CAP 5516
Medical Image Computing
(Spring 2025)

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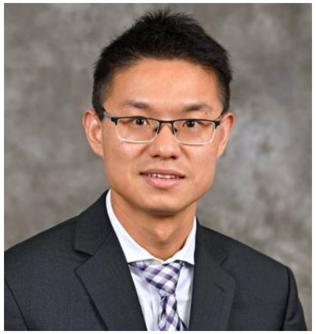
UCF CENTER FOR RESEARCH IN COMPUTER VISION

Lecture 1: Course Introduction

About the instructor



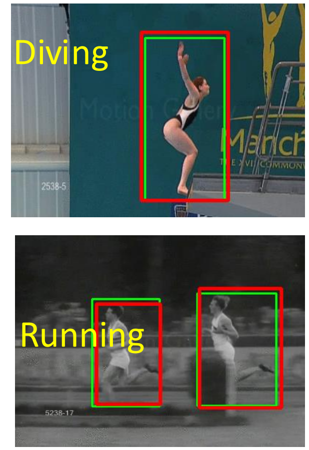
Chen Chen, Ph.D.

Associate Professor
Center for Research in Computer Vision (CRCV)

Research Interests:
Computer Vision
Machine Learning
Image and Video Processing

https://www.crcv.ucf.edu/chenchen/

Action detection



Red: Our detection Green: Ground Truth

Video object segmentation

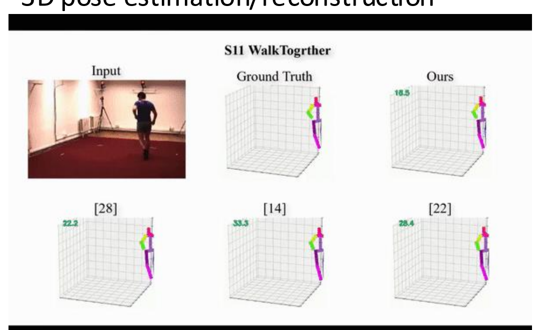
ICCV'17 BMVC'19

Research Highlight

- Computer Vision
  - *Object detection and tracking*
  - *Action detection and recognition*
  - *Human 2d/3d pose estimation*
  - *Image semantic segmentation*
  - *Image restoration*
- Machine Learning
  - *Efficient deep learning*
  - *Robust machine learning*
  - *Federated learning*

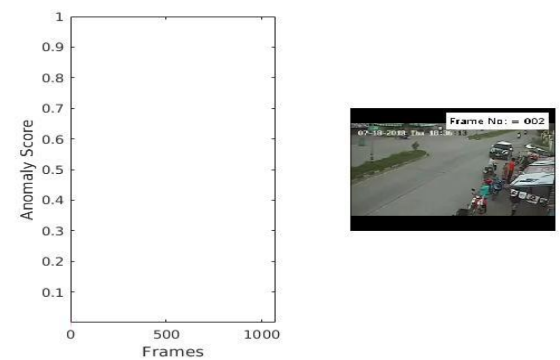
Object detection in aerial images

3D pose estimation/reconstruction



CVPR'18, CVPR'20

Video anomaly detection



CVPR'18

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Efficient 3D CNN for <u>Real-time</u> Brain Tumor Segmentation (MICCAI 2019)

- Light-weight and efficient 3D CNN for 3D MRI brain tumor segmentation
  - 3.88M parameters (low memory overhead)
  - Inference time (s) for a single 3D volumetric segmentation
    - 0.019s on one GPU
    - 20.6s on one CPU

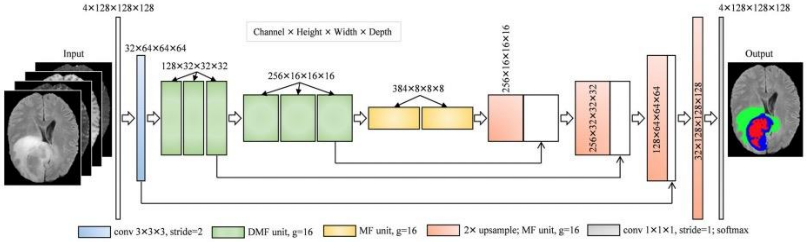
Lower values the better

Higher values the better

Model	Params(M)	FLOPs	Dice_score(%)		
			ET	WT	TC
0.75× MFNet (**ours**)	**1.81**	**13.36**	79.34	90.22	84.25
MFNet (**ours**)	3.19	20.61	79.91	90.43	84.61
DMFNet (**ours**)	3.88	27.04	80.12	90.62	84.54
3D U-Net [1]	16.21	1669.53	75.96	88.53	71.77

BraTS 2018 validation set

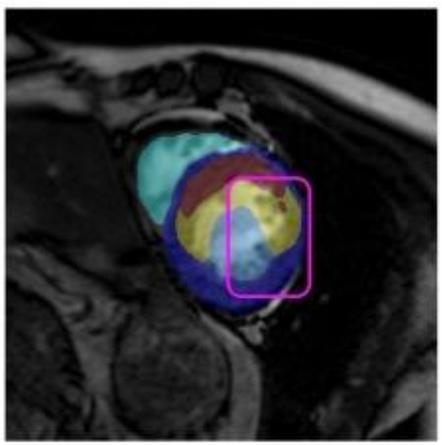
Network architecture



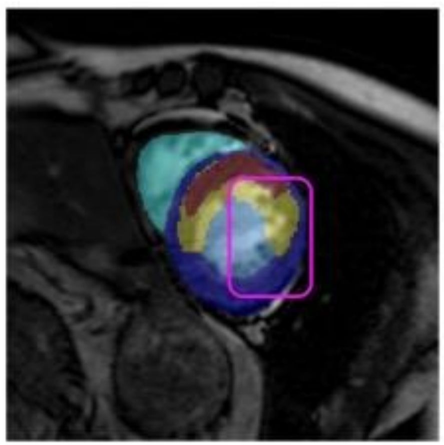
Chen, Chen, Xiaopeng Liu, Meng Ding, Junfeng Zheng, and Jiangyun Li. "3D dilated multi-fiber network for real-time brain tumor segmentation in MRI." In *International Conference on Medical Image Computing and Computer-Assisted Intervention*, pp. 184-192. Springer, Cham, 2019.

Multi-sequence Cardiac MR Images Segmentation (MICCAI 2020 Workshop)

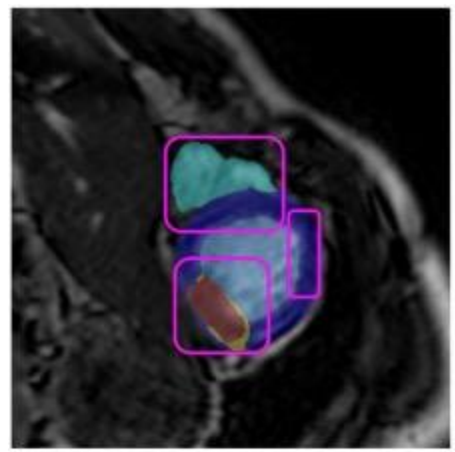
- Task: Myocardial pathology segmentation in cardiac magnetic resonance (CMR)
- Proposed method: Dual Attention U-Net



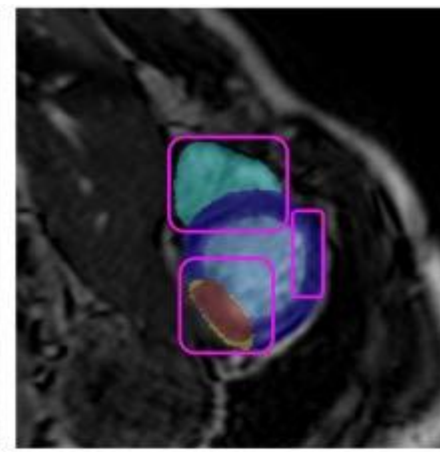
Ours



Ground truth



Ours



Ground truth

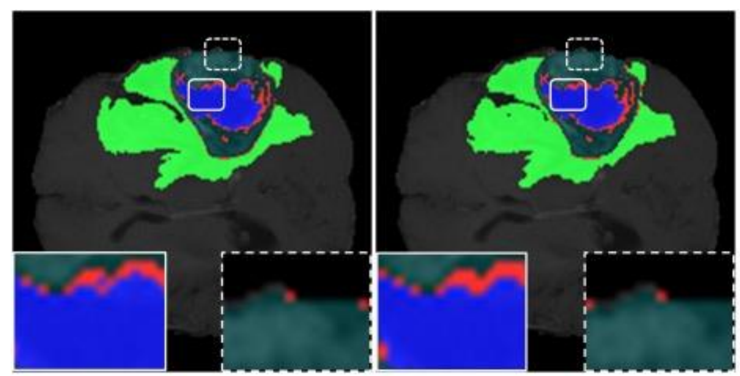
Yu, Hong, Sen Zha, Yubin Huangfu, **Chen Chen**, Meng Ding, and Jiangyun Li. "Dual Attention U-Net for Multi-sequence Cardiac MR Images Segmentation." In Myocardial Pathology Segmentation Combining Multi-Sequence CMR Challenge, pp. 118-127. Springer, Cham, 2020.

