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Colored Object Detection Using 5 Dof Robot Arm Based Adaptive Neuro-Fuzzy (ANFIS) Method

Mujiarto[1,2], Asari Djohar[2], Mumu Komaro[2], Mohamad Afendee Mohamed[3], Darmawan Setia Rahayu[4], W. S. Mada Sanjaya[5,*], Mustafa Mamat[3], Aceng Sambas[1], Subiyanto[6]

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Abstract

In this paper, an Adaptive Neuro Fuzzy Inference System (ANFIS) based on Arduino microcontroller is applied to the dynamic model of 5 DoF Robot Arm presented. MATLAB is used to detect colored objects based on image processing. Adaptive Neuro Fuzzy Inference System (ANFIS) method is a method for controlling robotic arm based on color detection of camera object and inverse kinematic model of trained data. Finally, the ANFIS algorithm is implemented in the robot arm to select objects and pick up red objects with good accuracy.

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Keywords*: Robot Arm, Adaptive Neuro Fuzzy Inference System, Inverse Kinematic Model, Color Detection*

1.0 Introduction

Over the last decade, researchers have attempted to solve problems in engineering with the help of ANFIS such as: ANFIS for tractor starter motor [1], railway wheels [2], external gear pumps [3], mo-tor DC [4], robotic [5], nonlinear three-tank system [6], emissions of a diesel engine [7], automatic parking [8], automatic voltage regulator [9], magnetorheological damper [10], aircraft auto-landing [11], surface roughness in grinding process [12] and welded aluminium pipes [13].

The robot manipulator control presents a major concern in robotics research at preent. In the literature, Mehmet constructed a control of 2-DOF direct-drive robot arm based fractional fuzzy adaptive sliding-mode method [14], Amer et al created 3 DOF planar robot manipulators based adaptive fuzzy sliding mode control [15], Pierrot et al investigated a new design of a 4-DOF parallel manipulator for high-speed and high-acceleration pick and place operations [16], Lotfazar et al explained a dynamic equations of motion of a 5 DoF robot manipulator based integrator backstepping method [17], Alavandar and Nigam described control of 6-DOF robot manipulator using Adaptive Neuro-Fuzzy Inference System [5] and Klanke et al contructed a dynamic path planning for a 7-DOF robot Arm [18]. In the last few years, several new design of robotic manipulator have been proposed [19-21].

Motivated by the above, writers focused on control of the new design 5-DOF robot arm based Adaptive Neuro Fuzzy Inference System (ANFIS). In this study presented color object detection, inverse kinematic model and Adaptive Neuro-Fuzzy (ANFIS) method as machine learning based on MATLAB. Finally, ANFIS method will be implemented to 5 DoF robot arm to pick up and place colored object.

Received September 2, 2016; Revised December 25, 2016; Accepted January 11, 2017

2.0 System Overview

Figure 1 describes that the webcam detects a colored object. Next, it is divided into two processes: the first process is to create training data, consisting of the coordinates of centroid colored objects and collecting data of servo angle. The second process is testing the system, after obtaining the coordinates of the centroid colored objects, then the test data of colored objects in accordance with the trained data. Data is processed to obtain a servo angle based on Adaptive Neuro-Fuzzy (ANFIS) method, which is used to drive servo motor of Robot Arm. All processes work in realtime based on MATLAB and Arduino microctroller.

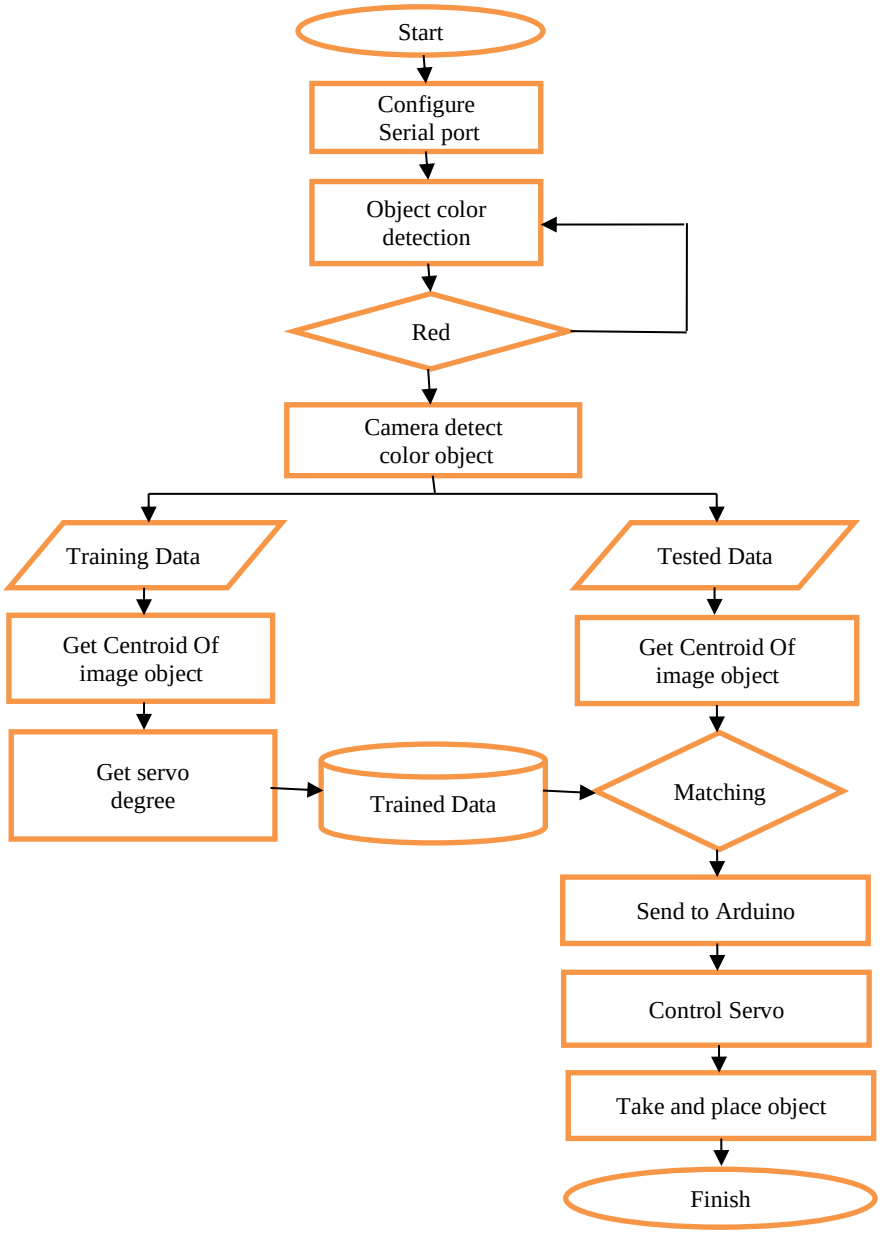


Figure 1: General System Scheme of Colored Object Detection

3.0 Color Detection

Webcam is a device that can be used as a sensor in detecting a colored object through image processing. The algorithm and inter-faces build based on MATLAB. Color detection can be done by transforming the image color space. The steps of red color detection using MATLAB are as follows:

1. Enable original video.
2. Extract each frame on the original video.
3. Transform the color space that originally resides in the RGB color space into the HSV color space.
4. Red segmentation of HSV color space based on H (0.8 to 1), S (0.5 to 1) and V (0.1 to 1).
5. Running all frames of the processing sequentially in video form.
6. The selected color object will be marked with a rectangle.

