Aim at AIM

Artificial Intelligence in Medicine

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Robust fluoroscopic respiratory gating for lung cancer radiotherapy without implanted fiducial markers

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Received 20 September 2006, in final form 30 November 2006
Published 15 January 2007
Online at stacks.iop.org/PMB/52/741

Fluoroscopic intensity fluctuation vs. time

Fluoroscopic gating without implanted fiducial markers for lung cancer radiotherapy based on support vector machines

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Machine Learning in Medicine

- Interesting but limited
- Progresses slowly, linearly, incrementally
- Not revolutionary, not disruptive
- Not going to transform medicine

Is that so?!
AlphaGo retires from competitive Go after defeating world number one 3-0

by Sam Byford | @345triangle  May 27, 2017, 5:17am EDT

AlphaGo vanquishes world’s top Go player, marking AI’s superiority over human mind
From Deep Blue to AlphaGo

- 1997 IBM chess-playing computer Deep Blue defeated Garry Kasparov
- However we still have Go - the holy grail for AI in board games
- $10^{170}$ possible board configurations > # of atoms in the known universe
- It will take decades...
AlphaGo

- 10/2015
  - AlphaGo vs Fan Hui 2p (three time European Go Champion)
  - Result: 5 to 0
  - First time a computer Go program had beaten a professional human player
AlphaGo

3/2016

- AlphaGo vs Lee Sedol 9p (Strongest Go player in the last decade)
- Result: 4 to 1
- Used 1,920 CPUs and 280 GPUs
AlphaGo

~ 1/2017

- AlphaGo vs a long list of top Go players including many world champions for fast paced online matches
- Registered as “Master” on two online board game platforms
- Result: 60 to 0
- 10 games per day

“Humans have evolved in games in thousands of years—but computers now tell us humans are all wrong. I think no one is even close to know the basics of Go.” – Ke Jie
AlphaGo

- 5/2017
  - AlphaGo vs Ke Jie 9p (currently No.1 Go player in the world)
  - The final battle between man and machine in the board game
  - Result: 3 to 0
  - AlphaGo: no more competitive Go playing
DeepMind General AI

- Systems that can learn to solve any complex problem without needing to be taught how
- Agents should not be pre-programmed, but rather, able to learn automatically from their raw inputs and reward signals from the environment.
Deep Q-network (DQN) playing Breakout
The 6 Most Exciting AI Advances of 2016

- AlphaGo beats world champion at the game Go
- Tesla's Autopilot brings man with blood clot to hospital
- Swarm AI predicts the Kentucky Derby
- Microsoft's AI understands speech better than humans
- AI predicts US election
- AI improves cancer diagnosis

http://www.techrepublic.com/article/the-6-most-exciting-ai-advances-of-2016/
Auto Piloting Cars
Zillow’s Zestimate

109 King Ranch Rd, Southlake, TX 76092

4 beds · 3 baths · 4,021 sqft Edit

Edit home facts for a more accurate Zestimate.

Note: This property is not currently for sale or for rent. The description below may be from a previous listing.

Amazing custom home on a nice large 1 acre lot that boasts large back yard paradise space for the kids. Nice stately circle drive as you arrive. Back yard is a paradise w sparkling salt water pool & spa, built in grill area large Pergola for relaxing while the kids play in the pool. Inside this wonderful custom home an

SOLD
Sold on 04/11/17

Zestimate:
$814,264

I disagree

Home Shoppers are Waiting

655 shoppers are looking in your neighborhood and price range.

EST. REFI PAYMENT
$3,106/mo
See current rates

Contact Agent

Or call 817-330-9935 for more info
Zillow Prize

- A contest designed to inspire the brightest scientific minds to compete to improve the Zestimate® home valuation algorithm

- **Public qualifying round**
  - May 24, 2017 - Jan 17, 2018
  - participants will develop a model to improve the Zestimate residual error

- **Final round**
  - Feb. 1, 2018 - Jan 15, 2019
  - 100 teams compete for $1M prize
  - build an algorithm to predict the actual sales price of homes
Main Reasons for AI Advances

- Computing power (GPU etc)
- Deep learning algorithms
  - smarter weight initialization (layer-wise, transferred, etc)
  - better non-linear transformation (ReLU, etc)
  - significantly deeper network topology
- Big data
- Cloud computing
AIM – IBM Watson
IBM Watson

