C-NCA

CHAINED NEURAL CELLULAR AUTOMATA FOR FAST AND ACCURATE THERMAL ABLATION ESTIMATION

AUTHORS

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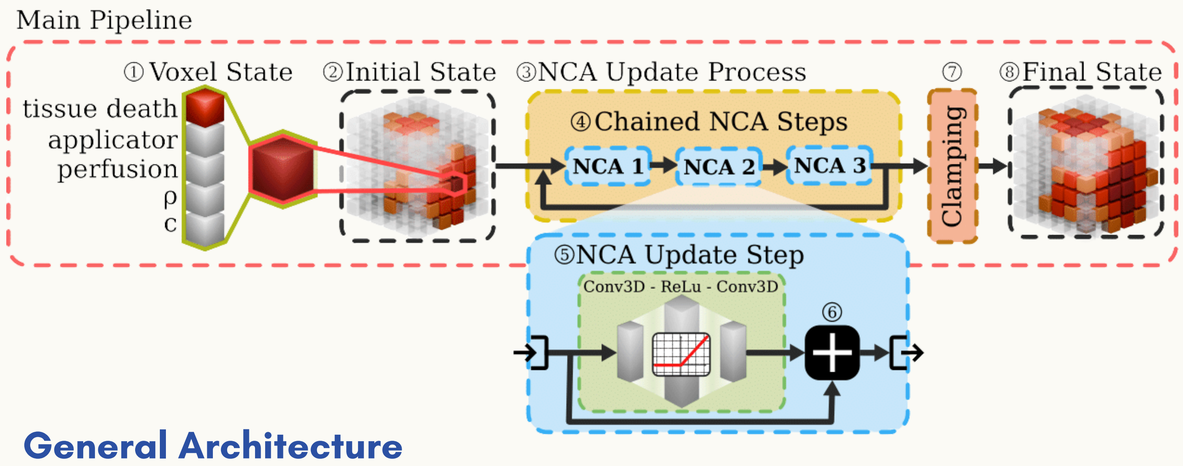
INTRODUCTION

Liver tumor ablation is challenging due to a **complex anatomy** [1]. **Thermal ablation** therapies like **Radiofrequency** (RFA) and **Microwave** (MWA) are popular alternatives for patients who are not candidates for resection. These procedures involve the insertion of **multiple needles** to deliver localized thermal energy directly to the tumor, inducing cell death through coagulative necrosis.

Clinical Need: interactive and automatic planning require
- Precise simulation of ablation
- Fast computation of 15 mn of treatment

METHODOLOGY



General Architecture
- Input/output: a voxel grid with channels representing tissue properties and ablation parameters
- Iterative chained NCA update steps to refine predictions progressively

Training and Optimization
- Improve convergence times by training across a range of iteration counts for the chained NCA steps
- Increase robustness to divergence by reinjecting data

Experimentation Details:
- Used a Finite Difference Method (FDM) [2] and a cell death model [3] for **ground truth** generation and **comparison**
- Evaluated models at resolutions of 2 mm, 3 mm, and 4 mm

DATA AND METRICS

Dataset Generation
- 3500 semi-synthetic cases
- Access : figshare.com/s/a4d1e9a9ededdcdeef39

Parameter Sweep
- 25 tumors, 7 patient anatomies
- 1-5 applicators, semi-random placement

Physical Organ Properties
- IRCADb-01 segmentation dataset [4]
- IT'IS dataset of tissue properties [5]

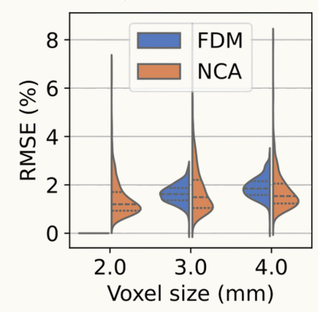
Metrics
- Root Mean Square Error (RMSE)
- Computation time (fps) to evaluate efficiency

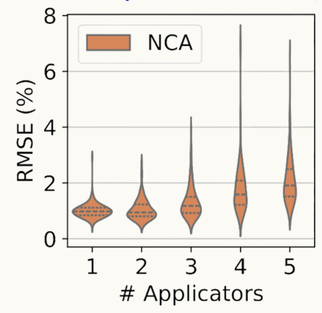
(IT'IS dataset)