The detection result of the colored object has the centroid coordinate position (x; y) as shown in Figure 2.

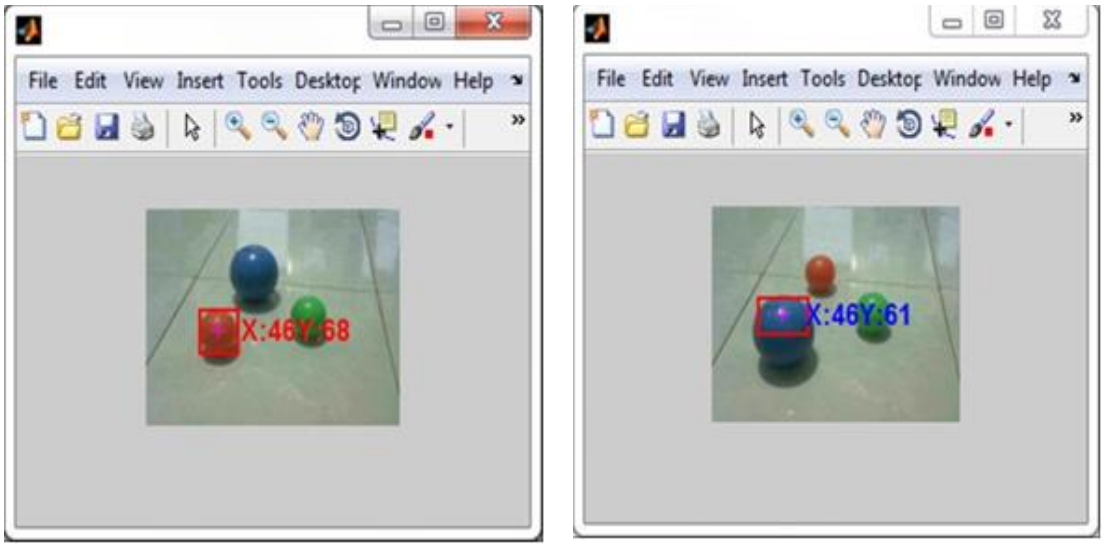


Figure 2: Interface of Color Detection with Coordinate

Figure 3: Hardware of Robot Arm 5 DOF

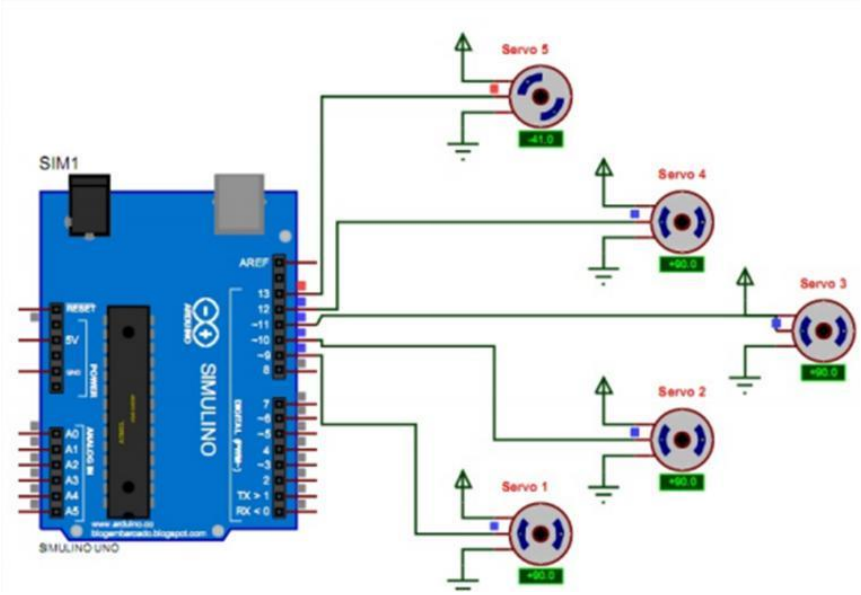


Figure 4: Schematic of Robot Arm

4.0 Hardware of Robot Arm

The main component of the 5 DOF robot arm are: Arduino board, webcam, motor servo, battery, cables and Robot Arm hardware construction, as shown in Figure 3. The schematic of 5 DOF robot arm is shown in Figure 4. Robot arm has 5 servos connected to each arduino pin. Servo1 connect to pin 9, Servo 2 connect to pin 10, Servo 3 connect to pin 11, Servo 4 connect to pin 12 and Servo 5 connect to pin 13.

5.0 Inverse Kinematic Model and Adaptive Neuro-Fuzzy

This work describes the basics of ANFIS network structure and its hybrid learning rule. Motivated by the major idea of fuzzy logic inference procedure on a feedforward network structure, Jang [22] constructed a fuzzy neural network model. The adaptive neuro fuzzy inference system (ANFIS) structure is depicted in Figure 5.

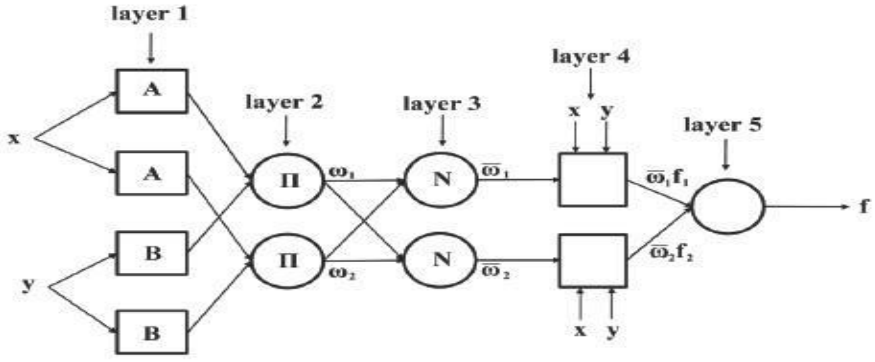


Figure 5: ANFIS Structure

Kinematics studies are conversion from Cartesian coordinates (*x*, *y*, *z*) to the moving angle of the joint (θ_1, θ_2, θ_3) of the mechanical Robot Arm. Kinematic classified to two part are Forward Kinematic (from joint angle to coordinate) and Inverse Kinematic (from coordinate to joint angle) [23].

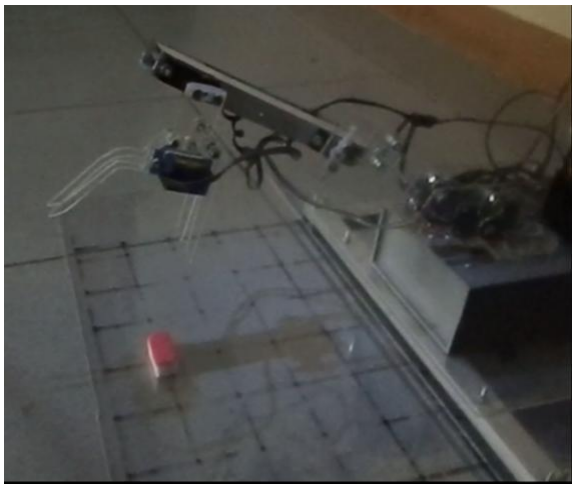
In this work, the data needed for training of ANFIS is obtained from the inverse kinematics models of the robot arm to take and place a colored object on certain coordinate. The data consist by input data as *x* and *y* coordinate, and the output data of servo's angle as Servo1-Servo 5 shown at Table 1. Webcam is used to obtain the coordinate data values from

the evaluation color object detection. The video capture configure as 640 x 480 pixel. When objects are in certain coordinates, we will get a servo angle capable of moving to reach the object. Furthermore, data will be used as training data in adaptive neuro fuzzy inference system (ANFIS).

