Application of Artificial Intelligence

Radhakrishnan Delhibabu

School of Computer Science and Engineering
Vellore Institute of Technology (VIT), Vellore
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First words...

Thanks for invited me for the seminar.

Special Thanks...

Prof. Dr. Marat Arslanov, Chair of Algebra and Mathematical Logic and Head of Mathematical center, Kazan Federal University.
Prof. Dr. Kalimullin Iskander Head of Department, Artificial intelligence and digitalization of mathematical knowledge, Kazan Federal University.

Outline

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About my University

VIT

- Vellore Institute of Technology (VIT), India
- One among the Top 10 and the only private institution of India (Shanghai ARWU Ranking 2021)
- Ranked within the top 200 in Asia (QS - Asia University Rankings 2022)
- Seven Subjects of VIT are ranked by QS World University Ranking by Subject 2021
- 12th best research institution of India (NIRF Ranking, Govt. of India 2021)
- 12th best engineering institution of India (NIRF Ranking, Govt. of India 2021)
- NAAC Accreditation with the highest grade in the last three consecutive cycles
- Recognized as Institution of Eminence(IoE), Govt. of India

My PhD Scholars

PhD Scholars: Ramesh Kumar, Ankareddy Rajesh, Sobana Sumi and Shaik Mohammed.

My Project Collaborators

Collaborators: Dr. A. T. Prabhakar, (Neurology, CMC Hospital) Dr. Natesan Damodaran (Neurosurgeon, Amrita Hospital), Prof. Sisir Roy (NIAS) Prof. Vijaianand (VIT) and Prof. Balakrishnan (VIT)

Working Title AI - Project

- Dynamic of Belief: Abduction, Horn Knowledge Base And Database Update (Applied Mathematical Logic) - SERB
- AI-based Automated remote VEEG console (Cognitive Science) - DBT
- Rapid, non-invasive diagnosis of COVID-19 infection and comorbidities (Bio Science) - DST
- Securing Networking Medical Device (Blockchain) - DRDO

Working Title AI - My PhD Scholars

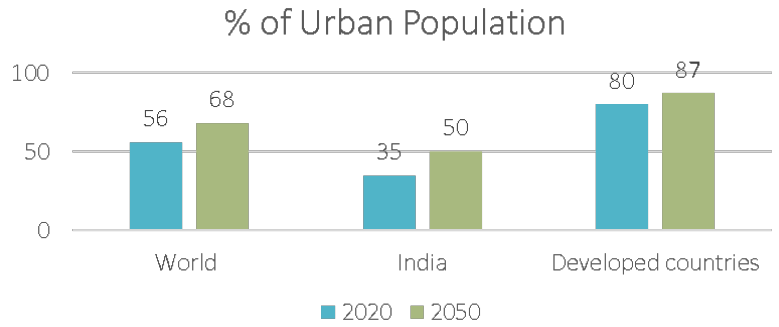
- Applicability of Machine Learning Algorithms to Predict Data Center Anomalies
- Precise Urban Waterbody Management (PUWM) using DEM, IOT & Analytics
- Understanding Brain-computer interface control via functional connectivity of Neocortex and Hemodynamic Responses of Meditation in Human Brain Related to Memory and Emotional Processing.
- Brain Tumor classification using Deep Learning Techniques in Histology Images.

Outline

Precise Urban Waterbody Management (PUWM)

Precise Urban Waterbody Management (PUWM) - Why?

- Urbanization is inevitable
- % of urban population is expected to increase, more significantly in developing countries



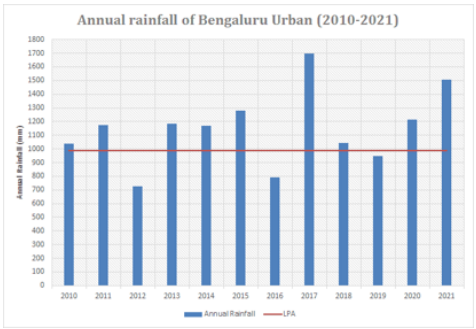
Source: UN (World Urbanization Prospects 2018)

- Rapid urbanization causing severe strain on the urban waterbodies
- Urbanization to be more sustainable
- There is a need for Urban Waterbody management system

Bangalore Waterbodies Scenario

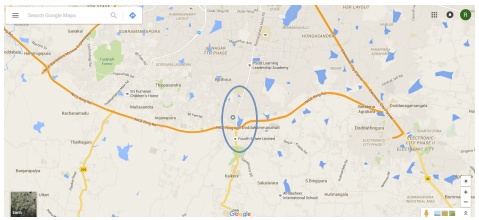
- In 1960s, number of lakes around 920
- In 2014, Only 210 of lakes identified by Bangalore authorities
- Of these 210 lakes, only a few are in good state

PUWM - Why?...



Src: https://bengaluru.citizenmatters.in/

Above average rainfall last two years



Src: Google Earth

Gottigere, South Bangalore

Gottigere Lake

Basavannapura Lake

Hulimavu Lake

Basavannapura Lake

PUWM - Why?..Smart Water Management (SWM)

- Water management is evolving towards ICT enabled Smart Water Management (SWM)

- SWM consists of
  1. Smart Devices
  2. Smart Solution
  3. Smart Service

Source: Choi, G.W., Chong, K.Y., Kim, S.J. et al. SWMI: new paradigm of water resources management for SDGs. Smart Water 1, 3 (2016). https://doi.org/10.1186/s40713-016-0002-6

- Smart Water Management (SWM) can be categorized as
  1. Integrated Water Resource Management (IWRM) - Source
  2. Smart Water Grid (SWG) - Distribution

PUWM Why?... Potential IWRM solution

An IWRM solution consists of spatially correlated IoT Based Hydro Informatics , Hydro Model and Analytics

<table>
<tr><th>Hydro Informatics</th><th>Digital Watershed</th><th>Analytics</th></tr>
<tr><td>Watershed snapshot
Vol. and Flow Data
Alert and Events</td><td>Spatial and Attribute
Earth Observations
Imagery etc.</td><td>Actual Data - from In situ sensors</td></tr>
<tr><td rowspan="3">Watershed Historical Reporting</td><td>Land Use
Transport network
Utility network
Administrative etc.</td><td>Predicted Data - from Hydro model</td></tr>
<tr><td rowspan="2">Hydro Model</td><td>Best Case Data - from No land use scenario</td></tr>
<tr><td>What-if Data - from What-if model</td></tr>
</table>

IWRM challenges in Urban Waterbody Management

Challenges in UWM
Dynamic nature of urban waterbody catchment
Sensitivity to deviation

Key Considerations in UWM
Adaptability to catchment changes
High Solution Accuracy

- IWRM is instituted to study River Watersheds and the same might not be applicable for urban waterbody environments
- There is a need for an IWRM system suitable for managing urban waterbodies Precise Urban Waterbody Management (PUWM)

PUWM Goals & Objectives

Goals
Monitor the status of water body
Identify the problems in catchment of water body
Assess the Impact of proposed land use changes
Identify solutions for current problems and potential problems due proposed land use changes

Objectives	High Accuracy	High Adaptability
Deep Leaning based Earth observation data from VHR images and Synthetic Aperture Radar for spatial & attribute data, Land use data		
Machine Learning based Intelligent Urban Runoff Model		
Hydro informatics using IoT based solution with WSN at core		
Hydro Analytics to identify current problems and predict impact of proposed land use		

Research Problem

A proven approach for Precision Based Urban Waterbody Management (PUWM)

1	**Architecture for Precise Urban Waterbody Management [PUWM]**
	Design considerations and Architecture Approach for the Precise Urban Waterbody management
2	**ML based Intelligent Hydrological model for the PUWM**
	The hydrological model to have capability to take in data of the digital catchment, meteorological input (rainfall) and compute the various hydrological processes like surface runoff at the precision required by PUWM
3	**Develop an adaptive and repeatable approach for digitalization of a urban waterbody catchment using deep learning**
	A Digital catchment of a waterbody should include • Digital Earth Model(elevation, terrain and surface) • Spatial and attribute data of waterbody • Land use, transport network, utility network

Research Problem...

A proven approach for Precision Based Urban Waterbody Management (PUWM)

4	**IoT based Hydro Informatics system suitable for PUWM**
	PUWM Hydro Informatics system to handle volumetric and flow data and derived events/alerts in the catchment both real time and also of archived data for a specific time slot. PUWM Hydro informatics solution to contain suitable WSN that includes suitable sensor network topology, access technology etc.)
5	**PUWM Hydro analytical system**
	PUWM Hydro Analysis component should facilitate a comparative analysis and volume and flow data between the following sources and identify the problems in catchment • Actual - Data from In-Situ sensors • Predicted - Data from PUWM Hydro model • What-if - Data from What-if model • Best Case Data from No land use scenario

PUWM - Results

Primary outcome: A proven approach that helps to

1. Rejuvenate the existing degenerated waterbodies
2. Avoid the negative effects on waterbodies due to inevitable future urbanization

1. Architecture for Precision Urban Waterbody Management (PUWM)
2. Evaluated ML based Intelligent Hydro Model for PUWM
3. A proven approach for a Deep Leaning based Digital Catchment
4. A proven approach for a IOT based Hydro Informatics system for PUWM
5. A proven approach for PUWM Hydro Analytical system

Tumor Classification Using Deep Learning Techniques

Tumor Classification Using Deep Learning Techniques

- Medical image - clinical information for diagnosis.
- Extract features.
- Patient healthcare early detection, diagnosis,disease prevention and treatment.
- Various Image modalities.
- Histology Image - presence or absence of disease, disease grading, effect on tissues.
- Quantitative image analysis - image analysis, pathology.

Histology Image

- Signs of disease under microscope (staging and grading).
- Sectioning - frozen, paraffin.
- Staining - H & E.
- Fluorescent and bright field microscope.

