Fibro-QuanNet

Pulmonary Fibrosis Prognosis Prediction using Quantum Machine Learning

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Dissertation by

Mr Nuwin Godakanda Arachchi

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Supervised by

Mr Guhanathan Poravi

Agenda

Presentation Overview

- Problem Domain
- Research Gap
- Aim of the Research
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Problem Domain

- Pulmonary fibrosis (PF) is a **progressive** lung disease caused by **damaged or scarred** lung tissue, occasionally prefixed as idiopathic PF (IPF), when of unknown causality (Devaraj, 2014)

- As per state-of-the-art medical practice, the deterioration/ scarring of the lung tissue is **irreversible**, merely leaving patients with symptom management using **therapy** and clinical drug trials. (Mayo Foundation for Medical Education and Research, 2021)

- The scarred/ damaged area will **fibrous** the pulmonic tissue, **obstructing the exchange of carbon dioxide and oxygen** gasses in the alveoli, thereby leaving the **body deprived of the oxygen** required for blood oxygenation and less lung volume. (American Lung Association, 2022)

In a nutshell

Pulmonary fibrosis is a progressive pulmonary condition in which state-of-the-art medical practices are defenseless leaving experts to yield critical decisions based on the prognosis of lung functionality manually, which is time-consuming and prone to error.

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Research Gap

- Utilizing **meta-data** along with **pulmonary HRCT imagery** has never been attempted before, thus proving a large gap in research. (Rachel, 2020)

- PF prognosis prediction has never reached the **quantum advantage** yet, thus opening a clear gap in achieving the advantage. (Niknejad, 2022)

- **Quantum Variational Cirtuits** has never been integrated with **quantile regression models** before. (Kistler et al., 2022)

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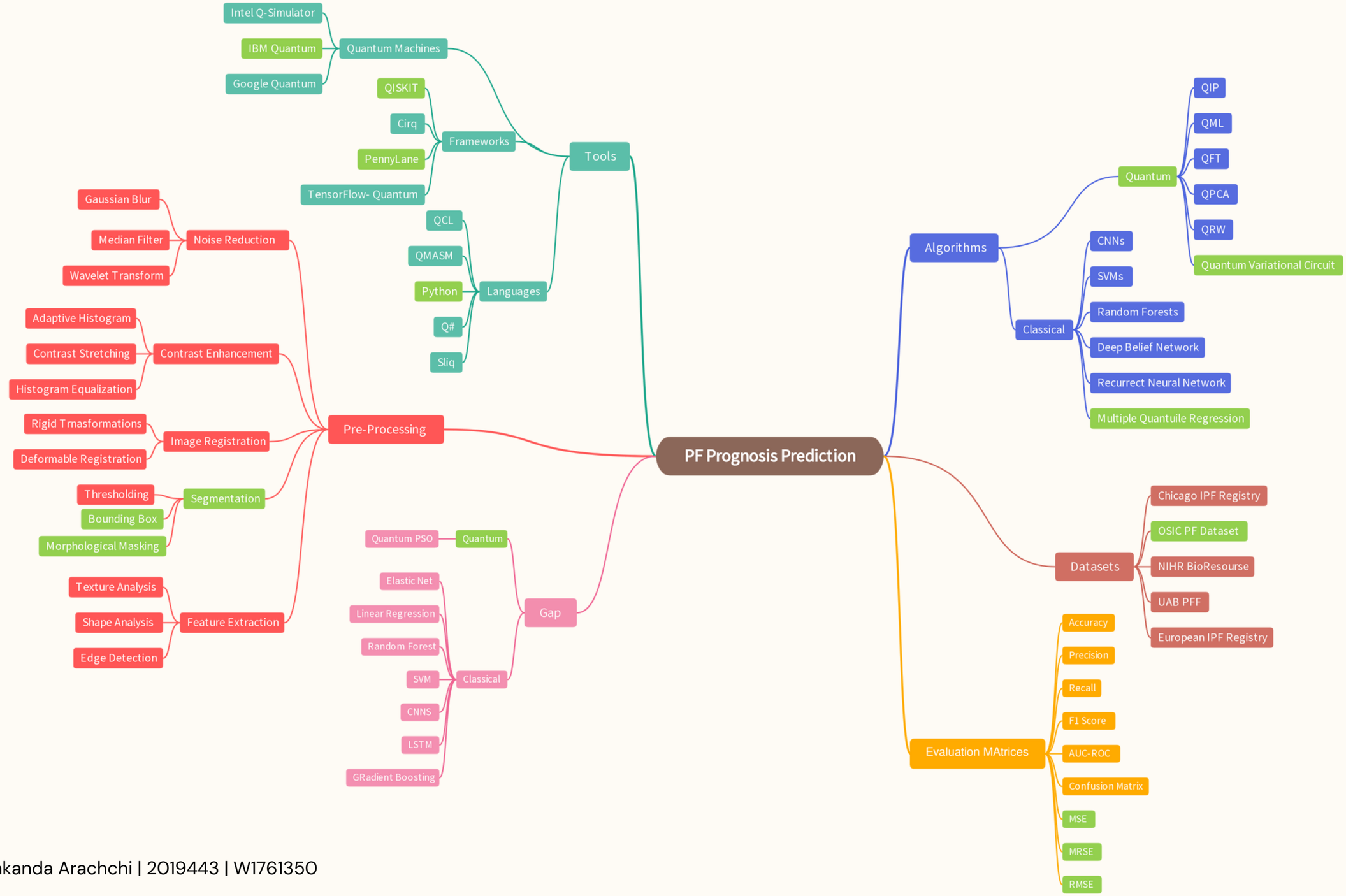

