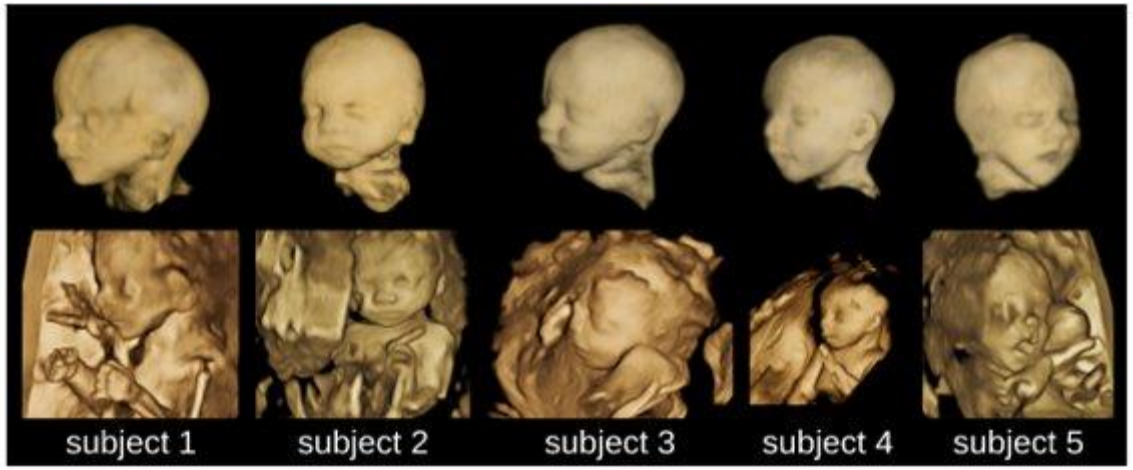
Water, vegetables, stools

More objective & consistent detection

S. Nakarmi, …, **B. Khanal**. Deep-learning assisted detection and quantification of (oo)cysts of Giardia and Cryptosporidium on smartphone microscopy images. ICLR Workshop 2021

Intelligent Fetal Imaging and Diagnostics





Addresses

- Limited Field of View
- Consistency across different operators
- Less expertise required

R. Wright, …, **B. Khanal,** et al. Complete Fetal Head Compounding from Multi-View 3D Ultrasound… MICCAI 2019
R. Wright, …, B. KHanal, et al. Fast fetal head compounding from multi-view 3D ultrasound. MedIA 2023.

NAAMII

KING'S College LONDON

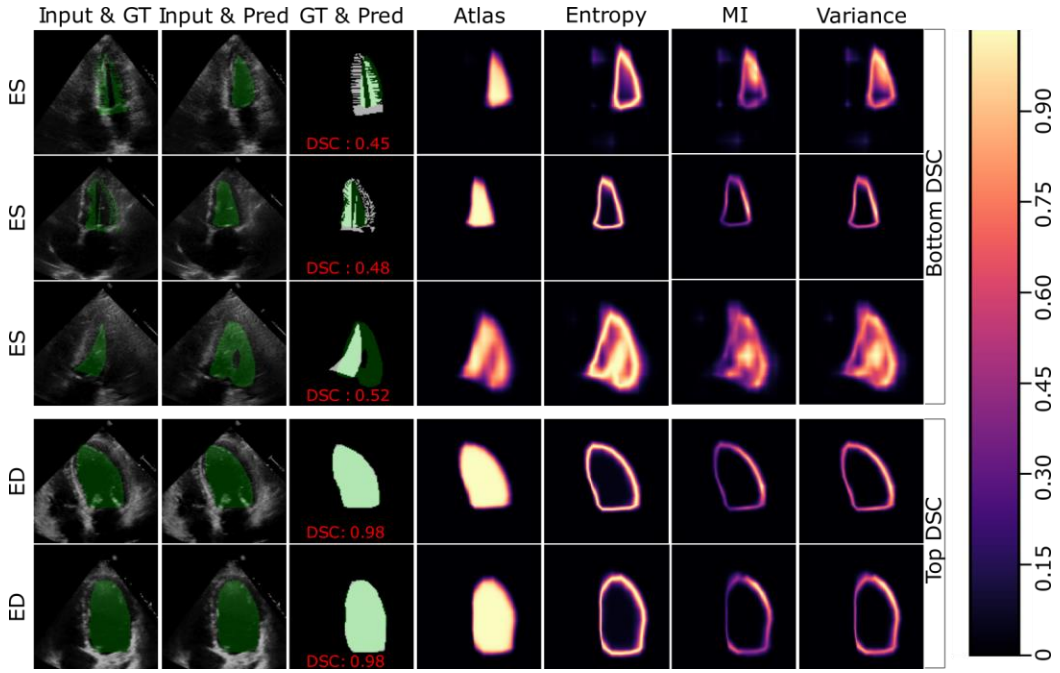
Imperial College London

iFIND

Uncertainty Based Quality Control in Biometrics Estimation

Automated cardiac structures segmentation at End Systole and End Diastole

Volume estimation, Ejection fraction; Important markers for Cardiovascular Disease



