

## Chapter 5

# A Rigorous Analysis of the Harmony Search Algorithm: How the Research Community can be Misled by a “Novel” Methodology

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### ABSTRACT

*In recent years a lot of novel (mostly naturally inspired) search heuristics have been proposed. Among those approaches is Harmony Search. After its introduction in 2000, positive results and improvements over existing approaches have been reported. In this paper, the authors give a review of the developments of Harmony Search during the past decade and perform a rigorous analysis of this approach. This paper compares Harmony Search to the well-known search heuristic called Evolution Strategies. Harmony Search is a special case of Evolution Strategies in which the authors give compelling evidence for the thesis that research in Harmony is fundamentally misguided. The overarching question is how such a method could be inaccurately portrayed as a significant innovation without confronting a respectable challenge of its content or credentials. The authors examine possible answers to this question, and implications for evaluating other procedures by disclosing the way in which limitations of the method have been systematically overlooked.*

### 1. INTRODUCTION

Recent years have witnessed the introduction of numerous search heuristics, many of them inspired by metaphors from nature, physics and life. One of these, *Harmony Search*, has attracted considerable attention through its reported success based on the metaphor of jazz music improvisation,

where jazz musicians try to improve harmonies over time. Since its introduction in the year 2000, *Harmony Search* has been the subject of many publications. At the time this paper was written, Google Scholar (<http://scholar.google.com>) gave a total of 586 hits for “*Harmony Search*”, with 329 hits for publications since 2007 and even a book about this method has been published recently (Geem, 2010). A lot of positive results and improvements over existing approaches

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have been reported, which suggest that *Harmony Search* could be a promising method with a lot of potential for future improvements. In this paper we take a closer look at *Harmony Search* and try to understand what is really behind the metaphor of jazz improvisation and this presumably novel search heuristic.

The remaining part of the paper is organized as follows. In the next section we give a formal introduction of *Harmony Search* together with an overview about the developments regarding this heuristic in the last decade. Section 3 is dedicated to the well known and established search heuristic *Evolution Strategies* and to a rigorous comparison between *Evolution Strategies* and *Harmony Search*. With the background knowledge obtained in that part, we discuss in section 4 some representative publications regarding *Harmony Search* more in detail. We finish the paper with an extensive discussion in section 5 as well as with conclusions and an outlook about possible further work in section 6.

## **2. HARMONY SEARCH**

*Harmony Search* (HS) is a search heuristic based on the improvisation process of jazz musicians (Geem et al., 2001). In jazz music the different musicians try to adjust their pitches, such that the overall harmonies are optimized due to aesthetic objectives. Starting with some harmonies, they attempt to achieve better harmonies by improvisation. This analogy can be used to derive search heuristics, which can be used to optimize a given objective function instead of harmonies. Here the musicians are identified with the decision variables and the harmonies correspond to solutions. Like jazz musicians create new harmonies by improvisation, the HS algorithm creates iteratively new solutions based on past solutions and on random modifications. While this framework leaves a lot of space for interpretation, the basic

HS algorithm is always described in the literature in the following way.

The HS algorithm initializes the Harmony Memory (HM) with randomly generated solutions. The number of solutions stored in the HM is defined by the Harmony Memory Size (HMS). Then iteratively a new solution is created as follows. Each decision variable is generated either on memory consideration and a possible additional modification, or on random selection. The parameters that are used in the generation process of a new solution are called Harmony Memory Considering Rate (HMCR) and Pitch Adjusting Rate (PAR). Each decision variable is set to the value of the corresponding variable of one of the solutions in the HM with a probability of HMCR, and an additional modification of this value is performed with a probability of PAR. Otherwise (with a probability of  $1 - \text{HMCR}$ ), the decision variable is set to a random value. After a new solution has been created, it is evaluated and compared to the worst solution in the HM. If its objective value is better than that of the worst solution, it replaces the worst solution in the HM. This process is repeated, until a termination criterion is fulfilled. More detailed descriptions of this algorithm can be found in Geem et al. (2005c), Mahdavi et al. (2007), and Geem (2005a). Algorithm 1 gives an overview about the HS algorithm using pseudo code.

Since its introduction in the year 2000, *Harmony Search* has been subject of many publications. It has been applied to pipe network design (Geem et al., 2000; Geem et al., 2002), the design of water distribution networks (Geem, 2000; Geem, 2006a; Geem, 2007b; Geem, 2008), vehicle routing (Geem et al., 2005a; Geem, 2005b), the generalized orienteering problem (Geem et al., 2005c), the geometry design of geodesic domes (Saka, 2007), satellite heat pipe design (Geem & Hwangbo, 2006), the design of steel sway frames (Degertekin, 2008; Saka, 2009), the design of grillage systems (Erdal & Saka, 2006; Erdal & Saka, 2008), university course timetabling (Al-

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