

CAPSTONE PROJECT:

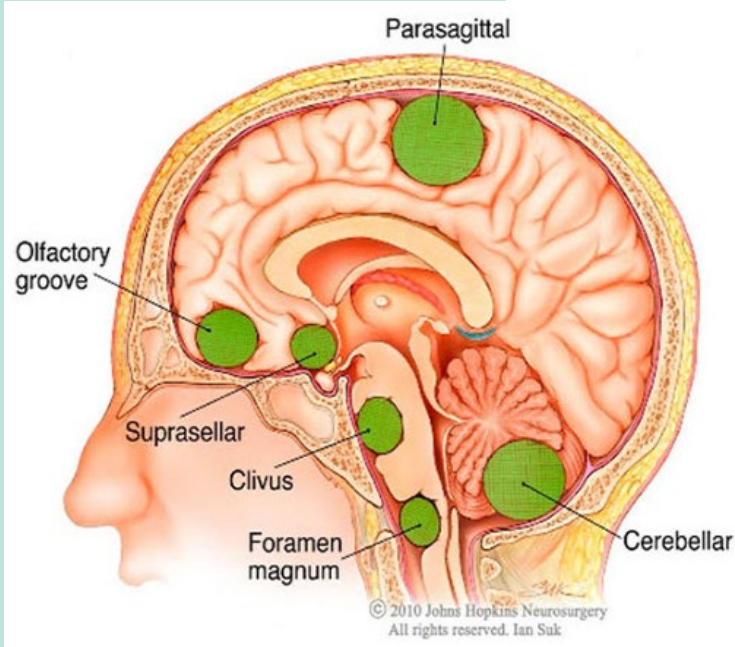
ML, BRAIN TUMORS & MRI

Constance Lin
DSI-41



CONTENTS

1. BACKGROUND
2. PROBLEM STATEMENT
3. EDA / PREPROCESSING
4. PART 1: MODELLING ALGORITHMS
5. RESULTS
6. PART 2: Q&A RAG MODEL
7. DEMONSTRATION
8. LIMITATIONS/ FURTHER DISCUSSIONS/ RECOMMENDATIONS
9. REFERENCES



BACKGROUND

- Brain tumors are growth of cells in the brain or near the brain
- Many different types of brain tumors exist [1, 2]
 - Gliomas
 - Meningiomas
 - Pituitary tumors
 - Nerve tumors
- Magnetic Resonance Imaging (MRI) is usually the preferred way to diagnose brain tumors [3]

Singapore

Singapore hospitals struggle to meet demand for radiographers, pharmacists amid shortage in healthcare workers

Industry players said the shortage is driven by multiple factors including an ageing population, new technology, and the expansion of healthcare infrastructure.

<https://www.channelnewsasia.com/singapore/allied-health-professionals-healthcare-nurses-hospitals-shortage-radiographers-pharmacists-3861226>

The Growing Problem of Radiologist Shortages: Perspectives From Singapore

Charles Xian Yang Goh ¹, Francis Cho Hao Ho ²

Affiliations + expand

PMID: 38016677 PMCID: PMC10700991 DOI: 10.3348/kjr.2023.0966

<https://pubmed.ncbi.nlm.nih.gov/38016677/>

"The fact of the matter is that there's not enough radiologists. We need AI to come and help; they are not meant to take over the radiologists," said Mr Lim.

With the help of FxMammo to screen the mammograms, the radiologists improved in their detection of breast cancer, he said, leading to about a fifth of time saved on average.

<https://www.channelnewsasia.com/asia/artificial-intelligence-ai-replace-steal-jobs-work-healthcare-doctor-nurse-call-centre-4082086>

Singapore's healthcare spending is likely to continue rising; targeted support needed: Gan

He added that the government continues to bear a significant and growing share of the national health expenditure, from 40 per cent in 2013 to 46 per cent in 2018.

<https://www.businesstimes.com.sg/international/singapore-budget-2021/singapores-healthcare-spending-likely-continue-rising-targeted>

6) Households spent an average of 5.5% of their monthly expenses on healthcare

In 2017/2018, households spent an average of \$4,906 a month, but how much of it was on healthcare?

Here's the proportion of monthly household expenditure spent on healthcare (%):

	2007/2008	2012/2013	2017/2018
All Households	5.3	4.5	5.5
Lowest 20%	6.0	5.6	7.8
<u>2nd quintile</u>	5.5	4.4	<u>5.7</u>
3rd quintile	5.5	4.9	5.7
4th quintile	5.3	4.6	5.0
Highest quintile	4.8	4.0	4.8

<https://smartwealth.sg/healthcare-cost-statistics-singapore/>

Appropriate use of diagnostic imaging tests

Increasing access and demand in diagnostic imaging results in dramatic increase in volume and complexity of imaging studies; although these bring benefits to patients, they also put a strain on healthcare workers and the financial resources of the national health system. Wellness issues, such as repetitive stress injury, fatigue and burnout, need to be addressed before they reach a tipping point. The first target should be inappropriate use of diagnostic imaging services that are not supported by evidence. Decisions to undergo imaging tests require a sound understanding of the utility, limitations and potential harm of the procedures, and are best advised by medical professionals, made jointly with patients whenever possible.

<https://annals.edu.sg/transforming-radiology-to-support-population-health/>

SAY HI !

MEDICAL OFFICER TOM

- medical officer (MO) in the radiology department in a specialized public hospital
- Gets rotated to different medical specialties every 6 months
- Started off learning how to report x-ray images, and now only learning how to report advanced scans
 - Not as confident especially if there are edge cases
- Covers night shifts as well in the A&E department
 - Stressful: long shift hours (12 hours) with limited manpower
 - Compounded by the fact that seniors are not always around the full 12 hours as everyone take turns to be on breaks
 - mostly x-rays (and it can get a lot!)
 - occasional specialized exams needed such MRI are usually because of special circumstances
 - A&E doctors need the radiology report to be out quickly so they can decide the next course of action



CLINICIAN SAM & MR TAN THE PATIENT

- Dr Sam saw Mr Tan (aged 50) for a range of symptoms such as headache, and occasional slurred speech with some numbness in his arms
 - Sent Mr Tan to do a CT brain to rule out any bleeding which could cause headaches & some x-rays to investigate for cause of arm numbness
 - Since symptoms are not resolved, he decides to send Mr Tan to do a MR Brain Stroke scan to investigate slurred speech
 - On scanning, the radiographers found a tumor in the brain which may possibly explain his symptoms
 - Mr Tan is reluctant to do further scans even though it is necessary because he already paid for the CT scans and x-rays previously and he only have \$300 in his Medisave a year to use on such scans
 - He wonders if it is necessary to do further scans and if he needs to go for treatment, there could be further costs which he wants to save money for



