Electronic Supplementary Material (ESI) for Analyst.

HFM-Tracker: A Cell Tracking Algorithm Based on Hybrid Feature Matching

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Common types of cellular deformation

During the detection and tracking of MCF-7 cells, we primarily focused on three types of cellular morphological changes: elongation, contraction, and division. Each type of change reflects the characteristics of the cell under different physiological or pathological states. During elongation, MCF-7 cells may come into contact with surrounding cells, thus participating in intercellular information exchange. Contraction of MCF-7 cells, on the other hand, is related to the process of cell death and may indicate that the cell is in the later stages of apoptosis. Finally, in analyzing the division of MCF-7 cells, our approach is to retain the original cell identifier for one of the daughter cells after division, while assigning a new identifier to the other newly formed daughter cell.

Models and algorithms for contour offset regression

To substantially improve cell detection and, as a result, advance the accuracy of cell tracking, we have refined the existing contour regression model by integrating a novel Contour Attention (CA) mechanism. This modification entails integrating cell boundary information directly into the CA module. Specifically, after constructing the initial cell contours and obtaining the original images using an initial contour-based model, we first employs multi-layer circular convolutional networks to extract key features of the cell contours. Subsequently, given the extracted contour features, the CA module is utilized, which leverages category-independent contour boundary predictions for supervision. The edge map generated by the CA module is then passed to several additional convolutional layers, followed by a sigmoid activation function to produce an image-level attention map. This attention map is multiplicatively combined with the contour offset values outputted by the contour offset prediction module, allowing for an adaptive reweighting of the predicted contour offsets, thereby enhancing the accuracy of contour prediction. This methodology ensures a more precise and effective approach to cell contour detection and tracking.

Validation of the HFM-Tracker algorithm

To validate the performance superiority of the HFM-Tracker algorithm, we conducted a comparison with other existing cell tracking algorithms[1-3]. As reflected in the results presented in the table S1, our method achieved the highest performance metrics among all the algorithms compared. Specifically, compared to the latest ByteTrack algorithm, the HFM-Tracker exhibited improvements of 0.9% in AP, 1.9% in MOTA, and 2.8% in IDF1. These comparative outcomes further underscore the exceptional capability of the HFM-Tracker in the domain of cell tracking.

Table S1 Comparison of HFM-Tracker algorithm with other existing cell tracking algorithms

Model	AP	MOTA	IDP	IDR	IDF1
JDE[2]	42.10%	61.90%	57.80%	45.20%	50.70%
TransTrack[1]	45.20%	70.80%	66.40%	53.70%	59.40%
ByteTrack[3]	46.80%	73.50%	69.60%	56.70%	62.50%
This work	**47.70%**	**75.40%**	**72.90%**	**59.20%**	**65.70%**

References

1. P. Sun, J. Cao, Y. Jiang, R. Zhang, E. Xie, Z. Yuan, C. Wang and P. Luo, *arXiv preprint arXiv:2012.15460*, 2020.
2. Z. Wang, L. Zheng, Y. Liu, Y. Li and S. Wang, presented in part at the European Conference on Computer Vision, 2020.
3. Y. Zhang, P. Sun, Y. Jiang, D. Yu, F. Weng, Z. Yuan, P. Luo, W. Liu and X. Wang, presented in part at the European Conference on Computer Vision, 2022.

