Mohammad Arafat Hussain, Ph.D.
Postdoctoral Research Associate, School of Computing Science
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April 3, 2021

The Faculty Search Committee
School of Engineering Science
Simon Fraser University, Burnaby, BC V5A 1S6, Canada

Subject: Application for the position of Assistant Professor in the School of Engineering Science.
Research focus: Biomedical Engineering

Dear Members of the Faculty Search Committee,

I am submitting my application for the tenure-track position of Assistant Professor in the School of Engineering Science at Simon Fraser University. My curriculum vitae, research statement, teaching statement, as well as the statement of my past experiences in supporting equity, diversity, and inclusion, are enclosed. Prof. Ghassan Hamarneh at Simon Fraser University, and Profs. Rafeef Garbi and Antony J. Hodgson at the University of British Columbia have agreed to submit letters of recommendation in support of my application, and their contact information is also enclosed.

I am currently a postdoctoral research associate in the School of Computing Science at Simon Fraser University, under Professor Ghassan Hamarneh. I have been developing novel machine learning techniques to improve the computed tomography (CT) and X-ray-based Corona virus disease 2019 (COVID-19) detection, which would help clinicians in rapid COVID-19 diagnosis and treatment planning. My research is aiming to address the challenges of (1) insufficient annotated COVID data for deep model training by developing novel semi-supervised and unsupervised learning methods, (2) learning the discriminatory radiomic features between COVID-19 and community-acquired pneumonia (CAP) using learnable histogram-based deep neural network, and (3) scanner variance that results in under-performance in cross-domain training-testing by developing novel domain adaptation techniques.

As a graduate student under the supervision of Professor Rafeef Garbi at the University of British Columbia, Vancouver, I primarily focused on kidney cancer detection and analysis in CT using machine learning. In the clinical environment, radiologists rely on a manual ellipsoid to estimate total kidney volume for primary kidney functionality analysis. I proposed a convolutional neural network (CNN)-based automatic kidney localization and segmentation-free volume estimation method, a more reliable and more accurate alternative approach. I also addressed the problem of using sparsely annotated data in 2D CNN by proposing the collage data representation in the multiple instances learning framework, a computationally inexpensive alternative of computationally expensive 3D CNN. Clear cell renal cell carcinoma, a common type of kidney cancer, is positively associated with mutated genes identified by renal biopsy-based genome sequencing. I developed a noninvasive CNN-based automatic approach that enabled predicting the mutated genes by learning the CT image features. Further, I developed a learnable image histogram-based CNN that enabled learning CT textural features directly from images to determine cancer grades and stages, which could be used as an alternative to a percutaneous renal-biopsy-based approach.

My independent research aim is inspired by both my graduate and postdoctoral studies. I shall investigate topics related to the cancer radiomics, which may provide quantitative decision support in cancer detection and treatment. Radiomics refers to extracting high-dimensional quantitative features from multi-modal medical images, followed by mining correlations between these features and cancer diagnosis/prognosis. I aim to contribute to this field by developing novel artificial intelligence (AI) techniques for extracting quantitative features from medical images, finding practical approaches to combine imaging features with clinical and genomic information, and finally mining these data to detect vital disease-specific radiomic biomarkers.

I have considerable experience as an educator. I taught multiple undergraduate courses and laboratory sessions at Eastern University Bangladesh as a Senior Lecturer. I also worked as a Teaching Assistant at the University of British Columbia in nine courses (multiple times each) in eighteen semesters. As a faculty member, I am especially interested in teaching visual signal computing and processing, computer vision in medicine, medical imaging fundamentals, and AI application in medical image analysis.

I am currently applying for the membership of the Association of Professional Engineers and Geoscientists of British Columbia (APEGBC). I am also a **permanent resident** of Canada.

As a faculty member, I can contribute to the research, innovation, and education of Simon Fraser University by solving critical biomedical engineering problems and beyond using artificial intelligence. This prestigious university, especially with expert faculties and resources, is a perfect match to continue my academic journey. Please contact me with any questions you may have, and thank you for considering my application.

Sincerely,
Mohammad Arafat Hussain

Mohammad Arafat Hussain, Ph.D.

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EDUCATION & TRAINING

- **Simon Fraser University (SFU)** — Burnaby, BC
  Postdoctoral Research Associate, School of Computing Science — 04/2020-Present
- **University of British Columbia (UBC)** — Vancouver, BC
  Ph.D. in Biomedical Engineering (Research Focus: Deep Learning in Medical Image Analysis) — 04/2020
  M.A.Sc. in Biomedical Engineering — 05/2015
- **Bangladesh University of Engineering & Technology (BUET)** — Dhaka, Bangladesh
  M.Sc. in Electrical and Electronic Engineering — 04/2013
  B.Sc. in Electrical and Electronic Engineering — 02/2011

OFFERS, AWARDS & HONOURS

- **Postdoctoral Fellowship Offer**, Boston Children's Hospital & Harvard Medical School — 2020
- **Postdoctoral Fellowship Offer**, Mass. General Hospital & Harvard Medical School - *Declined* — 2019
- **Postdoctoral Fellowship Offer**, School of Medicine, Stanford University - *Declined* — 2019
- **MICCAI Graduate Student Travel Award**, MICCAI Society — 2019
- **Conference Travel Grant for ICICS Graduate Students**, UBC, Vancouver — 2017
- **Outstanding Reviewer Recognition**, Elsevier — 2016
- **Four Year Fellowship**, UBC, Vancouver — 2015-2019
- **Doctor of Philosophy (DPhil) Admission Offer**, University of Oxford - *Declined* — 2015
- **MICCAI Student Travel Award**, MICCAI Society — 2014
- **Graduate Support Initiative**, UBC, Vancouver — 2013/2015/2016
- **Singapore-Bangladesh Society Scholarship**, BUET — 2009
- **American Association of Bangladeshi Engineers & Architects Scholarship**, BUET — 2009
- **Dean's List Award**, BUET — 2008
- **Ministry of Education Scholarship**, Government of the People's Republic of Bangladesh — 2004-2008

PUBLICATIONS

Google Scholar Profile: https://scholar.google.ca/citations?user=hFwvdQcAAAAJ&hl=en

Journal/Conference Papers Under Review:

R1. Journal: **Hussain MA**, Hamarneh G, Garbi R.: ImHistNet: Deep Radiomics with Learnable Image Histograms for Renal Carcinoma Grading and Staging. *Computerized Medical Imaging and Graphics*, 2020. [**CMIG-D-20-00757**, Impact Factor: 3.750]

R2. Conference: **Hussain MA**, Mirikharaji Z, Momeny M, Marhamati M, Neshat AA, Garbi R, Hamarneh G.: Active Deep Learning from Noisy Teacher for Semi-Supervised 3D Image Segmentation with Application to CT Scans of COVID-19 Pneumonia Infection. *International Conference on Medical Image Computing and Computer-Assisted Intervention (MICCAI)*, 2021.

