Trajectory reconstruction for proton computed tomography with machine learning

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Bergen pCT collaboration
Progression of my talk

- Cancer therapy
- Hadron Therapy
- Proton Computed tomography
- Processing pCT detector signals
- Results
Cancer therapy
Cancer therapy

The 3 main methods:
• Surgery
• Chemotherapy
• Radiation therapy
Hadron therapy
Hadron(proton) therapy

- Cancer therapy
- Using radiation
- Utilize the Bragg peak of proton
- Ambulant treatment
Challenges for Hadron therapy

- Traditional tomography was not made for protons
- Hadron therapy needs map of stopping power
- Data processing needs to be fast for ambulant treatment
Proton Computed Tomography
Proton computed tomography (PCT)

- High energy (200 MeV) protons beamed through a phantom
- These are scattered on the particles of the phantom
- The detector measures position of the hits and energy deposition (by the clusters of the hits)
- Detector layers are ALICE ALPIDE chips
Proton computed tomography (PCT)

- The detector signals processed
- Reconstruct the trajectories based on the position and energy deposit of the hits
- Extract initial angles and kinetic energy
- Rotate and translate the system around the phantom
- Get a 3D map
Data processing with machine learning

• To predict angle we need to reconstruct the trajectories
• For the image reconstruction:
  • Scattering angles
  • Initial kinetic energy
• Do not need all the trajectories, only the reliably reconstructed ones
• Reconstructing particle path with traditional algorithms takes too much computational time
• Deep Neural Networks can evaluate fast
• Learn complex connections between data
Data structure

- Using data simulated from openGate (Geant4 medical extension)
  - Therefore tracking information is available
  - Large number ($O(1e5)$) of events may be generated
- Measurement is done in frames with 100-200 primaries (event)
- For every detector layer:
  - middle of every hit (X,Y coordinate)
  - size (energy deposition)
Methods

• From last layer iterate through the whole detector system

Layer 25 → Layer 24 → Layer 23 → Layer 22

Incoming irradiation

Evaluation of the model
Methods

• From last layer iterate through the whole detector system
• Try to connect the next layer with the previous ones while using results from the previous connections, using a transformer architecture
Methods

- From last layer iterate through the whole detector system
- Try to connect the next layer with the previous ones while using results from the previous connections, using a transformer architecture
- Randomly change the order of every data point (x, y, energy) after each layer
Results
Learning curve

- Training for 1000 epochs
- Training data size for one phantom is around 100,000 event
- Target dimension is normalized (every values is in the same scale) for better learning properties
- Loss is mean squared error
- Mean of the three target prediction values
Results
Summary & outlook

Summary:
The application of Deep Learning for trajectory reconstruction looks promising (the Bergen pCT has achieved 87% accuracy with similar methods) and fast enough.

Outlook:
• Get better results with the energy section
• Make the model more general
• Evaluate on real detector data

Supporters:
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• OTKA K135515
• Doktoranduszi Kivállósági Ösztöndíj Program
• Wigner Scientific Computer Laboratory
Thank you for your attention
Resources

- [https://www.uwa.edu.au/study/courses/master-of-surgery](https://www.uwa.edu.au/study/courses/master-of-surgery)
- [https://www.saferadiationtherapy.com/radiation-therapy-2/](https://www.saferadiationtherapy.com/radiation-therapy-2/)