Doctoral Dissertation Defense Announcement

“Deep Learning and Machine Learning Approaches in Advanced Magnetic Resonance Imaging for Reducing Cancer Treatment-Induced Cardiotoxicity”

Dana (Dayeong) An
Candidate for Doctor of Philosophy
Joint Department of Biomedical Engineering
School of Graduate Studies
Medical College of Wisconsin & Marquette University

Committee in Charge:
El-Sayed Ibrahim, PhD (Mentor)
   Amit Joshi, PhD
   Andrew Nencka, PhD
   John LaDisa, PhD
   Daniel Rowe, PhD
   Bo Wang, PhD

Date: Wednesday, January 31st, 2024
Time: 10:00 AM (CST)
Defense Location: HUB – A5520/A5628
Zoom: https://mcw-edu.zoom.us/j/96017622255?pwd=WWRQNXFxS3BNVGJxUXdNREpGblFCQT09
Meeting ID: 960 1762 2255    Passcode: cQ7pc3Ni
Graduate Studies:
Digital Signal Processing
Nuclear Magnetic Resonance
Industrial Mathematics II
Developments in Computer Software – Deep Learning
Ethics & Integrity in Science
Systems Physiology
Journal Club MRI
Research Ethics Discussion Series
Seminar in Biomedical Engineering
Reading and Research
Doctoral Dissertation
Abstract

Radiation therapy (RT) stands as a cornerstone in the battle against cancer, especially in the context of lung and breast cancers. Its instrumental role has led to a pronounced decrease in the rates of cancer recurrence and associated mortality. Nonetheless, an unintended consequence of this success manifests in cancer survivors. Specifically, those who have been exposed to thoracic RT find themselves at a heightened risk of RT-induced cardiotoxicity, a detrimental side-effect of the treatment that contributed to their survival. While a plethora of studies have delved into chemotherapy-induced cardiotoxicity, our understanding of RT-induced cardiotoxicity, particularly in the domain of lung cancer, remains embryonic.

Currently, detecting RT-induced cardiotoxicity heavily relies on the evaluation of the left ventricular ejection fraction (LVEF) using echocardiography as the primary diagnostic tool. However, its limitation is starkly evident when it fails to discern the embryonic stages of subclinical cardiovascular diseases (CVD), which might eventually spiral into a more pronounced cardiac dysfunction. The usage of echocardiography, despite its affordability and accessibility, presents challenges, including variable acoustic window quality, geometric assumptions, and operator dependency. Conversely, cardiac magnetic resonance imaging (MRI), regarded as the gold standard for cardiac function evaluation, offers enhanced diagnostic capabilities, particularly with its ability to assess myocardial strain at regional levels. This could potentially serve as an early diagnostic tool for incipient cardiac anomalies. However, MRI's extended scan durations and associated costs are recognized limitations.

In response to these diagnostic challenges, this study aims to harness deep learning (DL) methodologies. The objective is to devise a DL algorithm capable of automatically generating both global and regional cardiac function metrics from a selectively streamlined set of MRI images. This DL-based approach seeks to overcome the limitations of existing diagnostic tools, offering a more granular perspective on cardiac function. Additionally, the study is investigating specific MRI parameters to determine potential early markers of RT-induced subclinical cardiac dysfunction, utilizing diverse animal RT models.

The intended outcome of this research initiative is twofold: a deeper comprehension of RT's cardiovascular implications and the development of preemptive tools against RT-induced cardiotoxicity. The anticipated impact is a more individualized and timely intervention for patients fostering enhanced clinical outcomes and potentially leading to a reduction in the healthcare burdens associated with cardiotoxicity in cancer survivors.
DAYEONG AN

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EDUCATION

Medical College of Wisconsin, Milwaukee, WI
Ph.D. Candidate in Biomedical Engineering
February 2024

Marquette University, Milwaukee, WI
M.S. in Computational Sciences
July 2018

Minnesota State University, Mankato, MN
M.S. in Mathematics and Statistics
July 2014

Minnesota State University, Mankato, MN
B.S. in Mathematics, Minor in Economics
July 2012

RESEARCH INTEREST

MRI, Medical Imaging, Image Processing, Deep Learning, Machine Learning, Computer Vision

TECHNICAL STRENGTHS

Computer Languages
Python, MATLAB, R, C, C++, SAS

Machine Learning Libraries
Pytorch, Tensorflow, Keras, OpenCV

Software & Tools
SQL, Excel, LaTeX

CERTIFICATIONS AND WORKSHOPS

GE MR Programming Workshop (EPIC and Orchestra)
August 2019
Specilized in GE EPIC software design, modifying pulse sequences, and image reconstruction using GE Orchestra SDK with applied knowledge in MATLAB and C++
Organizer: GE Healthcare and University of Wisconsin

Actuarial Exam P/1 (Probability)
November 2013
Successfully passed Exam P, focusing on probability concepts applicable in actuarial science and risk management.
Organizer: Society of Actuaries/Casuity Actuarial Society

PUBLICATIONS

Myocardial Contractility Pattern Characterization in Radiation-Induced Cardiotoxicity Using Magnetic Resonance Imaging: A Pilot Study with ContractiX, Tomography, 9(1), 36-49.

