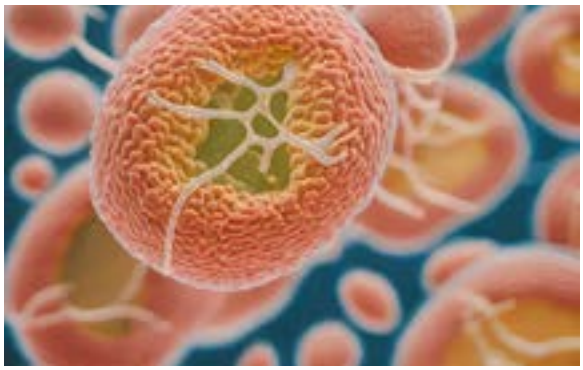
Exploring Flagella-Driven Motility in Biological Cells

Overview

The exploration of motile biological cells, like sperm cells, equipped with flagella, is crucial, extending beyond the comprehension of mere locomotion mechanics. The understanding of flagella dynamics is pivotal as it forms the basis for various medical applications, such as drug delivery, using bio-inspired micro-robots. Studying the dynamics of flagellar movement in sperm cells is imperative as it helps in unveiling intricate locomotion details and designing effective biomedical solutions and interventions based on biological cells.



Keywords

object detection
physics-informed neural networks
symbolic regression
flagellar-driven motility
sperm cells
micro-robotics
cell motility
trajectory prediction
online onject tracking

Situation

The University of Twente is at the forefront of developing micro-robots based on biological cells, including sperm cells. Comprehensive knowledge of cell motility dynamics is essential to create efficient cell-based micro-robots. Operating such microrobots online in the bloodstream poses significant challenges due to the low optical visibility encountered with standard equipment. Hence, incorporating object detection, object tracking, and trajectory prediction becomes indispensable.

Solution

We employed an Object Detection Neural Network coupled with Physics-Informed Neural Networks to interpolate flagella and extract relevant motility parameters accurately. To predict the probability distribution of the subsequent n-steps effectively, a Recurrent Neural Network was utilized. This synergy of technologies enabled precise tracking, detection, and trajectory prediction of the cells, paving the way for advanced studies and applications in micro-robotics based on biological cells.

Requirements

Rapid and accurate cell and flagella detection, interpolated with n-points.

Interpolation of flagella using relevant equations to extract cell motility parameters (i.e. in various media).

Real-time cell tracking and trajectory probability distribution prediction to monitor and anticipate cellular movements.

Benefits and Results

- Enhanced Detection and Tracking: The integrated approach ensures fast and accurate detection and tracking of cells and flagella, providing a robust base for further analysis and application development.
- Advanced Interpolation and Parameter Extraction: The precise interpolation of flagella and the extraction of relevant parameters enable a deeper understanding of cell motility dynamics.
- Real-time Trajectory Prediction: The ability to predict the trajectory probability distribution in real-time facilitates efficient monitoring and control of cell-based micro-robots.
- Innovative Micro-Robotic Development: Understanding and leveraging flagella-driven motility lead to the development of innovative and efficient micro-robots for medical applications such as targeted drug delivery.
- Cross-Disciplinary Applications: The derived insights and developed solutions have the potential to revolutionize not just biomedical engineering but also other domains requiring intricate movement and control mechanisms.

This approach opened up new avenues in the exploration of not only flagellar-driven motility, but provided vital insights and laying down a foundational framework for the development of advanced, efficient, and application-specific micro-robots.