Inverse kinematic model data consisting of coordinate data (*x* and *y*) of colored objects, and 5 servos angles with trained data (Cal = Calibration) and tested data (ANFIS = Adaptive Neuro Fuzzy Inference System training) are presented in Table 1. Experiment result using Adaptive Neuro Fuzzy Inference System shows rhe effectiveness of the approach in control Robot Arm to pick and place the colored object.

Table 1: The database of Inverse Kinematic Model to Control Robot Arm

Coordinate		Servo1		Servo2		Servo3		Servo4		Servo5	
x	y	Cal	ANFIS	Cal	ANFIS	Cal	ANFIS	Cal	ANFIS	Cal	ANFIS
107	205	113	110.998	174	168.341	50	60.4521	38	44.3076	105	105
105	205	113	111.646	174	168.48	50	60.1876	38	44.3137	105	105
103	207	113	112.239	174	169.507	50	58.4371	38	44.8238	105	105
107	210	113	110.602	174	170.347	50	57.0496	38	45.2488	105	105
102	210	113	112.193	174	170.746	50	56.3749	38	45.5633	105	105



(a) Find colored object

(b) Pick colored object

(c) Place colored object

Figure 6: Experimental result of the arm robot

6.0 Implementation of Color Detection

As shown in Figure 6, the robot arm detects a red object with the help of a webcam. Next, the robot picks up the object and moves it in the space provided. Experimental results show that the robot arm is capable of performing its tasks to detect colored objects, retrieve and move objects by control system using ANFIS.

7.0. Conclusion

In this work, ANFIS has been utilized to obtain the solution of inverse kinematic problem of 5 DOF robot arm. In this approach, invers kinematics relations of robot are used to obtain the data for training of ANFIS. Image processing been processed by algorithm based on MATLAB to detection of colored object. Finally, the implementation of red color detection and coordinate to control 5 DoF of Robot Arm based on Arduino microcontroller works ef-fective to take and place the colored object.

Acknowledgement

This The authors thank the Government of Malaysia for funding this research under the Fundamental Research Grant Scheme (FRGS/1/2017/ICT03/Unisza/02/2-RR229) and also Universiti Sultan Zainal Abidin, Terengganu, Malaysia.

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**Corresponding author E-mail:madasws@gmail.com*

Abstract

In this paper, an Adaptive Neuro Fuzzy Inference System (ANFIS) based on Arduino microcontroller is applied to the dynamic model of 5 DoF Robot Arm presented. MATLAB is used to detect colored objects based on image processing. Adaptive Neuro Fuzzy Inference System (ANFIS) method is a method for controlling robotic arm based on color detection of camera object and inverse kinematic model of trained data. Finally, the ANFIS algorithm is implemented in the robot arm to select objects and pick up red objects with good accuracy.

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Keywords*: Robot Arm, Adaptive Neuro Fuzzy Inference System, Inverse Kinematic Model, Color Detection*

1.0 Introduction

Over the last decade, researchers have attempted to solve problems in engineering with the help of ANFIS such as: ANFIS for tractor starter motor [1], railway wheels [2], external gear pumps [3], motor DC [4], robotic [5], nonlinear three-tank system [6], emissions of a diesel engine [7], automatic parking [8], automatic voltage regulator [9], magnetorheological damper [10], aircraft auto-landing [11], surface roughness in grinding process [12] and welded aluminium pipes [13], power system stabilizer [14], photovoltaic system [15], turbo-generators [16] and dynamic voltage restorer [17].

The robot manipulator control presents a major concern in robotics research at present. In the literature, Mehmet constructed a control of 2-DOF direct-drive robot arm based fractional fuzzy adaptive sliding-mode method [18], Amer et al created 3 DOF planar robot manipulators based adaptive fuzzy sliding mode control [19], Pierrot et al investigated a new design of a 4-DOF parallel manipulator for high-speed and high-acceleration pick and place operations [20], Lotfazar et al explained a dynamic equations of motion of a 5 DoF robot manipulator based integrator backstepping method [21], Alavandar and Nigam described control of 6-DOF robot manipulator using Adaptive Neuro-Fuzzy Inference System [22] and Klanke et al constructed a dynamic path planning for a 7-DOF robot Arm [23]. In the last few years, several new designs of robotic manipulator have been proposed [24-26].

Motivated by the above, writers focused on control of the new design 5-DOF robot arm based Adaptive Neuro Fuzzy Inference System (ANFIS). In this study presented color object detection, inverse kinematic model and Adaptive Neuro-Fuzzy (ANFIS) method as machine learning based on MATLAB. Finally, ANFIS method will be implemented to 5 DoF robot arm to pick up and place colored object.

The remainder of this paper is organized as follows: Section 2 presents the general system overview of colored object detection. Section 3 presents the color detection of the object

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based MATLAB. Section 4 describes schematic and hardware of Robot Arm. The architecture of ANFIS is presented on section 5. Implemented ANFIS method to Robot Arm to take and place the colored object presented on section 6 and section 7 discusses the benefits of the studied adaptive neuro fuzzy method and conclusions are presented.

2.0 System Overview

Figure 1 describes that the webcam detects a colored object. Next, it is divided into two processes: the first process is to create training data, consisting of the coordinates of centroid colored objects and collecting data of servo angle. The second process is testing the system, after obtaining the coordinates of the centroid colored objects, then the test data of colored objects in accordance with the trained data. Data is processed to obtain a servo angle based on Adaptive Neuro-Fuzzy (ANFIS) method, which is used to drive servo motor of Robot Arm. All processes work in real-time based on MATLAB and Arduino microcontroller.

