CAP-5516 Medical Image Computing (Spring 2025)
Project Ideas/Topics

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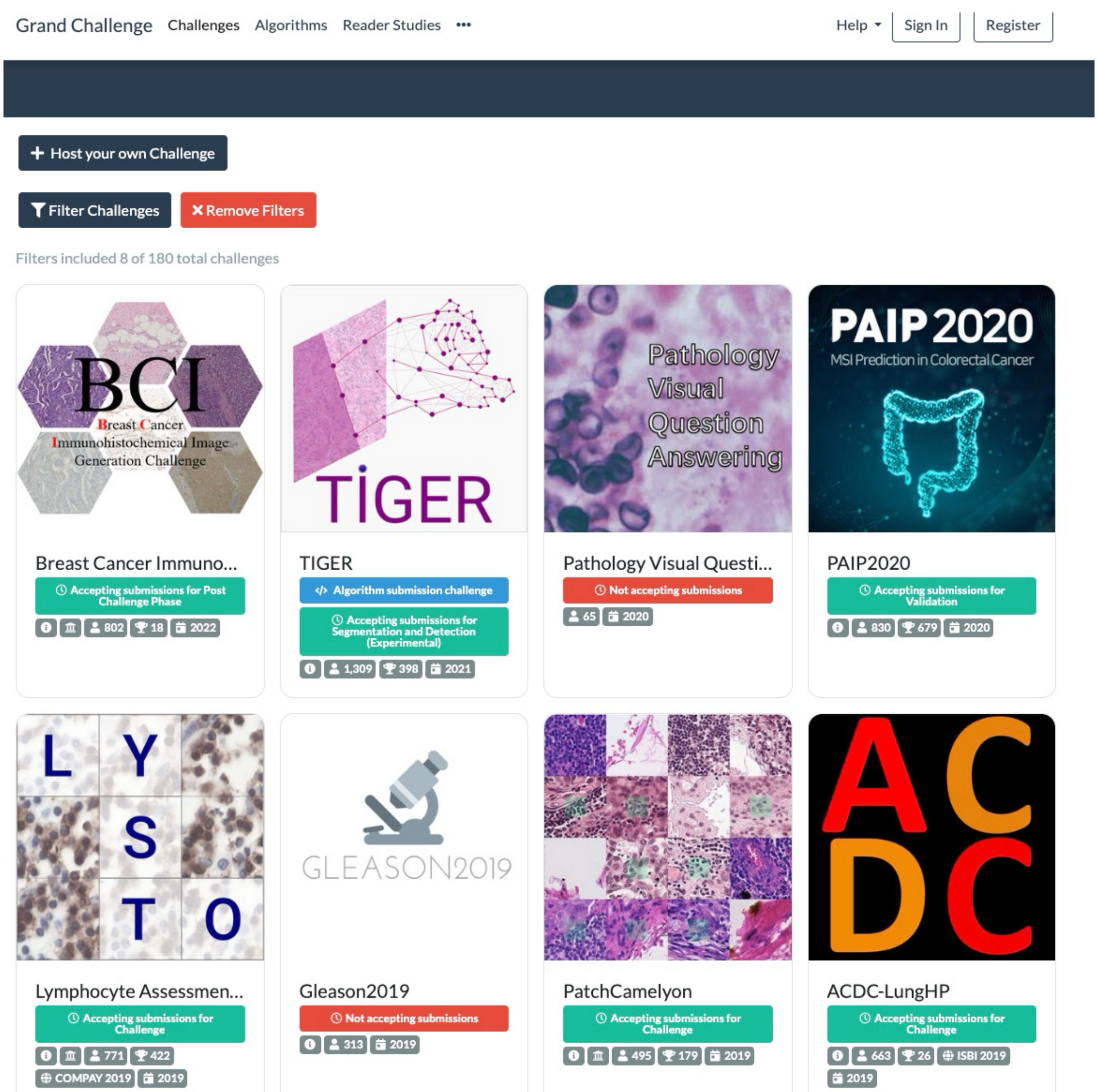
Note: The project must be medical image analysis using deep learning methods.