POTENTIAL STAKE HOLDERS

1. Healthcare workers

- radiologists can leverage on technologies to help [4]
- radiographers/ nurses can spend more time with patients instead of rushing through the multitude of cases/ administrative tasks [7]

2. Patients

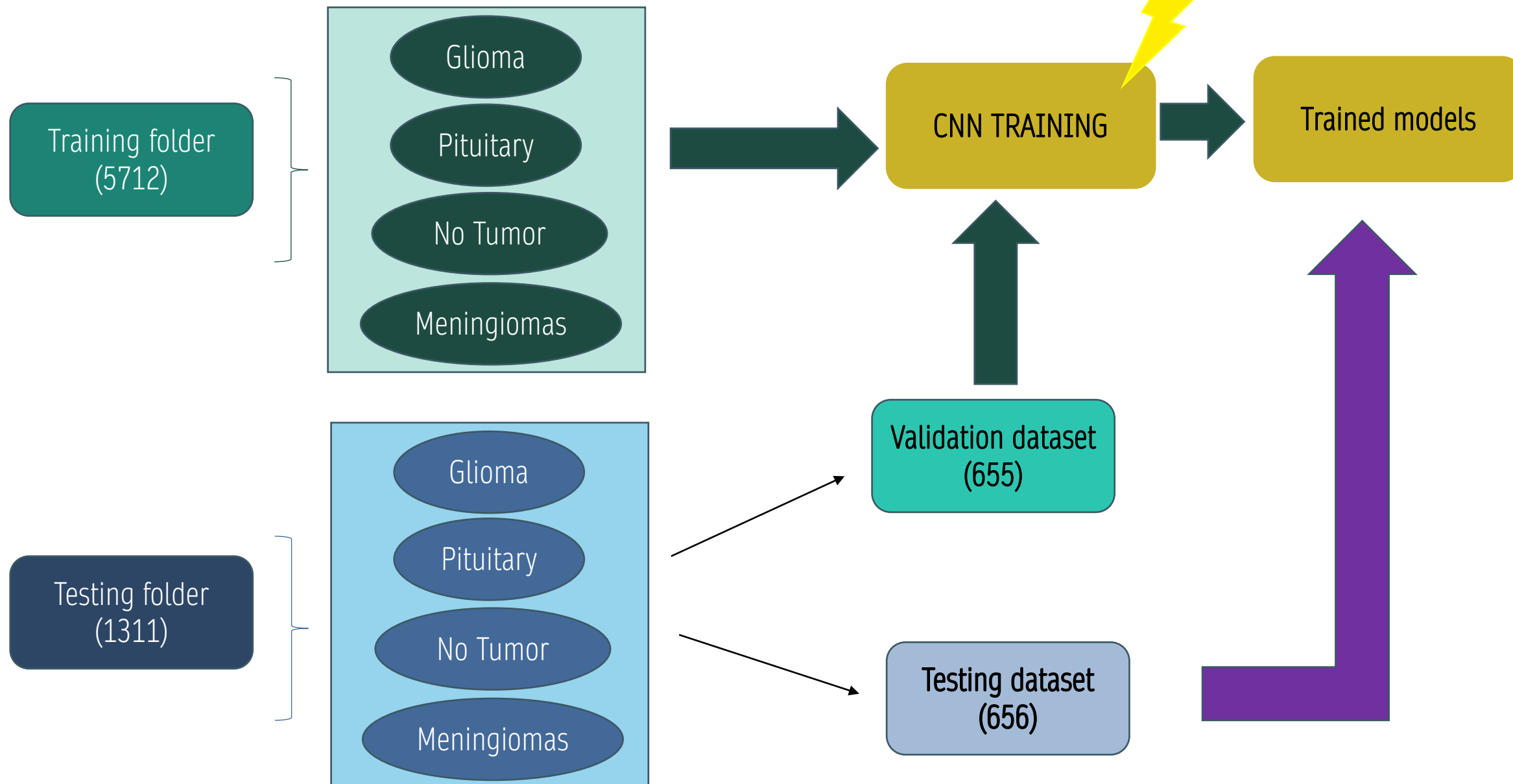
- cost of MRI starts from about \$1000 (non-subsidized) [6]
- Medisave can be used up to \$300 per year (only) [6]
- can spend less money on scans to get diagnosis

PROBLEM STATEMENT

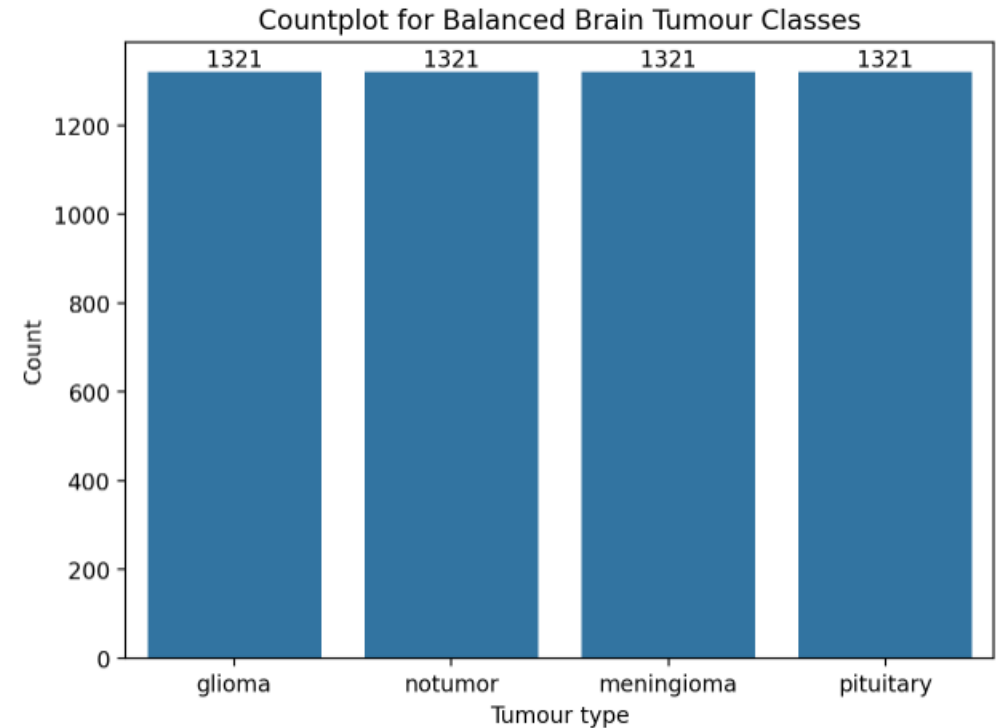
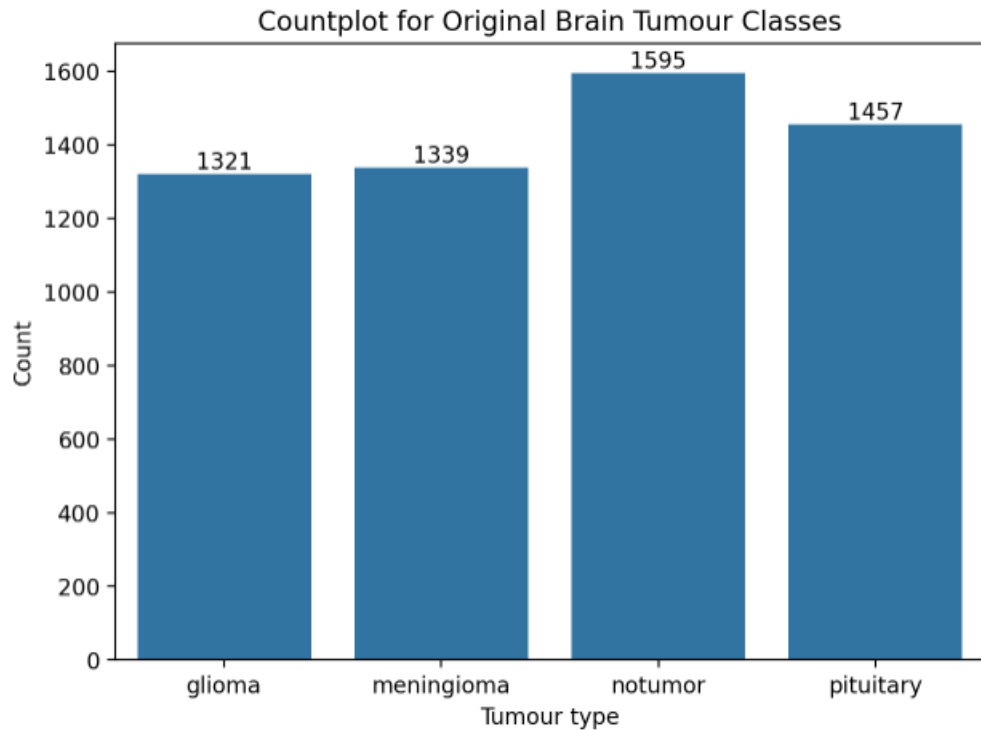
Are pre-trained ML models accurate enough to identify different* brain tumors from MRI images to aid in diagnosis?

