Knowledge Based Treatment Planning

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IMRT Planning

Patient’s CT
Patient Disease Info

Physician
Patient’s Other Tx Info

PTV/Rx OAR Constraints
Outcome Based Guidelines

IMRT Planning
Trial-and-error

Final Plan
**IMRT Planning**

- Physician Review
- Final Plan
- IMRT Planning
  
  - Trial-and-error Iteration

  - PTV, Rx
  - OAR Constraints
  - Patient Anatomy & Structures
  - Knowledge Model

**IMRT Planning: The Trial-And-Error Process**

- Define the optimization DVH objectives
- Get the bixel-blocks (segments)
- Calc. the dose distribution
- Review the DVHs & Dose Distributions

**IMRT Planning: The Trial-And-Error Process**

- OAR dose sparing is patient specific and often better than the conservative population-based guidelines
- Lack of objective measure to identify patient-specific OAR sparing to guide the trial-and-error process

Bladder DVHs from Prostate Plans

Parotid DVHs from HN Plans
**IMRT Planning: The Trial-And-Error Process**

- **Experience matters**
  - More experience usually leads to better plan quality and less planning time.
- **Planning time matters**
  - Adequate planning time usually leads to better planning quality.
  - Complexity of the plan leads to exponential increase of planning time.
- **Planning objectives matters**
  - Objectives closer to individual patient goals lead to more efficient planning, sometimes better plan quality.
  - Template based objectives leave more room for improvement and more plan quality variations.

**Knowledge Modeling For IMRT Planning**

- To provide patient specific dose sparing references, based on an array of patient anatomical features, prior planning experience, and outcome-based guidelines.
  - Understand the patient's anatomical, physiological and other factors that influence plan design of dose coverage.
  - Quantify their individual influence via mathematical modeling and machine learning.
  - Codify treatment planning experience and guidelines using knowledge engineering.
  - Model these factors to guide treatment planning for new cases.

**Knowledge of Dose Distribution**

  - Danthai Thongphiew, PhD Thesis 2007, Case Western Reserve University.
- Towards Clinical Implementation Of Online Adaptive Radiation Therapy for Prostate Cancer.
  - Taoan Li, PhD Thesis expected 2013, Duke University.
Knowledge of Dose Distribution

- Experience Learned From Online Adaptive Radiation Therapy (Online ART)
- Hypothesis:
  - Anatomical changes from same patient can be coded through deformable registration
  - Wrapping the dose distribution from original plan to the new anatomy reinforces the dose conformity, and carries the same dose sparing preferences for this patient

Step 1. Deform the Original Dose for New Anatomy

Original Plan in Database

New Plan Dose Distribution Via Deformable Registration

Step 2. Auto-Optimization With Linear Goal Programming

Target: \[ D_i - d_i^+ + d_i^- = D_i^0 \]

OARs: \[ D_i - d_i^- \leq D_i^0 \]

Minimize: \[ \sum_{i \in T} w_T (d_i^+ + d_i^-) + \sum_{i \in NT} w_{NT} f(d_i^-) \]

Voxel based – flexible control, solved in 1-2 min.
Direct dose based – what’s formulated, what’s delivered
Step 3. Plan Quality Vs. Dose Objectives

Step 3. Plan Quality QA: ART vs. Eclipse

A planning quality evaluation tool for prostate adaptive IMRT based on machine learning

IMRT Planning For Online Adaptive RT

- Step 1. Deformable registration of CBCT and CT
  Wrap CT dose to CBCT anatomy
  - known perfect dose
- Step 2. Run auto-optimization to get fluence map
  - known optimization parameters
- Step 3. Run auto plan quality QA
  - known plan quality parameters
Knowledge Training

Database of High-Quality Treatment Cases

Base Anatomy (PTV, OARs)

Data base of High quality treatment plan

Anatomy (PTV, OARs)

Plan (3D Dose)

Descriptor variables

input : X

Model training:
Deformable Registration

Characteristics

Data base of High quality treatment plan

Database of High Quality Treatment Cases

New Patient’s Anatomy

Deformable Registration

New Dose Distribution

Knowledge Application

Base Plan (3D Dose)

Knowledge of DVH Distribution

Modeling Inter-Patient Variation of Organ-At-Risk Sparing in IMRT Plans: An Evidence-Based Plan Quality Evaluation

Yuan et al

MO-D-BRB-10 Monday 2:00:00 PM - 3:50:00 PM Room: Ballroom B

Duke University Radiation Oncology

AAPM 2012
Knowledge of DVH Distribution

Figure (17): A) An example of a DVH of the target, B) An example of DVH of the OAR, C) The prescribed dose based on the given DVHs and voxel position

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Knowledge of DVH Distribution

- Distance to target histogram (DTH): PCS
- Distance to OAR (DOH): PCS
- OAR volumes
- PTV volume
- Fraction of OAR volume overlapping with PTV (overlap volume)
- Fraction of OAR volume outside the treatment fields (out-of-field volume)
- Tightness of the geometric enclosure of PTV surrounding OAR
- Curvature of specific OAR
- PTV dose homogeneity
- PTV hotspot
- OAR DVHs

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Example Of Parotid Sparing Modeling

Examples of Rectum DVH Modeling

Example of Bladder DVH Modeling
IMRT Planning Parameters: More Than DVHs

how the dose distribution should look like 

Optimizer

Iteratively minimizing the difference between calculated DVH and DVH objectives

Knowledge Training

Database of high-quality treatment cases

Anatomy

Dose/Plan features

Descriptor variables input: X

Response variables output: Y

Model training: Machine learning

Knowledge Application

New Patient's Anatomy

Characterized by features

Y=f(X)

Dose/Plan

High Quality Treatment Plan

Knowledge of DVH Distribution

Dicom Data Import

Case Name

PTV Name

Dx (Sp)

Dicom file directory

Dicom file directory

Program directory

Out DVH comments
Knowledge of Patient Specific Trade-offs & Preferences

Individualized Trade-Off of Dose Coverage and Sparing in IMRT Planning
Yuan et al
SU-E-T-626 Sunday 3:00:00 PM - 6:00:00 PM Room: Exhibit Hall

Rt Kidney (Pink) Carries 70% of Patient’s Renal Function

IMRT1  IMRT2
Modeling of Trade-off: Parotid

Actual Parotid
- Actual Rt Parotid
- Actual Lt Parotid
- Modeled Rt Parotid without Trade-off
- Modeled Rt Parotid with Trade-off
Knowledge Based IMRT Planning

- Plan quality can rival human expert planner
- Planning time can be fast (minutes)
- Knowledge of IMRT planning can be independent of delivery platforms (e.g., VMAT vs. IMRT)
- Allow more freedom (such as beam angle, beam energy)
- Allow interactive process
- Integrate with all sources of knowledge
- Truly individualized, patient-specific treatment planning

Thank You & Happy Planning
With All Types of Knowledge Formats