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FCT Fundação para a Ciência e a Tecnologia
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Creativity, Soft Methods and Metaheuristics*

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1 Introduction

Some ideas, methods and tools of Creativity and Soft Methods, in connection with Metaheuristics, will be presented. The correspondent work, still going on, investigates the advantages and the utilization of creative thinking and soft Operational Research (soft OR) to resolve difficult Optimization problems and to evaluate and compare dissimilar approaches based on Metaheuristics (Mh). We believe it constitutes an innovative challenge by proposing to combine, articulate and merge diverse procedures and techniques, from different areas. Relevance, power and success of Mh are well-known for decades. But open questions are still around: the choice of a Mh? In the presence of a concrete optimisation problem – which 'effective, efficient' Mh (able to produce an 'optimal'/acceptable solution), at the cost of a 'reasonable' computing time, should be selected? And after making a selection (how to do it?), there is no universal way to improve it, to elect adequate strategies or to tune its parameters. The choice of a 'good' Mh and the adjustment of the correspondent parameters suggest, or call upon innovative ideas and tools, eventually out of the specific area. Obviously, expertise and experience of the users are of great value.

'Quality' of solutions and computational times are not the only and necessarily most important criteria for analysing or selecting a Mh. Very often, effectiveness of a solution approach has to be evaluated in the context of practical problem solving. Solutions and methods cannot be isolated from the problematic of understanding the right problem and from the agreement on a convenient (but approximate) model. Flexibility, easiness, robustness, appeal, experience may represent other criteria to take into account.This paper also sketches a framework for a coherent and comprehensive comparative evaluation of Mh.

Mh are themselves the outcome of fantastic creative processes. How many metaphors from nature and/or social behavior inspired these general heuristic methods! Who could imagine, some decades ago, that procedures based on natural evolution were competing to solve hard combinatorial optimization problems?

Section 2 refers to creativity, mentions well-known talents/abilities of creative persons/groups and introduces the principles of divergent thinking and convergent thinking in connection with the Creative Problem Solving method. Section 3 proposes and somehow integrates methods and tools from creativity and soft OR in the environment of optimization with Mh. The objective is to contribute for

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better working procedures. An outline of a framework for a coherent and comprehensive comparative evaluation of Mh is proposed. Finally, a list of references is included.

2 Creativity

The book 'The art of problem solving' [1] is probably the first book on creativity in Operational Research [1]. Another interesting paper of the same author is 'Creativity in problem solving and planning: a review' [2]. Paul Torrance has been a pioneer in creativity research and education for more than 50 years. When referring to creativity he says:

> "Creativity defies precise definition. This conclusion does not bother me at all. In fact, I am quite happy with it. Creativity is almost infinite. It involves every sense - sight, smell, hearing, feeling, taste, and - even perhaps the extrasensory. Much of it is unseen, nonverbal, and unconscious. Therefore, even if we had a precise conception of creativity, I am certain we would have difficulty putting it into words." E.P. Torrance (1988), in [10].

[9] gives a short definition of creativity that encapsulates many other definitions presented in the literature:

> "Among other things, it is the ability to challenge assumptions, recognize patterns, see in new ways, make connections, take risks, and seize upon chance."

Talents and tools

There is a variety of talents/abilities that characterises creative individuals or groups [16]:

- Fluency: the production of multiple problems, ideas, alternatives or solutions. It has been shown that the more ideas we produce, the more likely we are to find a useful idea or solution.
- Flexibility: the ability to process ideas or objects in many different ways given the same stimulus. It is the ability to delete old ways of thinking and begin in different directions. It is adaptive when aimed at a solution to a specific problem, challenge or dilemma.
- Originality means getting away from the obvious and commonplace or breaking away from routine bound thinking. Original ideas are statistically infrequent. Originality is a creative strength, which is a mental jump from the obvious. Original ideas are usually described as unique, surprising, wild, unusual, unconventional, novel, weird, remarkable or revolutionary.
- Elaboration is, in particular, the capacity of 'doing', of structuring, composing and preparing complex situations.

Special techniques/tools may be used in creative processes: Brainstorming, Verbal checklists, Provocative questions, Visual stimulation (Pictures, Objects), Analogies and Metaphors, Mind Maps, Cognitive Maps [5], Rich Pictures [3]. Talents and tools may be associated.

