Méthodes pour l'automatisation de la dosimetrie pour les traitements radiothérapiques.

Methods for automatization of the dosimetry for radiotherapy treatments.

Thèse de doctorat de l'université Paris-Saclay

Spécialité de doctorat: ...
École doctorale n° 573 Interfaces : matériaux, systèmes, usages, ED INTERFACE
Graduate School: Sciences de l'Ingénierie et des Systèmes, SIS

Thèse préparée dans les unités de recherche **Radiothérapie** (Institut Régionale du Cancer de Montpellier), **Advanced Research** (TheraPanacea), et **MICS, Mathématiques et Informatique pour la Complexité et les Systèmes** (Université Paris-Saclay, CentraleSupélec) , sous la direction de **Nikos Paragios**, Professeur, et la co-direction de **Paul-Henry Cournède**, Professeur

Thèse soutenue à Paris-Saclay, le JJ mois AAAA, par

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Composition du jury

Membres du jury avec voix délibérative

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THESE DE DOCTORAT

NNT : 2020UPASA001

université PARIS-SACLAY
ÉCOLE DOCTORALE
Interfaces:
matériaux, systèmes, usages

Titre: Méthodes pour l'automatisation de la dosimetrie pour les traitements radiothérapiques.

Mots clés: Mathématiques, Intelligence Artificielle, Radiothérapie

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Title: Methods for automatization of the dosimetry for radiotherapy treatments.

Keywords: Mathematics, Artificial Intelligence, Radiotherapy

Abstract: Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

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Acknowledgments

A PhD is more than just hard work; it thrives on mentorship, collaboration, and unwavering support.

[...]

List of Contributions

- Teaching: *Consistency and Reproducibility of Grades in Higher Education: A Case Study in Deep Learning replace icon*

- ArXiV: Radiotherapy Dosimetry: A Review on Open-Source Optimizer
- ESTRO: A Novel Framework for Multi-Objective Optimization and Robust Plan Selection Using Graph Theory
- SFPM: Dose Volume Histograms Guided Deep Dose Predictions
- AIME: Radiotherapy Dose Optimization via Clinical Knowledge Based Reinforcement Learning (full paper coming soon)
- ASTRO: Clinically Dependent Fully Automatic Treatment Planning System
- SFRO: Attention Mechanism on Dose-Volume Histograms for Deep Dose Predictions

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Introduction

Abstract

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1.1 Introduction to Cancer

1.1.1 what is cancer?

Cells proliferating

DNA messed up

variety of cancer

some safe

(e.g.: mole/freckle)

some not safe

worse make the human die

1.1.2 who is concerned?

more and more ppl

1.1.3 risk factors

environment impacts the probability of getting cancer

(e.g.: UV exposure)

living habits as well

(e.g.: smooking)

genetic impacts as well (e.g. "cancer gene")

1.1.4 possible treatments

surgery

RT

chemotherapy

combination

1.1.5 10 cancer markers

cell proliferation

reprogram cellular metabolism

stop cell growth arrest

evade apoptosis

escape immune system

ability to undergo a sufficient number of successive cell cycles of growth and division to generate macroscopic tumors

create new blog vessels to get nutriments

allow cell escape and metastasis formation

change cellular response phenotypic via plasticity

senescence

cancer can be considered as a living thing on its own

beyond the cellular level, impacting tissues

1.1.6 4 cancer conditions

mutation

epigenetic reprogramming

inflammatory context

disruption of microbiota

1.1.7 phases of cancer

initiation

promotion

tumorigenesis + neoangiogenesis

evolution (local, regional, metastasis)

1.1.8 cancer classification:

tumor, node, mestastasis

stages classification:

stage 0 which corresponds to a so-called in situ tumor

stage 1 which corresponds to a single, small tumor

stage 2 which corresponds to a larger local volume

stage 3 which corresponds to invasion of the lymph nodes or surrounding tissues

stage 4 which corresponds to a wider extension in the body in the form of metastases

1.1.9 cancer causes

various reasons why

environment

inherited mutations

mistake in DNA copy

1.1.10 personalized treatments

revolution

rapid advances

help of mathematics

help of AI

1.2 Introduction to Mathematical Optimization

1.2.1 optimization def

selection of a best element, with regard to some criteria

1.2.2 in math: more precisely

optimization problem consists of maximizing or minimizing a real function by systematically choosing input

1.2.3 notion of allowed set

1.2.4 discrete vs continuous optim

1.2.5 many real-world and theoretical problems may be modeled in continuous general framework

1.2.6 max(f) <=> min(-f) hence only min

1.2.7 notion of local vs global min

1.2.8 feasibility

1.2.9 existance

1.2.10 optim algos

1st order

gradient descent

line search

quasi-newton methods

2nd order

newton's method

0th order

brute force

heuristics

1.2.11 least squares

1.2.12 multi-objective optimization

1.3 Introduction to Artificial Intelligence

1.3.1 quick def

1.3.2 general idea

1.3.3 common architectures

FC

MLP

CNN

RNN

transformers

1.3.4 Classic AI vs Learning AI

1.3.5 Machine learning vs Artificial Intelligence vs Deep Learning

1.3.6 applications

1.3.7 learning types

supervised

un-supervised

self-supervised

reinforcement / semi-supervised

1.3.8 tasks

classical tasks

regression

classification

partitioning

dimension reduction

generative AI

images => training is difficult

text

1.3.9 recent progress

computer vision

playing games

(a way to assess intelligence)

image generation

text generation

healthcare

Radiotherapy

Abstract

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2.1 Patient Path

2.1.1 Detection / diagnostic

2.1.2 RT Prescription

2.1.3 CT scan

2.1.4 Contouring

2.1.5 Treatment Planning

2.1.6 Irradiation Sessions

2.1.7 Follow-up

2.2 Machines

2.2.1 Molds / 3D-RT

2.2.2 MLC-LINAC

2.2.3 Tomotherapy

2.2.4 CyberKnife

2.2.5 Brachytherapy

2.3 Irradiations techniques

2.3.1 IMRT

Step and Shoot

Sliding Window

2.3.2 VMAT

2.4 Treatment Planning Systems

2.4.1 Manufacturer

Eclipse (Varian)

ONE | Planning (Elekta)

Precision (Accuray)

2.4.2 Non-manufacturer

RayStation (RaySearch)

matRad (German Cancer Research Center - DKFZ)

AutoPlan (TheraPanacea - coming soon)

2.5 Dosimetry steps

Challenges

2.5.1 BOO

2.5.2 FMO

2.5.3 LF

2.6 Simulation

Dosimetry Optimization

Abstract

3.1 Optim engine: classic and dose mimicking

3.2 relation between optim doses (distance and network)

3.3 ESTRO (novel approach with graph theory)

Automation: Classical Approach

Abstract

4.1 RL + classic optim algo (AIME / ASTRO)

Automation: Deep Dose

Abstract

5.1 DVH guided deep dose + dose mimicking algo (SFPM / SFRO)

Conclusion

Perspectives