Quantitative Imaging in Radiomics and Machine Learning

AI in Radiation Oncology – Now and in the Future

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TU-GH-DBRB-0
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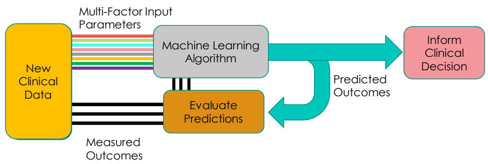
Disclosures

Grants from Varian Medical Systems

Artificial Intelligence is poised to soon be a routine part of our reality

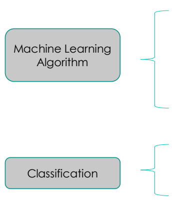
https://www.msn.com/en-us/news/technology/boston-dynamics-is-gearing-up-to-produce-thousands-of-robot-dogs/ar-BBKUhKC?ocid=spartandhp

Machine Learning



Pattern Matching
Fact Finding
Typically, Black Box Predictions

Machine Learning

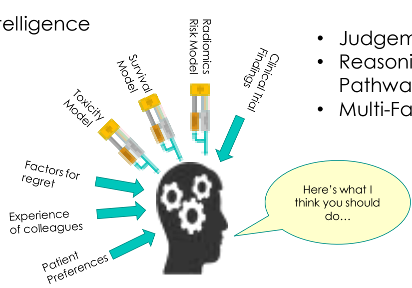


- Deep Neural Network
- Support Vector Machine
- Random Forest
- Conditional Random Forest
- Naïve Bayes
- Bayesian Additive Regression Trees
- Logistic Regression
- …

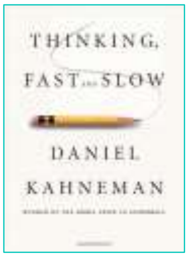
- K-means clustering
- Distribution Models
- Density Based
- ….

Algorithms are widely available (R,Python, C#.Net, …), but can have issues:
- Susceptibility to overfitting
- Interpretability
- Accuracy

Artificial Intelligence



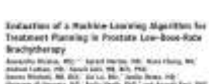
- Judgement
- Reasoning Pathways
- Multi-Factor



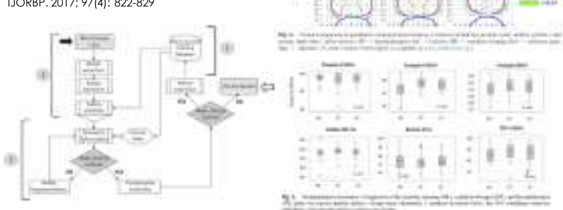
- All physicians would like to learn from experience
  - We don't want to treat according to the "last error" or "last success"
  - But our memories are very selective
- "In my experience…"

TS Lawrence, PBDW 2018

We are seeing ML increasingly applied across a wide range of Radiation Oncology tasks

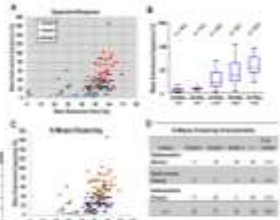


IJORBP. 2017; 97(4): 822-829



A Novel Methodology using CT Imaging Biomarkers to Quantify Radiation Sensitivity in the Esophagus with Application to Clinical Trials

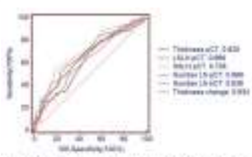
Scientific Reports. 2017; 7:6034 (DOI:10.1038/s41598-017-05003-x)



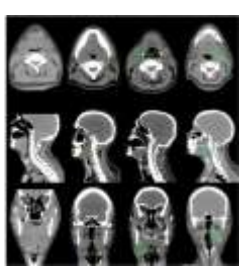
Support Vector Machines Model of Computed Tomography for Assessing Lymph Node Metastasis in Esophageal Cancer with Neoadjuvant Chemotherapy

J Comput Assit Tomogr 2017; 41:455-460

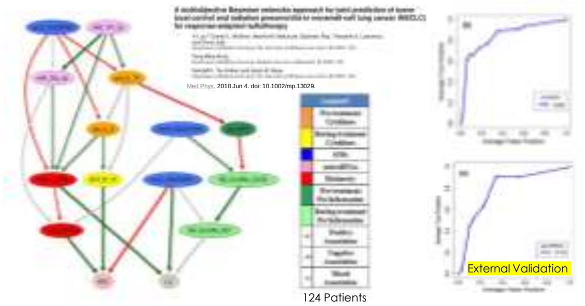
AUC	AUC	SE	95% CI
Thickness on pCT	[illegible]	[illegible]	[illegible]
LSLN on pCT	[illegible]	[illegible]	[illegible]
SSLN on pCT	0.705	[illegible]	[illegible]
Number of LN on pCT	[illegible]	[illegible]	[illegible]
Number of LN on bCT	[illegible]	[illegible]	[illegible]
Thickness change	[illegible]	[illegible]	[illegible]

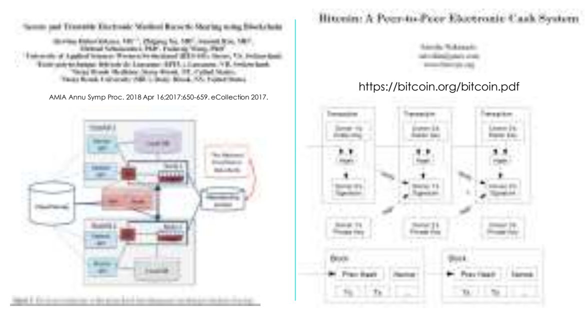


Deep Learning Algorithm for Auto-Delineation of High-Risk Oropharyngeal Clinical Target Volumes With Built-In Dice Similarity Coefficient Parameter Optimization Function



