Utilizing AI-based 2D Segmentation for 3D Medical Imaging Analysis

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Abstract

The recent advancement in AI has led to the development of innovative segmentation models, which allow precise object recognition and mask generation from various inputs. The Segment Anything Model (SAM), a new AI segmentation model, is capable of producing high-quality object masks from input prompts for all objects in an image. This research aims to develop pipelines for applying the SAM 2D segmentation model on 3D imaging medical data, enabling the creation of masks for 3D data. This technique will prove particularly useful for tasks such as illustrating the structure of objects in 3D imaging data and locating tremors, which are critical for accurate diagnosis and further analytics.

Introduction

Importance of 3D Segmentation for Medical Imaging

- Enables detailed visualization of internal body structures using modalities such as Computed Tomography (CT), Micro-Computed Tomography (micro-CT or X-ray), or Magnetic Resonance Imaging (MRI) scanners
- Essential for diagnosing diseases, planning surgeries, and monitoring treatment progress

Introduction to Segment Anything Model (SAM)

- SAM produces high-quality object masks from input prompts such as points or boxes and can generate masks for all objects in an image
- Trained on a dataset of 11 million images and 1.1 billion masks, demonstrating strong zero-shot performance on a variety of segmentation tasks
- Development of pipelines for applying SAM on 3D medical imaging data to enhance the accuracy in illustrating structures and locating tremors

Example of a 2D image (left) before and after applying the Segment Anything Model (SAM); the generated image mask is displayed on the right.

Methods

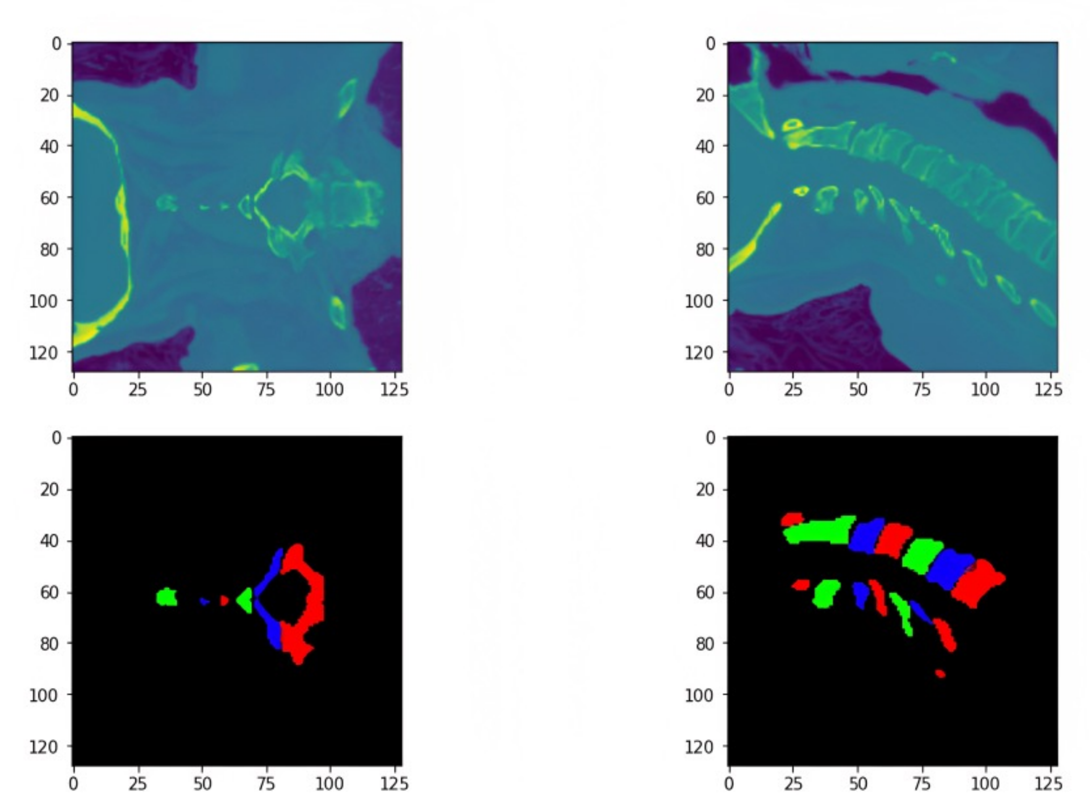
The objective of the segmentation process is to target specific objects or structures in 3D images. Two different methods are employed for this purpose.

1. Uniform Slicing and Mask Propagation:

- Slice the 3D image uniformly to obtain multiple 2D slices
- For each 2D slice, generate a mask using the Segment Anything Model (SAM)
- Propagate obtained mask either upwards or downwards as adjacent slices are similar, and differences are subtle.
- Label points on each slice to identify the movement and shifting of point prompts across slices
- Apply registration algorithms to find the transformation from one slice to another

2. Non-Uniform Slicing and Object Reconstruction

- The image is sliced non-uniformly along directions defined by a normal vector represented in ax + by + cz
- Several slices are taken, and the parts of the slice lying within the object are recorded
- The parts of the slice within the object are considered together to determine the boundary of the object
- The target object is reconstructed by bringing together bunches of planes at various angles and getting the contour of each object



Example of the segmented cervical spine viewed from the superior (top) and the lateral (left) directions

Discussion

Although the entire pipeline for 3D segmentation has not yet been fully developed, we plan to compare both methods based on accuracy and efficiency. During the process, we have perceived and identified pros and cons for the two methods.

For the first method, Uniform Slicing and Mask Propagation:

- Pro: The registration algorithm is quite well developed, and the matrices describe the translation from points in one slice to another slice accurately
- Con: When parts of the image are not captured initially, it is necessary to determine when the object ends in the sequence of slices and how to loop back around to capture more of the object

For the second method, Non-Uniform Slicing and Object Reconstruction:

- Pro: Edge cases can be better handled, providing a more robust solution in scenarios where the object has irregular shapes or boundaries
- Con: Requires more effort in pre-processing, specifically in placing point prompts. The non-uniform slicing also necessitates a more complex analysis to determine the boundary of the object accurately

Moving forward, the development of the pipeline will involve further refinement of both methods, addressing the identified cons, and optimizing the process for better accuracy and efficiency. Additionally, we will conduct a comprehensive evaluation of both methods on a diverse set of 3D medical imaging data to ascertain their effectiveness and applicability in real-world three-dimensional imaging data.

References

- Kirillov, A., Mintun, E., Ravi, N., Mao, H., Rolland, C., Gustafson, L., Xiao, T., Whitehead, S., Berg, A. C., Lo, W.-Y., Dollár, P., & Girshick, R. (2023). Segment Anything. arXiv:2304.02643. [cs.CV]. https://arxiv.org/abs/2304.02643
- Segment anything. (n.d.). Meta AI. https://segment-anything.com/

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