Some project ideas can be found from the following resources:
https://grand-challenge.org/
MICCAI workshops and challenges:
https://conferences.miccai.org/2023/en/challenges.asp
https://conferences.miccai.org/2023/en/workshops.asp
https://conferences.miccai.org/2024/en/challenges.asp
https://conferences.miccai.org/2024/en/workshops.asp
https://www.kaggle.com/competitions?tagIds=4202-Healthcare
https://www.kaggle.com/search?q=medical+image+in%3Adatasets



Example Projects:

1. Diffusion models for medical image analysis (e.g., image generation, segmentation, etc.)

Other related topics:

- Diffusion model for super resolution, data generation, segmentation, etc.
- Generation of the different modalities of MRI volume, e.g., T1-weighted to T2 or Flair
- Tumor generation?
- Diffusion method for data augmentation, in particular rare or hard examples, or examples in tail classes?
- CT to MRI?
- EEG signal to real image?
- Text to medical image generation? (text to 2D medical image generation, text to 3D medical image (e.g., 3D MRI data) generation)
- Text and other conditions (e.g., segmentation masks) for medical image (2D or 3D) generation using (customized) ControlNet? You may want to leverage or evaluate the some general (nature image domain) **text-to-video or image-to-video** generation models for text/image to 3D medical data (e.g., 3D MRI) generation.
- Conduct a comprehensive evaluation of the feasibility of nature image generation models (e.g., Stable Diffusion models, ControlNet) for medical image generation?

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

References:

[1] Breast Cancer Immunohistochemical Image Generation: a Benchmark Dataset and Challenge Review
https://arxiv.org/pdf/2305.03546.pdf

BCI dataset download:

Google Drive: https://drive.google.com/drive/folders/1oHxLJTjUuNoE0ZnpkyntlymTWy777EFt?usp=sharing

[2] BCI: Breast Cancer Immunohistochemical Image Generation through Pyramid Pix2pix
https://bupt-ai-cz.github.io/BCI_for_GrandChallenge/

[3] Adaptive Supervised PatchNCE Loss for Learning H&E-to-IHC Stain Translation with Inconsistent Groundtruth Image Pairs

https://link.springer.com/epdf/10.1007/978-3-031-43987-2_61?sharing_token=8APKjymWEeqR1wAuE7YOOve4RwlQNchNByi7wbcMAY7jxNo0bliUewITgRTD3ZK5zaKOhqHCsVOERYJLgKAQ56Z9O05hje6LjixMJK0aDFGuYzXDatYEbpClGBWcpr5_lX-qttIPexkDmIT7sRVHm6YZ2wNxwU1hZxmR4SuueVw%3D

[4] Sample-Specific Debiasing for Better Image-Text Models
https://static1.squarespace.com/static/59d5ac1780bd5ef9c396eda6/t/64d1955d9ec2f716e2b44ad2/1691456861903/ID08_Research+Paper_2023.pdf

[5] EEG to fMRI Synthesis Benefits from Attentional Graphs of Electrode Relationships
https://static1.squarespace.com/static/59d5ac1780bd5ef9c396eda6/t/64d19b3e1de8702c6be95e0e/1691458369632/ID39_Research+Paper_2023.pdf

[6] Diffusion-Based Data Augmentation for Nuclei Image Segmentation
https://link.springer.com/epdf/10.1007/978-3-031-43993-3_57?sharing_token=MaKHGs4GQDpqtj0okxYf8fe4RwlQNchNByi7wbcMAY7Wch1OeXcjGb3IfQ5_NEou76mpPdK4lMtLPXT-qlK2YaM3Ta7H7S1TkilFzawNz4cxLqRwWr4OwD7OjG6s5zZLzx1PLBzWzMBLe5ohff3BrZ4eewjkqeDWSMGClyF6EYk%3D

[7] Deep learning based synthesis of MRI, CT and PET: Review and analysis

2. Train or adapt large foundation models (e.g., SAM) for medical image computing

References and resources:

[1] Medical SAM Adapter: Adapting Segment Anything Model for Medical Image Segmentation
https://arxiv.org/pdf/2304.12620.pdf

[2] SA-Med2D-20M Dataset: Segment Anything in 2D Medical Imaging with 20 Million masks
https://arxiv.org/pdf/2311.11969.pdf

[3] Quilt-1M: One Million Image-Text Pairs for Histopathology [NeurIps 2023] (Oral)https://github.com/wisdomikezogwo/quilt1m

[4] BIOMEDGPT: OPEN MULTIMODAL GENERATIVE PRE-TRAINED TRANSFORMER FOR BIOMEDICINE
https://arxiv.org/pdf/2308.09442.pdf
https://github.com/PharMolix/OpenBioMed

[5] Are Large Language Models Ready for Healthcare? A Comparative Study on Clinical Language Understanding

https://static1.squarespace.com/static/59d5ac1780bd5ef9c396eda6/t/64d19a43b3b9d407b8364de4/1691458116186/ID34_Research+Paper_2023.pdf

[6] TIER: Text-Image Entropy Regularization for Medical CLIP-style models
https://static1.squarespace.com/static/59d5ac1780bd5ef9c396eda6/t/64d1a7b5bbaa8263069bdee5/1691461558916/ID128_Research+Paper_2023.pdf

[7] MA-SAM: Modality-agnostic SAM Adaptation for 3D Medical Image Segmentation
https://arxiv.org/pdf/2309.08842.pdf

[8] Segment Anything Model for Medical Image Segmentation: Current Applications and Future Directions https://arxiv.org/pdf/2401.03495.pdf

3. Pulmonary Nodule Detection and Classification in Lung CT

Summary

- Develop a deep learning model to detect and classify pulmonary nodules (benign vs. malignant) in 3D lung CT scans.
- Focus on building an automated pipeline that includes both nodule localization and classification.
- Evaluate performance using sensitivity, specificity, and detection F1 scores.