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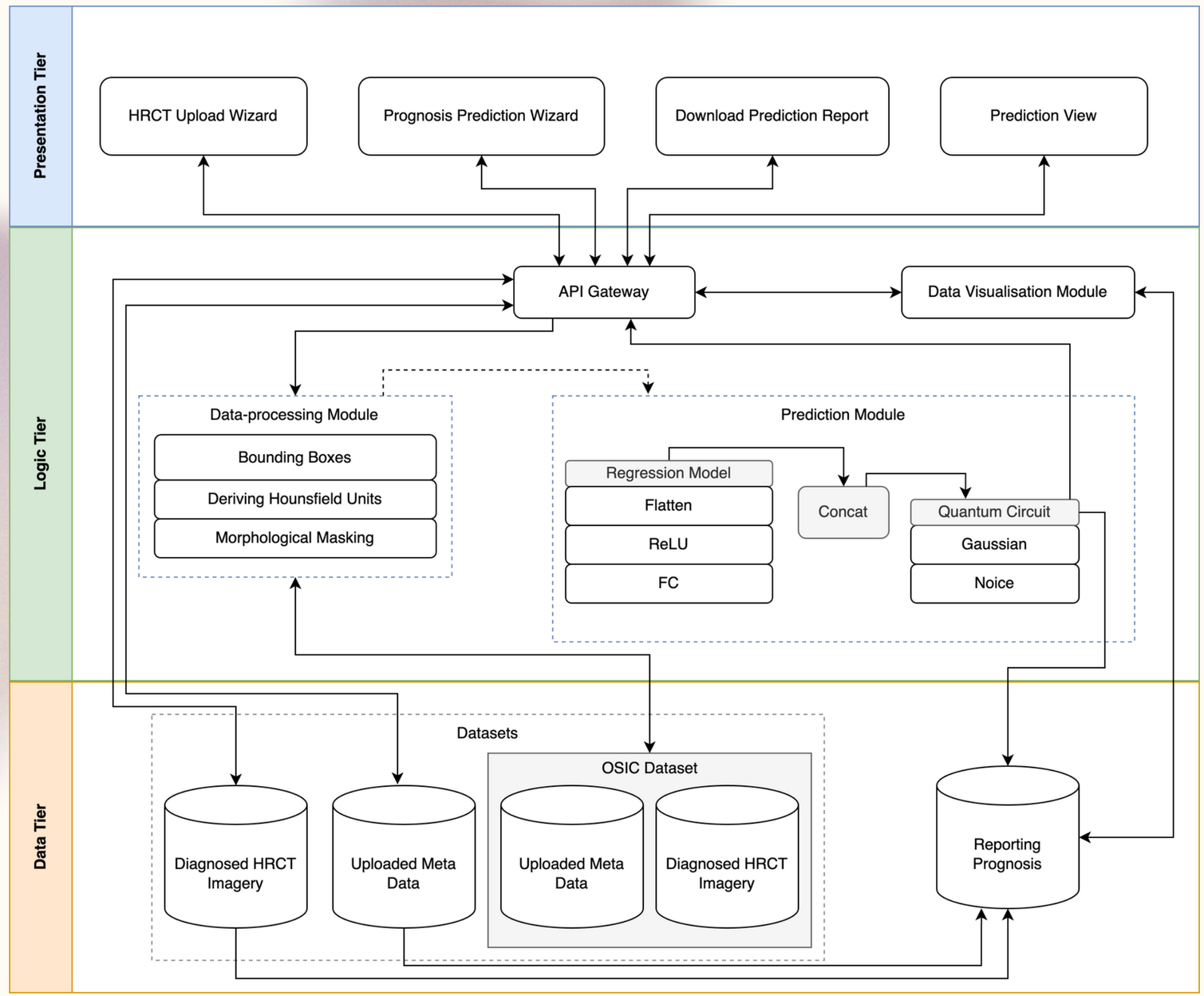
Aims of the Research