Creative Problem Solving

During a creative 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 few most promising ideas (Fig. 1).

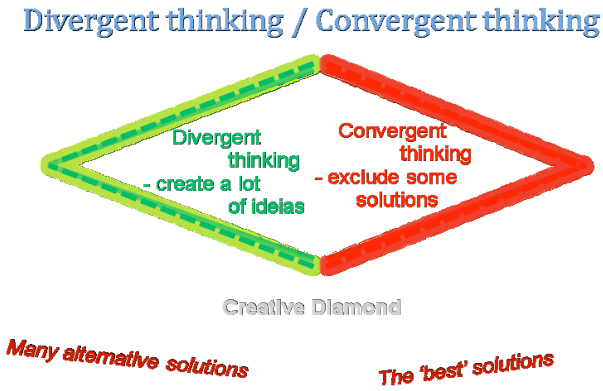

Figure 1: Divergent thinking and Convergent thinking

There are well established rules for these procedures and they will be mentioned, after an introduction, in the context of their relevance to working with Mh. Divergent thinking and Convergent thinking have regularly been exploited in workshops and future conferences to promote creativity, innovation and strategy consensus. In a specific context, the report [15] summarises a workshop on 'Facilitating to Deal with Combinatorial Optimization Problems'.

Divergent thinking and Convergent thinking phases are an expected part of creative processes. They go along with the six-step model for a systematic approach to CPS – Creative Problem Solving [11], [4], [12]:

1. Mess finding, 2. Fact finding, 3. Problem finding, 4. Idea finding, 5. Solution finding and 6. Acceptance finding.

A description of each of the steps and the list of the more relevant competences (during each step) or what to do or think about are condensed in [17].

3 Creativity, Soft Methods and Metaheuristics

> "Assuming that the way experts or others formulate problems will lead to a solution is often wrong. Experts are only experts within the box that defines their expertise. But solutions to most problems that arise within the box are found outside of it. What is needed is out-of-the ordinary thinking, "crazy" ideas, without fear of the ridicule. Encouragement of "crazy" ideas ought to be the norm at organizational meetings."
>
> Ackoff, R.L. and Rovin, S. (2005) Beating the System, Using creativity to outsmart bureaucracies, Berret-Koehler Publishers, Inc., SF, USA.

We think that there are some advantages and a seminal value in the utilization of creative thinking and soft methods to deal with difficult optimization problems and to evaluate and compare different approaches based on Mh. Understanding what is the problem/model, discussing the approaches and implementing the solution methods should not be isolated. Especially if one is facing a real complex problem. Emphases of soft OR methods are: structuring messy, complex problem situations rather than solving well-defined problems; exploring the differing views of the participants; and facilitating participation and engagement, rather than analyzing quantitative aspects and models.

Mh are the outcome of unlikely creative processes, merging ideas of different areas. Their relevance, power and success are well-known but the open question is still here: the choice of a Mh? In the presence

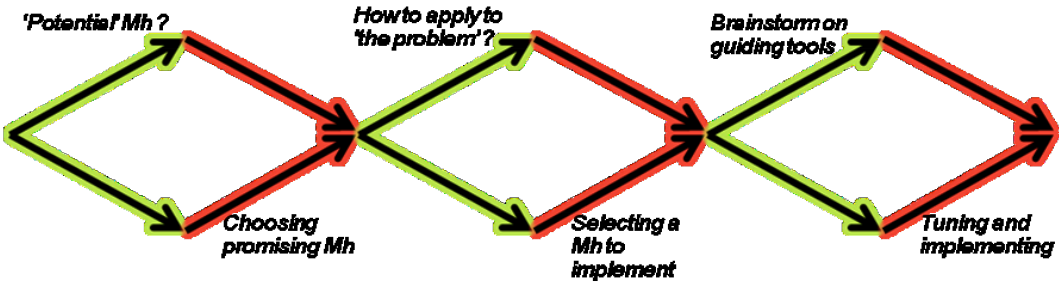

Figure 2: Resolution process

of a concrete optimisation problem – which 'efficient' Mh (able to produce an 'optimal'/acceptable solution), at the cost of a 'reasonable' computing time, should be selected? Moreover, even after making a selection, there is no universal way to improve it, to elect adequate strategies or to tune its parameters. On the other hand, the weak theoretical results about Mh are of almost no practical use! In conclusion there is no complete 'rational' guide to select or to implement a Mh, what is not a good sign.

