Capstone Practicum Report

Graduate Capstone Practicum

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Abstract

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This report demostrates my work as a research assistant for a deep learning project that aimed to automate the segmentation and classification of pre-clinical hyperspectral images of atrial tissue undergoing radiofrequency ablation. My responsibilities included tasks such as data preprocessing, algorithm research, and model training. This practicum provided me with invaluable learning opportunities that helped me attain a deep understanding of complex deep learning architectures. Additionally, it fostered my teamwork and collaboration skills while enhancing my communication abilities for future career endeavors.

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Company Name and Short Description

Dr. Varduhi Yeghiazaryan [2], an assistant professor at the Zaven P. and Sonia Akian College of Science and Engineering (CSE) at the American University of Armenia, is leading a research project titled "Fully Automated GPU-Based Parallel Analysis of Pre-Clinical Multidimensional Hyperspectral Datasets." The Afeyan Family Foundation [3] is funding this project. The project is co-lead by CSE professor Narine Sarvazyan and lecturer Aram Butavyan. The project aims to develop a deep-learning-based procedure that is accelerated by graphics processing units (GPUs). The procedure seeks to automatically segment and classify hyperspectral images of atrial tissue undergoing radiofrequency ablation. The L.A. Orbeli Institute of Physiology provides the dataset of hyperspectral images of atrial tissue. The team consists of recent AUA graduates, including Yeva Gabrielyan (BSCS '19 and MSCIS '22), Sona Bezirganyan (BSCS '22), Lusine Davtyan (BSCS '22), and Arpi Hunanyan (BSDS '22 and MSCIS '24). The research aims to leverage advanced imaging techniques and contribute to interdisciplinary research capacity in Armenia while advancing clinical applications.

American University of Armenia

The American University of Armenia (AUA) [1] is a highly esteemed university in Yerevan, Armenia, offering its students a wealth of opportunities. AUA has been accredited by the Western Association of Schools and Colleges Senior College and University Commission, which speaks to the high quality of education it provides. Since its establishment in 1991, AUA has been committed to preparing its students for success in their chosen fields. In addition, AUA has recently placed greater emphasis on research, allowing students to participate in exciting research projects. By attending AUA, students can receive a high-quality education and gain valuable experience to help them achieve their professional goals.

Orbeli Institute of Physiology

The Institute of Physiology NAS RA [4] was established in 1943. It was named after academician L.A. Orbeli in 1959. The institute was founded based on the physiological achievements of

Armenian scientists who had previously worked in higher education institutions and Yerevan State University. The L.A. Orbeli Institute of Physiology NAS RA is the primary scientific center of physiology in Armenia, with a focus on neurophysiology. This includes studying the integrative and plastic properties of the nervous system and the central regulation mechanisms of motor and vegetative functions of organisms. The institute operates the Physiological Society of Armenia and the Armenian Association of International Brain Research Organization (IBRO).

Project Supervisor Contacts

Supervisor: Varduhi Yeghiazaryan
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Varduhi Yeghiazaryan is an assistant professor at the Akian College of Science and Engineering, American University of Armenia. She received her DPhil (PhD) from Oxford University, United Kingdom, for research in medical image analysis. Her research interests include medical image analysis, parallel computation on GPUs, deep reinforcement learning, computation on graphs.

Project Description

Project Title: Fully Automated GPU-Based Parallel Analysis of Pre-Clinical Multidimensional Hyperspectral Datasets

Project Description

The ablation procedure is vital for treating arrhythmia or irregular heartbeats. During this procedure, doctors target and destroy abnormal heart tissue that causes an irregular rhythm. Success depends on completely removing the problematic tissue.

Our project focuses on detecting these treated areas within the heart. We are utilizing hyperspectral images (HSI) of human, bovine, and porcine heart tissues. HSI is an image cube taken by a special camera that captures various wavelengths of light, providing detailed information about the tissue composition.

We aim to compare existing advanced machine learning algorithms, previously tested on landscape HSI data, to analyze these human, bovine, and porcine heart tissues and accurately identify the regions where ablation has occurred. HSI classification involves examining each pixel in the image and assigning it a specific class based on the information gathered from all the channels.

Our research, which aims to detect ablated tissue regions effectively, has the potential to significantly enhance the effectiveness of the ablation procedure. This, in turn, could open up new avenues for research in medical hyperspectral data, ultimately leading to improved patient outcomes in treating arrhythmias.

