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Design Neuro-Fuzzy On-line Tuning Controller for Sensitive Dental Actuator

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Abstract

In this research, Neuro-fuzzy fuzzy feedback linearization controller is recommended for sensitive three degrees of freedom dental actuator. To design stable high quality controller conventional feedback linearization controller is recommended. Conventional feedback linearization (FL) controller is a nonlinear, stable, and reliable controller. This controller is model-base and in uncertain situation, model-base is challenge. The nonlinear dynamic formulation problem in highly nonlinear system has been solved by fuzzy logic theorem. Fuzzy logic theory is used to estimate the system dynamics. This type of controller is free of mathematical dynamic parameters of plant. When system works in uncertainty, the nonlinearity term of system is not equal to equivalent term of FL controller. According to this technique, the number of rule base is reduced with respect to have PID like fuzzy logic controller. The simulation results show that the proposed controller works well in various situations. Based on result and discussion, proposed method can eliminate chattering in certain and uncertain condition. This controller reduces the level of energy due to the torque performance. This controller removed the fluctuation in presence of uncertainties.

Keywords: *proportional-integral-derivative controller, feedback linearization controller, fuzzy logic theory, multi degrees of freedom actuator, dental actuator, system uncertainty*

1. System

The international organization defines the robot as "an automatically controlled, reprogrammable, multipurpose manipulator with three or more axes." The institute of robotic in The United States Of America defines the robot as "a reprogrammable, multifunctional manipulator design to move material, parts, tools, or specialized devices through various programmed motions for the performance of variety of tasks"[1].

Robot manipulator is a collection of links that connect to each other by joints, these joints are divided into main three categories:

- Revolute joint: revolute joint has rotary motion around an axis and has one angular DOF, Figure 1 shows revolute joint.

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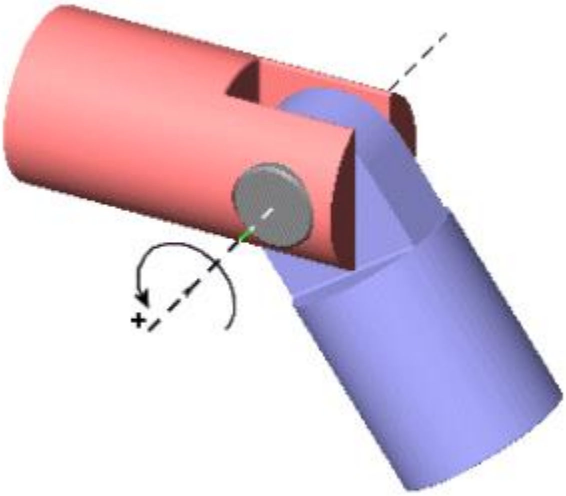

Figure 1. Revolute (1 DOF) Joint

- Prismatic joints: prismatic joint has linear motion around an axis and included one translates DOF, Figure 2 shows the prismatic joint [2-3].

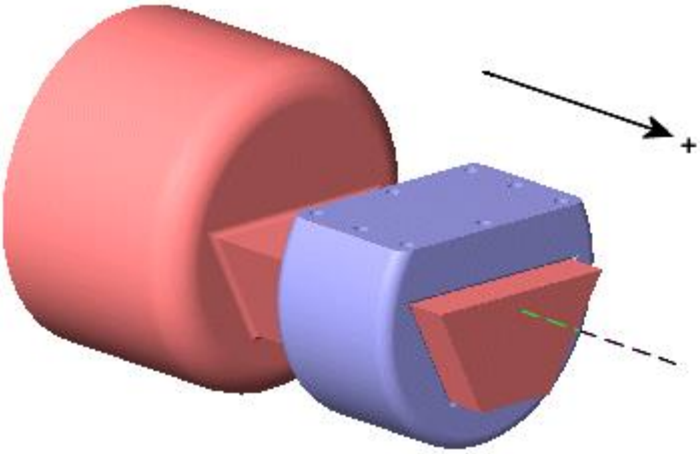

Figure 2. Prismatic (1 DOF) Joint

- Spherical joints: spherical joint (actuator) consisting of three DOF. Figure 3 shows the three degrees of freedom (spherical) joint.

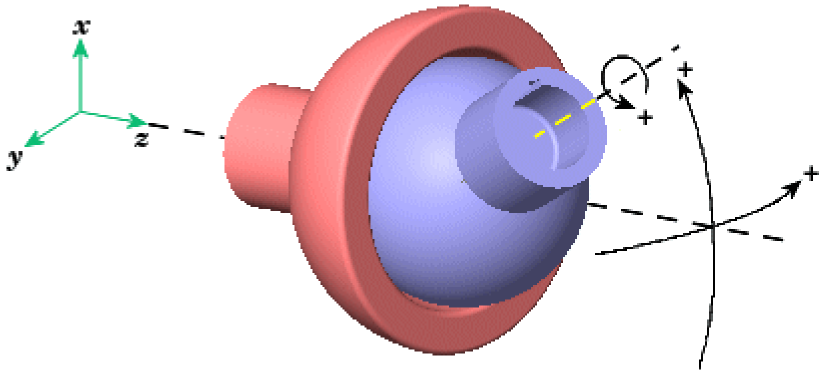

Figure 3. Three Degrees of Freedom (Spherical) Joint

The equation of a spherical motor governed by the following equation:

