Topological Approach of the Golgi Apparatus: Towards a Discriminating Modelling?

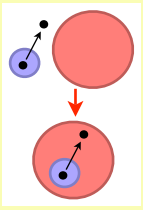
M. Poudret, J.-P. Comet, P. Le Gall, A. Arnould and P. Meseure

A Topological Approach

Most of the biological mechanisms depend on:
- modelcules exchanges between membrane-bouned compartments;
- dynamics of the neighbouring relations within the compartmentation;

The Golgi Apparatus is an organelle of the secretory pathway of the living cell. It has a strong topological strucuration. Beacuse of observation limitations, the topology of the Golgi apparatus is misunderstood and several representations exist.

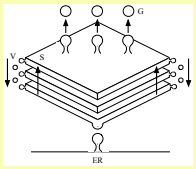
Representing both topology, biochemistry and geometry with topology-based geometric modelling. We propose a framework that may help biologist in discriminating Golgi Apparatus representations.

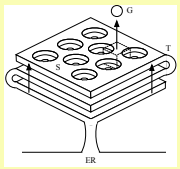


Phagocytosis

The Golgi Apparatus [1]

Electron micrograph of a Golgi Apparatus



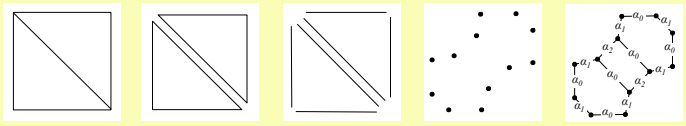


Two representations

Modelling Biological Compartments

n-dimensional generalised map [2]

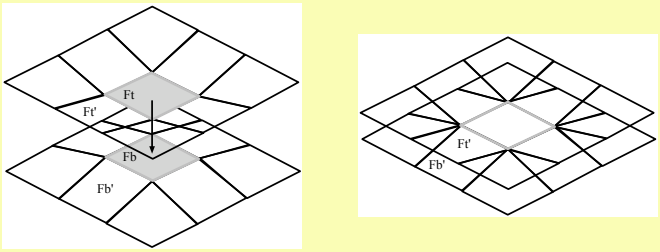
Let $n \geq 0$. An n-G-map is an edge-labelled graph $G = (V_G, E_G)$ with labels in $\Sigma_E = \{\alpha_0, \ldots, \alpha_n\}$, s. t.:
- for all $v \in V_G$, $l \in \Sigma_E$, there exists a unique $v' \in V$ s. t. $(v, l, v') \in E_G$;
- for each $v \in V_G$, for all $\alpha_i, \alpha_j \in \Sigma_E$ s. t. $0 \leq i < i+2 \leq j \leq n$, there exists a cycle $(\alpha_i, \alpha_j, \alpha_i, \alpha_j)$ that reaches v.



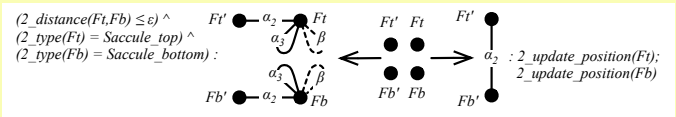
From geometry to topology

Transformation Meta-rule [3]

Let us consider Σ_E a set of labels and $\beta \in \Sigma_E$ a new label. A graph transformation meta-rule on β, noted $L \leftarrow K \rightarrow R$, is a graph transformation rule where L, K and R are edge-labelled graphs with labels in $\Sigma_E \cup \{\beta\}$ and satisfying both following properties:
- for each edge in L (resp. R) of the form (v, β, v'), then $v = v'$;
- there exists at least in L an edge of the form (v, β, v). Graphically β-edges are noted with dotted lines.

