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Ovarian Cancer Detection in Computed Tomography by Body Part Regression and Multiple Instance Learning

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Abstract

This thesis presents a classification workflow that using deep learning models for the detection of ovarian cancer in computed tomography (CT) images. The workflow consists of two models: a body part regression (BPR) model and a multiple instance learning (MIL) classification model. Manual annotation of ovarian cancer is difficult to obtain, so the BPR model is used to first obtain the pelvis bounding box, followed by the MIL model to classify the cancer. Through this workflow, the algorithm effectively filters out irrelevant body parts, such as the head, legs, and abdomen, and acquires the pelvis region that always contains the ovary. The algorithm is trained and evaluated using datasets from Chang Gung Memorial Hospital, and the results show an AUC of 0.889 on the test set. These findings demonstrate the potential of the algorithm to accurately classify ovarian cancer in CT images without requiring segmentation masks or manual annotation.

Problem Description

Ovarian cancer ranks among the most prevalent cancers affecting women in Taiwan, posing significant health risks and challenges to the medical community. According to statistical data released by the Ministry of Health and Welfare of Taiwan in 2021, the number of ovarian cancer-related deaths ranks 10^{th} among all cancer-related deaths [1]. Early detection plays a crucial role in successful treatment, as it directly impacts treatment efficiency and patient survival rates.

Computed Tomography (CT) is a commonly used medical imaging modality for screening and diagnosing ovarian cancer. However, CT scans often capture images of multiple organs, which generates a large amount of unnecessary information. Furthermore, accurately segmenting the ovarian region and tumors remains a challenging task due to the complexity and variability of these structures.

To address these issues, we propose the development of a body part regression algorithm that accurately locates the pelvic cavity in CT images. This algorithm enhances the focus on ovarian cancer-related features without the need for additional manual annotations. Once the pelvic region was identified, we utilized a MIL classification model to detect ovarian cancer.