TransBTS: Multimodal Brain Tumor Segmentation Using Transformer (MICCAI 2021)

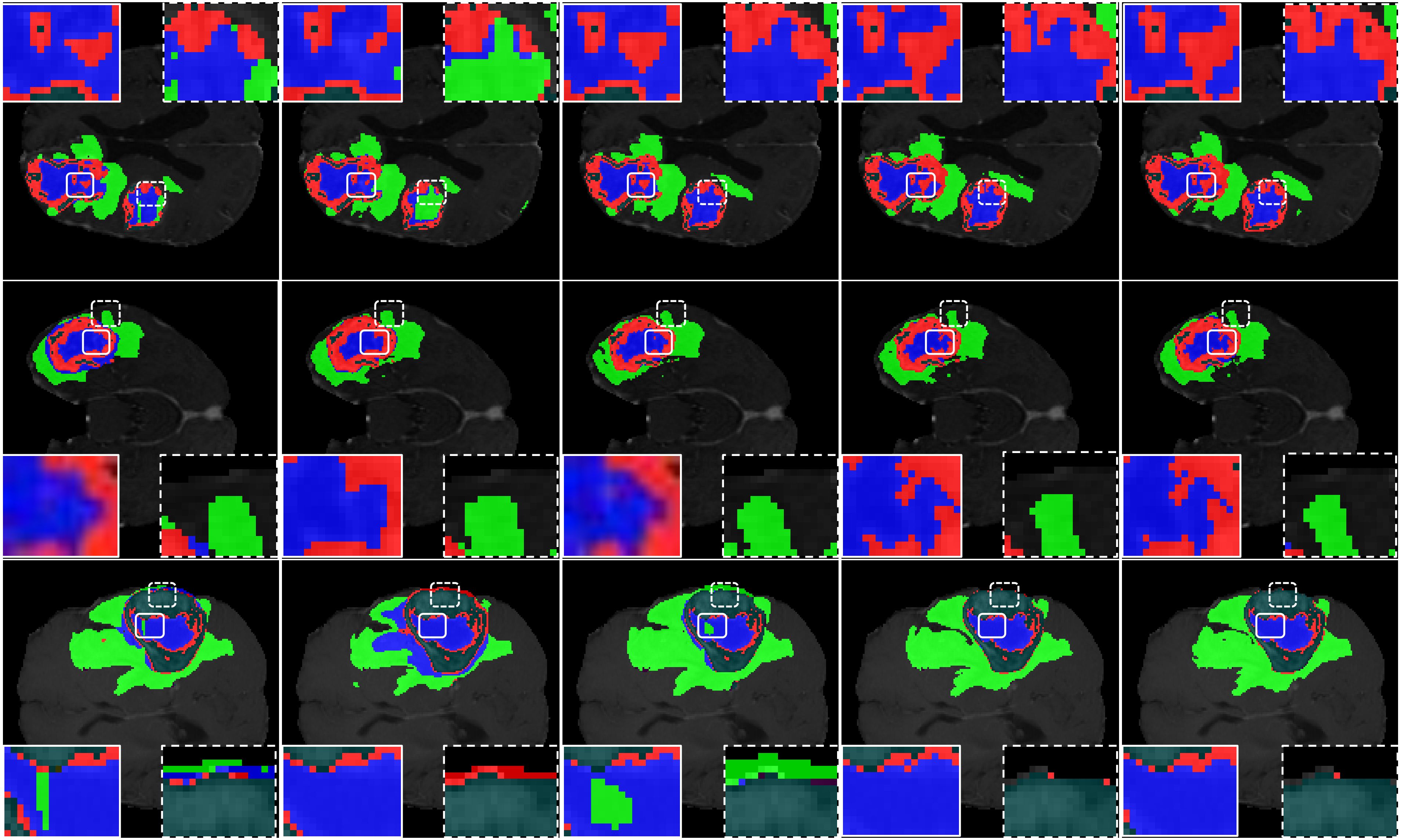
- First attempt of exploiting Transformer in 3D CNN for 3D MRI Brain Tumor Segmentation
  - Novel network design: incorporating Transformer in 3D CNN to unleash the power of both architectures
  - State-of-the-art performance on two benchmarks: BraTS 2019 and 2020

BraTS 2020 validation set

Method	Dice Score (%) ↑		
	ET	**WT**	**TC**
3D U-Net [6]	68.76	84.11	79.06
Basic V-Net [12]	61.79	84.63	75.26
Deeper V-Net [12]	68.97	86.11	77.90
Residual 3D U-Net	71.63	82.46	76.47
TransBTS w/o TTA	78.50	89.00	81.36
TransBTS w/ TTA	**78.73**	**90.09**	**81.73**

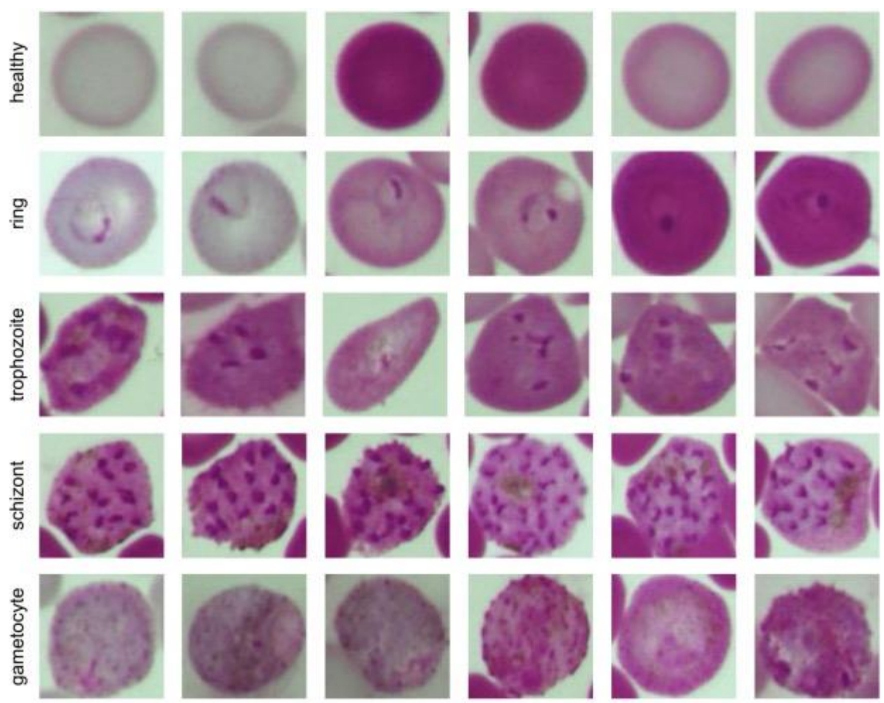


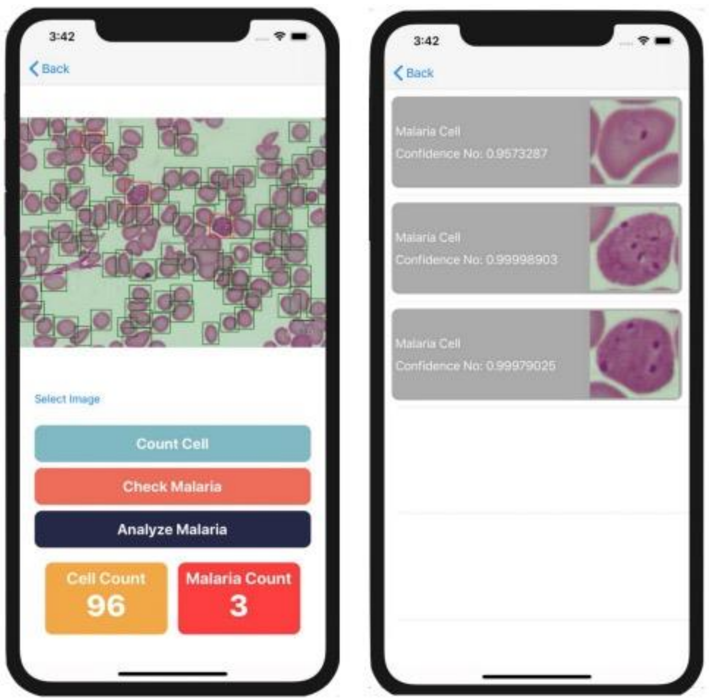
Wang, Wenxuan, **Chen Chen**, Meng Ding, Hong Yu, Sen Zha, and Jiangyun Li. "Transbts: Multimodal brain tumor segmentation using transformer." In *International Conference on Medical Image Computing and Computer-Assisted Intervention*, pp. 109-119. Springer, Cham, 2021.



