RGC Ref. No.:
UGC/FDS17/M10/19
(please insert ref. above)

RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

Submission Deadlines:
1. *Auditor's report with unspent balance, if any: within **six** months of the approved project completion date.*
2. *Completion report: within **12** months of the approved project completion date.*

Part A: The Project and Investigator(s)

1. Project Title

Radiomics-based prognostic modelling of radiotherapy outcomes for head and neck tumours using an artificial intelligence approach

2. Investigator(s) and Academic Department(s) / Unit(s) Involved

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	Prof. TANG Fuk Hay/Professor	School of Medical and Health Sciences, Tung Wah College
Co-Investigator(s)	Prof. LAW Maria Yuen Yee/Professor	School of Medical and Health Sciences, Tung Wah College
Co-Investigator(s)	Prof. LEE Victor Ho-fun/ Clinical Associate Professor	Department of Clinical Oncology, The University of Hong Kong
Co-Investigator(s)	Dr. XU Zhiyuan/ Associate Consultant	Clinical Oncology Center, The University of Hong Kong Shenzhen Hospital
Co-Investigator(s)	Dr. LI Jishi/ Associate Consultant	Clinical Oncology Center, The University of Hong Kong Shenzhen Hospital
Co-Investigator(s)	Mr. CHEUNG Kin-man/ Senior Physicist	Clinical Oncology Center, The University of Hong Kong Shenzhen Hospital
Co-Investigator(s)	Mr. CHAN Wai/ Senior Radiation Therapist	Clinical Oncology Center, The University of Hong Kong Shenzhen Hospital

3. Project Duration

	Original	Revised	Date of RGC / Institution Approval *(must be quoted)*
Project Start Date	01/01/2020	No	09/09/2019
Project Completion Date	31/12/2022	(1st revision) 30/06/2023 (2nd revision) 31/12/2023	(1st revision) 19/12/2022 (2nd revision) 04/07/2023
Duration *(in month)*	36 months	(1st revision) 42 months (2nd revision) 48 months	
Deadline for Submission of Completion Report	31/12/2023	31/12/2024	

4.4 Please attach photo(s) of acknowledgement of RGC-funded facilities / equipment. Please see Appendix 1.

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. To assess and correlate the extent of damage to surrounding normal tissues from a radiation dose delivered to head and neck tumours during a course of radiation therapy based on radiomics
2. To propose a model for predicting organ/tissue damage following radiotherapy treatment
3. To develop a radiomics-based intelligence system to predict a patient's prognosis during the course of radiotherapy treatment

5.2 Revised objectives (no change)

Date of approval from the RGC: _____

Reasons for the change: _____

_____

1.

2.

3. ....

5.3 Realisation of the objectives
(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)

Objective 1
For this objective, we have completed a research paper: : Tang, F.-H.; Cheung, E.-Y.-W.; Wong, H.-L.; Yuen, C.-M.; Yu, M.-H.; Ho, P.-C. Radiomics from Various Tumour Volume Sizes for Prognosis Prediction of Head and Neck Squamous Cell Carcinoma: A Voted Ensemble Machine Learning Approach. Life 2022, 12, 1380. https://doi.org/10.3390/life12091380.

In this, we evaluated the effect of various sizes of tumour volume and assess and correlate the extent of damage to surrounding tissues that may affect the prognosis of head and neck A voted ensemble approach with a combination of multiple machine learning algorithms is proposed in this study. Our result indicted that there was no significant difference between the various target volumes for the prognostic prediction of HNSCC patients so far our method was based planning target volume.

Objective 2:
This objective is addressed in the paper: Tang F, Chu CY-W, Cheung EYW. Radiomics AI prediction for head and neck squamous cell carcinoma (HNSCC) prognosis and recurrence with target volume approach. BJR Open 2021; 3: 20200073.
In this study, we developed a deep learning artificial neural networks (DL-ANN) model to predict death prognosis and cancer recurrence rate based on the features extracted from GTV and PTV of the CT images. The PTV radiomics features with DL-ANN model could achieve 77.7% accuracy with overall AUC equal to 0.934 and 0.932 when predicting HNSCC-related death prognosis and cancer recurrence respectively. This is a very high performance for prediction.