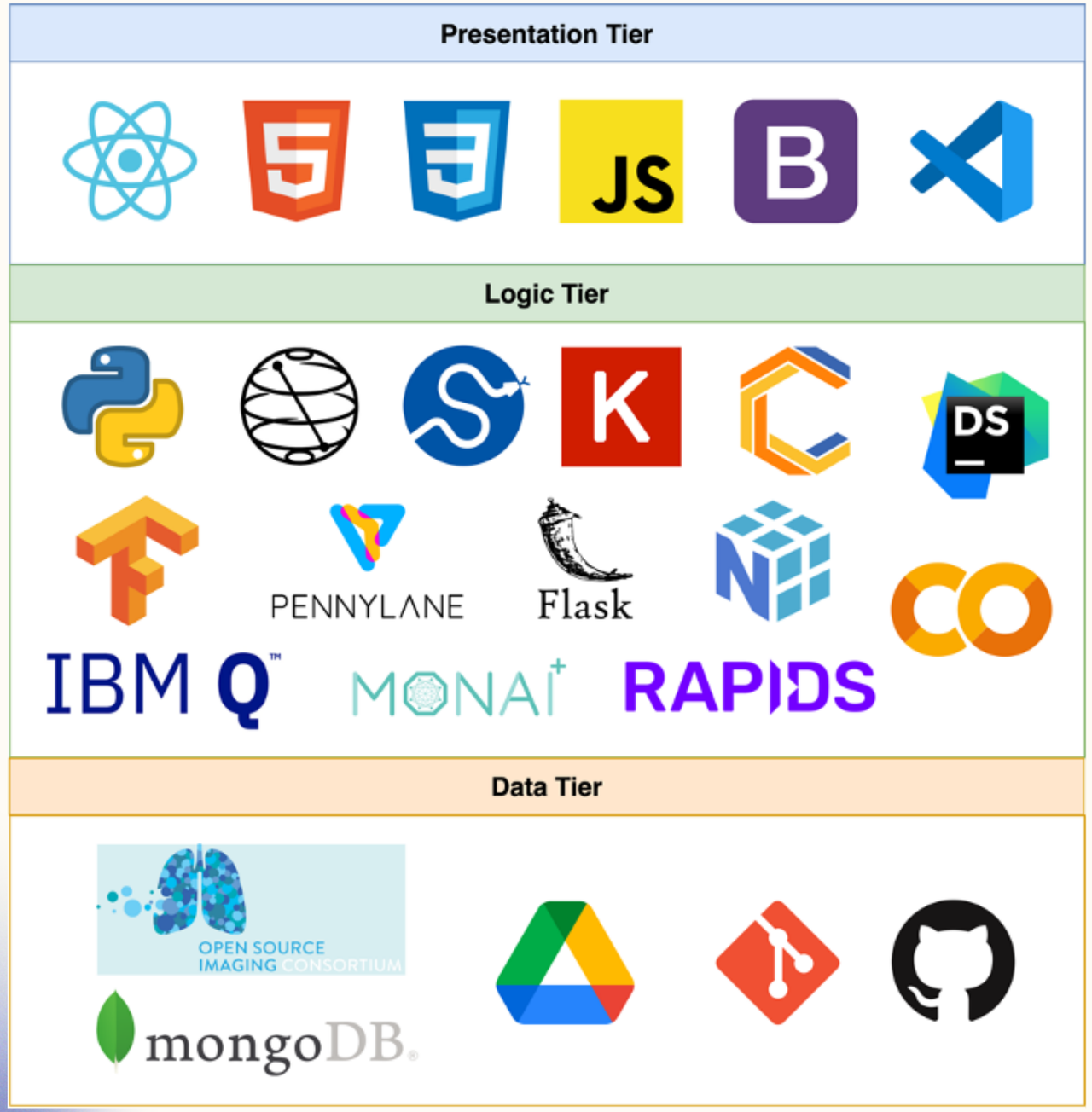
This research aims to *design, develop, and evaluate* a **novel prediction model** which is capable of **providing accurate and efficient prognosis predictions** of pulmonary fibrosis utilizing High-Resolution Computer Tomography data through **quantum machine learning**.

