Brain Stroke Analysis from Non-Contrast Brain CT and Path-planning for Robot-assisted Thrombectomy

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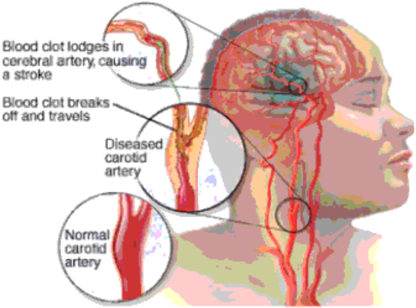
Problem Statement

Background

- A stroke is a medical emergency. Prompt treatment is crucial to reduce brain damage and other complications.
- There are *two prominent causes of stroke*: a blocked artery (**ischemic stroke**), or leaking or bursting of a blood vessel (**hemorrhagic stroke**).



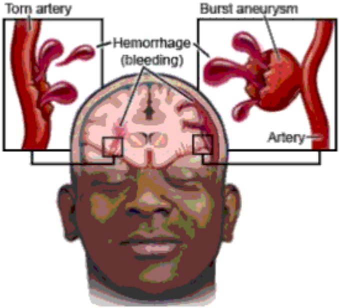


Figure: Depiction of brain strokes.

Problem Statement

Module A: Detect and localize stroke infarcts on NCCT volumes

- Slice-wise segmentation of stroke infarct.
- 2D and 3D feature fusion for context-aware segmentation.
- Rendering a 3D visualization of the stroke infarct location.
- Potentially, make quantitative measurements to aid *module B*.

Module B: Perform path-planning for robot-assistive intervention

- Assistive intervention using a 6-DOF robotic arm.
- Reinforcement learning (RL) to quickly.
- Specific focus on smooth operation in a precision setting.

Overall System Design

Solution Architecture

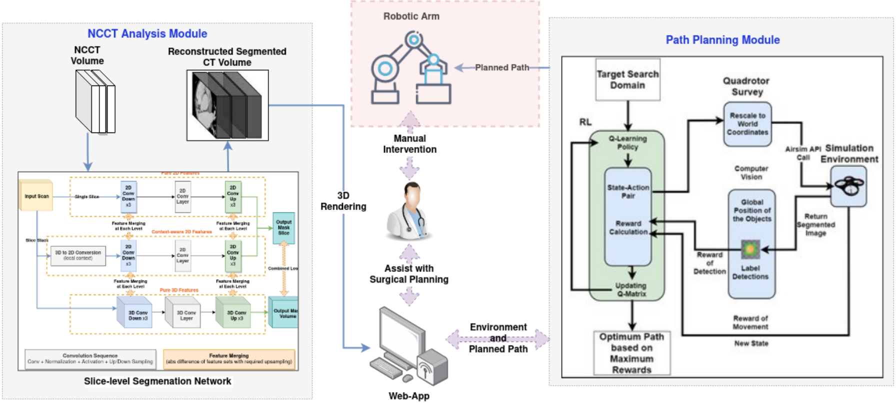
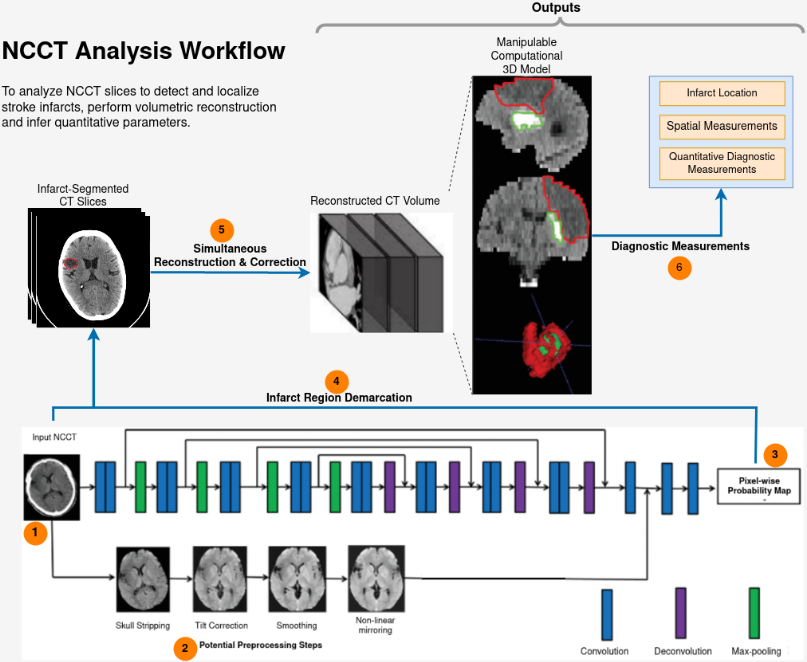


Figure: Architecture of the proposed solution.