Dice scores taking most certain predictions

Test Set	First 20%	First 40%	First 60%	First 80%	Full Dataset (100%)	Current SOA
CAMUS-ED	0.953	0.946	0.944	0.935	0.932	0.939*
CAMUS-ES	0.944	0.936	0.928	0.923	0.911	0.916*
Dynamic-ED	0.946	0.942	0.939	0.936	0.930	0.927
Dynamic-ES	0.929	0.921	0.914	0.909	0.899	0.903

** Current SOA result with manual cleaning of bad quality images, while ours is automated based on uncertainty output*

L. Dahal, A. Kafle, and **B. Khanal**. Uncertainty Estimation in Deep 2D Echocardiography Segmentation. *arXiv preprint arXiv:2005.09349* (2020)

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- Inventing new technology when needed!

Improving quality of health service delivery in overburdened tertiary centers

Understanding biology and human body for better health care

Biplanar X-ray to 3D reconstruction

Rural Trauma

- No CT scan available
- Generate 3D from X-ray

Shakya, M, and **Khanal, B.**. Benchmarking Encoder-Decoder Architectures for Biplanar X-ray to 3D Bone Shape Reconstruction. Under review

Benchmarking Biplanar X-ray to 3D Bone Reconstruction

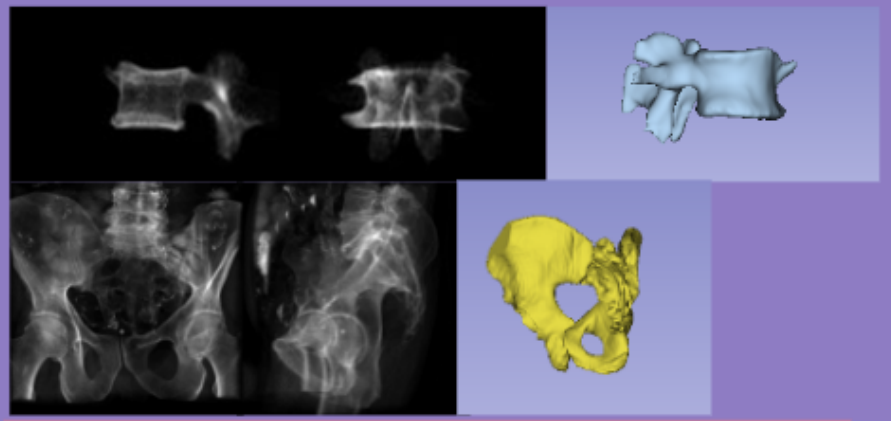
Mahesh Shakya, Bishesh Khanal

Why X-ray to 3D Reconstruction?

- 3D segmentations useful in surgery planning but not always accessible
- **X-ray to 3D: high availability, lower cost.**