Journal Papers:

J1. **Hussain MA**, Hamarneh G, Garbi R.: Cascaded Regression Neural Nets for Kidney Localization and Segmentation-free Volume Estimation. *IEEE Transaction on Medical Imaging*, 2021. [PDF] [Accepted, Impact Factor: 6.685, No of Reviewers: 5, DOI: 10.1109/TMI.2021.3060465]

J2. **Hussain MA**, Hodgson AJ, Abugharbieh R.: Strain-initialized Robust Bone Surface Detection in 3-D Ultrasound. *Ultrasound in Medicine & Biology*, 43(3), pp. 648-661, 2017. [PDF] [Impact Factor: 2.514, No of Reviewers: 3, DOI: 10.1016/j.ultrasmedbio.2016.11.003]

J3. **Hussain MA**, Alam F, Rupa SA, Awwal R, Lee SY, Hasan MK.: Lesion Edge Preserved Direct Average Strain Estimation for Ultrasound Elasticity Imaging. *Ultrasonics*, 54(1), pp. 137-146, 2014. [PDF] [Impact Factor: 3.065, No of Reviewers: 3, DOI: 10.1016/j.ultras.2013.05.010]

J4. Hasan MK, **Hussain MA**, Ara SR, Lee SY, Alam SK.: Using Nearest Neighbors for Accurate Estimation of Ultrasonic Attenuation in the Spectral Domain. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, 60(6), pp. 1098-1114, 2013. [PDF] [Impact Factor: 2.743, No of Reviewers: 3, DOI: 10.1109/TUFFC.2013.2673]

J5. **Hussain MA**, Anas EM, Alam SK, Lee SY, Hasan MK.: Direct and Gradient-based Average Strain Estimation by Using Weighted Nearest Neighbor Cross-correlation Peaks. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, 59(8), pp. 1713-1728, 2012. [PDF] [Impact Factor: 2.743, No of Reviewers: 3, DOI: 10.1109/TUFFC.2012.2376]

J6. **Hussain MA**, Alam SK, Lee SY, Hasan MK.: Robust Strain-estimation Algorithm Using Combined Radiofrequency and Envelope Cross-correlation with Diffusion Filtering. *Ultrasonic Imaging*, 34(2), pp. 93-109, 2012. [PDF] [Impact Factor: 1.571, No of Reviewers: 3, DOI: 10.1177/016173461203400203]

Conference/Workshop Proceedings (Peer-Reviewed Full-Length):

C1. **Hussain MA**, Hamarneh G, Garbi R.: ImHistNet: Learnable Image Histogram Based DNN with Application to Non-invasive Determination of Carcinoma Grades in CT Scans. *International Conference on Medical Image Computing and Computer-Assisted Intervention (MICCAI)*, pp. 130-138, 2019, Shenzhen, China. [PDF] [Acceptance Rate: 30%, No of Reviewers: 3, DOI: 10.1007/978-3-030-32226-7_15]

C2. **Hussain MA**, Hamarneh G, Garbi R.: Renal Cell Carcinoma Staging with Learnable Image Histogram-based Deep Neural Network. *International Workshop on Machine Learning in Medical Imaging (MLMI)*, pp 533-540, 2019, Shenzhen, China. [PDF] [Acceptance Rate: 30%, No of Reviewers: 3, DOI: 10.1007/978-3-030-32692-0_61]

C3. **Hussain MA**, Hamarneh G, Garbi R.: Noninvasive Determination of Gene Mutations in Clear Cell Renal Cell Carcinoma Using Multiple Instance Decisions Aggregated CNN. *International Conference on Medical Image Computing and Computer-Assisted Intervention (MICCAI)*, pp. 657-665, 2018, Granada, Spain. [PDF] [Acceptance Rate: 30%, No of Reviewers: 5, DOI: 10.1007/978-3-030-00934-2_73]

C4. **Hussain MA**, Amir-Khalili A., Hamarneh G, Abugharbieh R.: Segmentation-free Kidney Localization and Volume Estimation Using Aggregated Orthogonal Decision CNNs. *International Conference on Medical Image Computing and Computer-Assisted Intervention (MICCAI)*, pp. 612-620, 2017, Quebec-City, Canada. [PDF] [Acceptance Rate: 30%, No of Reviewers: 3, DOI: 10.1007/978-3-319-66179-7_70]

C5. **Hussain MA**, Amir-Khalili A., Hamarneh G, Abugharbieh R.: Collage CNN for Renal Cell Carcinoma Detection from CT. *International Workshop on Machine Learning in Medical Imaging (MLMI)*, pp. 229-237, 2017, Quebec-City, Canada. [PDF] [Acceptance Rate: 30%, No of Reviewers: 3, DOI: 10.1007/978-3-319-67389-9_27]

C6. **Hussain MA**, Hamarneh G, O'Connell TW, Mohammed MF, Abugharbieh R.: Segmentation-free Estimation of Kidney Volumes in CT with Dual Regression Forests. *International Workshop on Machine Learning in Medical Imaging (MLMI)*, pp. 156-163, 2016, Athens, Greece. [PDF] [Acceptance Rate: 30%, No of Reviewers: 3, DOI: 10.1007/978-3-319-47157-0_19]