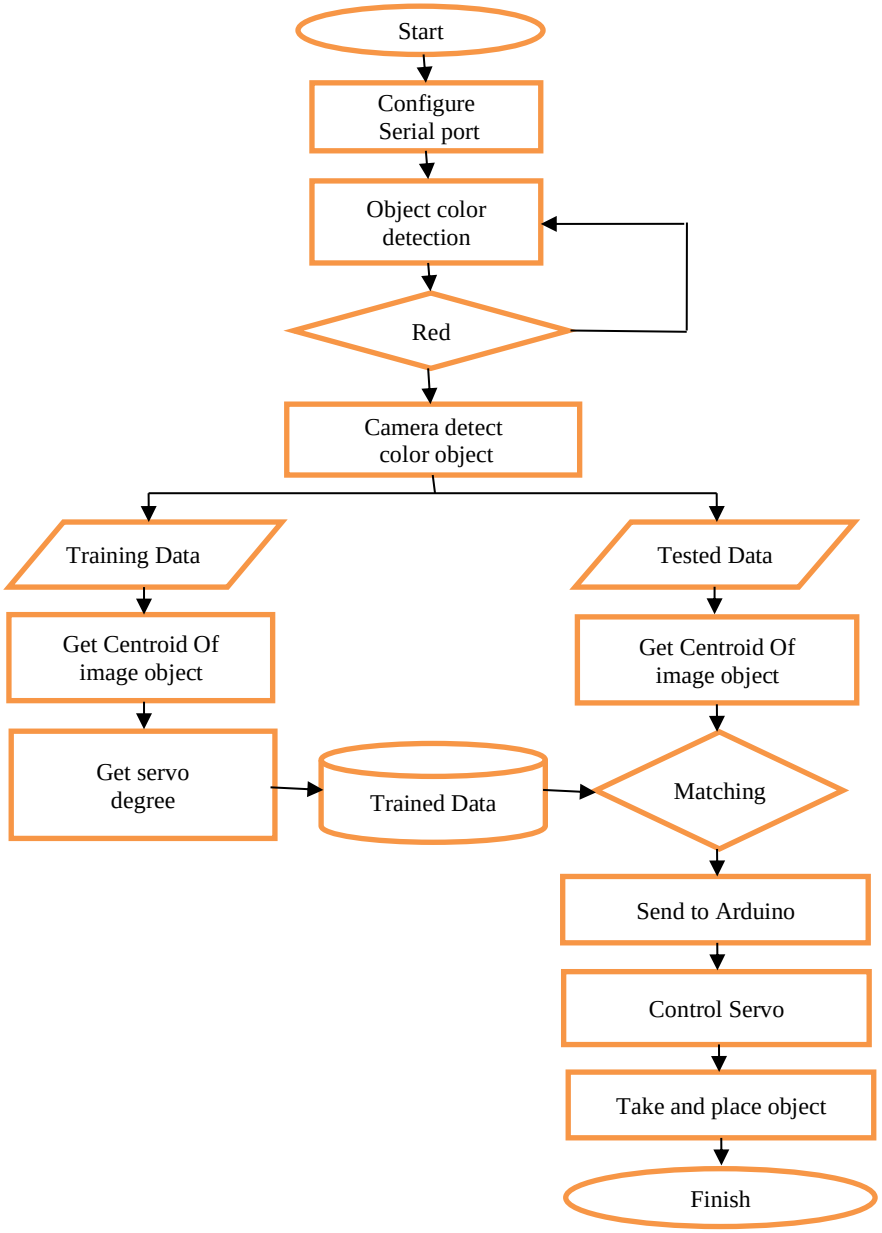

Figure 1: General System Scheme of Colored Object Detection

3.0 Color Detection

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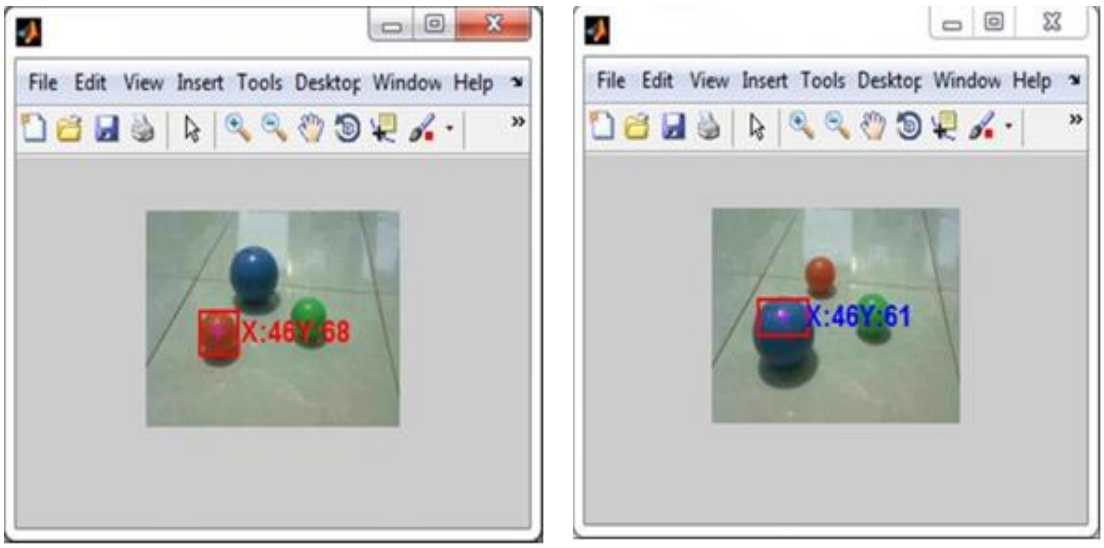

Figure 2: Interface of Color Detection with Coordinate

Figure 3: Hardware of Robot Arm 5 DOF

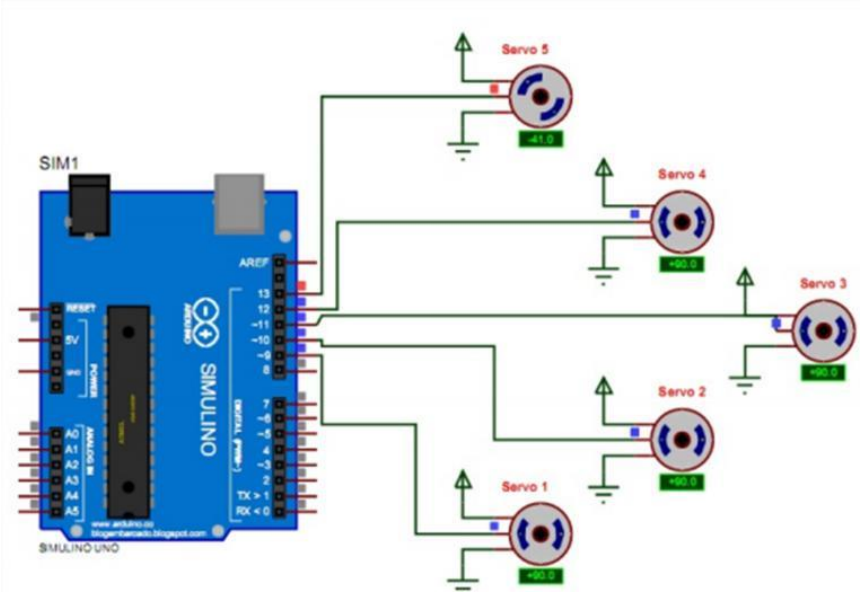

Figure 4: Schematic of Robot Arm

4.0 Hardware of Robot Arm

The main component of the 5 DOF robot arm are: Arduino board, webcam, motor servo, battery, cables and Robot Arm hardware construction, as shown in Figure 3. The schematic of 5 DOF robot arm is shown in Figure 4. Robot arm has 5 servos connected to each arduino pin. Servo1 connect to pin 9, Servo 2 connect to pin 10, Servo 3 connect to pin 11, Servo 4 connect to pin 12 and Servo 5 connect to pin 13.

5.0 Inverse Kinematic Model and Adaptive Neuro-Fuzzy

This work describes the basics of ANFIS network structure and its hybrid learning rule. Motivated by the major idea of fuzzy logic inference procedure on a feed forward network structure, Jang [27] constructed a fuzzy neural network model. The adaptive neuro fuzzy inference system (ANFIS) structure is depicted in Figure 5.

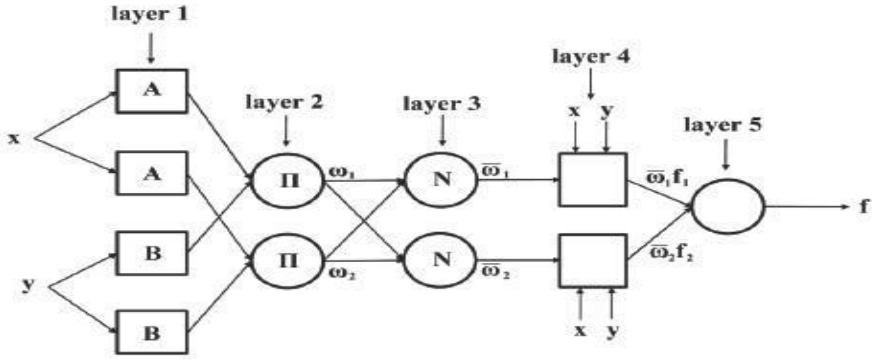

Figure 5: ANFIS Structure

Kinematics studies are conversion from Cartesian coordinates (*x*, *y*, *z*) to the moving angle of the joint (θ_1, θ_2, θ_3) of the mechanical Robot Arm. Kinematic classified to two part are Forward Kinematic (from joint angle to coordinate) and Inverse Kinematic (from coordinate to joint angle) [28].

