Solving the Inverse Kinematic problem of a Robot Arm using the Error Back-propagation algorithm

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Extended Abstract

Recently a number of solutions for the inverse Kinematic problem of a Robot Arm have been presented based on neural networks (N.N.). Various approaches based on the Kohonen's "self-organization mapping algorithm" [5], the Hopfield's network [3], the multilayer perceptron model [2,4] have been considered in order to avoid the Jacobian matrix singularities of the Pseudoinverse method [1] and to extend the optimization criteria in the case of redundant manipulators. When the problem is encountered as a general N.N. learning problem, then the memory and learning time requirements become huge in most practical applications and the accuracy of the solutions "yielded good results but were not accurate enough to be practically utilized" [2]. Intelligent approaches associating Jacobian control techniques and N.N. learning algorithms have been already achieved more accurate solutions [3].

In this paper the inverse Kinematic problem of a Robot Arm is solved using the Error back-propagation algorithm in a hybrid network consisting of three serial connected operators as shown in fig. 1.

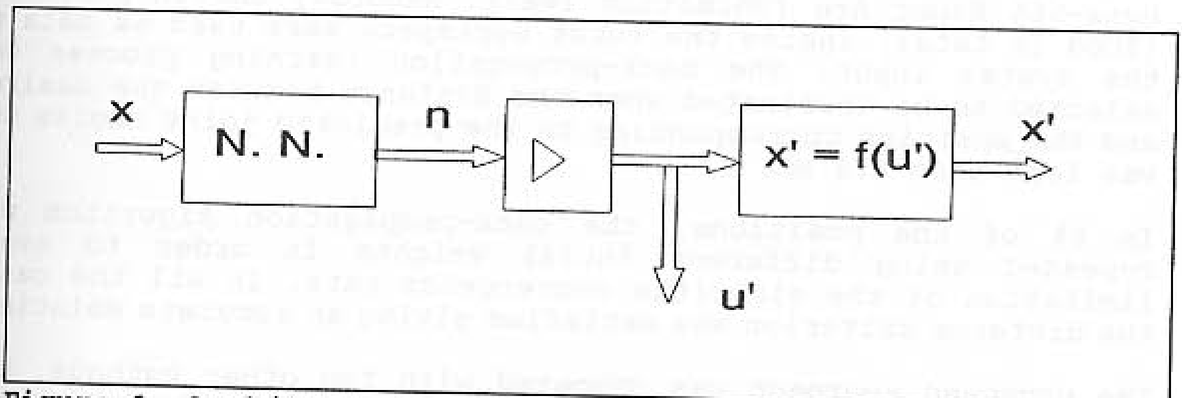

Figure 1. Architecture of the Hybrid N.N. and Kinematic function non-linear System

The system elements can be briefly described as follows: A three layer percepton network emulates the inverse function, mapping the desired position of the end-effector of a Robot Arm (x) to the network output vector (n). In the next stage the N.N. output vector is linearly transformed. This module produces an approximation for the joint angles (u'). The last module simulates the direct Kinematic equations (f) producing from the set of angles (u'), the arm position (x').

Our approach employs the Error back-propagation algorithm to minimize the squared-euclidian distance (eq.1) of the desired position from the system output position, in order to obtain an accurate solution for the inverse Kinematic problem:

$$E = |x - x'| \tag{1}$$

The above system structure resolves some crucial problems:

(a) The parameters of the linear transformation module adapt the N.N. output vector into an acceptable angle space for a specific Robot Arm. An application dependent set of parameters can be used to solve any position in the workspace.

(b) The identification of an invalid workspace position can be obtained examining the neural network output convergence to the limited values.

(c) In the proposed method, the robot joint angle limits and the Jacobian matrix required to be known which in the majority of the applications are well defined.

(d) The generalized N-degrees-of-freedom inverse Kinematic problem is solved in our approach. The optimization criterion of the Error back-propagation algorithm can be easily extended to more intelligent solutions.

Experiments

The efficiency of the proposed solution has been measured for the Puma-566 Robot Arm (Unimation 1987). Randomly chosen positions (3000 in total) inside the robot workspace were used as data to the system input. The back-propagation learning process was selected to be terminated when the distance between the desired and the position corresponding to the predicted joint angles set was less than 0.1 mm.

In 6% of the positions, the back-propagation algorithm was repeated using different intial weights in order to avoid limitation of the algorithm convergence rate. In all the cases the distance criterion was satisfied giving an accurate solution.

The proposed approach was compared with two other methods, the well known Pseudoinverse method [1] and a relatively new method [6] which solves the inverse kinematics problem using Genetic Algorithms. The detailed analysis and comparative results will be presented in the full paper.

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