GrANdTruthNet: biomedical image processing

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Quantitative analysis of Ultrasound Images

Rationale

Deep learning methods for medical ultrasound image analysis have grown exponentially over the last few years. In the specific field of ultrasound image analysis, recent studies have shown good results in multiple tasks such as image segmentation, classification, anomaly detection, and image denoising.

Methods

The core algorithm of the application we developed are Convolutional Neural Networks (CNN). This type of network can be declined in different ways for different tasks. Respectively, Unet was used for Segmentation tasks, Fast-RCNN for Detection, ResNets for classification. All the developed systems have been made available as open-code in the specific publications.

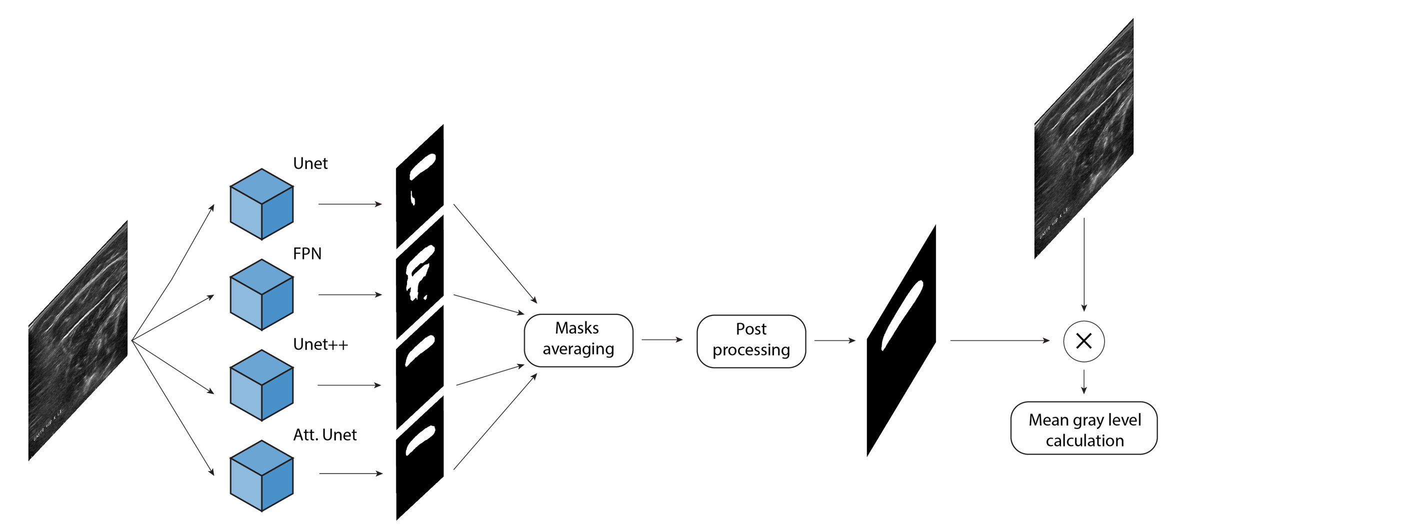
Applications and Results

1. **Muscle US Image segmentation and quantification**
   - Segmentation: Precision 0.81 ± 0.15 ; Recall 0.94 ± 0.08
   - Mean Grayscale value in CSA: ICC(2,1) = 0.99
2. **Intima Media Complex Segmentation and Thickness measurement**
   - Segmentation: Dice 0.828 ± 0.107
   - IMT Abs.Error 0.148 ± 0.089 mm (intraOp Abs.Err 0.121 ± 0.108 mm)
3. **Optic Nerve Sheath segmentation and Diameter measurement**
   - Segmentation: Dice 0.719 ± 0.139
   - OND/ONSD correlation with manual Op. rho = 0.69