- 2011: won Jeopardy!
- 2013: decision making assistance for lung cancer treatment, w/ Memorial Sloan Kettering Cancer Cen
- natural language processing, information retrieval, knowledge representation, automated reasoning, etc
Bridge data and knowledge seamlessly to transform decision-making in healthcare

Medical Literature

Guidelines

Institutional Knowledge

Exogenous data – 60%

Genomics data – 30%

Clinical data – 10%

Courtesy of IBM Watson
Purpose-Built Healthcare Cloud and Extensive Data Repository

- HIPAA Enabled/GxP-Compatible
- End-to-End Security
- Purpose Built for Health Data
- Continuous Updates
- Business Continuity/Resiliency

- 200M+ lives
- 100M+ patient records
- 30B+ images
- 1.2M medical abstracts
- 40M+ research documents
- 4M+ drug patents

Courtesy of IBM Watson
Innovative Cognitive Solutions with Watson APIs

Oncology & genomics
- Watson for Genomics
- Watson for Oncology
- Clinical Trial Matching for Oncology

Imaging
- Watson Imaging for cardiac disease
- Voice to Report (V2R) for Cardiologists and Radiologists
- Cognitive Breast Advisor

Life sciences
- Clinical trials
- Watson for Drug Discovery
- Watson for Patient Safety

Value based care
- Next Generation Population Health Suite
- Next Generation Payer Analytics
- Next Generation Provider Portable Analytics

Government
- Social Program Management
- Health & Human Services
- Next Generation Program Integrity

Adaptable Cognitive API Services
- Deep Learning
- Sequence Learning
- Natural Language Processing
- Domain-specific Annotation, Curation

Currently available | Available; additional cognitive integration in process | In development

Courtesy of IBM Watson
Solution Landscape for Oncology & Genomics

Watson Health Oncology & Genomics Offerings

Watson for Oncology (WFO)

Helps oncologists identify evidence-based, patient-centric treatment regimens

Watson for Clinical Trial Matching (CTM)

Helps quickly identify clinical trials for a physician’s consideration with their patients

Watson for Genomics (WFG)

Watson Genomics from Quest Diagnostics

Helps scale the power of precision medicine at your practice

Courtesy of IBM Watson
### Patient Cases

<table>
<thead>
<tr>
<th>Filter patients:</th>
<th>Sort by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>cervical</td>
<td>Last Modified Date</td>
</tr>
</tbody>
</table>

#### [shared] Cervical patient list case
- **Diagnosis:** Cervical Cancer, **Gender:** , **Age:** , **Patient ID:**
- **Last Updated:** 04/17/2017, 9:18:37 PM

#### SM_Cervical 2
- **Diagnosis:** Cervical Cancer, **Gender:** Female, **Age:** 35, **Patient ID:** SM_Cervical 2
- **Last Updated:** 03/02/2017, 8:44:10 PM

#### SM_Cervical
- **Diagnosis:** Cervical Cancer, **Gender:** Female, **Age:** 53, **Patient ID:** SM_Cervical
- **Last Updated:** 02/20/2017, 8:43:59 AM

Total: 3

---

Courtesy of IBM Watson
Clinical Information

**Summary**

Patient attributes to identify treatment plan options

**Required**

**Comorbidities**

Specify the severity of any comorbidities present. Assume all else normal

- Fistula: Required
- Inflammatory bowel disease: Required

**Please Verify:** Attributes below correctly reflect the patient's condition.

**Patient characteristics**

- Age: 25 years old
- Performance status: Derived
- Gender: Female
- ECOG 0 (Asymptomatic) or KPS 90-100

**Staging characteristics**

**Courtesy of IBM Watson**
## Treatment Plan Options

### Treatment Options

- **Definitive chemoradiation therapy**

  - Recommended
  - For Consideration
  - Not Recommended

### Chemoradiation

<table>
<thead>
<tr>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definitive pelvic RT (3D) + concurrent cisplatin + brachytherapy</td>
</tr>
<tr>
<td>Definitive pelvic RT (3D) + concurrent cisplatin + 5-fluorouracil + brachytherapy (cisplatin / fluorouracil / leucovorin)</td>
</tr>
<tr>
<td>Definitive pelvic RT (IMRT) + concurrent cisplatin + brachytherapy</td>
</tr>
<tr>
<td>Definitive pelvic RT (IMRT) + concurrent cisplatin + 5-fluorouracil + brachytherapy (cisplatin / fluorouracil / leucovorin)</td>
</tr>
<tr>
<td>Definitive extended-field RT (3D) + concurrent cisplatin + brachytherapy (cisplatin / fluorouracil / leucovorin)</td>
</tr>
<tr>
<td>Definitive extended-field RT (3D) + concurrent cisplatin + brachytherapy</td>
</tr>
<tr>
<td>Definitive extended-field RT (IMRT) + concurrent cisplatin + brachytherapy (cisplatin / fluorouracil / leucovorin)</td>
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</tr>
</tbody>
</table>

