Rain Water Algorithm: Newton's Law of Rain Water Movements During Free Fall and Uniformly Accelerated Motion Utilization

Totok R. Biyanto*
Process Design, Control and Optimization Laboratory
Department of Engineering Physics
Institut Teknologi Sepuluh Nopember, Indonesia
trb@ep.its.ac.id

Matradji
Process Design, Control and Optimization Laboratory
Department of Engineering Physics
Institut Teknologi Sepuluh Nopember, Indonesia
matradji@ep.its.ac.id

Henokh Y. Febrianto
Department of Industrial Engineering
Pusan National University, South Korea
joelhenokh@gmail.com

Naindar Afdanny
Process Design, Control and Optimization Laboratory
Department of Engineering Physics,
Institut Teknologi Sepuluh Nopember, Indonesia
afdanny14@mhs.ep.its.ac.id

Ahmad Hasinur Rahman
Process Design, Control and Optimization Laboratory
Department of Engineering Physics
Institut Teknologi Sepuluh Nopember, Indonesia
ahmad.hasinur13@mhs.ep.its.ac.id

Kevin Sanjoyo Gunawan
Process Design, Control and Optimization Laboratory
Department of Engineering Physics
Institut Teknologi Sepuluh Nopember, Indonesia
kevin13@mhs.ep.its.ac.id

Gabriella P. Dienanta
Process Design, Control and Optimization Laboratory
Department of Engineering Physics,
Institut Teknologi Sepuluh Nopember, Indonesia
gabrielladienanta@yahoo.co.id

Titania N. Bethiana
Department of Chemical Engineering
Institut Teknologi Sepuluh Nopember, Indonesia
titania.nb@gmail.com

***Abstract*— Rain Water Algorithm is a new algorithm that inspired by the pattern of physically rain water movements from air to the lowest place on the earth. It is necessary to evaluate the new algorithm with other algorithm utilizing known mathematical function that available in Comparing Continuous Optimizers (COCO) especially Black Box Optimization Benchmarking (BBOB) to analyze the performance of proposed algorithm. Optimization results exhibit that the purposed algorithm has surpass performance than others algorithms such as Genetic Algorithm (GA) and Simulated Annealing (SA).**

Keywords— Algorithm; Benchmark; Optimization; Rain Water

I. Introduction

Optimization algorithm is a technique to obtain optimum values or to solve optimization problem that can be divided into heuristic and metaheuristic optimizations. Metaheuristic optimization methods are widely applied to solve large-scale optimization problems that hard to solve due to non-linear and complex problem. Metaheuristic algorithms are based on phenomena taken from nature, such as the cooling process of molten metal through annealing, survival of the fittest, immune system, big bang-big crunch theory, social culture, music improvisation, and swarm intelligence [1-5]. They utilize these phenomena during the iterations to modify the search direction to find optimum solutions in optimization. Exploration and Exploitation are two main components of some metaheuristic algorithm. Exploration is to find solution more deeply than exploitation. More exploration slows down the convergence of the procedure although it increases the probability of finding the global or near-optimum solution and more exploitation makes the algorithm converge quickly often to a local optimum of the optimization problem [6].

Modern metaheuristic optimization approaches can be classified into two types: algorithms that are constructed after a thorough problem examination and algorithms that carry out change along the process on the basis of the success of the components thus adapting to the problem.

One of metaheuristic optimization algorithm is stochastic algorithm that work based on code such as Genetic Algorithm (GA) [7] and Simulated Annealing (SA) [8]. Nature phenomena commonly is used to develop this optimization algorithm. Rain Water Algorithm is a new algorithm that inspired by physical movements of rain water by utilizing Newton's Law motion. Each number of rain water indicate random values of some optimized variables. Initially, each rain water has varies in mass and elevation. They will fall on the ground by following the free fall movement with velocity is square root of gravity acceleration time elevation. This velocity will represent as initial velocity of rain water in the ground. The next movement is uniformly accelerated motion along the rain water travel to find out the lowest place on the ground as shown in Fig. 1. The lowest place in the ground is represent as objective function of optimization.

The performance of algorithm can be measured using Black Box Optimization Benchmarking (BBOB) method [9]. The types of benchmark noisy that utilize in this paper i.e. Gaussian noise, Uniform noise and Seldom Cauchy noise. The complexities of optimization problem is proportional with time consumption. The proposed algorithm has the minimum time consumption to reach global optimum compared to the other algorithm such as GA [7] and SA [8].

