©2016 Published in 4th International Symposium on Innovative Technologies in Engineering and Science 3-5 November 2016 (ISITES2016 Alanya/Antalya - Turkey)

In a research on how to use inverse kinematics solution of actual intelligent optimization method

*1Serkan Dereli, 2Raşit Köker
1Computer Technology Department, Sakarya Vocational School Sakarya University
2Electrical and Electronic Engineering, Faculty of Technology, Sakarya University

Abstract

The kinematics that handles issue of motion and one of the most important parts of the control process of robot manipulator divided into inverse and forward kinematics. While the forward kinematics is determined the position of the end effector using variables of joint, the inverse kinematics is obtained value of joint variables from end effector. Although the forward kinematics is relatively easier than the inverse kinematic solution, the inverse kinematics is much more difficult and complex. In particular, the increasing number of joints of the robot is more difficult this solution. Today, intelligent optimization algorithms are frequently encountered in a solution to the inverse kinematics that is described as both difficult and also non-lineer problem. This paper explains that intelligent optimization methods used in inverse kinematics solution. Thus, researchers who are interested in this field will have a thorough investigation.

Keyword: Robotic, inverse kinematics, intelligent optimization methods

1. Introduction

The inverse kinematics solution is a major problem in robotic research area. If it is concerned about the trajectory planning, dynamic and control problems of a robot arm, firstly, kinematic model of the robot arm will be created [1]. Kinematics is divided into forward and inverse. While forward kinematic that determine position and orientation of end effector from joint angles is more easily and uncomplicated and calculated with closed form [2], inverse kinematic that converts position and orientation of the robot manipulator end-effector from Cartesian space to joint space more complicated and many traditional method such as geometric, iterative and algebraic are inadequate [3].

Traditional methods such as geometric, algebraic and iterative methods have been used for a long time for inverse kinematic solution. However, each method has certain disadvantages. Algebraic methods do not guarantee closed-form solutions. Geometric methods are used to the maximum three-jointed robot arm because of solving complex. Iterative methods are approached only one point and this point is connected to the starting point [4]. If the robot arm joint structure is very complex inverse kinematics solution takes a long time with this method [5]. Nowadays, especially 6-DOF and 7-DOF robot arm is eminently attractive to both the academy and the industry. Because it is known that if more than the number of joint the robot arm kinematic performance, maneuverability and dynamic performance is enhanced [6].

*Corresponding author: Address: Computer Technology Department, Sakarya Vocational School Sakarya University, 54187, Sakarya TURKEY. **E-mail address: dereli@sakarya.edu.tr, Phone: +902642953220**

Nowadays, intelligent optimization techniques such as evolutionary algorithms, neural networks, genetic algorithms, particle swarm optimization, artificial bee colony is often preferred in order to shorten the duration of inverse kinematics solution of a complex structure robot arm [7]. To use these techniques, inverse kinematics problem should be converted into a fitness function to find the best solution [8].

2. Actual Intelligent Optimization Methods Used in Inverse Kinematics

2.1. Artificial Neural Network

ANN has been developed, inspired by learning mechanisms between the human brain's and human behavior. With the ability to learn using examples and experiences are much more flexible and powerful [9]. Therefore, it is frequently used in many fields. Due to the difficult process, ensure that the learning system is the only disadvantage of the neural network. However, if the neural network learning is done properly, the solution is obtained at least error and successfully [4].

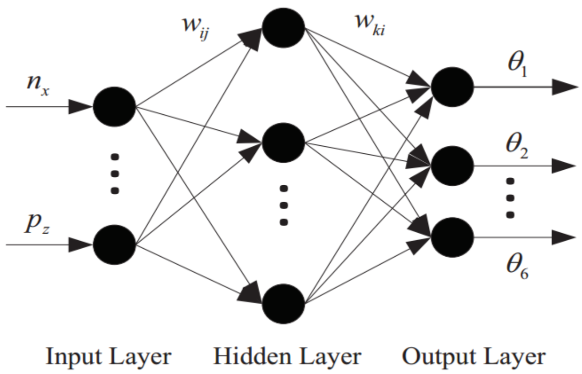


Figure 1. Developed for reverse kinematics, sample ANN design [1]

Studies conducted in inverse kinematics solution on the network training algorithms come into more prominence. Research on BP (Back Propagation) algorithm is more prominent than the use of other algorithms [9]. In particular, Back Propagation are frequently used with learning algorithm of Levenberg. Because, this algorithm gives more effective results in this way [1]. As is known, if neural network don't train very well, insecurity will be revealed. Therefore, Elman network that is a feedback network reveals effective results [10].