Malaria Life-Cycle Classification in Thin Blood Smear Images

- A new large scale microscopic image malaria dataset
- A two-stage approach for malaria detection and malaria life-cycle-stage classification
- A mobile application is developed





Arshad, Qazi Ammar, Mohsen Ali, Saeed-ul Hassan, **Chen Chen**, Ayisha Imran, Ghulam Rasul, and Waqas Sultani. "A Dataset and Benchmark for Malaria Life-Cycle Classification in Thin Blood Smear Images." Neural Computing and Applications, 2021.

Med-DANet: Dynamic Architecture Network for Efficient Medical Volumetric Segmentation

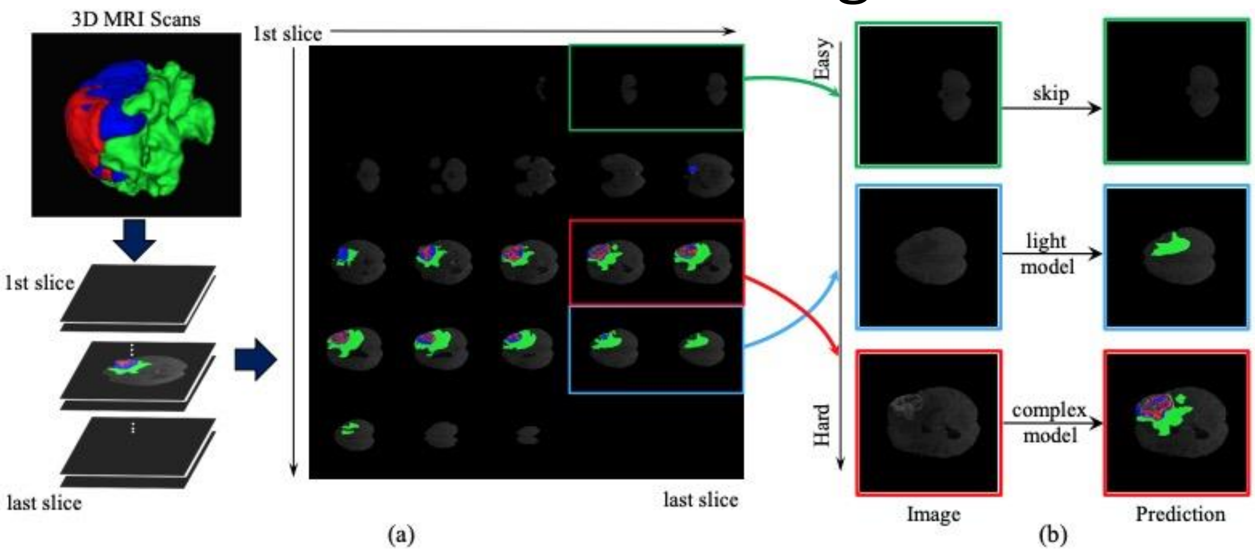
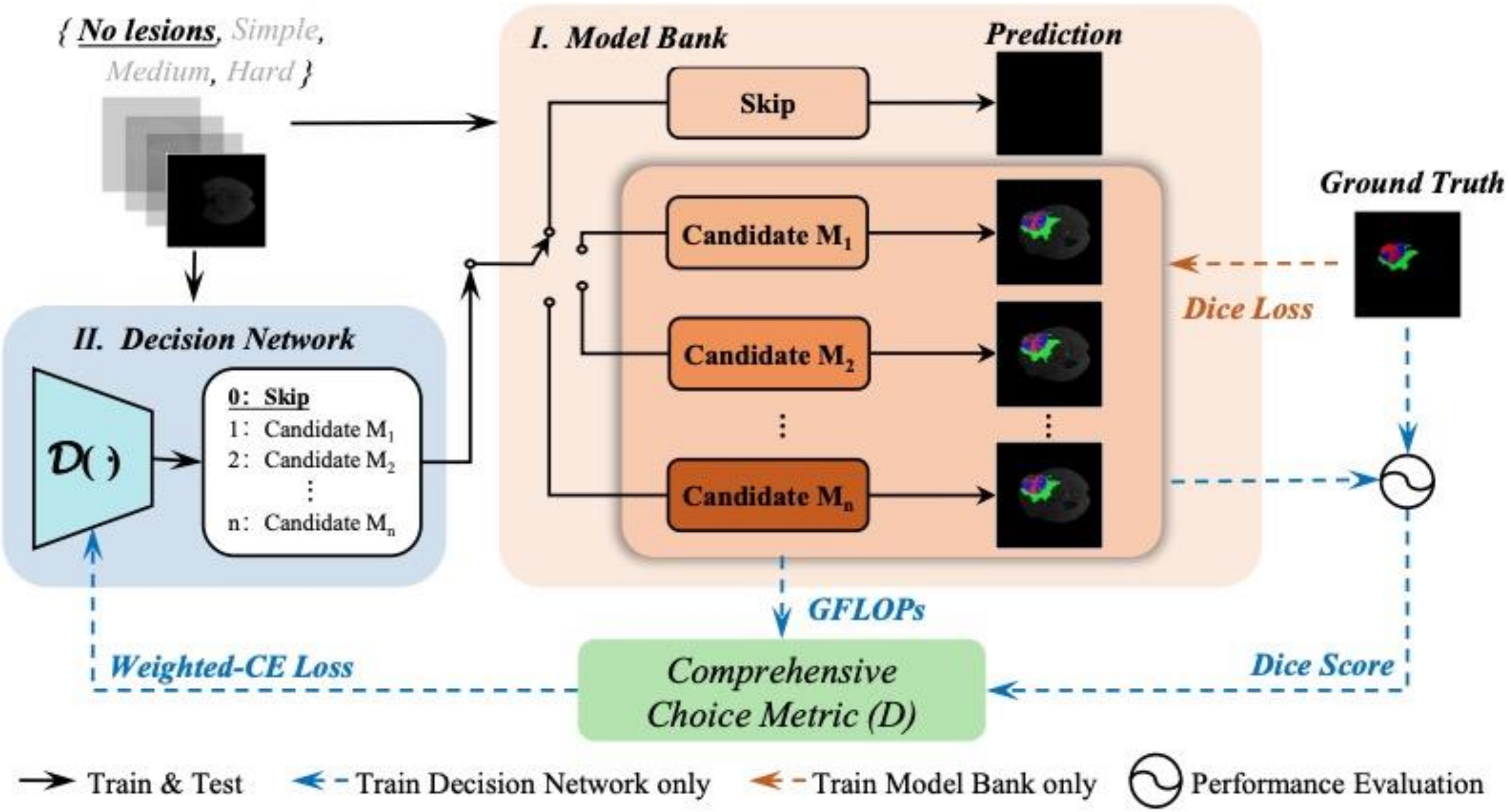


Fig. 1. (a) The illustration of image content distribution along slice dimension of an MRI case (Axial View) from the BraTS 2019 dataset. The blue regions denote the enhancing tumors, the red regions denote the non-enhancing tumors, and the green ones denote the peritumoral edema. (b) The main idea of our proposed framework for dynamic inference. For image slices with diverse segmentation difficulty, our framework realizes efficient and accurate segmentation by adaptively adjusting the architecture, selecting the optimal network in the Model Bank which consists of several networks with different model complexities. In this way, our framework can dynamically decide to "slack off" or "work hard" according to different samples.

Wang, W., Chen, C., Wang, J., Zha, S., Zhang, Y., & Li, J. (2022). Med-DANet: Dynamic Architecture Network for Efficient Medical Volumetric Segmentation. In European Conference on Computer Vision (pp. 506-522).

Med-DANet: Dynamic Architecture Network for Efficient Medical Volumetric Segmentation



Wang, W., Chen, C., Wang, J., Zha, S., Zhang, Y., & Li, J. (2022). Med-DANet: Dynamic Architecture Network for Efficient Medical Volumetric Segmentation. In European Conference on Computer Vision (pp. 506-522).

