Validation of Contour Extraction Using YOLACT for Analysis of NK Cell Chemotaxis

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Abstract. Immune cells play a pivotal role in assessing the overall health status of the human body. In cases of endometriosis, a condition characterized by abnormal tissue growth outside the uterus, the activity of natural killer (NK) cells, a subset of immune cells, is found to be reduced. To efficiently analyze this phenomenon, researchers employ image processing techniques. This study adopts the YOLACT image processing framework, aiming to expedite the analysis time and evaluate the accuracy of the processing.

Keywords: cell analyze · endometriosis · instance segmentation

1 Introduction

The activity of NK (natural killer) cells is one of the factors that indicate the health status of the human body. Numerous studies have been conducted on the relationship between NK cells and endometriosis, and Sampson's theory of endometrial transplantation [1] and Mayer's theory of endometrial transformation [2] are supported as a mechanism for the development of endometriosis. Both theories are known to be related to the fragility of the host's immune function, especially in terms of cytotoxicit [3–6]. In addition to cytotoxicity, chemotaxis is also considered to be an important component of antigen processing ability [7], and in fact, a decrease in chemotaxis of NK cells has been reported in endometriosis [8,9]. The analysis of NK cells is performed manually, and this analysis work is very time-consuming and places a heavy burden on the operator. Therefore, there is a need to develop a tool to efficiently analyze the video images of the cells taken, and image processing to extract the cells is necessary to realize such a tool. Although it is possible to perform rough contour extraction by using luminance features such as thresholding, it is necessary to perform robust processing against noise by using machine learning because the boundary conditions of NK cell images are shifted due to contact and optical noise. YOLACT [10] is a machine learning model that performs instance segmentation to recognize individuals in an image, and is capable of obtaining shape information because it discriminates each pixel.

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2 NK Cell Image

The illustration in Fig. 1 depicts an NK cell, serving as a representative example. In microscopic NK cell images, the central region exhibits a darker appearance, while the surrounding area appears brighter in contrast to the background [11,12]. Remarkably, NK cells are characterized by their ability to undergo body shape changes and participate in phagocytosis through the extension of pseudopodia. Consequently, integrating shape information through segmentation, along with positional data, facilitates a comprehensive and intricate analysis of these cells.

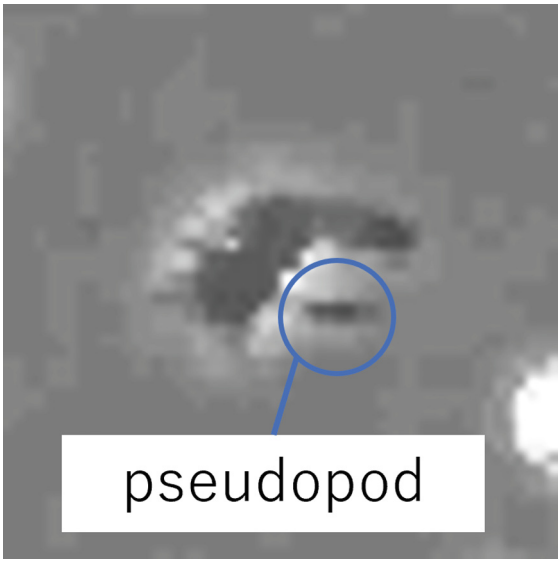

Fig. 1. Example of cell image

3 Segmentation by YOLACT

YOLACT [10], a machine learning model developed by Bolya et al., specializes in instance segmentation. Instance segmentation involves pixel-level classification of objects in an image, providing both class and object information. Leveraging this technique, we can directly obtain the shape of a cell from the predicted region of the cell in the image.

Figure 2 illustrates the structure of YOLACT. Initially, FPN performs feature extraction on the input image. Subsequently, Protonet creates a prototype mask using the extracted features, while PredictionHead generates bounding boxes, class labels, and mask coefficients.

Through the combination of prototype masks and mask coefficients, YOLACT produces the segmentation output for each individual object. This segmentation output precisely delineates the cellular region in the image, allowing for accurate shape analysis at the pixel level.

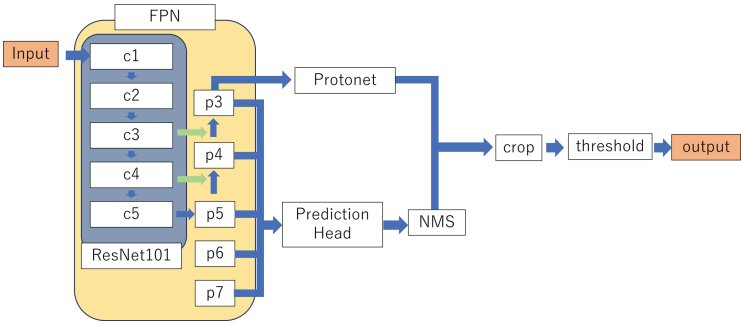

Fig. 2. Structure of YOLACT

4 Experiment

In this study, we examine a total of 300 frames from a video capturing cells through a microscope. The analysis focuses on two specific cells, and we employ both manual segmentation and YOLACT segmentation methods for our investigation. By comparing the results obtained from these two approaches, we assess the analysis time, circularity measurements, and movement speed of the cells.