---

Courtesy of IBM Watson
Definitive pelvic RT (3D) + concurrent cisplatin + brachytherapy

Rationale

This treatment option is: Recommended

3D conformal technique is preferred over Intensity-Modulated Radiation Therapy for definitive therapy when the tumor is in place. If using Intensity-Modulated Radiation Therapy, pay close attention to tumor regression and organ motion throughout the course of treatment.

Cisplatin is the preferred radio-sensitizing chemotherapy for chemoradiation administration due to additional toxicity burden associated with other regimens.

Patients with 4cm to 5cm tumors confined to the cervix (FIGO stage IB2) can consider either definitive chemoradiation therapy or radical hysterectomy with sentinel lymph node algorithm. These treatments have different acute and delayed toxicities but are considered equally curative options.
Definitive pelvic RT (3D) + concurrent cisplatin + brachytherapy

Rationale

This treatment option is: **Recommended**

- 3D conformal technique is preferred over Intensity-Modulated Radiation Therapy for definitive therapy when the tumor is in place. If using Intensity-Modulated Radiation Therapy, pay close attention to tumor regression and organ motion throughout the course of treatment.

This treatment option is: **For Consideration**

- Cisplatin is the preferred radiosensitizing chemotherapy for chemoradiation administration due to additional toxicity burden associated with other regimens.

- Patients with 4cm to 5cm tumors confined to the cervix (FIGO stage IB2) can consider either definitive chemoradiation therapy or radical hysterectomy with sentinel lymph node algorithm. These treatments have different acute and delayed toxicities but are considered equally curative.

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Courtesy of IBM Watson
Definitive pelvic RT (3D) + concurrent cisplatin + brachytherapy

Chemoradiation in locally advanced cervical carcinoma: an analysis of cisplatin dosing and other clinical prognostic factors.


Abstract

Objectives The aim of this study was to evaluate the effect of number of chemotherapy cycles and other clinical and pathologic factors on progression-free (PFS) and overall survival (OS) in patients with newly diagnosed cervical cancer. Methods We identified 118 patients with locally advanced cervical cancer (stages IB2-IVA) treated with combination weekly cisplatin (40 mg/m2) and radiation therapy (RT) between 2003 and 2007. Kaplan-Meier and Cox proportional hazard models were utilized to evaluate PFS and OS for associations with number of chemotherapy cycles and other factors. Results The majority of patients had stage IB2 or II disease (70%), squamous histology (91%), and size less than 6 cm (85%). Median RT duration was 50 days and 95% received brachytherapy. Thirty percent of patients completed less than 6 cycles of chemotherapy, and estimated PFS and OS were 63% and 75%, respectively. In multivariate analyses, the number of chemotherapy cycles was independently predictive of PFS and OS. Patients who received less than 6 cycles of cisplatin had a worse PFS (HR 2.65; 95% CI 1.35-5.17; p=0.0048) and OS (HR 4.47; 95% CI 1.83-10.9; p=0.001). Advanced stage, longer time to RT completion, and absence of brachytherapy were also associated with decreased OS and PFS (p less than 0.05). Similar results were found when...
Definitive pelvic RT (3D) + concurrent cisplatin + brachytherapy

Treatment: Chemoradiation

Radiation to the pelvis with a target dose of 4500 cGy delivered in 25 fractions, followed by brachytherapy with a target dose of 2800 cGy delivered in 4 fractions over 2 insertions, approximately 1 week apart, using High Dose Rate. 40mg/m² concurrent cisplatin (capped at 70mg) given weekly for the duration of EBRT (5-6 weeks total). Total duration of treatment should not exceed 8 weeks. Brachytherapy may begin during the last week of EBRT. For IIB and earlier stage patients: Intracavitary brachytherapy is preferred.

Base treatment administration information is provided by MSK for reference purposes only. Patient-specific dosing must be determined based on the patient’s individual presentation and calculated separately.

