

# OPERAS: a Formal Framework for Multi-Agent Systems and its application to Swarm-based systems

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**Abstract.** Swarm-based systems are biology-inspired systems which possess characteristics of multi-agent systems (MAS) with the most prominent ones being the local control over the decisions taken and their highly dynamic structure which continuously changes. This class of MAS is of a particular interest because it exhibits emergent behaviour through self-organisation and finds itself applicable to a wide range of domains, with some of them characterised as mission critical. It is therefore implied that the use of a formal framework and methods would facilitate modelling of a MAS in such a way that the final product is fully tested and safety properties are verified. In this paper, we present OPERAS, an open formal framework that facilitates modelling of MAS and describe how a particular instance of this framework, namely *OPERAS<sub>XC</sub>*, could employ existing formal methods and integrate the most prominent characteristics of finite state machines and biological computation systems, such as X-machines and P Systems respectively. We demonstrate how the resulting method can be used to formally model a swarm-based system of autonomous spacecrafts and discuss the flexibility and advantages of this approach.

## 1 Introduction

Lately, there has been an increasing interest toward biological and biology-inspired systems. From the smallest living elements, the cells, and how they form tissues in organisms to entire ecosystems and how they evolve, there is growing investigation on ways of specifying such systems. The intention is to create software that mimics the behaviour of their biological counterparts. Examples of biological systems of interest also include insect colonies (of ants, termites, bees etc.), flocks of birds, tumours growth—the list is endless.

The motivation behind the development of such software systems varies. To start with, there is the apparent need of biologists to simulate and observe their behaviour, acquire a better understanding of the operations taking place within