2.2. Particle Swarm Optimization

Because It is based on the structural collaboration between the particles, PSO based on the swarm behavior has a strong intelligent infrastructure [5]. This algorithm is useful for global optimization problems and it has a wide range of applications and it is a strong method [11]. The inverse kinematic solution of 4-DOF [12], 6-DOF [13] and 7-DOF [5] manipulator robots have been demonstrated to produce the best solutions with PSO algorithm. Almost all of the research that the algorithm used to obtain the best results, the problem is expressed as a fitness function, because optimization algorithms work in this way. [8]

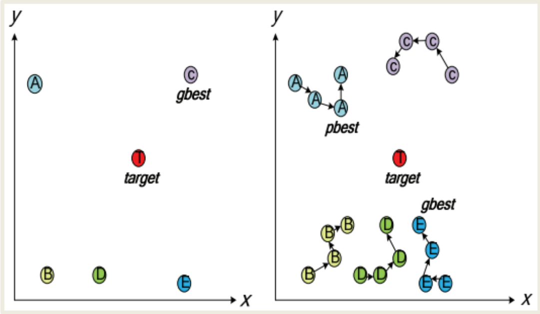


Figure 2. Geometrical illustration of the PSO algorithm (5)

If known robots such as Stanford, PUMA and KUKA are used in research, solution should obtained by comparing the results of multiple algorithms [12-13]. However, if a new robot design is done, the best solution has been demonstrated by obtaining a solution [5]. The results were revealed in terms of working time of algorithms, value of the joint angles and error rate of the end effector.

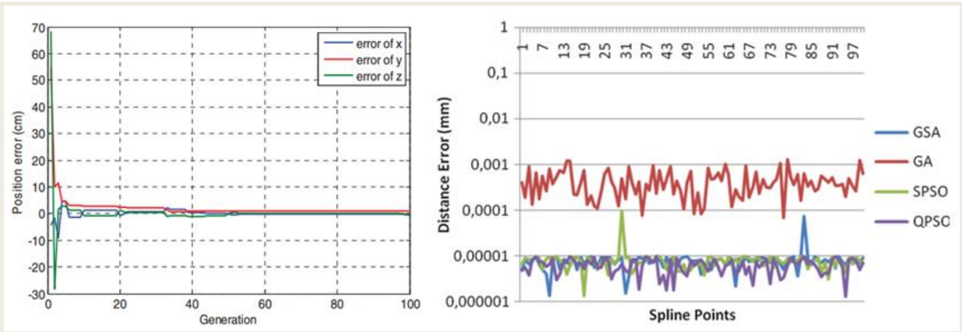


Figure 3. Thanks to error rate of end effector revealed a result graphic of example [5-12]

If the PSO which the initial value is assigned randomly is applied to a real robot, the robot manipulator will reach the destination reeling.

2.3. Artificial Bee Colony

ABC algorithm is an intelligent optimization algorithm that models the behavior of foraging of honey bees. Artificial Bee Colony that was proposed by Karaboğa in 2005 is a optimization techniques based on the swarm intelligence [14]. ABC algorithm has led researchers to use in solving a wide range of optimization problems because it has a simple working principle and comprises a small number of parameters and easy to apply [15].