5 Result

The observed results from the analysis provide valuable insights into the efficiency and accuracy of YOLACT compared to manual segmentation. The significant time advantage offered by YOLACT, approximately 1/30 faster, highlights its potential as a time-saving tool for large-scale image analysis tasks. Furthermore, the examination of circularity variation in Figs. 3 and 4 allows us to understand how the shape of the cells evolves over time. Comparing the circularity measurements obtained from both manual and YOLACT segmentation in Table 2, we find that most of the errors lie within a narrow margin of 0.1. This demonstrates the reliability of YOLACT in accurately capturing the circularity of the cells. Even for the remaining half, where the errors are within 0.2, the differences are still relatively small, suggesting that YOLACT provides reasonably accurate shape information. These findings collectively highlight the effectiveness of YOLACT in streamlining the analysis process without compromising accuracy. The capability of YOLACT to rapidly process large amounts of data while maintaining comparable shape measurements to manual segmentation makes it a

promising tool for cell image analysis. Nonetheless, it is essential to acknowledge certain limitations. YOLACT's performance may be influenced by factors such as image quality, cell density, and segmentation parameters, which could lead to slight discrepancies in the results. Additionally, manual segmentation might still be preferred in cases where a higher level of precision or specialized analysis is required, particularly in complex cellular environments. In conclusion, this study demonstrates the potential of YOLACT as a time-efficient and reliable tool for cell image segmentation. By combining its advantages with manual segmentation, researchers can achieve a more comprehensive understanding of cell behavior and characteristics. Future research could explore further optimizations and parameter tuning to enhance YOLACT's performance and adaptability in various microscopy-based studies (Table 1).

Table 1. Performance comparisons on each cell

	cell A		cell B	
	manual	YOLACT	manual	YOLACT
time	58:17	1:35	1:00:38	1:50
circularity	0.558	0.517	0.519	0.480
move	3.337	3.366	1.265	1.551

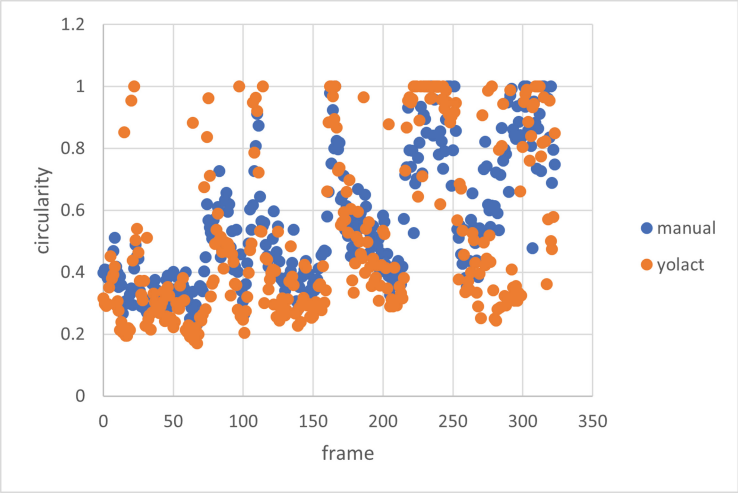

Fig. 3. Comparison of manual and YOLACT segmentation for cell A

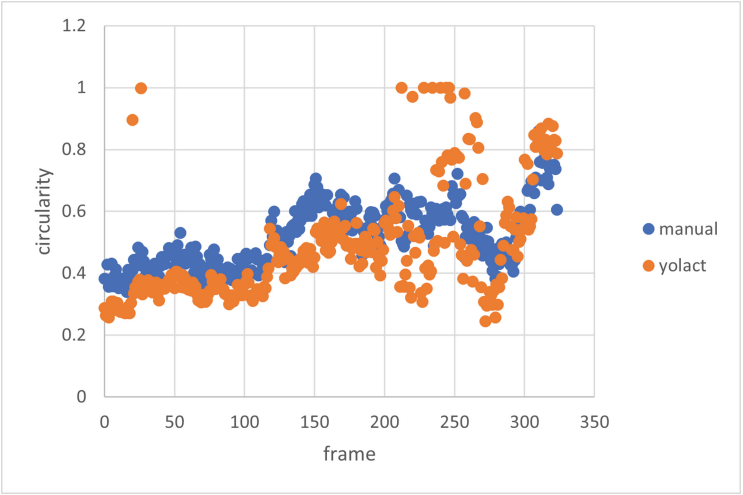

Fig. 4. Comparison of manual and YOLACT segmentation for cell B

Table 2. Distribution of errors in each data

	cell A	cell B
Error(< 0.1)	174	191
Error($0.1 < 0.2$)	86	104
Error($0.2 < 0.3$)	28	14
Error($0.3 < 0.4$)	11	7
Error($0.4 < 0.5$)	12	6
Error(> 0.5)	13	2

6 Conclusion

In this study, we conducted a comparison between human segmentation and YOLACT segmentation techniques. The experimental results demonstrated that YOLACT segmentation provided values that closely approximated those obtained through human segmentation. Moving forward, our primary objective is to correlate these segmentation data with cell behavior. By analyzing the relationship between the segmentation results and cell dynamics, we aim to gain deeper insights into cellular processes and their implications on overall cell health and function. This research lays the foundation for future investigations into the potential applications of YOLACT segmentation in understanding cell behavior and advancing our understanding of cellular biology. By refining and expanding our analyses, we can unlock new avenues for cellular research and contribute to advancements in various scientific and medical fields.

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