NCCN Supportive Care Info

Cisplatin with Concurrent Radiation
Definitive pelvic RT (3D) + concurrent cisplatin + brachytherapy

Adverse Reactions Reported Incidence %

Cisplatin

Contraindications/Precautions

Courtesy of IBM Watson
Adverse Reactions Reported Incidence % for Cisplatin

- Immunosuppression
- Hearing loss
- Hyperuricemia
- Tinnitus

Sort by: Incidence Percentage

Severe
Moderate
Mild

Courtesy of IBM Watson
AIM – Some of Our Work in Cancer Radiotherapy
Treatment Outcome Prediction

Jing Wang, Ph.D. Associate Professor
Treatment outcome prediction

- Is crucial for personalized treatment selection

- May reduce overtreatment or under-treatment for the management of various cancers
Additional Treatment for Certain Patients

- SBRT has been established as the standard of care for local control in medically inoperable NSCLC patients:
  - High local control rate (>95% in three years)
  - Relatively high distant failure rate (31% in five years, RTOG 0236)

- Stratify patients with high risk of distant failure:
  - Additional systemic therapy may reduce the risk and improve overall survival
  - The toxicity of the systemic therapy could itself contribute to increased mortality

Timmerman et al; *JAMA* 2010, 303(11), 1070-1076
Zhou et al; *Radiotherapy & Oncology* 2016, 119(3), 501-504
Overtreatment May Be Avoided

- **Locally advanced esophageal cancer**
  - Standard treatment: neoadjuvant chemoradiation therapy followed by surgery
  - Complete responders to chemoradiation therapy have superior outcomes regardless of whether they undergo surgical resection

- **How can we accurately identify those complete responders and safely defer surgery?**

Clinical Trial for Breast Cancer

- Eliminating Breast Cancer Surgery in Exceptional Responders With Neoadjuvant Systemic Therapy (NCT02945579) at MDACC
  - Identify pathological complete responders (pCR) after completing chemotherapy but before beginning radiation therapy
  - Surgery will be skipped for pCR
  - Biopsy of the breast to test for evidence of disease
    - Sample location dependent
Radiomics:

- The development of processes for high-throughput extraction of quantitative features that result in the conversion of images into mineable data and the subsequent analysis of these data for decision support.
Process of Radiomics

I. Image patients
II. Identify ROI
III. Render in 3D
IV. Extract Features

Robert J. Gillies; Paul E. Kinahan; Hedvig Hricak; *Radiology* **2016**, 278, 563-577
Many of steps sound very familiar

- Region of interest identification / segmentation
- Imaging feature extraction
- Model building

Computer-aided diagnosis and detection (CAD)
Uniqueness of Radiomics

- Not limited to a single imaging modality
  CT/PET/MRI, any standard-of-care imaging
- Not limited to imaging input
  Prediction not limited to disease diagnosis

Robert J. Gillies; Paul E. Kinahan; Hedvig Hricak; *Radiology* 2016, 278, 563-577
Imaging Features

- **Intensity histogram**
  - mean, median, min, max, range, skewness, kurtosis

- **Shape or geometry feature**
  - volume, major axis length, minor axis length, eccentricity, elongation, orientation, perimeter, compactness, surface to volume ratio,

- **Texture features** (Gray –level co-occurrence matrix, Gray – level run-length matrix, wavelet transform)
  - Energy, Entropy, Correlation, Contrast, Variance, Sum Mean, Inertia, Cluster Shade, Cluster Tendency, Homogeneity, Max Probability, Inverse Variance

Zhang et al; *Medical Physics* 2015, 42, 1341-1353

Aerts et al; *Nature Communication* 2014, 5
Dimensionality Reduction

- Number of extracted features larger than number of samples

- Reproducible, informative and non-redundant
  - Test-retest to identity reproducible features
  - Informative: High dynamic range
  - Identify redundancy feature based on correlation coefficients.

- Additional feature selection during the modeling process

Kumar et al; *Magnetic Resonance Imaging* **2012**, 30, 1234-1248
Imaging Variations

- Acquisition protocols
- Processing methods
- Reconstruction algorithms

Conclusions

Most of the radiomic features were significantly affected by the reconstruction algorithms. Inter-reconstruction algorithm variability was greater than inter-reader variability for entropy, homogeneity, and GLCM-based features.