* We will look at 3 types of tumours today

PROCESS



EDA: TRAINING DATA



Performed undersampling without replacement on Training data
Important to get balanced classes for training in CNN

Training data
(5284)

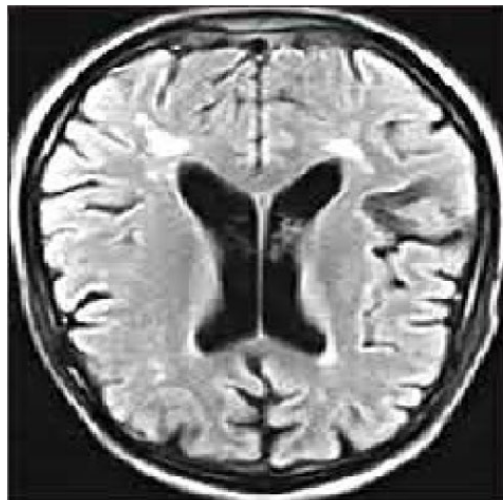
PREPROCESSING

- Did not remove original images that are blurred or tilted – useful for adding variety to the dataset for model training
- Adjust image size for pretrained model usage
- Normalise image pixel

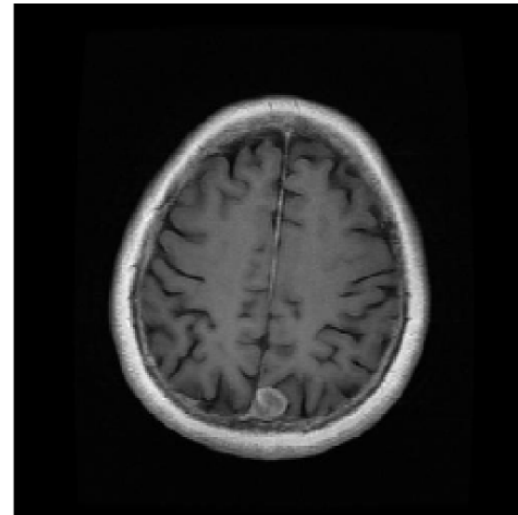
notumor



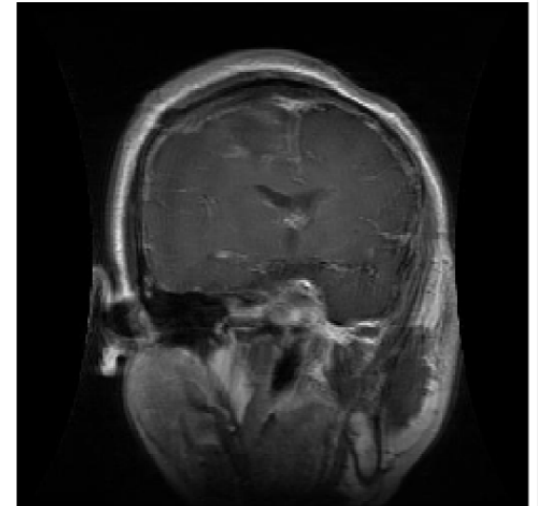
notumor

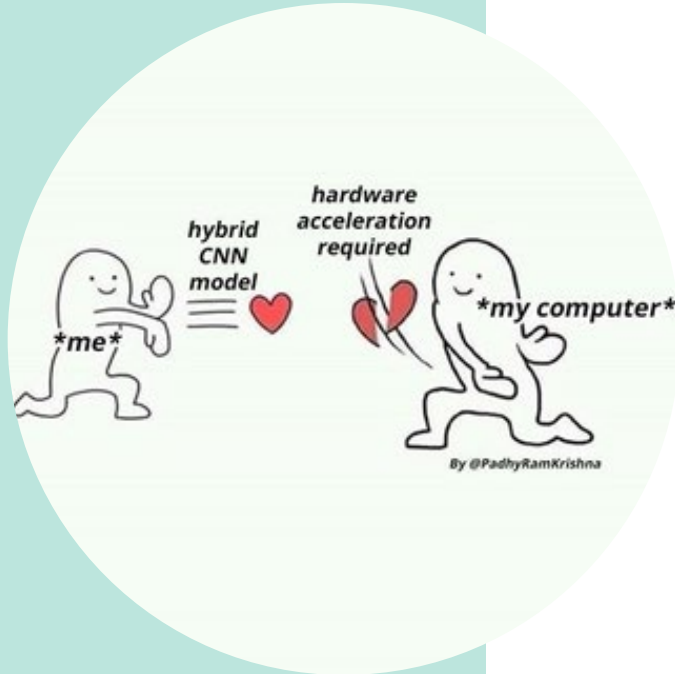


meningioma



glioma





MODELLING ALGORITHMS

- Use Convolutional Neural Networks (CNN)
- Pre-trained models used
 - VGG16
 - ResNet50
 - EfficientNetB2
- Customized the top layer to give 4 outputs at the end
- Regularization attempted i.e. early stopping
- Different optimizers attempted i.e. Adam vs RMSprop