NCCT Analysis Workflow

To analyze NCCT slices to detect and localize stroke infarcts, perform volumetric reconstruction and infer quantitative parameters.



Follow-up: Review 1 Comments

Support the hypothesis that slice-wise segmentation produces improved results

- Prepared a formal proof to support the statement.
- Our experiments on the chosen dataset show consistent results.

Unsupervised segmentation with dimensionality reduction can still produce good segmentation results.

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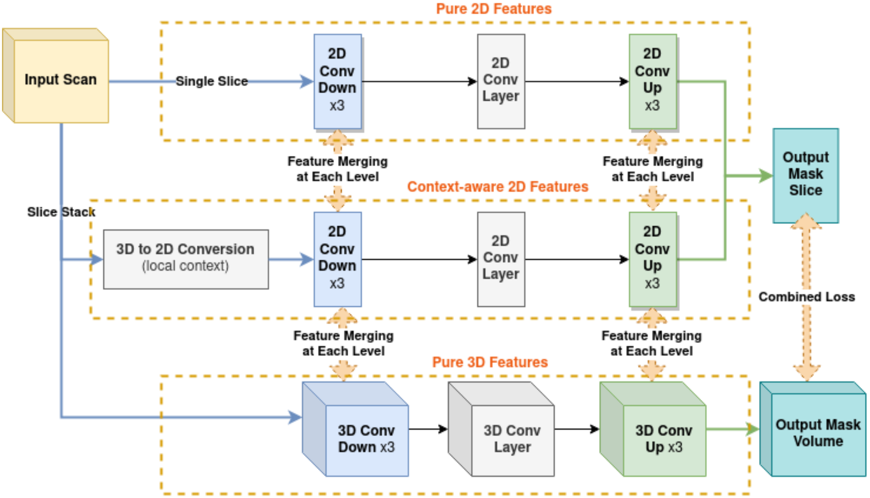
Datasets Chosen

- A peer-reviewed *Intracranial Hemorrhage Segmentation* dataset [1] comprising 2500 brain window images and 2500 bone window images collected from 82 patient samples.
- A proprietary manually-annotated NCCT scan dataset from Chettinad Healthcare.

Source Code

`https://github.com/karthik-d/Vision-For-Robot-Path-Planning`

Proposed Segmentation Network



Convolution Sequence
Conv + Normalization + Activation + Up/Down Sampling

Feature Merging
(abs difference of feature sets with required upsampling)

Key Contributions

Key challenge areas

- Limited investigation of the third axis — prediction models frequently miss stroke infarcts of very small sizes.
- Pure NCCT-based analysis is less explored than perfusion CTs and weighted MRIs.
- Resolution of closely-spaced lesion infarcts.

Highlights of the proposed solution

- ✓ 2D and 3D feature fusion.
- ✓ Combination of loss functions: **Dice Loss** and **Binary Cross Entropy**.
- ✓ Combined loss of 2D and 3D supervision.
- ■ "Smoothing effect" that reduces "jagged" and "broken" effects.
- ■ Successfully resolves closely-spaced lesion infarcts despite smoothing.