Mezbahur Rahman, Dayeong An, Mahammad Shaha Alam Patwary (2016)

Dayeong An and Mezbahur Rahman (2015)
Maximum Likelihood Parameter Estimation for Beta Inverse Weibull Distribution, Far East Journal of Mathematical Sciences (FJMS), 97(2), 131-137.

Under review:
Dayeong An, Alison Kriegel, Brian Fish, Suresh Kumar, Carmen Bergom, Marek Lenarczyk, John Baker, El-Sayed H. Ibrahim
Radiation-Induced Cardiotoxicity in Hypertensive Salt-Sensitive Rats. A Feasibility Study
Dayeong An, Andrew Nencka, Patrick Clarysse, Pierre Croisille, Carmen Bergom, El-Sayed H. Ibrahim
Enhancing Myocardial Strain Analysis with MyoNet: A Deep Learning-Based Approach in Cine Cardiac MRI

In submission:
Dayeong An, El-Sayed H. Ibrahim
Utilizing Advanced Machine Learning Classifications to Elucidate Early Markers of Radiation-Induced Cardiotoxicity in Brown Norway strain consomic rats through Cardiac Magnetic Resonance Imaging

ABSTRACTS

Dayeong An, El-Sayed H. Ibrahim (2023)
Cardiovascular Magnetic Resonance Evaluation of Radiation Therapy Induced Cardiotoxicity: A Comparative Analysis Between Hypertensive and Normotensive Models, Society for Cardiovascular Magnetic Resonance (SCMR)

Dayeong An, El-Sayed H. Ibrahim (2023)

Dayeong An, El-Sayed H. Ibrahim (2023)
Myocardial strain as a sensitive measure for early detection of radiation-induced cardiotoxicity in hypertensive salt-sensitive rats, Global Cardio Oncology Summit (GCOS)

Dayeong An, El-Sayed H. Ibrahim (2022)
Myocardial strain generation from cine MR images using an automated deep learning network, International Society for Magnetic Resonance in Medicine (ISMRM)

Dayeong An, El-Sayed H. Ibrahim (2022)
Automatic myocardial displacement field generation by deep learning from CMR cine images, Society for Cardiovascular Magnetic Resonance (SCMR)

Dayeong An, El-Sayed H. Ibrahim (2022)
Myocardial displacement field generation from CMR cine images by image-to-image translation deep learning networks, The 32nd Annual School of Graduate Studies and Office of Postdoctoral Education
**Research**

**Dayeong An, El-Sayed H. Ibrahim (2022)**
Radiation therapy-induced regional cardiac dysfunction revealed by AI-supported magnetic resonance imaging, MCW Cancer Center Scientific Retreat

**Dayeong An, El-Sayed H. Ibrahim (2022)**
Deep Learning based global cardiac function assessment from MR tagged images, Chicago Regional Cardiovascular Research Symposium

**Dayeong An, El-Sayed H. Ibrahim (2021)**
Automatic global cardiac function assessment from CMR tagged images, Cardiovascular Center Virtual Research Retreat

**Dayeong An, El-Sayed H. Ibrahim (2021)**
Artificial Intelligence techniques allow for automatic and fast evaluation of cardiac function. A proof-of-concept study, MCW Community Engagement

**Dayeong An, El-Sayed H. Ibrahim (2020)**
Automatic global cardiac function assessment from CMR tagged images, Society for Cardiovascular Magnetic Resonance (SCMR)

**Dayeong An, El-Sayed H. Ibrahim (2020)**
Deep-Learning based Heart Segmentation of MRI Tagged Images, MCW GSA Symposium

**AWARDS AND FUNDING**

**Scholarship Grant Recipient**
*GCOS, Madrid, Spain 2023*

**Educational Stipend Recipient**
*ISMRM Annual Meeting, Toronto, Canada 2023*

**Poster competition winner, the second place in the doctoral category and featured research**
*Poster competition at Marquette University: Myocardial strain generation from cine MR images by deep learning*

**The winner for Graduate School Research Poster Session**
*The 32nd Annual School of Graduate Studies and Office of Postdoctoral Education Research at Medical College of Wisconsin: Myocardial displacement field generation from CMR cine images by image-to-image translation deep learning networks*

**Scholarship Grant Recipient**
*The 2018 Grad Cohort Workshop for Women, San Francisco, CA 2018*

**2017 Summer Stipend Recipient**
*Awarded by APN Health, LLC. WI: Left Atrium CT Segmentation and Statistical Structural Remodeling*
**2016 Summer Stipend Recipient**
*Awarded by Department of Computational Sciences at Marquette University: Spatial Autocorrelation and Autoregressive Models with Delta Dental Data*