In this work, the data needed for training of ANFIS is obtained from the inverse kinematics models of the robot arm to take and place a colored object on certain coordinate. The data consist by input data as *x* and *y* coordinate, and the output data of servo's angle as Servo1-Servo 5 shown at Table 1. Webcam is used to obtain the coordinate data values from

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Inverse kinematic model data consisting of coordinate data (*x* and *y*) of colored objects, and 5 servos angles with trained data (Cal = Calibration) and tested data (ANFIS = Adaptive Neuro Fuzzy Inference System training) are presented in Table 1. Experiment result using Adaptive Neuro Fuzzy Inference System shows the effectiveness of the approach in control Robot Arm to pick and place the colored object.

Table 1: The database of Inverse Kinematic Model to Control Robot Arm

Coordinate		Servo1		Servo2		Servo3		Servo4		Servo5	
x	y	Cal	ANFIS	Cal	ANFIS	Cal	ANFIS	Cal	ANFIS	Cal	ANFIS
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105	205	113	111.646	174	168.48	50	60.1876	38	44.3137	105	105
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107	210	113	110.602	174	170.347	50	57.0496	38	45.2488	105	105
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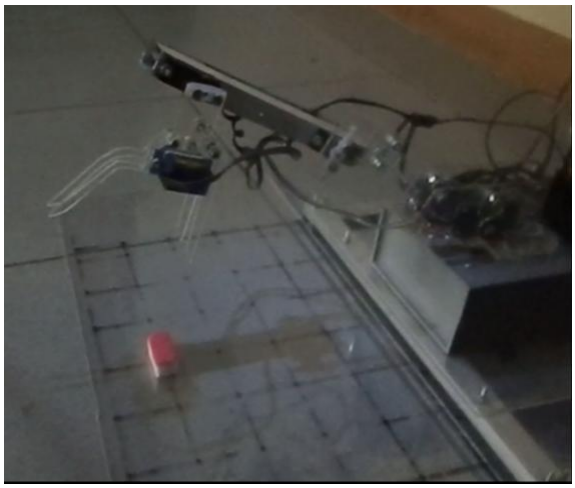

(a) Find colored object

(b) Pick colored object

(c) Place colored object

Figure 6: Experimental result of the arm robot

6.0 Implementation of Color Detection

As shown in Figure 6, the robot arm detects a red object with the help of a webcam. Next, the robot picks up the object and moves it in the space provided. Experimental results show that the robot arm is capable of performing its tasks to detect colored objects, retrieve and move objects by control system using ANFIS. When compared with some literature [18-23], the results of this study indicate a better level of accuracy.

7.0. Conclusion

In this work, ANFIS has been utilized to obtain the solution of inverse kinematic problem of 5 DOF robot arm. In this approach, invers kinematics relations of robot are used to obtain the data for training of ANFIS. Image processing been processed by algorithm based on MATLAB to detection of colored object. Finally, the implementation of red color detection and coordinate to control 5 DoF of Robot Arm based on Arduino microcontroller works effective to take and place the colored object.

Acknowledgement

This The authors thank the Government of Malaysia for funding this research under the Fundamental Research Grant Scheme (FRGS/1/2017/ICT03/Unisza/02/2-RR229) and also Universiti Sultan Zainal Abidin, Terengganu, Malaysia.

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We have improved our spelling mistakes and errors.

2. Improve analyzing and present comparison of your results to those obtained in similar studies. The "result and discussion" section reports the most important findings, including analysing results as appropriate. It is very important to prove that your manuscript has a significant value and not trivial.

We have improved as reviewer suggestion.

3. Please add structure of article in the end of Introduction

We have added structure of the end of Introduction

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Fwd: Six (6) other articles for your consideration

18 pesan

mafendee@unisza.edu.my <mafendee@unisza.edu.my> 21 Agustus 2018 11.16
Kepada: acenx.bts@gmail.com

Dear Dr,

Your article has been accepted by IJEECS. Sorry that it took longer than I promised. They gave some generic comments (below), please take a look into that and revise if appropriate. Return to me as soon as possible.

Best Regards.

-------- Original Message --------
Subject: Six (6) other articles for your consideration
Date: 2018-08-20 07:16
From: IJEECS Editor <ijeecs.iaes@gmail.com>
To: M A Mohamed <mafendee@unisza.edu.my>

Dear Dr. Mohamad Afendee Mohamed,

It is my great pleasure to inform you that your 6 papers are ACCEPTED and will be published on forthcoming issue of the Indonesian Journal of Electrical Engineering and Computer Science (http://iaescore.com/journals/index.php/IJEECS [1]), a Scopus indexed journal.

In preparing your final paper, please make sure that:

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aceng sambas <acenx.bts@gmail.com> 21 Agustus 2018 13.49
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Best Regards

Aceng Sambas

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Tamansari Gobras, Indonesia.
Email: acengs@umtas.ac.id,

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aceng sambas <acenx.bts@gmail.com> 21 Agustus 2018 22.22
Kepada: M A Mohamed <mafendee@unisza.edu.my>

Dear
Dr. Afandee

I am glad our article is accepted.
It is good journal (Q2). reputable journal.
Of course, I shall take care for revised.
I shall send it with soon.
Thanks

Best Regards

Aceng Sambas

Dept. of Mechanical Engineering
Universitas Muhammadiyah Tasikmalaya
Tamansari Gobras, Indonesia.
Email: acengs@umtas.ac.id,

[Kutipan teks disembunyikan]

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aceng sambas <acenx.bts@gmail.com> 27 Agustus 2018 23.04
Kepada: M A Mohamed <mafendee@unisza.edu.my>

Dear
Dr. Afandee

Enclosed our paper for IJEECS.
I have revised it.

Best Regards

Aceng Sambas

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mafendee@unisza.edu.my <mafendee@unisza.edu.my> 28 Agustus 2018 18.31
Kepada: aceng sambas <acenx.bts@gmail.com>

Dear Dr,

Thank you so much.

Best Regards.
[Kutipan teks disembunyikan]

---

aceng sambas <acenx.bts@gmail.com> 1 September 2018 09.30
Kepada: M A Mohamed <mafendee@unisza.edu.my>

Dear
Dr. Afandee

You are welcome.
if you have finished with payment.
please let me know.

Best Regards

Aceng Sambas

Dept. of Mechanical Engineering
Universitas Muhammadiyah Tasikmalaya
Tamansari Gobras, Indonesia.
Email: acengs@umtas.ac.id,

[Kutipan teks disembunyikan]

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aceng sambas <acenx.bts@gmail.com> 2 September 2018 09.22
Kepada: M A Mohamed <mafendee@unisza.edu.my>

Dear
Dr. Afandee

Congrat... Our paper
both of our articles have entered the Scopus database.
Regarding IJEECS, have you made a payment ?
Thanks

Best Regards

Aceng Sambas

Dept. of Mechanical Engineering
Universitas Muhammadiyah Tasikmalaya
Tamansari Gobras, Indonesia.
Email: acengs@umtas.ac.id,

Pada tanggal Sel, 28 Agt 2018 pukul 18.31 <mafendee@unisza.edu.my> menulis:
[Kutipan teks disembunyikan]

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mafendee@unisza.edu.my <mafendee@unisza.edu.my> 2 September 2018 13.00
Kepada: aceng sambas <acenx.bts@gmail.com>

Dear Dr,

I just requested the bursary to make the payment to IJEECS. It will take a couple of weeks.