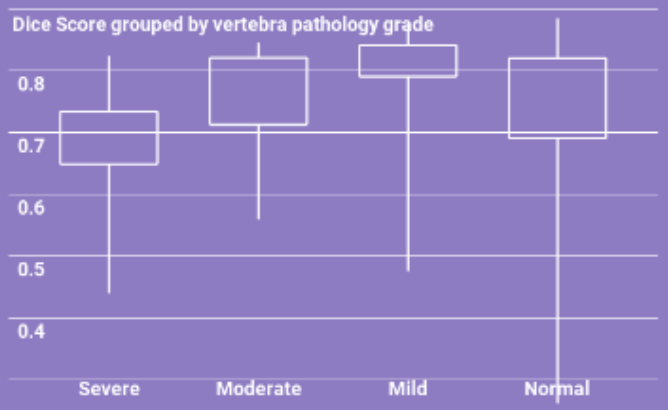
Approaches

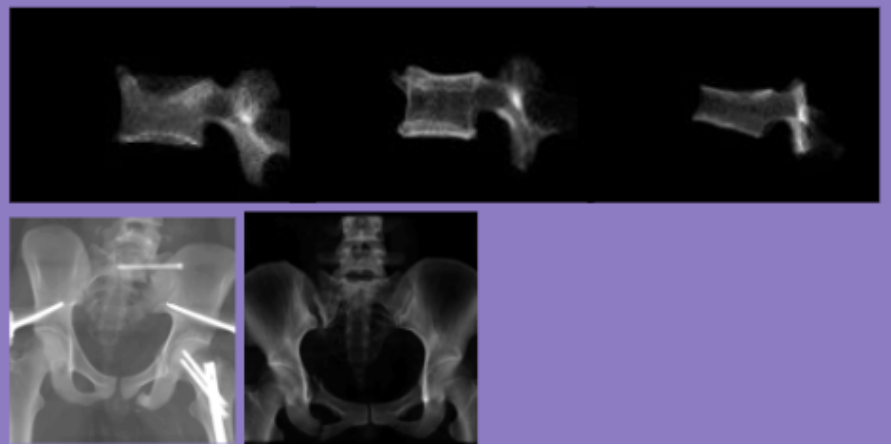
- Statistical Shape Model (poor out-of-training performance)
- 2D to 3D Registration (slow)
- Deep learning approach (data-hungry)



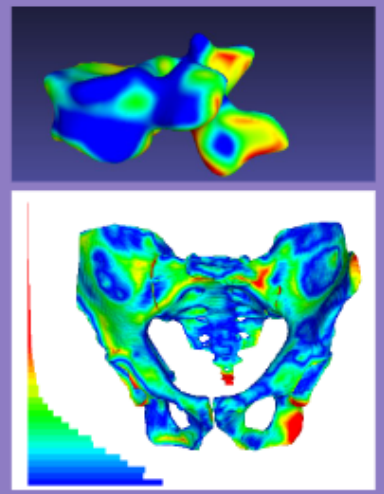
How can we improve performance on clinically relevant parameters of interest?

Gap: Medical Datasets are skewed. They usually contain fewer abnormal samples than healthy ones. AI models performance is biased towards majority class but results on these abnormal samples may be clinically more important.





How do current state of the art perform in public dataset? (Not as well as reported.)



Error: Red, Green, Blue color denote positive, zero and negative distance to ground truth. Avg reconstruction error 2.5 mm Trained on the challenging public Vertebra Dataset (VerSe[1]).

Shakya, M, and **Khanal, B.**. Benchmarking Encoder-Decoder Architectures for Biplanar X-ray to 3D Bone Shape Reconstruction. Under review

