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Single Information Space as a Means of Increasing the Efficiency of Medical Institutions Control in the Penal System

The article reflects features of a single information space for prison health. The main requirements to creation of a new information system management of medical institutions are identified.

Key words: information technology, single information space, prison health.

УДК 621.865.8

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INVERSE KINEMATICS SOLUTION IMPROVEMENT USING A NEURAL FUZZY LOGIC MODEL

The aim of this paper is to achieve an enhanced control of multi-joints robots based on the Adaptive Neuro-Fuzzy Inference System (ANFIS). First a database for training and a learning algorithm were proposed. A defined arm workspace was used to build the training database. Then the joints' angles which enable the end-effector from accessing the desired locations were derived. A six degrees of freedom robotic arm mounted on wheelchairs of the type iARM was adopted which is used to help handicapped people to carry out specific tasks.

Key words: fuzzy logic, artificial neural networks, inverse kinematics, manipulators, ANFIS.

In solving the inverse kinematics problem, algebraic methods don't guarantee finding solutions [2], geometric ones reach several solutions provided initial conditions for the first three arm joints' angles [3], and iterative methods give a unique solution but taking singularities in consideration [4]. All these methods require a considerable computation time. Recently, a lot of research appeared [5, 6, 7], about using artificial intelligence techniques for finding solutions of several complex control issues, with the ability to learn, interpret and explain decisions. Neural networks are considered good in pattern recognition, and non-linear approximation, but how decisions are reached is not clear. Fuzzy logic systems are useful when dealing with imprecise data, they explain and demonstrate how the decision was reached, but they cannot automatically recognize the rules, which they use to reach the decisions. Thus creating a hybrid system which contains both techniques leads to neuro-fuzzy systems, which can overcome their limitations, and offer an efficient inverse kinematics solution for multi-joints robots. Fuzzy systems behavior can be determined depending on the rules and thus its performance can be improved by tuning those rules [7]. For tuning the fuzzy logic rules parameters used in control systems, neural networks are used. Although the fuzzy logic systems using verbal expressions (linguistic labels or variables) symbolize the knowledge into rules, it requires considerable design and tuning time of the affiliation functions.

Robotic platforms used to help handicapped people consist of a platform and a robotic arm fixed on it, which moves within the platform framework using certain operating software. Platforms are divided into [1]: desktop mounted robotic systems (e.g., DeVAR and MySpoon), rail mounted manipulators (e.g., ProVAR), mobile robots (e.g., Gecko and Care Bot), wheel-chair mounted robotic arms (e.g., iARM).

This paper handles arm modeling and geometric specifications determination, examines the mathematical model development and the kinematics solution, and then suggests ANFIS type neuro-fuzzy model to carry out simulations, focusing on specific arm workspace for building the training database. The iARM robotic arm was adopted. MATLAB, using fuzzy logic and robotics libraries, was used for modeling and simulation.

iARM Inverse Kinematics

The iARM manipulator (figure 1) is a six joints robotic arm [1] with a bilateral gripper. It has a light weight of 9 kg and requires low energy. Joints are driven by DC motors using speed transformers positioned at the base. Its geometric structure offers a primary position which occupies limited space (fold position). When a command is given the arm moves from the fold position to the required location. The arm can be controlled by electrical signals originating from the human brain (BCI). Arm movement should not affect chair stability, guidance, control, maneuvering, movement ability, user convenience, and vision range. Workspace is selected to reflect the specific users' requirements of the chairs [1]. Coordinates axes are chosen relative to the arm base origin. Horizontal *xy* planes are determined to cover a height range between 5.08 cm and 142.24 cm above the ground level. Vertical planes are determined by intersecting the horizontal plane *yz* in several points which

Получено 05.02.14

determines the planes covered by the arm in front of and behind the coordinate's origin. To describe the kinematics of the arm, Denavit-Hartenberg (DH) parameters should be determined (α_{i-1}, a_{i-1}, θ_i, d_i) for each arm frame K_i.

