Realistic knowledge-based waiting times for radiotherapy patients

Addressing the pain of waiting

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Realistic knowledge-based waiting times for radiotherapy patients – addressing the pain of waiting

Winners of Q+ Challenge 2014
Patients experience...
...3 different types of waiting in radiation oncology

1. Treatment planning
   - Waiting at home by the phone
   - Can last days to weeks

2. Daily-fractionated treatments
   - Waiting in the waiting room
   - Can last minutes to hours

3. Consultations with physician
   - Waiting in the waiting room
   - Can last minutes to hours

• Difficult for staff to predict.

• Only rough estimates are given based on experience.

Can we build an algorithm to accurately predict how long a patient is expected to wait?
Solution: Machine learning

• **Goal:** To provide radiotherapy patients with *personalized predictions* regarding how long they will wait for the provision of care in the Department of Radiation Oncology at the MUHC

• **How:** Learn data from previous patients to make predictions for future patients.
What is machine learning?

- **Subfield of Artificial Intelligence**

- **Learning**: Any process by which a system improves from experience

- **Machine Learning**: Written computer programs that automatically improve their performance through experience

- They are programs that can **learn from data**
Why machine learning?

• Develop systems that can automatically adapt themselves to individual users
  • Personalized information

• Discover new knowledge from large databases
  • Data mining, correlations (ex: beer and diapers)

• Mimic human thought-process to replace monotonous/laborious tasks

• Tackle systems that are too complex to construct analytically
  • Dynamic program instructions (ex: human brain)
How does ML work?

1. Define the problem
   • Not knowing how long to wait.

2. Define your dataset
   • Putting in historical patient information such as:
     • Time of the appointment, doctor, diagnosis, etc.
     • Getting out the duration of an appointment to infer a waiting estimate.

3. Choosing the right algorithm
   • There is no perfect model; only a model that is good enough.

4. Validate your algorithm
   • Divide your existing dataset into training and testing sets.
   • Cross-validate.
Appointment Timeline

On a typical treatment day for a particular resource

- **START**
- **IMRT**
- **SRS**
- **3D**
- **IMRT**
- **RA**
- **ELECTRON**
- **...**
- **END**

Grey: Past durations 
(definite / already happened)

Red: Delays

Yellow: ML predictions 
(duration)

Green: Total wait

Blue: Treatment type

Patient arrives
Checks in

Scheduled start of treatment

Actual start of treatment

--- Delayed by 10 mins

--- Expected 5 min delay

--- No delay expected

--- Expected 10 min delay
Defining features
Traits that can explain appointment delays

Patient
- Diagnosis
- Oncologist
- Treatment machine
- Age
- Day of the week
- Hour of the day
- Month
- Plan
- # of treatment fields
- Fraction number

Input (Vector) → ML Model → Output (Real Number)

Patient #1
-
-
- (Trait)

Patient #2
-
-
- (Trait)

Patient #3
-
-
- (Trait)
• ML relates closely to mathematical optimization theory

• Cost function for building a model

• Training means solving:
  
  \[
  \text{minimize } \frac{1}{2}\|w\|^2 \\
  \text{subject to } \begin{cases} 
  y_i - \langle w, x_i \rangle - b \leq \epsilon \\
  \langle w, x_i \rangle + b - y_i \leq \epsilon 
  \end{cases}
  \]

• In non-linear space, kernel functions are applied to transform feature space to linear space (Kernel trick)

• Replace \( x_i \) with \( \varphi(x_i) \) – Polynomial, Gaussian, Hyperbolic
Results
Results

Residual histogram

--- Mean error: 0.25 mins
--- Median error: 0.5 mins
--- Standard deviation: ~8 mins
Conclusion

• Machine learning can be successfully applied to waiting times in Radiation Oncology.

• Future work
  • Feature analysis (correlations, patterns)
  • Algorithm tuning (optimization parameters)
  • Exploring the code (Python scripts)
  • Communicate waiting times to patients (patient app)
  • Gather feedback from patients

• This can have a significant impact on patient lives and staff workflow!
Thanks!

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