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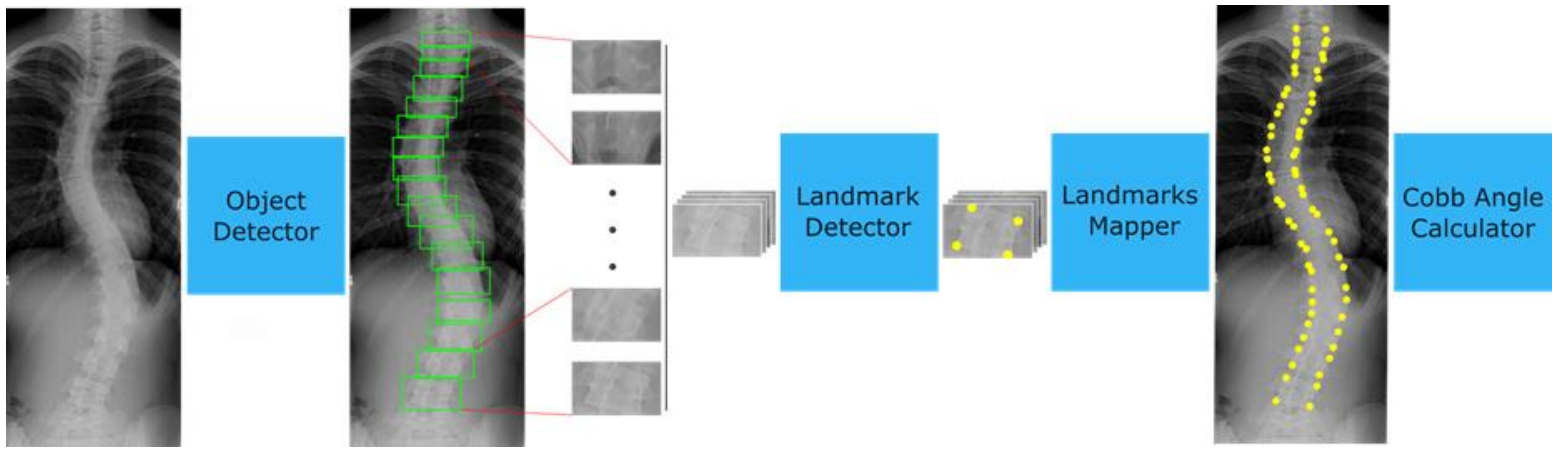
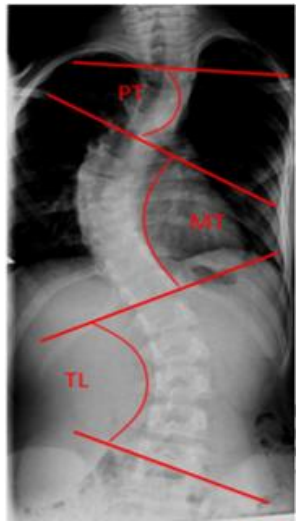
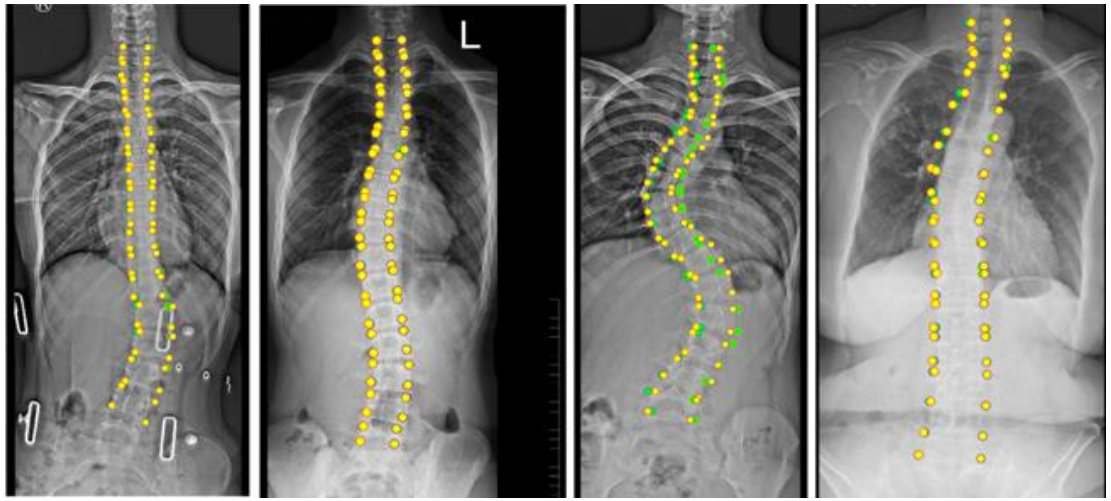
Automatic Cobb Angle Detection







Scoliosis

- Common in adoloscents
- Permanent disability or fatal if untreated
- Cobb angle an important marker
  - Tedious for surgeons
  - High inter-rater variability

Khanal, B., Dahal, L., Adhikari, P., & **Khanal, B**. Automatic Cobb Angle Detection using Vertebra Detector and Vertebra Corners Regression. *Workshop MICCAI 2019*.
Sheng, L., …, **Khanal, B**., et al. Evaluation and comparison of accurate automated spinal curvature estimation algorithms with spinal anterior-posterior X-Ray images: The AASCE2019 challenge. *Medical Image Analysis 2021*.

