Prospectus

Automated radiation therapy treatment plan generation combining prior data and novel optimization techniques

Public private partnership in waste management

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Bowen Xiang

Spring, 2020

Department of Biomedical engineering

Signed: Bowen Xiang

Approved: ____ Date _________________

Instructor Name (Dr. Tsai-Hsuan Ku), Department of Engineering and Society

Approved: ____ Date _________________

Tech advisor Dr. Tyler Watkins

Automated radiation therapy treatment plan generation combining prior data and novel optimization techniques

Current radiation treatment planning relies on human expertise and experimental determination of achievable radiation dosimetry. This project aims to predict achievable radiation dose utilizing the power of artificial intelligence and big data.

Importance of the problem and Critical Barrier to Overcome:

The quality and ultimate success of cancer treatment around the world depends on available technology and the human ability to harness that technology. Highly specialized training of physicians, physicists, dosimetrists, and radiation therapists can ensure high quality radiation treatment. However, it is our view that artificial intelligence may have the ability to enhance treatment efficiency, improve treatment quality, and overcome human limitations in implementing advanced technologies. The critical barrier to overcome is providing an in-depth understanding of patient-specific achievable dosimetry and the inherent tradeoffs in radiation dose delivery. An ability to accurately characterize dose and dose surrogates such as the dose volume histogram (DVH) which takes into account the trade-off between target coverage, normal tissue dosimetry, and varying delivery methods has not been developed. This deficiency is largely due to variability of anatomical structures between patients and physician preference models.

Improvement in Clinical Practice:

If patient-specific radiation dose can be predicted a priori; we predict three major clinical advantages to current clinical methods: (1) efficiency, (2) consistency, (3) quality. An example is inverse planning in Intensity Modulated Radiation Therapy (IMRT). IMRT treatment plan quality depends on the planner's level of experience (Wu et al., 2011) and the amount of time the planner invests in developing the plan,(Wu et al., 2011) It has been shown, by providing an estimate of radiation dose, the planner can find a similar or better plan faster (ref). For the consistency of treatment, a data-driven AI approach will inherently compare treatment plans with acceptable prior treatment data with added ability to avoid human errors. Finally, a complete understanding of patient-specific dosimetric tradeoffs will inherently improve patient-specific plan quality independent of training and experience, and will ultimately improve treatment outcome.

Transforming the field of Radiation Therapy:

Historical, manual methods of radiation treatment planning will be replaced by automation. In order to ensure quality is consistent and preserve the necessary physician decision making, the automation should provide a patient-specific plan set including theoretically achievable DVH values and tradeoffs. We will present an automated algorithm to perform this crucial step in integration of AI in clinical radiation oncology.

We are creating a dosimetric prediction model which allows a priori estimation of 3d dosimetry, DVHs, and the tradeoff space for dose, Organ at Risk (OARs), and varying delivery strategies. When estimating the 3D dose distribution of patients, we consider the high and low gradient dose distributions based on prior dosimetry, similar to the method of Ahmed et al(Ahmed et al., 2017). The high gradient dose distributions are mainly driven by the target dose and surface shape, while low gradient dose distribution increases the dependence on the target volume. FDVH curve is generated from the assumption that the target is uniformly covered by the prescribed dose. We estimate the best possible sparing which is the lowest possible DVH for the OARs of any patient at the given full coverage target volumes by the prescribed doses. This method should also be applicable to the challenges posed by the anatomical structure of specific patients.

Explain gaps the project is intended to fill

What we need to do now is to solve how to use appropriate methods to find out the central points of anatomical structures from different patients to determine the DVH of OARs.

Potential contribution of this work to the scientific field(s) and public health

The method is completely different from other knowledge-based plans because it is independent of treatment plans and previous experience and close to the lowest possible DVH of OAR. It can make us give the required feasible dose of patients more accurately.

Summarize novel findings to be presented as preliminary data in the Approach section

The project we are developing right now is to reconstruct the work of Dr. Saeed and improve the program based on his method. The algorithm does not require a database of prior plans but rather derives the FDVH from assuming that the targets are uniformly covered with the prescription doses. It is easily parameterized based on a short list of model geometrical datasets. The method is agnostic to the planning technique and beam arrangement, requiring only the regions of interest, the energy, and, optionally, the CT dataset as inputs. This is the merit but also the disadvantage of this method. It is designed to approximate the lowest possible OAR DVH based on that OAR's geometrical relationship with the target, but a not likely achievable one for the class of plans in the presence of realistic competing objectives. The method is best suited for the parallel OARs close to the target and is currently implemented for coplanar beam arrangements (Ahmed et al., 2017). We are trying to eliminate the limitation by query the 5 most similar previous patients from the database in order to help the clinician to make the best decision. For right now, we are applying the combination of high gradient spread function (HGDS) and low dose spread function (LDS) to the voxel outside the target to find the DVH of the outside voxel as accurate as possible. The ultimate goal of our program is to provide a better tool for the clinicians and give them a chance to monitor the DVH of space outside the target and find the most similar previous case for the current patient and thus make the best decision.

More specifically, the innovation that we want to make when the project is done is to make the model we use right now more realistic and feasible. In other words, these are also the challenges we are facing. At the end of our project, we can find out the DVH for each voxel in the region of interest and our program should solve the problem due to the irregular shape of the organ and overlap among the organs. Therefore, when the clinicians query the previous patient data, they will have a more accurate and precise similarity between the data and the current patient.