Why It's Interesting

- Early detection of malignant nodules is crucial for improving lung cancer survival rates.
- Offers the chance to explore 2D vs. 3D CNNs or advanced transformer-based architectures for volumetric data.

Dataset

- **LIDC-IDRI Dataset** (Lung Image Database Consortium and Image Database Resource Initiative)
- *Link:* https://wiki.cancerimagingarchive.net/display/Public/LIDC-IDRI

Potential Approaches

- **3D CNN-based Detection**: Use networks such as 3D U-Net or VNet to segment and locate nodules.
- **Classification Module**: Use a secondary CNN or transformer to classify nodule patches as benign or malignant.
- **Multi-task Learning**: Combine detection and classification in one framework for efficiency.

References/Resources

1. **Data Source (LIDC-IDRI)**: https://wiki.cancerimagingarchive.net/display/Public/LIDC-IDRI
2. **3D U-Net Paper**: Çiçek, Ö., Abdulkadir, A., Lienkamp, S.S., et al. "3D U-Net: Learning Dense Volumetric Segmentation from Sparse Annotation." *MICCAI*, 2016.
3. **Transformer for 3D**: Hatamizadeh, A., et al. "UNETR: Transformers for 3D Medical Image Segmentation." *arXiv preprint*, 2021.

4. Diabetic Retinopathy Classification and Lesion Localization

Summary

- Use deep learning to classify retinal fundus images into different severity levels of diabetic retinopathy (DR).
- Optionally include lesion localization (e.g., microaneurysms, hemorrhages) via heatmaps or attention maps.

Why It's Interesting

- Diabetic Retinopathy is a leading cause of preventable blindness worldwide.
- Attention mechanisms or visualization techniques can show which retinal lesions influence model decisions.

Datasets

- **APTOS 2019** on Kaggle: https://www.kaggle.com/c/aptos2019-blindness-detection
- **Diabetic Retinopathy** Kaggle Dataset: https://www.kaggle.com/c/diabetic-retinopathy-detection

Potential Approaches

- **Transfer Learning**: Start with ImageNet-pretrained backbones (e.g., ResNet, EfficientNet).
- **Vision Transformers (ViT)**: Explore attention-based classification for high-resolution images.
- **Lesion Localization**: Use Grad-CAM or Grad-CAM++ to generate saliency maps.

References/Resources

1. **Kaggle APTOS 2019**: https://www.kaggle.com/c/aptos2019-blindness-detection
2. **Kaggle DR Detection**: https://www.kaggle.com/c/diabetic-retinopathy-detection
3. **ViT Paper**: Dosovitskiy, A., et al. "An Image is Worth 16x16 Words: Transformers for Image Recognition at Scale." *arXiv preprint*, 2020.

5. Automated Polyp Detection and Segmentation in Colonoscopy Images

Summary

- Build a deep learning system to detect and segment polyps in colonoscopy images or video frames.
- Evaluate using segmentation metrics (Dice, IoU) and detection metrics (precision, recall).

Why It's Interesting

- Early detection of colorectal polyps can significantly lower colorectal cancer mortality.
- Real-time detection is valuable in clinical endoscopy, placing emphasis on computational efficiency.

Dataset

- **Kvasir-SEG**: A public dataset for polyp segmentation.
- *Link:* https://github.com/dhirajsr/Kvasir-SEG

Potential Approaches

- **U-Net Variants** (e.g., ResUNet, UNet++): For segmentation of polyp regions.
- **Transformers or YOLO**: For real-time detection of polyps.
- **Mask R-CNN**: Combine detection and segmentation in a single pipeline.

References/Resources

1. **Kvasir-SEG Dataset**: https://github.com/dhirajsr/Kvasir-SEG
2. **UNet++**: Zhou, Z., Siddiquee, M.M.R., et al. "UNet++: A Nested U-Net Architecture for Medical Image Segmentation." *DLMIA*, 2018.
3. **Real-time Detection**: Explore YOLO-based methods for polyp localization in endoscopic video frames.