PRE-TRAINED MODELS

MODEL	NUMBER OF LAYERS	INPUT IMAGE SIZE	MODELLING ATTEMPTS
VGG-16	16	224 x 224	Version 1: <ul style="list-style-type: none">• Pretrained model original architecture except the top layer• Optimizer: Adam Version 2: Same as Version 1 + Regularization Version 3: Same as Version 2 except the optimizer is changed to RMSprop
ResNet50	50	224 x 224	
EfficientNetB2	342	260 x 260	

A comparison between VGG16, VGG19 and ResNet50 architecture frameworks for Image Classification

<https://ieeexplore.ieee.org/document/9687944>

Complete Architectural Details of all EfficientNet Models

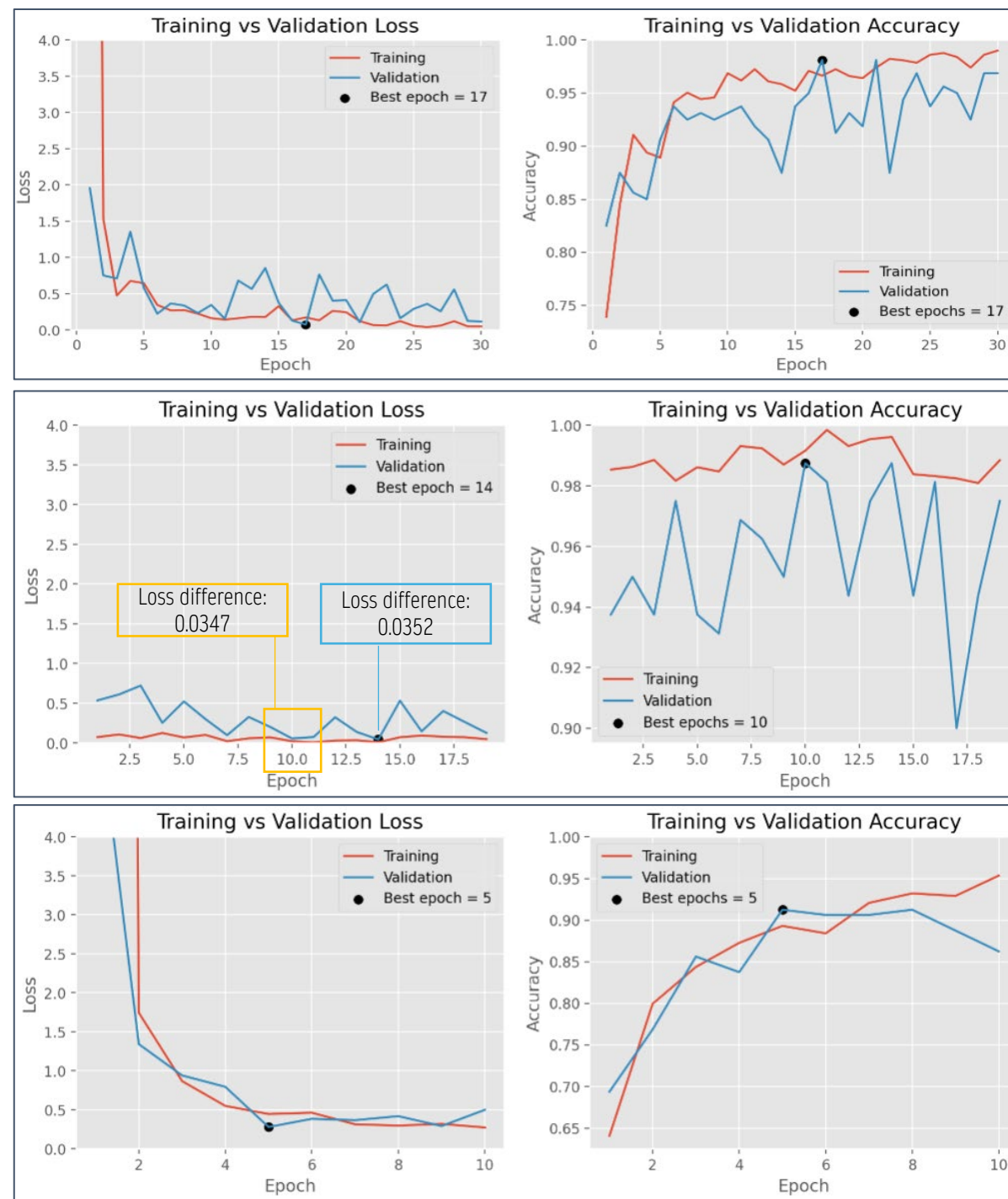
<https://towardsdatascience.com/complete-architectural-details-of-all-efficientnet-models-5fd5b736142>