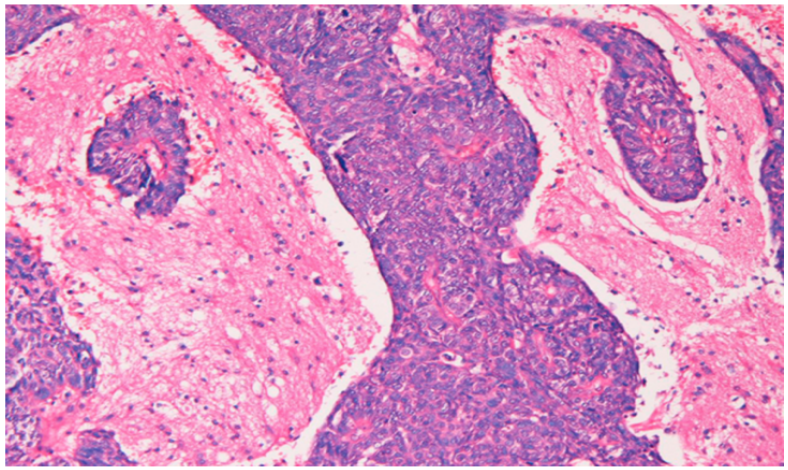


Figure: Hematoxylin and eosin stained image of brain tumor

Image downloaded from www.researchgate.net

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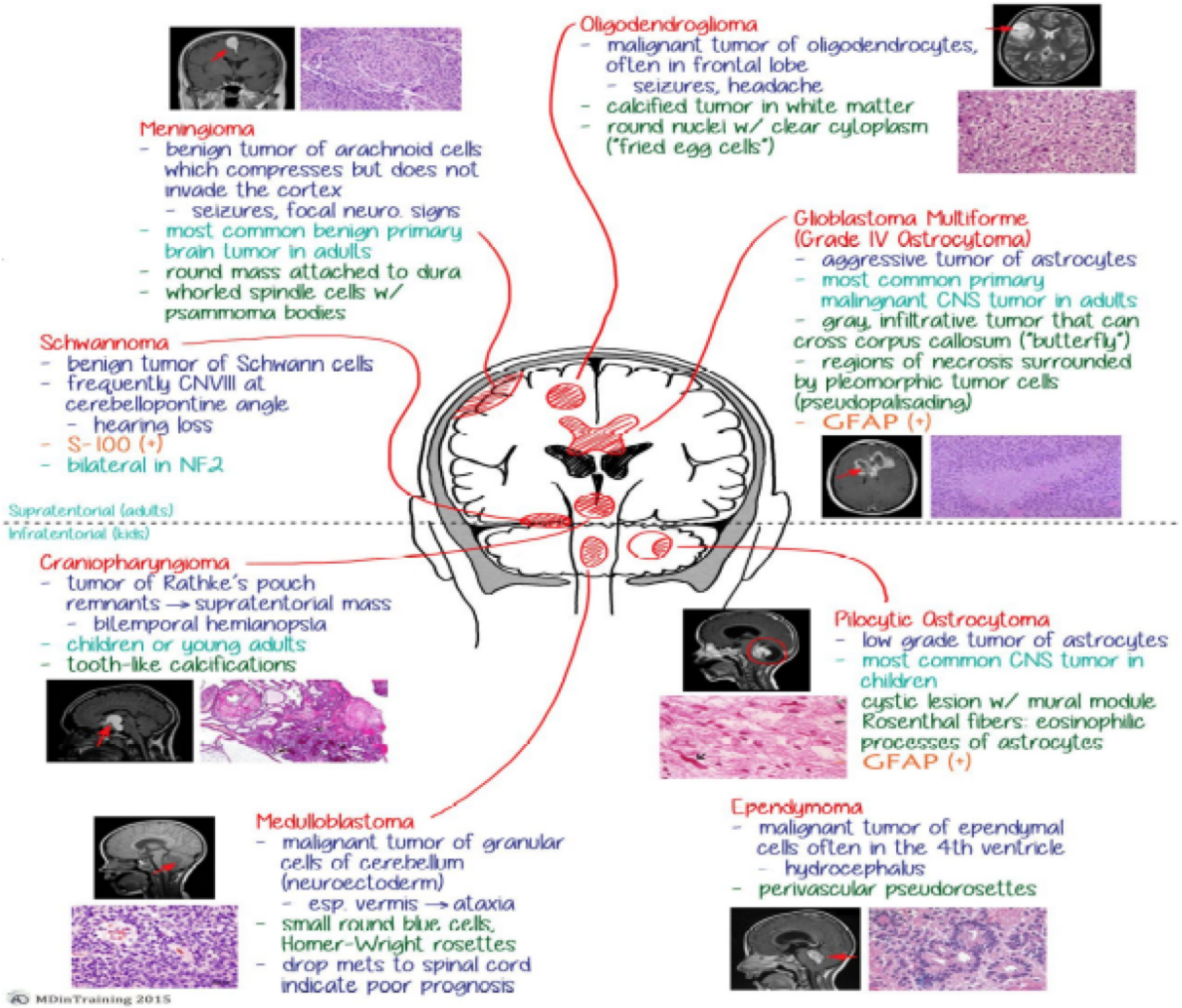

Figure: Brain Tumor Classification

Image downloaded from www.pathologyoutlines.com

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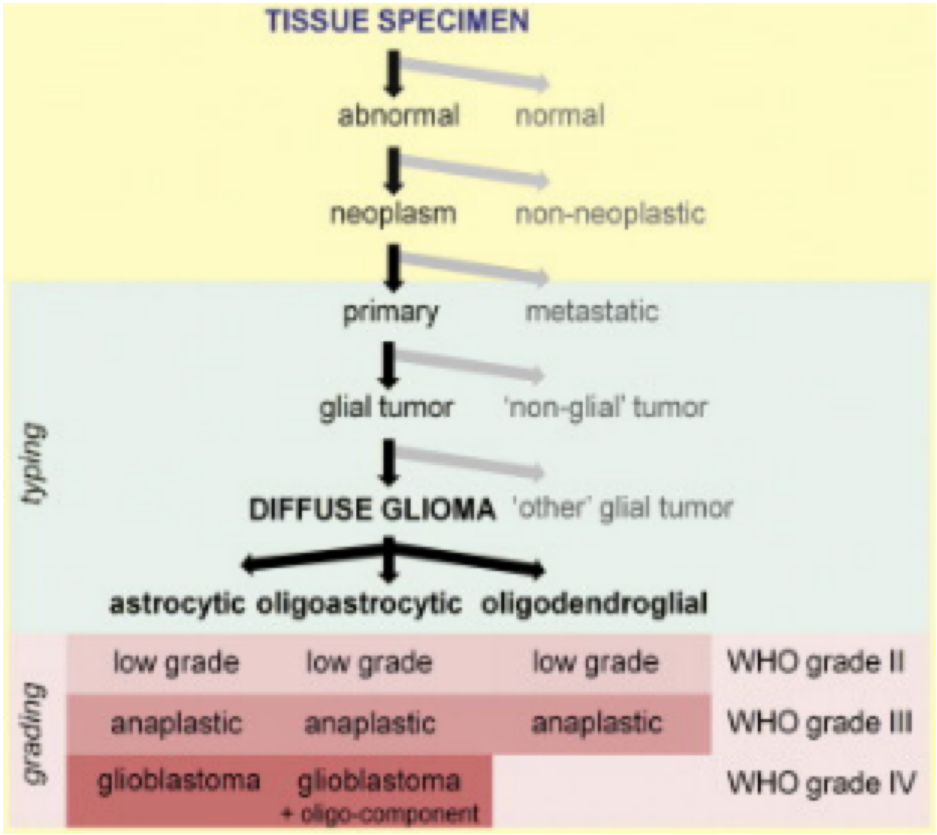

Figure: Grades Of Brain Tumor

Image downloaded from www.pathologyoutlines.com

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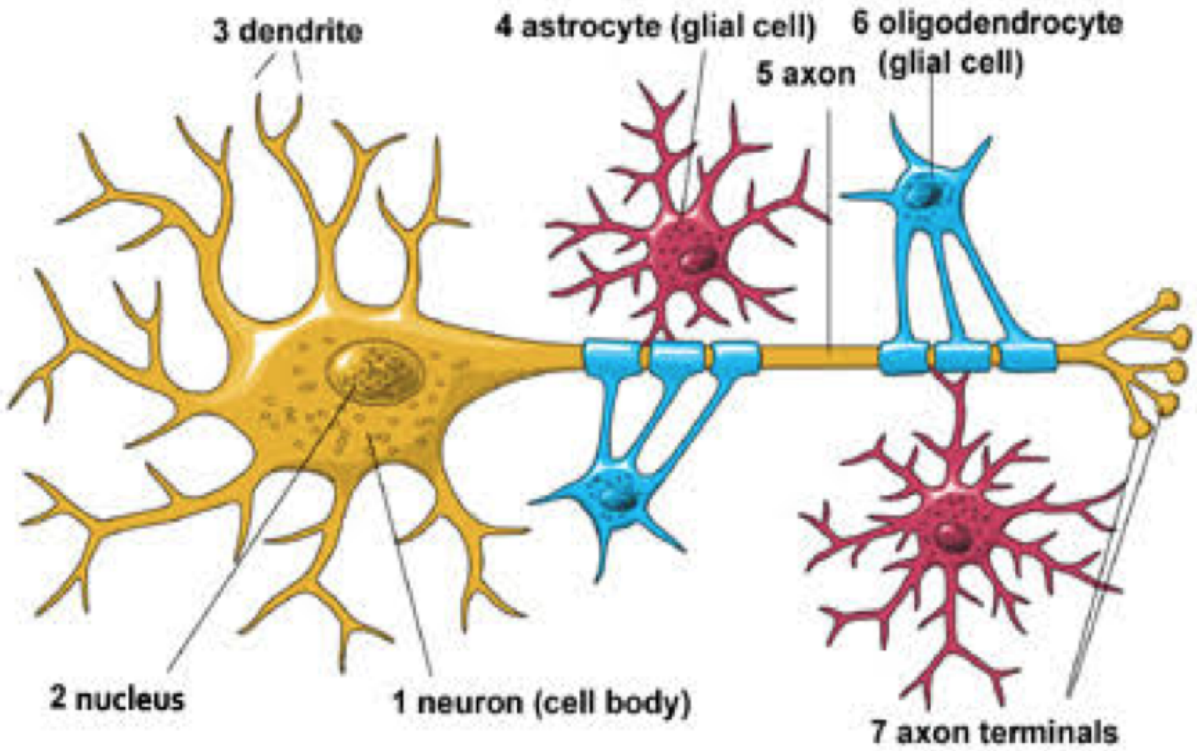

Figure: Internal Structure Of Brain With Tumor Identification

Image downloaded from www.pathologyoutlines.com

Deep Learning

- Enhance performance of existing machine learning.
- Good results-detection, segmentation, classification.
- Neural Networks architectures-human like decision.
- Deep neural networks-ANN, CNN, RCN, etc.