6. Domain Adaptation for Cross-Modality Medical Image Segmentation

Summary

- Train on one modality (e.g., MRI) and adapt the model to another modality (e.g., CT) with limited or no labels in the target domain.
- Evaluate performance by measuring segmentation accuracy (Dice, IoU) on the target modality.

Why It's Interesting

- Labeled medical data is often modality-specific and scarce.
- Domain adaptation (DA) can reduce or eliminate the need for large target-domain annotations.

Dataset

- **Multi-Modality Whole Heart Segmentation (MM-WHS) Challenge**
- *Link:* http://www.sdspeople.fudan.edu.cn/zhuangxiahai/0/mmwhs/

Potential Approaches

- **GAN-based DA**: Use CycleGAN or other image-to-image translation methods to align MRI and CT appearances.
- **Self-Supervised Learning**: Pretrain a model on unlabeled target images for better feature extraction.
- **Hybrid Approaches**: Combine style transfer with standard segmentation networks to handle domain shift.

References/Resources

1. **CycleGAN**: Zhu, J.-Y., Park, T., Isola, P., et al. "Unpaired Image-to-Image Translation using Cycle-Consistent Adversarial Networks." *ICCV*, 2017.
2. **Self-Supervised Learning**: Chen, T., Kornblith, S., Norouzi, M., et al. "A Simple Framework for Contrastive Learning of Visual Representations." *ICML*, 2020.
3. **Domain Adaptation in Brain Lesion Segmentation**: Kamnitsas, K., et al. "Unsupervised Domain Adaptation in Brain Lesion Segmentation with Adversarial Networks." *MICCAI*, 2017.

7. Weakly-Supervised Pathology Image Classification (Advanced)

Summary

- Perform tumor classification in whole-slide pathology images (WSIs) using only slide-level labels (e.g., "tumor" vs. "normal").
- Employ multiple instance learning (MIL) or attention-based pooling to locate malignant regions without precise annotations.

Why It's Interesting

- Pixel-level annotation in pathology is time-consuming and expensive.
- Weakly-supervised or MIL approaches leverage high-level labels effectively.

Dataset

- **Camelyon16 or Camelyon17** for lymph node metastasis detection
- *Link:* https://camelyon16.grand-challenge.org/

Potential Approaches

- **MIL Framework**: Attention-based or embedding-based multiple instance learning for slide-level classification.
- **Heatmap Generation**: Visualize suspicious regions that contribute most to the classification.
- **Self-Supervision**: Pre-train feature extractors on unlabeled histopathology patches.

References/Resources

1. **Attention-based MIL**: Ilse, M., Tomczak, J., and Welling, M. "Attention-based Deep Multiple Instance Learning." *ICML*, 2018.
2. **Camelyon16 Dataset**: Ehteshami Bejnordi, B., et al. "Diagnostic Assessment of Deep Learning Algorithms for Detection of Lymph Node Metastases in Women With Breast Cancer." *IEEE Transactions on Medical Imaging*, 2017.
3. **Self-Supervised in Pathology**: Li, X., et al. "Self-Supervised Learning for Large-Scale Histology Image Classification." *IEEE CVPR*, 2021.

Read MICCAI papers to find out more project ideas:
https://conferences.miccai.org/2023/papers/categories/
https://papers.miccai.org/miccai-2024/
https://www.kaggle.com/search?q=medical+image+in%3Adatasets

Medical Image Datasets:

- Open-Access Medical Image Repositories
  - https://www.aylward.org/notes/open-access-medical-image-repositories
- Computer Vision Online Image Archive – medical image
  - https://homepages.inf.ed.ac.uk/rbf/CVonline/Imagedbase.htm#biomed
- Google Dataset Search: https://datasetsearch.research.google.com/
- Kaggle dataset search: https://www.kaggle.com/datasets
- MedMNIST v2: A Large-Scale Lightweight Benchmark for 2D and 3D Biomedical Image Classification: https://medmnist.com/
- RadImageNet: An Open Radiologic Deep Learning Research Dataset for Effective Transfer Learning https://www.radimagenet.com/
- PatchCamelyon: The PatchCamelyon benchmark is a new and challenging image classification dataset. It consists of 327.680 color images (96 x 96px) extracted from histopathologic scans of lymph node sections. Each image is annoted with a binary label indicating presence of metastatic tissue. PCam provides a new benchmark for machine learning models: bigger than CIFAR10, smaller than imagenet, trainable on a single GPU. https://github.com/basveeling/pcam
- Quilt-1M: One Million Image-Text Pairs for Histopatholog [NeurIps 2023] (Oral) https://github.com/wisdomikezogwo/quilt1m

https://www.kaggle.com/search?q=medical+image+in%3Adatasets