System Design

- Follows a three-tier architecture.
- The logic layer contains the prediction models



Implementation



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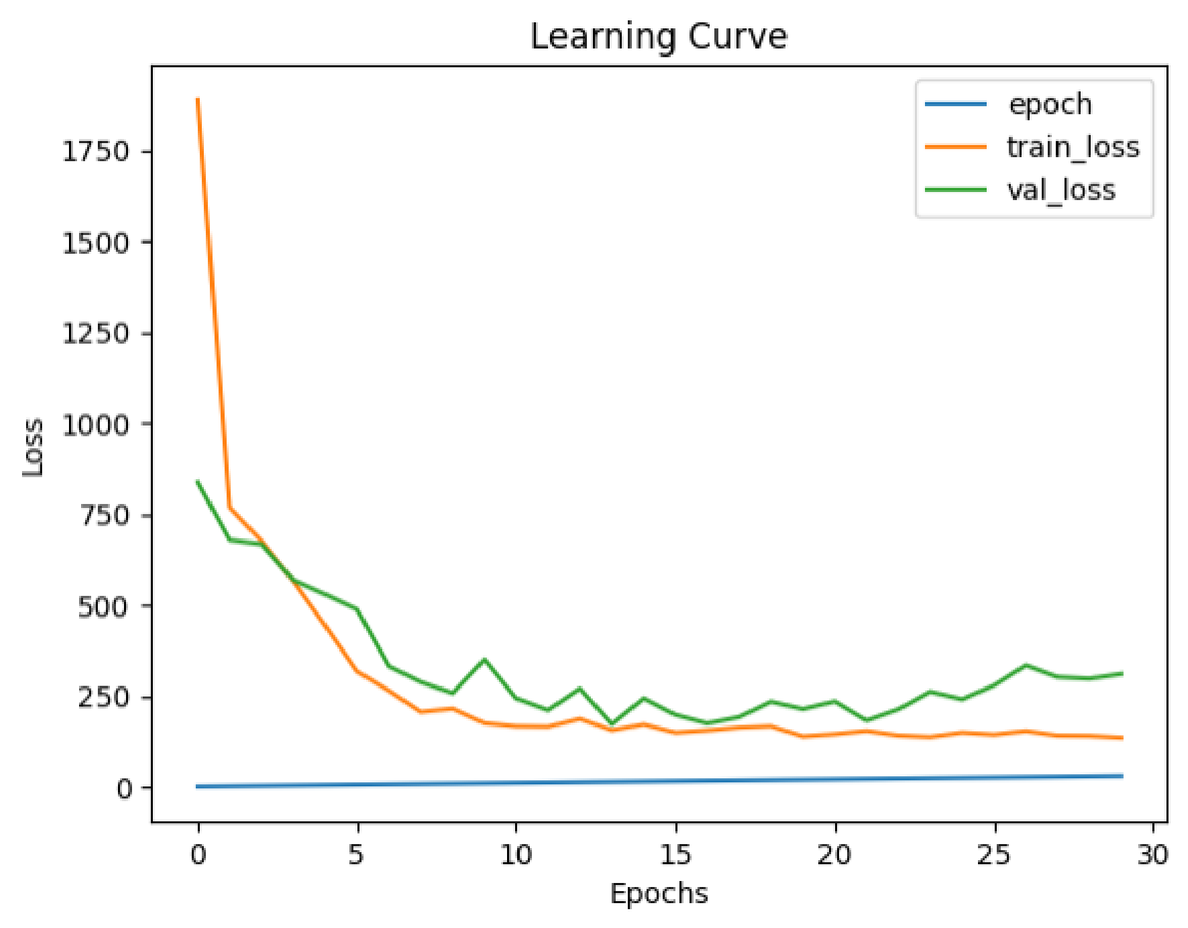
Demonstration