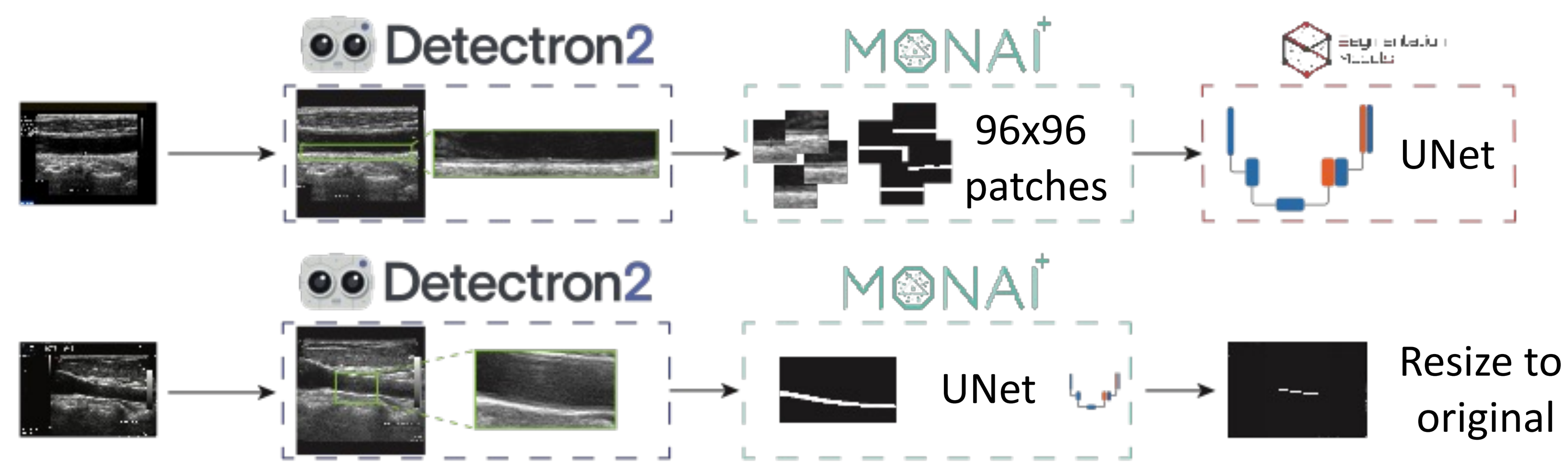
Limitations

- Need for manual annotation and lack of consensus between operators
- Few samples for studying pathological cases

Muscle US Image segmentation and quantification



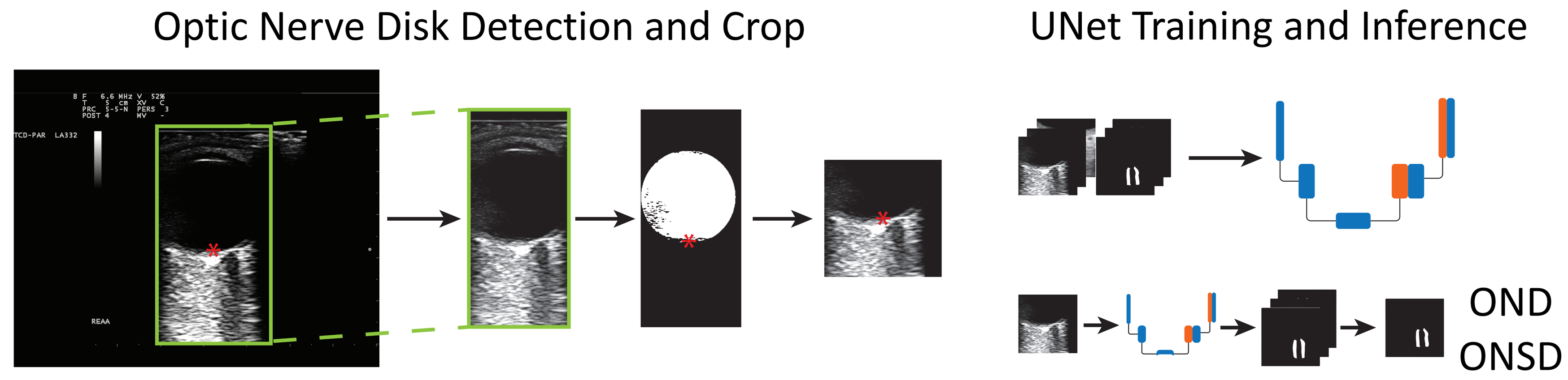
Intima Media Complex Segmentation and Thickness measurement