Published: October 14, 2016 • http://dx.doi.org/10.1371/journal.pone.0164924

Acquisition and reconstruction standardization
1990, TCIA

2010, UTSW
Segmentation Variations

- CTV is available

Variations in clinical target volume (CTV) between observers A–D

Mukesh et al; *Br J Radiol.* 2012
Imbalanced Data

Table 1. Illustration of imbalanced dataset for prediction results.

<table>
<thead>
<tr>
<th></th>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>TP=1</td>
<td>FN=2</td>
</tr>
<tr>
<td>Negative</td>
<td>FP=2</td>
<td>TN=15</td>
</tr>
</tbody>
</table>

\[
\text{Accuracy} = \frac{TP+TN}{TP+FN+FP+TN} = \frac{16}{20} = 0.80,
\]

\[
\text{Sensitivity} = \frac{TP}{TP+FN} = \frac{1}{3} = 0.33,
\]

\[
\text{Specificity} = \frac{TN}{FP+TN} = \frac{15}{17} = 0.88.
\]
Different applications should emphasize different criteria

- In lung SBRT: add potentially toxic treatment to the standard-of-care
  - High specificity is desired to minimize false positive

- In eliminating breast surgery trial: remove one treatment modality from the standard-of-care
  - High sensitivity is desired to minimize false negative
An iterative multi-objective immune algorithm (IMIA) was proposed to solve this problem.

Zhou et al, *PMB*, under revision
Iterative Multi-objective Immune Algorithm (IMIA)

Step 1: Initialization
- Binary encoding used for feature
- Real number encoding used for model parameters

Step 2: Clonal operation
- Proportional cloning utilized according to the crowding distance

Step 3: Mutation operation
- Each locus in individual mutated according to mutation probability

Step 4: Deletion operation
- Only keep unique solution

Step 5: Optimal solution selection
- Phase 1: The solution candidates were selected according to the preset thresholds of sensitivity and specificity.
- Phase 2: The candidate with the highest AUC was selected as the final solution.
**Distant failure prediction for early stage NSCLC after SBRT**

- 52 early stage NSCLC patients
- 12 experienced distant failure

Clinical parameters

<table>
<thead>
<tr>
<th>Demographic parameters</th>
<th>Tumor characteristics</th>
<th>Treatment parameters</th>
<th>Pretreatment medicine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Primary diagnosis</td>
<td>Number fractions</td>
<td>Antiinflammatories</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>Central tumor or not</td>
<td>Dose per fraction</td>
<td>Anitdiabetic</td>
</tr>
<tr>
<td>Gender</td>
<td>Tumor size</td>
<td>BED</td>
<td>Metformin</td>
</tr>
<tr>
<td></td>
<td>Histology</td>
<td></td>
<td>Statin</td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td></td>
<td>ACE inhibitor</td>
</tr>
<tr>
<td></td>
<td>Stage</td>
<td></td>
<td>ASA</td>
</tr>
</tbody>
</table>

Solutions with PET/CT/clinic as input features

Red label: final selected solution;
Green labels: selected feasible solutions;
Blue labels: unselected solutions
Rectum Toxicity Prediction

Xuejun Gu, Ph.D. Associate Professor
Algorithm flowchart

3D-2D Surface Dose Flattening

RSDM: rectum surface dose map

Gradient-weighted class activation map
3) VGG-16 CNN with transfer learning

- The VGG-16 CNN (16 layers, 13 convolution layers and 3 fully-connected layers) is used as the prediction model.
- Instead of training from scratch, we pre-trained the VGG-16 CNN with a large natural image dataset ImageNet (1.2 million images with over 1000 categories).
- The 2D RSDMs are used to further fine-tune the network.
Study design and initial Prediction of Rectal toxicity using GEC-ESTRO dose parameters

- 42 cervical cancer patients treated with combined BT and EBRT, including 12 patients who developed ≥Grade 2 rectal proctitis (bleeding) and 30 without rectal toxicity

- Rectum was contoured from bottom of ischium to the rectosigmoid junction (6cm~9cm in the patient cohort)

- Prediction capability was compared with logistic regression that performed on D0.1/1/2cc rectal doses

- For prediction evaluation, a leave-one-out method is used, and the prediction accuracy is quantified by the accuracy (ACC), sensitivity (SEN), specificity (SPE) and area under the curve (AUC)
**Results: Prediction Comparison**

- The dose volume parameters \( D_{0.1/1/2cc} \), which has no spatial information, are not ideal rectum toxicity predictors.
- Incremental performance is observed when more convolutional layers are included in fine-tuning.
- The AUC values increase gradually where the ROC curves approach the upper left gradually when including more layers for fine-tuning.