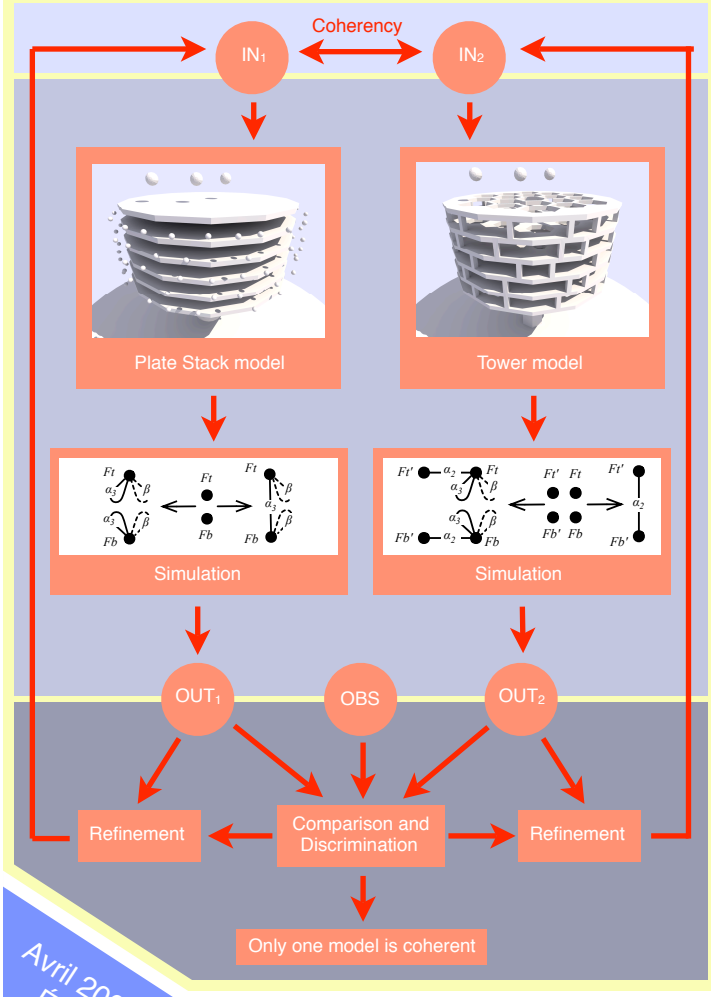


The Golgi saccule perforation



Perforation meta-rule

Towards a Discriminating Modelling?



Conclusion

Basing our work on topology-based geometric modelling, we have introduce transformaiton rules that allow us to model three dynamics of the biological compartments: biochemistry, geometry and topology.

We have present two topology-based models: The Plate Stack model and the Tower model, they implement two of the main hypotheses on the Golgi Apparatus. We have given examples of rules that can be use in order to animate these models.

Finally, we have sketched the models refinement loop that may help the biologist to find relevant parameters that discriminate the Plate Stack and the Tower model.

Perspectives

In order to propose our tools to non computer science experts, we have to improve the abstraction level of our transformation rules. A good level may work directly on compartments, abstracting the *n*-G-maps basic elements.

The recognition of all dynamical aspects is not finished yet. We have to complete the writing of the transformation rules set that involve the dynamics of Plate Stack and Tower models.

We have to implement the simulator that, starting form an application strategy of the transformation rules, animate the model. The result of a simulation process is a set of parameters that must be study by expert in order to refine and/or discriminate models.

References

1. F. Képès, A. Rambourg and B. Satiat-Jeunemaître. Morphodynamics of the secretory pathway. *International review of cytology*, 242:55-120, 2004
2. P. Lienhardt. Subdivision of n-dimensional spaces and n-dimensional generalized maps. In *SCG'89*, pages 228-236. ACM Press, 1989.
3. M. Poudret, J.-P. Comet, P. Le Gall, A. Arnould and P. Meseure. Topology-based geometric modelling for biological cellular processes. In *LATA'07*, to appear in LNCS, April 2007.

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Évry

Modélisation de systèmes biologiques complexes dans le contexte de la génomique