

# A Fuzzy Multi-Agent System for Combinatorial Optimization

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## INTRODUCTION

NP-complete problems, like many of those arising in industry, cannot be approached with exact tools in reasonable time, so, approximation approaches are required. Among such approaches, heuristics and metaheuristics methods are considered as very useful tools to obtain reasonably good solutions in limited time for such complex problems, but their application is far from trivial.

Nowadays, solving combinatorial optimization problems with the help of parallel and distributing processing is a very active field of research. These methods offer the possibility to speed up computations and especially the multi-search metaheuristics, with varying degrees of cooperation, are often used to perform a greater exploration of the search space.

It is usual to visualize an optimization problem as a landscape with peaks, valleys, depths, and the problem consist in finding the highest peak. Under this view, it is natural to associate metaheuristics with optimization or search agents that move across the landscape, each one with its own strategy and using in different ways the information that is available to it.

We present a cooperative strategy multiagent-based to solve combinatorial optimization problems, where both internal solver agents and coordinator agent have been modeled how fuzzy agents using soft computing techniques.

The motivations for this approach are to solve larger problem instances and to obtain robust tools in the sense of offering high quality solutions despite of variations in the characteristics of the problem instances, taking

advantages of as soft computing techniques (Verdegay, 2003) as multi agent systems (Luck, McBurney, & Preist, 2003).

## A FUZZY RULE-BASED COOPERATIVE STRATEGY MULTI-AGENT FOR OPTIMIZATION

The main idea of this approach can be summarized by imagining an expert's committee in charge to solve some concrete problem. The committee is chaired by a coordinator, who knows all general aspects of concerned problem and particular features of any member of the team. Besides the coordinator knows when an obtained solution can be considered acceptable (i.e., he knows when to stop). Each member is an expert in solving problems by a specific approach, although possibly each one could be also expert in other solving methods. In this context each expert in the committee work alone, but all at the same time. The coordinator receives reports from the experts with the results they obtain. The committee is a natural metaphor to implement in agent architecture (Luck et al., 2003; Talukdar, 1999).

Communication between agents is necessary in cooperative strategy because the agents may exchange their goals and knowledge to solve problems. There are different communication forms (Mas, 2005): not communication, primitive communication, plan and information passing, blackboard model, message passing, and high-level communication. Blackboard model is used in this approach and consist a shared

global memory on which agents can write and read information.

Also, the agents need to coordinate their resources. There are different techniques of coordination (Mas, 2005) such as negotiation, functionally cooperative precise, organizational structure, and multi-agent planning. The last technique is used in this approach and consist a future actions and interactions plan to all agent levels in system. This plan resolves goal disparities and provides a major cooperation. The planning multi-agent can be centralized or distributed. Centralized planning is based in a coordinator node that defines a global plan from information and individual agent plans. In distributed planning each agent define his plan with a partial vision of another agents plan. Centralized planning is used in this work.

Then, committee idea is designed as a fuzzy cooperative strategy multi-agent architecture based, with two coordinated levels in centralized planning and blackboard model communication (Figure 1).

We conceive the fuzzy solver agents how a fuzzy adaptive neighborhood search heuristic, FANS (Pelta, Blanco, & Verdegay, 2002). FANS provides an optimisation tool where expert's knowledge could be expressed and tested using fuzzy concepts and heuristic decision rules, leading to an expressive and powerful system. By means of a fuzzy valuation, represented in FANS by fuzzy sets, a fuzzy measure of the generated solutions is obtained. Fuzzy valuations may represent concepts like "acceptability," "goodness," etc. Thus, a degree of acceptability (goodness) is calculated for each solution and such degrees are used by FANS at the decision stages. FANS moves between solutions,

which satisfy the idea of acceptability with at least a certain degree or threshold  $\lambda$ . Using schedulers enable FANS to modify its behavior as a function of the search state. In particular, the operator used to generate solutions is changed when the search seems trapped, leading the search to intermediate escaping mechanism. When this mechanism fails, a classical restart operator is applied.

We model the fuzzy coordinator agent with a set of fuzzy rules that are used to control and modify the behavior of solver agents. The coordinator agent knows all of the general aspects of the concerned problem and the particular features of any worker of the team of experts (i.e., internal agents). Besides, the coordinator agent knows when an obtained solution can be considered acceptable (i.e., he or she knows when to stop). It has two important tasks: Collect information about performance's in-agents and send orders to in-agents for adapt his or her behaviors.

Formally, the multi-agent system designed here is:

$$MAS = (FANS; FRB; P)$$

where,

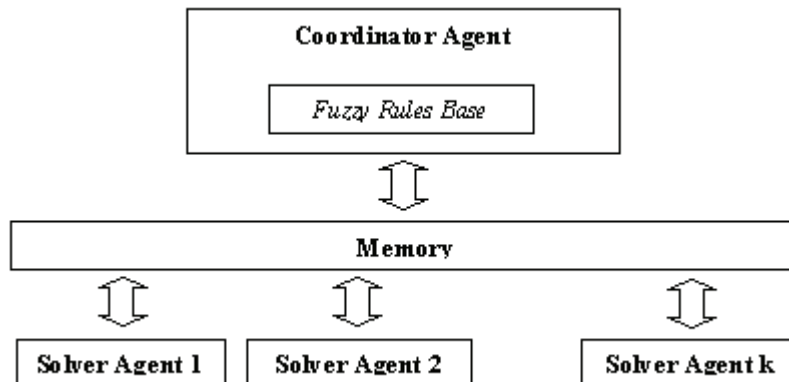
**FRB:** Fuzzy rules base,

**P:** Set of initial parameters that defines in-agent's behaviour, and FANS (solver agents) is a structure formalized and explained in (Pelta et al., 2002) as:

$$FANS = (NS; O; OS; \mu(.); Pars; (cond; action))$$

where,

Figure 1. Multi-agent system proposed



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