<table>
<thead>
<tr>
<th>Fine-tuning strategy</th>
<th>SEN</th>
<th>SPE</th>
<th>ACC</th>
<th>AUC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train from scratch</td>
<td>66.7%</td>
<td>36.7%</td>
<td>45.2%</td>
<td>0.45</td>
</tr>
<tr>
<td>Fine-tune only fc8</td>
<td>25.0%</td>
<td>70.0%</td>
<td>57.1%</td>
<td>0.40</td>
</tr>
<tr>
<td>Fine-tune fc7-fc8</td>
<td>41.7%</td>
<td>56.7%</td>
<td>52.4%</td>
<td>0.55</td>
</tr>
<tr>
<td>Fine-tune fc6-fc8</td>
<td>50.0%</td>
<td>60.0%</td>
<td>57.1%</td>
<td>0.60</td>
</tr>
<tr>
<td>Fine-tune conv5-fc8</td>
<td>83.3%</td>
<td>93.3%</td>
<td>90.5%</td>
<td>0.91</td>
</tr>
<tr>
<td>Fine-tune conv4-fc8</td>
<td>75.0%</td>
<td>90.0%</td>
<td>85.7%</td>
<td>0.92</td>
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<tr>
<td>Fine-tune conv3-fc8</td>
<td>75.0%</td>
<td>100.0%</td>
<td>92.9%</td>
<td>0.95</td>
</tr>
<tr>
<td>Fine-tune conv2-fc8</td>
<td>75.0%</td>
<td>96.7%</td>
<td>90.5%</td>
<td>0.95</td>
</tr>
<tr>
<td>Fine-tune conv1-fc8</td>
<td>75.0%</td>
<td>93.3%</td>
<td>88.1%</td>
<td>0.96</td>
</tr>
</tbody>
</table>

**Figure 5.** ROC analysis of VGG-16 trained from scratch or fine-tuned with different layers.
Brain Mets Delineation

Xuejun Gu, Ph.D. Associate Professor
Brain Metastases

- Metastatic brain tumors (cancer that spreads from other parts of the body to the brain), such as Breast, Melanoma, Kidney, GI, Thyroid, Lung, Ovarian, Testicular.

- The incidence of brain metastases has been increasing with improvements in cancer therapies and prolonged survival.

- About 100,000 people in the United States are diagnosed with brain metastases. Approximately 20 to 40 percent of people with cancer develop this complication and often occurs as multiple.

- Stereotactic radiosurgery (SRS) is one of standard-care options for brain metastases.

- A critical step in SRS treatment planning is the delineation of tumor/target volumes.
Study aim and proposed solution

- To design an accurate and automatic brain metastases target delineation strategy for SRS

- The method should
  - Be able to delineate small lesions (<1.500cc)
  - Simultaneously delineate multiple lesions
  - Be fast enough to fit clinical workflow

- Proposed a deep convolutional neural network based automatic delineation strategy: **En-DeepMedic**
**En-DeepMedic architecture**

**Input section**: generates multi-scale image patches

**Convolution section**: sequentially generates feature maps by convolution operations

**Fully connected section**: fuses all the feature maps

**Classification section**: is designed to generate the categorical probability for each voxel.
Training and Validation Study Design

- 240 brain metastases patients with T1c MRI scans collected at the University of Texas Southwestern Medical Center (UTSW) from 2009 to 2014
- All brainmets were manual contoured by neurosurgeon and used as ground truth.
- Dataset were splitting into training : validation: testing = 3:2:1
- Segmentation accuracy evaluation metrics:
  1) DICE coefficients,
  2) Surface-to-surface distance (SSD)
  3) Sensitivity
  4) Specificity
  5) Area under the curve (AUC)
Sample Case Result

- A 65-year-old male patient who underwent Gamma Knife radiosurgery for brain metastasis of melanoma.
— A 65-year-old male patient who underwent Gamma Knife radiosurgery for brain metastasis of melanoma.