Sorry to ask, but which are these two articles? I forgot which ones.

Best Regards.
[Kutipan teks disembunyikan]

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aceng sambas <acenx.bts@gmail.com> 2 September 2018 13.11
Kepada: M A Mohamed <mafendee@unisza.edu.my>

Dear
Dr. Afandee

a new four scroll and a new Jerk syste (see attachment).
Your docuiment in database scopus is 50 document. Congrat..

For Hamiltonian system, have you made a payment ?
It is good system.

Best Regards

Aceng Sambas

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Universitas Muhammadiyah Tasikmalaya
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Email: acengs@umtas.ac.id,

[Kutipan teks disembunyikan]

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2.PNG
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mafendee@unisza.edu.my <mafendee@unisza.edu.my> 2 September 2018 13.20
Kepada: aceng sambas <acenx.bts@gmail.com>

Thank you Dr. Now I remember there is one paper left to be paid. I will do it and get back to you soon.
[Kutipan teks disembunyikan]

---

aceng sambas <acenx.bts@gmail.com> 2 September 2018 13.25
Kepada: M A Mohamed <mafendee@unisza.edu.my>

Dear
Dr. Afandee

Thanks a lot Dr.
After many articles, you need to increase the H-index in Scopus.
Don't worry, I will help you to improve it.
Thanks

Best Regards

Aceng Sambas

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Universitas Muhammadiyah Tasikmalaya
Tamansari Gobras, Indonesia.
Email: acengs@umtas.ac.id,

[Kutipan teks disembunyikan]

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aceng sambas <acenx.bts@gmail.com> 13 September 2018 06.10
Kepada: M A Mohamed <mafendee@unisza.edu.my>

Dear
Dr. Afandee

Regarding IJEECS, Is it done for payment ?
Thanks

Best Regards

Aceng Sambas

Dept. of Mechanical Engineering
Universitas Muhammadiyah Tasikmalaya
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Email: acengs@umtas.ac.id,

[Kutipan teks disembunyikan]

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mafendee@unisza.edu.my <mafendee@unisza.edu.my> 13 September 2018 07.03
Kepada: aceng sambas <acenx.bts@gmail.com>

Dear Dr.,

Still with our bursary, hopefully by next week it will be paid. This time I requested them to make the payment since it is for 6 articles altogether.

I will let you know the soonest I got a new info from them.

Best Regards.
[Kutipan teks disembunyikan]

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aceng sambas <acenx.bts@gmail.com> 13 September 2018 07.08
Kepada: M A Mohamed <mafendee@unisza.edu.my>

Dear
Dr. Afandee

Ok Thank you Dr.
It is good paln.
Also, IJEECS is a good journal (Q2).
Thanks

Ok, thank you.
Best Regards

Aceng Sambas

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Universitas Muhammadiyah Tasikmalaya
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mafendee@unisza.edu.my <mafendee@unisza.edu.my> 13 September 2018 07.25
Kepada: aceng sambas <acenx.bts@gmail.com>

Dear Dr.,

First time, I submitted 5 articles altogether and it was all accepted and paid.
For the second round, I submitted another 6 articles (including yours) and it was accepted pending the payment.
Now I have another two articles and waiting for some more before submitting.

Most likely the articles will be accepted but the procedure of the journal to take up some times (to remain as a scopus indexed) before issuing accepting letter.

Best Regards.
[Kutipan teks disembunyikan]

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aceng sambas <acenx.bts@gmail.com> 29 September 2018 08.23
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---------- Forwarded message ----------
From: <mafendee@unisza.edu.my>
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aceng sambas <acenx.bts@gmail.com> 29 September 2018 08.24
Kepada: "Mujiarto , ST, MT" <mujiarto@umtas.ac.id>

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[IJEECS] Editor Decision

2 pesan

T. Sutikno <ijeecs@iaescore.com> 10 Agustus 2018 16.56
Balas Ke: "T. Sutikno" <ijeecs.iaes@gmail.com>
Kepada: Aceng Sambas <acenx.bts@gmail.com>

The following message is being delivered on behalf of Indonesian Journal of Electrical Engineering and Computer Science.

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Dear Prof/Dr/Mr/Mrs. Aceng Sambas,

We have reached a decision regarding your paper submission entitled "Colored Object Detection Using 5 Dof Robot Arm Based Adaptive Neuro-Fuzzy (ANFIS) Method" to Indonesian Journal of Electrical Engineering and Computer Science, a Scopus indexed journal (SJR 2017: 0.182, Q3 on Electrical and Electronic Engineering, Q3 on Computer Networksand Communications, Q3 on Hardware and Architecture, Q3 on Signal Processing)..

Our decision is: Revisions Required.
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Please state your technical result (one of the four types of technical results above) in your paper.
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4. Body – structured by headings and subheadings
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Colored object detection using 5 dof robot arm based adaptive neuro-fuzzy method

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ABSTRACT

In this paper, an Adaptive Neuro Fuzzy Inference System (ANFIS) based on Arduino microcontroller is applied to the dynamic model of 5 DoF Robot Arm presented. MATLAB is used to detect colored objects based on image processing. Adaptive Neuro Fuzzy Inference System (ANFIS) method is a method for controlling robotic arm based on color detection of camera object and inverse kinematic model of trained data. Finally, the ANFIS algorithm is implemented in the robot arm to select objects and pick up red objects with good accuracy.

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1. INTRODUCTION

Over the last decade, researchers have attempted to solve problems in engineering with the help of ANFIS such as: ANFIS for tractor starter motor [1], railway wheels [2], external gear pumps [3], motor DC [4], robotic [5], nonlinear three-tank system [6], emissions of a diesel engine [7], automatic parking [8], automatic voltage regulator [9], magnetorheological damper [10], aircraft auto-landing [11], surface roughness in grinding process [12] and welded aluminium pipes [13], power system stabilizer [14], photovoltaic system [15], turbo-generators [16] and dynamic voltage restorer [17].

The robot manipulator control presents a major concern in robotics research at present. In the literature, Mehmet constructed a control of 2-DOF direct-drive robot arm based fractional fuzzy adaptive sliding-mode method [18], Amer et al created 3 DOF planar robot manipulators based adaptive fuzzy sliding mode control [19], Pierrot et al investigated a new design of a 4-DOF parallel manipulator for high-speed and high-acceleration pick and place operations [20], Lotfazar et al explained a dynamic equations of motion of a 5 DoF robot manipulator based integrator backstepping method [21], Alavandar and Nigam described control of 6-DOF robot manipulator using Adaptive Neuro-Fuzzy Inference System [22] and Klanke et al constructed a dynamic path planning for a 7-DOF robot Arm [23]. In the last few years, several new design of robotic manipulator has been proposed [24-26].

Motivated by the above, writers focused on control of the new design 5-DOF robot arm based Adaptive Neuro Fuzzy Inference System (ANFIS). In this study presented color object detection, inverse kinematic model and Adaptive Neuro-Fuzzy (ANFIS) method as machine learning based on MATLAB. Finally, ANFIS method will be implemented to 5 DoF robot arm to pick up and place colored object.