Denavit–Hartenberg parameters

i	α_{i-1} (rad)	a_{i-1} (inch)	θ_i (rad)	d_i (inch)
1	0.00	0.00	0.00	15.43
2	–π/2	0.00	0.00	7.57
3	0.00	15.74	0.00	–3.93
4	–π/2	0.00	0.00	12.99
5	π/2	0.00	0.00	0.00
6	–π/2	0.00	0.00	5.31

The homogenous transform which relates the end-effector frame to the fixed base frame, and describes its position and orientation through the kinematics chain is given by the transformation matrix ${}^0_6T$ [8, 9]:

$$
{}^0_6T = {}^0_1T \cdot {}^1_2T \cdot {}^2_3T \cdot {}^3_4T \cdot {}^4_5T \cdot {}^5_6T = \\
= \begin{bmatrix} r_{11} & r_{12} & r_{13} & x \\ r_{21} & r_{22} & r_{23} & y \\ r_{31} & r_{32} & r_{33} & z \\ 0 & 0 & 0 & 1 \end{bmatrix} = A_1 \cdot A_2 \ldots A_6; \qquad (1)
$$

$$
A_1 = \begin{bmatrix} c_1 & -s_1 & 0 & 0 \\ s_1 & c_1 & 0 & 0 \\ 0 & 0 & 1 & 15.40 \\ 0 & 0 & 0 & 1 \end{bmatrix}; \quad A_2 = \begin{bmatrix} c_2 & 0 & -s_1 & 0 \\ s_2 & 0 & c_2 & 0 \\ 0 & -1 & 0 & 7.57 \\ 0 & 0 & 0 & 1 \end{bmatrix};
$$

$$
A_3 = \begin{bmatrix} c_3 & -s_3 & 0 & 0 \\ s_3 & c_3 & 0 & 0 \\ 0 & 0 & 1 & -3.937 \\ 0 & 0 & 0 & 1 \end{bmatrix};
$$

$$
A_4 = \begin{bmatrix} c_4 & 0 & -s_4 & 0 \\ s_4 & 0 & c_4 & 0 \\ 0 & -1 & 0 & 12.99 \\ 0 & 0 & 0 & 1 \end{bmatrix};
$$

$$
A_5 = \begin{bmatrix} c_5 & 0 & s_5 & 0.00 \\ s_5 & 0 & c_5 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}; \quad A_6 = \begin{bmatrix} c_6 & 0 & -s_6 & 0 \\ s_6 & 0 & c_6 & 0 \\ 0 & -1 & 0 & 5.315 \\ 0 & 0 & 0 & 1 \end{bmatrix}.
$$

Figure (1) shows the platform's measurements relative to the base frame.

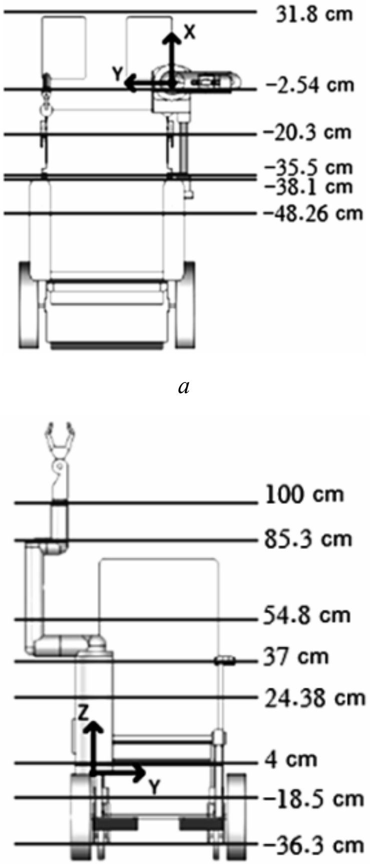
ANFIS Model

ANFIS model is an adaptive network, and a framework to derive fuzzy systems. The used mechanism is a Sugino type [5, 6], where every input takes three affiliation functions. The 2D input space is divided into nine overlapping fuzzy regions. Each of these regions is covered by an *if-then* rule. The rules condition part defines a fuzzy region, while the result part determines this region output. In the 1st layer each node i is an adaptive node, containing parameters which require modification where output is defined as follows:

$$
O_{1,i} = \mu_{Ai}(x), \text{ for } i = 1, 2, 3; \qquad (2)
$$
$$
O_{1,i} = \mu_{Bi-3}(y), \text{ for } i = 4, 5, 6
$$

x, y constitute inputs to the affiliation functions and they are in fact the fuzzy controller inputs coming from the system sensors. The output is the affiliation values (affiliation degrees) for the condition part in the rules. This layer contains parameters which will be trained, and they are the affiliation functions parameters of the condition part. The adaptive network training and parameters adjustment lead to the emergence of new rules with a new condition part and new form of affiliation functions. Affiliation functions with adjustable parameters should be chosen, and the generalized bell function might be used:

$$
\mu_A(x) = \frac{1}{1 + \left[\left(\frac{x - c_i}{a_i}\right)^2\right]^{b_i}}. \qquad (3)
$$



a

b

Figure 1. The platform's a) horizontal plane, b) vertical plane

The modifiable parameters here are{c, a, b} for each affiliation function, with a total of 12 adjustable parameters in the rules' condition part (premise parameters). In the 2nd layer nodes are constant nodes (i.e. don't contain any adjustable parameters), and these nodes simply multiply incoming signals, as follows:

$$O_{2,i} = w_i = \mu_{A_i} \times \mu_{B_i},\ i = 1, 2, 3. \tag{4}$$

What represents the output in each node is the separation signal or the base firing strength. Simply the *T*-norm coefficient can be used, which performs a fuzzy-*And* operation as an alternative. In the 3rd layer nodes are fixed nodes which calculate the signal strength ratio of each base relative to the total signal power as follows:

$$O_{3,i} = \overline{w_i} = \frac{w_i}{w_1 + w_2 + w_3},\ i = 1, 2, 3. \tag{5}$$

This output is called the normalized firing strengths. In the 4th layer nodes constitute adaptation nodes with the following format:

$$O_{4,i} = \overline{w_i} f_i = \overline{w_i}(p_i x + q_i y + r_i),\ i = 1, 2, 3. \tag{6}$$

Three new adjustable parameters (consequent parameters) p, q, r appear, where its modification affect the result part of Sugino fuzzy rules producing new rules with a new result part. The 5th layer contains a single fixed node which conducts a sum operation of the fourth layer output, and the result here is the output of Sugino system. Final output:

$$O_{5,1} = \sum\nolimits_i \overline{w_i} f_i = \frac{\sum_i w_i f_i}{\sum_i w_i}. \tag{7}$$

ANFIS model can be trained using either the back propagation algorithm BPA or the minimum square estimator algorithm. This training process is called the *hybrid learning algorithm*. If the condition part parameters values of the ANFIS structure were fixed it is possible to express the total output as a linear structure containing the rules result part parameters (p_1, q_1, r_1, r_2, p_2, q_2) as follows:

$$\begin{aligned} f &= \frac{w_1}{w_1 + w_2 + w_3} f_1 + \frac{w_2}{w_1 + w_2 + w_3} f_2 + \\ &+ \frac{w_3}{w_1 + w_2 + w_3} f_3 = \overline{w_1} f_1 + \overline{w_2} f_2 + \overline{w_3} f_3 = \\ &= (\overline{w_1 x}) p_1 + (\overline{w_1 y}) q_2 + (\overline{w_1}) r_1 + (\overline{w_2 x}) p_2 + \\ &+ (\overline{w_2 y}) q_2 + (\overline{w_2}) r_2 + (\overline{w_3 x}) p_3 + (\overline{w_3 y}) q_3 + (\overline{w_3}) r_3. \end{aligned} \tag{8}$$