Objective 3:
The radiomic-based intelligence system was established and published in the work: Tang, F.-H.; Fong, Y.-W.; Yung, S.-H.; Wong, C.-K.; Tu, C.-L.; Chan, M.-T. Radiomics-Clinical AI Model with Probability Weighted Strategy for Prognosis Prediction in Non-Small Cell Lung Cancer. Biomedicines 2023, 11, 2093. https://doi.org/10.3390/ and
Tang FH, Xue C, Law MY, Wong CY, Cho TH, Lai CK. Prognostic Prediction of Cancer Based on Radiomics Features of Diagnostic Imaging: The Performance of Machine Learning Strategies. J Digit Imaging. 2023 Jun;36(3):1081-1090. doi: 10.1007/s10278-022-00770-0. Epub 2023 Feb 13. PMID: 36781589; PMCID: PMC10287586.
The system is not only applied to head and neck tumour, but also to lung cancer.
On the whole, we have achieved 100% of the objectives.

5.4 Summary of objectives addressed to date

Objectives *(as per 5.1/5.2 above)*	**Addressed** *(please tick)*	**Percentage Achieved** *(please estimate)*
1. To assess and correlate the extent of damage to surrounding normal tissues from a radiation dose	yes	100%, see paper in “Life”.
2.. To propose a model for predicting organ/tissue damage following radiotherapy treatment	yes	100% see paper in “ BJR
3. To develop a radiomics-based intelligence system to predict a patient’s prognosis during the course of radiotherapy treatment	yes	100% see paper in “Biomedicine” and “Journal of Digital Imaging”

6. Research Outcome

6.1 Major findings and research outcome
(Maximum 1 page; please make reference to Part C where necessary)

1. **AI Model for Head and Neck Cancer Prognosis Prediction**
   We successfully developed a deep learning neural network specifically designed to predict prognosis in head and neck cancer patients through a target volume approach. The model demonstrated an accuracy of 77.7%, achieving an Area Under the Curve (AUC) of 0.934 for predicting HNSCC-related mortality and 0.932 for cancer recurrence. These findings equip oncology professionals with a valuable tool to enhance patient management in head and neck cancer.
2. **Enhanced AI Method for Cancer Prediction**
   Initially, we created a deep learning model for cancer prediction; however, we recognized the limitations of relying solely on radiomic data. To improve predictive accuracy, we integrated multiple machine learning algorithms and developed a weighted voting method to address the individual limitations of these algorithms. Furthermore, we introduced a probability-weighted approach to effectively combine clinical and radiomic data. This comprehensive strategy resulted in a remarkable AUC of 0.949, showcasing significant advancements in cancer prediction.
3. **Formulation of Solutions for Imbalanced Data**
   In this study, we proposed three strategies to improve model performance in the context of imbalanced data:
   1. Utilizing various machine learning models
   2. Implementing a weighted voting model
   3. Developing a probability-weighted model
      These approaches aim to enhance the robustness and accuracy of predictions in scenarios with imbalanced datasets.

6.2 Potential for further development of the research and the proposed course of action *(Maximum half a page)*

The potential for further development of the radiomic research base is substantial, here are some considerations:

1. Improvement for Small and Imbalanced Data

- **Data Augmentation Techniques**: Implement advanced data augmentation strategies to artificially expand small datasets. Techniques like rotation, scaling, and elastic deformations can help create more training examples.
- **Synthetic Data Generation**: Explore generative models (e.g., GANs) to create synthetic radiomic data that can help balance classes and enhance model robustness.
- **Statistical Methods**: Develop sophisticated statistical techniques to analyze small and imbalanced datasets effectively. This may include bootstrapping or Bayesian approaches to improve estimates and reduce bias.

2. Development of Multi-Radiomic Approaches

- **Integration of Multi-Omics Data**: Combine radiomic data with genomic, proteomic, and transcriptomic data for a more comprehensive analysis. This could lead to better insights into tumor biology and treatment response.
- **Machine Learning Models**: Develop multi-modal machine learning models capable of handling diverse data types. Techniques like multi-instance learning or ensemble methods could enhance predictive accuracy by leveraging the strengths of different data sources.
- **Clinical Outcome Correlation**: Focus on correlating multi-omic data with clinical

outcomes, such as survival rates or treatment responses. This can help validate the clinical utility of the combined data approach.