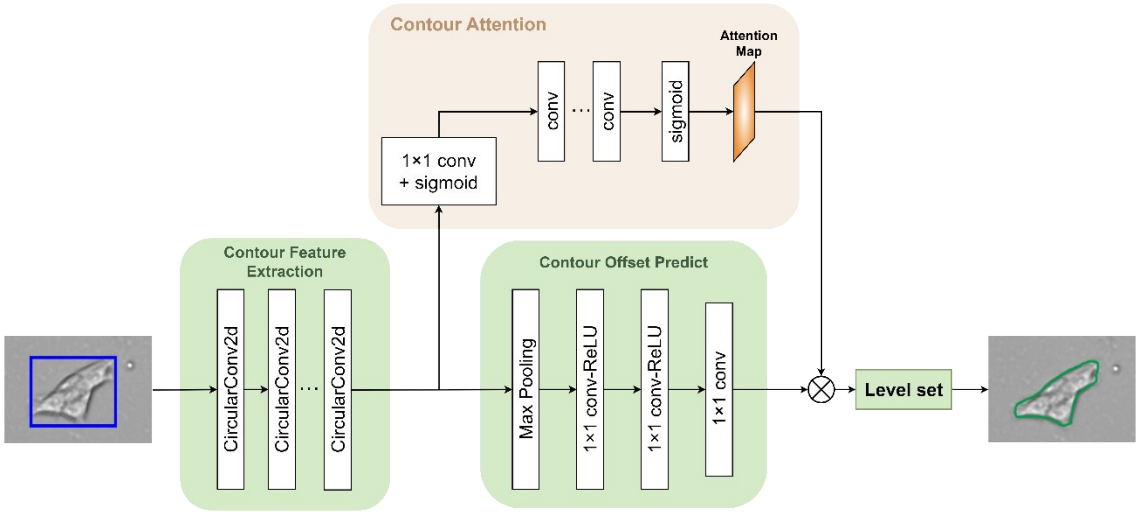

Fig. S1 Framework diagram of Contour Offset Regression Model Based on CA Module.

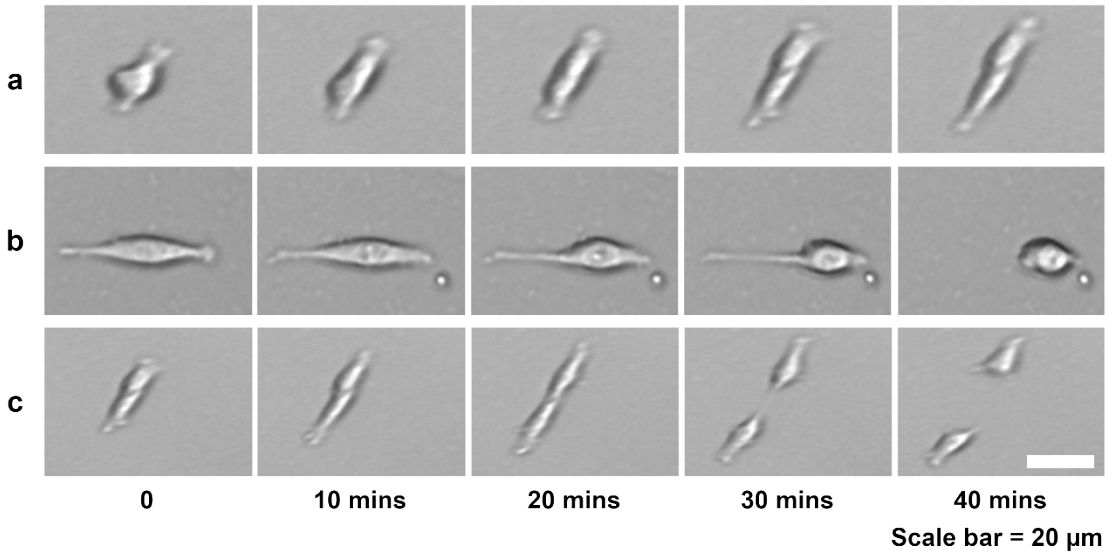

Fig. S2 Common types of cellular deformation: (a) cell elongation; (b) cell contraction; and (c) cell division.

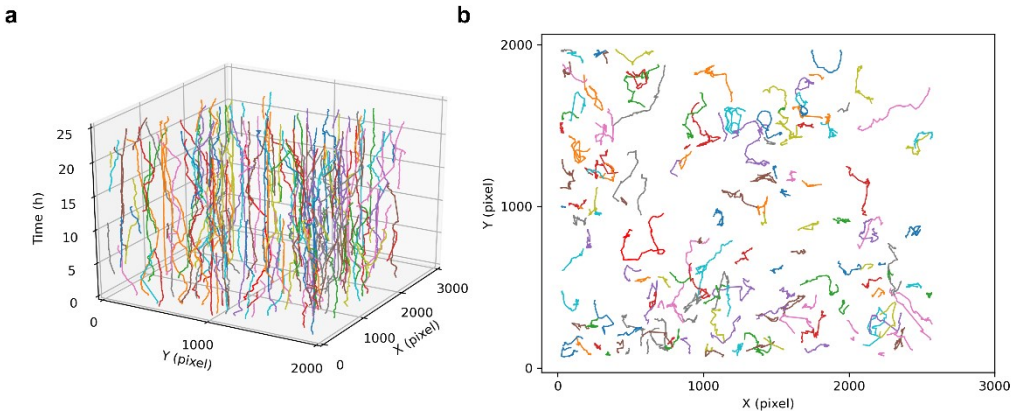

Fig. S3 Trajectory tracking of MCF-7 Cells in the presence of 500 μM hydrogen peroxide over 24 hours. (a) displays the time-space three-dimensional motion trajectory, and (b) shows the spatial two-dimensional motion trajectory.