Key Themes in Nepal's Context

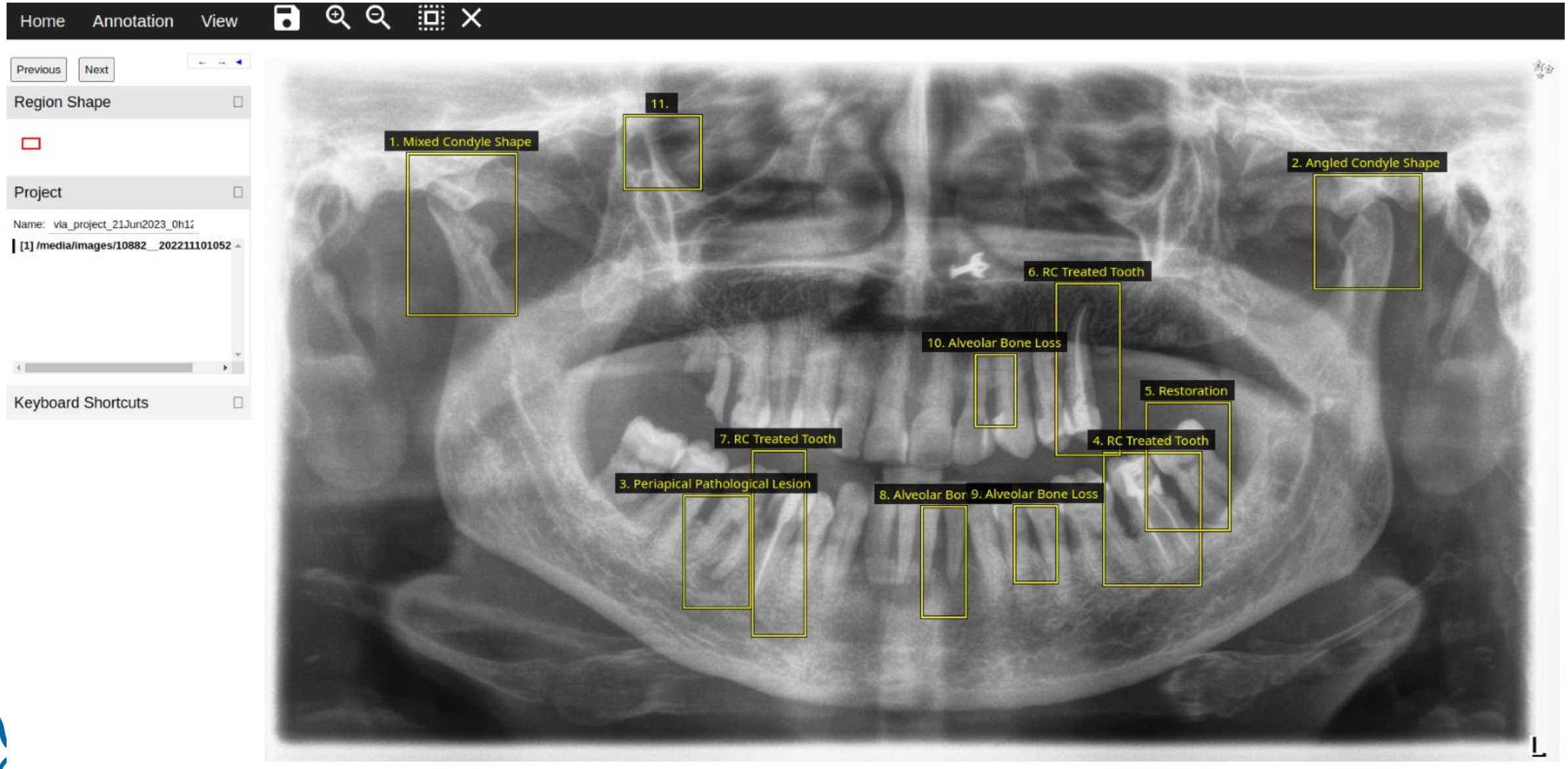
Empowering general-public for prevention and early detection

Broadening the scope of health services in primary and community health centers

Improving quality of health service delivery in overburdened tertiary centers

Understanding biology and human body for better health care

Dental Structures and Anomalies Detection



Key Themes in Nepal's Context

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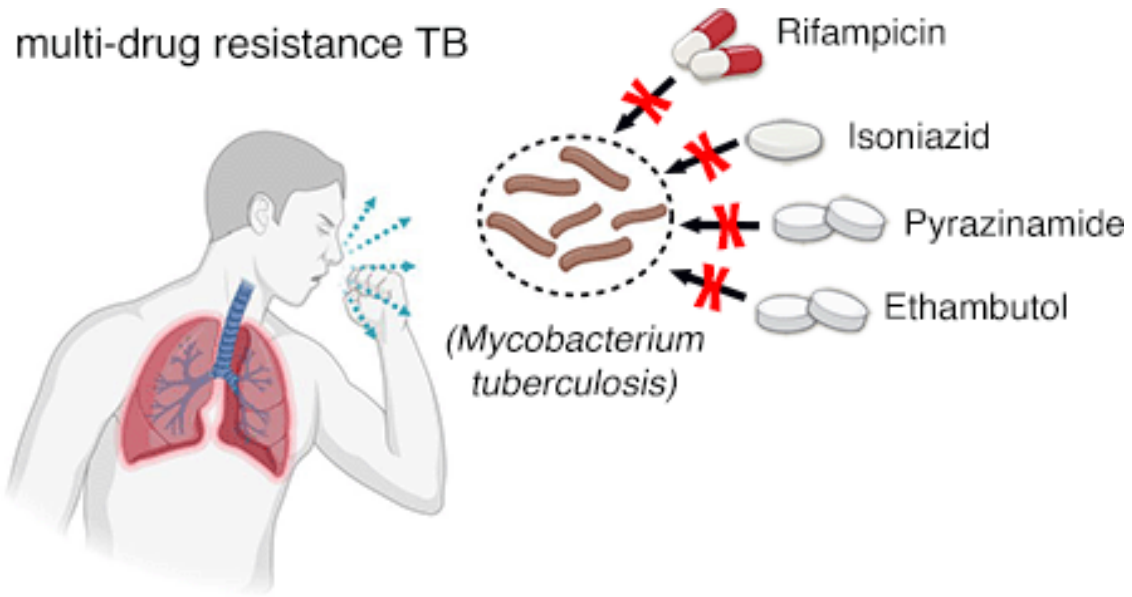
Tuberculosis (TB): a major infectious disease

