Developing knowledge models to enable rapid learning in radiation therapy

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AAPM
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DukeHealth

Disclosures

- NIH/NCI R01 Grant
- Varian Research Grant

Funding Overview

- Mechanism: R01, standard
- Study Section: RTB
- PI: Q Jackie Wu & Yaorong Ge
- Submission History: prior R21 as pilot study, R01 submitted 2 times

Clinical Motivation/Significance

- The proposal aims to develop a comprehensive and integrated set of models and methods that will enable rapid learning in radiation therapy.

Relevant Prior Experience/Preliminary Data

- List if anything made you uniquely qualified to lead this work. Did you have a PhD in the topic or a long research history?
  - R21 as pilot study
  - Research experience in the study area
- What preparation work did you do to be well positioned for funding?
  - R21 first with clear deliverables

Relevant Prior Experience/Preliminary Data

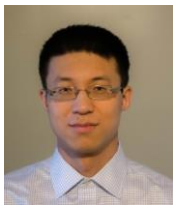
- Describe key preliminary data used in your grant submission
  - Several publications
  - Solid clinical data (KBP has demonstrated its clinical significance by our own group and others)

Specific Aims

- Specific Aim 1: Develop and enhance knowledge models to cover significant cancer sites and treatment scenarios.
- Specific Aim 2: Translate the models into clinical practice to provide best-achievable patient-specific RT planning and enable continuous improvement of the models via incremental learning.
- Specific Aim 3: Validate the knowledge models and assess the performance and value of the rapid learning framework.

Key Scientific Outcomes –

Viewed From A Researcher's Rapid Learning :0



- Jiahan Zhang
- PHD in Physics
- Started as 2 year Postdoc working on technical components of the project
- As clinical experience accumulates, research role also has expanded to co-investigator style
- Currently as senior MP resident and mentoring MS student projects on knowledge modeling
- Working together on future projects

Ensemble learning: a case study with knowledge-based treatment planning

Jiahan Zhang[1], Tianyi Xie[1], Yang Sheng[1], Chunhao Wang[1], Fang-Fang Yin[1], Jackie Wu[1], and Yaorong Ge[2]

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[1]Duke University Medical Center, Durham, NC
[2]University of North Carolina at Charlotte, Charlotte, NC

Methods

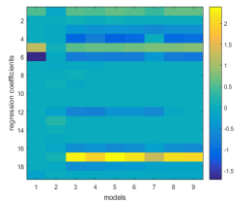
Why stacking linear models?

- Regularization path:

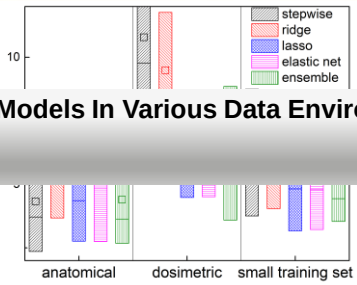
Regression coefficients changes in a nonlinear fashion with respect to regularization parameter(s)

- Distinct characteristics of different models:

Different models work well in different environments: training set size, feature collinearity, number of features ….



Results



Improve Models In Various Data Environment

Modeling of multiple PTVs in knowledge-based planning

Jiahan Zhang[1], Yang Sheng[1], Chunhao Wang[1], Tianyi Xie[1], Fang-Fang Yin[1], Yaorong Ge[2], and Jackie Wu[1]

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[1]Duke University Medical Center, Durham, NC
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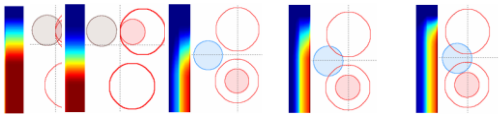
Methods: proposed feature

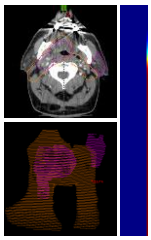
Generalized distance-to-target histogram (gDTH)

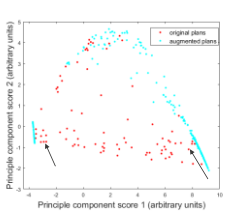
- gDTH(i,j): proportion of OAR volume with distance to PTV1 smaller than d(i), and distance to PTV2 smaller than d(i)+d(j).
- Sufficiently represents the shape distribution of OAR volume with respect to two PTV surfaces.