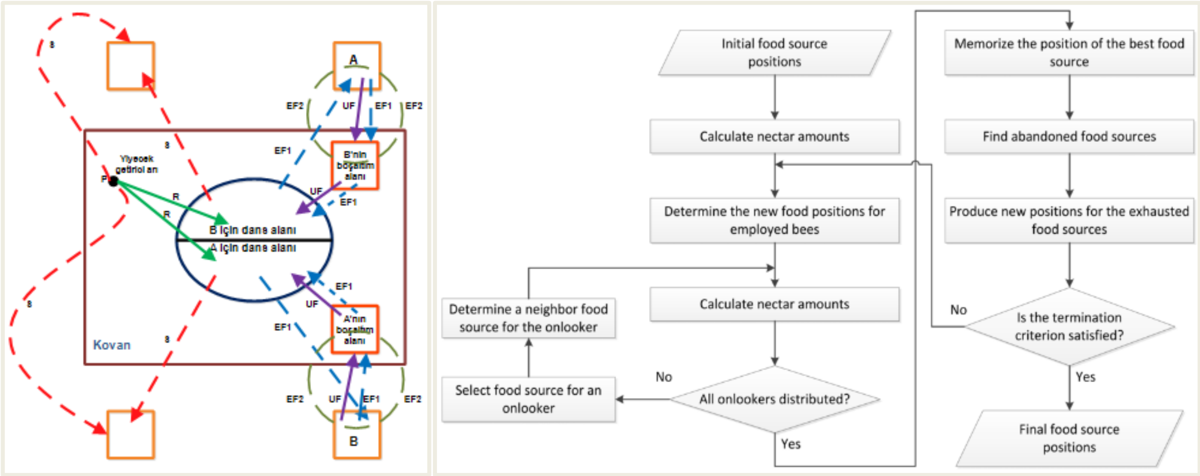
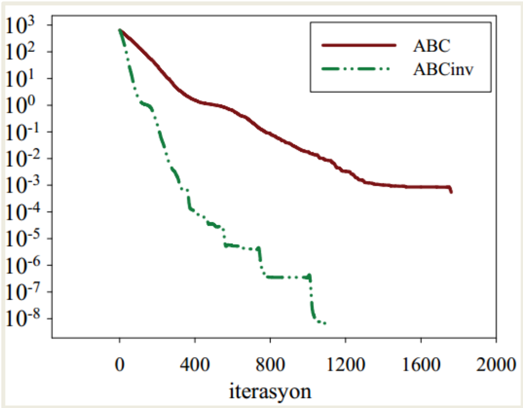


Figure 4. Artificial Bee Colony Algorithm [16]

Studies conducted in recent years reveal that to explore new solutions mechanism of ABC algorithm is working very well, however this studies demonstrate that the mechanism to do local search of ABC algorithm between neighboring solutions can be improved [14]. Therefore, ABC algorithm has been used in inverse kinematics solution trial by be developed.



JOINT-1 T-TEST RESULT FOR DIFFERENT ALGORITHMS

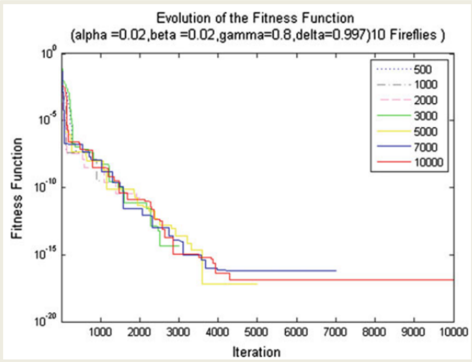
	Bees	BP	EA
μ	1.3210	1.5059	1.4504
σ	0.0511	0.0623	0.0665
upper bond	1.3575	1.5505	1.4980
lower bond	1.2844	1.4613	1.4028
t(0.025)		2.2622	2.2622
t-test		7.260704	4.88306

Figure 5. Comparison Standart ABC and be developed ABC (left fig.), Bee, BP and EA comparison (right fig.)

Because local search making mechanism between neighboring solutions is weak. Convergence rate is too slow. Therefore, the solution time and the number of iteration (You can see in Figure 5) leads to increase [17].

2.4. Firefly Algorithm (FFA)

Firefly algorithm that is proposed by Dr. Xin-She Yang (Cambridge University - 2007) is a meta-heuristic optimization algorithm based on the social behavior of the fireflies in tropical climates [18]. This algorithm has various similarities with other swarm intelligence-based algorithm. However, the concept is simple and practical [19]. In addition, firefly algorithm is easy to implement and much superior to other algorithms in terms of accuracy and efficiency. FFA is based on the firefly bugs behaviour, including the light emission, light absorption and the mutual attraction, which was developed to solve the continuous optimization problems [20].