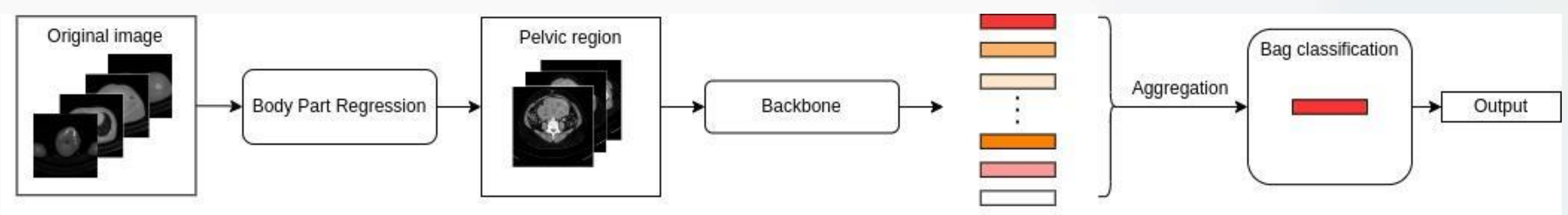
Method

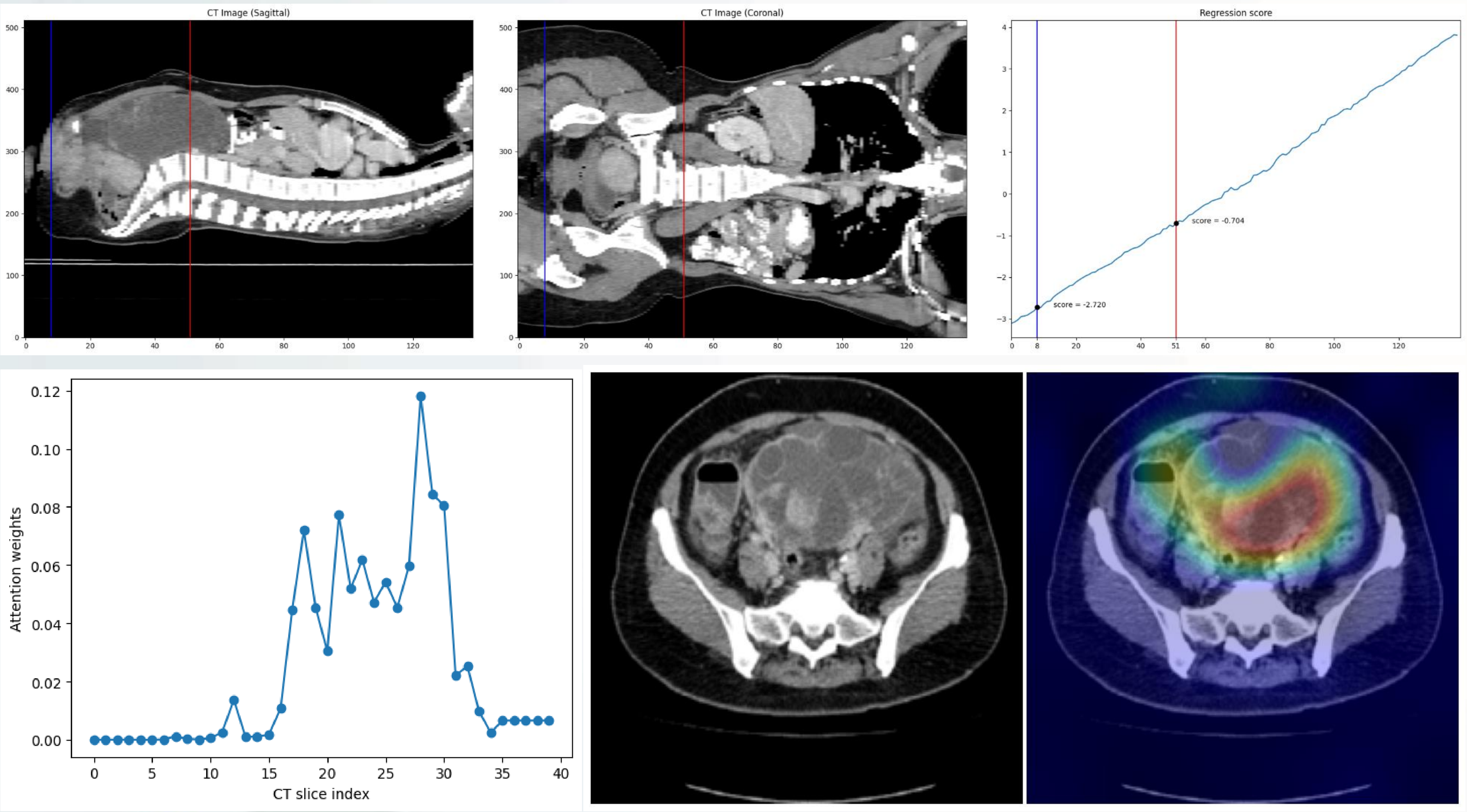
Body part regression (BPR) model [2] [3] is primarily trained using the distance and sequential order between CT slices. Sorting of the different CT images can be done by the score, thereby establishing the relationship between the score and the body part location.

Multiple instance learning (MIL) classification model mainly consists of two major components: model backbone and aggregation function.

Backbone is a module designed to encode images into meaningful feature vectors. In our process, CNN backbone is EfficientNet V2 [4] . This step transforms the 2D images (instances) in each bag into meaningful feature vectors.

Aggregation involves summarizing the multiple instances into a single representation and making a final prediction based on this representation. Common choices for aggregation functions include max pooling and mean pooling.





Validation set	AUC	Accuracy	Sensitivity	Specificity
3D DenseNet 121	0.841	0.750	0.941	0.630
Attention MIL	0.950	0.886	0.941	0.852

Test set	AUC	Accuracy	Sensitivity	Specificity
3D DenseNet 121	0.812	0.674	0.824	0.577
Attention MIL	0.889	0.814	0.882	0.769

Results

In the BPR model, each 2D CT image is assigned a score as the output. A higher score indicates that the image is located in a more superior body location. From the results of the model, it can be observed that when we select a score range of -2.8 to -0.7, this interval corresponds to a complete pelvic region. Similar scores were found for the same anatomical regions across different CT images.

In the classification model, we chose the "attention" mechanism as the aggregation function. During inference stage, each 2D image will have a corresponding attention weight, where a larger weight indicates a greater impact on the final prediction. Results indicate that the regions with higher attention weights are often located in ovaries and ovarian cancer. Further more, we employed Grad-CAM to visualize each 2D CT slice. The visualization shows the key image (i.e., the CT slice with the high attention weight) for the corresponding attention weight.

Based on the results presented in the table, it shows that MIL outperformed 3D DenseNet121 in both the validation and test sets. It demonstrated higher specificity with comparable sensitivity, which also imply that MIL has better accuracy.

Conclusions

This thesis introduces a novel workflow for detecting ovarian cancer in CT images without the need for manual labeling. Initially, a BPR model is employed to obtain the indices of lower and upper pelvis, which are subsequently used for selecting the relevant pelvic images. Following image pre-processing, a MIL model is utilized to discriminate ovarian cancer. The proposed method exhibits outstanding performance and also offers the advantage of model interpretability via attention weights and Grad-CAM, thereby indicating its promising prospects for clinical implementation in the medical domain.

References

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