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Water cycle algorithm: A detailed standard code

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Received 22 May 2015; received in revised form 24 December 2015; accepted 21 March 2016

Abstract

Inspired by the observation of the water cycle process and movements of rivers and streams toward the sea, a population-based metaheuristic algorithm, the water cycle algorithm (WCA) has recently been proposed. Lately, an increasing number of WCA applications have appeared and the WCA has been utilized in different optimization fields. This paper provides detailed open source code for the WCA, of which the performance and efficiency has been demonstrated for solving optimization problems. The WCA has an interesting and simple concept and this paper aims to use its source code to provide a step-by-step explanation of the process it follows.

Keywords: Metaheuristic algorithms; Water cycle algorithm; Global optimization

Required metadata

Current code version

C1	Current code version	v1.0
C2	Permanent link to code/repository used of this code version	https://github.com/ElsevierSoftwareX/SOFTX-D-15-00035
C3	Legal Code License	MATLAB Site-License (Korea University, License Number: 1081614)
C4	Code versioning system used	Word Press
C5	Software code languages, tools, and services used	MATLAB R2015a
C6	Compilation requirements, operating environments & dependencies	MATLAB, Windows, Mac OS X, Linux and experimental, Android/iOS support
C7	If available Link to developer documentation/manual	http://www.ali-sadollah.com/water-cycle-algorithm-wca
C8	Support email for questions	ali_sadollah@yahoo.com

1. Introduction

The water cycle process, also known as the hydrological or the H_2O cycle, explains the unceasing movement of water on, above, and below the surface of the earth. It consists of several phases such as evaporation, precipitation, and surface run-off [1]. As we observe in nature, streams flow into rivers and rivers flow into the sea. Finally, all the rivers and/or streams end up in the sea, the most downhill (low-altitude) place in the world [2].

Therefore, similar to a metaheuristic swarm optimization algorithm, this phenomenon lends itself to finding a global optimal solution or a near-optimal solution via effective exploration and exploitation. Inspired by this observation, the water cycle algorithm (WCA) has been developed as a new metaheuristic algorithm [3].

One of the advantages of the WCA is the lower number of insensitive user parameters it requires, which means that the WCA can address a wide range of optimization problems using the fixed user defined parameters.

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http://dx.doi.org/10.1016/j.softx.2016.03.001

Please cite this article in press as: Sadollah A, et al. Water cycle algorithm: A detailed standard code. SoftwareX (2016), http://dx.doi.org/10.1016/j.softx.2016.03.001

Over the last few years, the WCA has been successfully applied to several varieties of optimization problems such as water resources, civil engineering, and mathematics [4,5].

This paper aims to extend the application of WCA to additional optimization problems by making the source code of the algorithm available. This would assist users to improve or modify the current version of the WCA code. A unified code for the WCA is also offered.

The remainder of this paper is organized as follows. Section 2 presents the motivations and the significance of distributing the unified code of the WCA. The standard WCA along with its detailed processes is given in Section 3. The main source code of the WCA, written in MATLAB, is provided in Section 4. An illustrative example and its link to the WCA are presented in Section 5 to provide a comparison with other optimizers. The impact of the source code of the form in which the WCA is used on research activities is given in Section 6. Finally, a summary of this paper appears in Section 7.

2. Motivation and significance

The source code, which is available online, is capable of addressing various optimization problems arising in many different fields of study. This availability is expected to assist readers to save time in accessing the source code and to provide them with a fair comparison with other optimizers.

Some examples of WCA contributions are finding more optimal values in terms of cost (i.e., cheaper structures) [4,6] and weight (i.e., lighter products) [7].

Detailed explanations regarding the source code appear in Section 4. Lately, the WCA has gained more attention and by making its source code publicly available, the chance of other researchers using this optimizer in their applications is increased. Regarding its realistic application, the open source code of WCA can be implemented in robot path planning problems, because it can act as optimization software for finding the least distance to a destination point by a robot, and it can also be considered as one of the alternatives for the optimization toolbox used in MATLAB.

3. Water cycle algorithm: Idea, motivation, and design

The WCA mimics the flow of rivers and streams toward the sea and was derived by observing the water cycle process. Let us assume that there are some rain or precipitation phenomena. An initial population of design variables (i.e., population of streams) is randomly generated after the raining process. The best individual (i.e., the best stream), classified in terms of having the minimum cost function (for minimization problems), is chosen as the sea [3].

Then, a number of good streams (i.e., cost function values close to the current best record) are chosen as rivers, whereas the remaining streams flow into the rivers and the sea.

Starting the optimization algorithm requires the generation of an initial population representing a matrix of streams of size $N_{pop} \times D$, where D is the dimension. Hence, this matrix, which is generated randomly, is given as (the rows and column represent the population size (N_{pop}) and the number of design variables, D, respectively):

$$Total\ population = \begin{bmatrix} Sea \\ River_1 \\ River_2 \\ River_3 \\ \vdots \\ Stream_{Nsr+1} \\ Stream_{Nsr+2} \\ Stream_{Nsr+3} \\ \vdots \\ Stream_{N_{pop}} \end{bmatrix} = \begin{bmatrix} x_1^1 & x_2^1 & x_3^1 & \cdots & x_D^1 \\ x_1^2 & x_2^2 & x_3^2 & \cdots & x_D^2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_1^{N_{pop}} & x_2^{N_{pop}} & x_3^{N_{pop}} & \cdots & x_D^{N_{pop}} \end{bmatrix}. \tag{1}$$

In the first step, N_{pop} streams are created. Then, a number of best individuals N_{sr} (minimum values) are selected as the sea and rivers. The stream which has the minimum value (objective function) among the others is considered as the sea. In fact, N_{sr} is the summation of the number of rivers (which is defined by the user) and a single sea. The rest of the population (N_{stream}) are considered as streams flowing into the rivers or may alternatively flow directly into the sea.

Depending on the magnitude of the flow, each river absorbs water from streams. Hence, the amount of water entering a river and/or the sea varies from stream to stream. In addition, rivers flow to the sea, which is the most downhill location. The designated

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