Intelligent health IT systems for delivering personalized cancer therapy

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Outline

- Introduction
- Background
  - Problems in the clinic
  - Respiratory motion management
- IS + PCT
  - HIS app1 (Breast Cancer)
  - Fuzzy logic + GA app (Lung Cancer)
  - HIS app2 (Lung Cancer)
Introduction - Spread of Cancer in Norway

- In 2008, 26,121 (new cases)
  - 14,000 (men), 12,121 (women).
- Most common cancers in Norway:
  - Prostate, female breast, colon and lung.
- Cancer in thorax region:
  - Breast cancer:
    - In 2004, 694 women and 3 men died of breast cancer.
  - Lung cancer:
    - In 2009, there were 2,646 new cases found out of which 2,060 died.

Evidence shows 18% decrease in the risk of death with every 10-Gy increase in biologically equivalent dose. (Machtay et al., Int J Radiat Oncol Biol Phys 63(2):S66)
Introduction – Personalized cancer therapy

Each tumor is a highly
- complex,
- individualistic and
- dynamic System

In practice,
The treatment is given depending upon the stage (grade) of the tumor rather than the individual makeup of the tumor.

Need for personalized cancer therapy (PCT)
Benefits of using Intelligent IT systems

For each tumor/patient:

- ANN can learn to model and predict nonlinear phenomenon – cancer progression/dynamics
- Fuzzy boundaries in tissues/organs can be better handled by a FL approach (ex. FCM segmentation)
- Hybrid intelligent systems (Adaptive neuro-fuzzy) can learn and adapt to changing tumor dynamics
IS + PCT

Texture based Segmentation and Recognition (Lung)  
GA & FCM

Respiratory Motion Prediction (Breast)  
HIS App 1

Intelligent IT systems

Hybrid Modeling and Prediction (Lung)  
HIS App 2

Personalized Cancer Therapy Enhancement
Outline

Introduction

Background
  • Problems in the clinic
  • Respiratory motion management
Problems in clinic

- Tumor moves with respiration
- Respiratory motion compensation required
  - **Breast cancer** – avoid excessive doses to the heart and lungs
  - **Lung cancer** – Interobserver variation
  - **Lung Cancer** - Tumor localization
Interobserver variability

Which one is correct?
Distortion due to motion

Tumor
Current practices

- Margins are added to compensate for uncertainties due to:
  - Distortion
  - Delineation errors

- Leads to:
  - Increase dose to normal tissues
  - Restricts dose escalation

- PTV – planning target volume
- CTV – Clinical target volume
State of the art in radiosurgery

Problems:
- Latency
- Tumor Localization
For tumors that move with breathing

Breast cancer

- How to avoid dose to heart and lung (Breast cancer)
- Increase dose to tumor

Soln:

- Can use external tracking with surrogate marker for predicting tumor position!
For tumors that move with breathing:

- Lung cancer patients
  - Surrogate Marker - Correlation between internal tumor motion and marker motion may not be consistent - internal tracking!

- Alternatively,
  - 4DCT, segmentation, recognition based solution!
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Problem Statement

**Breast cancer**

- tumor moves with respiration
- Respiratory motion compensation required w/o coaching

**Soln:** To predict respiratory motion in breast cancer patients by using ANFIS in cases when patients are coached and uncoached.
Data Collection from Real Time Position Management System (RPM)
Coached & Uncoached Data

Patient ID = 492 with and without coaching

Amplitude in AP direction (mm)

# Data points

coached
uncoached
Modelling - Hybrid Intelligent System

Adaptive Neuro Fuzzy Inference System (ANFIS)
Results

Root mean square error (RMSE) for a 20 second interval:
- *Coached*: 6% of respiratory amplitude.
- *Uncoached*: 35% of respiratory amplitude.
Conclusion

Dose delivery can be better planned by using prediction and coaching so that:

- Dose to the organs at risk (heart, lungs) can be reduced/avoided
- Time of delivery increased
- Dose can be escalated
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Problem Statement

- Lung cancer – Interobserver variation in tumor delineation causing unnecessary irradiation of healthy tissue

- Solution - To develop an unsupervised texture based segmentation and soft tissue recognition system by combining different intelligent technologies
System Design