C7. **Hussain MA**, Shourov RM.: Compressively Sensed Ultrasound Radio-frequency Data Reconstruction Using the Combined Curvelets and Wave Atoms Basis. *International Conference on Electrical and Electronic Engineering (ICEEE)*, pp. 209-212, 2015, Rajshahi, Bangladesh. [PDF] [Acceptance Rate: 35%, No of Reviewers: 3, DOI: 10.1109/CEEE.2015.7428257]

C8. **Hussain MA**, Shourov RM, Khan SN.: Towards Real-time 3D Geometric Nonlinear Diffusion Filter and Its Application to CT and MR Imaging. *18th International Conference on Computer and Information Technology (ICCIT)*, pp. 462-467, 2015, Dhaka, Bangladesh. [PDF] [Acceptance Rate: 40%, No of Reviewers: 3, DOI: 10.1109/ICCITechn.2015.7488115]

C9. **Hussain MA**, Guy P, Hodgson AJ, Abugharbieh, R.: Automatic Bone Segmentation in Ultrasound using Combined Ultrasound Strain Imaging and Envelope Signal Power, *2015 International Meeting on Computer Assisted Orthopaedic Surgery (CAOS)*, pp. 1-4, 2015, Vancouver, Canada. [PDF] [No of Reviewers: 3]

C10. **Hussain MA**, Hodgson AJ, Abugharbieh R.: Robust Bone Detection in Ultrasound Using Combined Strain Imaging and Envelope Signal Power Detection. *International Conference on Medical Image Computing and Computer-Assisted Intervention (MICCAI)*, pp. 356-363, 2014, Boston, MA. [PDF] [Acceptance Rate: 30%, No of Reviewers: 3, DOI: 10.1007/978-3-319-10404-1_45]

C11. Kabir HM, Alam SB, Azam MI, **Hussain MA**, Sazzad AR, Sakib MN, Matin MA.: Non-linear Down-sampling and Signal Reconstruction, Without Folding. *4th UKSim European Symposium on Computer Modeling and Simulation*, pp. 142-146, 2010, Pisa, Italy. [PDF] [Acceptance Rate: 40%, No of Reviewers: 3, DOI: 10.1109/EMS.2010.34]

Peer-reviewed Abstracts:

A1. **Hussain MA**, Anas EM, Alam SK, Lee SY, Hasan MK.: Improved Elasticity Imaging by Maximizing the Weighted Peaks of the Nearest Neighbor Cross-correlation Function. *2012 American Institution of Ultrasound in Medicine (AIUM) Annual Convention and Preconvention Program*, Phoenix, Arizona. March 29 - April 1, 2012. [PDF]

A2. **Hussain MA**, Alam SK, Lee SY, Hasan MK.: A Robust Strain Estimation Algorithm Using Combined Radiofrequency and Envelope Cross-correlation. *Ultrasonic Imaging and Tissue Characterization Symposium*, Rosslyn, Virginia. June 11-13, 2012. [PDF]

Non Peer-reviewed Abstracts:

O1. **Hussain MA**, Hamarneh G, Garbi R.: Kidney Cancer Detection and Analysis from CT Using Deep Learning. *2nd Annual School of Biomedical Engineering Symposium*, 2019, Vancouver, Canada. [PDF]

O2. **Hussain MA**, Hamarneh G, Garbi R.: Learnable Image Histogram Based Deep Neural Network with Application to Noninvasive Determination of Renal Cell Carcinoma Grades in CT Scans. *Research Day: The Future of Health Symposium*, Nov 8, 2019, Vancouver, Canada. [PDF]

Theses:

T1. **Hussain MA**.: Volumetric Image-based Supervised Learning for Renal Cancer Detection and Analysis. Ph.D., UBC, 2020. Supervisor: Prof. Rafeef Garbi. [PDF]

T2. **Hussain MA**.: Robust Bone Detection in Ultrasound Using Combined Strain Imaging and Envelope Signal Power Detection. M.A.Sc., UBC, 2015. Supervisors: Prof. Rafeef Garbi & Prof. Antony J. Hodgson. [PDF]

T3. **Hussain MA**: Average Strain Estimation for Ultrasound Elastography Using Exponentially Weighted Nearest Neighbors. M.Sc., BUET, 2013. Supervisor: Prof. Md Kamrul Hasan. [PDF]

T4. Islam MT and **Hussain MA** (Equal Contribution): Ultrasound Strain Imaging in Wavelet Domain. B.Sc., BUET, 2011. Supervisor: Prof. Md Kamrul Hasan. [PDF]

SUMMARY OF RESEARCH ACCOMPLISHMENTS

My research interest lies in developing novel deep learning techniques for real-life applications including medical image analysis and computer vision. Please see my research summary webpage (https://arafathm.github.io/research/) for details. A very brief summary of my research accomplishments are also presented below:

1. **COVID-19 Detection and Analysis from CT and X-ray**
   I am currently investigating the computed tomography (CT)- and X-ray-based discriminatory radiomic features between COVID-19 and community-acquired pneumonia (CAP). My aim is to discover critical differences in seemingly similar COVID-19 and CAP infections in the lungs, which would help clinicians in rapid COVID-19 diagnosis and treatment planning. Meanwhile, I developed an active learning approach [R2] that uses an example re-weighting strategy, where machine-annotated samples are weighted based on the similarity of their gradient directions of descent to those of expert-annotated data. Preliminary study results are available in these links [L1], [L2].
2. **Learnable Image Histogram-based Deep Neural Network**
   I developed a learnable image histogram module in the convolutional neural network (CNN) framework for automatic kidney cancer grading and staging - this approach is the first, to our knowledge, that learns diffused textural features in an image, and it's application in computed tomography (CT)-based cancer grading and staging could be a potential alternative to the invasive renal biopsy-based cancer grading and staging [R1][C1][C2].
3. **Multiple Instance Decision Aggregated CNN for Gene Mutation Prediction**
   I developed a CT-based multiple instance decision aggregated CNN approach for noninvasive determination of gene mutation in kidney cancer - this approach could be used as a potential alternative to the invasive renal biopsy-based whole-genome sequencing for gene mutation detection [C3].
4. **Mask-RCNN and Orthogonal Decision Aggregated CNN for Kidney Localization in CT**
   I developed a CNN-guided Mask-RCNN and an orthogonal decision aggregated CNN-based automatic kidney localization approach for the CT scans that enables the radiologists in rapid subsequent kidney functionality analysis in the clinical environment [J1][C4].
5. **Collage Image Representation in the Multiple Instances Learning Framework**
   I developed a collage image representation in the multiple instances learning framework, enabling the use of sparsely annotated data in 2D CNN, which is a computationally inexpensive alternative to the computationally expensive 3D CNN [C5].
6. **Segmentation-free Kidney Volume Estimation Using Machine Learning**
   I developed two techniques for segmentation-free kidney volume estimation using dual regression forests, CNN, and FCN. These methods are two potential and more accurate alternatives to the manual ellipsoid fitting-based kidney volume estimation approach typically used in the clinical environment. Our methods also bypass the computationally expensive segmentation procedure altogether [J1][C4][C6].
7. **Compressively-sensed Ultrasound RF Data**
   I developed a combined Curvelets and WaveAtoms basis-based compressively sensed ultrasound RF data reconstruction approach [C7].
8. **Geometric Diffusion Filter**
   I developed a near real-time 3D geometric non-linear diffusion filter for the CT/MR image denoising [C8].
9. **2D Strain-initialized Surface Growing for Bone Detection in 3D Ultrasound**
   I developed a 2D strain initialized surface growing approach for automatic bone surface delineation in 3D ultrasound.

This method could be used as an alternative to the time-inefficient manual bone delineation in ultrasound-guided minimally invasive surgery [J2].

10. **Bone Detection in 2D Ultrasound**
I developed a combined strain imaging and envelope signal power-based robust bone boundary detection approach for the 2D ultrasound. This elastography-based bone detection approach robust to false positives at fatty tissue layer [C9][C10].
11. **Ultrasound Strain Imaging**
I developed novel ultrasound strain imaging techniques using weighted nearest neighbors for accurate early breast cancer detection [J3][J5][J6][A1][A2].
12. **Ultrasound Attenuation Estimation**
I developed two novel ultrasound attenuation estimation technique for accurate breast carcinoma analysis [J4].

TEACHING EXPERIENCE

Graduate Teaching Assistant, UBC, Vancouver 01/2014 - 12/2019

Conducted tutorials, invigilation, grading and laboratory demonstrations for the following courses:
- Signals and Systems (Winter T2 2013, Winter T1 2016, 2017, 2018, 2019)
- Electrical Engineering Design Studio (Winter T2 2014)
- Digital Systems and Microcomputers (Winter T2 2015, 2016, 2017)
- Economic Analysis of Engineering Projects (Summer 2016)
- Machine Learning and Data Mining (Summer 2017)
- Introduction to Computation in Engineering Design (Summer 2017, 2018, 2019, and Winter T1-2 2017)
- Engineering Electromagnetics (Winter T2 2018)

Senior Lecturer, Eastern University, Dhaka, Bangladesh 05/2015 - 08/2015

Conducted lectures, invigilation, grading and laboratory demonstrations for the following courses:
- Microprocessor and Interfacing (Spring 2015)
- Microprocessor and Interfacing Laboratory (Spring 2015)
- Measurement and Instrumentation (Spring 2015)
- Measurement and Instrumentation Laboratory (Spring 2015)
- Solid State Devices (Spring 2015)
- Electronic Project Design (Spring 2015)

SUPERVISORY EXPERIENCE

- **Rohit Somasundaram** Professional Master's Intern, School of Computing Science, SFU
Project title: COVID-19 diagnosis from chest X-ray images
- **Yilin Shi** Professional Master's Intern, School of Computing Science, SFU
Project title: COVID-19 diagnosis from CT scans

REVIEWING EXPERIENCE

- IEEE Transactions on Neural Networks and Learning Systems
- IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control
- IEEE Access
- Ultrasonics Journal - Elsevier
- Computers in Biology and Medicine Journal - Elsevier
- Deep Learning in Medical Image Analysis - Springer
- Medical Image Computing and Computer Assisted Intervention - Springer

INVITED TALKS/PRESENTATIONS

- **University of British Columbia, School of Biomedical Engineering, Vancouver, BC** 10/2020
Title: Volumetric Image-based Supervised Learning Approaches for Kidney Cancer Detection & Analysis
- **Harvard University, Center for Advanced Medical Computing and Analysis, Boston, MA** 11/2019
Title: Volumetric Image-based Supervised Learning for Renal Cancer Detection & Analysis
- **Stanford University, Division of Developmental-Behavioral Pediatrics, Palo Alto, CA** 10/2019
Title: Kidney Cancer Analysis Using Volumetric Image-based Supervised Learning
- **University of British Columbia, Centre for Molecular Medicine and Therapeutics, Vancouver, BC** 09/2019
Title: Kidney Cancer Detection and Analysis from CT Using Deep Learning

LEADERSHIP SKILLS

- **Secretary** (Elected Position) 05/2016 - 04/2017
  Electrical and Computer Engineering Graduate Student Association (ECEGSA), UBC
- **Field Volunteer** (Awarded the honorary 'Life Membership' for outstanding service) 01/2003 - 12/2007
  Bangladesh Red Crescent Society
- **Lead of Event Organizers** 01/2006 - 12/2010
  Department of Electrical & Electronic Engineering, BUET, Dhaka, Bangladesh

COMPUTATIONAL SKILLS

- HPC on Compute Canada clusters
- C/C++, MATLAB, Python, TensorFlow/Keras, PyTorch, Caffe, $\LaTeX$

SELECTED WORKSHOPS/TRAINING ATTENDED

- **Privacy and Information Security Fundamentals** 2019
  University of British Columbia, Vancouver
- **Teaching Skills for Engineering Teaching Assistants** 2016
  University of British Columbia, Vancouver
- **Preventing and Addressing Workplace Bullying and Harassment** 2014
  University of British Columbia, Vancouver

