Data Integrity Systems for Organ Contour in Radiation Therapy Planning

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Purpose/Objectives

- The concept of data integrity systems for mapped organ contours in radiation therapy aims to improve both the accuracy and consistency of data. New advances in automated segmentation technology paired with radiotherapy dose calculations have improved the ability of clinicians to accurately contour boundaries of organs at risk in radiotherapy.
- However, with any qualitative, manually completed activity, there are margins of error, which if not detected, can have implications on the treatment of patients and how physicians treat future patients.
- Poorly or spuriously mapped contours by physicians and residents has the potential to result in erroneous radiation dosing of critical, noncancerous anatomy and has the potential to skew predictive models developed by data scientists to extrapolate post-treatment parameters, such as weight loss and dysphagia.
- The purpose of this research is to develop effective data integrity models for contoured anatomy in a radiotherapy workflow for both real-time and retrospective analysis. It aims to improve the quality of clinical data for data scientists and physicians, minimizing the risk of radiation overdose to critical anatomy for patients.

Materials/Methods

- The contour data used in this study comes from the Oncospace database, a learning health system comprised of clinical radiotherapy patient data.
- Within this study, two classes of contour integrity models were developed: data driven models and contiguousness models. The data driven models aim to highlight contours which deviate from a gross set of contours from similar disease sites and encompass the following regions of interest (ROI): bladder, femoral heads, spinal cord, and rectum.
- Data driven models were built using ROI volume and extent. ROI volume Extent was calculated by querying run-length encoded binary mask data for contours and computing indices in 3D space using the following equations. The spinal cord and rectum disease site models use slice-based extent, which computes lateral and anterior-posterior indices at each superior slice.
- The contiguousness models, which individually analyze the geometry of contours to detect possible errors, are applied across many different ROI's and are divided into two metrics: Extent and Region Growing over volume.
- The extents algorithm iterates across a row of voxels to ensure that they extent in a linear manner and do not have gaps. The region growing algorithm selects a voxel in the contour and grows throughout all neighboring voxels until no growth path remains.
- For each data driven model, the algorithm was developed on a developmental patient list and tested on a different list of patients with the same contours. A blind review was done over all model sets to check for false negative detections.

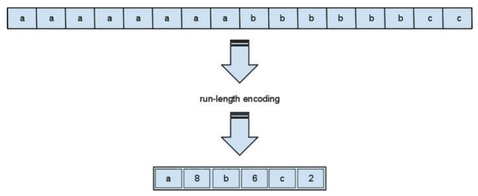


Fig 1. Shows a diagram explaining run length encoding. Run length encoding is a lossless data compression method which stores long runs of data into single data counts. A common application of this methodology is in JPEG files.

Results

- After completing the analysis, all data integrity models were successful at detecting suspicious or abnormal contours within the clinical workflow, however, to differing levels.
- After analysis, we found that 70% of detected bladder contours were verified as suspicious. The spinal cord and rectum models verified that 73% and 80% of contours were suspicious respectively. The contiguousness models were the most accurate models and the Region Growing model was the most accurate submodel.
- 100% of the detected noncontiguous contours were verified as suspicious, but in the cases of spinal cord, femoral heads, bladder, and rectum, the Region Growing model detected additional two to five suspicious contours that the Extent model failed to detect. All data driven models failed to detect all suspicious contours.
- The Region Growing contiguousness model produced zero false negatives in all regions of interest other than prostate. The contiguousness via extent model took an average of 0.2 s per contour. The region growing method had a longer runtime which was dependent on the number of voxels in the contour.

Table 1: Results of Data Driven Models

Region of Interest	Integrity Model or Metric	Contours Tested	Contours Detected as Suspicious	Contours Verified as Suspicious	False Negative Suspicious Contours
Bladder	CT Emptiness Verification	594	36	25	5
Right Femoral Head	Femoral Head Distinction Model	559	235 Detected with Ball/Shaft; 115 Detected with Ball only	235 Ball/Shaft Verified; 94 Ball only verified	N/A
Left Femoral Head	Femoral Head Distinction Model	561	274 Detected with Ball/Shaft; 76 Detected with Ball only	274 Ball/Shaft Verified; 65 Ball only verified	N/A
Rectum	Slice Based Extent Model	1148	12	10	9
Spinal Cord	Slice Based Extent Model	1148	30	22	60