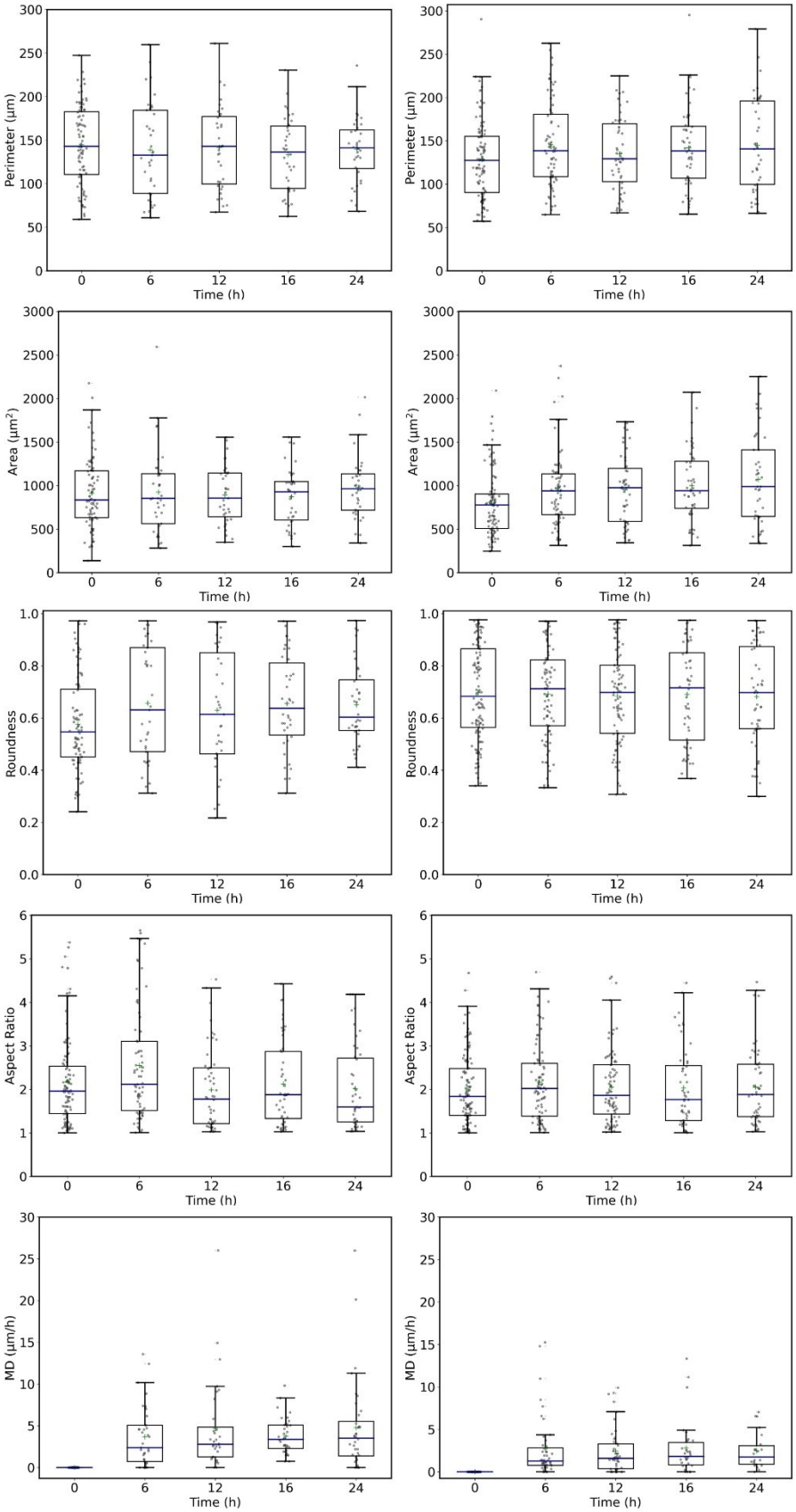

Fig. S4 Statistical results of perimeter, area, roundness, and MD of MCF-7 Cells over 24 hours under normal conditions (Left) and 500μm Hydrogen Peroxide Stimulation (Right).