Anomaly detection for treatment planning and a learning health system in radiotherapy

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Contents

I. Summary

The final objective of the entire project is to improve quality of clinical data available to physicians in order to minimize the risk involved with radiotherapy for cancer patients. The target goal for the time period given is to improve the integrity of the contour model data using a learning health system by implementing tools that can help identify potentially erroneous data with statistical anomaly detection. We aim to build a framework that allows modular insertion of various detection rules in order to allow active approach using constantly updated clinical databases. Previous integrity checking focused on pre analyzed methods across a set of patients for standardized integrity and treatments.

Figure 1: The Cyberknife robot

II. Background, Specific Aim and Significance

As the average lifespan of an individual around the world increases due to medical advances and general healthcare, the probability of an oncogenic mutation occurring also increases. Our bodies experience millions of mutations every day when doing genetic replication and has a robust system for detecting and eliminating such errors. However, as our age increases, the probability of the system missing a mutation or deteriorating increases dramatically. According to the 2015 NCI's Surveillance, Epidemiology, and End Results program, it was determined that the median age of cancer diagnosis is 66 years. 25.4% new cancers occur in the 65-74 year age group and over 75% of all new cancers occur past the age of 55 years. Several types of cancers are also much more common in younger children and adolescents than adults due to having origins in the developmental time period of our lives. For example, neuroblastoma usually starts in the fetus/embryonic stage of our life.

As cancer accounts for 22.5% of total deaths in the United States in the past 5 years, treatment options for cancer become an increasingly important medical problem. There are several main treatment plans at the moment, including surgery, radiation therapy, and chemotherapy. At the moment, there is also a lot of development in immunotherapy, targeted/precision therapy, hormone therapy, and stem cell transplantation. In the past ten years and the future ten years, radiation therapy is becoming increasingly part of the treatment paths for cancer patients. It is projected by 2020 that 35% of cancer patients will have some form of radiation therapy as one of their primary options.

Radiation therapy involves bombarding cells with high energy waves, such as x rays and electrons, in order to cause cell death. The main way that the waves work is by damaging the DNA of the cell and preventing cell division. There are two main ways radiation therapy is done. First, internal radiation therapy, where a radioactive source is placed inside of the body. Second, external radiation therapy, where high energy waves are directed at a target location.

However, radiotherapy has several drawbacks. First, the high energy waves can be directed, but are not selective in their target. If there are any healthy cells in the neighborhood of the affected location, then the waves can kill both cancer cells and healthy cells. There is some research demonstrating that healthy cells have better regeneration after such an operation, but even well designed treatments can not guarantee the lack of side effects. This is especially true for operations involving more delicate regions of the human body, such as tumors that may overlap with the spine.

Modern radiotherapy plans involve mapping organ and tumor contours before the radiotherapy operation in order to let oncologists better understand patient anatomy. By understanding how the tumor interacts with the surrounding environment, the radiotherapy treatment can be better designed for increased accuracy and consistency. Currently, these contour models involve a heavy manually component, with doctors and technicians taking individual slices and combining them for a final image. There has been some work to improve the workflow with some automation to build the contour models through software, however, sometimes such software can result in very unusual builds and results.

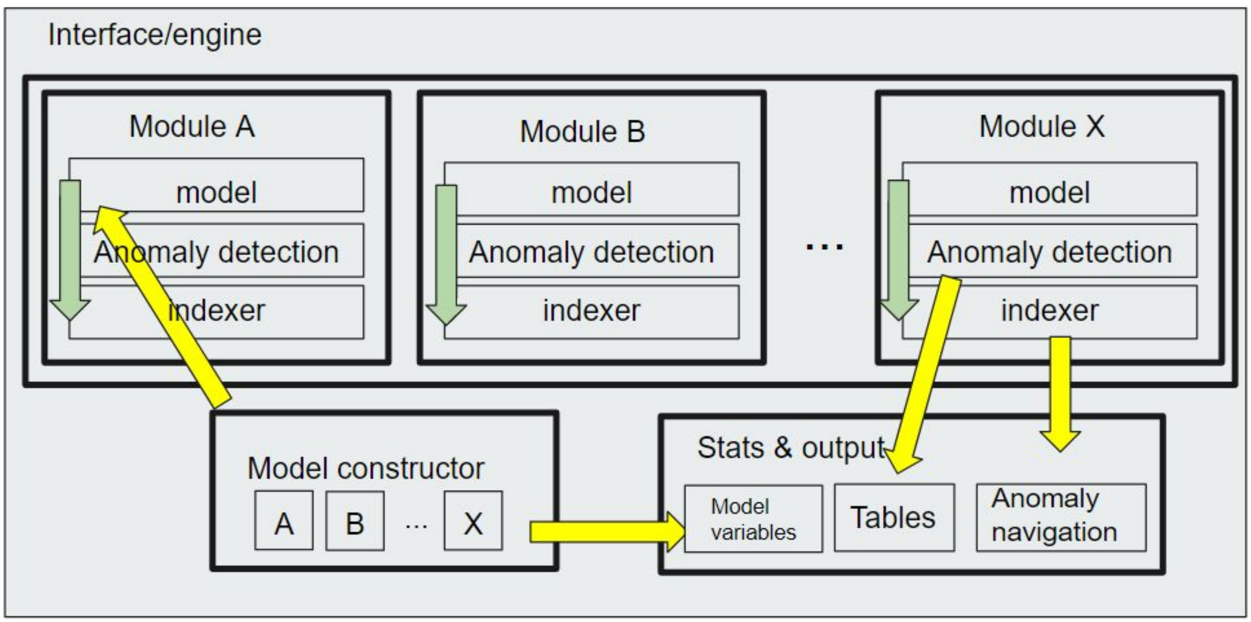
Since these treatments have small margins of error, any inconsistency and flaw in the built models can have a significant effect on the future treatment of patients. For example, if a model demonstrated that the tumor did not cross the spine when it really does, then the radiotherapy operation could send high energy waves into the spine, causing severe injury and permanent disabilities. Due to this, these contour models need to have integrity checks in order to catch such mistakes early in the planning process.