The remainder of this paper is organized as follows: Section 2 presents the general system overview of colored object detection. Section 3 presents the color detection of the object based MATLAB. Section 4 describes schematic and hardware of Robot Arm. The architecture of ANFIS is presented on section 5. Implemented ANFIS method to Robot Arm to take and place the colored object presented on section 6 and section 7 discusses the benefits of the studied adaptive neuro fuzzy method and conclusions are presented.

2. SYSTEM OVERVIEW

Figure 1 describes that the webcam detects a colored object. Next, it is divided into two processes: the first process is to create training data, consisting of the coordinates of centroid colored objects and collecting data of servo angle. The second process is testing the system, after obtaining the coordinates of the centroid colored objects, then the test data of colored objects in accordance with the trained data. Data is processed to obtain a servo angle based on Adaptive Neuro-Fuzzy (ANFIS) method, which is used to drive servo motor of Robot Arm. All processes work in real-time based on MATLAB and Arduino microcontroller.

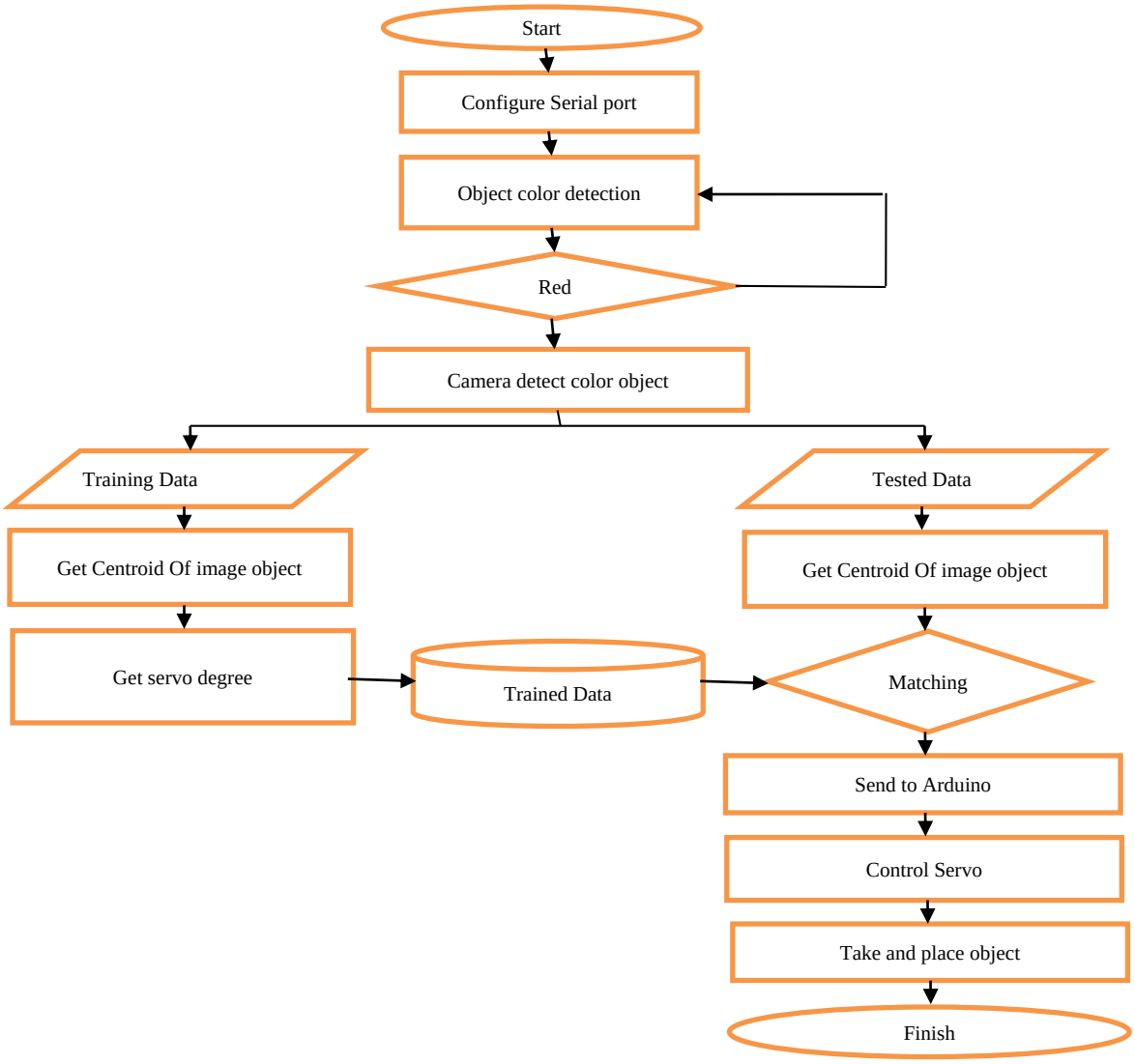


Figure 1. General System Scheme of Colored Object Detection

3. COLOR DETECTION

Webcam is a device that can be used as a sensor in detecting a colored object through image processing. The algorithm and inter-faces build based on MATLAB. Color detection can be done by transforming the image color space. The steps of red color detection using MATLAB are as follows:

1. Enable original video.
2. Extract each frame on the original video.
3. Transform the color space that originally resides in the RGB color space into the HSV color space.
4. Red segmentation of HSV color space based on H (0.8 to 1), S (0.5 to 1) and V (0.1 to 1).
5. Running all frames of the processing sequentially in video form.
6. The selected color object will be marked with a rectangle.

The detection result of the colored object has the centroid coordinate position (x; y) as shown in Figure 2.

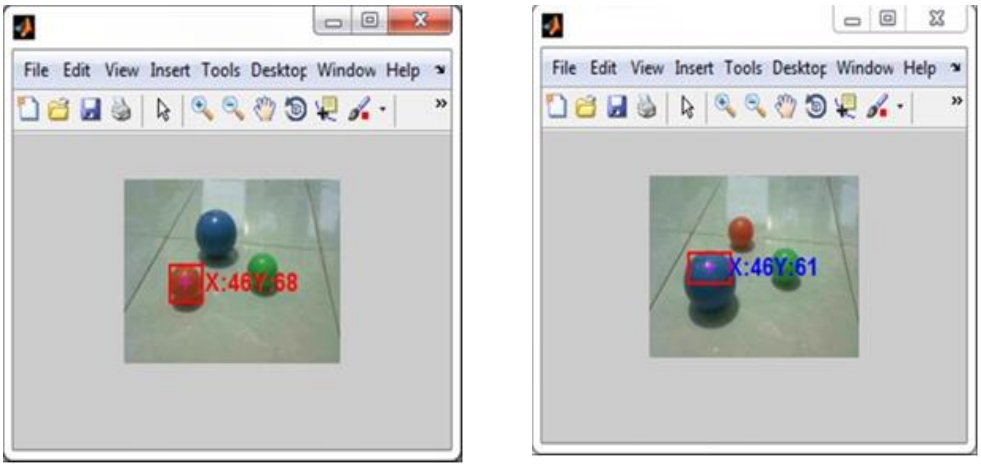


Figure 2. Interface of Color Detection with Coordinate

4. HARDWARE OF ROBOT ARM

The main component of the 5 DOF robot arm are: Arduino board, webcam, motor servo, battery, cables and Robot Arm hardware construction, as shown in Figure 3. The schematic of 5 DOF robot arm is shown in Figure 4. Robot arm has 5 servos connected to each arduino pin. Servo1 connect to pin 9, Servo 2 connect to pin 10, Servo 3 connect to pin 11, Servo 4 connect to pin 12 and Servo 5 connect to pin 13.

