Cell nucleus visualization with phenotypic characteristics

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Abstract

In order to elucidate the mechanism of development of multicellular organisms, it is important to quantify the spatiotemporal features (phenotypic characteristics) of cells appearing during cell division and to analyze their relationship (correlation). Furthermore, in order to analyze whether correlating phenotypic characteristics certainly, it is necessary to observe the shape of the cell nucleus with its features. We proposed a system that visualizes the phenotypic features and the three-dimensional shape of the cell nucleus. There was a problem that visualization of information such as the position of the cell nucleus which can not be individually observed when plural cell nucleus shapes are displayed in the three-dimensional shape of cell nucleus is insufficient. In order to solve such problems, we have improved several cell nuclei and phenotype-specific visualization methods. In the experiments, we performed user evaluation for experts who research the developmental dynamics of the cells. This system enabled them to analyze them smoothly and come up with new ideas.

**Keywords**: Phenotypic characteristics, Cell nuclear shape, Semi-transparent rendering.

**Index Terms**: K.6.1 [Management of Computing and Information Systems]: Project and People Management—Life Cycle; K.7.m [The Computing Profession]: Miscellaneous—Ethics

# Introduction

In life science research, efforts to elucidate the mechanism of multicellular organism generation using nematode (*C. elegans*) which is one of representative model organisms are being actively carried out. In order to elucidate it, research is being carried out as to whether a phenotypic feature develops under the influence of other features. We previously developed a system that narrows down pairs with high correlation between nematode phenotypic characteristics up to the 8 cell stage and visualizes the three dimensional shape of the cell nucleus having the selected features in association with each other. [1]

　Since the cell nucleus shape changes with time, when phenotypic features (ex. Cell nucleus migration distance) expressed over multiple time steps are chosen, it is necessary to observe the outline of multiple cell nuclei at a glance In an average shape. However, since the average shape is not an actual cell nucleus shape, it is necessary to look at individual cell nuclei. In addition, in the case of phenotypic features relating to position and distance (ex. Distance of cell nucleus from center of gravity of feature embryo), it is difficult to grasp the position and distance only from the cell nucleus shape. Therefore, it is necessary to visualize them.

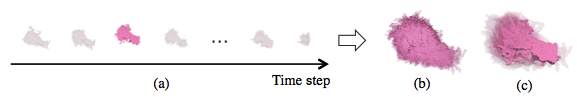
In this research, when phenotypic features expressed over multiple time steps are selected, we propose methods to visualize cell nuclei having the characteristics in chronological order and a visualization method of phenotypic characteristics of position and distance.

# Theory

In this chapter, we propose two visualization methods of cell nucleus having a phenotypic characteristic.

## Visualization of 3D cell nuclei

Figure 1(a) shows how the shapes of several cell nuclei with certain phenotypic characteristics change with time. First, in order to display the outline of multiple cell nuclei, all the cell nuclei are overlapped and displayed as shown in Figure 1(b). When we wanted to observe a specific cell nucleus shape, as shown in Figure 1(c), the designated cell nucleus was rendered opaque and the other cell nuclei were translucently drawn. When rendering multiple semitransparent cell nuclei at once, it is necessary to sort polygons in case of isosurfaces, so we performed the stochastic rendering technique[2].



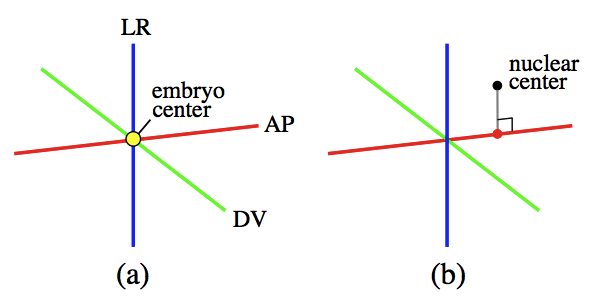
1. (a) shows the time course of the cell nucleus shape, (b) shows the result of superimposing all the cell nuclei in (a), and (c) shows the result of designating and highlighting a specific cell nucleus shape.

## Visualization of phenotypic characteristic

A representation was added about the phenotypic characteristics, the position of the cell nucleus, the distance between the center of gravity of the cell nucleus from the center of gravity of the embryo, and the migration distance of the cell nucleus.

