Designing Minimum Discomfort Medical Fixtures using Submodular Coverage Algorithms

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***Abstract*— to be finalized!**

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I. INTRODUCTION

Every year, [todo:X] cases of cancer are treated with Radiation therapy in United States. External Radiation Therapy, along with its variations, is a common form of radiotherapy treatment. With external radiation therapy, radiation is usually administered as a complex combination radiation beams directed at the tumor. Advanced techniques of dose calculation and treatment delivery are employed to permit design of treatment fields to maximize the differential in dose delivered to tumors and healthy tissue.

Accuracy and precision in patient positioning is essential for success of external radiation delivery systems. Since radiation therapy is delivered over multiple sessions, repeatability of a patient positioning system is important to maintain registration between the patient and radiation delivery equipment.

Presently, a variety of patient positioning systems are employed in clinical procedures. However, most if not all of these systems are one-size-fits-all. This leads to problems in maintaining conformance between simulated and physically delivered radiation dose distributions over multiple sessions. Furthermore, these patient positioning systems are inconvenient for the patients often requiring local anesthesia to relieve pain.

For instance, stereotactic radiotherapy (SRT) is used primarily for treating tumors in the brain. The procedure has sub-millimeter accuracy, but assumes exact patient to machine registration. Commercially available head positioning solutions for SRT usually require the patient's head to be placed in a cubical frame with multiple pegs securing the head in its place. One example of such a system is illustrated in figure 1. These pegs are uncomfortable and the the frame only allows the head to be placed in a small set of orientations.

Additionally, the ability to easily position the head in any orientation simplifies planning for radiation dose in external radiation therapy. For e.g., if a patient is immobilized in a non-supine position, reaching tumor might become easier due to decreased hindrance from healthy tissue.

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Fig. 1. The figure shows a Leskell Coordinate Frame G used for Stereotactic Radiosurgery. As illustrated in the picture, the patient head is placed in a frame and secured in place with use of multiple pins

The key insight in building a principled solution for immobilization is customization to patient anatomy. We propose a solution which leverages redundant point contacts and uses surface contacts. This higher degree of customization is also facilitated by recent advances in additive manufacturing and 3D printing.

After a 3D reconstruction of the patient anatomy using a CT (or MRI) scan, we use redundant contact points and surface contacts to the set of minimal grasp points required for immobilization. This reduces maximum force at any contact point. The benefit of inclusion of additional contact points is a submodular function, which allows us to find the optimal set in reasonable time.

This study builds upon the previous work from Schulman et al [1]. In this paper,

- We describe an algorithm which minimizes maximum contact force and immobilizes the subject.
- We evaluate the performance of algorithm on multiple instances of [todo:X] body parts.
- We create a patient specific head positioning system using 3D printing.

II. RELATED WORK

Fixing the frame to the patients head is simplicity itself - four self-tapping screws keep the lightweight frame firmly and accurately in place, while local anesthesia minimizes any patient discomfort during the procedure.

Its excellent robustness and quality guarantees precise and simple repositioning in routine cranial as well as head, neck and shoulder immobilization.

REFERENCES

[1] J. D. Schulman, K. Goldberg, and P. Abbeel, "Grasping and fixturing as submodular coverage problems," 2011.