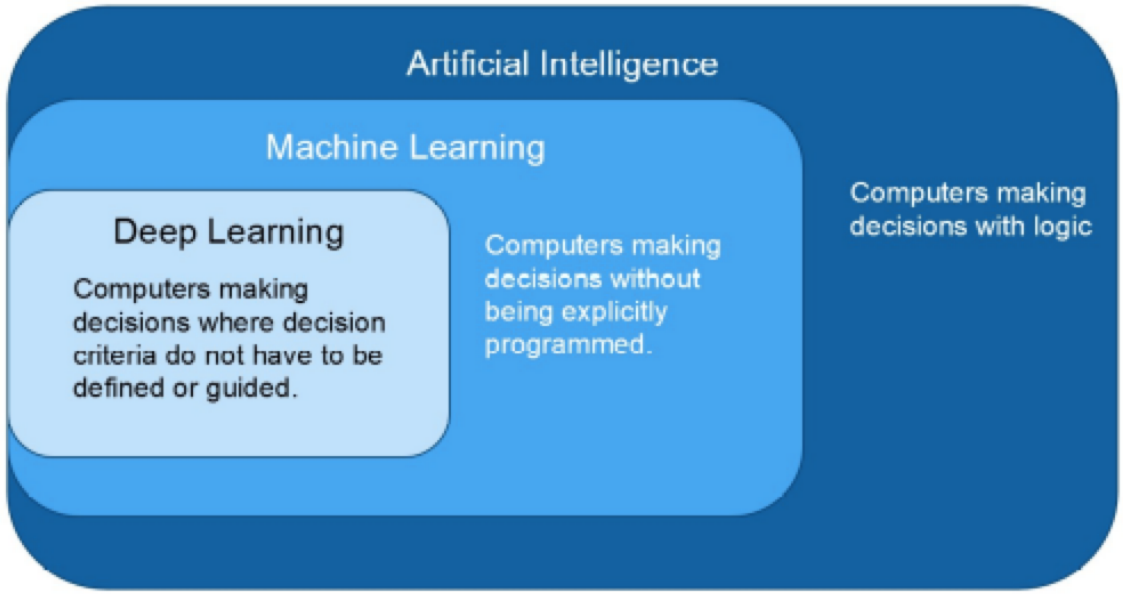

Figure: Image describing Deep Learning, Machine Learning and Artificial Intelligence

Image downloaded from Google

Motivation

- Cancerous tumor features are hard to detect.
- Light and fluorescence microscope provide low resolution of nano particles in tissue selection.
- Cell types, evaluating nano particles of bio distribution of brain - limited tissues.
- High execution time.
- To reduce pathology time in benign tumor.

Problem Statement

- Complex clinical representation.
- Time consuming - several slides with multiple staining.
- Lack of dataset - training, quality labelled data.
- Large size of single image - more information on report.
- Less accuracy with high execution time.

Research Objective

- To analyses, malignant characteristics of the tumor based on histopathological molecular features.
- To discriminate accurate overall survival - color, shape and size.
- To get better classification accuracy by Convolution Neural Network.
- Molecular features - Nuclear atypia, mitotic cells, microvascular proliferation, pseudopalisiding necrosis, large blood vessels.

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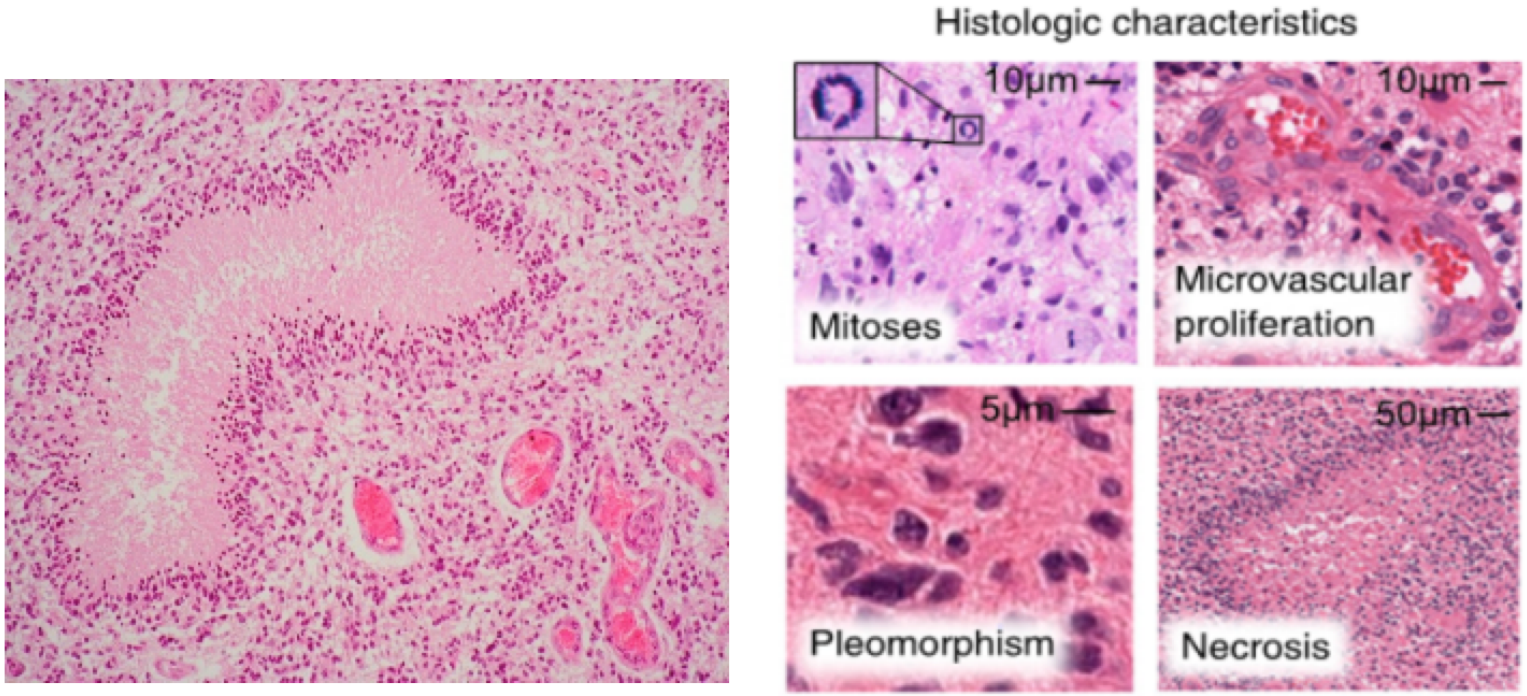

Figure: Histopathology Image Of Brain Tumor With Molecular Features

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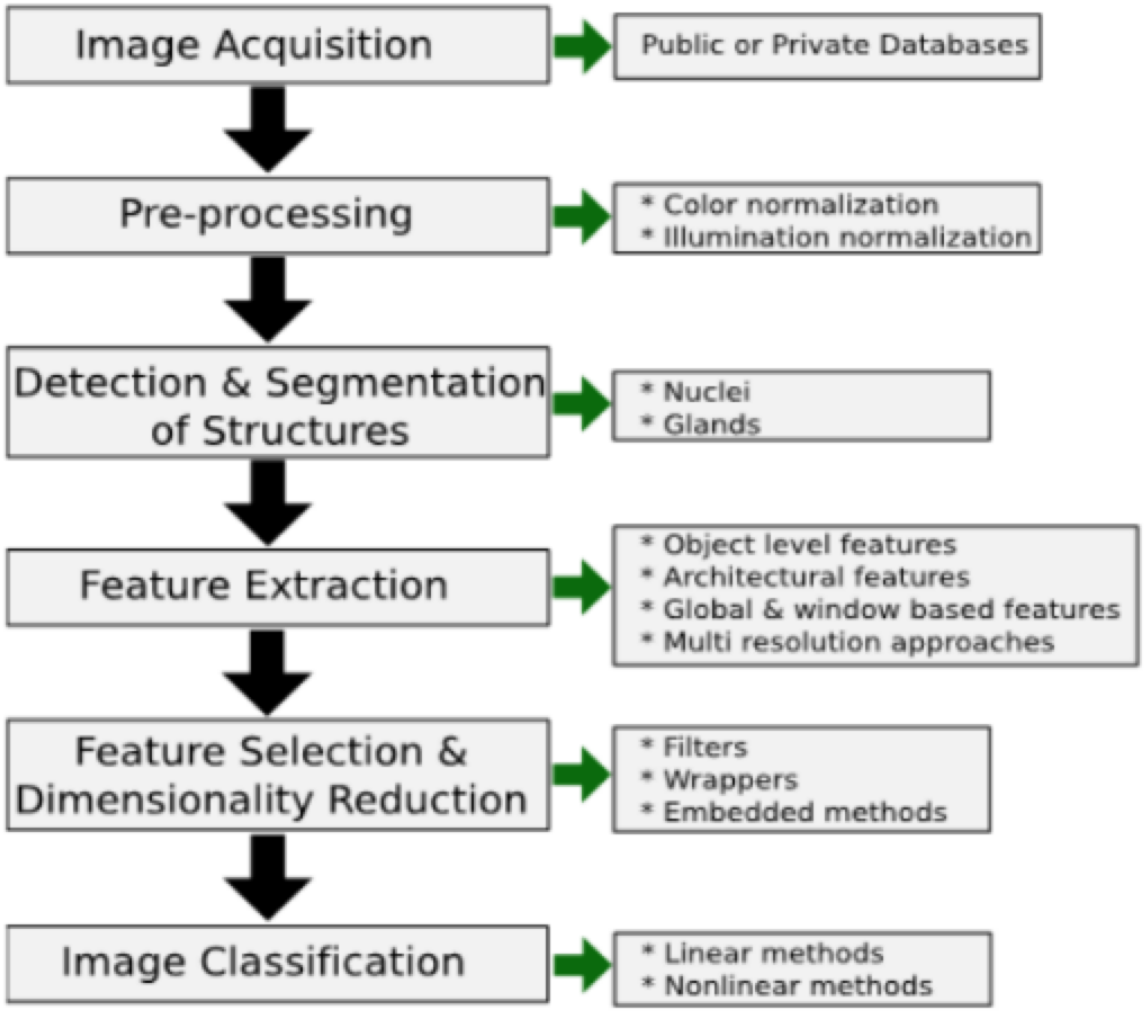