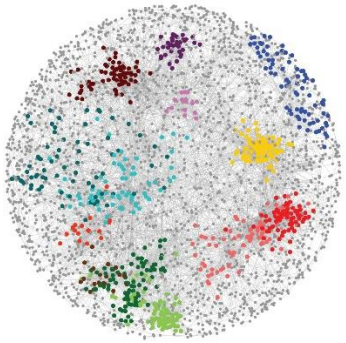


- Nepal has high TB burden
- TB bacteria are spread from person to person through the air
- Multi-drug resistant TB is biggest bottleneck in its eradication
- Gene mutations leading to multi-drug resistant TB are largely unknown

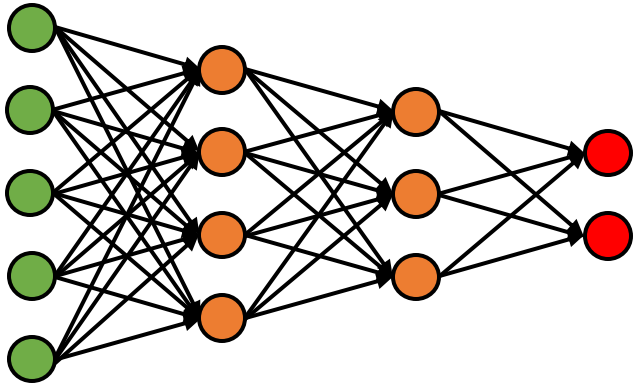
Prediction of multi-drug resistant Tuberculosis

TB mutations

ACCTGCTACACGCGGCAGGCAACTATGCCCAACGG
ATGACAGGACTGCTTGACGGCAAACGGATTCTG
GTTAGCGGAATCATCACCGACTCGTCGATCGCGTTTC
GGAGGTTCCATCGTCGGCATGGACTTCGACCCGACCCGGGCGAT
GTTAGCGGAATCATCACCGACTCGTCGATCGCGTTTC



Protein-Interaction Network



Predicting drug-resistant TB and drug-resistant mutations

Understand mechanisms and interactions of genes

(work under progress)

Outline

Very Brief Intro to NAAMII

Brief Intro to AI

AI avenues in Nepal's Healthcare

Ethical Considerations

AI and Ethics

AI Ethics Survey in Nepal

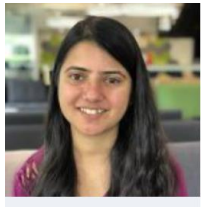
Team: Shreyasha Paudel, Aatiz Ghimire, Bishesh Khanal

Project Goals

The main goal of this project is to do a landscape mapping of understanding and approaches to AI Ethics in Nepal among three key stakeholders: Technology Students, Technology Professionals, and Policymakers.

There is an immense potential of AI in helping positively transform the economic situation of countries like Nepal. However, there is also a big risk that the AI-driven development dramatically broadens the gap of the existing digital divide. In this context, there is a need for national conversation and shared vocabulary among different stakeholders to understand each other's concerns and challenges. A shared vocabulary is necessary between users, policy-makers, activists, and developers of AI to further the growth of the industry in an ethical and responsible manner. This project will fill the gap by doing a survey and publicizing challenges and gaps in understanding of issues related to AI ethics.

The survey design will be informed by state of the research and similar reports published in the global context and link it to gaps and challenges that may exist due to local context within Nepal. The main outcome of this project will be an informational resource that will contribute to an increased understanding and shared vocabulary among multiple stakeholders regarding ethical concerns with AI. We also believe that the insights from this project will be helpful for other developing countries with a rapidly growing AI ecosystem and provide opportunities and shared vocabulary to address ethical concerns among different stakeholders.