Results

Training & Validation Loss Curve



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Benchmarking

Research	Dataset	Regression Mode	LLL	RMSE
Proposed Fibro QuanNet *Quantum ML Approach*	OSIC	Hybrid Quantile Regression	-7.128	212.33
(Nazi et al., 2021) *State-of-the-art Classical ML Approach*	OSIC	ResNet, EfficentNet-b1, EfficentNet-b2, EfficentNet-b3,	-6.68	201.5
(Mandal et al., 2020) Classical ML Approach	OSIC	Quantile Regression, Ridge, ElasticNet	-6.92	189.3
(Wong et al., 2021) Classical ML Approach	OSIC	ElasticNet	-6.28	183.7

Limitations

Pure Quantum Algorithm

A purely quantum neural network was attempted during the research, however, scrapped due to non-performance. This is a physical **limitation due to the limited availability of qubits** in the freely available quantum hardware access

Metadata

·The system only takes meta-data input of a patient's age, gender, and smoking status, **limited to which are made available by the dataset** used during the training. However, **genetic information, which is also a key dependency has not been accounted for** anywhere in the meta-data inputs.

Quantum Hardware

In accordance with the current state-of-the-art quantum computer, the only viable option for quantum resources is **utilizing quantum stimulations** for the processing of information. Thus, the entire gain from quantum computing cannot be evaluated just as yet!

Future Work

Pure Quantum Algorithm

With an higher amount of qubits made available, it would be possible to utilize these qubits and build and train a potential quantum neural networking model. With IBMs goal towards reaching 300 qubits, the capacity available for free tier plans could be made higher, which may allow and support the use and development of pure quantum models.

Explainable AI

Introducing explainable AI into the domain of prognosis prediction systems, would also be a great piece of enhancement to the domain. Viewing the chronological steps taken by a machine learning model in the health industry would bring more trustworthiness into the health care-AI industry and MedTech.

Evaluations - Technical

Name	Professional Background	Latest Academic Qualification
Prof. Amira Abbas	Postdoctoral Researcher - Quantum ML @ University of West-Michigan	PhD in Quantum computing, theoretical machine learning and quantum machine learning (Durban)
Dr. Kinshuk Sengupta	Lead Scientist @ Microsoft Quantum Research Centre - India	PhD in Machine Learning and Information Systems (India)
Dr. Suresh Parthasarathy	Principal Research Developer @ Microsoft Research Center - India	PhD in Applied Sciences and Information Systems Engineering (India)
Ms Senuri Gunaratne	Research Assistant and Lecturer @ University of West-Michigan	PhD (Reading) in Big Data Engineering and Machine Learning (USA)
Mr Rahul Kalubowila	Research Assistant @ University of Colombo	MSc (Reading) in Computer Science Research
Mr Rashan Peiris	CTO @ iTelaSoft - Australia	MSc in Computer Sciences (UK)
Mr Indaka Raigama	Visting Lecturer & CEO @ iTelaSoft - Australia	BSc in Computer Science (Colombo LK)
Mr Deepadharshan Gnanajothi	Products Architect @ iTelaSoft - Australia	BEng in Software Engineering (UK)
Ms Pubodanee Ranathunga	Tech Lead @ iTelaSoft - Australia	MSc in Advance Software Engineering (UK)