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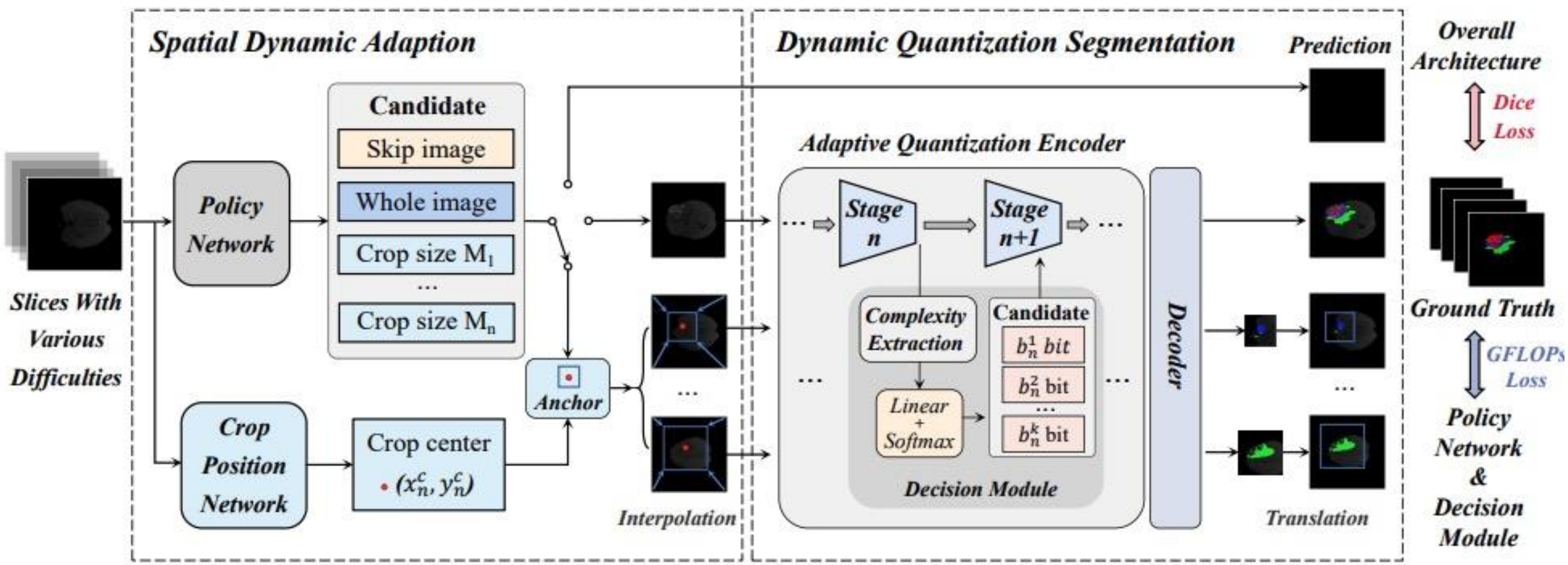
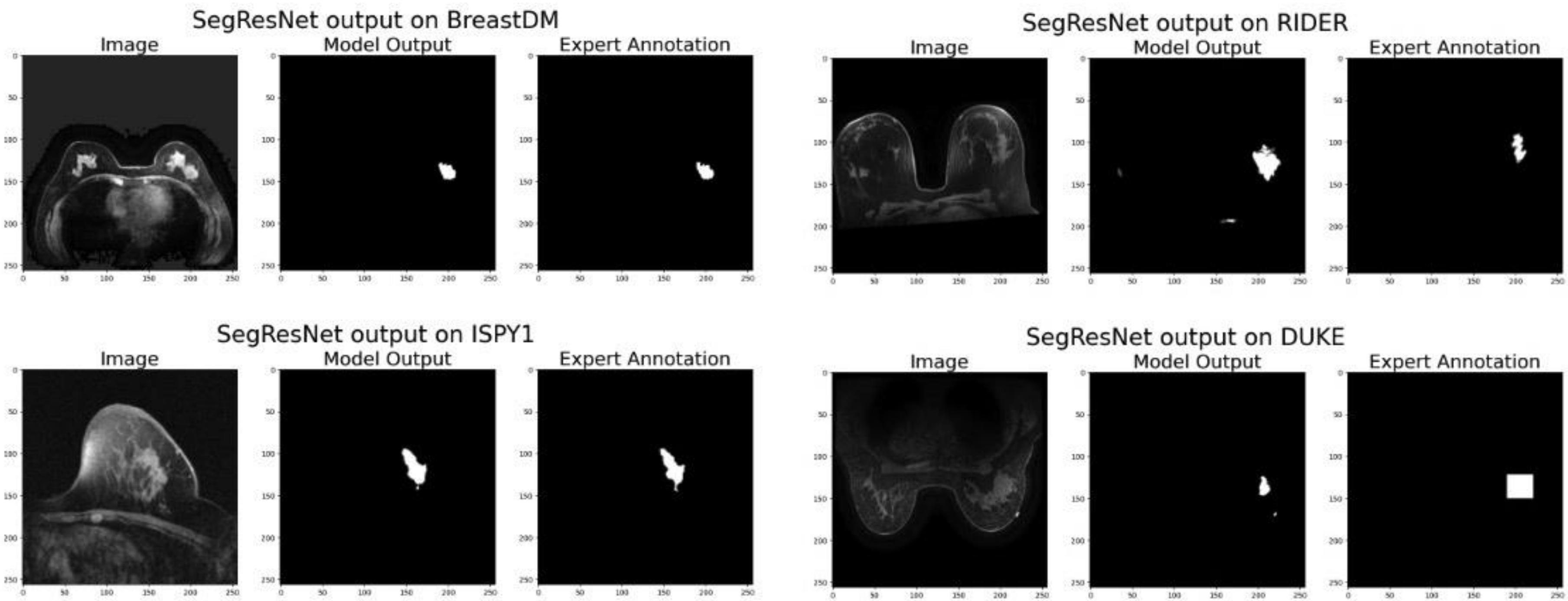
Med-DANet V2: A Flexible Dynamic Architecture for Efficient Medical Volumetric Segmentation



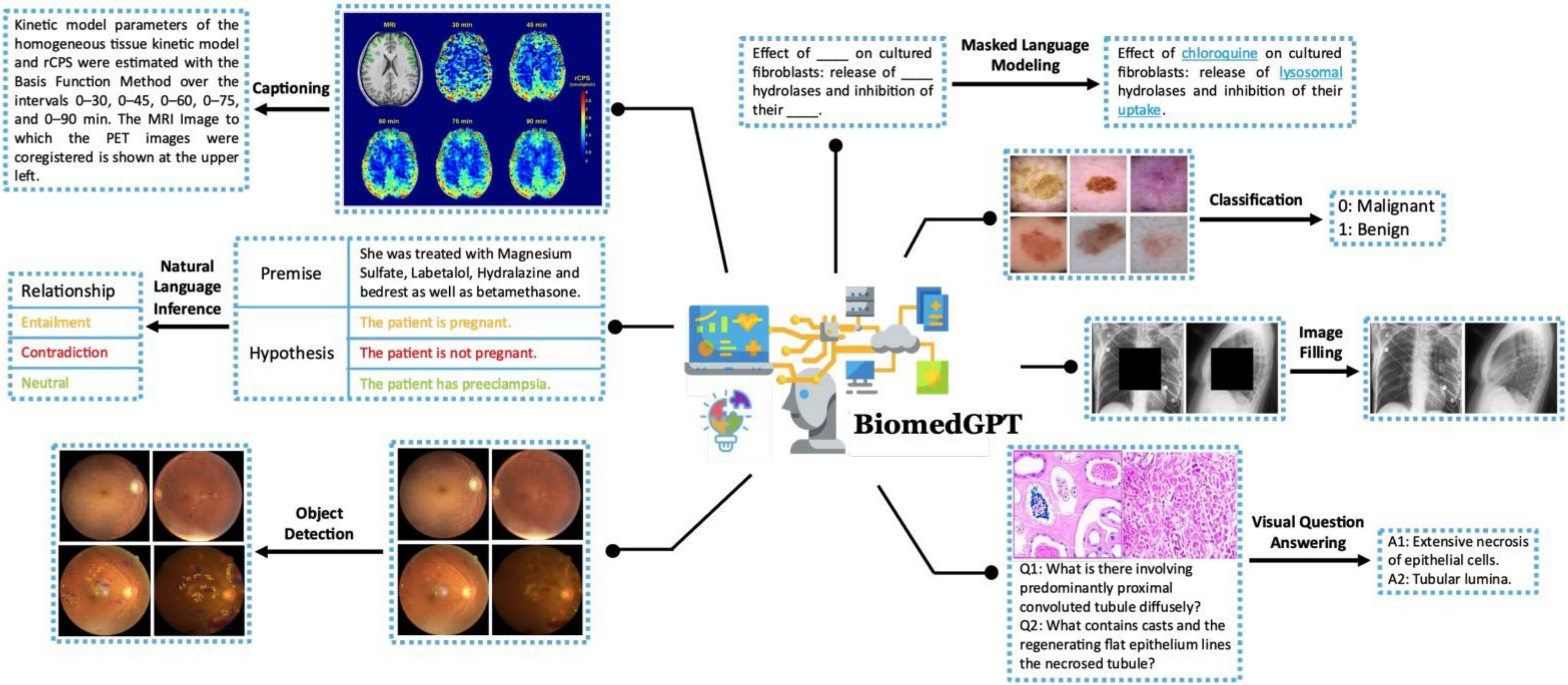
Shen, Haoran, et al. "Med-DANet V2: A Flexible Dynamic Architecture for Efficient Medical Volumetric Segmentation." Proceedings of the IEEE/CVF Winter Conference on Applications of Computer Vision. 2024.