Figure: Machine learning steps in histology image

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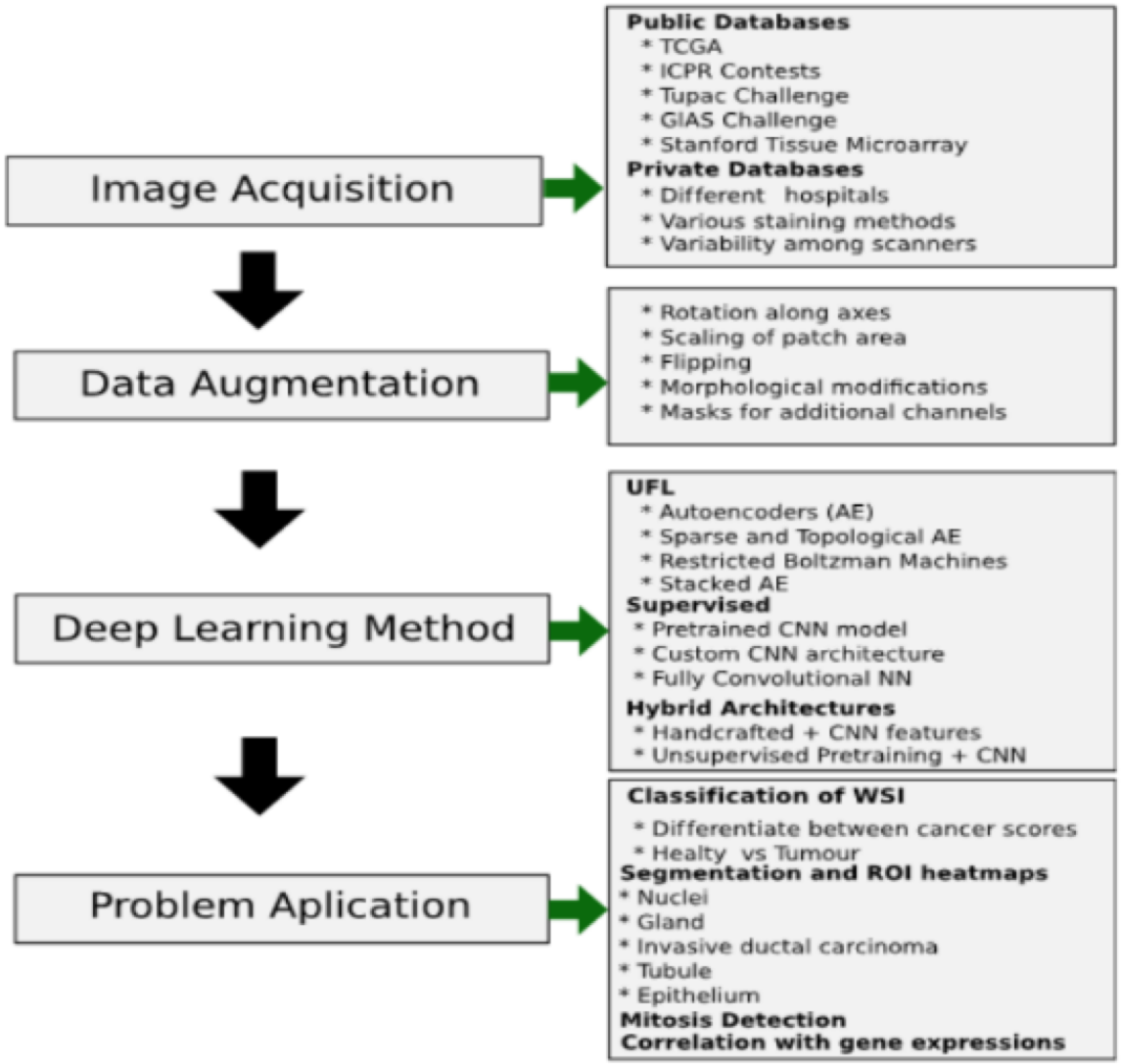

Figure: Deep learning steps in histology image

Convolution Neural Network

- Convolution with filter
- Non-linear
- Pooling
- Fully Connected Layer
- Training and Testing
- Backpropagation

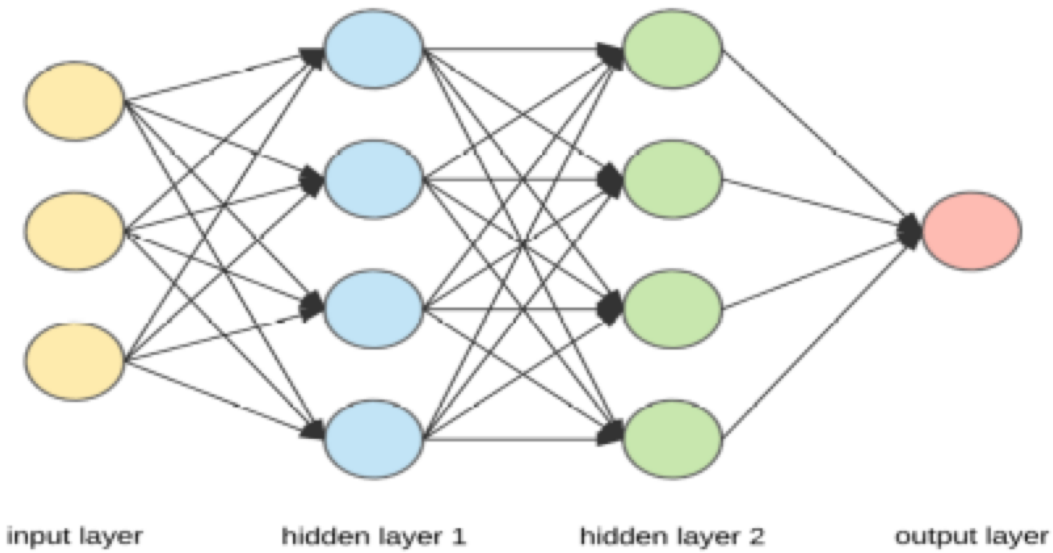

Figure: Neural Network

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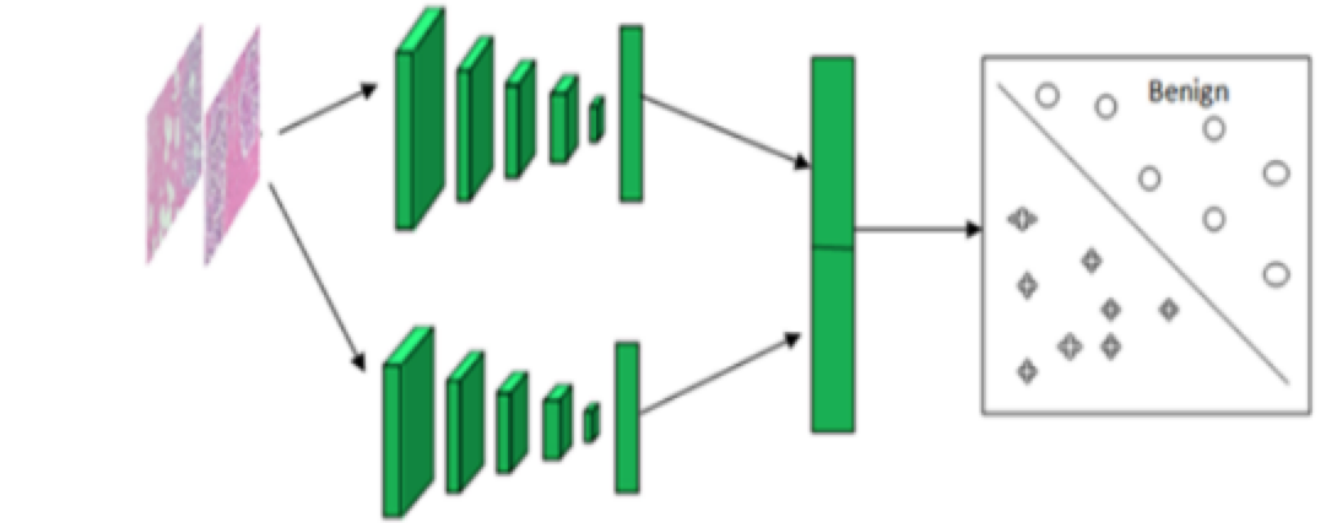

Figure: Histology image classification as benign or malignant

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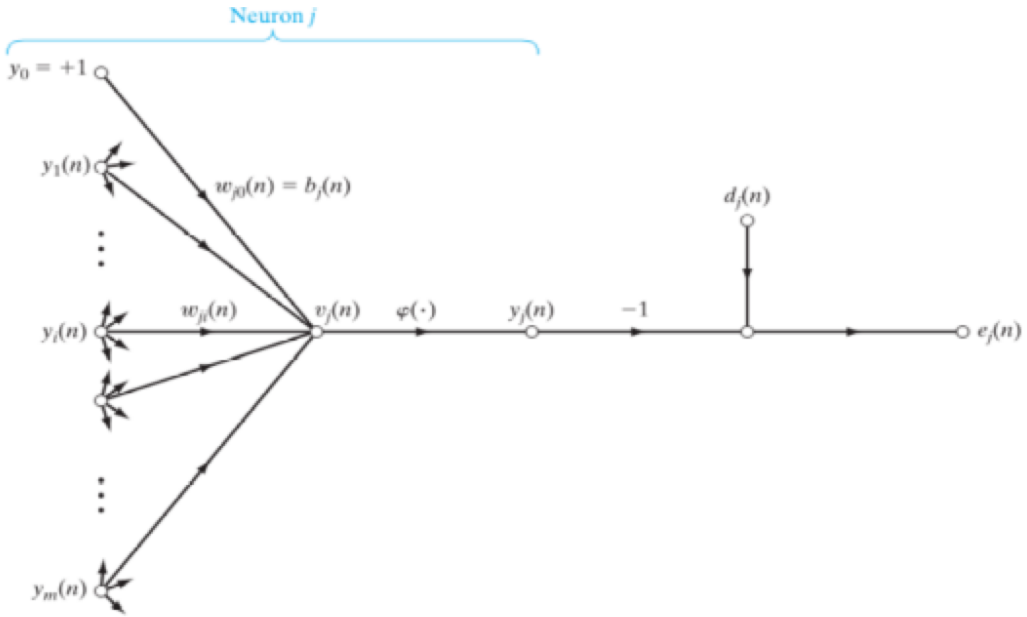


$$e_j(n) = d_j(n) - y_j(n) \quad 1$$

$$\mathscr{E}_j(n) = \frac{1}{2}e_j^2(n) \quad 2$$

$$\mathscr{E}(n) = \sum_{j \in C} \mathscr{E}_j(n) = \frac{1}{2}\sum_{j \in C} e_j^2(n) \quad 3$$

$$v_j(n) = \sum_{i=0}^{m} w_{ji}(n) y_i(n) \quad 4$$

$$y_j(n) = \varphi_j(v_j(n)) \quad 5$$

$$\frac{\partial \mathscr{E}(n)}{\partial w_{ji}(n)} = \frac{\partial \mathscr{E}(n)}{\partial e_j(n)} \frac{\partial e_j(n)}{\partial y_j(n)} \frac{\partial y_j(n)}{\partial v_j(n)} \frac{\partial v_j(n)}{\partial w_{ji}(n)} \quad 6$$

$$\frac{\partial \mathscr{E}(n)}{\partial e_j(n)} = e_j(n) \quad 7$$

$$\frac{\partial e_j(n)}{\partial y_j(n)} = -1 \quad 8$$

$$\frac{\partial y_j(n)}{\partial v_j(n)} = \varphi_j'(v_j(n)) \quad 9$$

$$\frac{\partial v_j(n)}{\partial w_{ji}(n)} = y_i(n) \quad 10$$

$$\frac{\partial \mathscr{E}(n)}{\partial w_{ji}(n)} = -e_j(n)\varphi_j'(v_j(n))y_i(n) \quad 11$$

$$\Delta w_{ji}(n) = -\eta \frac{\partial \mathscr{E}(n)}{\partial w_{ji}(n)} \quad 12$$

$$\Delta w_{ji}(n) = \eta \delta_j(n) y_i(n)$$

$$\delta_j(n) = \frac{\partial \mathscr{E}(n)}{\partial v_j(n)} = \frac{\partial \mathscr{E}(n)}{\partial e_j(n)} \frac{\partial e_j(n)}{\partial y_j(n)} \frac{\partial y_j(n)}{\partial v_j(n)} = e_j(n)\varphi_j'(v_j(n))$$

Figure: Backpropogation

Con...