Quality of solutions, number of iterations/computational time are not the only and necessarily most important criteria for analysing or selecting Mh. And even if they were, the legitimate question 'Which Mh for a specific problem?' could not get a clear recommendation. Certainly they are well-suited for questioning the efficiency and efficacy, but the effectiveness of a solution approach should also be evaluated in the context of practical problem solving. Other criteria should be taken into account and, quite often, they are intuitively used for relevant practical purposes. In this context a new tool will be presented later.

The process depicted in Fig. 2, will be a basis for a more detailed discussion. It is about the problematic of dealing and structuring the resolution of problems with Mh. Comprises phases of divergent and convergent thinking, as part of a CPS process – the researcher should perceive that there is a dimension of creativity in a project with Mh. Brainstorming sessions involving at least the elements of the team, are a convenient way for divergent phases.

Comparing, choosing and evaluating Mh

Mh are very powerful and flexible means applicable, potentially, to any optimisation problem. But comparing and choosing them is a hard job. Evaluating a particular Mh is also complicate. This is well known but there is a risk of credibility if no 'solution' is found. We do not think a 'solution' will emerge from the 'Mh context' alone.

The ideas involved in the previous sections, together with various schemes and procedures taken from soft OR, may be of some help to structure and capture the environment of comparing and choosing Mh and to facilitate the handling of quantitative and qualitative/soft information, simultaneously.

We briefly outline a few methods and tools to simultaneously organise properties and characteristics of a set of Mh – those that are under study. Information may arise from personal experience, from publications and other sources.

SWOT analysis may also be adapted to study and analyse advantages and drawbacks of each method, as a complement, to the overview of the Mh eventually considered in Table 1. As stated in [14]: 'the primary goal of the SWOT analysis is to assist in selecting the Mh with the best possibilities of implementing a divergent/convergent search strategy'. Obviously, identifying opportunities, threats, strengths and weaknesses (concepts which should be adapted) are of importance to create a good

implementation.

Table 1: SWOT Analysis for Memetic Algorithms

Memetic Algorithms	**Opportunities** easily applied to ### intensification by local search; —	**Threats** long time in local search —
Strengths convergence by survival of the fittest; hybridisation (LS); finds local optima; —	**Strategies S-O** possibilities for various LS procedures —	**Strategies S-T** ???
Weaknesses convergence by survival of the fittest; —	**Strategies W-O** ???	**Strategies W-T** ???

These tables may be completed for a Mh, in general, or for a very specific application. Table 1, which is quite incomplete, points up the idea of an application of Memetic Algorithms [13]. Observe that besides assisting to organise and clarify thoughts these tables may also be useful for team discussion and decision making.

Strategic Choice Approach (SCA) [8] is another problem structuring/soft method 'which deals with the interconnectedness of decisions problems in an explicit yet selective way. Its most distinctive feature is that it helps people working together to make more confident progress towards decisions by focusing their attention on possible ways of managing uncertainty as to what they should do next' [6]. The framework distinguishes four complementary modes: shaping mode, designing mode, comparing mode and choosing mode. We suggest that some of the ideas involved in SCA, in particular in the modes of comparing and choosing, could be of some help. Without going into the details, tools such as the ones illustrated inTable 2 and Fig. 4 could be employed by individuals or groups to study, improve, classify and evaluate Mh.

Table 2: Comparing different schemes

	Quality	Comp. time	Simplicity	Adaptability	Robustness	Theory	? ?
Mh1	* * *	t t	s s	✓✓✓✓	r r r r	+ +	-
Mh2	* *	t t t	s s s	✓	r r r	+ + +	-
Mh3	-	-	-	-	-		-
Mh4	* *	t t	s	✓✓✓	r r r	+	-

Table 2 may include qualitative and quantitative data – this is a very significant point. The relative importance of each criterion may be defined/agreed. Just looking at this table, it may be concluded that Mh4 is dominated by Mh2.

Associated with SCA, there is the STRAD2 software. In particular, windows equivalent to an advantage comparison grid, such as the one of Fig. 3 (a balance window), allow for adjustments of positions and changes in ranges. A 'combined' row presents the mean position of all the advantage assessments in the rows above. Of course a formula will aggregate the ranges.