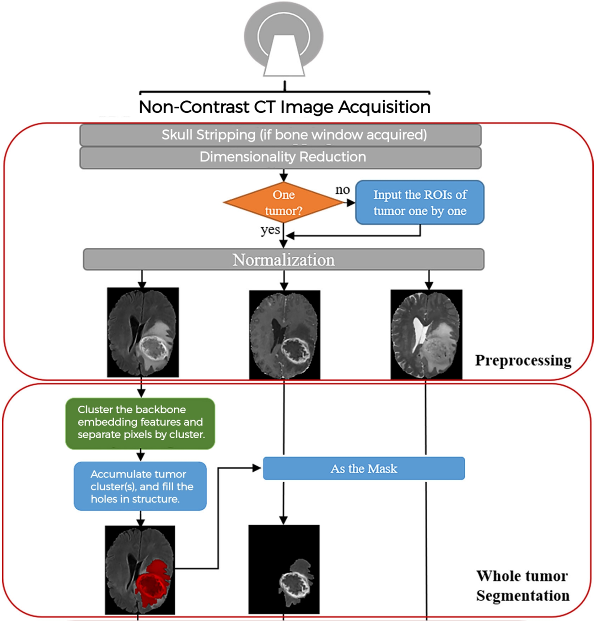
Stroke Infarct Segmentation Approaches

Table: Comparison of segmentation approaches on open-access datasets.

Approach	Backbone	Dataset	DSC	Mean IoU	AuROC
FPN	EffNet-B0	Peer-Reviewed Open-Access Intracranial Hemorrhage Dataset [1]	41.18%	28.20%	-
UNet	EffNet-B0		46.73%	30.42%	-
PSPNet			40.21%	27.51%	-
DeepLabV3+			33.82%	17.43%	-
Best UNet *			44%	27.5%	-
ChanVese [2]*			70%	-	-
M-Net			70.41%	59.95%	86.13%
Proposed			**76.11%**	**64.52%**	**89.15%**
Clustering Analysis			**52.72%**	**46.09%**	

*reported results from literature

Unsupervised Segmentation to Assist Manual Annotation



Demo (cont.)

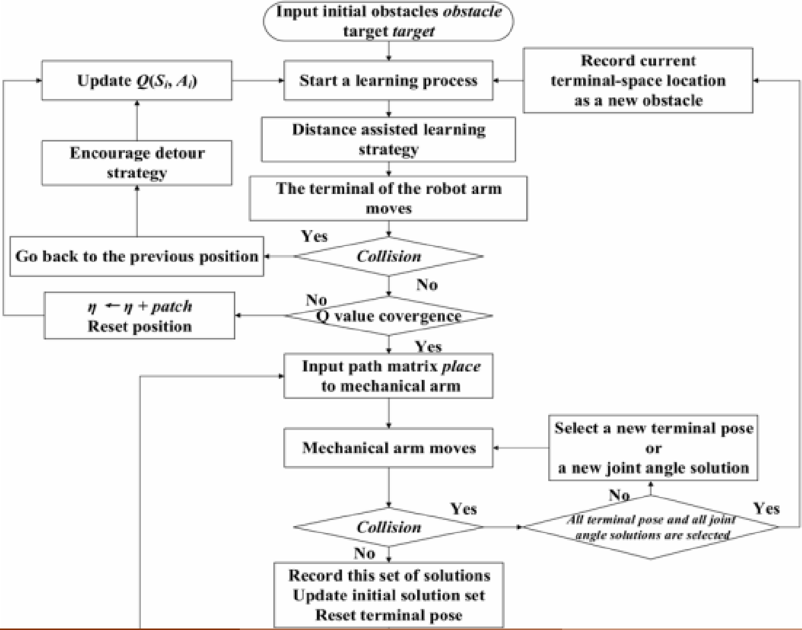
NCCT Analysis Module

- Qualitative analysis of results [Link].
- Web-app for 3D segmentation demo [Link].

Path-planning Module

- Comparison of Deep-RL and Q-Learning [Link].
- Result representation of Q-Learning [Link].
- Web-app to assist robotic surgery for neurosurgeons [Link].