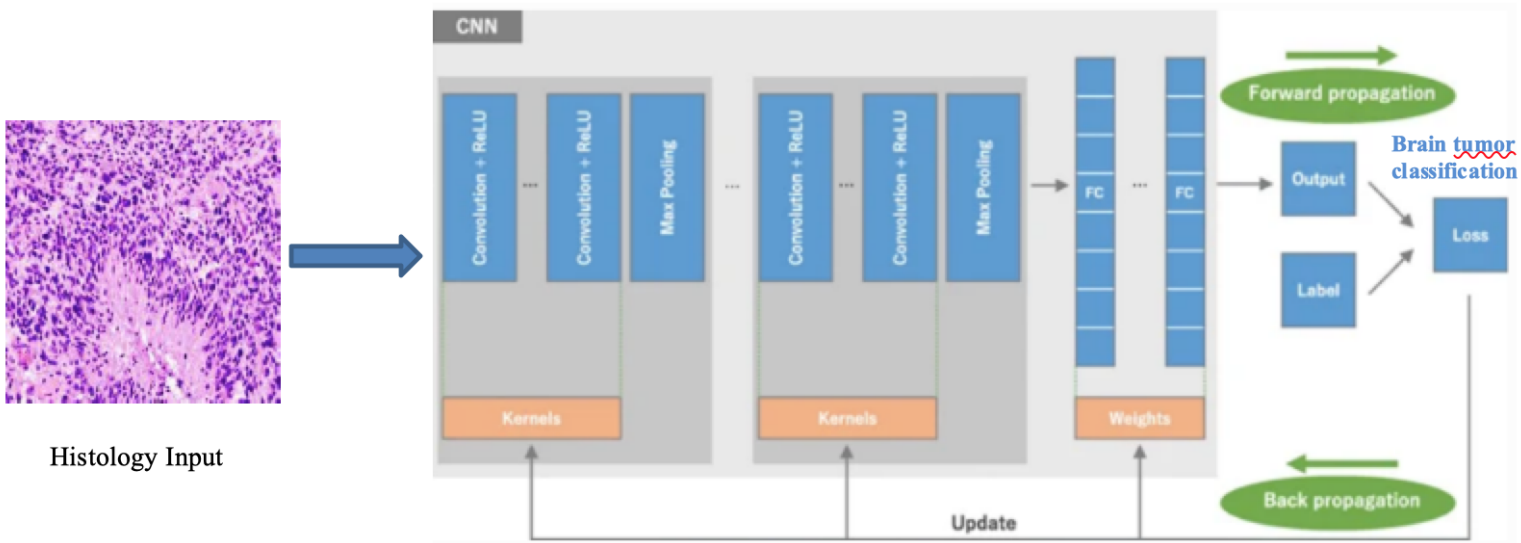


Figure: Processing steps of proposed system

Outline

Automated Tele-Video EEG facility

Automated Tele-Video EEG facility

- Electroencephalogram (EEG) is vital for making diagnosis and treatment for epilepsy. Currently available EEG machines are very expensive and human resource intensive. This prevents care to be provided at non-urban areas.
- Late diagnosis, Lack of access to an appropriate medical specialist, Lack of evaluation tools at semi-urban and rural areas and Poor medicine access
- To reduce the treatment for this disabling disease, the diagnostic tools should be available at the taluk and districts hospitals

Objective

- To develop an automated Tele-Video-EEG machine
- To explore and study validation of efficacy and safety
- To get the approval of the Central Drugs Standard Control Organization CDSCO
- To explore manufacturing and sales of this Automated Tele-EEG machine
- To get user feedback and iterate our Automated Tele-EEG machine n subsequent versions

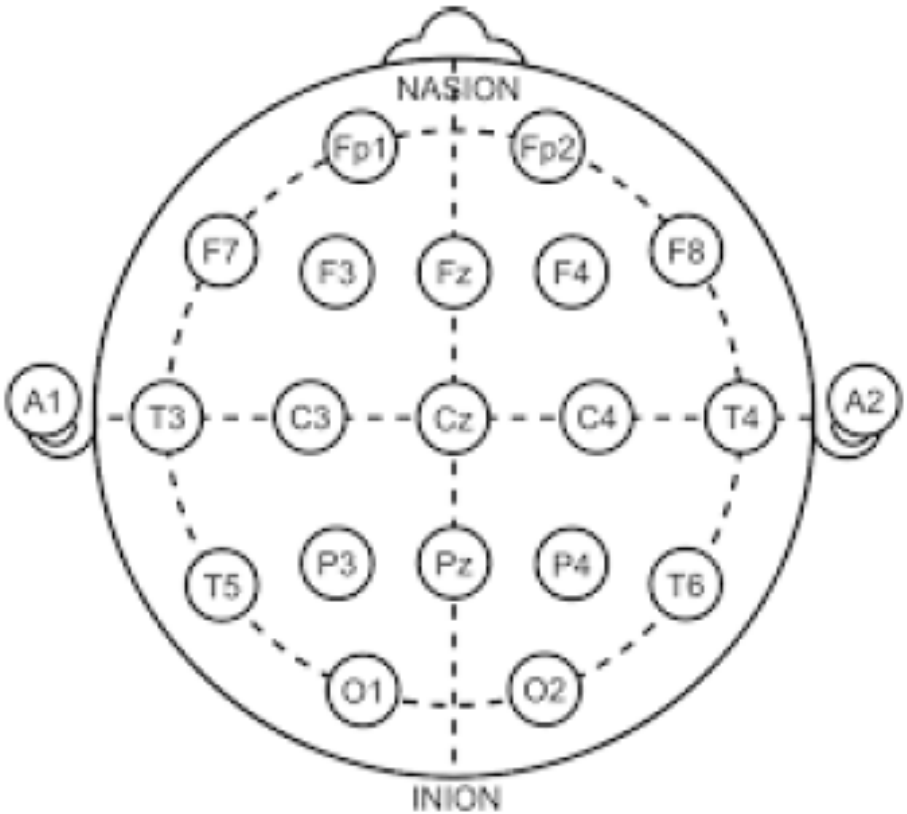
Opportunity

We proposed to develop and validate an Automated Tele-EEG facility with following qualities:

- Easy to use minimize training and maintenance.
- A robust in-built error identifying and alerting system.
- Patient-friendly - pain-free and mobile.
- Digitally transmit the signals to the central reporting center and provide a report at the Point-Of Contact.
- Real-time use of AI in spike and artifact detection in the community setting.
- Resting-state analysis in the community setting using AI.
- To be a part of the telemedicine system
- Cost-effective

Automated Tele-Video EEG facility

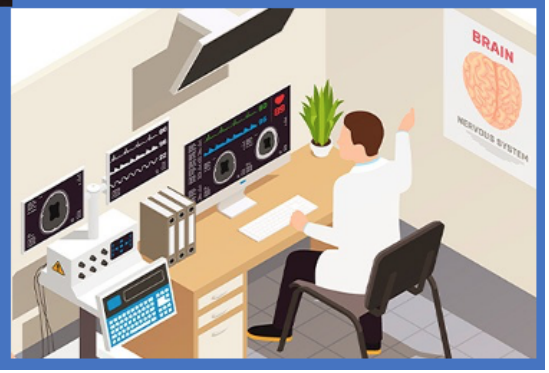
Electrode locations of International 10-20 system for EEG (electroencephalography) recording