VGG16

With early stopping

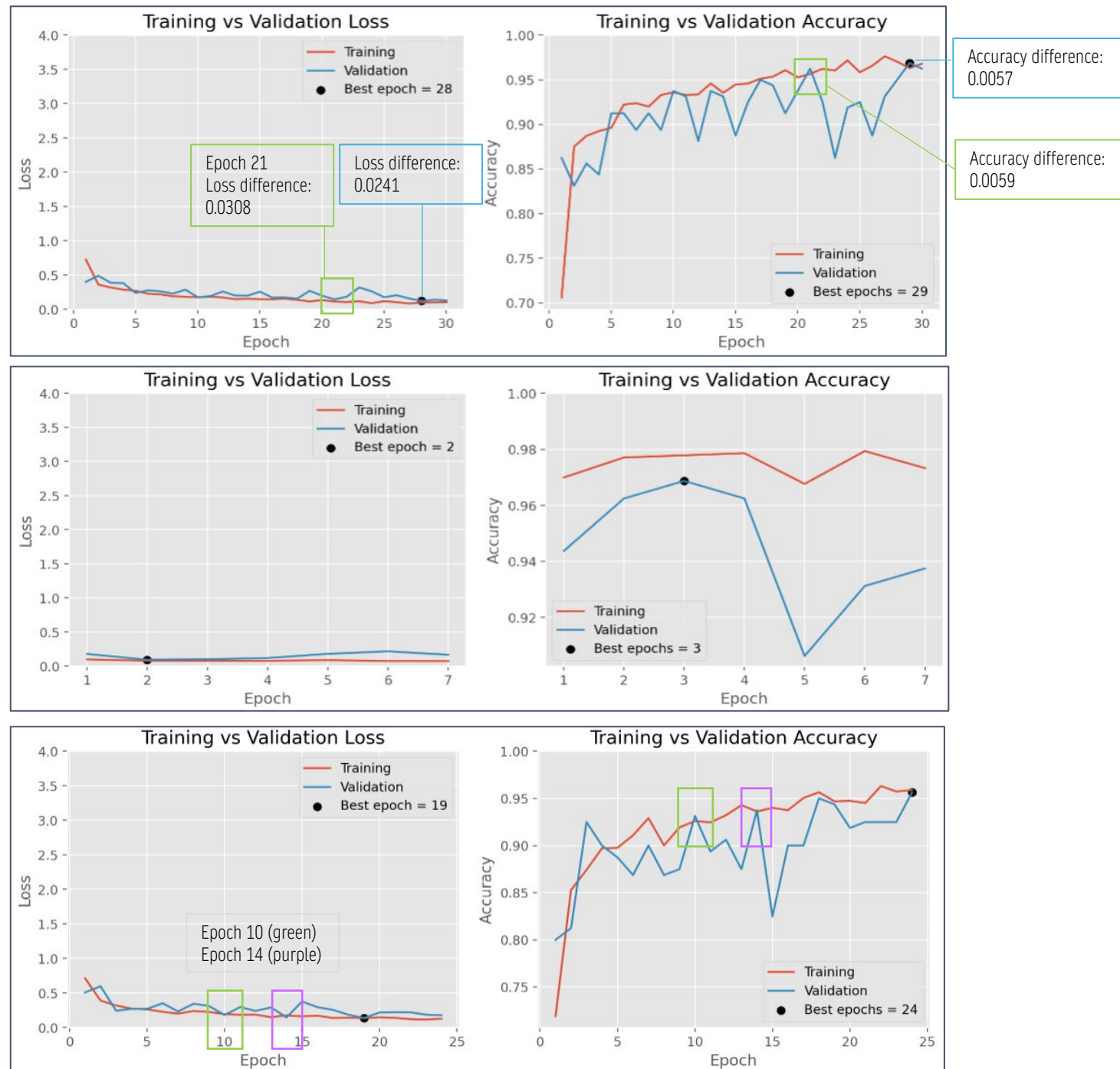
Different optimizer
(RMSprop)



RESNET50

With early stopping

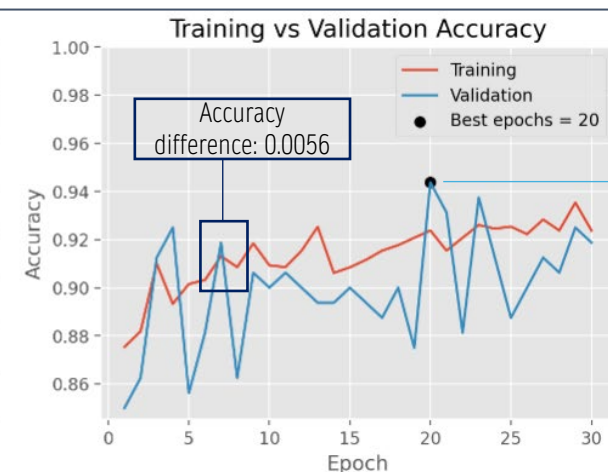
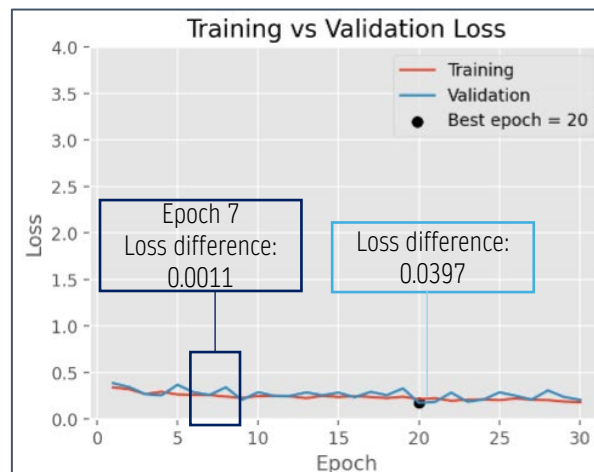
Different optimizer
(RMSprop)



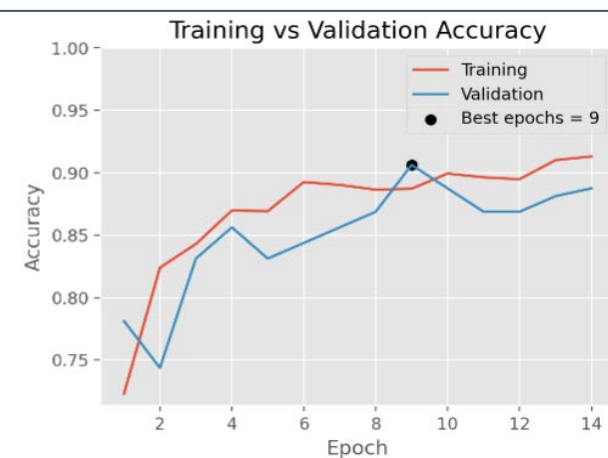
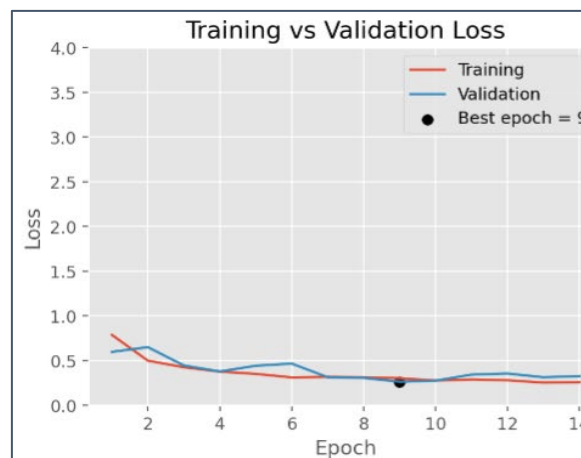
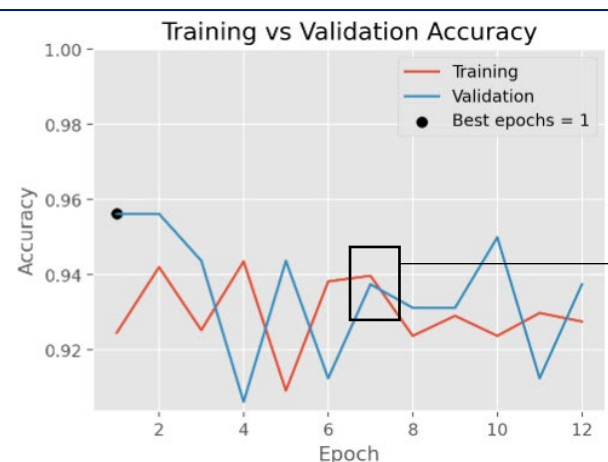
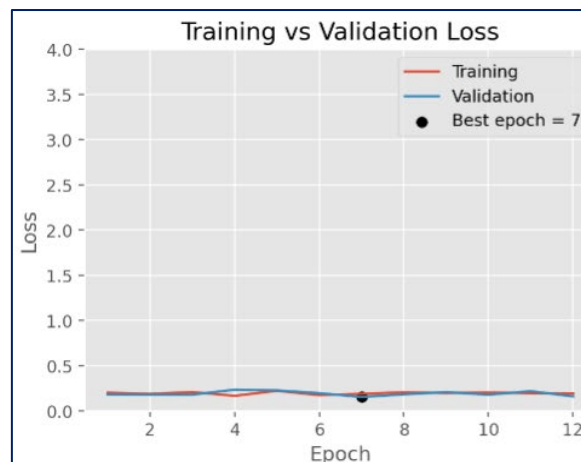
EFFICIENT NET_B2

