INTRODUCTION

Signalling dynamics in intestinal stem cells (ISCs) are essential since they provide valuable insight into fundamental biological processes. ISCs can regenerate themselves, releasing new stem cells from a stem cell pool located in the crypts and developing into specialised cell types including enterocytes, goblet cells, and Paneth cells that comprise the intestinal epithelium. Researchers can uncover critical principles that underlie intestinal stem cells and other types of stem cell biological systems by exploring the complex mechanisms that govern stem cell regulation, cell fate determination, and tissue development \cite{[1]}.\\

Signalling events that take place for a short timescale from seconds to minutes influences stem cell behaviour, including their determination of fate. The effect of these signalling events on cells takes 5-7 days, including cell differentiation or self-renewal and migration of cells from the crypt base to the luminal surface \cite{[2]}. Researchers attempting to understand and predict stem cell function present challenges due to this temporal discrepancy.\\

In vitro and in vivo models are often utilised for stem cell studies. The in vitro, models allow researchers to view and follow biological responses with live imaging capabilities. The in vitro model struggles to adequately replicate the complex and dynamic in vivo environment for a long period of time \cite{[3]}. Researchers use in vivo models to study cell fate, allowing for a more realistic understanding of stem cell behaviour and fate determination. However, live imaging can be challenging due to factors like tissue complexity, limited accessibility, and technical restrictions, which make it difficult to observe and track signalling events and their long-term effects in real-time \cite{[4]}.

Advancements in deep learning algorithms have revolutionized computer vision, leading to significant breakthroughs in applications like object recognition and tracking \cite{[5]}. These methods have received a lot of interest in the field of biomedical research because of their ability to explain challenging biological events \cite{[6]}. One significant application is developing a computer vision tool using a deep learning algorithm for understanding signalling dynamics in intestinal stem cells which can play a vital role in determining the fate of stem cells. This study is important as it may uncover the complex signalling processes that take place within intestinal stem cells by tracking individual cells and tracing their paths over time using the concept of Multiple Object Tracking (MOT). This will help in gaining insights into the cell's movement behaviour and interaction pattern. The algorithm for deep learning will utilize annotated videos of intestinal stem cells along with convolutional neural networks (CNNs) for feature extraction \cite{[7]} and recurrent neural networks (RNNs) to track the movement of cells over time. It will be trained on a vast dataset of annotated videos to learn the traits that indicate the presence and movement of cells.

2. Aim and Objectives (150-200 words)

2.1 Aim

The primary aim of this project is to create highly accurate algorithms based on deep learning, which can effectively detect and analyse cells present in intestinal stem cell videos. The primary focus is tracking these cells' movement and gathering relevant insights for further analysis.

2.2 Objectives

This work will focus on three main objectives as follows:

- Primary objective is to develop and train a deep learning model capable of accurately detecting intestinal stem cells in video frames.

- Secondary objective is to compare and implement multiple object-tracking models that can precisely trace the motion trajectory of intestinal stem cells \cite{[8]} \cite{[9]} \cite{[10]} \cite{[11]}. This involves using Kalman filter tracking techniques and the Hungarian algorithm for data association \cite{[9]} \cite{[10]} \cite{[11]}.

- Assessing the performance and accuracy of the developed cell detection and path tracing methods.

3. Overview of Progress (500-700 words)

The in-depth literature review conducted on cell detection and tracing motion trajectory reveals wide recognition of deep learning approaches particularly those using convolutional neural network (CNN) and recurrent neural network (RNN). Fine-tuning pre-trained models or transfer learning on specific datasets, has proven to be effective in achieving accurate cell identification. It is important to acknowledge that these findings mostly apply to general cell recognition and tracking. However, no previous research on intestinal stem cells (ISCs) was not found. This indicates a potential advantage in the application of a deep learning approach in understanding the signalling dynamics of intestinal stem cells towards detection and tracking the path of these cells.

A new and efficient system for object detection framework proposed in \cite{[12]} is based on Region Proposal Network (RPN), which first generates a set of region proposal and then use the classifier to classify the proposal and regress their bounding boxes. Another popular framework is YOLO (You Only Look Once) \cite{[13]} which is a single-shot object detector which divides the image into S x S grid cells and predicts the probability of each cell having an object. Paper \cite{[6]} has proposed a multi-task learning framework that performs both cell detection and cell tracking. \cite{[7]} introduced cell detection using deep convolutional neural networks to extract features from images and compressed sensing to reconstruct images from features. Simple Online and Realtime Tracking (SORT), introduced in \cite{[9]} is a new method for multiple object tracking (MOT) which uses the Kalman filter to track objects over time which uses association metrics to link tracked objects in succeeding frame

and StrongSORT from \cite{[10]} is improved performance of DeepSORT that is more robust to motion blur.

Currently, efforts are concentrated on doing extensive preprocessing procedures that involve extracting frames from the video and applying image processing. Image processing includes resizing and normalising the size of each frame and scaling each pixel value between 0 to 1. Adaptive contrast adjustment and unwanted noise reduction using Gaussian or median filtering for prevention of important features. Data augmentation techniques include rotation, translation and flipping to augment the dataset.

In the image provided, Figure 1(a) displays the original blood cell image. Figure 1(b) exhibits contrast adjustment, while Figure 1(c) showcases threshold and noise adjustment. These preprocessing techniques can also be applied to Intestinal stem cells for cell identification purposes.

According to research in cell tracking /cite{[4]} there are several challenges that may arise, such as identifying cell deformation, distinguishing cells from other particles, and dealing with low-resolution images that render cells insignificant in the image.

4. Project Plan (300-400 words)

- Outline the remaining tasks and timeline for completing the project.

- Provide a detailed breakdown of the steps required to accomplish the objectives mentioned earlier.

- Highlight any upcoming milestones or significant deliverables.

- Discuss any potential risks or challenges that may be encountered during the remaining stages of the project and propose mitigation strategies.

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This project is a computational study that uses deep learning to develop algorithms for detecting and tracking intestinal stem cells in videos. The goal is to gain insights into the behavior of these cells and improve our understanding of intestinal regeneration.