<table>
<thead>
<tr>
<th>Lesion position</th>
<th>Volume</th>
<th>DCs</th>
<th>MSSD(mm)</th>
<th>STSSD(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>right globus pallidus</td>
<td>0.293cc</td>
<td>0.87</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>left paracentral lobule</td>
<td>0.276cc</td>
<td>0.85</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>left mid frontal</td>
<td>0.221cc</td>
<td>0.79</td>
<td>0.5</td>
<td>0.5</td>
</tr>
</tbody>
</table>
The obtained AUC is 0.98 ± 0.01 (*1 represents a perfect test*)
CT Dose Reduction

Xun Jia, Ph.D. Associate Professor
Methods – CT Images
Methods – Sinograms
Methods – Patches

12 Noise-Free Sinograms

12 Noisy Sinograms
Methods – Training Stage

[Diagram of a neural network with convolution and ReLU layers, depicting the training stage with weights and activations.]
Methods – Denoising

Validation
Noisy Sinograms
Methods – Denoising and Reconstruction

- BM3D
- Median Filter

Noisy Sinograms → 36 Denoised Sinograms → 36 Denoised Images
Results

<table>
<thead>
<tr>
<th>Noise-Free</th>
<th>Noisy</th>
<th>Median Filter</th>
<th>BM3D</th>
<th>CNN</th>
</tr>
</thead>
</table>

Images showing the results of noise-free, noisy, median filter, BM3D, and CNN processed images.
## Results

<table>
<thead>
<tr>
<th>Image</th>
<th>Relative Difference</th>
<th>PSNR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Noisy</td>
<td>Median Filter</td>
</tr>
<tr>
<td>1</td>
<td>0.71</td>
<td>0.33</td>
</tr>
<tr>
<td>2</td>
<td>0.75</td>
<td>0.35</td>
</tr>
<tr>
<td>3</td>
<td>0.76</td>
<td>0.35</td>
</tr>
<tr>
<td>4</td>
<td>0.66</td>
<td>0.31</td>
</tr>
<tr>
<td>5</td>
<td>0.81</td>
<td>0.36</td>
</tr>
<tr>
<td>6</td>
<td>0.68</td>
<td>0.28</td>
</tr>
<tr>
<td>7</td>
<td>0.62</td>
<td>0.29</td>
</tr>
<tr>
<td>8</td>
<td>0.65</td>
<td>0.31</td>
</tr>
<tr>
<td>9</td>
<td>0.71</td>
<td>0.33</td>
</tr>
<tr>
<td>10</td>
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<td>0.31</td>
</tr>
<tr>
<td>11</td>
<td>0.89</td>
<td>0.40</td>
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<tr>
<td>12</td>
<td>0.92</td>
<td>0.41</td>
</tr>
<tr>
<td>Average</td>
<td>0.74</td>
<td>0.34</td>
</tr>
</tbody>
</table>
Potential AI Applications in RT

- Physician prescription decision support
  - IBM Watson + Radiomics
- Automatic tumor and organ segmentation
- Automatic treatment planning
- Automatic patient setup for treatment
- Treatment monitoring
- Automatic error detection (Spelling check)
- Patient follow up
- ... ...
Challenges in AIM

- Often there is no big data in medicine
  - Dataset size is too small for deep learning
  - Solutions: Multi-institutional collaboration, Data augmentation, Data simulation

- Data quality is often a problem
  - Temporal and spatial variation in datasets
  - Solution → data cleaning using deep learning

- Not supporting multiple choices for physicians and patients
  - Trade offs of various options
  - Pareto surface
Challenges in AIM

- Limited to existing knowledge
  - Interpolation not extrapolation
  - How to generate new treatment protocols
- Often require pre-programming/structured data
  - Solution → general AI?
Interested?

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Best Medical Schools: Research
- 16,400 employees and an annual operating budget of ~$2.8B
- 3,600 medical, graduate, and health professions students, residents, and postdoctoral fellows each year
- > $427M per year research funding
- Treat 100,000 hospitalized patients and oversee > 2.2M outpatient visits a year

Best Medical Schools: Primary Care
Six Nobel Price Recipients since 1985

Alfred Gilman, MD, PhD, 1994
Dr. Johann Deisenhofer, 1988
Michael Brown, MD, 1985
Joseph Goldstein, MD, 1985
Bruce A. Beutler, MD, 2011
Thomas Südhof, MD, 2013

22 members of the National Academy of Sciences (NAS)
18 members of the National Academy of Medicine
Acknowledgement (UTSW AIM Team)
Thank You