With early stopping

Different optimizer
(RMSprop)



Accuracy difference:
0.002



ACCURACY SCORE SUMMARY

- Early stopping gave better and quicker results for all 3 models
- Adam optimizer have higher accuracy scores in general
- Accuracy can reach up to 96%
 - can be accompanied by higher loss as well
 - ResNet50 have the lowest loss

Scores			
Model	ADAM	RMSPROP	$\frac{TP+TN}{TP+TN+FP+FN}$
VGG-16	0.96	0.90	
ResNet50	0.94	0.92	
EfficientNetB2	0.91	0.86	

SUMMARY OF TUMOR METRIC

			CORRECT PREDICTIONS OUT OF ALL PREDICTIONS	HOW MANY ACTUAL RECORDS CORRECTLY PREDICTED	HARMONIC MEAN OF RECALL & PRECISION
TUMOR	MODEL	OPTIMIZER	PRECISION $\frac{TP}{TP+FP}$	RECALL $\frac{TP}{TP+FN}$	F-1 SCORE
No Tumor	VGG16	Adam	0.99	0.99	0.99
Pituitary	ResNet50	Adam	0.97	0.97	0.97
Glioma	ResNet50	RMSprop	0.93	0.91	0.92
Meningioma	ResNet50	RMSprop	0.84	0.86	0.85

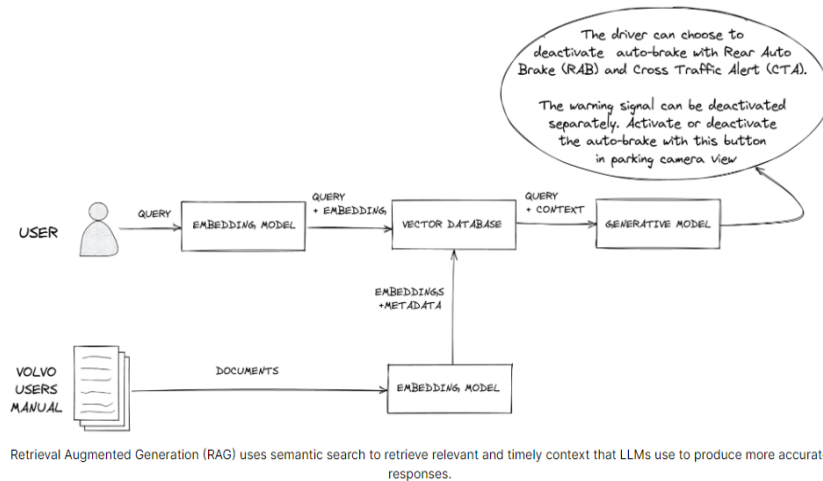
BEST MODEL



**RESNET50
(RMSprop)**

Q&A MODEL

What is it?



<https://www.pinecone.io/learn/retrieval-augmented-generation/>

What did I input in?

- general safety guidelines on doing MRI scans after implantation of coronary stents, orthopedic implants, embolism coils etc.
- research articles on implantable medical devices, MRI safety for radiographers, projectile distances of objects in the scanner

How is it being done?

1. Load the document/ PDF/ website URL
→ "loaded document"
2. Split the loaded document into chunks
3. Store the chunks
→ Usually stored as embeddings aka chunk is being converted to numbers
4. Input a question
5. Retrieve information from the stored embeddings
6. Returns an answer to the question via a LLM such as ChatGPT3.5

DEMONSTRATION

#bestie ChatGpt model



You

What is Lo Hei in relation to Magnetic Resonance Imaging?



ChatGPT

Lo Hei is not directly related to Magnetic Resonance Imaging (MRI). Lo Hei, also known as Yu Sheng, is a traditional Chinese salad dish that is typically eaten during the Lunar New Year festivities. It's a symbolic dish where various ingredients are tossed together with chopsticks while people shout auspicious phrases, symbolizing good luck, prosperity, and abundance for the coming year.

On the other hand, Magnetic Resonance Imaging (MRI) is a medical imaging technique used to visualize internal structures of the body in detail. It uses strong magnetic fields and radio waves to generate images of organs and tissues. These two concepts are unrelated, and there is no direct connection between Lo Hei and MRI.



RAG model

"Lo Hei, in the context of Magnetic Resonance Imaging (MRI), refers to a study conducted to evaluate the projectile risk of smaller ferromagnetic objects inside MRI scanners. The study aimed to provide local relevance to practice in Singapore by assessing the potential risks associated with objects that could be carried by individuals or found near an MRI scanning room. The study highlighted the importance of understanding the ferromagnetic activity of various objects to prevent accidents and ensure safety in MRI environments."

Original Article

Local cOinage and Hospital Equipment Index (Lo Hei): projectile distance of Singapore coinage and healthcare-related equipment in a 3T magnetic resonance imaging scanner

Shao Jin Ong^{1,2}, FRCR, PhD, James TPD Hallinan^{1,2}, MBBS, FRCR, Deborah Khoo³, MBBS, MMed, Desmond Hoon¹, BSc (Hons), MSc, Koon Liang Chia¹, BSc (Hons), MSc, Joanne Hang¹, BSc (Hons), Lycia Teo⁴, MBBS, MRCPsych, Peijing Su⁵, MBBS, MRCP, Michael Ong⁶, BSc (Hons), MSc, Bertrand Ang^{1,2}, MBBS, FRCR, Swee Tian Quek^{1,2}, MBBS, FRCR

¹Department of Diagnostic Imaging, National University Hospital, ²Department of Diagnostic Radiology, Yong Loo Lin School of Medicine, National University of Singapore, ³Department of Anaesthesia, National University Hospital, ⁴Department of Psychiatry, Ng Teng Fong General Hospital, ⁵Division of Rehabilitation Medicine, Department of Medicine, National University Hospital, ⁶Centre for Health Professionals Training, National University Health Systems, Singapore

[10] ✓ 4.0s

... 'Lo Hei, in the context of Magnetic Resonance Imaging (MRI), refers to a study conducted to evaluate the projectile risk of smaller ferromagnetic objects inside MRI scanners.'

