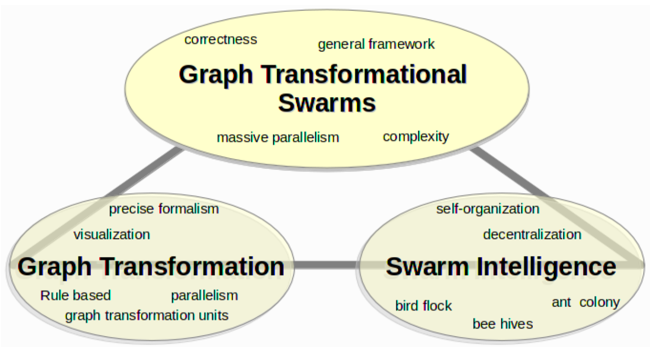
Graph-transformational Swarms in Logistics

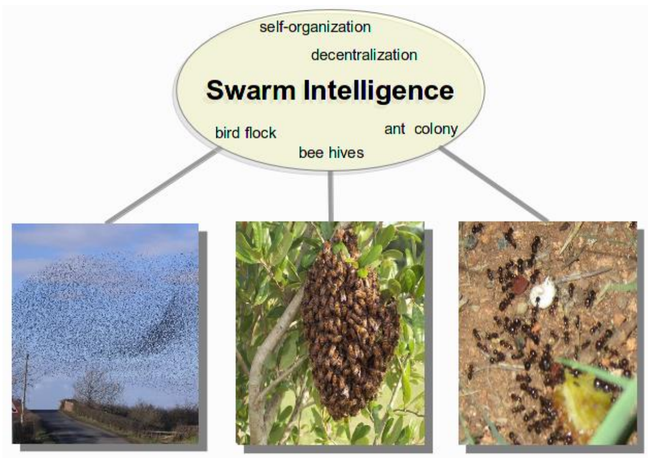
Logistics networks grow increasingly, becoming more and more difficult to be planned and controlled. Additionally to the large number of processes within such networks, the external environment is changing continuously. Nevertheless, the nowadays mostly applied control strategies are central and often turn out to be inflexible to deal with such large and dynamic networks. One of the most significant current paradigm that face this complexity is the so-called autonomous control approach. This approach proposes that the logistics objects, such as containers or trucks, receive their own computing processors and make their decisions autonomously. Therefore, they can react locally and quickly to changes in the environment. However, a major challenge within this kind of decentralized approach is how the individuals act and cooperate with each other to reach a desired global goal.

This work intends to face this challenge being inspired by nature, especially by *swarm intelligence.* This is achieved using the formal and exact methods of *graph transformation*. In other words it proposes a combination between the ideas of swarm intelligence and the methods of graph transformation, introducing the notion of *graph-transformational swarms* (see the figure below).

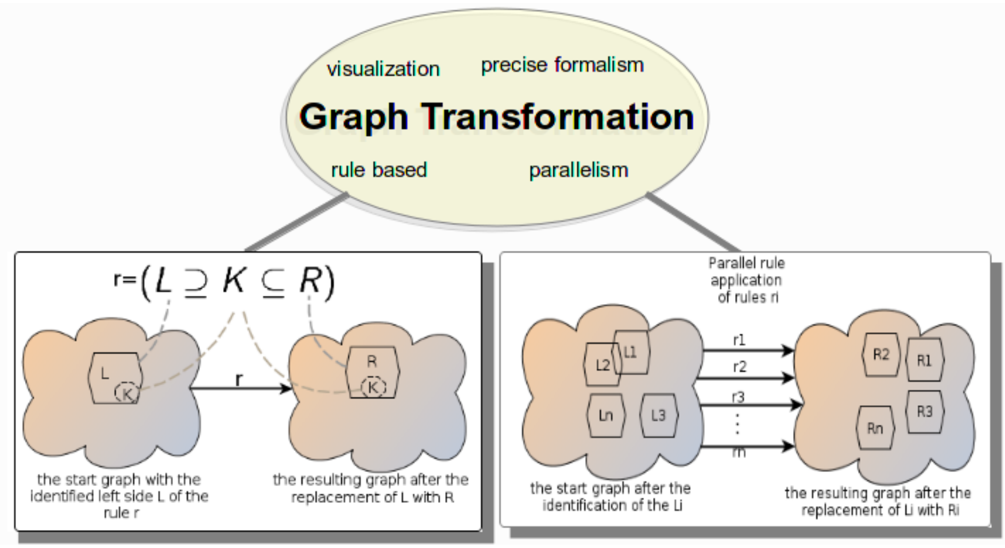


Swarm Intelligence

Swarm intelligence in nature describes the group behaviour of social animals. Such animals continuously solve very complex problems. For instance ant colonies as well as bee hives build nests and manage the resources inside it. Furthermore, they forage for food, transporting it in an efficient and flexible way. School of fishes and flocks of birds travel over very long distances. They act as one body in face of predator attacks and they overcome complex hydrodynamic constraints. Such problems therefore have a logistics aspect. Being inspired by swarms in the nature to solve logistics problem seems to be “selfevident”.



Several studies agree on the assumption that the complex group behavior in such systems results from relatively simple rules on the individual level. For example, the response to a predator attack from a fish school emerges from two rules which every fish in the group follows: 1. Remain close to your neighbors, 2. Avoid collisions with your neighbours.



Such rules and other ideas of swarms in the nature have been successfully used in computer science. Very promising results have been developed so far in optimization.

However, the proposed solutions and methods are in most cases highly adjusted to a particular problem. Moreover, there seems to be no common framework covering different approaches to swarms. This work proposes graph-transformational swarms as an attempt to fill this gap.

Methods

Graph transformation is used as a modeling approach. It offers a framework for a formal description of changes in graphs.

Graphs are usually used to visualize problems in logistics and computer science. They enable to represent structures consisting of entities and the relationships between them. Such a structure corresponds in turn to a given state of a system (in particular, the initial state or the goal state). Graph transformation extends the static representation capability of graphs by offering the possibility of specifying the dynamics of a system. The main key for this is the notion of rules. A rule defines what should be deleted and/or added in a graph environment. Its application is defined formally in the graph transformation framework.

The formal framework of graph transformation is powerful enough to solve arbitrary computational problems and provides methods to analyse them with respect to correctness and complexity.

Graph transformation provides additionally the concept of parallel rule application, which this work uses to formalize the simultaneous actions in swarms.

Outcome

A graph-transformational swarm consists of an arbitrary number of members of the same kind or of a small number of different kinds. The members act simultaneously in a common environment which is represented as a graph.

Therefor, given a logistics problem, which can be modeled by a graph, graph-transformational swarm can easily be used to offer a swarm based solution of the problem. The framework proposes different strategies of communication between the members themselves and with their environment. Furthermore it offers solutions to analyze and visualize the development of the model over time.

In addition to the practical aspect of this work the theoretical one is of a high importance. The computational aspects of the developed framework is intensively investigated.

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