A Breast Cancer MRI Tumor Segmentation Benchmark



Bilic, A., & Chen, C. (2024). BC-MRI-SEG: A Breast Cancer MRI Tumor Segmentation Benchmark. *arXiv preprint arXiv:2404.13756*.

BiomedGPT



Zhang, K., Zhou, R., Adhikarla, E., Yan, Z., Liu, Y., Yu, J., ... & Sun, L. (2024). A generalist vision–language foundation model for diverse biomedical tasks. *Nature Medicine*, 1-13.

Course Information

Term: Spring 2025

Class Meeting Days: TR

Class Meeting Time: 12:00PM - 01:15PM

Class Meeting Location:

Modality: VL

Credit Hours: 3.00

Zoom link

https://ucf.zoom.us/j/6156319806

Instructor Information

Chen Chen

Title: Associate Professor

Office Location: HEC 221

Office Hours:

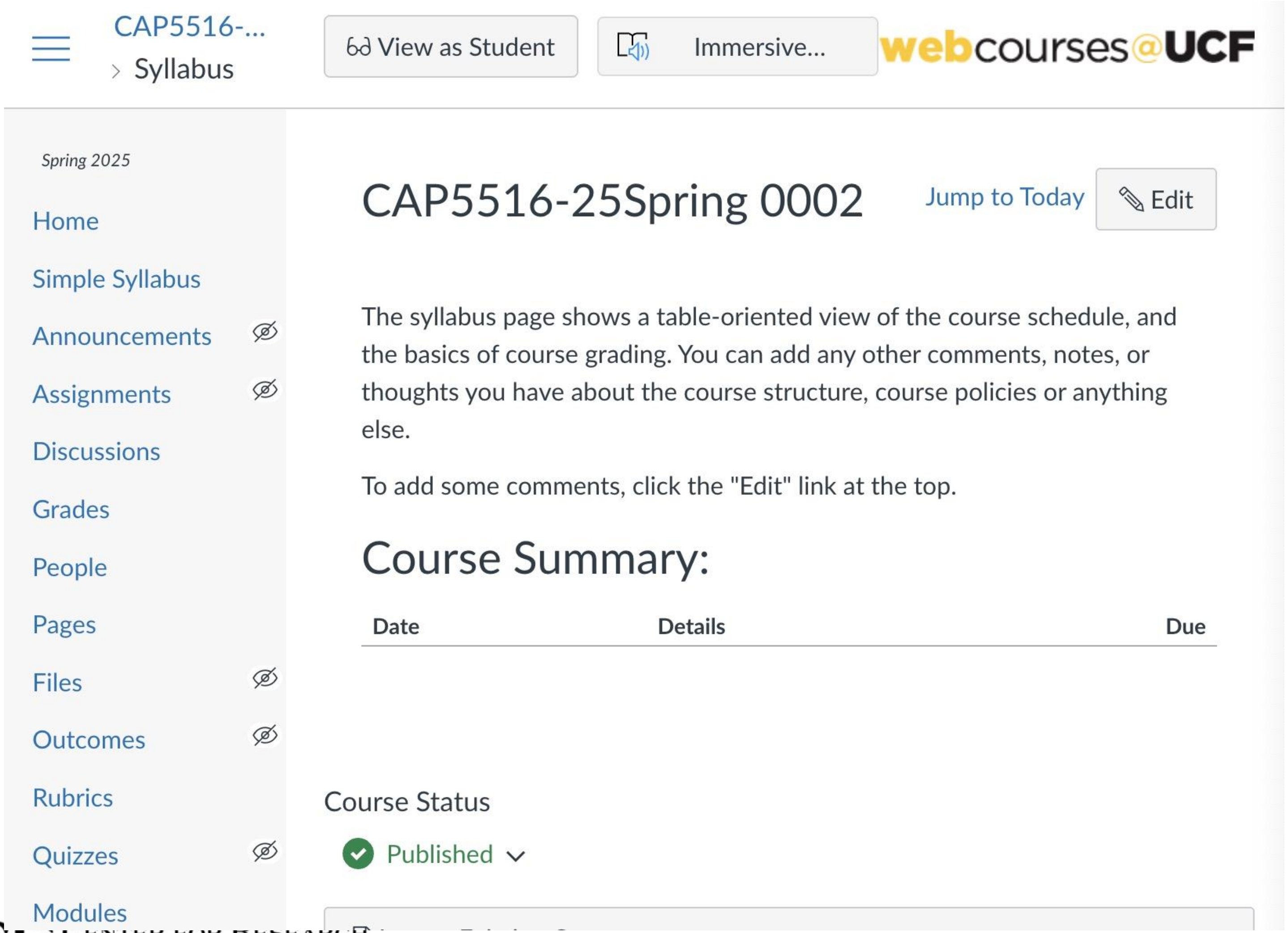
1:30 - 2:30 PM on Tuesday and Thursday, or by appointment

Email: Chen.Chen@ucf.edu

Teaching Assistants

Ming Li (mingli@ucf.edu)

Webcourses@UCF



Webcourses@UCF

- Sending reminders, notifications, etc.
- Post course materials, recorded lecture videos
- Submitting reports and assignments
- Discussions

Syllabus

- Textbook
- Reading materials
- Prerequisites and preparation
- Course requirement
- Grading policy
- General Statements

Textbook

- There is no textbook for this class. We will discuss some of the recent top-quality research papers in the course materials.

- Recommended supplemental textbook
  - Suetens, P. Fundamentals of Medical Imaging, Cambridge University Press
  - Prince, J. & Links, J. Medical Imaging Signals and Systems, Prentice Hall
  - Bankman, Isaac. Handbook of Medical Imaging: Processing and Analysis, Academic Press
  - Pattern Recognition and Machine Learning, Christopher M. Bishop (2006). "Deep Learning" by Ian Goodfellow, Yoshua Bengio, Aaron Courville (free online: http://www.deeplearningbook.org/
  - Online textbook "Computer Vision: Algorithms and Applications" by Richard Szeliski
  - Introduction to Machine Learning, Ethem Alpaydin (2014), MIT Press. https://www.cmpe.boun.edu.tr/~ethem/i2ml3e/
  - Artificial Intelligence: A Modern Approach, (Third edition) by Stuart Russell and Peter Norvig.

Recommended Resources (1)

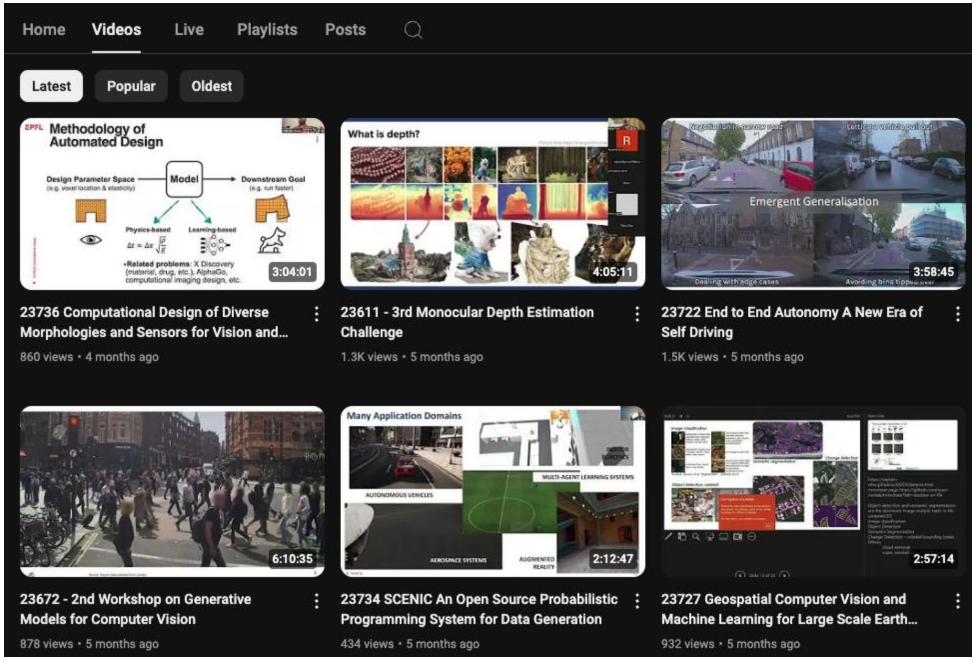
- CS231n: CS231n: Deep Learning for Computer Vision: http://cs231n.stanford.edu
- Theories of Deep Learning (STATS 385): https://stats385.github.io
- CAP5415 – Computer Vision:

https://www.crcv.ucf.edu/courses/#cap-5415-computer-vision

- Python for Computer Vision: http://programmingcomputervision.com/downloads/ProgrammingComputerVision_CCdraft.pdf