3. Future Directions

- **Standardization of Data**: Establish standardized protocols for data collection and analysis to facilitate reproducibility and comparison across studies.
- **Collaborative Platforms**: Create collaborative networks or platforms that pool resources and data from various institutions, allowing for larger datasets that can enhance model training and validation. At this stage, we form a Greater China Radiomic Research hub which involves: South China Normal University, Southeast University, Najing. Advanced Research Institute at Shenzhen, Chinese Academic of Science.

- **Translational Applications**: Focus on translating findings from radiomic research into clinical practice, aiming for tools that assist in decision-making, personalized treatment plans, and improved patient outcomes.

By tackling these areas, the radiomic research base can evolve significantly, leading to more robust analyses and impactful clinical applications.

7. Layman's Summary

(Describe in layman's language the nature, significance and value of the research project, in no more than 200 words)

The development of radiomic prediction for cancer treatment means we can know if a treatment will work even before starting it. In simpler terms, we can predict how likely a patient is to survive for five years after treatment. This is the exciting promise of radiomics research.

To make accurate predictions, we need to consider various factors, like blood test results, genetic changes, the patient's age, overall health, and medical history. In our study, we focus on imaging data, which is essential for managing patients effectively.

Radiomics involves analyzing medical images to extract many features that help identify patterns not easily seen by the eye. This can lead to better diagnoses and a clearer understanding of tumor characteristics. The data we gather can help create personalized treatment plans by predicting how well a patient might respond to different treatments.

Overall, our radiomics project is a major advancement in cancer care, aiming to improve diagnosis, tailor treatments to individual patients, and ultimately enhance patient outcomes.

Part C: Research Output

8. Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project
(Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				**Author(s)** *(denote the corresponding author with an asterisk*)*	**Title and Journal / Book** *(with the volume, pages and other necessary publishing details specified)*	**Submitted to RGC** *(indicate the year ending of the relevant progress report)*	**Attached to this Report** *(Yes or No)*	**Acknowledged the Support of RGC** *(Yes or No)*	**Accessible from the Institutional Repository** *(Yes or No)*
Year of Publication	**Year of Acceptance** *(For paper accepted but not yet published)*	**Under Review**	**Under Preparation** *(optional)*						
2021	**2021**			Tang F, Chu CY-W, Cheung EYW*	**British Journal of Radiology**	**2022**	**yes**	**Yes (we wrote to journal but the acknowledgement is not appeared in the article**	**Yes**
2022	**2022**			Tang, F.-H.; Cheung, E.-Y.-W*.; Wong, H.-L.; Yuen, C.-M.; Yu, M.-H.; Ho, P.-C.	**Life** 2022, 12, 1380.	**2022**	**yes**	**yes**	**yes**
2023	**2023**			Tang, F.-H*.; Fong, Y.-W.; Yung, S.-H.; Wong, C.-K.; Tu, C.-L.; Chan, M.-T.	. Biomedicines 2023, 11, 2093	**2023**	**yes**	**yes**	**yes**
2023	**2023**			Tang FH, Xue C, Law MY,*	**Journal of Digital Imaging**	**2023**	**yes**	**yes**	**yes**

				Wong CY, Cho TH, Lai CK.					
NA		**yes**		TANG Fuk Hay[1*], , CHAN Wai[2**], LAW Maria YY[1], CHEUNG Kin Man[2], XU Zhi-Yuan [2], SHEN Lin[2], LEE Victor Ho-Fun [2, 3], LI Ji-Shi[2***]	**PLOS**	**TBC**	**No**	**yes**	**NA**

9. Recognized International Conference(s) In Which Paper(s) Related To This Research Project Was / Were Delivered

(Please attach a copy of each conference abstract)

Month / Year / Place	**Title**	**Conference Name**	**Submitted to RGC** *(indicate the year ending of the relevant progress report)*	**Attached to this Report** *(Yes or No)*	**Acknowledged the Support of RGC** *(Yes or No)*	**Accessible from the Institutional Repository** *(Yes or No)*
26-29 Aug 2020/Dublin	Development of radiomic-based model for prediction of treatment outcome for patients with head and neck cancers undergoing radiotherapy	International Society of Radiographers and Radiological Technologists.	2021	no	yes	no

10. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning

(Please elaborate)

The research and result has band contributed to teaching under the subject Contemporary Cancer Therapy (MED4010). Also the research experience and new knowledge has been transferred to Honors Year Project.