Figure 3. Hardware of Robot Arm 5 DOF

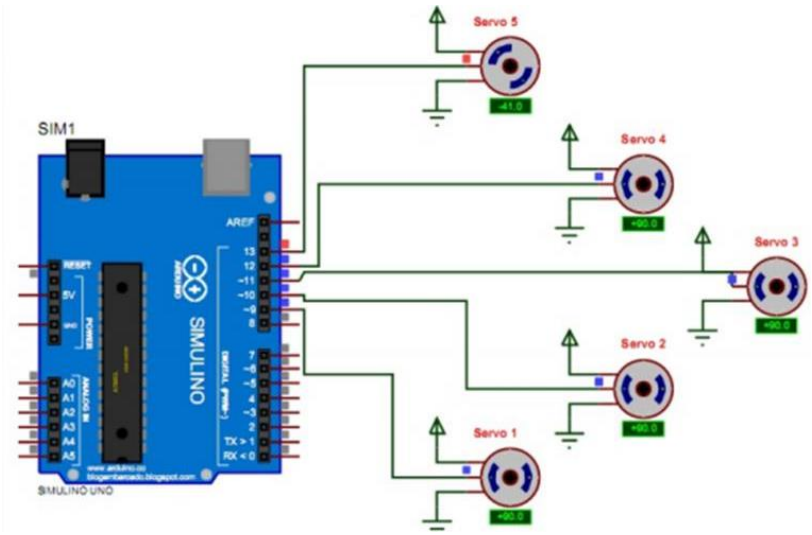


Figure 4. Schematic of Robot Arm

5. INVERSE KINEMATIC MODEL AND ADAPTIVE NEURO-FUZZY

This work describes the basics of ANFIS network structure and its hybrid learning rule. Motivated by the major idea of fuzzy logic inference procedure on a feed forward network structure, Jang [27] constructed a fuzzy neural network model. The adaptive neuro fuzzy inference system (ANFIS) structure is depicted in Figure 5.

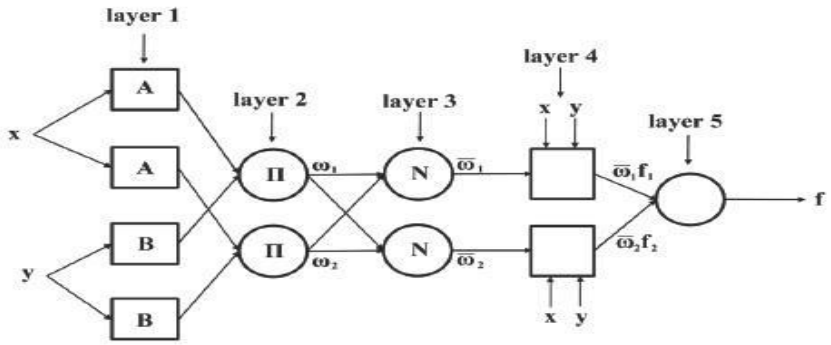


Figure 5. ANFIS Structure

Kinematics studies are conversion from Cartesian coordinates (*x*, *y*, *z*) to the moving angle of the joint (θ_1, θ_2, θ_3) of the mechanical Robot Arm. Kinematic classified to two part are Forward Kinematic (from joint angle to coordinate) and Inverse Kinematic (from coordinate to joint angle) [28].

In this work, the data needed for training of ANFIS is obtained from the inverse kinematics models of the robot arm to take and place a colored object on certain coordinate. The data consist by input data as *x* and *y* coordinate, and the output data of servo's angle as Servo1-Servo 5 shown at Table 1. Webcam is used to obtain the coordinate data values from the evaluation color object detection. The video capture configure as 640 x 480 pixel. When objects are in certain coordinates, we will get a servo angle capable of moving to reach the object. Furthermore, data will be used as training data in adaptive neuro fuzzy inference system (ANFIS).

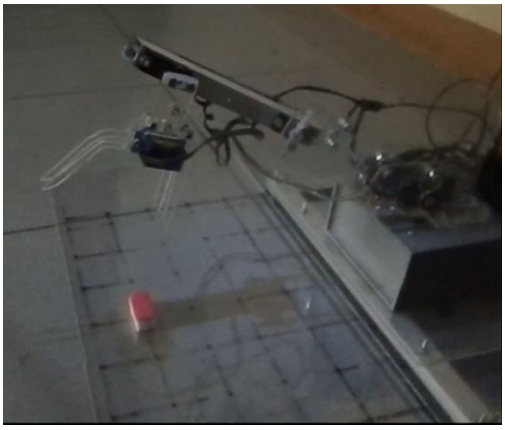
Inverse kinematic model data consisting of coordinate data (*x* and *y*) of colored objects, and 5 servos angles with trained data (Cal = Calibration) and tested data (ANFIS = Adaptive Neuro Fuzzy Inference System training) are presented in Table 1. Experiment result using Adaptive Neuro Fuzzy Inference System shows the effectiveness of the approach in control Robot Arm to pick and place the colored object.

Table 1. The database of Inverse Kinematic Model to Control Robot Arm

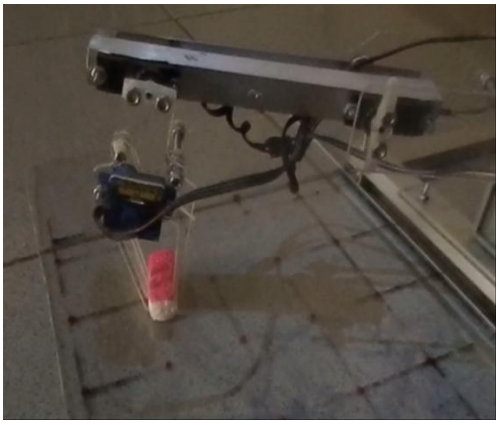
Coordinate		Servo1		Servo2		Servo3		Servo4		Servo5	
x	y	Cal	ANFIS	Cal	ANFIS	Cal	ANFIS	Cal	ANFIS	Cal	ANFIS
107	205	113	110.998	174	168.341	50	60.4521	38	44.3076	105	105
105	205	113	111.646	174	168.48	50	60.1876	38	44.3137	105	105
103	207	113	112.239	174	169.507	50	58.4371	38	44.8238	105	105
107	210	113	110.602	174	170.347	50	57.0496	38	45.2488	105	105
102	210	113	112.193	174	170.746	50	56.3749	38	45.5633	105	105

6. IMPLEMENTATION OF COLOR DETECTION

As shown in Figure 6, the robot arm detects a red object with the help of a webcam. Next, the robot picks up the object and moves it in the space provided. Experimental results show that the robot arm is capable of performing its tasks to detect colored objects, retrieve and move objects by control system using ANFIS. When compared with some literature [18-23], the results of this study indicate a better level of accuracy.



(a) Find colored object



(b) Pick colored object

(c) Place colored object

Figure 6. Experimental result of the arm robot

7. CONCLUSION

In this work, ANFIS has been utilized to obtain the solution of inverse kinematic problem of 5 DOF robot arm. In this approach, invers kinematics relations of robot are used to obtain the data for training of ANFIS. Image processing been processed by algorithm based on MATLAB to detection of colored object. Finally, the implementation of red color detection and coordinate to control 5 DoF of Robot Arm based on Arduino microcontroller works effective to take and place the colored object.

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