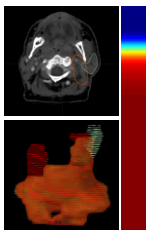


Methods: data augmentation

Visualization with gDTH PCA





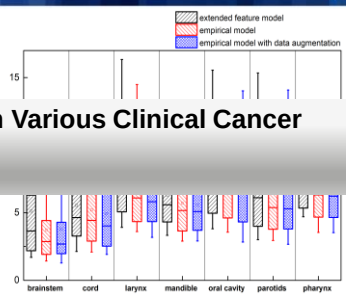


Results

Data: 148 HN 2PTV sequential boost cases

Improve Models In Various Clinical Cancer Types

DVHs.



Exploring tradeoff hyperplanes with a knowledge-based model

Jiahan Zhang[1], Yaorong Ge[2], Yang Sheng[1], Chunhao Wang[1], Qiuwen Wu[1], Fang-Fang Yin[1], Q. Jackie Wu[1]

[1]Duke University Medical Center, Durham, NC
[2]University of North Carolina at Charlotte, Charlotte, NC

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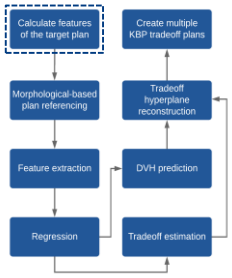
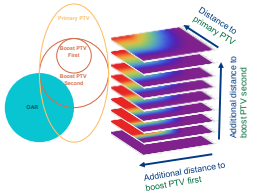
Methods and materials

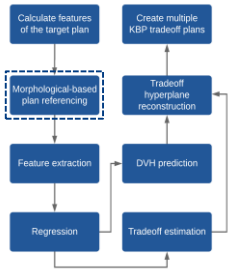


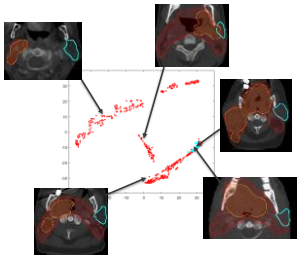


Generalized distance-to-target histogram (gDTH)

Modeling of multiple planning target volumes for head and neck treatments in knowledge-based treatment planning, Med Phys, 2019

Methods and materials





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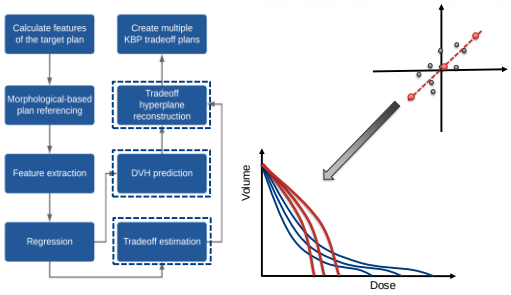
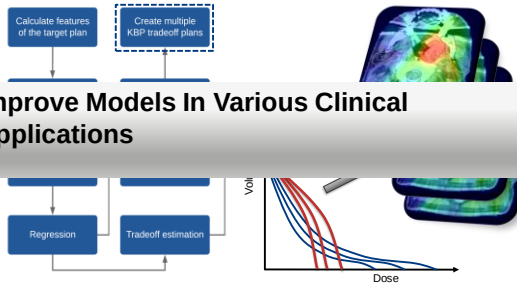
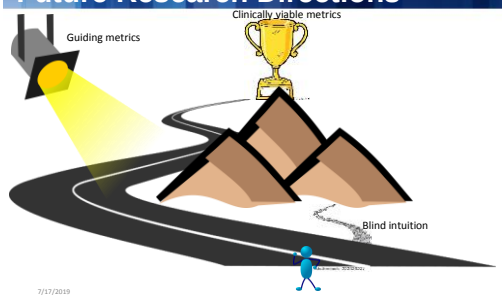


Methods and materials



Improve Models In Various Clinical Applications

Future Research Directions



Future Research Directions

- Develop trustworthy knowledge Models or AI models in a comprehensive clinical workflow
  - Human-centered
  - Autonomous
  - Multi-agent