11. Student(s) Trained

(Please attach a copy of the title page of the thesis)

Name	Degree Registered for	Date of Registration	Date of Thesis Submission / Graduation
	Bachelor of Medical Science (Honours) Radiation Therapy Major	2018	2020

12. Other Impact

(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)

1. At this stage, we form a Greater China Radiomic Research hub which involves: South China Normal University, South East University, Najing. Advanced Research Institute at Shenzhen, Chinese Academic of Science. 1 paper and 1 patent are generated from this collaborative network.
2. The research on this work has attracted a donation in kind of HK$3.6M from Eleka company for the Radiotherapy Information System for the radiomic research

13. Statistics on Research Outputs

	Peer-reviewed Journal Publications	Conference Papers	Scholarly Books, Monographs and	Patents Awarded	Other Research Outputs (please specify)

			Chapters			
No. of outputs arising directly from this research project	4	1	0	1* *Patent in progress	Type	No.

*** The patient is a collaborative work with South China Normal University.**

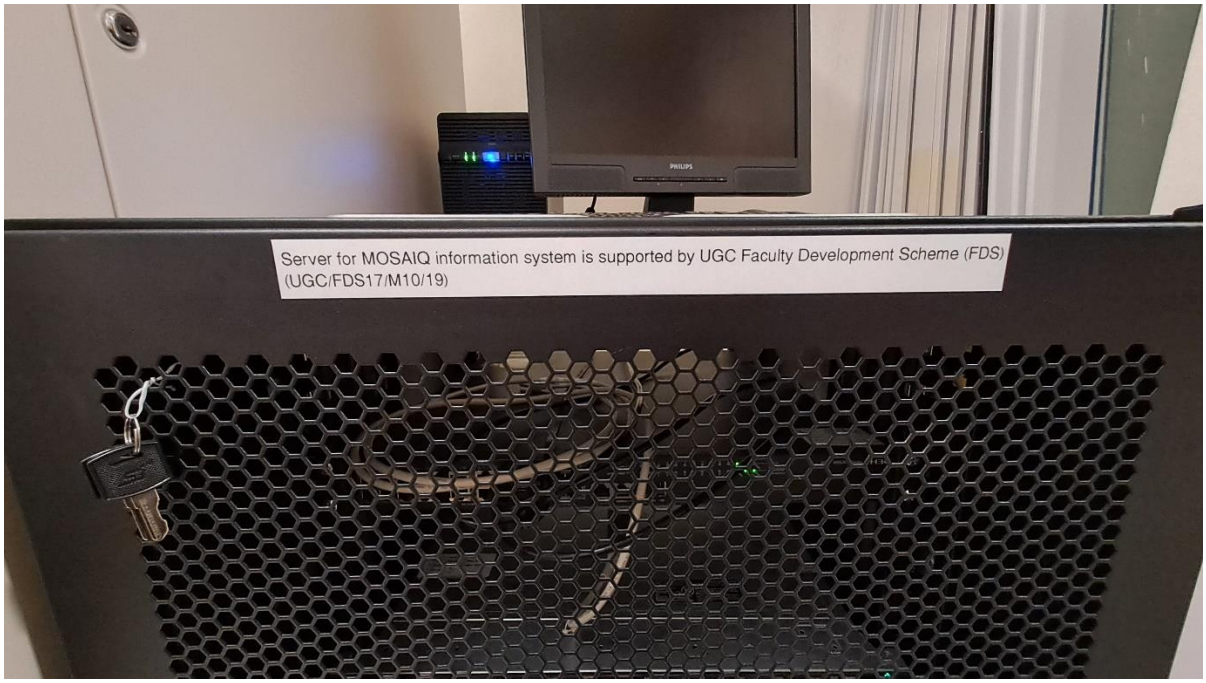
14. Public Access Of Completion Report

(Please specify the information, if any, that cannot be provided for public access and give the reasons.)