Public private partnership in waste management

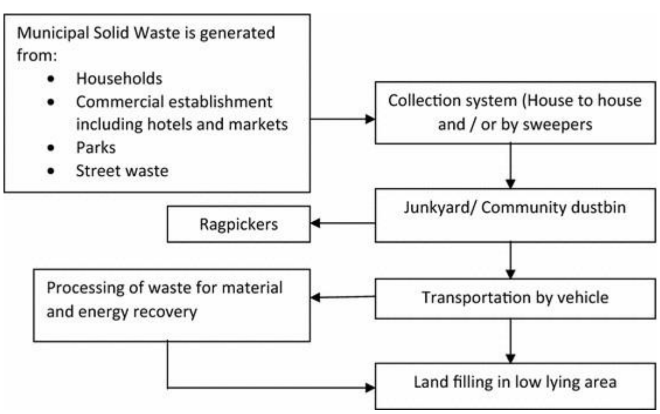
Introduction

Public private partnership (PPP), involving collaboration between government agency and private sector company, plays an important role in waste management system. There are two different collaboration systems including monopoly and distributed waste management. The decision to choose which system will be used is not easy since there are both advantages and disadvantages in both systems and too many factors that need to consider. Interpretative flexibility, meaning each technology artifact has different meanings and interpretations for various social groups, is another important term that will be used in my research. Since our team project is trying to innovate a more efficient waste system, my analysis of these two systems is inevitable and could be useful for our final solution.

My research starts with a controversy for RecycLA. RecycLA is an garbage-hauling program which is a perfect example of monopoly waste management. It switched multi-family residential buildings, restaurants, factories and other businesses from the open market, in which they could negotiate with the garbage company of their choice, to an exclusive franchise system, in which the city selects one trash hauler for that area, sets the rates and regulates the service. The supporters argued that by creating little trash monopolies, the city could set more aggressive requirements, including stricter recycling targets and higher wage mandates. However, the price of waste disposal for residents is skyrocketing over these years. Since the waste management system can have such significant influences on residents' life, we feel responsible to figure out the advantages and disadvantages of these two systems. Charlottesville and LA are different cities and citizens in these two cities have different concerns. Therefore, my research question is to explore influences of different models of PPP in different cities.

The waste management systems in LA and Charlottesville will be compared and discussed in my research in order to figure out the advantages and disadvantages of both systems. Furthermore, since the different situations in these two cities, my research could also be provided as a suggestion for deciding which system will best fit in other cities.

Literature review



The waste management price including tax and bill from company is what concerns the citizens most. In order to figure that out, first we need to have a basic understanding of the whole process of how the waste is treated. The collection, transfer and transport of waste are basic activities of waste management systems all over the world. These activities all use energy and fuels, primarily of fossil origin. Electricity and fuel consumptions of the individual processes were reviewed and greenhouse gases (GHG) emissions were quantified (Eisted, Larsen, & Christensen, 2009). These are the part of the cost in waste management.

Moreover, a fundamental understanding of monopoly and distributed system could also be helpful for understanding my research. The theory of public choice views the government bureaucracy as a neoclassical actor seeking to maximize public budgets and public power. As such, government service production is expected to be excessive, inefficient and unresponsive to citizen desire for choice. Privatization, in this context is offered as a panacea to break apart government monopoly, promote efficiency through competition, and provide citizens with greater choice in a market context. Charles Tiebout first challenged the notion of public market failure by arguing that, at least at the local government level, a market does exist for public services providing both competitive pressures on local government managers to be efficient, and choice to mobile citizen consumers. Thus, the importance of competitive markets has figured heavily in the US privatization debate (Warner & Bel, 2008).

STS framework and method

Social construction of technology (SCOT) diagram is an indispensable tool for my research. Since there are different stakeholders, problems and solutions in these two cities, two SCOT diagram will be created for better comparison. For these two examples, the stakeholders are the same including municipal government, private sectors and citizens. They have different concerns in different cities. Speaking of collecting date, I would interview the citizens in Charlottesville to ask their opinions for current waste system and I will create online questionnaires to collect the opinion of citizens in LA. Since government policy of waste management could also affect the decision, I will try to meet with officers in relevant departments. Last but not least, private-sector companies also play an important role in this model, I will also try to meet with staff in the company to ask their opinions.

Bibliography:

Wu, B., Ricchetti, F., Sanguineti, G., Kazhdan, M., Simari, P., Jacques, R., … McNutt, T. (2011). Data-driven approach to generating achievable dose-volume histogram objectives in intensity-modulated radiotherapy planning. *International Journal of Radiation Oncology, Biology, Physics*, *79*(4), 1241–1247. https://doi.org/10.1016/j.ijrobp.2010.05.026

Wu, B., Pang, D., Simari, P., Taylor, R., Sanguineti, G., & McNutt, T. (2013). Using overlap Volume histogram and IMRT plan data to guide and automate VMAT planning: A head-and-neck case study. *Medical Physics*, *40*(2), 021714. https://doi.org/10.1118/1.4788671

Ahmed, S., Nelms, B., Gintz, D., Caudell, J., Zhang, G., Moros, E. G., & Feygelman, V. (2017). A method for a priori estimation of best feasible DVH for organs-at-risk: Validation for head and neck VMAT planning. *Medical Physics*, *44*(10), 5486–5497. https://doi.org/10.1002/mp.12500

Eisted, R., Larsen, A. W., & Christensen, T. H. (2009). Collection, transfer and transport of waste: Accounting of greenhouse gases and global warming contribution. *Waste Management & Research*, *27*(8), 738–745. https://doi.org/10.1177/0734242X09347796

Warner, M. E., & Bel, G. (2008). Competition or Monopoly? Comparing Privatization of Local Public Services in the Us and Spain. *Public Administration*, *86*(3), 723–735. https://doi.org/10.1111/j.1467-9299.2008.00700.x