

# A Better Understanding of the Behaviour of Metaheuristics: A Psychological View

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**Abstract.** This paper aimed to show the idea that concepts and methods from Creative Problem Solving can also be useful in dealing with developing Metaheuristics. A dynamic approach based on Divergent and Convergent Thinking can be used to understand the modus operandi and behaviour of this kind of optimization solvers.

**Keywords:** Creative Problem Solving, Metaheuristics, Divergent Thinking, Convergent Thinking.

## 1 Introduction

In Operations Research, Metaheuristics are useful when finding the best solution of a optimization problem is computationally very expensive using global optimization methods. The key is to provide a way of finding a good enough solution in a fixed amount of time.

Metaheuristics, as the suffix says, are upper level heuristics. They are intelligent strategies to design or improve general heuristic procedures with high performance [10,8,9]. They are iterative procedures that smartly guide a subordinate heuristic, combining different concepts to suitably explore and operate the search space. Over time, these methods have also come to include any procedures that employ strategies for overcoming the trap of local optimality in complex solution spaces, especially those procedures that utilize one or more neighborhood structures as a mean for defining admissible transitions from one solution to another, or to transform solutions in a constructive process.

To get good solutions, any Metaheuristic must establish an adequate balance between two overlayed process: Diversification and Intensification. Diversification is a mechanism that forces the search of solutions into unexplored areas of

the search space. Intensification is a mechanism that explores more thoroughly the portions of the search space that seem promising in order to make sure that the best solution is in these areas.

In Psychology, Creative Problem Solving has two key concepts: Divergent and Convergent Thinking. Divergent thinking (creative thinking) starts from a common point and moves outward into a variety of perspectives. It generates something new or different. It involves having a different idea that works as well or better than previous ideas. Convergent thinking (critical thinking) is cognitive processing of information around a common point, an attempt to bring thoughts from different directions into a union or common conclusion.

The focus of this work is on studying the links between Psychology and Operations Research when solving problems. We believe that these preliminary notes can inspire new view points in optimization solvers development.

## 2 Creative Problem Solving

In [18] Rubinstein stated that the most creative human problem solvers have an unusual capacity to integrate the two modes of conscious functions of the two brain hemispheres, and move back and forth between the holistic and sequential, between intuition and logic, between the fuzzy field of a problem domain and a clear specific small segment of a field.

Such people can be outstanding artists and scientists because they combine the strong attributes of both. We refer to reader to prominent references in Creative Problem Solving are [14,20,21,5,6] for more extensive coverage of this topic.

During a Creative Problem Solving process it is convenient to start with Divergent thinking to produce as many ideas or solutions as possible and thereafter to switch to Convergent thinking to select the most promising ideas. The terms Divergent and Convergent thinking were coined by a psychologist in [12].

By other side, Diversification and Intensification are components that appear in many Metaheuristics. These concepts emerge with Tabu Search (TS) Metaheuristic [11]. Diversification generally refers to exploration, the ability to visit many and different regions of the search space, whereas Intensification refers to the exploitation of the accumulated search experience to obtain high-quality solutions within promising regions.

## 3 How Metaheuristics Work?

A Metaheuristic is formally defined as an iterative generation process which guides a subordinate heuristic by combining intelligently different concepts for exploring and exploiting the search space, learning strategies are used to structure information in order to find efficiently near-optimal solutions [17].

As aforementioned, the two forces that largely determine the behaviour of a Metaheuristic are Intensification and Diversification. A unifying view on Intensification and Diversification was proposed in [2], recommending that every Metaheuristic approach should be designed with the aim of effectively and efficiently

exploring a search space. The search performed by a Metaheuristic approach should be smart enough to both intensively explore areas of the search space with high quality solutions, and to move to unexplored areas of the search space when necessary. The right balance between Intensification and Diversification is needed to obtain an effective Metaheuristic. This balance should rather be dynamical, it should not be fixed or only privileging one direction.

Autonomous Search (AS) systems represent a new research field defined to address the challenge of fine-tuning Metaheuristics [13]. An AS system should provide the ability to modify its internal components (heuristics, inference mechanisms, etc.) when exposed to changing external forces and opportunities. AS corresponds to an instance of Self-adaptive Systems with the objective of improving its problem solving performance by adapting its search strategy to the problem at hand. AS can be defined as search processes that integrate control in their solving process either by self adaptation or by supervised adaptation [4,3,7].

Other very promising research direction in order to improve the performance of Metaheuristics is the hybridization of Metaheuristics [1,19,16,16,15].

## 4 Conclusion

Diversification and Intensification are components that appear in many Metaheuristics. The relations with Divergent and Convergent thinking should be considered, since benefits may accrue by analysing and combining concepts and methods originating from Psychology.

For example, uncertainty is present in most instantations of Metaheuristics using randomness, then a predisposition to tolerate and to deal with uncertainty may be gained from creativity, in particular from Divergent thinking and Convergent thinking.

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