Path-planning workflow



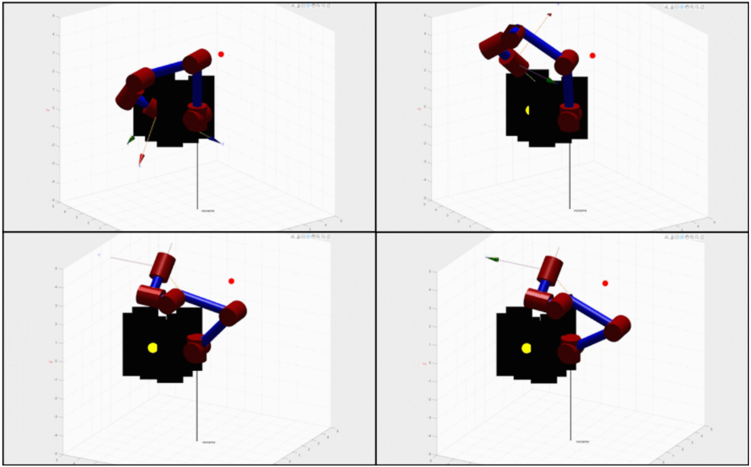
Follow-up: Review 1 Comments

Choice of design — Deep RL vs. RL

- Performed preliminary investigations to identify pros and cons.
- Discussed with mentor and domain experts.
- Decided to pursue an RL-based solution.

Key Contributions

- Modified distance function for the reward function: combination of chebyshev and parameterized minkowski distance.
- Simulated annealing method to control extent of exploration.
- Improved performance than existing Q-learning approaches.



Demo

NCCT Analysis Module

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Expected Outcomes

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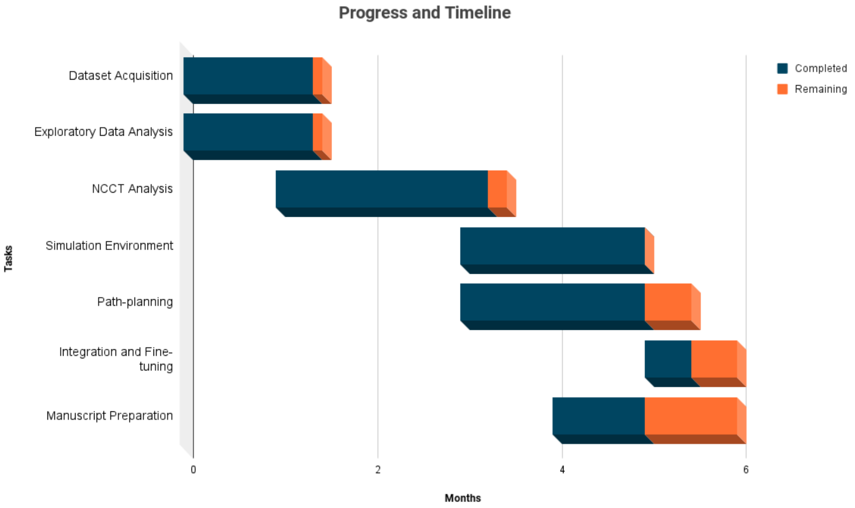
In correlation with the proposed objectives, we aim to deliver the following,

- Research progress and publication in deep learning -based improved segmentation of stroke infarcts from NCCT slides.
- Research progress and publication for path planning in a precision medical environment.
- Mobile/Web -based application to render 3D localization of stroke infarcts and to perform preliminary robotic arm -assisted surgical planning by neurosurgeons.

Project Timeline

Timeline and Progress



Relevance in Healthcare

Relevance in Healthcare

- The identification of the stroke type is crucial to treatment decisions.
- *Computed Tomography (CT)* and *Magnetic Resonance Imaging (MRI)* are the typical imaging methods in screening stroke patients.
- However, for **rapid diagnosis** and treatment, crucial for **acute strokes**, CT is a faster, easily-available, and cost-effective modality – hence, it is more widely used [2].
- *Thrombectomy*, the invasive excision of a clot, is the preferred treatment for Ischemic Strokes.
- Treatment of Hemorrhagic Strokes is more complex and case-specific, and is not the focus of this study beyond the level of type identification.

References

M. Hssayeni, M. Croock, A. Salman, H. Al-khafaji, Z. Yahya, and B. Ghoraani, “Computed tomography images for intracranial hemorrhage detection and segmentation,” *Intracranial Hemorrhage Segmentation Using A Deep Convolutional Model. Data*, vol. 5, no. 1, p. 179, 2020.

W. L. Nowinski, J. Walecki, G. Półtorak-Szymczak, K. Sklinda, and B. Mruk, “Ischemic infarct detection, localization, and segmentation in noncontrast ct human brain scans: review of automated methods,” *PeerJ*, vol. 8, p. e10444, 2020.

Thank You