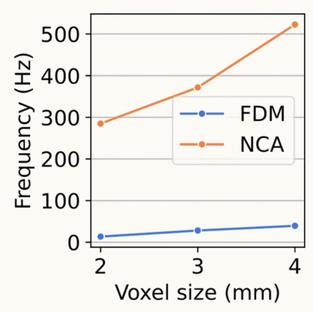
RESULTS AND ANALYSIS

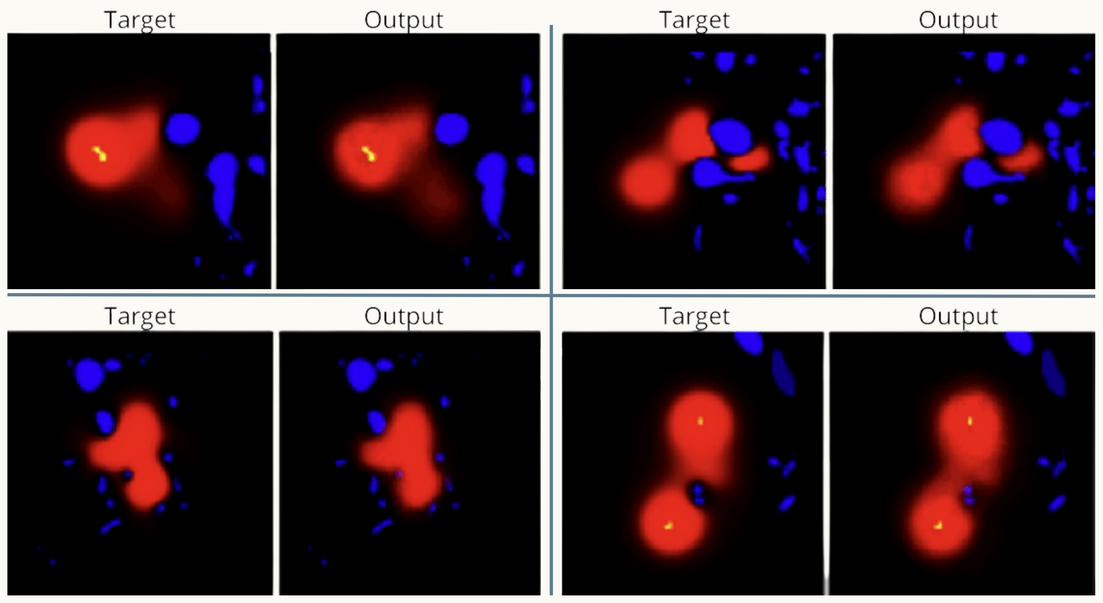
Ground truth: FDM at 2mm resolution

Key Findings
- Low RMSE indicates high accuracy at 2mm (1.43%)
- C-NCA outperforms FDM at 3 mm and 4 mm resolutions
- Consistent performance with multiple applicators
- High frame rates (> 250 fps for 2mm)







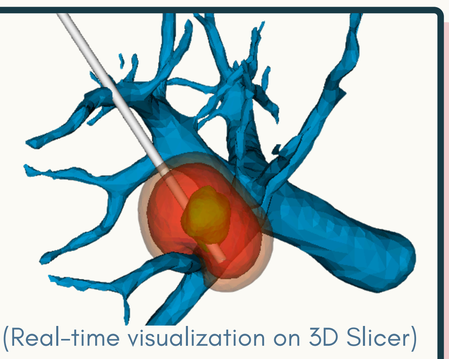


Target (FDM) and Output (C-NCA) pairs at 2 mm resolution

KEY FEATURES AND BENEFITS

Features
- Multi-needle support
- Tissue properties
- Adjustable parameters

Benefits
- Efficient:
  - Fast (15 mn ablation in <0.004 s at 2 mm resolution)
  - Laptop-friendly (12k parameters)
- Versatile:
  - RFA, MWA, cryoablation
  - Suitable for interactive or automatic planning



(Real-time visualization on 3D Slicer)

CLINICAL POTENTIAL AND FUTURE WORK

Clinical Potential
- Improves novice usability via interactive feedback
- Ready for desktop use in clinics

Future Work
- Apply to MWA and cryo with minimal changes
- Integrate in automatic planners

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