DEMONSTRATION

#bestie ChatGpt model



You

Can you give me the website list that is stated in the Safety Guidelines for Magnetic Resonance Imaging in Clinical Use document?



ChatGPT

I can't provide a direct list from the document since it's not part of my training data, and I don't have access to specific documents or their contents. However, I can suggest some reputable websites commonly referenced in safety guidelines for MRI:

1. American College of Radiology (ACR): The ACR offers a variety of resources related to MRI safety, including guidelines and recommendations.
 - Website: <https://www.acr.org/>
2. The Joint Commission: This organization provides accreditation and certification for healthcare organizations and offers resources on MRI safety.
 - Website: <https://www.jointcommission.org/>
3. Radiological Society of North America (RSNA): RSNA often publishes guidelines and safety recommendations for various imaging modalities, including MRI.
 - Website: <https://www.rsna.org/>
4. International Society for Magnetic Resonance in Medicine (ISMRM): ISMRM is a professional association dedicated to promoting communication, research, development, and applications in the field of magnetic resonance.
 - Website: <https://www.ismr.org/>
5. European Society of Radiology (ESR): ESR may have guidelines and resources related to MRI safety.
 - Website: <https://www.myesr.org/>

These organizations often publish guidelines, standards, and safety recommendations that healthcare professionals refer to when establishing MRI safety protocols and practices. If you have access to the Safety Guidelines for Magnetic Resonance Imaging in Clinical Use document, it's best to consult the list provided within that document for the most accurate information.



Websites list

Name	Site
Association of Anaesthetists of Great Britain and Ireland	www.aagbi.org
British Association of MR Radiographers (BAMRR)	www.bamrr.org/
British Institute of Radiology (BIR)	www.bir.org.uk
British Standards Institute (BSI)	www.bsigroup.com
Department of Health (DH)	https://www.gov.uk/government/organisations/department-of-health
Department of Health, Social Services and Public Safety for Northern Ireland (DHSSPS)	www.dhsspsni.gov.uk/
European Committee for Electrotechnical Standardization (CENELEC)	www.cenelec.org
Food and Drug Administration (FDA)	www.fda.gov
Health and Safety Executive (HSE)	www.hse.gov.uk
Institute of Chemical Engineers (IChemE)	www.icheme.org
Institute of Physics and Engineering in Medicine (IPEM)	www.ipem.ac.uk
International Commission on Non-Ionizing Radiation Protection (ICNIRP)	www.icnirp.de
International Electrotechnical Commission (IEC)	www.iec.ch

RAG model



GENERAL ASSEMBLY



Capstone Project: ML, Brain Tumors & MRI

MR Question-Answer Model

This is a proof-of-concept question-answer model with retrieval capabilities. 🙌

Enter Question Here:

Can you give me the website list that is stated in the Safety Guidelines for Magnetic Resonance Imaging in Clinical Use document?

Give me an answer!

The websites listed in the Safety Guidelines for Magnetic Resonance Imaging Equipment in Clinical Use document are:

1. Association of Anaesthetists of Great Britain and Ireland - www.aagbi.org
2. British Association of MR Radiographers (BAMRR) - www.bamrr.org/
3. British Institute of Radiology (BIR) - www.bir.org.uk
4. British Standards Institute (BSI) - www.bsigroup.com
5. Department of Health (DH) - <https://www.gov.uk/government/organisations/department-of-health>
6. Department of Health, Social Services and Public Safety for Northern Ireland (DHSSPS) - www.dhsspsni.gov.uk/
7. European Committee for Electrotechnical Standardization (CENELEC) - www.cenelec.org
8. Food and Drug Administration (FDA) - www.fda.gov
9. Health and Safety Executive (HSE) - www.hse.gov.uk
10. Institute of Chemical Engineers (IChemE) - www.icheme.org
11. Institute of Physics and Engineering in Medicine (IPEM) - www.ipem.ac.uk
12. International Commission on Non-Ionizing Radiation Protection (ICNIRP) - www.icnirp.de
13. International Electrotechnical Commission (IEC) - (website not provided)

GENERAL LIMITATIONS FACED

- Assumed that the images in the dataset are representative of the Singapore population
- Literature lack of definitive numbers for what is “accepted accuracy” in medical imaging
 - is 80% accuracy good enough? Or is 90% and above accepted?
 - how much loss is accepted? 10% or 20%?
- Precision-Recall debate
 - Which metric is prioritized in the trade-off?
 - Does the metric importance change depending on medical specialty/ specific condition to treat/ in the presence of comorbidities etc.?
- RAG QA model only trained on a small corpus of PDF data
 - generally works but not 100% accurate all the time
 - basis of QA model is using ChatGPT
 - there is a possibility it can give answers that are not exactly from the trained PDFs despite prompt incorporated



INSIGHTS & DISCUSSION POINTS

1

MODEL PERFORMANCE

Our **customized “basic”** models can predict testing data with an accuracy of at least 90%

* Potentially able to be implemented to be used in hospitals

- More crucial part lies in having a framework to be able to quantify accuracy-loss level that is applicable for different use cases
- ✓ potential discussion point if ML is to be used as a complimentary tool
- ✓ possibility of institution-dependent levels of tolerances as "accepted accuracy" i.e. public hospital vs specialized institutes such as NNI, KKH

2

POTENTIAL PERFORMANCE OF RAG QA MODEL DEMONSTRATED

Comparison of models showed that our model were able to answer specific questions pertaining to our “private” data

* More fine tuning is required

- yet to be determined if having more data will mean that the phrasing of the questions can afford to be less precise but still get yield acceptable responses