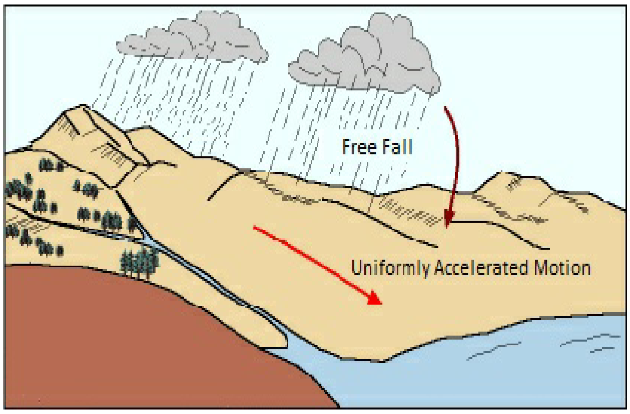

Fig. 1. Rain water movement during free fall and uniformly accelerated motion

II. Rain Water Algorithm

This section will described flowchart of Rain Water Algorithm. The initialization stages is performed by determine the number of rain water, number of iteration, dimensions, lower and upper bound of optimized variables. Furthermore, random value of height and mass of each rain water are determined.

The velocities (V_0) and positions (S_0) of rain water are calculated to find out time that needed of rain water to the ground. Dijkstra's Algorithm is utilized to determine the positions between rain water on the ground. The rain water will move to the lowest positions with each velocities depended on the mass and elevation. New positions will be updated follow the Newton's law of motion. The flowchart of this algorithm is shown in Fig. 2.

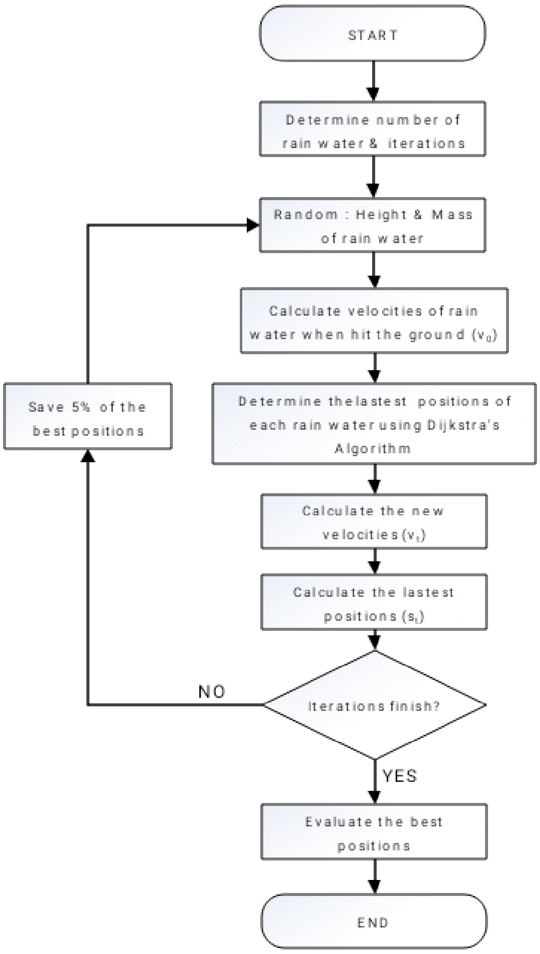

Fig. 2. Rain Water Algorithm Flowchart

III. Experimental Results

The BBOB method is used to measure the performance of proposed algorithm. In this paper used 6 types of noisy benchmark function i.e. Gaussian noise (FGN), Uniform noise (FUN) and Seldom Cauchy noise (FCN) as shown in Table I.

Parameter settings that used for first initialization in all algorithm are, total population and iteration that used in GA is 100 and 100 respectively. Mutation and crossover probability is set at 0.05 and 0.8. In SA algorithm, the number of cooling factor is 0.8, the number of Boltzmann constant is 1 and the number of maximum rejections is 100. For Rain Water Algorithm, the number of rain water are set at 100, the number of iterations are set at 100, gravity acceleration is set at 10, the initial velocities are zero.

TABLE I. NOISY BENCHMARK FUNCTION

Fun.	Test Problem	Objective Function	Search Range	Dim.
f_1	Sphere with moderate Gaussian noise	$f_1(x) = f_{GN}(\sum_{i=1}^{D} x_i^2, 0.01)$	[-5 to 5]	20
f_2	Sphere with moderate Uniform noise	$f_2(x) = f_{UN}(\sum_{i=1}^{D} x_i^2, 0.01\,(0.49 + \frac{1}{D}), 0.01)$	[-5 to 5]	20
f_3	Sphere with moderate Seldom Cauchy noise	$f_3(x) = f_{CN}(\sum_{i=1}^{D} x_i^2, 0.01, 0.05)$	[-5 to 5]	20
f_4	Rosenbrock with moderate Gaussian noise	$f_4(x) = f_{GN}(\sum_{i=1}^{D-1}(100(x^2 - x_{i+1})^2 + (x_i - 1)^2), 0.01)$	[-5 to 5]	20
f_5	Rosenbrock with moderate Uniform noise	$f_5(x) = f_{UN}(\sum_{i=1}^{D}(100(x^2 - x_{i+1})^2 + (x_i - 1)^2), 0.01\,(0.49 + \frac{1}{D}), 0.01)$	[-5 to 5]	20
f_6	Rosenbrock with moderate Seldom Cauchy noise	$f_6(x) = f_{CN}(\sum_{i=1}^{D}(100(x^2 - x_{i+1})^2 + (x_i - 1)^2), 0.01, 0.05)$	[-5 to 5]	20

