Qualitative modelling of microbial community functioning

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Observation of microbial communities reveals interactions between their constituent entities (operational taxonomic units or species) when the community performances can be compared with those of isolated entities. From a microbial ecology standpoint, it is essential to gain insight into these interactions to be able to predict the performances of microbial communities (e.g. biogas production). Most models consider interactions in pairs (predator/prey, consumer/resource) although experience shows that interactions between more than two entities is common (facilitation, inhibition). However, the formalization and study of models that take more complex interactions into account are hampered by the combinatorial explosion in the number of possibilities (with 100 entities, there are roughly 5,000 possible 2 x 2 interactions, and around 4 million 4 x 4 interactions). Hence, in practice the number of possible assemblies that can be observed is limited.

Eco&Sols and MISTEA joint research units (UMRs) have proposed a new qualitative modelling approach to understand this complexity*. This approach is based on a classification of entities and entity communities, with community classes being determined by rules regarding interactions between entity classes. This approach has, for instance, generated a description of the behaviour of microbial communities of different sizes formed with seven isolated strains. On average, 3-strain communities performed better than isolated strains and than 7-strain communities. The observed behaviour was accurately described by three strain classes interacting according to a dominance rule, i.e. a common interaction pattern in ecology. Actually the probability of obtaining a certain community class is maximal for a 3-strain community.

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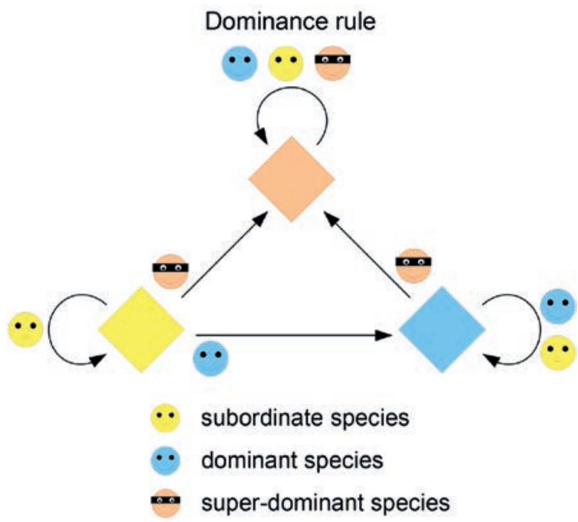

▲ ***The presence of a dominant or even super-dominant species in a community implies that the community performs in a dominant or super-dominant way.*** *From Jaillard* et al.*, 2014.* Functional Ecology*. 28: 1523-1533.*

Knowledge modelling – spatiotemporal ontologies (landscape, biodiversity, images)

The analysis of complex systems at various spatiotemporal scales based on different types of monitoring data is a major challenge in many scientific areas. Two key elements are involved in these analyses, i.e. knowledge of various scientific experts and monitoring data. Regarding the former element, through knowledge engineering, the explicit formalization of this knowledge in ontology form is an advance in terms of sharing and capitalization. For the latter element, satellite imaging —thereby shifting the focus from a local to a more global scale—enables assessment of vast areas, thus reducing the need for field monitoring. Various projects enabled us to explain how ontology-formalized knowledge can generate innovative solutions via satellite image analysis by reducing the semantic gap*:

• The use of ontologies for automated satellite image interpretation regardless of the analysis paradigm (pixel or object). The interpretation is the result of reasoning based on contextual knowledge (built from expert knowledge) regarding image subjects extracted previously by processing (see *Fig. 1 below*).

• Joint exploitation of ontology-based reasoning and unsupervised pixel classification. This reasoning enables semantic pixel labelling from knowledge derived from the target domain. The generated labels then serve as a guide for the classification task, which facilitates discovery of new classes while also enhancing the initial labelling. Figure 2 shows an applied example.

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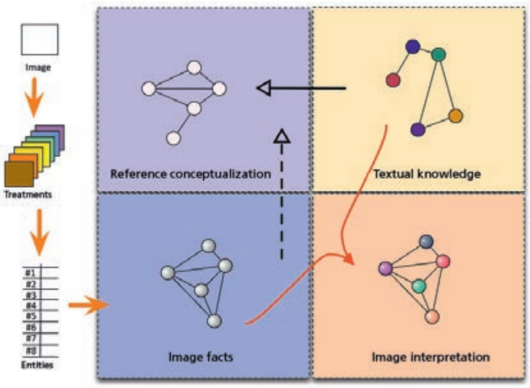
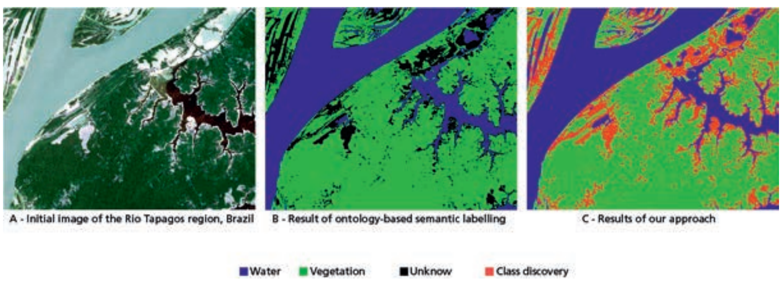
* Images are described digitally whereas users are interested in their semantic content. Determining relationships between digital and semantic levels is a challenge that must be addressed to overcome the so-called 'semantic gap'.



▲ ***Figure 1. Overview of the semantic interpretation principle. From Andrès S., 2013.*** Ontologies dans les images satellitaires : interprétation sémantique des images. *Computer Science PhD thesis. UM, France.*



▲ ***Figure 2. Application of the approach to an image of the Amazon region, Brazil.*** *From Chahdi H., 2017.* Apports des ontologies à l'analyse exploratoire des images satellitaires. *Computer Science PhD thesis. UM, France.*