RECOMMENDATIONS



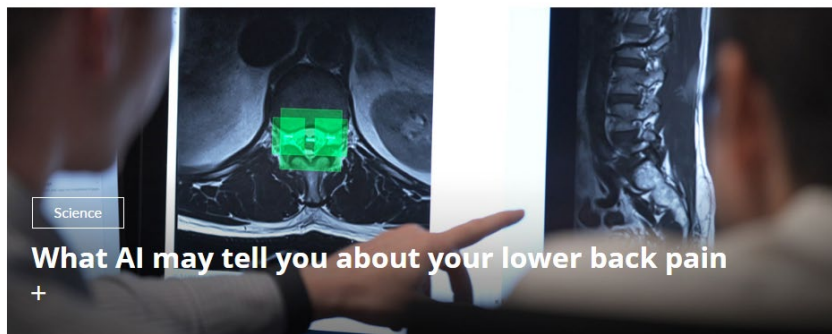
Data scientists

TAILORED MODEL TRAINING

- collect diagnostic images of our local population:
 - more accurate reflection of the types of tumors we deal with in local context
- attempt ensemble or voting classifier of these current 3 models to see if the result is better
- use CT images to train the model instead of MRI or using a combination
- adaptation to different institutions' usage requirements
 - i.e. junior radiologists rostered to A&E department during night shifts
 - they would benefit from the help as they have to report many different studies
 - i.e. junior radiologists in specialized institutes

TAILORED QA MODEL

- paid PDF textbook version on MRI safety, bioeffects and patient management – from a commonly referred to website by radiographers
 - Determine if added info will achieve more precise answers
- potentially incorporate different companies' implants information sheets to the model
 - a common platform across public healthcare institutions (PHIs) where healthcare professionals can make use of it to check implant compatibilities for their patients before ordering the scans
 - most of time they are publicly available but all over the internet/ radiographers have to email to the companies for it/comes with the product in the packaging



What AI may tell you about your lower back pain

Published on 17 January 2024

A programme called SpineAI can identify more serious underlying causes of lower back pain more accurately and efficiently.

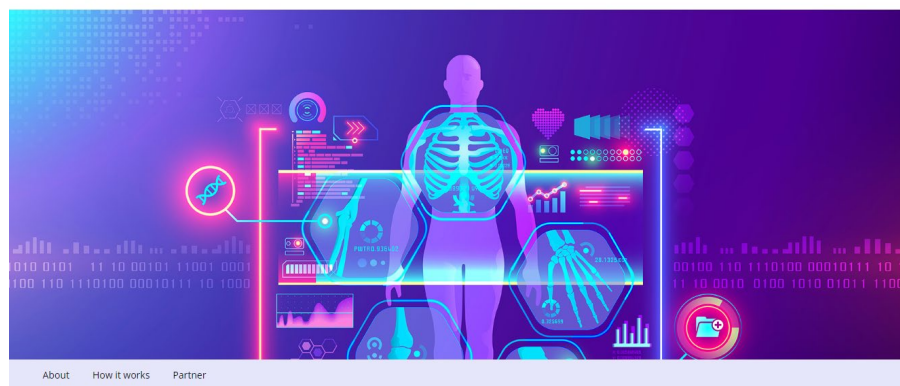
SHARE
()

<https://www.nuhsplus.edu.sg/article/what-ai-may-tell-you-about-your-lower-back-pain/>

When analysing these MRI images for spine-related diseases, Dr Makmur shared that SpineAI can help radiologists who work on a large volume of scans to identify abnormalities more efficiently. AI also helps automate tedious tasks such as measurements and labelling, which frees radiologists to focus on higher-value work.

According to the team behind it, SpineAI saves 200 hours of time for a radiologist per year.

“Patients benefit because they can get their diagnoses quicker,” said Dr Tan. “And if we are able to pick up something on the scan that needs urgent treatment, I’ll know about it sooner and can bring the patient back to get treated in a more timely fashion.”



ABOUT AI MEDICAL IMAGING PLATFORM FOR SINGAPORE PUBLIC HEALTHCARE (AIMSG)

Medical imaging is an important component of modern healthcare delivery. It ensures appropriate screening and diagnosis, enables preventive care and allows appropriate management of diseases. It also provides important prognostic data and risk stratification of health-related outcomes.

ABOUT COMMUNITY ACQUIRED PNEUMONIA AND COVID-19 ARTIFICIAL INTELLIGENCE (AI) PREDICTIVE ENGINE (CAPE)

Community Acquired Pneumonia and COVID-19 Artificial Intelligence (AI) Predictive Engine (CAPE) is an AI-enabled tool that can predict the severity of pneumonia in patients, including COVID-19 patients, based on a chest x-ray image. This Smart Health AI predictive engine enables closer monitoring and treatment of patients with severe pneumonia for improved patient outcomes through timely triaging and treatment.

CAPE was co-developed by Synapse and a multi-disciplinary team at Changi General Hospital (CGH), one of several public healthcare institutions searching for ways to fortify their preparations and responses when COVID-19 first reached Singapore.



Uses both radiology images and electronic medical records data



Predicts the expected pneumonia severity via deep learning



Enables prioritisation of healthcare resources



THANK YOU!



DSI-41
CLASSMATES



WASEEM



RUSTAM



DR GEOIPHY, DR DESMOND, DR
DANIEL, HAPPY MR FRIENDS
AND ALL MY EX-COLLEAGUES-
TURNED-FRIENDS WHOM I
ASKED FOR IDEAS AND
OPINIONS ON CLINICAL
RELATED MATTERS



COFFEE



LIFE-SAVING
ONLINE
RESOURCES



GERMAINE
(WHO ASK TO BE
MENTIONED)

REFERENCES

- [1] <https://www.mayoclinic.org/diseases-conditions/brain-tumor/symptoms-causes/syc-20350084>
- [2] <https://www.hopkinsmedicine.org/health/wellness-and-prevention/the-most-common-brain-tumor-5-things-you-should-know>
- [3] <https://www.cancer.net/cancer-types/brain-tumor/diagnosis#:~:text=MRIs%20create%20more%20detailed%20pictures,are%20different%20types%20of%20MRI.>
- [4] <https://pubmed.ncbi.nlm.nih.gov/38016677/>
- [5] <https://www.channelnewsasia.com/singapore/allied-health-professionals-healthcare-nurses-hospitals-shortage-radiographers-pharmacists-3861226>
- [6] <https://www.moh.gov.sg/news-highlights/details/subsidies-for-mri-scans>
- [7] <https://www.channelnewsasia.com/asia/artificial-intelligence-ai-replace-steal-jobs-work-healthcare-doctor-nurse-call-centre-4082086>
- [8] <https://annals.edu.sg/transforming-radiology-to-support-population-health/>
- [9] <https://ieeexplore.ieee.org/document/9687944>
- [10] <https://towardsdatascience.com/complete-architectural-details-of-all-efficientnet-models-5fd5b736142>
- [11] <https://smartwealth.sg/healthcare-cost-statistics-Singapore/>
- [12] <https://www.nuhsplus.edu.sg/article/what-ai-may-tell-you-about-your-lower-back-pain/>
- [13] <https://www.synapse.sg/healthtech/health-ai/ai-medical-imaging-platform>