EMPLOYMENT HISTORY

- **Postdoctoral Research Associate** 04/2020 - Present
  SFU, Burnaby, BC
- **Laboratory Technologist/Admin** 06/2018 - 04/2020
  Biomedical Signal and Image Computing Laboratory, UBC, Vancouver
- **Graduate Research Assistant** 05/2013 - 03/2020
  UBC, Vancouver
- **Graduate Teaching Assistant** 01/2014 - 12/2019
  UBC, Vancouver
- **Senior Lecturer** 05/2015 - 08/2015
  Eastern University, Dhaka, Bangladesh
- **System Engineer** 01/2013 - 04/2013
  Sheikh Hasina National Institute of Burn and Plastic Surgery, Dhaka, Bangladesh
- **Research Engineer** 07/2011 - 12/2012
  BUET, Dhaka, Bangladesh
- **Software Engineer** 02/2011 - 06/2011
  Samsung R&D Institute, Dhaka, Bangladesh

REFERENCES

Prof. Ghassan Hamarneh, Ph.D.
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Prof. Rafeef Garbi, Ph.D.
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Prof. Antony Hodgson, Ph.D.
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RESEARCH STATEMENT

Mohammad Arafat Hussain (mahussai@sfu.ca)

1. Objective

Machine learning (ML) methods learn from image features to perform the classification and segmentation tasks. These features are generally categorized into statistical and non-statistical types [1]. 'Statistical' features (e.g., intensity heterogeneity in terms of histogram, kurtosis, skewness, etc.) are extensively used in medical image-based applications [2], e.g., detecting lesions and extracting clinically relevant features in the tumors [3, 4]. However, hand-engineering is used to generate these 'statistical' features and often challenging to design optimally [4]. Although supervised deep learning using a deep neural network (DNN) is preferred over the hand-engineered feature-based conventional ML approaches because of its ability to learn features automatically [5], these features are 'non-statistical' type [1]. A recent study [6] showed that the conventional deep learning architectures have a significantly lower capacity to capture tumor shape and heterogeneity properties, necessary for automatic tumor characterization. Therefore, my research objective is to develop novel techniques in the DNN framework to enable disease-specific automatic statistical feature learning directly from raw medical images for tumor characterization.

2. Background

There is a rich body of previous work in radiomic- and radiogenomic-based tumor analysis. 'Radiomics' refers to the use of computational or statistical approaches to extract large numbers of quantitative features from radiological images to develop predictive models, ultimately aiming to enable personalized clinical management [7]. Further, the strategy of correlating tumor radiomic features to the underlying mutations in genes referred to as 'Radiogenomics' [8]. Tumors are typically heterogeneous, and clinical approaches (e.g., tissue biopsies) often fail to characterize the entirety of the tumor [7]. In contrast, radiomics and radiogenomics consider the whole tumor and surrounding region for better tumor characterization. Radiomic and radiogenomic features are often combined with clinical information for better tumor prognosis and clinical decision support (Fig. 1). However, using deep learning in radiomics and radiogenomics currently falls short because of several challenges, including but not limited to the following:

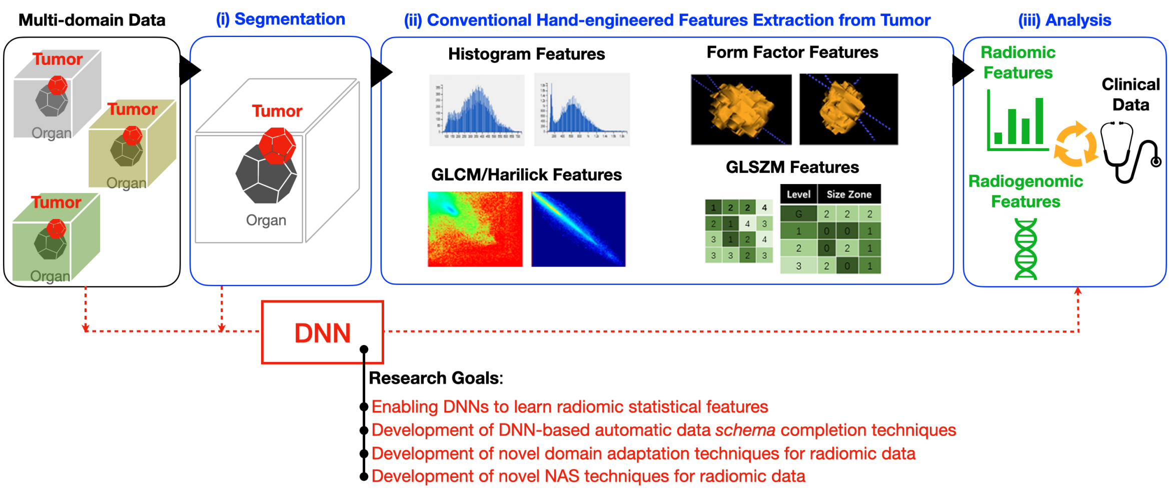

Figure 1: Conventional working pipeline of hand-engineering the radiomic and radiogenomic features for tumor analysis, and my research goals.

2.1. Inability of DNNs in Learning Statistical Features: Different statistical methods are used to hand-engineer the radiomic features, which include first-order (e.g., histogram-based features), second-order (e.g., gray-level co-occurrence matrix [GLCM]), and higher-order statistics (e.g., gray-level size zone matrices [GLSZM] features). However, these methods require prior segmentation of the tumor, a bottleneck of the traditional radiomics pipeline [7] (Fig. 1). Besides, the hand-engineered features cannot be task-specifically optimized. On the other hand, despite the capability of the convolutional neural network (CNN), a variant of DNN, in learning task-specific context features, it tends to put less emphasis on the diffused 'statistical' image features [1] that are often important for medical imaging applications, e.g., tumor characterization and analysis. Few CNN-based approaches try to extract features of statistical nature by incorporating an additional module (e.g., learning histogram [1], channel-wise global average pooling [9], learning histograms of gradients [10]). However, these modules are designed to work on top of the conventional CNN-learned nonstatistical context features.