Preprocessing:
- Noise removal
- Contrast Enhancement

Feature Extraction & selection:
- Gabor filtering
- Selection of feature images

GA & FCM:
- Initialization of cluster centers by GA
- FCM Clustering

Performance measurement:
- Accuracy
- Sensitivity

Recognition - Simple SVM:
- Data balancing
- Multi-class Recognition

Feature extraction:
- Region description
- Feature extraction
# Results - 12 Classes Identified

<table>
<thead>
<tr>
<th>#</th>
<th>CLASS</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LLUP</td>
<td>Left Lung Upper Part or Inner Part</td>
</tr>
<tr>
<td>2</td>
<td>LLLO</td>
<td>Left Lung Lower Part</td>
</tr>
<tr>
<td>3</td>
<td>LLIP</td>
<td>Left Lung Inner Periphery</td>
</tr>
<tr>
<td>4</td>
<td>LLOP</td>
<td>Left Lung Outer Periphery</td>
</tr>
<tr>
<td>5</td>
<td>RLUP</td>
<td>Right Lung Upper Part or Inner Part</td>
</tr>
<tr>
<td>6</td>
<td>RLLO</td>
<td>Right Lung Lower Part</td>
</tr>
<tr>
<td>7</td>
<td>RLIP</td>
<td>Right Lung Inner Periphery</td>
</tr>
<tr>
<td>8</td>
<td>RLOP</td>
<td>Right Lung Outer Periphery</td>
</tr>
<tr>
<td>9</td>
<td>LEIN 1</td>
<td>Lesion #1 Innermost core</td>
</tr>
<tr>
<td>10</td>
<td>LEOP 1</td>
<td>Lesion #1 Outer Periphery</td>
</tr>
<tr>
<td>11</td>
<td>LEIP 1</td>
<td>Lesion #1 Inner Periphery</td>
</tr>
<tr>
<td>12</td>
<td>BACK</td>
<td>Background Regions</td>
</tr>
</tbody>
</table>
Advantages

- Fully automatic FCM texture based segmentation and recognition without user intervention
- Accuracy of delineation
  - 89.04% (Lesion).
  - 94.04% (Right Lung)
  - 94.06% (left Lung).
- Average sensitivity of classifier - 89.48%
Video Clip - Automatic Segmentation
Conclusion

- Automatic segmentation
  - Removes interobserver variation in tumor delineation
  - Reduction in healthy tissue irradiation and dose escalation
  - Facilitates automatic tracking of tumor and motion model building
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Lung Cancer - For compensating respiratory motion, a model is required for precisely locating the tumor at the time of radiation delivery

Solution - Model and predict deformation of texture segmented regions (tumor) from 4DCT data
Image Registration

- Elastic image registration\(^1\)
- Rigid and non-rigid parameters extracted
  - Non-rigid -128x128 matrices
    - PCA projection for reducing the data
  - Projected component used for ANFIS modelling and prediction

Optical Flow Maps

Source | Target | Rigid | Non Rigid
--- | --- | --- | ---
[Image] | [Image] | [Image] | [Image]

Source | Target | Rigid | Non Rigid
--- | --- | --- | ---
[Image] | [Image] | [Image] | [Image]
Results- Lesion sequences (Seg/Pred)

Lesion sequence from segmentation

Lesion from ANFIS Prediction
Conclusion

Advantages

- Reduced irradiation of surrounding healthy tissues by motion management
- Increased dose delivery to the tumor
Summary

Intelligent and adaptive tools are developed/under development for enhancing personalized cancer therapy:

- Breast cancer patients
  - Respiratory motion management (External surrogate)
- Lung patients - Interobserver variation
  - Automatic soft tissue segmentation and recognition system from CT data
- Lung patient - Respiratory motion modelling
  - Intelligent modelling and prediction from deformation of texture segmented tissues from 4DCT
Graphical User Interface
Future plans

Combine prediction and modelling for accurate pose determination of tumor and OAR at the time of delivery:

International Collaboration

- Germany – RFS - 4DCT modelling
- Italy – IT2FL – Uncoached patient prediction

Unfortunately, further work has been stopped due to change in department strategy !!
Thank You !