Shreyasha Paudel
Adj. Research Fellow

FUTURE-AI: Best practices for trustworthy AI in medicine

FUTURE-AI is an international, multi-stakeholder initiative for defining and maintaining concrete guidelines that will facilitate the design, development, validation and deployment of trustworthy AI solutions in medicine and healthcare based on six guiding principles: Fairness, Universality, Traceability, Usability, Robustness and Explainability.

1

Fairness

The Fairness principle states that medical AI tools should maintain the same performance across individuals and groups of indiv...

Learn More ▸

2

Universality

The Universality principle states that a medical AI tool should be generalisable outside the controlled environment where it wa...

Learn More ▸

3

Traceability

The Traceability principle states that medical AI tools should be developed together with mechanisms for documenting and monito...

Learn More ▸

4

Usability

The Usability principle states that the end-users should be able to use a medical AI tool to achieve a clinical goal efficientl...

Learn More ▸

5

Robustness

The Robustness principle refers to the ability of a medical AI tool to maintain its performance and accuracy under expected or ...

Learn More ▸

6

Explainability

The Explainability principle states that medical AI tools should provide clinically meaningful information about the logic behi...

Learn More ▸

Researchers Involved

FUTURE-AI: International consensus guideline for trustworthy and deployable artificial intelligence in healthcare. Under review

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FUTURE-AI: Trustworthy and Deployable AI in Healthcare

Problems

Errors and patient harm

Biases and increased health inequalities

Lack of transparency and accountability

Lack of data privacy and security breaches

Status

Absence of clear, widely accepted guidelines on how medical AI tools should be designed, developed, evaluated and deployed to be trustworthy

FUTURE-AI: International consensus guideline for trustworthy and deployable artificial intelligence in healthcare. Under review

FUTURE-AI: Trustworthy and Deployable AI in Healthcare

Problems

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Needs

Technically robust, clinically safe, ethically sound and legally compliant

Robustness, safety, security, fairness, transparency, traceability, accountability, generalisability, explainability, usability and responsible AI

Trusted and accepted by patients, clinicians, health organisations and authorities

FUTURE-AI: International consensus guideline for trustworthy and deployable artificial intelligence in healthcare. Under review

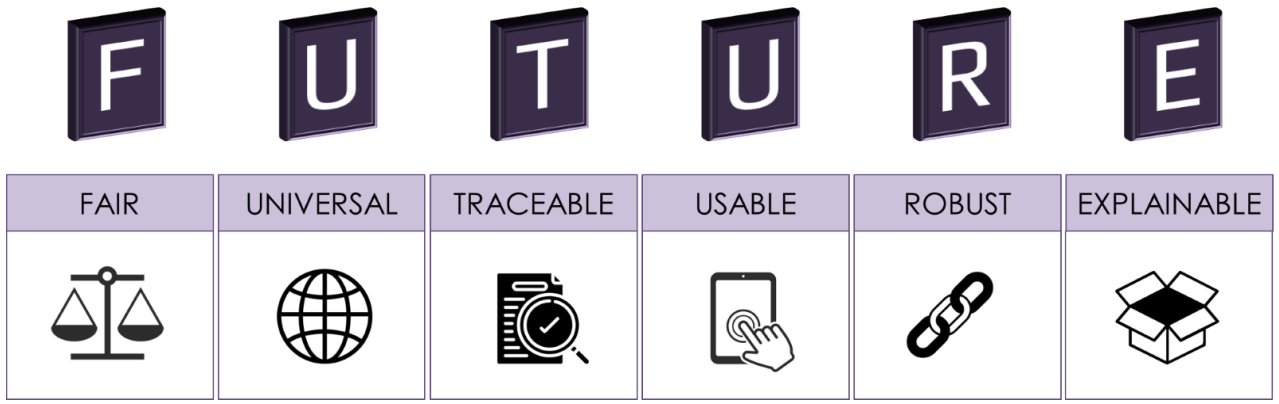
FUTURE-AI: Trustworthy and Deployable AI in Healthcare

Guidance for constructing medical AI tools that will be trusted, deployed and adopted in real-world clinical practice

A set of 28 best practices addressing technical, clinical, legal and socio-ethical dimensions of trustworthy AI

Covers the entire lifecycle of medical AI, from design, development and validation to regulation, deployment, and monitoring