Recommended Resources (2)

- Computer Vision Foundation open access (CVPR, ICCV conference papers over the past years)
- YouTube channel for CVF
  - https://www.youtube.com/channel/UC0n76gicaarsN_Y9YShWwhw/videos



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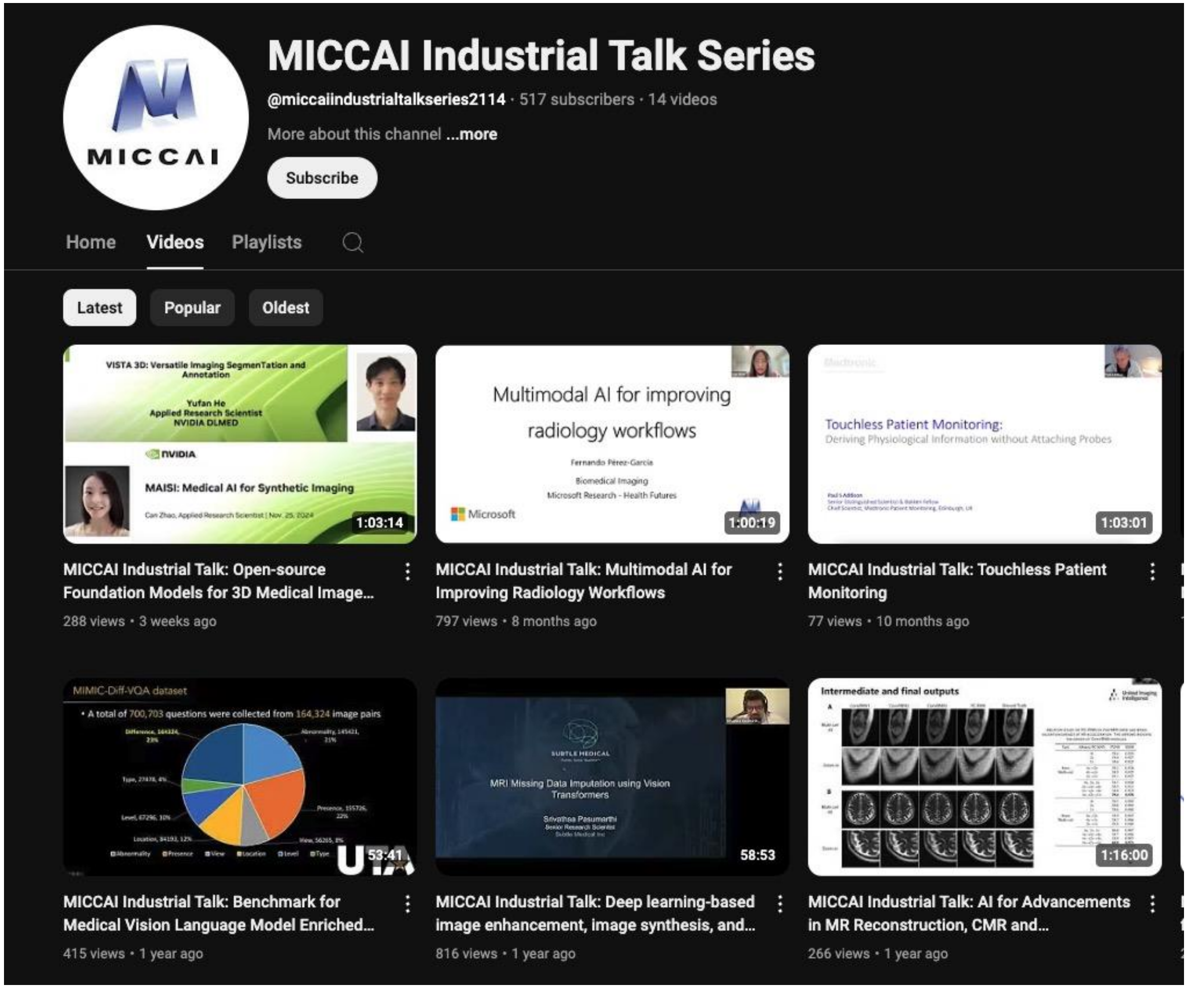
Recommended Resources (3)



MICCAI Industrial Talk Series: https://www.youtube.com/@miccaiindustrialtalkseries2114/videos

Conferences and Journals to Follow

- The top-tier conferences (double blind, acceptance rates are below 25%, high qual technical articles):
  - MICCAI (medical image computing & computer assisted intervention)
  - IPMI (Information Processing in Medical Imaging)
  - MIDL (Medical Imaging with Deep Learning)
  - Other conferences: IEEE ISBI, EMBC, ICIP and SPIE Med Imaging
  - Clinical Conferences: RSNA (>65.000 attendances), ISMRM, SNM
    - Vision and ML conferences: CVPR, NeurIPS, ICML, ICLR, ECCV, ICCV
- The top-tier technical journals:
  - IEEE TMI, TBME, PAMI, and TIP
  - Medical Image Analysis, CMIG, and NeuroImage
- The top-tier clinical journals relevant to MIC:
  - Radiology, Journal of Nuclear Medicine, AJR, Nature Methods, Nature Medicine, PlosOne, Radiology AI, …
- ArXiv, BioRxiv…

A few upcoming conferences

- MICCAI 2025
- https://conferences.miccai.org/2025/en/CALL-FOR-PAPERS.html

Topics of interest for MICCAI 2025 include, but are not limited to:

- Image formation and reconstruction
- Image segmentation and anomaly detection
- Integration of imaging and non-imaging data
- Multimodal data integration and analysis
- Computer-aided diagnosis
- Trustworthy and generalizable AI in medical imaging
- Image synthesis and augmentation for diverse populations
- Algorithmic fairness in medical imaging
- Surgical data science
- Image-guided robotic surgery
- Biomedical image computing for neglected diseases
- Point-of-care imaging solutions
- Image-based personalized medicine
- Clinical implementation and monitoring of imaging solutions
- Equity in medical imaging, including accessible and scalable solutions
- Teleradiology applications
- Imaging solutions for challenges specific to the Pan-Asian region

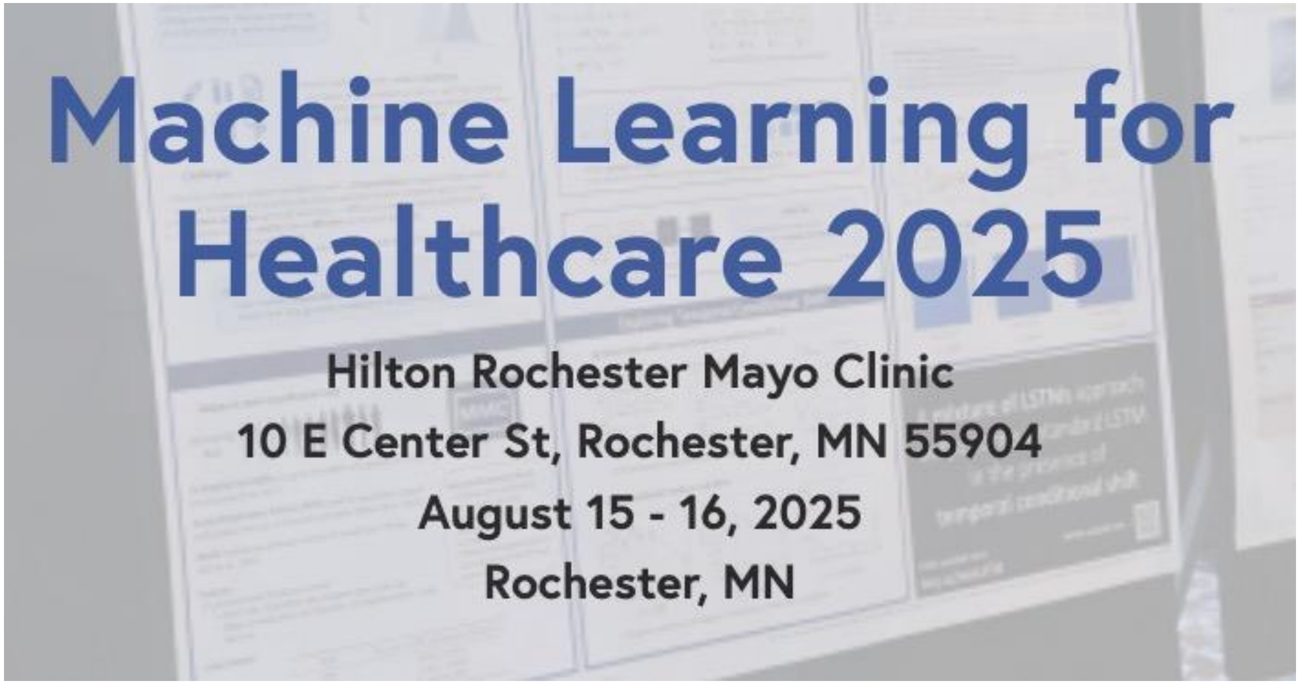
Submission deadlines:

Abstract registration:	13 February 2025
Submission deadline:	27 February 2025

(All times are 23:59 Pacific Time)

A few upcoming conferences

- Machine Learning for Healthcare 2025
- https://www.mlforhc.org/



A few upcoming conferences

- Medical Imaging with Deep Learning, 2025
- https://2025.midl.io/

Medical Imaging with Deep Learning

Salt Lake City, 9—11 July 2025

Full Papers

Full paper registration deadline	17 January 2025
Paper bidding	18 January - 24 January 2025
Full paper submission deadline	24 January 2025
Paper assignment	31 January 2025
Reviews due	14 February 2025
Rebuttal	21 February – 28 February 2025
Discussion period	1 March – 7 March 2025
Final decisions	Mid March 2025
Camera-ready deadline	1 June 2025

Short Papers

Short paper submission deadline	11 April 2025
Final decisions	1 May 2025
Camera-ready deadline	1 June 2025

A few upcoming conferences

- Conference workshops related to medical imaging
  - e.g. MICCAI 2023 workshops: https://conferences.miccai.org/2024/en/workshops.asp
  - The 15th International Workshop on Machine Learning in Medical Imaging (MLMI 2024): https://sites.google.com/view/mlmi2024

Prerequisites and Preparation

- Recommended preparation: basic probability, statistics, linear algebra, calculus, optimization.
  - CS231n: Deep Learning for Computer Vision: http://cs231n.stanford.edu
  - CAP5415 – Computer Vision: https://www.crcv.ucf.edu/courses/#cap-5415-computer-vision
- Proficient in programming languages (e.g., Python).
  - Programming Computer Vision with Python: http://programmingcomputervision.com/downloads/ProgrammingComputerVision_CCdraft.pdf
- General knowledge of deep learning frameworks: PyTorch, TensorFlow, Keras, etc.
  - PyTorch tutorial
    - https://web.stanford.edu/class/cs224n/materials/CS224N_PyTorch_Tutorial.html
    - http://cs231n.stanford.edu/slides/2021/discussion_4_pytorch.pdf
    - https://youtu.be/BL6uJxZB2TA
    - https://youtu.be/36EMl6DEvbk

Programming Resources

- **M**edical **O**pen **N**etwork for **AI (https://github.com/Project-MONAI)**
  - MONAI is a PyTorch-based, open-source framework for deep learning in healthcare imaging, part of PyTorch Ecosystem.
  - GitHub page: https://github.com/Project-MONAI/MONAI
  - MONAI modules overview: https://docs.monai.io/en/latest/highlights.html#datasets-and-dataloader
  - MONAI tutorials and medical image analysis examples: https://github.com/Project-MONAI/tutorials
  - **[Video Tutorial]** PyTorch and Monai for AI Healthcare Imaging - Python Machine Learning Course: https://www.youtube.com/watch?v=M3ZWfamWrBM&t=16429s
- MONAI Generative Models

https://github.com/Project-MONAI/GenerativeModels

Course Requirements

- Reading research papers and writing review reports
- Class participation
  - All students are expected to take part in class discussions
- Programming assignments
  - Three programming assignments
- Research project
  - Students will complete an individual or team (maximum of 2 members) research project (must be deep learning related) on a topic relevant to the course.
  - A few project ideas will be provided. If you would like to come up with your own project ideas, please discuss with the instructor.
- **Use of AI prohibited**. Only some Artificial Intelligence (AI) tools, such as spell-check or Grammarly, are acceptable for use in this class. Use of other AI tools via website, app, or any other access, is not permitted in this class. Representing work created by AI as your own is plagiarism, and will be prosecuted as such.

Grading Policy

- Paper Review Reports: 20%
- Programming Assignments (3): 50%
- Final Project: 30%

- **Late policy**
  - **A maximum of 3 days are allowed, with a reduction of 20% of the (full) points per day.**
  - **Submit report/assignment in webcourses**

Grading scale

Letter Grade	Percentage
A	94-100%
A-	90-93%
B+	87-89%
B	84-86%
B-	80-83%
C+	77-79%
C	74-76%
C-	70-73%
D+	67-69%
D	64-66%
D-	61-63%
F	0-60%

Final Project

- Project proposal
  - Feedback will be provided

- Final report, code, and project presentation

Computing Resources

- Google Colab
  - Google Colab tutorial: https://speech.ee.ntu.edu.tw/~hylee/ml/ml2021-course-data/hw/Colab/Google_Colab_Tutorial.pdf

- Kaggle
  - How to use FREE GPU & TPU on Kaggle
    https://www.youtube.com/watch?v=1QXdUWfipx0
    https://www.kaggle.com/dansbecker/running-kaggle-kernels-with-a-gpu
    https://www.youtube.com/watch?v=u9pIhOay8Fw

- UCF Newton GPU cluster
  - https://arcc.ist.ucf.edu/index.php/resources/newton/about-newton
  - User registration request: https://arcc.ist.ucf.edu/index.php/accounts/user-registration
  - UCF HPC GPU Accounts presentation by Dr. R. Paul Wiegand
    - https://www.crcv.ucf.edu/wp-content/uploads/2020/01/Wiegand-SP2020-CAP6412overview.pdf
    - Video: https://www.crcv.ucf.edu/wp-content/uploads/2019/03/Lecture-4.mp4

Academic Integrity

- Students should familiarize themselves with UCF's Rules of Conduct at <https://scai.sdes.ucf.edu/student-rules-of-conduct/Links to an external site.>. According to Section 1, "Academic Misconduct," students are prohibited from engaging in
- Unauthorized assistance: Using or attempting to use unauthorized materials, information or study aids in any academic exercise unless specifically authorized by the instructor of record. The unauthorized possession of examination or course-related material also constitutes cheating.
- Communication to another through written, visual, electronic, or oral means: The presentation of material which has not been studied or learned, but rather was obtained through someone else's efforts and used as part of an examination, course assignment, or project.
- Commercial Use of Academic Material: Selling of course material to another person, student, and/or uploading course material to a third-party vendor without authorization or without the express written permission of the university and the instructor. Course materials include but are not limited to class notes, Instructor's PowerPoints, course syllabi, tests, quizzes, labs, instruction sheets, homework, study guides, handouts, etc.
- Falsifying or misrepresenting the student's own academic work.
- Plagiarism: Using or appropriating another's work without any indication of the source, thereby attempting to convey the impression that such work is the student's own.
- Multiple Submissions: Submitting the same academic work for credit more than once without the express written permission of the instructor.
- Helping another violate academic behavior standards.
- Soliciting assistance with academic coursework and/or degree requirements.