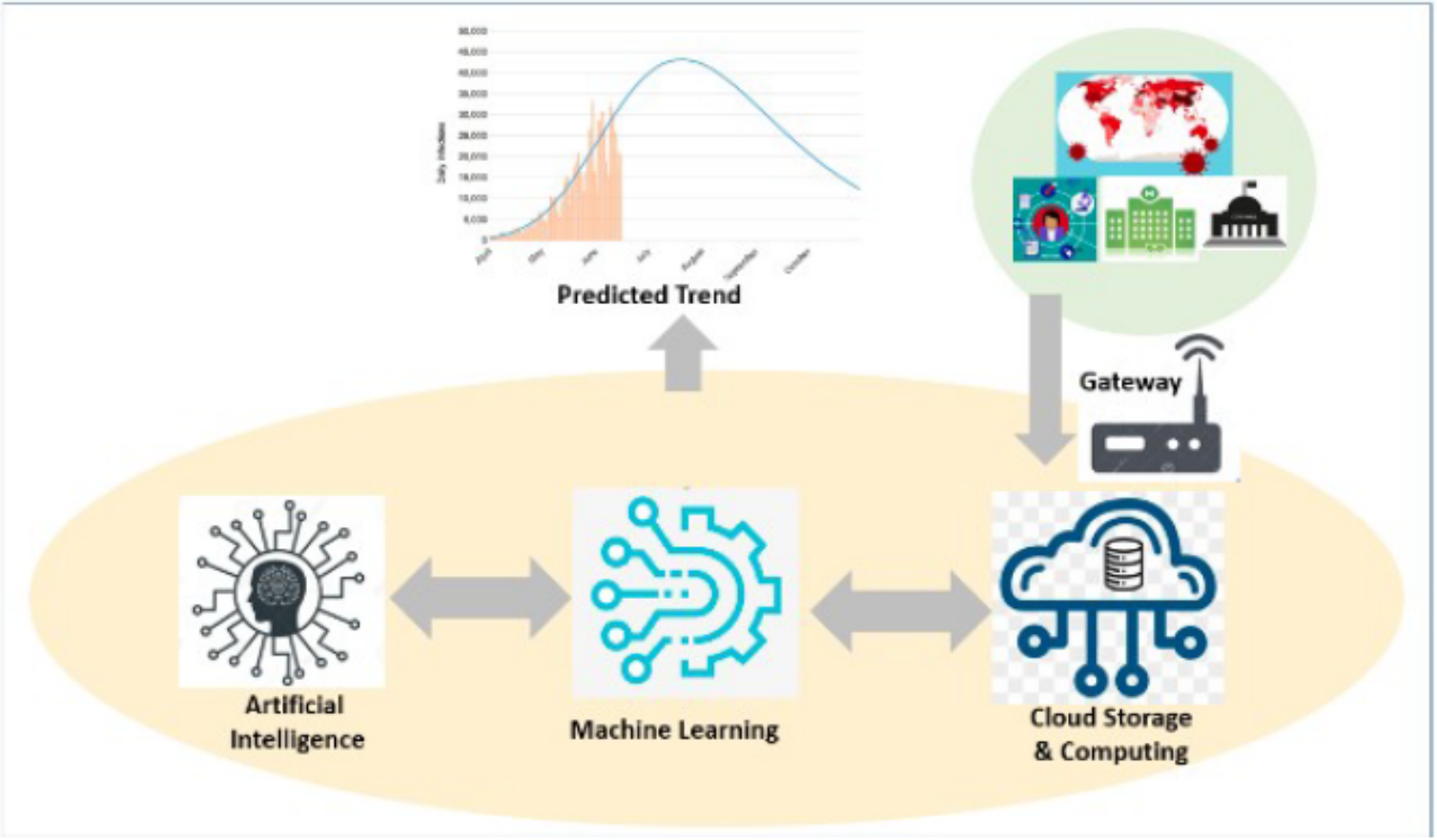
Layout of EEG

Automated Tele-Video EEG facility

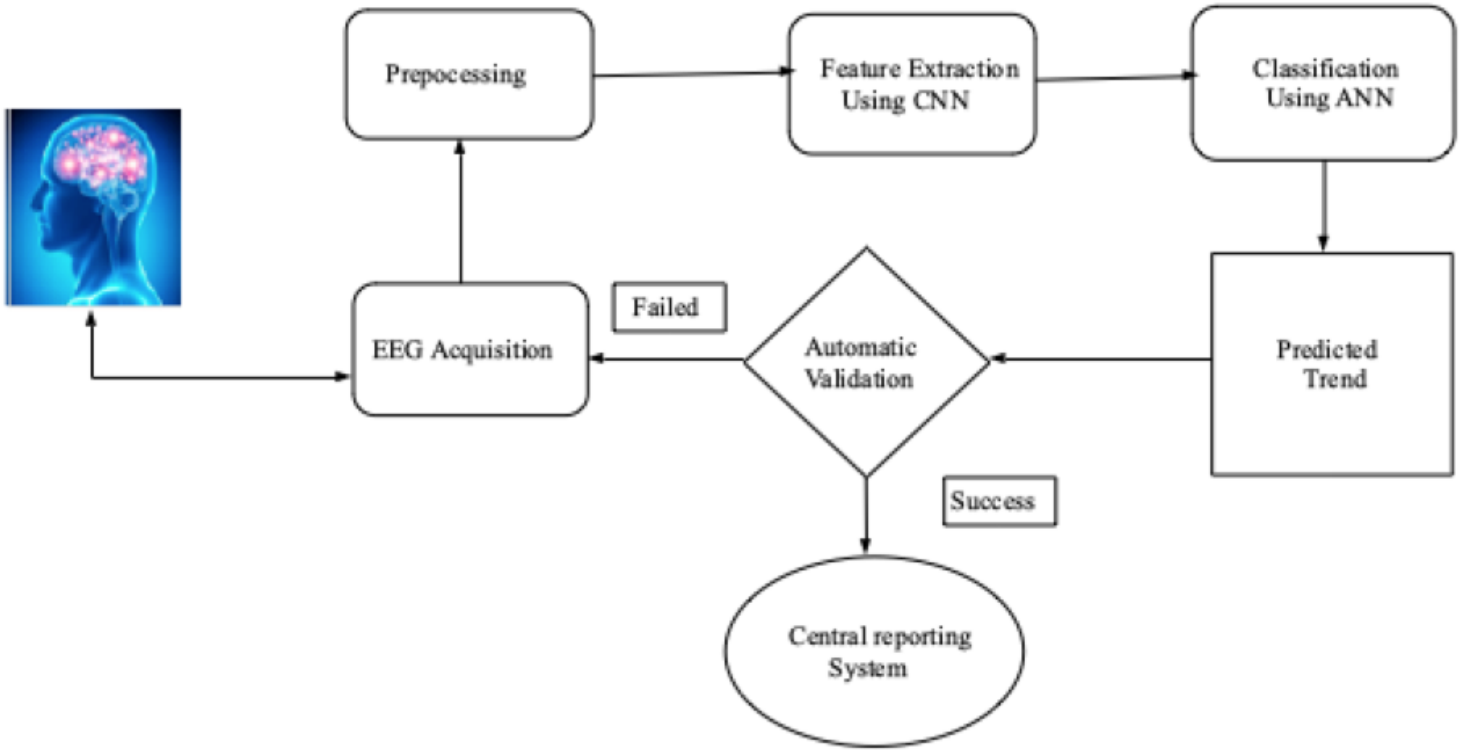
Electrode locations of International 10-20 system for EEG (electroencephalography) recording



Layout of Data Playing in the different Role



AI and Machine Learning Playing the Role



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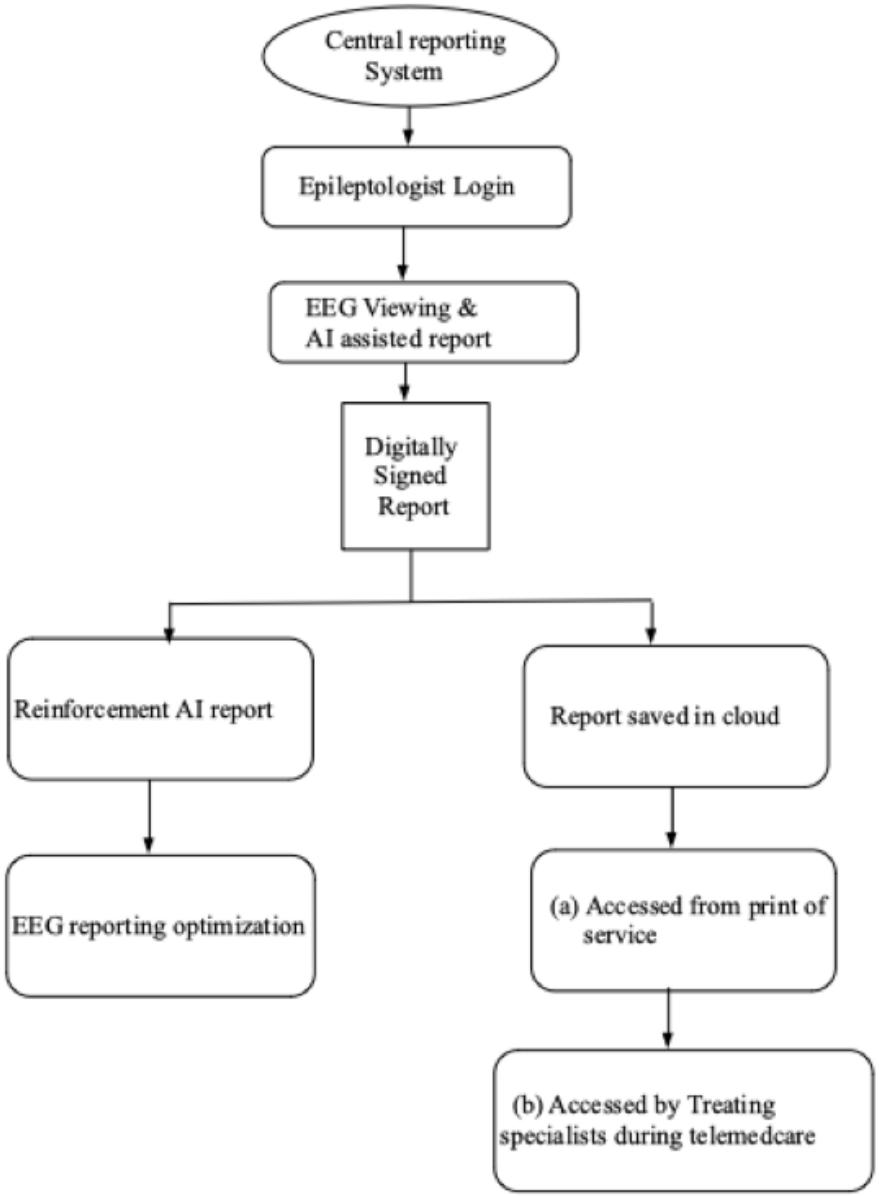

Central reporting System
Epileptologist Login
EEG Viewing & AI assisted report
Digitally Signed Report
Reinforcement AI report
EEG reporting optimization
Report saved in cloud
(a) Accessed from print of service
(b) Accessed by Treating specialists during telemedcare

Product as a solution

This product would be providing following solutions:

- Portable error-free high equality EEG machine.
- Easy to use by regular nurses with minimal additional training.
- In-built troubleshooting technology to ensure accurate and high quality EEG recording.
- Cloud-based data storage and retrieval .
- Tele-reporting and tele-patient care.
- 'Plug-in and Play' for tele-medicine kiosk.

The outcomes

- Reduce epilepsy treatment gap to less than 20
- Improved correct diagnosis of epilepsy
- Correct medicine dispensed to a greater number of patients
- Reduce misdiagnosis of non-epileptics by 50
- Improve Neurologists care to remote areas by 70

Novelty

- The present protocol would allow the Neurologists and Epileptologists to care for these unattended patients from their center. This would reduce the treatment gap and eventually the surgical gap of this disabling and debilitating disease. There are no clinically available EEG machines that look at resting-state connectivity.

Feasibility

- Evaluate patients with epilepsy
- A limited channel cap for long term monitoring at home
- A limited channel for a home-based sleep study
- Measure resting-state connectivity from EEG data
- Develop algorithms that can use resting stat EEG connectivity to predict cognitive function
- Screening of elderly for cognitive decline using the connectivity data
- Also can have compatibility with smartphones to stream data and give a prelim analysis
- There are no clinically available EEG machines that look at resting-state connectivity

Functional connectivity of Neocortex and Hemodynamic Responses of Meditation in Human Brain

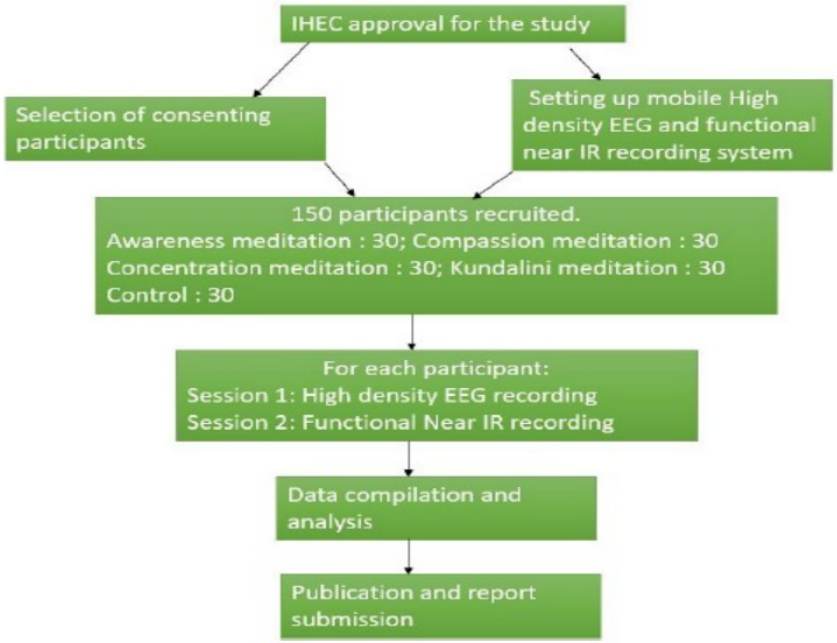
Functional connectivity of Neocortex and Hemodynamic Responses of Meditation in Human Brain

Understanding the significance of neural noise and the degree of coherence in different types of meditation. This information will help us to explore the mechanism of neural patterns of firing during meditation and cognitive processes. It will also explore the potentials of yoga in the management of cognitive deficits and emotionally related disorders.