2.2. Hidden Stratification in Data: Hidden stratification refers to the unrecognized subsets in a particular data superclass. It is a matter of concern that most medical ML models are often trained and validated using an incomplete set of possible labels and thus coarsely describe the meaningful variation within the data population. A recent study [11] showed that hidden stratification significantly affects the clinical outcomes when machine learning is used in medical image analysis. Hidden stratification is also a major risk factor in tumor characterization and analysis.

2.3. Domain Shift: Although DNN shows excellent performance in a large variety of computer vision tasks, it often fails to generalize on data across domains [12]. One of the reasons for this failure is the large difference between training and test data, which is typically referred to as the domain shift [13]. Domain shift also causes radiomic ML models to fail in generalizing across data and thus poorly performing when trained and validated on data from different domains [14].

2.4. Non-optimized Neural Architectures: As described above, the success of DNN in computer vision tasks is mostly due to its automation of the hierarchical feature extraction from the data rather than hand-engineering. However, almost all successful and well-known neural architectures are designed manually. Some recent studies [15, 16, 17] showed that automated architecture engineering, referred to as Neural Architecture Search (NAS), performs better than manually designed architectures in object classification, detection, and segmentation tasks. Since the prediction of a DNN, employed for radiomics or radiogenomics task, has significant implications on clinical decision support, the DNN architecture itself should be task-specifically optimized. However, the potential of NAS in clinical decision support is yet to be fully explored.

Therefore, the use of deep learning in radiomics and radiogenomics to make robust and dependable clinical decisions warrants significant research investigations.

3. Research Experience

During my M.Sc. studies at Bangladesh University of Engineering and Technology, and M.A.Sc. and Ph.D. studies at the University of British Columbia, I attempted to learn and apply the conventional signal processing techniques as well as machine learning techniques in multimodal (e.g., ultrasound, computed tomography [CT], magnetic resonance [MR]) medical image analysis. During my Ph.D., while working on kidney cancer detection and analysis using machine learning, I grew a special interest in developing novel techniques for statistical feature extraction using the DNN framework for better tumor characterization. Bellow, I summarize my research contributions to date, relevant to radiomics and radiogenomics:

3.1. Non-invasive Determination of Tumor Grade and Stage on CT using Radiomic Features: For cancer treatment planning, both 'grade' and 'stage' provide critical information on cancer severity. Cancer grading is the way of classifying the cancer cells in histopathologic images. The pathologist provides cancer a grade based on (a) how different they look from healthy cells, (b) how quickly they are growing and dividing, and (c) how likely they are to spread. On the other hand, staging is the way of classifying cancer based on the extent of cancer in the body. The stage is often based on the (a) size of the tumor, (b) whether cancer has spread (metastasized) to other parts of the body, and (c) where it has spread. It is suggested in the literature [18, 19, 20] that the use of CT radiomic features can complement and improve the accuracy and reproducibility of tumor grades and stages. However, the working pipeline of existing radiomics approaches involves hand-engineering the statistical features shown in Fig. 1.

In MICCAI 2019 and MLMI 2019, I proposed a novel DNN architecture [21, 22] for radiomics that specifically learn image textural features for automatic clear cell renal cell carcinoma (ccRCC) grading and staging. These features are statistical, which is different from the nonstatistical features extracted by conventional CNN. To my knowledge, my approach is the first that learns statistical features directly from raw medical images using the DNN framework. I presented a learnable image histogram (LIH) layer within a DNN framework capable of learning complex and subtle task-specific textural features from raw images directly, adhering to the classical input-output mapping.

3.2. Non-invasive Determination of Gene Mutation from CT using Radiogenomic Features: Knowledge of the genetic makeup of a tumor has a great prognostic value, which is helpful for treatment planning. Recent works [23, 24] have shown correlations between mutations in genes and different radiomic features in CT/MR images. Robust radiomic feature identification is typically performed by expert radiologists, relying on human visual inspection. However, this process is complicated, time-consuming, and suffers from high intra/inter-observer variability.

To tackle this problem, I developed a DNN approach [25] for radiogenomics that can efficiently learn CT-based ccRCC radiomic features for automatic determination of mutated genes. This approach combines the binary decisions (i.e., presence/absence of a mutation) for all tumor slices in a particular organ sample into a robust singular decision that ultimately determines whether an interrogated kidney sample has undergone a specific mutation or not. To my knowledge, this work was the first DNN-based approach for kidney radiogenomics and was published in MICCAI 2018.

3.3. COVID-19 vs. Community-Acquired Pneumonia Classification from X-ray/CT using Radiomic Features: As a form of pneumonia, COVID-19 infection causes inflammation of air sacs in either or both lungs and fills with fluid. This infection makes the patient difficult to breathe. Chest CT is found useful in detecting pneumonia from its radiographic features.

These features include bilateral and peripheral ground-glass and consolidative pulmonary opacities. However, it remains a significant challenge in separating COVID-19 pneumonia from typical community-acquired pneumonia (CAP) because seemingly similar radiographic features are seen for both COVID-19 and CAP. A large body of work has recently emerged that classifies COVID-19 and CAP from CT images, where most of the methods used either hand-engineered radiomic features or CNN-based features.

As a postdoctoral fellow, I have been working on COVID-19 vs. CAP classification in CT using DNN-based statistical feature learning. I extended my 2D LIH approach [21] into 3D so that it can learn statistical radiomic features from whole volume chest CT images. The preliminary results showed improved classification performance than by a standard 3D CNN. I have also been developing novel domain adaptation techniques to generalize COVID-19 detection models across datasets with consistent accuracy.