Swarm size	Mean fitness function	Variance of fitness function
10	1.2714×10^{-17}	1.3855×10^{-34}
20	5.4093×10^{-18}	2.4058×10^{-35}
30	4.1216×10^{-18}	1.3097×10^{-35}
40	3.2146×10^{-18}	8.9239×10^{-36}
50	2.1458×10^{-18}	3.6605×10^{-36}
60	1.7891×10^{-18}	2.8612×10^{-36}

Figure 6. Impact of swarm size and the number of iteration [21]

Because Firefly algorithm is a new algorithm, it is not used a lot in inverse kinematics calculations. In the existing studies, defining a fitness function based on the error rate that is the distance between the calculated position and the actual position, it was run firefly algorithm according to this value. Furthermore, as many algorithm such as PSO, ABC, ACO the effects of particle number and algorithm parameters (β, α, Y) in solution has also been investigated in studies [21].

2.5. Hybrid Methods

Combining multiple algorithms of which successful aspects are selected are developed methods in order to obtain the best value.

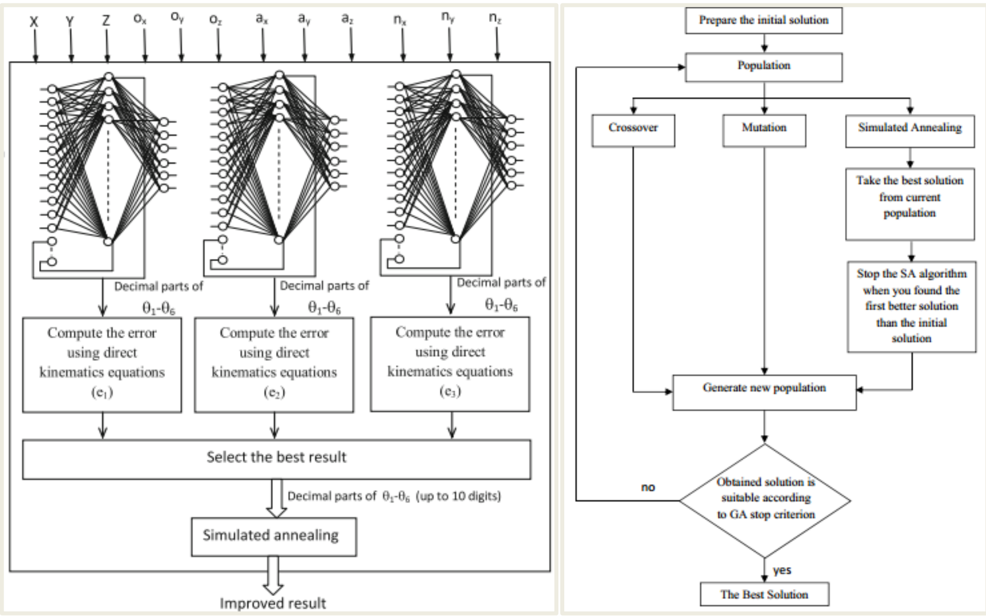


Figure 7. Combining two optimization algorithm for the best solution [22]

Intelligent optimization methods are widely used in the problems of which calculation is difficult, complex and long running time. However, the randomly selection of the initial value of some algorithms such as ABC, FFA, PSO adversely affect the robot orientation. In particular, when the differences between the initial value and the final value is more extreme, robot arm reaches the target point rolling. Neural networks of which its learning ability and convergence is very good are used effectively to prevent it. First, the robot arm is positioned on the target point with artificial neural networks. Then the error rate is minimized using a second algorithm such as simulated annealing, genetic [22-23-24].

3. Conclusions

This study the usage of intelligent optimization methods used in inverse kinematics solution that is one of the popular topics in the field of robotics reveals in detail. The Inverse kinematics that has a kind of non-linear problems is a much more difficult situation in a complex robot because of degree of freedom. Therefore, artificial intelligence techniques are often preferred in this problem. This research explains how to use the intelligent optimization methods of researches to solve this problem. In this way, researchers who have been working in this field will be a quick reference. Hybrid methods which are based on combining the strengths of two techniques are popular in the last few days in this solution. For example, combining simulated annealing and artificial neural network.

References

[1] Yuan T, Feng Y. A New Algorithm for Solving Inverse Kinematics of Robot Based on BP and RBF Neural Network. International Conference on Instrumentation and Measurement, Computer, Communication and Control 2014.