Task Description

Throughout our research endeavors, my responsibilities include various tasks:

- Weekly Discussions

  We have regular team meetings to discuss progress updates and plan future steps. During these meetings, we share our work and ideas, provide valid reasoning for our decisions, and accept feedback from our team members. We also pay close attention to our team members' work to understand the entire process and provide constructive feedback.

- Data Preprocessing

  We source our data from the Orbeli Institute, and sometimes the data is different in shape, setup, how it is captured, the type of material used, etc. Managing these differences to ensure well-constructed and consistent data is a task that involves developing Python pipelines. Overall, these pipelines read the files provided by the institute, preprocess them, and convert them to mat files, commonly used as input types in many machine learning algorithms. Additionally, I ensure data resizing when necessary and generate masks for ground truth. Since we have conducted different experiments, we have designed various masking techniques for those experiments.

- Research

  One of the most critical aspects of our project is research. As part of my tasks, I have studied existing papers and literature on HSI classification and detection of ablated heart tissues. Then, I have prepared presentations and documentation to present the algorithms to other team members and filter out the most relevant and crucial ones for further investigation. During the research, I have studied the architecture of convolutional neural networks, graph neural networks, transformers, and combinations of these networks more deeply.

- Model Training and Testing

  In these tasks, we train deep learning models on prepared data and test their performance rigorously. Through iterative experimentation, I adapt existing models for our data to

achieve optimal performance and ensure their robustness in various scenarios. I collaborate with team members to analyze the results, identify potential challenges, and develop strategies to enhance model performance.

- Periodic Updates:

  We regularly shared our latest findings with AUA and Orbeli Institute experts. Also, our team presented our results to guest professors who shared valuable insights on our current progress. I gained a lot of knowledge from these meetings. Our guests included Dr. Irina Voiculescu from the University of Oxford and Prof. Murray Loew from George Washington University. Additionally, my team and I worked on designing a scientific poster of our results and presented it at the BIO-SEE 2023 Annual Meeting. More information regarding the BIO-SEE 2023 Annual Meeting and the poster is demonstrated in Appendix [2].

- Scientific Paper Writing

  My team and I are currently writing a research paper using LaTeX. To ensure we produce high-quality work, we have divided the paper into sections and assigned each team member a section to work on. Once we have completed our sections, we review each other's work to ensure it is cohesive and accurate. Our ultimate goal is to publish our research in scientific journals and participate in conferences.

Conclusion

This capstone practicum has been an invaluable learning experience for me. I have developed a deep understanding of complex deep learning architectures, processed HSI data, gained teamwork and collaboration skills, and improved my ability to communicate technical concepts effectively to specialists and non-specialists. I am confident that these skills will be beneficial in achieving my future career goals.

Appendix A: BIO-SEE 2023 Annual Meeting Poster

The BIO-SEE 2023 Annual Meeting in Yerevan, Armenia, facilitated knowledge exchange among local and international biomedical researchers. It featured talks and poster presentations and underscored the importance of collaboration in advancing scientific understanding. AUA faculty and students actively participated, showcasing research and engaging in discussions. Our team also had a poster, which is demonstrated in Figure 1. Here [2] is the video from the BIO-SEE 2023 Annual Meeting, in which I demonstrated our work to local and international attendees.

Hyperspectral Image Classification of Ablated Cardiac Tissue using Deep Learning

Yeva Gabrielyan[1], Arpi Hunanyan[1], Lusine Davtyan[1], Sona Bezirganyan[1], Narine Sarvazyan[1,2,3], Varduhi Yeghiazaryan[1], Aram Butavyan[1]

AUA American University of Armenia
AKIAN COLLEGE of SCIENCE & ENGINEERING

[1]American University of Armenia
[2]George Washington University
[3]Orbeli Institute of Physiology

BIO-SEE 2023 Annual Meeting

Objective

We aim to develop real-time fully-automated procedures to analyse preclinical hyperspectral images (HSI) of the atrial tissue acquired during radiofrequency ablation procedures. Here we test the applicability of state-of-the-art hyperspectral image classification methods [1, 2, 3, 4] to separate ablated regions in excised left atrial tissue of large animals.

Methods

ASSMN [1] incorporates spectral and spatial feature extraction subnetworks, both constructed using LSTMConv blocks. It improves classification results by considering the varying importance of spectral and spatial components.