There exists such software setting some standards for models based off of previously collected data and standardized variables, however, there is no software that has an active approach to the problem. We hope to be able to build a framework to allow a module and active approach for integrity checking of mapped organ contours to detect these anomalies. We hope that by using updated and live clinical databases combined with this framework software, we can create a system that allows the user to implement unique integrity checks.

III. Framework

- Well documented API for developing new integrity checks
- Modular system that allows for insertion of new anomaly detection modules
- Indexer/tagging that marks data as suspect
- Stats output module to report all detected errors
- Allow real time check of single data point in interface

Below is an alpha concept draft of framework:



IV. Deliverables

Minimum

- Working Framework that allows for modular insertion of new integrity checks
- Documented API to develop new integrity checks

Expected

- Implemented existing errant detection modules into working framework
- Implement new anomaly detection modules

Maximum

- Develop and implement numerous new integrity checks
- Implement compatibility packet to allow other programs access to results easily

V. Dependencies

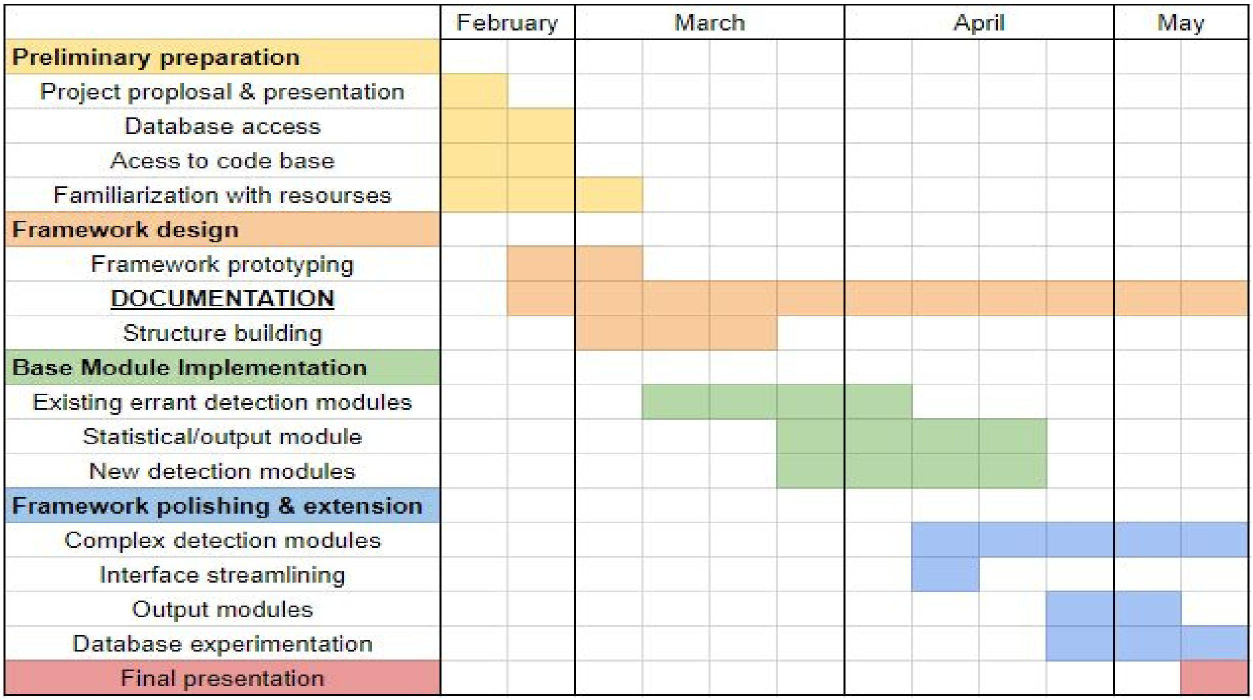
Our dependencies include:

- Access to Database
    - Status: Incomplete, We will coordinate with Dr. McNutt and Pranav to gain access to the database
        - Estimated resolution date: March: 1st
        - Alternative plan: Try to find other databases to work with
- Access to previous code
    - Status: Incomplete, We will coordinate with Dr. McNutt and Pranav to gain access to the previous code
        - Estimated resolution date: March: 1st
        - Alternative plan: Implement and develop own modules
- Access to computational power
    - Status: Incomplete, We will coordinate with Dr. McNutt and Pranav to gain access to computational power
        - Estimated resolution date: Unknown
        - Alternative plan: Work with smaller sample sizes as a proof of concept

VI. Management Plan

- Time management
    - Weekly Friday meeting with mentors
- Responsibilities
    - Daniel
        - Framework implementation
        - Model construction
        - New Module design
    - Vincent
        - Framework implementation
        - Statistic analysis & output
        - New Module design
- Project closeout
    - Final poster presentation

VII. Timeline



VIII. Milestones

Accomplishment	Estimated Date (dd/m/yyyy)	Current Status
Presentation	20/2/2018	Done
Proposal	26/2/2018	Done
Framework design	15/3/2018	In Process
Existing module implementation	25/3/2018	To Do
Statistical module	7/4/2018	To Do
First new module	7/4/2018	To Do
More complex modules	23/4/2018	To Do
Final presentation	11/5/2018	To Do

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