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2.2.1 Nuclear position

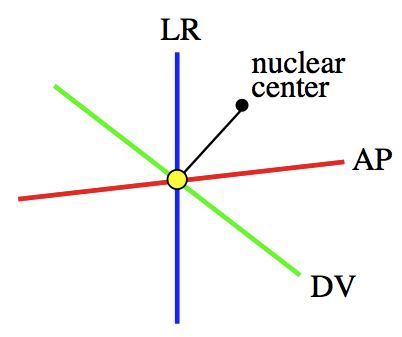


1. (a)線虫胚の前後軸(AP)、背腹軸(DV)、左右軸(LR)と胚の重心 (b)ある細胞核の重心からAP軸に垂線を引いた結果

AP、DV、LR軸に対する細胞核の位置を示すために、これらの軸と細胞核の重心を表示した。線虫胚には、胚の前後(AP)軸、背腹(DV)軸、左右(LR)軸[3]が定義されており、それぞれの軸は直交する。Fig.2(a)のように、AP軸を赤の線、DV軸を緑の線、LR軸を青の線、胚の重心を黄色の球で描画した。また、細胞核の重心を黒の球で可視化し、特徴量が計測された軸(Fig.2(b)ではAP軸)に垂線の足を下ろし、垂線の足をその軸の色の球で描画した。

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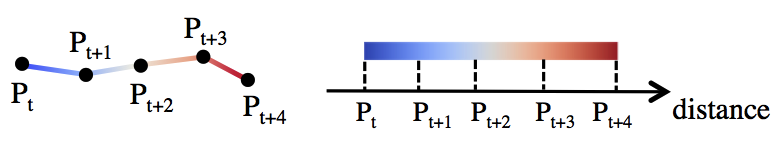
2.2.2 Distance between nuclear center to embryo center

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1. 胚の重心から細胞核の重心間を結んだ結果

胚の重心から細胞核の重心間の距離という表現型特徴を示すために、胚の重心と細胞核の重心を線で結んだ。

2.2.3 Distance of nuclear movement

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1. 細胞核の移動距離。線分の色をdiverging color mapで彩色した。

細胞核の移動距離という表現型特徴を示すために、その特徴が発現するtime step分の細胞核の重心を可視化し、それらを線で繋げた。Fig.4のPtはtime step tでの細胞核の位置である。点間の距離を計算し、開始点からの距離に応じて線をdiverging color map[4]を用いて彩色した。時間が進むにつれて青から赤の方向に細胞核が移動することを表す。

# Discussion

提案された仮説の有用性を示すために、以下の実験を行い、それに対する結果と2名のdomain expertの評価を述べる。

## 複数の細胞核の三次元可視化

表現型特徴「2細胞期のAB細胞の移動距離」を選択した時、その特徴を持つAB細胞は27time step分存在する。Figure 5(a)は27個の細胞を同時に重ねて可視化した結果である。Figure 5(b)は5time step目の細胞核を選択した結果であり、その細胞核がハイライトされていることが分かる。以前はFigure 5(a)のように複数の細胞が重なった結果しか観察できなかったが、評価

## 表現型特徴の可視化

Figure 6は表現型特徴「」を選択した結果である。

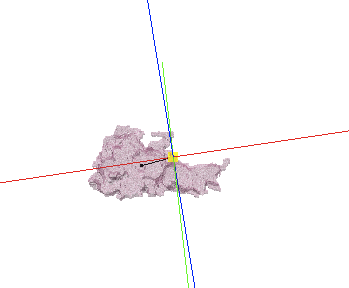
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Figure 7は表現型特徴「」を選択した結果である。

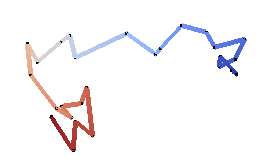
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Figure 8は表現型特徴「」を選択した結果である。

# Conclusion

本研究では

表現型特徴間の相関を計算するために、33個の線虫胚の特徴量が計測されているが、指定した表現型特徴を持つ細胞核を表示する際、今は1つの胚の細胞核と特徴の表示しか可視化していない。将来、全ての胚の細胞核と特徴の表示を可視化することで、特徴量が増加または減少していく様子を表せるだろう。

References

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