Objective

- To understand the neurophysiological changes in prolonged meditation are investigated as control features for a brain-computer interface technique.
- To study the degree of coherence in various types of meditation in different traditions and understand the significance of neural noise (both spatial as well as temporal) during meditation and cognitive processes.
- To explore the functional connectivity of the brain during different types of meditation and cognitive processes and explore the rhythmic activities of the brain during meditation in different traditions.
- To understand the role of different meditation practices in different traditions on memory and emotional processing.
- To develop an objective tool for study states of meditation and their neuronal correlates. This is a very important direction towards the formulation of a universal protocol for meditation research

Layout


IHEC approval for the study
Selection of consenting participants
Setting up mobile High density EEG and functional near IR recording system
150 participants recruited.
Awareness meditation : 30; Compassion meditation : 30
Concentration meditation : 30; Kundalini meditation : 30
Control : 30
For each participant:
Session 1: High density EEG recording
Session 2: Functional Near IR recording
Data compilation and analysis
Publication and report submission

Database Update and Cognitive Robotics

Decision Making - DB and Robotics

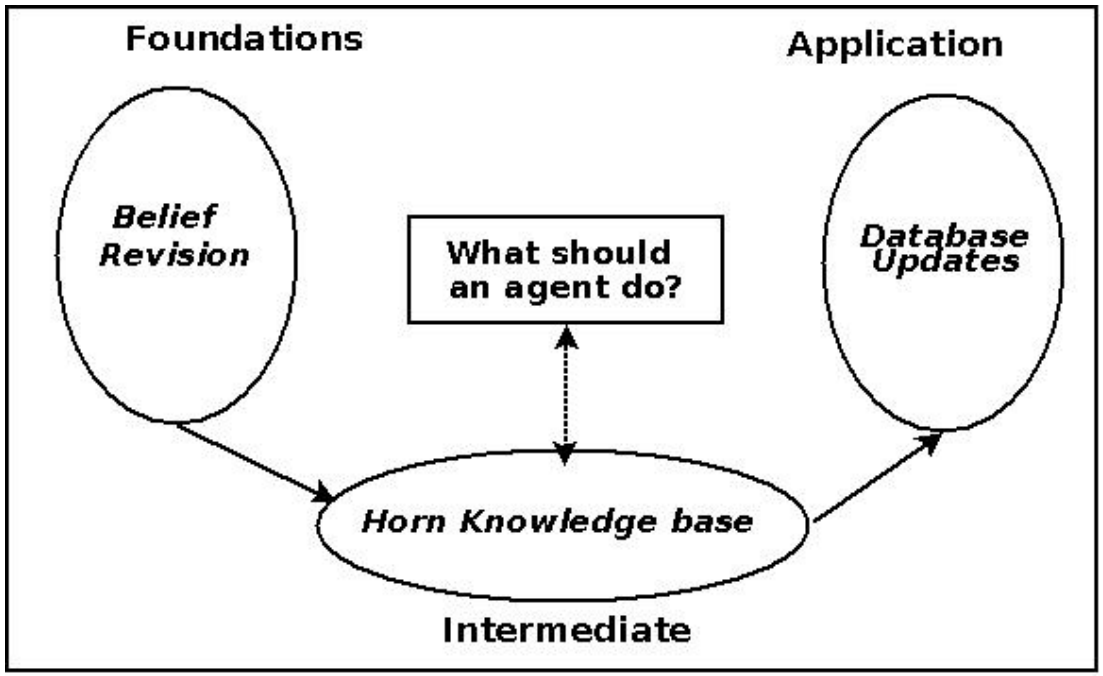
- Decision making is one of the fundamental cognitive processes of human being.
- This is a process that chooses a preferred option or a course of actions from among a set of alternatives on the basis of a given criteria or strategy.
- Generally it can be categorized into two theories : (a) Descriptive (b) Normative
- My work based on normative perspective, the analysis of individual decisions is concerned with the logic of decision making and rationality and the invariant choice it leads to.

Layout of study

- I am interesting in the question: What should an intelligent agent do based on its beliefs, abilities and preferences?
- How can we acquire and efficiently use information to make better decisions?
- A rational way of revision in the Databases Theory.
- Reasoning about Belief and Knowledge in the Cognitive Robotic.

Motivation

- Various philosophical works on belief dynamics (Horn revision - Delgrande, J.P, & Peppas, P. (2011)).
- View update (Minimal insert and/or delete)
- Unify this two fields closer to share the concepts



Motivation Example

s	Staff	Group
	Babu	CSE
	Gourinath	CSE

r	Group	Chair
	CSE	Abhishek
	IT	Gerhard

Con..

Immutable part: staff_chair(X,Y)← staff_group(X,Z),group_chair(Z,Y)

Updatable part: staff_group(Babu,CSE)←
staff_group(Gourinath,CSE)←
group_chair(CSE,Abhishek)←
group_chair(IT,Gerhard)←

Integrity constraint:
$\forall x, y, z$ (y=x) ← group_chair(x,y) $\wedge$ group_chair(x,z)
$\forall x, y, z$ (y=x)← group_chair(y,x) $\wedge$ group_chair(z,x)

Con..

$s \otimes r$	*Staff*	*Group*	*Chair*
	Babu	CSE	Abhishek
	Gourinath	CSE	Abhishek

Con..

$s \otimes r$	*Staff*	*Chair*
	Babu	Abhishek
	Gourinath	Abhishek

Suppose we want to delete from the database, staff_chair(Babu,Abhishek)
This work was done by Aravindan (1994).

We want to insert to the database with the information of,
staff_chair(Babu,Gerhard),
Which one need to delete or insert with minimal.

Con..

There are three plausible way to do this:
first case is, Babu and Gerhard belong to CSE, i.e, staff_group(Babu,CSE) $\wedge$ group_chair(CSE,Gerhard).
Need to delete both base facts group_chair(IT,Gerhard)$\leftarrow$,
we need to insert group_chair(CSE,Gerhard)$\leftarrow$ as a base fact

Assume that we have an algorithm that deletes the base facts
staff_group(Abhishek,CSE)$\leftarrow$ from the database.
staff_group(Babu,CSE)$\leftarrow$ insert to the base facts.

Con..

Second case, Babu and Gerhard belong to IT, that is staff_group(Babu,IT) $\wedge$ group_chair(IT,Gerhard).

Third case, Babu and Gerhard belong to x (free assignment of the group value), that is staff_group(Babu,x) $\wedge$ group_chair(x,Gerhard)

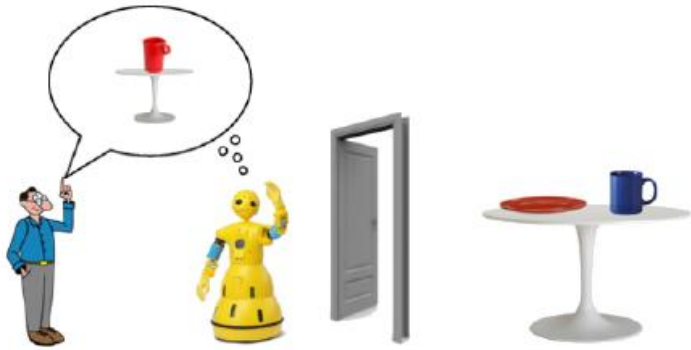
The Research Problem

- Our belief and knowledge can change over time.
- When we carry out change rationally?
- How this can be implemented for a specific application?

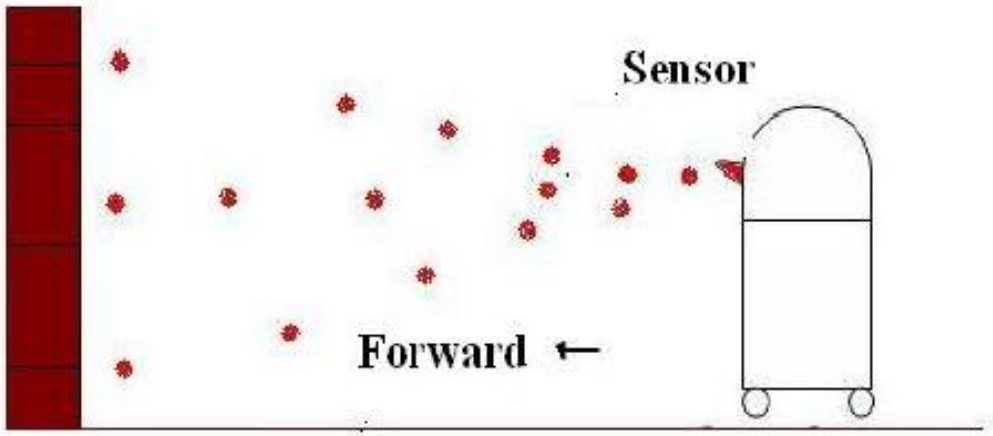
Modeling of Cognitive Robotics

- Planning as QBF
- Belief change with Noisy Sensing
- Causal Theories of Action and Change
- Only knowing

Cont...



Cont...