Note that a grid such as this one may be used for personal/group work carried on but also for structuring and comparing published works. Other tools such as the progress package could be taken into account.

Independently of the relevance of other issues (not necessarily quantitative), we understand that the development of statistical tests, to get a more 'scientific comparison', due to the lack of relevant theoretical analysis of Mh, should be encouraged. A reference about ongoing work in this line is in

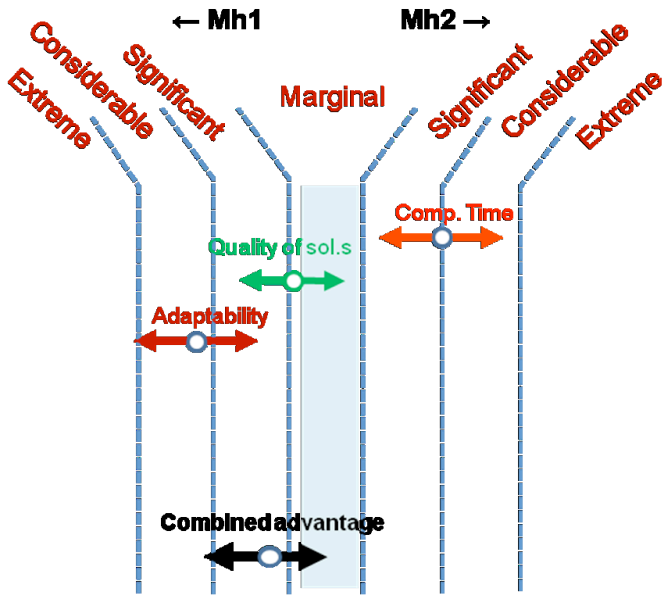

Figure 3: Advantage comparison grid for a selected pair, Mh1 and Mh2

[7]. Instruments as those introduced before (see for example Table 2 and Fig. 4) are a contribution to integrate soft and hard data.

Implementing Metaheuristics

Implementing a Mh is a pervasively imprecise decision-making process – quantitative aspects may be a good support, rational choices would be interesting if they are not overtaken, experience and intuition are frequently used. As proposed earlier, divergent/convergent thinking, as part of a creative attitude, may be helpful to plan, design, and parameterize a given Mh. The procedures of intensification/diversification, associated to search strategies, may also benefit. The designer should be conscious that there are many aspects involved in the implementation of Mh that are not susceptible of accurate/deterministic planning – a support from other areas of knowledge may be convenient. For instance, from the use of Memetic Algorithms in [13], the following elements could be identified and grouped for further study:

> Population structure – influences the number of agents, Crossover, Mutation, Local search: Choice of edges, facultative or not . . . , Number of local search iterations

and

> Random start, No improvements of best agents, Minimum improvements, Number of iterations without improvements, Change between diversification/intensification according to parameters.
>
> Mutation is influenced by two parameters: k (the frequency of this operation); d (the deepness of the Mutation).

In [14] the reader may find a complete report of divergent and convergent thinking as part of a search strategy. Fig. 4 and Fig. 5 are taken from this work.

In a project of using a Mh, the correspondent activities may undergo numerous revisions, between the interesting concentration on the set of principles of the Mh, such as: Neighbourhoods – simple,

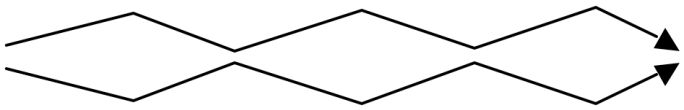

Figure 4: The shifting between convergent and divergent selection strategy

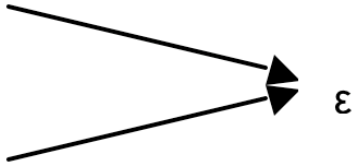

Figure 5: The overall convergence by decreasing threshold ϵ - the minimal difference in the objective value of individuals in a population.

extended, . . . , Memories – populations of solutions, tabu list, pheromone trails, . . . and the tuning of parameters.

Aspects to take into account in each of the phases have already been pointed out. Phases should be visited in turn (Fig. 2 and Fig. 4); for instance, if one is following a convergent thinking phase in tuning the parameters, it may be convenient to undergo a new divergent phase on tuning or even coming back to a divergent thinking phase in 'guiding tools'.

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