Information that Cannot Be Provided for Public Access	**Reasons**

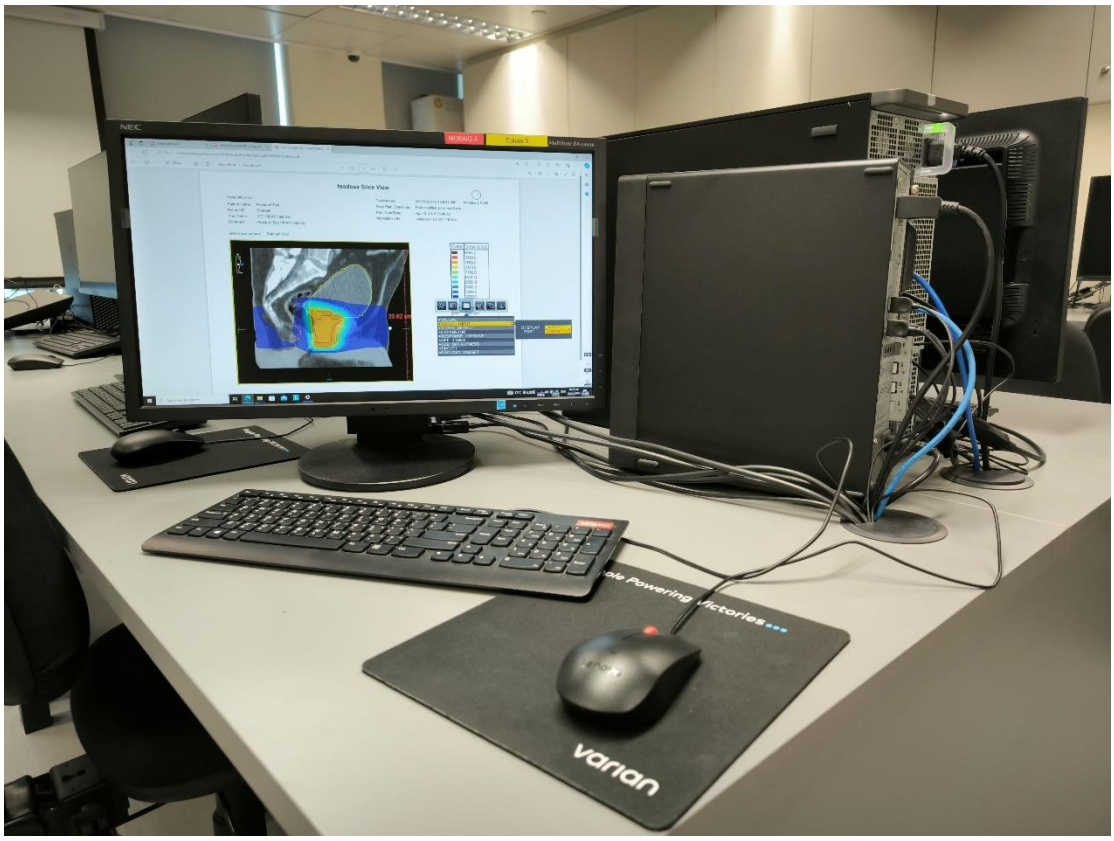
Equipment supported by FDS

1. Server and workstations for MOSAQI