Int J Radiation Oncol Biol Phys, 2018 ; 101(2):468-478





Areas where ML/AI are looking like they may become viable parts of radiation oncology clinical processes

- Auto-contouring
- Auto-planning and plan evaluation
- Diagnosis and planning approach recommendation
- Radiomics predictors for risk factors

Big Data and Predictive Analytics - Recalibrating Expectations

Thoughtful Identification of Risk-Sensitive Decisions

- "Prediction modelers frequently give scant attention to the formal properties of clinical decisions that might make them risk sensitive"
- "It is surprising how rarely good predictions are brought to bear on difficult clinical decisions in a way that affects clinical outcomes"

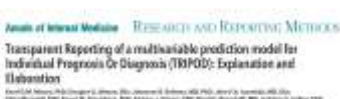
Shah ND, Steyerberg EW, Kent DM. Big Data and Predictive Analytics Recalibrating Expectations. JAMA. 2018;320(1):27–28. doi:10.1001/jama.2018.5602

Big Data and Predictive Analytics - Recalibrating Expectations

Calibration: The Achilles Heel of Prediction

- Benchmarking
- Test stability with variations with populations
- Test sensitivity to unmeasured cofactors
- Test reliability to correctly give the known answer
- Clinically interpretable

Shah ND, Steyerberg EW, Kent DM. Big Data and Predictive Analytics Recalibrating Expectations. JAMA. 2018;320(1):27–28. doi:10.1001/jama.2018.5602


Annals of Internal Medicine RESEARCH AND REPORTING METHODS

Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis (TRIPOD): Explanation and Elaboration

Ann Intern Med. 2015;162:W1-W73

Big Data and Predictive Analytics - Recalibrating Expectations

User Trust, Transparency, and Commercial Interests

- Hype or reality
- What's really going on in the ML black box?
- Influence of commercial, or other, gain

Shah ND, Steyerberg EW, Kent DM. Big Data and Predictive Analytics Recalibrating Expectations. JAMA. 2018;320(1):27–28. doi:10.1001/jama.2018.5602

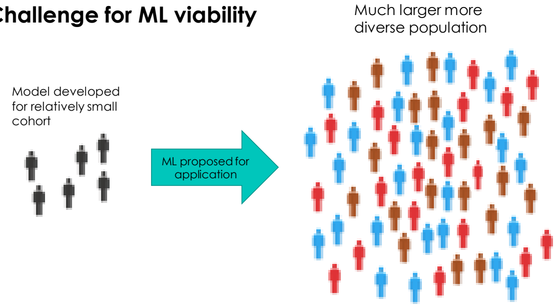
Big Data and Predictive Analytics - Recalibrating Expectations

Data Quality and Heterogeneity

- Volume and quality of data used in models
- Inconsistent coding practices
- Who is entering the data?
- Lack of standardization of data extracted from EHR

Shah ND, Steyerberg EW, Kent DM. Big Data and Predictive Analytics Recalibrating Expectations. JAMA. 2018;320(1):27–28. doi:10.1001/jama.2018.5602

Challenge for ML viability



There are challenges for AI
to match the sophistication of humans

https://www.theguardian.com/technology/2016/jun/30/tesla-autopilot-death-self-driving-car-elon-musk


The report of Task Group 100 of the AAPM: Application of risk analysis methods to radiation therapy quality management

M. Saiful Huq
Benedick A. Fraass
Peter B. Dunscombe
John P. Gibbons, Jr.
Geoffrey S. Ibbott
Arno J. Mundt
Sasa Mutic
Jatinder R. Palta
Frank Rath
Bruce R. Thomadsen
Jeffrey F. Williamson
Ellen D. Yorke

Let's place scripting in automation in the context of Failure Mode and Effects Analysis (FMEA)

- What could go wrong that would impact a patient?
- How likely is it that this will happen?
- How bad would it be if this happened?

Working Group on Treatment Planning – Sponsoring a new task group for scripting (R. Popple et al)

"The computer is magic, I can disconnect my brain"

Importance of building in sanity checks

- **Set plan dose to correct dose, but automate optimization to incorrect dose**
- Plan only has a prescribed dose (DPV) point so it looks like everything is OK.
- If physical dose point in high dose target were added, there would be a cross checkable sanity check

"The computer is magic, I can disconnect my brain"

Importance of building in sanity checks

- **Automated plan OAR metrics look OK, but structure (e.g. brain stem) is incorrectly drawn.**
- Automatically generated plan check says everything is OK
- Dig deeper on algorithms to automate checking algorithms, still need people for visual checks

https://www.flickr.com/photos/96369280@N00/albums/72157684077833246

- Special Issue of Medical Physics covering papers from Practical Big Data Workshop 2017 will be out soon
- **Includes recommendations for standards and best practices for ML and AI (I El Naqa et al.)**

Summary

- Medical physicists are exceptionally good at
  - rising to the occasion to create new tools with new technologies
  - extracting knowledge and understanding about systems from data
  - creating standardizations and guidelines to ensure safety and efficacy

- Machine learning solutions are developing rapidly for use in Radiation Oncology
- True AI to execute decision frameworks are also emerging

- Initiation of task group to promote safety and commissioning guidelines for automation is underway (WGTP)

- Is it is a good time to initiate similar task group efforts for AI and ML?
  - Safety
  - Commissioning
  - Communication
  - Standards