Ph.D. research topic

- Title of the proposed topic: 4D morphometric study of cell and tissue shape changes to computationally unravel the process of sea urchin embryo gastrulation
- Research axis of the 3IA: AI for Biology and Vice-versa
- **Supervisor (name, affiliation, email):** Grégoire Malandain, INRIA, gregoire.malandain@inria.fr
- Potential co-supervisor (name, affiliation): Matteo Rauzi, CNRS
- The laboratory and/or research group: Morpheme, I3S/INRIA

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Applying by sending an email directly to the **supervisor**.

The application will include:

- Letter of recommendation of the supervisor indicated above
- Curriculum vitae.
- Motivation Letter.
- Academic transcripts of a master’s degree(s) or equivalent.
- At least, one letter of recommendation.
- Internship report, if possible.

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- Description of the topic:

  Computational morphometric analysis has become an essential tool in modern biology to better understand how cell and tissue change shape during embryo development. In recent years, new microscopy techniques (e.g., SPIM) have enabled the digital image acquisition of developing embryos with unprecedented 3D spatial and temporal resolution allowing a fine reconstruction of all the morphogenetic processes concurring to shape the embryo [1].

  The acquisition of 3D+t high resolved image series results in huge amount of data. Dedicated sophisticated image analysis tools are required for their exploitation [2] and have proven their efficiency being successfully applied to several ascidian developing embryos constituted of tens of cells [3]. Very recently, in a joint collaboration between the Morpheme team and the Rauzi team (IBV, Nice, France), this computational tool has been extended to temporal 3D image series of the developing sea urchin embryo constituted by more than 1000 cells [4]. The resulting detailed morphometric information of each single cell leads the way to quantitative analysis of cell shape changes.
We are at present interested in better understating the mechanisms driving gastrulation in the sea urchin embryo [5]. During this developmental phase, the tissue located at the vegetal pole buckles initiating gut formation. Such changes in tissue shape are driven by stereotypic cell shape (e.g., bottle and wedge cells) and topological changes (cell intercalation). This has been qualitatively documented [5], however the dynamic of the changes has never been quantitatively investigated.

The goal of this doctoral project is to characterize the cell shape/topology and to perform cell population analysis to eventually unveil the key stereotypic processes driving tissue buckling. While cross-sectional shape analysis has been largely investigated in the literature, longitudinal shape analysis has been seldom addressed, mostly for statistical analysis, and more rarely for classification.

First intermediate goals consist in

- recognizing from the data stereotypical shape, and
- classifying embryo cells into homogeneous (in terms of dynamic changes) sub-populations.

For tractability purpose, it seems reasonable to first build compact shape evolution signatures so that handling thousands of cell shape evolution will be manageable. Building a priori descriptors of 3D+t shape may bias further analysis, and machine learning based approaches are more likely to provide unbiased descriptors. Among the numerous existing approaches, the versatility of the PointNet architecture [7] is appealing. Adapting it to 3D+t point clouds may be then the first contribution of this PhD project. From these representations, hierarchical clustering of similar 3D+t shapes will be addressed (e.g., by affinity propagation), giving access to the recognition of data stereotypical shape evolution.

This first results will allow to better characterize the timeline of the many events of the invagination process and thus give cues to distinguish among the several invagination process hypothesis [6].

We are seeking a very motivated and talented candidate with advanced expertise in computer science, mathematics or physics. We expect the candidate to have skills in several of the following fields: Image Processing and Analysis, Data Sciences, and Machine Learning (clustering, supervised classification, etc.). S/he should be proficient in programming in C/C++ and Python languages. Previous experience in biological or medical imaging will be considered as an asset.

Location: Inria-I3S Morpheme team, I3S, Sophia-Antipolis, France