Radiotherapy Information System



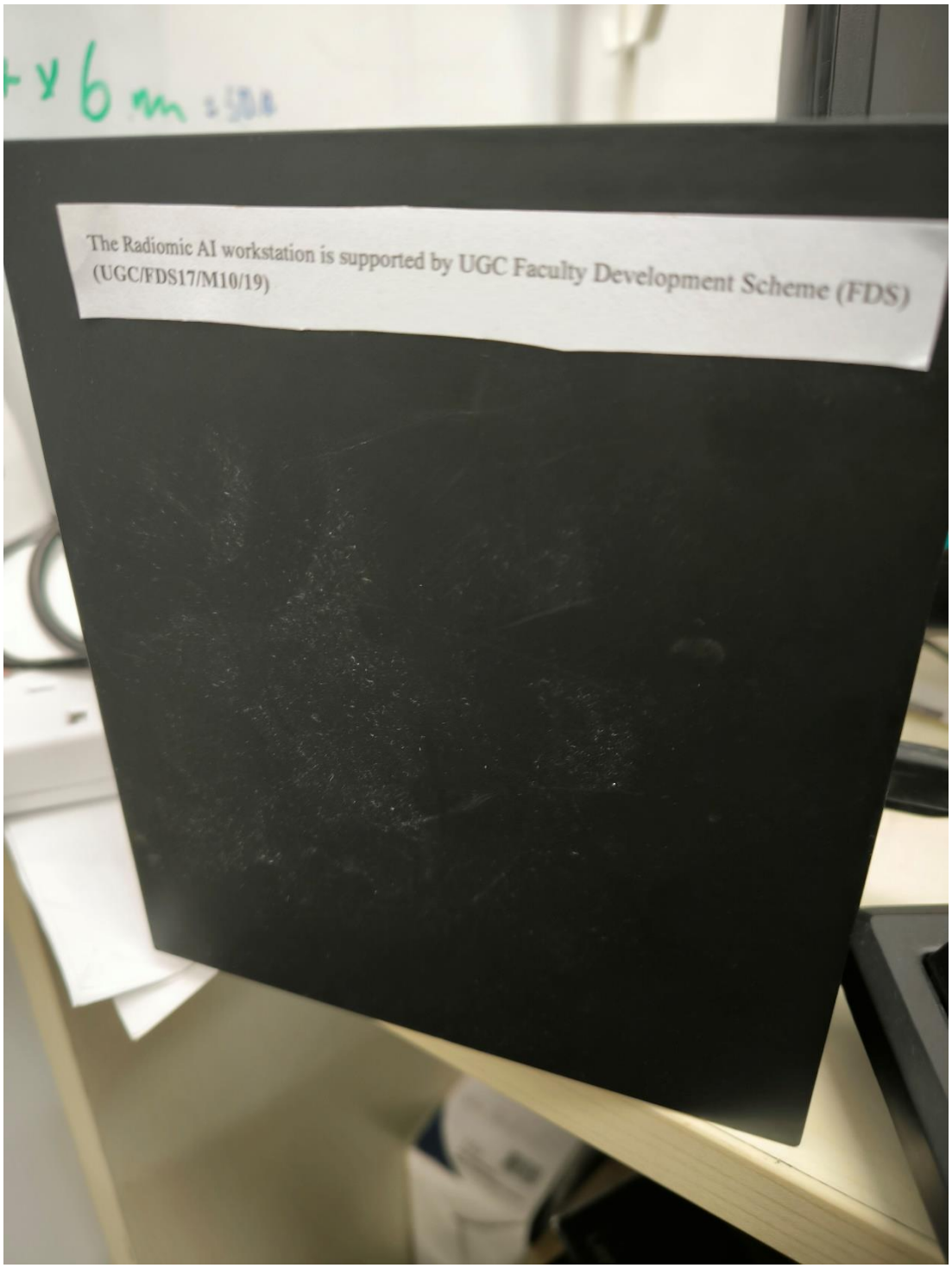
Server for MOSAQI server (close up)

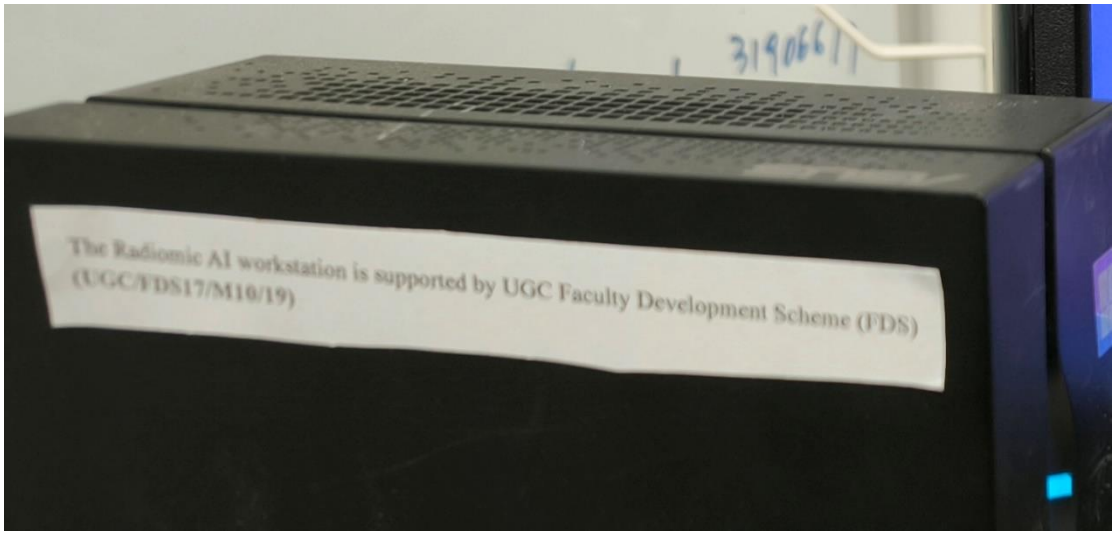
MOSAQI server (whole view)