[2] Huang HC, Xu SSD, Hsu HS. Hybrid Taguchi DNA Swarm Intelligence for Optimal Inverse Kinematics Redundancy Resolution of Six-DOF Humanoid Robot Arms. Mathematical Problems in Engineering 2014.

[3] Qiao SG, Liao QZ, Wei SM, Su HJ. Inverse kinematic analysis of the general 6R serial manipulators based on double quaternions. Mechanism and Machine Theory 2010.

[4] Dash KK, Choudhury BB, Khuntia AK, Biswal BB. A Neural Network Based Inverse Kinematic Problem. Recent Advances in Intelligent Computational Systems 2011.

[5] Huang HC, Chen CP, Wang PR. Particle Swarm Optimization for Solving the Inverse Kinematics of 7-DOF Robotic Manipulators. IEEE International Conference on Systems, Man, and Cybernetics 2012.

[6] Küçük S, Bingül Z. The inverse kinematics solutions of fundamental robot manipulators with offset wrist. IEEE International Conference on Mechatronics 2005.

[7] Wang XS, Hao ML, Cheng YH. On the use of differential evolution for forward kinematics of parallel manipulators. Applied mathematics and computation 2008; 205:760-796.

[8] Rokbani N, Alimi AM. IK-PSO, PSO Inverse Kinematics Solver with Application to Biped Gait Generation. International Journal of Computer Applications 2012; 58:33-39.

[9] Bingül Z, Ertunç HM, Oysu C. Comparison of Inverse Kinematics Solutions Using Neural Network for 6R Robot Manipulator with Offset. ICSC congress on Computational Intelligence Methods and Applications 2005.
[10] Köker R. Reliability-based approach to the inverse kinematics solution of robots using Elman's networks. Engineering Applications of Artificial Intelligence 2005; 18:685-693.
[11] Eberhart J, Kennedy RC. Particle swarm optimization. IEEE International Conference on Neural Networks 1995.
[12] Ayyıldız M, Çetinkaya K. Comparison of four different heuristic optimization algorithms for the inverse kinematics solution of a real 4-DOF serial robot manipulator. Neural Comput & Applic 2015.
[13] Durmuş B, Temurtaş H, Gün A. An Inverse Kinematics Solution using Particle Swarm Optimization. International Advanced Technologies Symposium (IATS'11) 2011.
[14] Babayiğit B, Özdemir R. Modified Artificial Bee Colony Algorithm for Numerical Function Optimization. Elektronik ve Bilgisayar Mühendisliği Sempozyumu 2012.
[15] Baştürk B, Karaboğa D. On the performance of artificial bee colony (ABC) algorithm. Application Soft Computer 2008.
[16] Karaboğa D. Yapay Zeka Optimizasyon Algoritmaları. Ankara: Nobel Yayınları; 2011.
[17] Çavdar T, Milani MR. A New Heuristic Approach for Inverse Kinematics of Robot Arms. American Scientific Publishers, 2012.
[18] Yang XS. Firefly Algorithms Formultimodal Optimization, Proceedings of the Stochastic Algorithms. Foundations and Applications, Lecture Notes in Computing Sciences, 2009, Vol 5792.
[19] Akyol S, Alataş B. Actual Swarm Intelligence Optimization Algorithms. Nevşehir Üniversitesi Fen Bilimleri Enstitü Dergisi 2012; 1: 36-50.
[20] Apostolopoulos T, Vlachos A. Application of the Firefly Algorithm for Solving the Economic Emissions Load Dispatch Problem. International Conference Journal of Combinatorics 2011.
[21] Rokbani N, Casals A, Adimi AM. IK-FA, a New Heuristic Inverse Kinematics Solver Using Firefly Algorithm. Applications in Modeling and Control 2015; 575:369-395.
[22] Köker R. A neuro-simulated annealing approach to the inverse kinematics solution of redundant robotic manipulators. Engineering with computer 2013; 29:507-515.
[23] Pham DT, Castellani M, Fahmy AA. Learning the Inverse Kinematics of a Robot Manipulator using the Bees Algorithm. IEEE International Conference on Industrial Informatics 2008.
[24] Köker R. A genetic algorithm approach to a neural-network-based inverse kinematics solution of robotic manipulators based on error minimization. Information Sciences 2013; 222:528-543.