Course Structure

- Lectures
  - Cover a few key and trending topics for medical image computing
    - Medical image processing (basics and fundamentals)
    - Introduction to deep learning (CNNs, Vision Transformer)
    - Medical image classification and segmentation (deep learning methods)
    - Generative models and their applications in medical image analysis
    - Self-supervised learning for medical image computing
    - Data privacy and federated learning for medical image computing
    - …
- Final project presentations

Tentative schedule

Date	Topic	Note
1/7/2025	Lecture 1 - Course introduction	
1/9/2025	Lecture 2 - How to review paper	
1/14/2025	Lecture 3 - Medical imaging (1)	
1/16/2025	Lecture 4 - Medical imaging (2)	
1/21/2025	Lecture 5 - Medical imaging (3)	
1/23/2025	Lecture 4 - Deep learning (1), CNNs, optimization, attention mechanism	
1/28/2025	Lecture 5 - Deep learning (2), vision transformer	
1/30/2025	Lecture 6 - Medical image classification	
2/4/2025	Lecture 7 - Medical image segmentation (1)	
2/6/2025	Lecture 8 - Medical image segmentation (2)	
2/11/2025	Lecture 9 - Efficient ML (efficient architectures, dynamic networks)	
2/13/2025	Lecture 10 - Efficient ML (dynamic networks)	
2/18/2025	Lecture 11 - Efficient ML (parameter efficient fine tuning)	

Tentative schedule

2/20/2025	Lecture 12 - Self-supervised learning (1)	
2/25/2025	Lecture 13 - Self-supervised learning (2)	
2/27/2025	Travel (WACV 2025) No class	
3/4/2025	Lecture 15 - Multi-modal learning, foundational AI model (1)	
3/6/2025	Lecture 16 - Multi-modal learning, foundational AI model (2)	
3/11/2025	Lecture 17 - GenAI for medical image analysis (1)	GenAI concept, GANs
3/13/2025	Lecture 18 - GenAI for medical image analysis (2)	Diffusion models
3/18/2025	No class (Spring break)	
3/20/2025	No class (Spring break)	
3/25/2025	Lecture 19 - Federated learning for medical image analysis (1) or Guest lecture	
3/27/2025	Lecture 20 - Federated learning for medical image analysis (2) or Guest lecture	
4/1/2025	Lecture 21 - Guest lecture	

Tentative schedule

4/3/2025	Lecture 22 - Guest lecture	
4/8/2025	Lecture 23 - Final Project presentation (1)	
4/10/2025	Lecture 24 - Final Project presentation (2)	
4/15/2025	Lecture 25 - Final project presentation (3)	
4/17/2024	Lecture 26 - Final project presentation (4)	
4/22/2024	Study Day – No Class	
4/24/2024	Exam week (no class), finish up project code and report	

Course Outcomes

- Outcomes
  - Understand the basics of medical image computing and know the state-of-the-art techniques for medical image analysis (lectures and paper reviews)
  - Hands-on experiences on solving medical image computing problems (programming assignments and course project)
  - Develop skills for conducting research (paper reviews, project presentation and reports)

The focus of this course

- Popular and fundamental deep learning techniques

- Their applications in medical image computing

2018 Turing Award Winners

Yann LeCun Geoffrey Hinton Yoshua Bengio

"For conceptual and engineering breakthroughs that have made deep neural networks a critical component of computing."

2024 Nobel Prize in Physics and Chemistry

- 2024 Nobel Prize in Physics was awarded to John Hopfield and Geoffrey Hinton for their foundational work in artificial neural networks

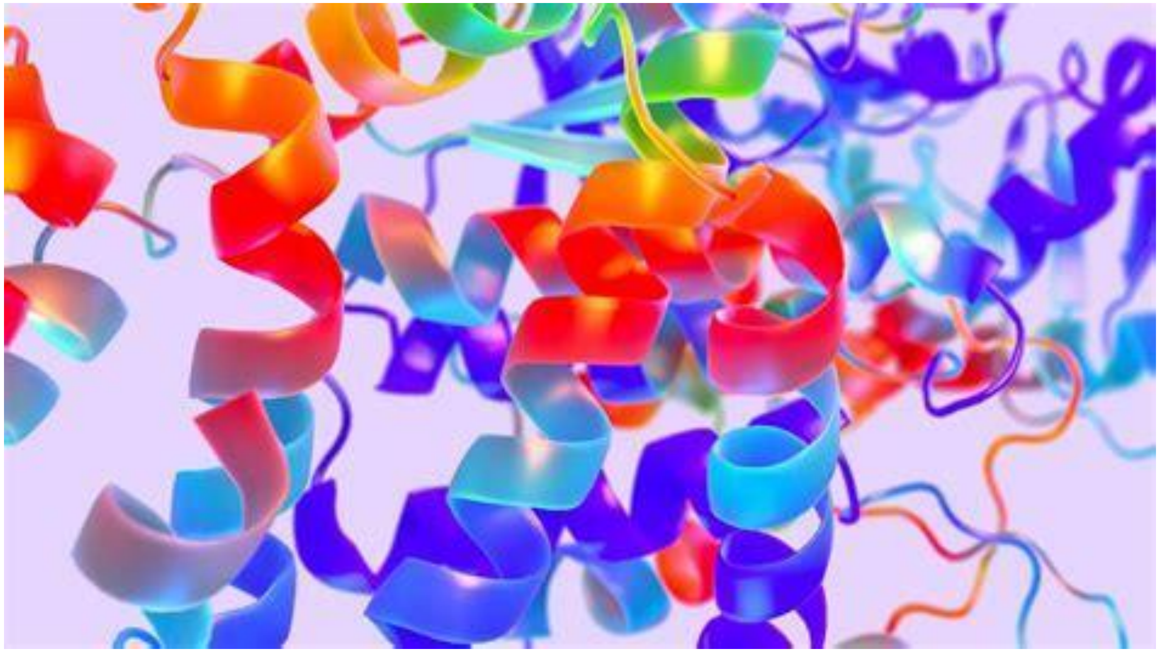
- The Nobel Prize in Chemistry was shared by David Baker, Demis Hassabis, and John Jumper for their use of AI to solve the protein-folding problem, essentially recognizing the significant impact of AI in both fields

Deep Learning Has Been Disruptive

- Computer Vision is impacting many areas
- Robotics: Self-driving cars, Robots
- Natural Language Understanding: Machine Translation, Chatbot
- Speech Recognition: Alexa, Siri
- Computer Graphics: Neural Rendering
- Medicine: Drug Discover
- Protein Folding
- Games: Alpha Go

….

Alpha Fold: Protein Structure Prediction



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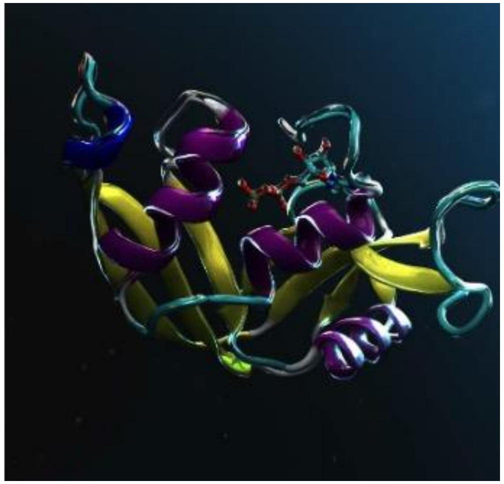
Drug Discovery

Solution Overview

NVIDIA

Accelerate Drug Discovery With Generative AI

Simplify and accelerate training of biomolecular models with NVIDIA BioNeMo.

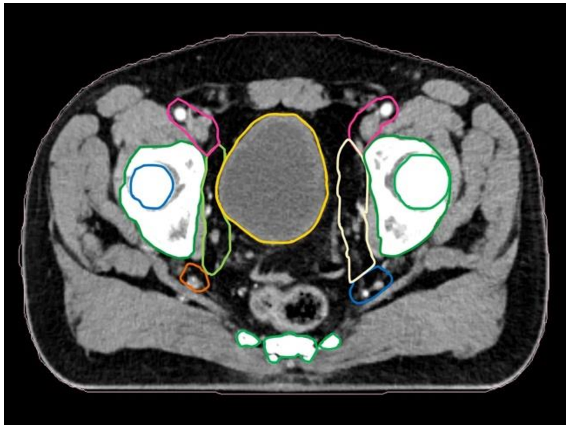


https://www.nvidia.com/en-us/clara/bionemo/

Real-world cases: how AI transformed biomedicine & healthcare

Case 1: CT-based pneumonia detection during the COVID-19 outbreak

- Each patient typically need to undergo CT imaging about 4 times from admission to discharge.
- For every CT scanning, staff need to manually contour three to four hundred CT images, and count the lung lobes or segments, and calculate the range of lesions in them to assess the severity.



This process can take **up to five to six hours**! But using AI, we just need **less than 20 seconds** for each scan, with a final accuracy rate of **over 90%**.

Information from China Science and Technology Museum

Slide Credit: Kai Zhang

UCF Center for Research in Computer Vision

Real-world cases: how AI transformed biomedicine & healthcare

Case 2: AI provides diagnosis for reference

- The mother plugged MRI notes into ChatGPT and got the suggestion that there may be Tethered Cord Syndrome (TCS).

- The boy visited neurosurgeon and finally being diagnosed and treated correctly.

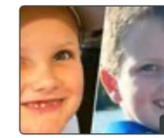
Posted by u/rustyyryan 23 days ago

2.3k

A boy saw 17 doctors over 3 years for chronic pain. ChatGPT found the diagnosis

today.com/health...

Use cases



410 Comments Share Save ...

No matter how many doctors the family saw, "the specialists would only address their individual areas of expertise", his mother says.

Information from Quora, today.com, RadiologyBusiness.com, and MDLinx.com

Slide Credit: Kai Zhang

Homework 0

- Complete the course survey

Next lecture

- How to review papers and write review reports

Thank you!

Question?