Automated Adaptive Decision Making with Deep Learning Neural Network

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07/29/2020

Acknowledgements

- Yoga Balagurunathan, PhD
- Tom Dilling, MD
- Heiko Enderling, PhD
- Jason Fleenor, MD
- Jennifer Frakes, MD
- Robert Gillow, PhD
- Luu Harrison, MD
- Sarah Hufn, MD
- Frost Johnson, MD
- Kejian Lai, PhD
- Eduardo Marro, PhD
- Jose Palacan, MD
- Dana Railroad, PhD
- Ahmad Tarhini, MD
- Michael Tomaszewski, PhD
- Shu Wasserman, MS

Trainees and staff
- Noora Ba Sultal
- James Goula, PhD
- Sunan Cui, PhD
- Jamalda Jamaluddin
- Yi Luo, PhD
- Dipesh Nirwale, PhD
- Abe Drosoph, PhD
- Julia Pakela
- Wenbo Sun, PhD
- Huan-Minh Tran, PhD
- Liu Wei, PhD
- Wei Zhang, PhD

Adaptive Radiotherapy (ART) Evolution

- Previous frameworks
- Current frameworks
- Proposed framework

Tung, Freeman, 2018
What? - ART in era of -omics

El Naqa et al., PMB (Journal highlights), 2017

Which? - radiotherapy response estimates

El Naqa, Wires, 2014

Integrative radiobiological modeling

Tumor control (TCP)/Normal tissue complication (NTCP) are multi-factorial and depend on: radiation dose and patients’ genomic (radiogenomics) and imaging (radiomics) characteristics before & during radiotherapy.

El Naqa, Methods, 2016
Outcome modeling by Machine learning (ML)

- **Generative models**
  - Model class-conditional PDFs and prior probabilities (Bayesian networks, Markov models)
  - To predict you need to know the system

- **Discriminant models**
  - Directly estimate posterior probabilities (logistic regression, neural networks, CNN, random forests, SVM)
  - Predict without knowing the system

Deep vs conventional machine learning

Multi-Objective Generative (Bayesian) Models

Multi-objective generative models can be used to predict multiple radiation outcomes simultaneously, which provides opportunities of finding appropriate treatment plans to solve the trade-off between competing risks.

Luo et al., Med Phys, 2018 (Editor's Choice)

Radiogenomics modeling with deep ML

Local control prediction in lung cancer

Composite deep neural network (DNN) architecture

Cui et al., IEEE TRPMS, 2018 (Best of Physics, ASTRO)

Deep Survival Radiomics model for Liver Cancer I

Wei et al., Physica Medica, 2021
Multi-objective radiogenomics model with deep survival neural networks I

How to optimize RT adaptation decision with ML?

Adaptive Radiation Oncology Decision Making with Deep Learning I
To ensure that the ML tool meets all applicable safety and performance standards (prediction) and that it meets contractual specifications before they happen, streamlining tasks and responding to changes in recognizing current weaknesses in the program, anticipating problems.

Selection of a benchmark data and evaluation endpoint and definition of performance metrics such as mean dose for targets and max dose to a volume available by body site: e.g. 1cc?

Assess sensitivity of the output of algorithms with training sets for specific disease types and other small structures not available.

Automated creation of plans for optimization and implementation of a national practice standard, within a practice, within a registry, clinical practice among physicians.

Partner with physicians to automate preparation of the plan for optimization and deployment, which includes manual preparation and/or datasets for analysis, e.g., inserting errors into delivery tests.

Monitor the relationship between decisions with prior practice and data analysis for software, document situations where results software passes and fails.

Evaluate against a subset of the received data, expecting identical results unless at the limit.

Repeat analysis of a subset of the document situations where the delivery file is incorrect. Document situations where results are within 5% or 2 cc (for optic nerve, OARs (Mayo Clinic))

Verify volumes for optimization and other small structures are consistent with those by human physician (planning directive)(Evans et al., 2009), (planning objectives)(Evans et al., 1998).

Confirm that quality control is performed correctly to avoid the risk of an incorrect expansion from target or OAR volumes. Risk being mitigated is an incorrect shift in clinical practice due to unreasonable or inappropriate portions of original trial?

Is the algorithm being used to support rather than replace the human oncologist decision making process? Is the algorithm supporting a practice standard?

Assess the frequency of patient-oriented tasks post-application of the plan for optimization and implemented for all patients or document situations where results are within 5% or 2 cc. Assess sensitivity of the output of algorithms with training sets for specific disease types and other small structures not available.

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Take home Messages

- Artificial intelligence/machine learning offers new opportunities to develop better understanding of oncology processes and improve its workflow and especially decision support systems.
- Varying machine learning algorithms can be deployed. Deep learning methods can incorporate data representation and task learning in the same framework.
- Collaboration between stakeholders (data scientists, clinicians, & biologists) will allow for safe and beneficial application of AI in biomedicine.

THANK YOU!