Evaluations - Problem Domain

Name	Professional Background	Latest Academic Qualification
Dr. Keerthi Gunasekara	Respiratory Physician- Ministry of Health LK	MBBS, MD, MRCP (Pulmonology), Consultant Physician
Prof. Aloka Pathirana	General Surgeon @ Lanka Hospitals, Professor of Surgery @ University of Sri Jayawardanapura	MBBS, MS.(Surgery), FRCS (England), FRCS (Edinburgh)
Dr. Akila Piyaratne	Judicial Medical Officer @ Monaragala Base Hospital, Sri Lanka	MBBS (Bangladesh)
Dr. Yumandhee Godakanda Arachchi	Medical Officer- Cardiology @ Durdans Hospital Colombo, Research Assistant @ Kothalawala Defence University, LK	MBBS, MD (UK), MPH (Colombo)
Ms. Hasanya Ratnayake	Medical Student @ GSMU (Belarus)	MBBS (Belarus)
Ms Sandapini Duggannarala	Medical Student @ KSMU (Russia)	MD (Russia)

Key Highlights from Evaluations

Technical Evaluations

"... especially the fact that the student has thought and ***utilised quantum computing for mere undergraduate research can be identified as an ambitious*** piece of work. ..." (Dr Kinshuk Sengupta)

"... and the way you have proven that ***classical machine learning algorithms, which are used daily, can be optimized with an addition of a quantum layer*** shows commitment and is a ***great research contribution*** for an undergraduate research project. ..." (Prof. Amira Abbas)

"... It is a ***smart and bold move to go with a quantum-classical hybrid approach*** for the model with a well-recognized circuit instead of the pure quantum algorithm, which shows you have ***thoroughly gone through the literature***. ..." (Dr Suresh Parthasarathy)

" ... In the process of my personal research activities, I ***have not seen a quantum-optimised regression model***, so the student's research gap is ***very well suited and ambitious for an undergrad program***. ..." (Ms Senuri Gunaratne)

Contribution to Body of Knowledge

Uses Patient Metadata

DICOM imagery and metadata data pre-processing model, capable of receiving the DICOM image file and a CSV file with patient metadata, and be able to convert into tensor outputs

Achieves Quantum Advantage

The research contributes a novel hybrid quantum-classical neural networking model, which is able to successfully predict prognosis of PF

Optimizes Simple Classical MQR

As proven by evaluators, the project proves that simple machine learning models such as MQR can be optimised substantially by simply adding a quantum layer into it.

Conclusion

Use of Existing Skills

Full-Stack Development

Machine Learning

Algorithmic Understanding and Knowledge

New Skills Acquired

Quantum Computing

Quantum Machine Learning

HRCT understanding and reconstruction

Problems & Challenges Faces

The selected domain area consisted of very complex mathematical phenomena in both computational and mechanical.

Hardware Resources

Lack of Experts

References

American Lung Association, N.H.C. (2022). Each Breath: Facts about Pulmonary Fibrosis. 7 Things Everyone Should Know about Pulmonary Fibrosis. Available from https://www.lung.org/blog/7-things-know-pulmonary-fibrosis [Accessed 6 September 2022].

Devaraj, A. (2014). Imaging: How to Recognise Idiopathic Pulmonary Fibrosis. European Respiratory Review, 23 (132), 215–219. Available from https://doi.org/10.1183/09059180.00001514.

Mayo Foundation for Medical Education and Research. (2021). Pulmonary fibrosis - Symptoms and causes. Mayo Clinic. Available from https://www.mayoclinic.org/diseases-conditions/pulmonary-fibrosis/symptoms-causes/syc-20353690 [Accessed 6 September 2022].

Guo, X., Schwartz, L.H. and Zhao, B. (2019). Automatic liver segmentation by integrating fully convolutional networks into active contour models. Medical Physics, 46 (10), 4455–4469. Available from https://doi.org/10.1002/mp.13735.

Huang, Y. et al. (2015). A functional genomic model for predicting prognosis in idiopathic pulmonary fibrosis. *BMC Pulmonary Medicine*, 15 (1), 147. Available from https://doi.org/10.1186/s12890-015-0142-8.

Lacedonia, D. et al. (2021). Downregulation of exosomal let-7d and miR-16 in idiopathic pulmonary fibrosis. *BMC Pulmonary Medicine*, 21 (1), 188. Available from https://doi.org/10.1186/s12890-021-01550-2.

Welinder, P. et al. (2010). The Multidimensional Wisdom of Crowds. *Advances in Neural Information Processing Systems*. 2010. Curran Associates, Inc. Available from https://papers.nips.cc/paper_files/paper/2010/hash/0f9cafd014db7a619ddb4276af0d69 2c-Abstract.html [Accessed 10 Januray 2023].

Thank you for listening!

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