This algorithm can be applied with a forward or backward path [5]. In the forward path the output is calculated until the fourth layer, and then the parameters are determined from the result part through the least square estimator (LSE). In the backward path the result part parameters are fixed and error is calculated and disseminated inversely, then the condition part parameters are adjusted depending on the gradient vector. The proposed system task is to solve the non-linear and time-variable differential equation (9) through the proposed model depending on the database, the proposed mathematical model, and the ANFIS neuro-fuzzy controller:

$$\theta(t) = f'(x(t)), \tag{9}$$

where $\theta_i = \theta(t)$, $i = 1, 2, 3, ..., n$ are the robot joints angles, and $x_j = x(t)$, $j = 1, 2, 3, ..., m$ are the Cartesian space position coordinates variables.

Simulation and Results

MATLAB was used for simulation in order to clarify the effectiveness of using the proposed neuro-fuzzy controller model in the deduction and control of the robot joints angles to reach the specified target. The robot has been studied in two respects: the modeling phase and building a dynamic model of the arm, and the control and inverse kinematics solution phase using the ANFIS neuro-fuzzy controller.

Six neuro-fuzzy controllers were designed and trained for producing the robot six joints angles values as shown in figure 2. The model consists of 78 nodes which in turn contain 138 adjustable parameters (108 linear and 30 non-linear). The proposed model has been trained on the iARM coordinates' data within a specific workspace allowed by the wheelchair movement as shown in figure 3. The reached number of the fuzzy rules in the controller is 27 rules.

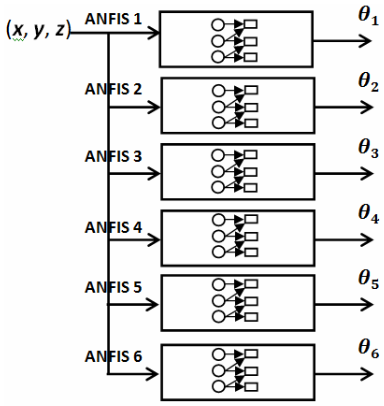


Figure 2. Neuro-fuzzy controller

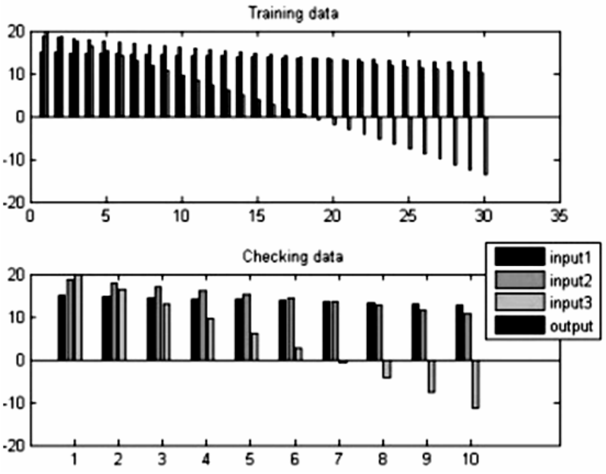


Figure 3. Training database

Figure 4 shows the used model structure, and figure 5 shows the input affiliation functions which are of the general bell type. We note that the result part parameters become ideal when the condition part parameters are fixed. The hybrid algorithm speed converges when decreasing the back propagation methodology search space dimension by fixing one of the parameters. In the experiment the ANFIS model required time periods to train 30 samples within a specific robot workspace are listed in the table. The training process takes place only once.

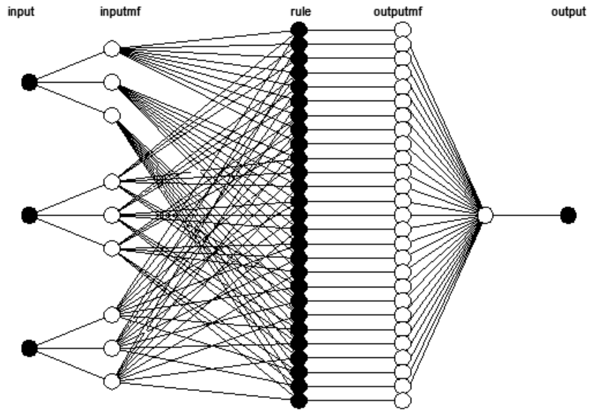


Figure 4. Proposed ANFIS model structure

Then the model is employed for calculating the joints angles. To determine the experimental coordinates (12.54, 10, –14.367) we get the joints angles values of the proposed ANFIS model faster by 50.9006 times than the iterative method. Figures 6 show a match between the joints angles values, and the error is acceptable to infer the inverse solution compared with the iterative method, except a difference in θ_1 value.