**EXPERIENCES**

<table>
<thead>
<tr>
<th>Medical College of Wisconsin, Milwaukee, WI</th>
<th>January 2021 - Present</th>
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<tbody>
<tr>
<td><strong>Research Assistant</strong></td>
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<tr>
<td>· Find-tuned U-Net and ResU-Net architectures to generate spatiotemporal myocardial displacement fields for strain analysis.</td>
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<td>· Implemented image-to-image translation networks to generate tagged images from corresponding cine inputs.</td>
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<td>· Constructed a GUI for strain-encoded (SENC) image-based strain analysis using MATLAB.</td>
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<td>· Developed an improved GAN to generate tagging grid patterns on cine images.</td>
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<td>· Developed modified U-Net architectures in both 2D and 3D for automated image segmentation of cine and tagged short-axis images.</td>
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<tr>
<td>· Segmented short-axis and long-axis cardiac MRI images, including both cine and tagged images.</td>
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<tr>
<th>Marquette University, Milwaukee, WI</th>
<th>August 2015 - December 2020</th>
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<tbody>
<tr>
<td><strong>Teaching Assistant</strong></td>
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<tr>
<td>· Modern Elementary Statistics (Fall 2015, Spring 2016)</td>
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<tr>
<td>· Mathematical Statistics (Spring 2016)</td>
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<tr>
<td>· Calculus 1 (Fall 2016)</td>
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<td>· Calculus 2 (Spring 2017)</td>
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<td>· Calculus 3 (Fall 2017)</td>
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<tr>
<td>· Statistical Methods (Spring 2018)</td>
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<tr>
<td>· Biocomputers Design Labs 1 (Fall 2019, 2020)</td>
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<tr>
<td>· Biocomputers Design Labs 2 (Spring 2020)</td>
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<tr>
<th>Globe University, Plymouth, MN</th>
<th>January 2015 - June 2015</th>
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<tbody>
<tr>
<td><strong>Adjunct Instructor</strong></td>
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<tr>
<td>· College Algebra I, Plymouth Campus (Winter 2015, Spring 2015)</td>
<td></td>
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<tr>
<td>· College Algebra I, Blaine Campus (Winter 2015)</td>
<td></td>
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<tr>
<td>· Foundations of Math I, Blaine Campus (Winter 2015, Spring 2015)</td>
<td></td>
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<tr>
<td>· Foundations of Math I, Brooklyn Center Campus (Winter 2015)</td>
<td></td>
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<tr>
<td>· Foundations of Math II, Brooklyn Center Campus (Spring 2015)</td>
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<tr>
<th>South Central College, North Mankato, MN</th>
<th>January 2015 - May 2015</th>
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<tr>
<td><strong>Adjunct Instructor</strong></td>
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<tr>
<td>· College Algebra (Spring 2015)</td>
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<tr>
<th>Century College, White Bear Lake, MN</th>
<th>August 2014 - December 2014</th>
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<tr>
<td><strong>Computer Lab Assistant &amp; Math Tutor</strong></td>
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<tr>
<th>Minnesota State University, Mankato, MN</th>
<th>August 2014 - December 2014</th>
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<tr>
<td><strong>Adjunct Instructor</strong></td>
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<tr>
<td>· Education &amp; Culture in US (Fall 2014)</td>
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<tr>
<th>Minnesota State University, Mankato, MN</th>
<th>August 2012 - May 2014</th>
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<tbody>
<tr>
<td><strong>Teaching Assistant</strong></td>
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</table>
- College Algebra (Fall 2012, Fall 2013, Spring 2014)
- Trigonometry (Spring 2013)

**ACTIVITIES**

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<tr>
<th>Organization</th>
<th>Role</th>
<th>Year</th>
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<tbody>
<tr>
<td>Radiological Society of North America</td>
<td>Member</td>
<td>2023 - 2024</td>
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<tr>
<td>International Society for Magnetic Resonance in Medicine</td>
<td>Member</td>
<td>2022 - 2024</td>
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<td>American Heart Association</td>
<td>Member</td>
<td>2021 - 2022</td>
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<tr>
<td>Institute of Electrical and Electronics Engineers</td>
<td>Member</td>
<td>2020 - 2023</td>
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<tr>
<td>American Statistical Association</td>
<td>Student Representative</td>
<td>2016 - 2018</td>
</tr>
<tr>
<td>American Mathematical Society</td>
<td>Member</td>
<td>2011 - 2014</td>
</tr>
<tr>
<td>World Language Organization at Minnesota State University</td>
<td>President</td>
<td>2011 - 2013</td>
</tr>
<tr>
<td>Student Association Mathematical Experiences Research</td>
<td>Presenter</td>
<td>2012 - 2012</td>
</tr>
<tr>
<td>Korean Students Association</td>
<td>Treasurer</td>
<td>2011 - 2012</td>
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