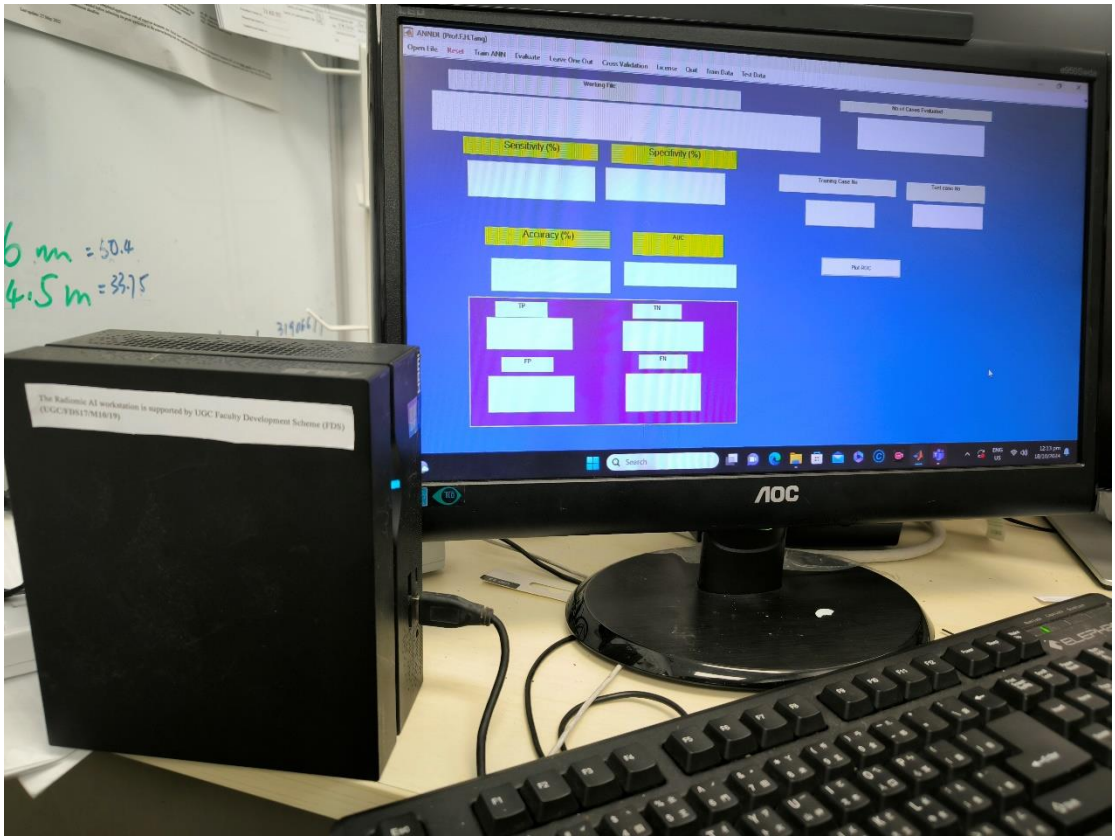


MASAQI information system (client view)

Radiomic workstation for development




The Radiomic AI workstation is supported by UGC Faculty Development Scheme (FDS)
(UGC/FDS17/M10/19)


Sensitivity (%)
Specificity (%)
Accuracy (%)
AUC
AOC