4. Research Plan

Broadly, in the next stage of my career as a faculty member, I plan to conduct innovative and collaborative research encouraging the expansion of human knowledge and scientific discoveries, contributing to the greater good of society. Contrary to popular belief, artificial intelligence (AI) is no one-size-fits-all solution for all research problems. Careful design and solution to a specific problem are required to harness the power of AI. As an early-stage researcher, I plan to explore significant research problems in medical image-based cancer diagnosis and treatment planning. I aim to research in the following fields to tackle the challenges of using deep learning in the clinical decision support system:

4.1. Learning Statistical Features using DNN Framework: I envision developing novel DNN frameworks for second-order and higher-order statistical feature extraction from raw medical images for better tumor characterization. I developed a learnable histogram approach in the DNN framework for first-order statistical feature extraction during my Ph.D. project. Next, I aim to design and implement a second-order feature extractor in the DNN framework. This DNN model would learn the task-specific hyper-parameters and variable weights to emphasize certain adjacencies (e.g., the co-occurrence of specific intensity values, co-occurrence estimating offset values), avoiding the conventional way of hard coding the parameters with some predefined values. Similarly, I aim to design and implement a higher-order feature extractor with learnable task-specific hyper-parameters.

4.2. Automatic Schema Completion of Data: Hidden stratification significantly affects the clinical outcomes, especially risking tumor characterization and analysis performance, when ML is used in a medical image analysis system. Finding all possible subclasses in a dataset is referred to as the 'schema completion.' Schema completion of medical data is often limited due to the lack of radiologist/pathologist's expertise. Besides, it is often time-consuming to exhaustively label all possible subclasses. However, missing important subclasses does not protect against important clinical failures. A recent study [11] showed in a limited capacity that unsupervised ML, such as K-means clustering, can find hidden subclasses in a data superclass. Therefore, I envision using unsupervised deep learning approaches to facilitate schema completion of radiomic and radiogenomic medical data. I will investigate DNN procedures, similar to autoencoders and generative adversarial networks, to find hidden strata in the radiomic data.

4.3. Domain Adaptation: Several challenges hinder efficient domain adaptation of a network across data domains. Usually, these challenges result from the inter and intradomain data imbalance [26]. Although many methods have been developed for domain adaptation/model generalizability, those methods used intradomain balanced data (i.e., balanced classes within a domain). However, in reality, medical imaging data are often intradomain imbalanced, which is not yet thoroughly investigated to date, except a few works (e.g., [26]). Therefore, I aim to design novel domain adapting DNNs and efficient loss functions to tackle variance across data domains, which would also be robust to both inter and intradomain data imbalance.

4.4. Neural Architectures Search: Neural architecture search (NAS) procedures can be broadly categorized into (1) global search space and (2) cell-based search space, depending on the search strategy. Typically, NAS of the global search space category operates on every smallest possible DNN unit (e.g., a node in a DNN layer) and the action (e.g., a rectifying operation), thus have large degrees of freedom [27]. On the other hand, NAS of cells-based search space category operates on a cell in a DNN, where a cell is referred to as the frequently repeated graphs [28]. Although there have been many NAS methods proposed in the literature, most of them only focus on CNNs for solving the task of object recognition and language modeling [29]. Moreover, the current NAS approaches are heavily inspired by the design of existing architectures and mostly targets typical computer vision tasks [29]. Therefore, I aim to investigate NAS from the medical image analysis perspective, especially for the DNN-based radiomic feature extraction.

Finally, in a more prolonged (10-20 years) term, I envision developing novel DNN-based techniques for multimodal data fusion (radiomic, radiogenomic, genomic, proteomic, clinical) to aid in better tumor/cancer diagnosis, prognosis, and treatment planning. I believe, if successful, my work would bring more trust on DNNs in clinical oncology management.

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TEACHING STATEMENT

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In Summer 2015, the Department of Electrical and Electronic Engineering at the Eastern University, Bangladesh appointed me as a Senior Lecturer to teach three courses (3 credits each) and three laboratory sessions (1.5 credits each). The average classroom size was about 60 students. Teaching these courses was one of the most fulfilling experiences of my life. This formal appointment also made me a second generation of teachers after my father. I believe the 'teacher gene' in me can contribute to educating society and mentoring young researchers. I want to add to the education sector by sharing my knowledge, learning from others, and creating new experiences.

1. Teaching Experience

My formal teaching experience started with my appointment as a teaching assistant (TA), during my M.A.Sc. at the University of British Columbia (UBC), Vancouver. Later, I continued to work as a TA during my Ph.D. studies. I was fortunate to work with professors with incredible teaching expertise who are often leaders in their research fields. I have learned a lot from their teaching techniques, their methods of simplifying in-depth technical topics, and their way of designing the curriculum and exams.

I have worked as a TA for nine courses for the Department of Electrical and Computer Engineering and the Department of Computer Science in a total of 18 semesters. At UBC, I had the opportunity to closely learn the art of teaching from several renowned professors at UBC as their TA. While working with them, I learned how to deliver complicated content in an easy and fun way, look at the class's response to make their learning experience better, and create a vibrant and engaging classroom where students feel encouraged to join discussions.

In Summer 2015, Eastern University Bangladesh appointed me as the primary instructor (Senior Lecturer) for Microprocessor and Interfacing, Microprocessor and Interfacing Laboratory, Measurement and Instrumentation, Measurement and Instrumentation Laboratory, Solid State Devices, and Electronic Projects Design. These courses had an average class size of 60 students. I enjoyed this challenge of being a primary instructor, as much as I enjoyed designing the contents and exams considering both theoretical and practical aspects of learning. To facilitate a **flipped classroom** learning environment, I used to spend around 5 minutes to summarize the contents from previous lectures at the beginning of a new lecture. During the lecture time, I used to provide lecture-related quizzes so that they can apply their knowledge instantly in solving small qualitative and quantitative problems. Again, at the end of the lecture, I would mention what to look forward to in the next lecture, often with related videos, to prepare ahead of the following lecture. This approach creates continuous, interrelated stories in the student's mind. I have also discussed industry trends and future research directions during lectures to generate more interest in the subject matter and foster creativity.