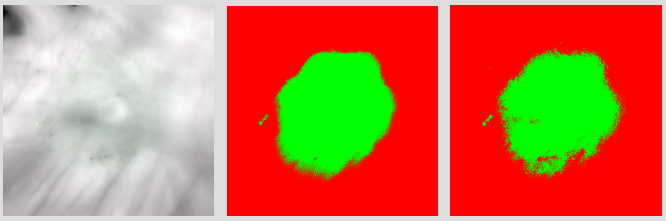
CNN-Enhanced GCN [2] combines the advantages of CNN and GCN, conducting feature learning on small-scale regular regions and large-scale irregular regions. It generates complementary spectral-spatial features at both pixel and superpixel levels.

WFCG [3] addresses the limitations of small sample sizes in CNN and the computational cost of GNN for HSI classification, effectively combining the strengths of superpixel-based GAT and pixel-based CNN through a feature fusion mechanism.

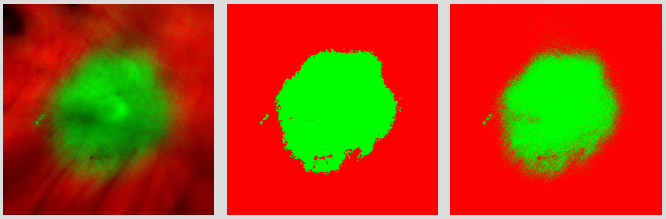
SpectralFormer [4] is an extension of the transformer architecture capable of capturing local information from neighboring bands of HS images and transfer memory-like components across layers of different depths with cross-layer skip connections.

Pseudo RGB images were generated using [5].

Ablated Bovine Heart Atrium

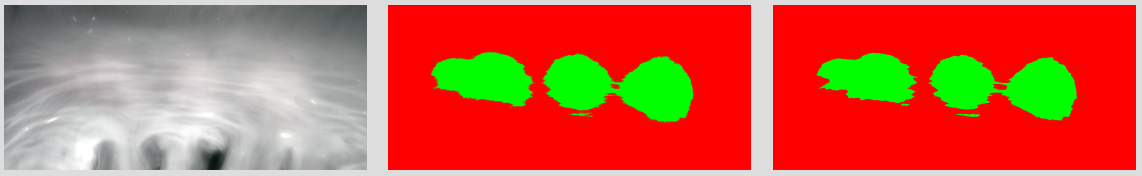


pseudo RGB image | ASSMN result | CNN-Enhanced GCN result

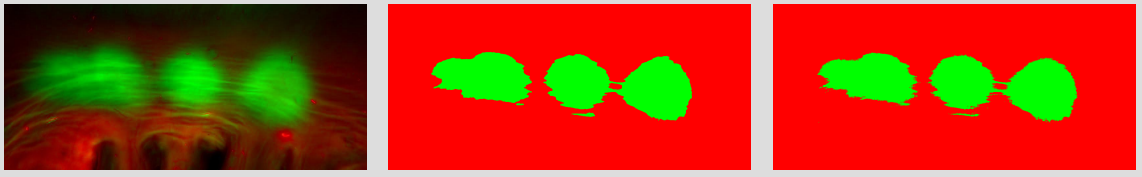


unmixed composite | WFCG result | SpectralFormer result

Ablated Porcine Heart Atrium



pseudo RGB image | ASSMN result | CNN-Enhanced GCN result



unmixed composite | WFCG result | SpectralFormer result

Comparison

The comparison of the four approaches using evaluation metrics: Overall Accuracy (OA), Average Accuracy (AA), Kappa Coefficient (κ). The best performer is in boldface; the runner-up is underlined.

Method	Bovine			Porcine		
	OA (%)	AA (%)	$\kappa \times 100$	OA (%)	AA (%)	$\kappa \times 100$
ASSMN	96.17	96.90	91.10	97.42	98.70	90.96
CNN-Enhanced GCN	**98.61**	**98.01**	**96.14**	**99.74**	<u>99.55</u>	**99.03**
WFCG	<u>97.58</u>	<u>97.61</u>	<u>93.33</u>	<u>99.62</u>	**99.62**	<u>98.56</u>
SpectralFormer	96.59	95.67	90.59	99.16	98.25	96.84

The results of the experiments suggest that all four selected approaches generate predictions with high accuracy. CNN-Enhanced GCN is the state-of-the-art hyperspectral image classification method which generates highest accuracies in almost all criteria, followed by WFCG that comes second.

Next steps: adapt/propose these or similar networks for semantic segmentation, i.e. make the approaches applicable and accurate for new HS images not seen during training.

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LaTeX TikZposter

Figure 1: BIO-SEE 2023 Annual Meeting Poster

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