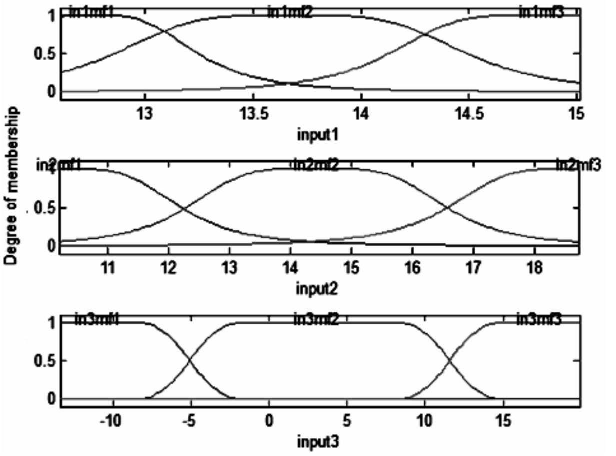
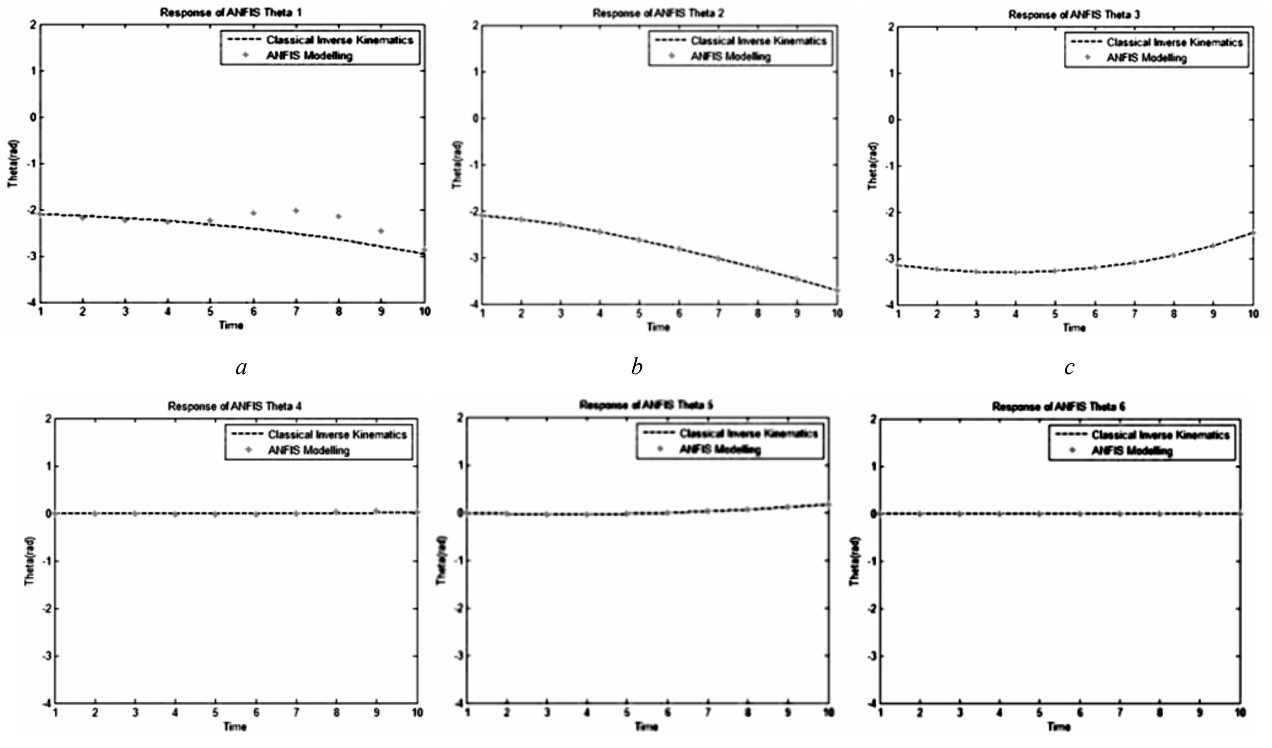