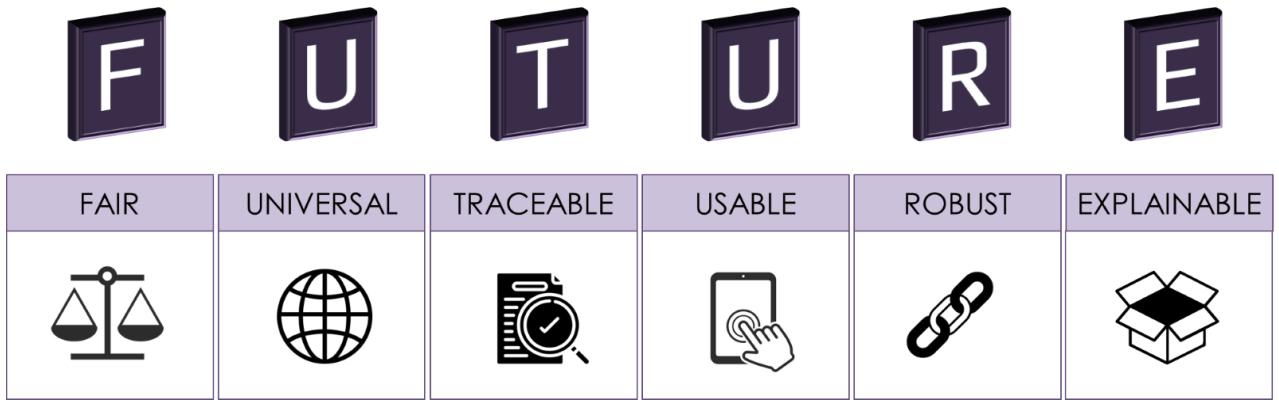
FUTURE-AI: International consensus guideline for trustworthy and deployable artificial intelligence in healthcare. Under review



Fair: Same performance across individuals and groups of individuals (including under-represented and disadvantaged groups)

Universal: Generalisable outside the controlled environment where it was built; to new patients and new users (e.g. new clinicians), and when applicable, to new clinical sites

Traceable: Mechanisms for documenting and monitoring the complete trajectory of the AI tool, from development and validation to deployment and usage



Usable: The end-users should be able to use a medical AI tool to achieve a clinical goal efficiently and safely in their real-world environment; easy functionalities and interfaces with minimal errors + clinically useful and safe

Robust: The ability of a medical AI tool to maintain its performance and accuracy under expected or unexpected variations in the input data. Existing research has shown that even small, imperceptible variations in the input data may lead AI models into incorrect decisions

Explainable: Medical AI tools should provide clinically meaningful information about the logic behind the AI decisions

FUTURE-AI: International consensus guideline for trustworthy and deployable artificial intelligence in healthcare. Under review

Ethical Considerations in AI research and product development

Problem Definition

Data Collection

Data Preprocessing

Training AI Model

Clinical Decision Making

Diagnosis and Treatment

Ethical Considerations in AI research and product development

Problem Definition

Who chooses the problems to solve?

What problems to solve?

Capacity, funding, …

Ethical Considerations in AI research and product development

Problem Definition

Who chooses the problems to solve?

What problems to solve?

Capacity, funding, …

Mindset?

Ethical Considerations in AI research and product development

Data Collection

Data Preprocessing

Training AI Model

(Digital) Data infrastructure and culture of recording data

Privacy, anonymization, information security

Preprocessing for one database may not work for another database

GPU and computational power availability

Ethical Considerations in AI research and product development

Retrospective Data

- Informed consent? Waiver?
- E.g. 10 Lakhs X-ray images from different hospitals -> anonymized and shared

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Personally Identifiable data vs not ?

- Cervix images
- Neuromascular disease severity from facial deformities (Dystonia)
- EMR data anonymized, registry data

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Sample size and statistical evaluation

- Sample size calculation during AI methods development is an open problem
- Model development and research is different from evaluating model's performance

Ethical Considerations in AI research and product development

Research and Product development

- Capacity development and building ability to build products in Nepal Vs
- Exploitated and the status of perpetually being consumer from foreign companies Vs
- Providing patients the best that is available in the world to save lives or improve quality

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- Regulations in Nepal for AI Software? Accountability? DDA?

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AI product regulations

- Evaluation: where and in what context?
- E.g. cervical pre-cancer detection accuracy: AI vs Gynecologist or AI vs nurses

AI: An Opportunity to Democratize Innovation in Medicine

Recent advances in Artificial Intelligence (AI) provides us a unique opportunity

Cutting edge and frontier research in medicine possible

Many problems relevant to Nepal and global south NEEDS cutting edge research but are GLOBALLY NEGLECTED

Identify REAL problems, Frontier research Needed & Possible!

Sustainability through innovation & entrepreneurship!!

Need to build facilitative contextualized regulations with no harm principles