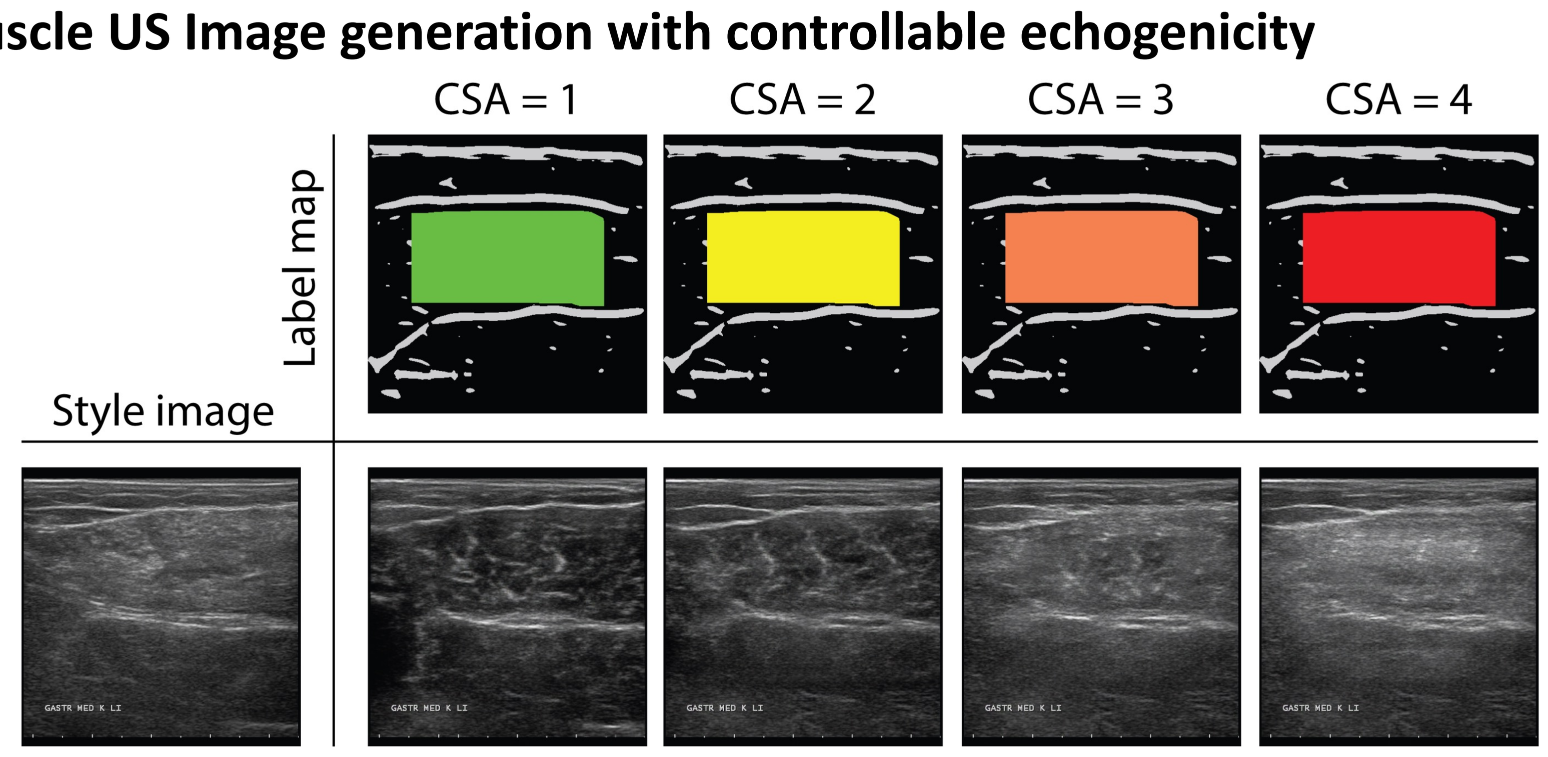
Optic Nerve Sheath segmentation and Diameter measurement