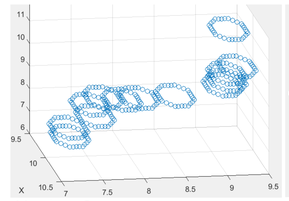
Table 2: Results of Contiguousness by Region Growing Model

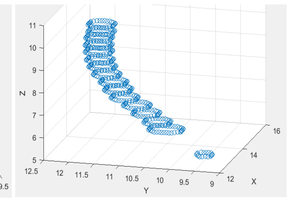
Region of Interest	Number of Contours Tested	Contours Detected as Suspicious	Contours Verified as Suspicious	False Negative Suspicious Contours
Bladder	594	10	10	0
Right Femoral Head	559	9	9	0
Left Femoral Head	561	15	15	0
Prostate	322	1	1	4
Rectum	769	19	19	0
Spinal Cord	1148	82	82	0
Brainstem	1140	14	14	0

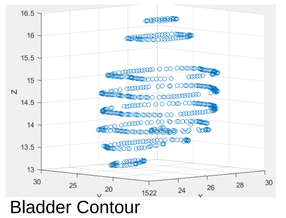
Table 3: Results of Contiguousness by Extents Model

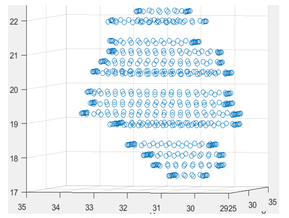
Region of interest	Contours tested	Contours detected as suspicious	Contours verified as suspicious	False negative suspicious contours
Bladder	594	8	8	2
Right femoral head	559	7	7	2
Left femoral head	561	13	13	2
Prostate	322	1	1	4
Rectum	769	14	14	5
Spinal cord	1148	80	80	2
Brainstem	1140	14	14	0

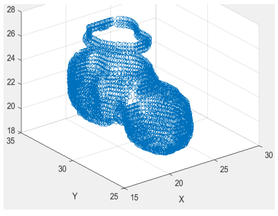
Examples of Detected Contours

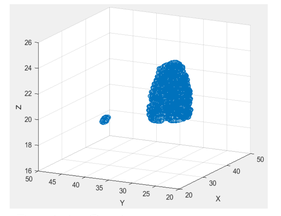

Urethra Contour

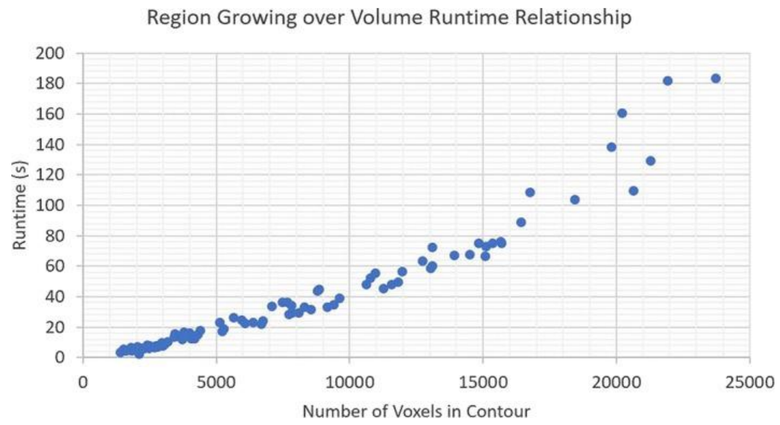

Urethra Contour


Bladder Contour


Bladder Contour


Femoral Head Contour


Prostate Contour



Discussion/Conclusion

- The data driven models are effective in finding specific cases of contours but, due to their lesser accuracy and more significant false negative percentages, are more suited for retrospective analytics.
- The contiguousness models are both suited for real time clinical use due to their zero false positive and minimal false negative percentages. The region growing algorithm does have a significantly longer runtime when compared to the extents model, it still is feasible for real time use and could be improved for a faster runtime in future iterations.
- More so, this study shows the need for contour integrity system in clinical radiotherapy during the planning process. Potentially, such a tool could be used in conjunction with CT and Atlas based auto-segmentation methodologies.
- Can minimize the risk of radiation overdose to critical anatomy in a clinical workflow but aid physicists, clinicians, and data scientists in the creation of post-treatment predictive models with the goal of further improving patient care.