Figure 5. Neuro-fuzzy controller input affiliation functions

ANFIS model training for the iARM robot joints angles

Angle	Training time	Angle calculation time
θ_1	1.7466	0.0151
θ_2	1.2718	0.0017
θ_3	0.5207	0.0019
θ_4	1.3314	0.0024
θ_5	0.6086	0.0021
θ_6	0.4873	0.0023



a *b* *c*

d *e* *f*

Figure 6. Difference between the 2 methods to infer: *a* – θ_1; *b* – θ_2; *c* – θ_3; *d* – θ_4; *e* – θ_5; *f* – θ_6

Conclusion

ANFIS model was used as an alternative model to the iterative inverse kinematic solution algorithm relying on a training and correction database, and a specific mathematical model of the adopted iARM robot. Simulation results showed a match between all the joints angles in this method and the iterative method, except for the values of the first angle. The proposed model proved to be faster by approximately 50 times than its counterpart method.

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Совершенствование процесса решения обратной кинематической задачи на основе модели нейронной нечеткой логики

Целью данной работы является улучшение контроля многозвенных роботов на основе нейронной сети с архитектурой ANFIS. Прежде всего предлагается база данных и алгоритм для обучения. Для построения базы данных для обучения используется определенное рабочее пространство. Затем находят углы в сочленениях, которые позволяют захватному устройству робота получить доступ к желаемым позициям. Рассматривается манипулятор робота с шестью степенями свободы типа iARM, установленный на инвалидных колясках, который используется, чтобы помочь людям с ограниченными возможностями выполнять конкретные задачи.

Ключевые слова: нечеткая логика, искусственные нейронные сети, обратная кинематическая задача, манипуляторы, ANFIS.

УДК 672.1

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ПЛАНИРОВАНИЕ ДИСКРЕТНОГО ПРОИЗВОДСТВА В УСЛОВИЯХ НЕПОЛНОТЫ ИНФОРМАЦИИ*

The solution of a problem of planning and replanning of discrete production by the fuzzy sets theory is submitted. This problem is a two-criterial optimization problem, where as criteria the costs of production and personnel opinion are considered.

Ключевые слова: планирование производства, неполнота информации, метод Заде.

Процесс планирования и перепланирования дискретного производства является сложной и трудоемкой задачей. Решению этой задачи посвящен целый ряд исследований, например, работы [1, 2, 3, 4]. Однако современные системы, работающие на алгоритмах MRPII [5, 6], используют только точную, дискретную информацию. Описание же реального процесса обычно осуществляется в условиях неполноты исходной информации. Попытки описания процесса планирования производства в условиях неполноты исходной информации представлены в работах [1, 4]. При этом особый интерес вызывает процесс перепланирования производства в условиях неполноты информации.

Предположим, что предприятию необходимо произвести определенное количество различных изделий к определенному сроку. При планировании с помощью ERP-систем [5] можно полагаться только на информацию, которая представлена в цифровом виде: технологический маршрут, загруженность рабочих центров, спецификация и т. д. Такой подход не может учитывать мнение экспертов, а также возможные возмущения системы [7].

Получено 21.02.14

* Работа выполнена при финансовой поддержке Минобрнауки РФ (договор № 02.G25.31.0068 от 23.05.2013г. в составе мероприятия по реализации постановления Правительства РФ № 218).