Fig. 3 shows Rain Water Algorithm has less of computational time to reach global optimum than SA, however GA provide fastest to obtain the local optimum solution.

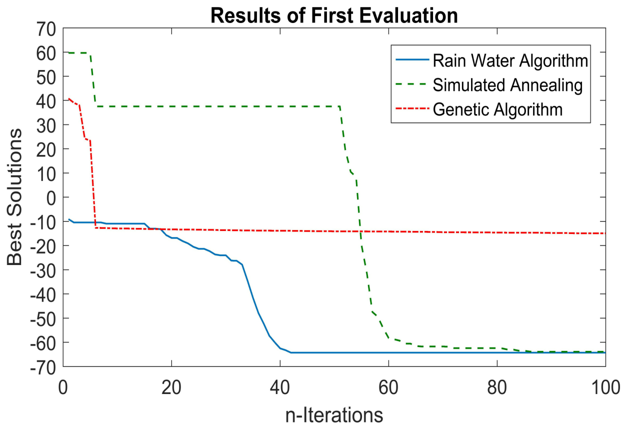

Fig. 3. Comparison of optimization result

The optimization results of BOBB test with 20 dimensions are tabulated in Table II. The results show that Rain Water Algorithm is able to reach global optimum.

TABLE II. RESULTS IN 20 DIMENSION

Fun		GA	SA	RWA
f_1	Min	-14.8819	-63.8754	**-64.2693**
f_2	Min	-11.5006	**-88.0677**	-55.3779
f_3	Min	-10.8461	**-78.1589**	-32.9741
f_4	Min	4.3482e+04	2.2310e+04	**1.7256e+04**
f_5	Min	5.4096e+04	5.1639e+04	**1.9293e+04**
f_6	Min	4.6363e+04	2.2145e+04	**1.5759e+04**

IV. CONCLUSION

In this paper, a new algorithm inspired by the pattern of physically rain water movements and Newton's Law Motion. The rain water will move to the lowest positions with each velocity depended on the mass and elevation. Global optimum is gained by updated the position followed the Newton's Law Motion. The results show that the performance of Rain Water Algorithm has outperformed than others algorithms.

ACKNOWLEDGMENT

The authors gratefully thank to Institut Teknologi Sepuluh Nopember (ITS) Surabaya for providing the facilities for conducting this research.

REFERENCES

[1] M. P. Saka and E. Dogan, "Recent developments in metaheuristic algorithms: a review," *Comput. Technol. Rev. 5*, pp. 31-78, 2012.

[2] M. P. Saka, E. Doğan and I. Aydogdu, "Analysis of Swarm Intelligence–Based Algorithms for Constrained Optimization," *Swarm Intelligence and Bio-Inspired Computation*, pp. 25-48, 2013.

[3] S. Voß, "Meta-heuristics: The State of the Art," *Lecture Notes in Computer Science*, pp. 1-23, 2001.

[4] X.-S. Yang and M. Karamanoglu, "Swarm Intelligence and Bio-Inspired Computation: An Overview," *Swarm Intelligence and Bio-Inspired Computation*, pp. 3-23, 2013.

[5] C. Blum and A. Roli, "Metaheuristics in combinatorial optimization: Overview and conceptual comparison," *ACM Computing Surveys (CSUR)*, vol. 35, no. 3, pp. 268-308, 2003.

[6] M. P. Saka, O. Hasançebi and Z. W. Geem, "Metaheuristics instructural optimization and discussions on harmony search algorithm," *Swarm and Evolutionary Computation*, vol. 28, p. 88–97, 2016.

[7] D. Goldberg, Genetic Algorithms in Search Optimization and Machine Learning, New York: Addison-Wesley, 1989.

[8] S. Kirkpatrick, "Optimization by simulated annealing: Quantitative studies," *Journal of Statistical Physics*, vol. 34, no. 5–6, p. 975–986, 1984.

[9] N. Hansen, et al., "Real-parameter black-box optimization benchmarking 2010: Experimental setup," Institut National de Recherche en Informatique et Automatique, Paris, 2010.