2. Mentoring Research Work of Master's and Ph.D. students

In addition to teaching experience, I had the privilege to participate as a research mentor at various levels, especially on the application of artificial intelligence for medical image computing and analysis. As a postdoctoral research associate at SFU, I independently supervised two master's intern students at SFU in Summer 2020. Currently, I directly mentor one master's student in her thesis work at SFU. As a senior Ph.D. student in Biomedical Signal and Image Computing Lab at UBC, I collaborated and helped other students in the lab. I also had the opportunity to mentor master's students from the University of Dhaka, Bangladesh..

Mentoring graduate and undergraduate students to create quality research work are one of my strongest passions. I enjoy sharing my expertise on how to explore exciting, novel, and essential problems; how to find innovative and optimal solutions for those problems; how to design impressive results and present them in a clear, straightforward way; how to write in clear and formal language so that the findings from our study are clear to readers, etc. Moreover, the best part is that in the process of sharing knowledge, I learn new things from each of the ongoing research collaborations. As a result, I have gained hands-on experience in working with graduate students and achieved successful publications.

3. Teaching Interest and Philosophy

I was trained in medical image analysis, empirical algorithmics, and machine learning by world-famous professors (Robert Rohling, Holger H. Hoos, and Mark Schmidt). I also developed deep understanding in different medical imaging modalities (e.g., ultrasound, computed tomography, magnetic resonance imaging, and position emission tomography) through research work and scientific papers. Therefore, I envision to develop and teach undergraduate and graduate level courses related to artificial intelligence and its application to medical image analysis at Simon Fraser University.

Designing classes that foster creativity is one of the most critical yet challenging parts of teaching. To add to the students' knowledge, during these courses, I plan to bring guest lecturers from academia and industry. As a faculty mentor, I plan to organize a similar hands-on experience for my students. I have plans to organize field trips for the students with local industry collaborators and bring collaboration opportunities. Specifically, for graduate courses, I plan to bring cutting-edge research findings to the classroom and train students to engage in creative, open thinking and to conduct research.

Computer science and its application to biomedical engineering, as a knowledge field is fast-moving. To teach our students how to keep up with this pace and then how to lead with new ideas and entrepreneurial spirit is a great challenge. As an educator, I look forward to taking on this challenge and giving my best to contribute to the education of society.

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Statement of Contributions to Diversity

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In modern society, diversity is a crucial ingredient for innovation and success. Members from different backgrounds (gender, race, age, and more) bring different ideas. To me, that is essential for the growth and prosperity of an organization. Creating an environment that fosters diversity and promotes inclusion is not easy. As a foreign-born minority in Canada, I appreciate the inclusive (work and educational) environment the University of British Columbia has created. My background and personal experiences have made me a firm believer in diversity. Through my activities as a faculty and an educator, I look forward to contributing to an environment where members from all backgrounds feel welcome.

1. Background and Past Activities

I grew up in a small town (Magura) in Bangladesh. Moving to the capital city (Dhaka) for my education was possibly my first big step towards diversity. With a population size of around 10 million (approx. 23 thousand people per square kilometer), Dhaka is a very densely populated city with people from diverse backgrounds, race, economic status, etc. That said, in most cases, I was representative of the majority. I have to admit that, back then, I was not very aware of the challenges faced by members of underrepresented communities. Nevertheless, I worked as a volunteer at the 'Bangladesh Red Crescent Society' in disaster relief management from 2003 to 2009. I have also been a founding member and volunteer of 'Panjeery'- a voluntary organization for social service in my home area of Bangladesh since 2003.

When I moved to Vancouver, BC, as an international student and minority for many aspects (race, ethnicity, language, etc.), I faced many challenges at school, at grocery stores, even with co-workers. My personal experiences made me realize that I have to face obstacles firsthand to be aware of those honestly. Later, by the time, I became mindful of the power of diversity and inclusion because of the inclusive environment of UBC. Vancouver and UBC have a very mature culture to celebrate diversity and protect the underrepresented community members' interests.

At UBC, I have actively participated in programs that add to my awareness of people from different backgrounds. I participated in the workshop titled "Preventing and Addressing Workplace Bullying and Harassment" conducted by UBC. In this certificate workshop, I participated in conversations and activities on appreciating different cultures and their diversity and effectively communicating with members from diverse cultural, religious, and ethnic backgrounds. I also worked as a volunteer mentor for two high school students from First Nations in 'Emerging Aboriginal Scholars Summer Camp' jointly organized by the Pacific Institute for the Mathematical Sciences (PIMS), the UBC Department of Mathematics, and UBC First Nations House of Learning in July 2014.

As my awareness grew, I started to contribute towards advancing diversity. I served as a Secretary and Acting President of the ECE Graduate Student Association (ECEGSA) at UBC for 2017-2018. During that period, I committed myself to make a difference in ensuring that everyone is given opportunities to excel in their scholarly and social activities. I tried to talk to each member personally so that they feel welcome joining our workshops, weekly socials, yearly celebrations, and out–of-school tours.

My Ph.D. supervisor, Prof. Rafeef Garbi, created an excellent example for learning about diversity and creating an inclusive workplace. As a senior member and lab admin of her research lab, I was often responsible for the on-boarding of new members, who are often international students. I have tried to create an inclusive environment for the new members where they feel welcome, and they know that they are 'welcome as they are.' As a TA with a class size of 150+, I have put forward my best effort to create an open environment where everyone can benefit equally from my classes. In addition to my duties, I have provided extra time and resources for the students who needed extra care. As a researcher, I am always aware of creating an inclusive environment, in remote calls and in person, to activate collaboration between researchers from diverse backgrounds.

2. Future Plans to Promote Diversity

As a faculty member, my goal will be to encourage a stronger sense of diversity and inclusion at my university and in my classroom. As a mentor, I want to treat students from different backgrounds equally, be aware of their challenges, and help them succeed. Specifically, I want to ensure that students from underrepresented communities are heard, and they feel welcome to share their voices. I plan to visit local junior colleges in the local community, give talks, engage in research dialogue, and identify potential graduate student candidates from underrepresented backgrounds.

On a global scale, there are intelligent people worldwide, and they equally deserve the opportunity to participate in higher education and research. I plan to create intellectual opportunities for students from across the globe. As an educator, my goal is to open up new opportunities to students, irrespective of their background.