Optic Nerve Disk Detection and Crop

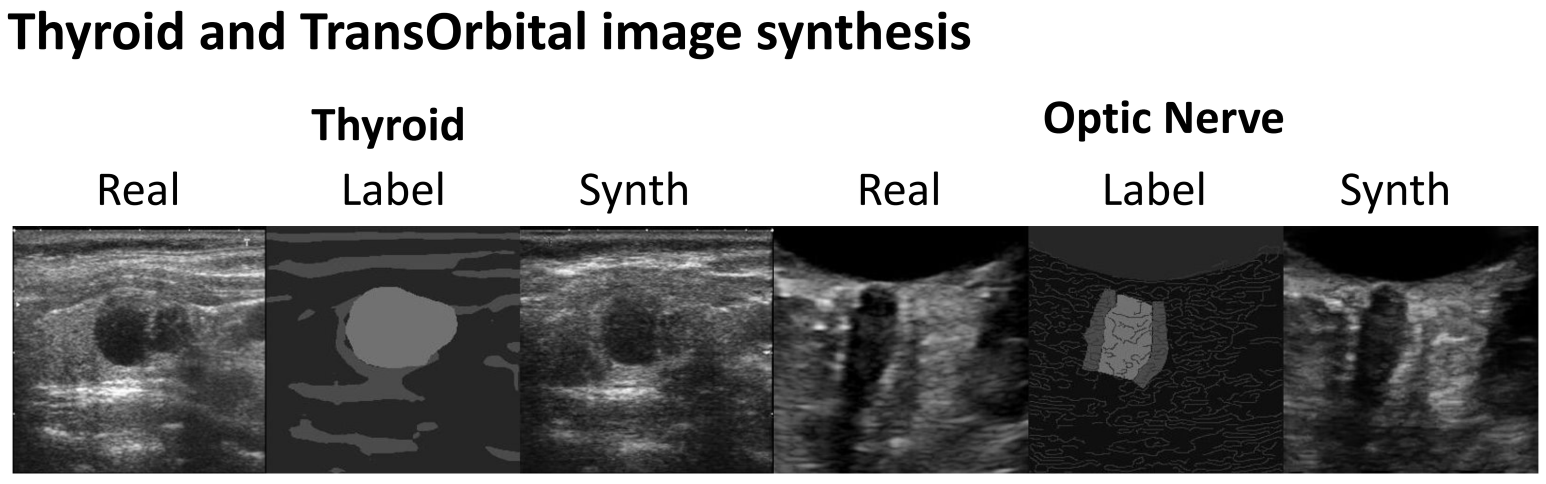
UNet Training and Inference



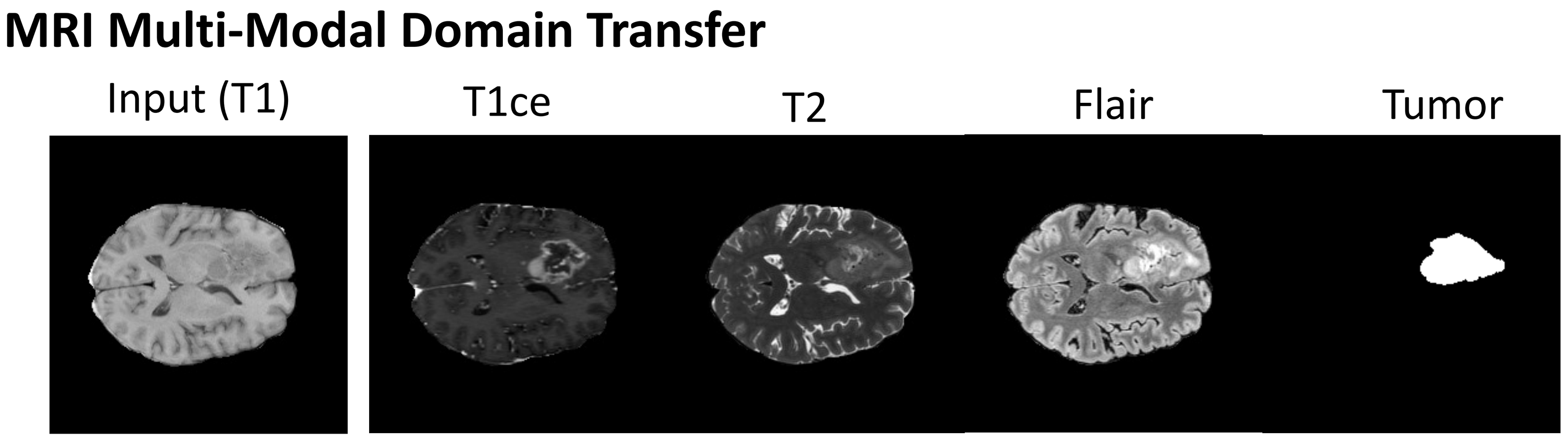
Muscle US Image generation with controllable echogenicity



US Thyroid and TransOrbital image synthesis



MRI Multi-Modal Domain Transfer



Multi-Modal Image Synthesis

Rationale

To tackle the limitations of "traditional" Deep Learning methods, current research is focused on the use of Generative models that learn to produce realistic samples provided an input that drives the generation process. This input can be a Class (e.g., a pathological class that is under-represented in a real dataset), or a Semantic Map, from which the model has to generate an image with a specific spatial relationship between the objects. Domain transfer is another application of generative models where an image of domain B (e.g., MRI T2) is inferred from an image of domain A (e.g., MRI T1).

Methods

The mostly used generative models are the Generative Adversarial Networks (GAN). We used StyleGAN for LabelMap generation when simulating thyroid US image and Optic Nerve images. SPADE model was used for Semantically controlled image generation. Pix2Pix and CycleGAN where used for Domain Transfer.

Applications and Results

1. **Muscle US Image generation with controllable echogenicity**
   - PSNR 20.16 ± 0.67 ; SSIM 0.38 ± 0.02
2. **US Thyroid image synthesis**
3. **US Transorbital Sonographic image synthesis**
4. **Multi-Modal MRI domain transfer**

Challenges

- Unstable training process
- Lack of fine control of texture features in the image

Hard skills		Soft skills	
01UJUIU	Human-Ai Interaction (25h)	01SWPRR	Time management (2h)
04QDBRP	Metodi statistici nei processi di progettazione, produzione e verifica (20h)	01RISRR	Public speaking (5h)
01UMNRV	Advanced deep Learning (30h)	01SHMRR	Entrepreneurial Finance (5h)
01UJBRV	Adversarial training of neural networks (15h)	02LWHRR	Communication (5h)
02QZURR	Pianificazione, gestione e analisi di ricerca clinica e di laboratori (15h)	01TUFRR	Research data management and open access publishing (15h)

List of publications

References

Tutors: Prof. Filippo Molinari, Prof. Kristen M. Meiburger, Prof. Massimo Salvi

PhD Day 2022
25th October 2022, Dental School, Torino