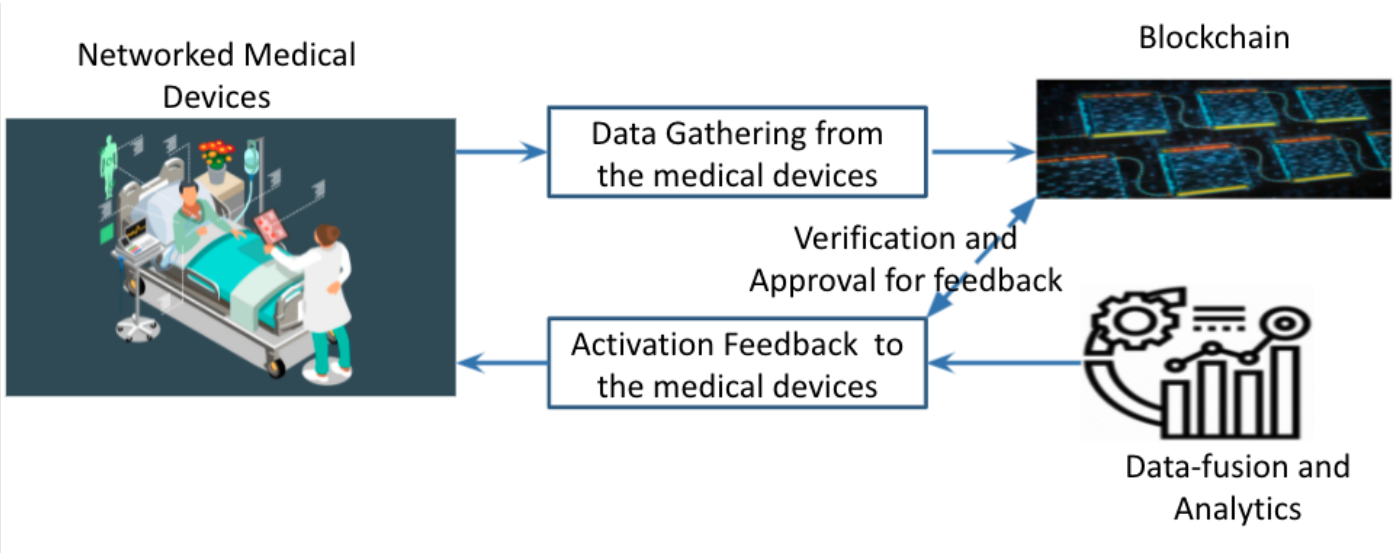
Outline

Securing Networked Medical Devices

Securing Networked Medical Devices

- Networked Medical Devices are aimed to improvise the quality of living as well as life-saving devices for the patients.
- These devices usually connected and talks with each other via hospital Ethernet or WiFi to upstream the data collected from the patients
- However, the medjacking attack is designed by the attackers so as to intervene into health devices, establish control and command to steal the sensitive medical data or to initiate replay attack thereby turning the life-saving device to life-threatening device (Example: Altering the infused insulin dosage level)

Layout of the study



The process of the work

- The medical devices integrated with the patients collect and upstream the data to processing server
- In the mean time, the data is stored on the blockchain
- Then the health-analytics server retrieves the data from the blockchain, apply sensor data fusion and accomplish the analytics
- Finally, the control feedback from the health-analytics demands the approval from blockchain before it is implemented successfully on the medical device

Predict Data Center Anomalies

Predict Data Center Anomalies

- Most of the New Applications/Legacy are moving towards Cloud Native Architecture.
- Most of the Applications are hosted on Hybrid Cloud.
- Compute/Network is becoming Dynamic in Nature.
- Most of the Today's anomaly detections are done isolation.
- Data Sources for Predictions : logs/events/Audit logs/Faults/Statistics/States/Flow Details/End Point Transitions/L4 - L7 Details/Structured/Unstructured.
- Correlating/Prediction & Remediation Across Compute/Storage/Network/Onprem/Cloud.

Major Modalities

- Telemetry Data.
- Topology
- End Point Data
- Boundary/Edges
- L4/L7 Device Statistics
- Deterministic States
- Predictions

Applications

- Data Center Operations
- Capacity Planning
- Remediations

Distributed Systems And Hybrid Cloud

- New Applications are migrating towards Cloud Native Architecture.
- Application are split into smaller isolated services.
- End Points are losing boundaries.
- Network functions are getting Virtualized and Dynamic.
- Applications are split between on-prem and on Cloud.

Application of Machine Learning

- Define the Use cases
- Collect Data
- Study and Identify Appropriate Machine Learning Algorithm
- Apply and Measure Accuracy
- Anomaly Prediction and Remediation.
- Capacity Planning and Forecast.
- Resource Optimization.

Motivation

- Mean Time to repair is very high in these Environments.
- Forecasting these Anomaly's and Re-mediating them will reduce the down time
- Helps in Capacity Planning.
- Helps in resource optimizations.

Challenges

- Data Comes from Multiple Sources
- Data is structured and Un-Structured
- Dynamic Nature of End Points (Floating)
- Boundaries are loosely defined.

The Research Problem

- Understand and Build Correlation between Various data sets (Interface Stats, End Point Moves, East to West Traffic, North South Traffic, L4/L7 Traffic, Routing Table)
- Collect Time Series Data
- Build Algorithms to Predict Anomaly's.
- Measure Accuracy of Following Anomaly's (Anomaly's due to internal App Misbehavior, Anomaly's due to Misconfigurations, Anomaly's Due to external App Misbehavior, Anomaly's due to L4/L7 Attacks)

Objective

To analyse and Predict following Anomaly's.

- Anomaly's due to internal App Misbehavior.
- Anomaly's due to Misconfigurations
- Anomaly's due to external App Misbehavior.
- Anomaly's due to L4/L7 Attacks
- Extend the above Work to Hybrid Cloud.
- Extend the above Work to Capacity forecast, Planning and Optimization.

Outline

Rapid, non-invasive diagnosis of COVID-19 infection and comorbidities

COVID-19

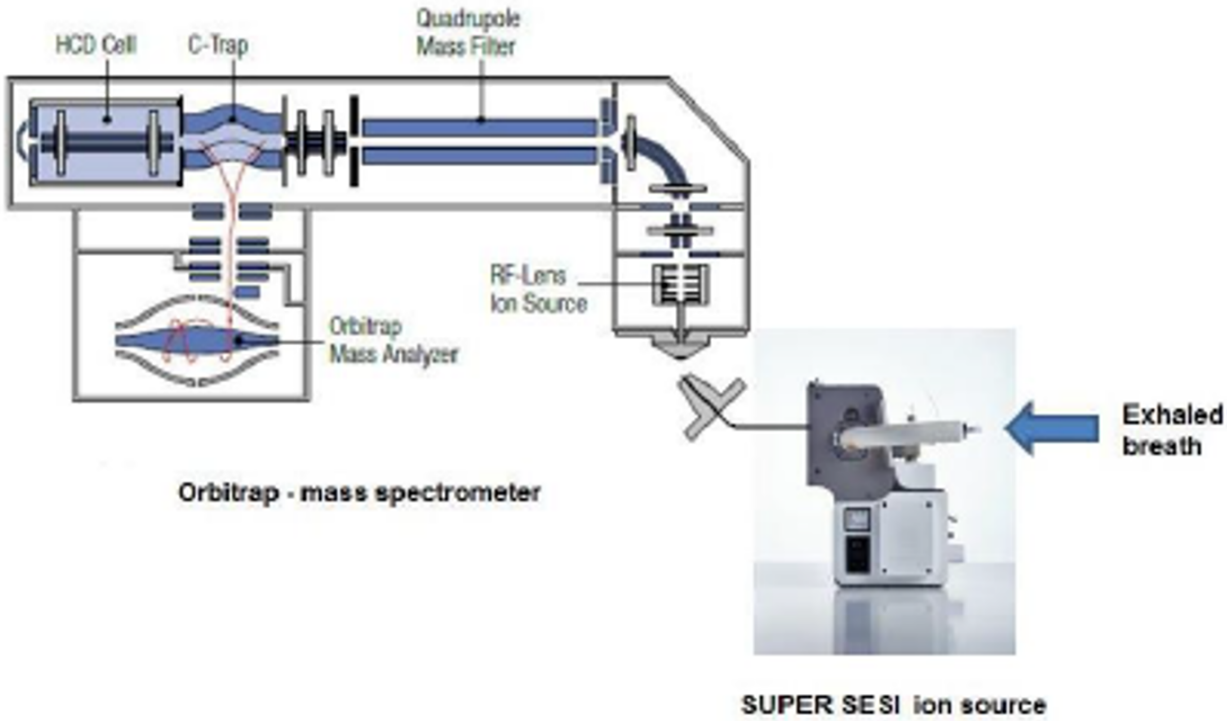
The main aim of this work is to analyze the VOC present in the human breath by MS-based methods for fast, online (in few seconds) diagnoses of COVID-19 infection, replacing the time consuming (usually 4-6 hours) RT-qPCR method and to quantify the extent of the infection of the infected patient without going for traditional X-ray based CT-scan.

Systematic Investigation

- To search for the VOC metabolites (biomarkers) from the breath of the COVID-19 infected patient and quantifying it relatively using SESI-MS.
- To understand the metabolic pathways that lead to the formation of the biomarkers. de
- To develop a method for fast, online screening (in a few seconds) for COVID-19 infection and to quantify the percentage of the infection of the lung based on the concentration of the biomarkers observed without going for harmful X-ray-based CT scans.
- To identify the comorbidities if any present in the COVID-19 patient through the breath analysis and to predict the suitable medical treatment and possible outcomes.
- Once the biomarkers are identified, relatively cheaper and portable online MS instruments like GC-IMS can be deployed for online point-of-care testing and to monitor/identify the sudden change in the conditions of the seriously ill COVID-19 patients in the ICU.

Mass Spectrometer

Schematics of the experimental setup. SUPER SESI ion source converts VOC in human breath to ions which are then taken to mass spectrometer where the masses are analyzed by orbitrap. The figures are adapted from Thermofisher and Fossil Ion Tech.



VOC biomarkers

Summary of VOC biomarkers measured in a human breath of the COVID-19 positive patients. The arrows pointing upwards indicate the increase in concentration and the one pointing downwards indicates the decrease in the concentration of the measured biomarker.

		Acid	Alcohol		Ketone			Aldehyde						Alkene		Alkane			
Reference	**Technique**	*Acetic acid*	*Isopropanol*	*1-Propanol*	*Acetone*	*Acetoin*	*2-butanone*	*Acetaldehyde*	*Pentanal*	*Heptanal*	*Octanal*	*Nonanal*	*Methylpent-2-enal*	*Isoprene*	*2,4-octadiene*	*1-chloroheptane*	*Dodecane*	*Tetradecane*	*Pentadecane*
Chen 2021	GC-IMS	↑	↑	↑↑	↓↓			↑											
Berna 2021 (pediatric)	GCxGCToF-MS				↓		↓			↑↑	↑↑	↑					↑		
Ruszkiewicz 2020	GC-IMS				↑↑		↑	↑↑		↑	↑↑			↑					
Grassin-Delyle 2021	PTRQToF											↑	↑↑		↑	↑↑			
Wadah Ibrahim 2021	TD-GC-MS			↑↑		↑					↑								↑
Cuili Xue 2021	GC					↑↑												↑↑	↑
M.Feuerherd 2021	MCC-IMS						↓↓		↓↓										

Table 1: The arrows pointing upwards and downwards indicate a rise in concentration and a decrease in the concentration of the measured biomarker, respectively.

Outline

Outcome

- Publication - 8 (5 journal and 3 conference)
- Project - 4 (DST, DBT, DRDO and SERB)
- Research Center - 2 (Cognitive lab in VIT and COVID lab in CMC Hospital)

Questions?

Thank you!

Download slides, data!
https://sites.google.com/site/rdelhibabu/
Emails: rdelhibabu@gmail.com, r.delhibabu@vit.ac.in