$$\boldsymbol{H}(\boldsymbol{q})\begin{bmatrix}\ddot{\alpha}\\ \ddot{\beta}\\ \ddot{\gamma}\end{bmatrix}+\mathbf{B}(\boldsymbol{q})\begin{bmatrix}\dot{\alpha}\dot{\beta}\\ \dot{\alpha}\dot{\gamma}\\ \dot{\beta}\dot{\gamma}\end{bmatrix}+\boldsymbol{C}(\boldsymbol{q})\begin{bmatrix}\dot{\alpha}^2\\ \dot{\beta}^2\\ \dot{\gamma}^2\end{bmatrix}=\begin{bmatrix}\tau_x\\ \tau_y\\ \tau_z\end{bmatrix} \quad \textbf{(1)}$$

Where τ is actuation torque, H (q) is a symmetric and positive define inertia matrix, B (q) is the matrix of coriolios torques, C (q) is the matrix of centrifugal torques.

This is a decoupled system with simple second order linear differential dynamics. In other words, the component $\ddot{q}$ influences, with a double integrator relationship, only the variableq_i, independently of the motion of the other parts. Therefore, the angular acceleration is found as to be:

$$\ddot{\boldsymbol{q}}=\boldsymbol{H}^{-1}(\boldsymbol{q}).\{\boldsymbol{\tau}-\{\boldsymbol{B}+\boldsymbol{C}\}\} \quad \textbf{(2)}$$

This technique is very attractive from a control point of view. Study of spherical motor is classified into two main groups: kinematics and dynamics. Calculate the relationship between rigid bodies and final part without any forces is called Kinematics. Study of this part is pivotal to design with an acceptable performance controller, and in real situations and practical applications. As expected the study of kinematics is divided into two main parts: forward and inverse kinematics. Forward kinematics has been used to find the position and orientation of task frame when angles of joints are known. Inverse kinematics has been used to find possible joints variable (angles) when all position and orientation of task frame be active [4].

The main target in forward kinematics is calculating the following function:

$$\boldsymbol{\Psi}(\boldsymbol{X},\boldsymbol{q})=\mathbf{0} \quad \textbf{(3)}$$

Where $\Psi(.)\in R^n$ is a nonlinear vector function, $X=[X_1,X_2,\dots\dots,X_l]^T$ is the vector of task space variables which generally task frame has three task space variables, three orientation, $q=[q_1,q_2,\dots.,q_n]^T$ is a vector of angles or displacement, and finally n is the number of actuated joints. The Denavit-Hartenberg (D-H) convention is a method of drawing spherical motor free body diagrams. Denvit-Hartenberg (D-H) convention study is necessary to calculate forward kinematics in this motor.

A systematic Forward Kinematics solution is the main target of this part. The first step to compute Forward Kinematics (F.K) is finding the standard D-H parameters. The following steps show the systematic derivation of the standard D-H parameters.

1. Locate the spherical motor
2. Label joints
3. Determine joint rotation (θ)
4. Setup base coordinate frames.
5. Setup joints coordinate frames.
6. Determineα_i, thatα_i, link twist, is the angle between Z_i and Z_{i+1} about an X_i.
7. Determine d_i and a_i , that a_i, link length, is the distance between Z_i and Z_{i+1} along X_i. d_i, offset, is the distance between X_{i-1} and X_i along Z_i axis.
8. Fill up the D-H parameters table. The second step to compute Forward kinematics is finding the rotation matrix (R_n^0). The rotation matrix from$\{F_i\}$ to $\{F_{i-1}\}$ is given by the following equation;

$$\boldsymbol{R_i^{i-1} = U_{i(\theta_i)} V_{i(\alpha_i)}} \tag{4}$$

Where $U_{i(\theta_i)}$ is given by the following equation;

$$\boldsymbol{U_{i(\theta_i)}} = \begin{bmatrix} \boldsymbol{cos(\theta_i)} & \boldsymbol{-sin(\theta_i)} & \boldsymbol{0} \\ \boldsymbol{sin(\theta_i)} & \boldsymbol{cos(\theta_i)} & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{0} & \boldsymbol{1} \end{bmatrix} \tag{5}$$

and $V_{i(\alpha_i)}$ is given by the following equation;

$$\boldsymbol{V_{i(\theta_i)}} = \begin{bmatrix} \boldsymbol{1} & \boldsymbol{0} & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{cos(\alpha_i)} & \boldsymbol{-sin(\alpha_i)} \\ \boldsymbol{0} & \boldsymbol{sin(\alpha_i)} & \boldsymbol{cos(\alpha_i)} \end{bmatrix} \tag{6}$$

So (R_n^0) is given by

$$\boldsymbol{R_n^0 = (U_1 V_1)(U_2 V_2) \dots \dots \dots (U_n V_n)} \tag{7}$$

The final step to compute the forward kinematics is calculate the transformation ${}_n^0T$ by the following formulation.

$$\boldsymbol{{}_n^0T = {}_1^0T . {}_2^1T . {}_3^2T \dots \dots . {}_n^{n-1}T} = \begin{bmatrix} \boldsymbol{R_n^0} & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{1} \end{bmatrix} \tag{8}$$

Figure 4 shows step input/output graph.

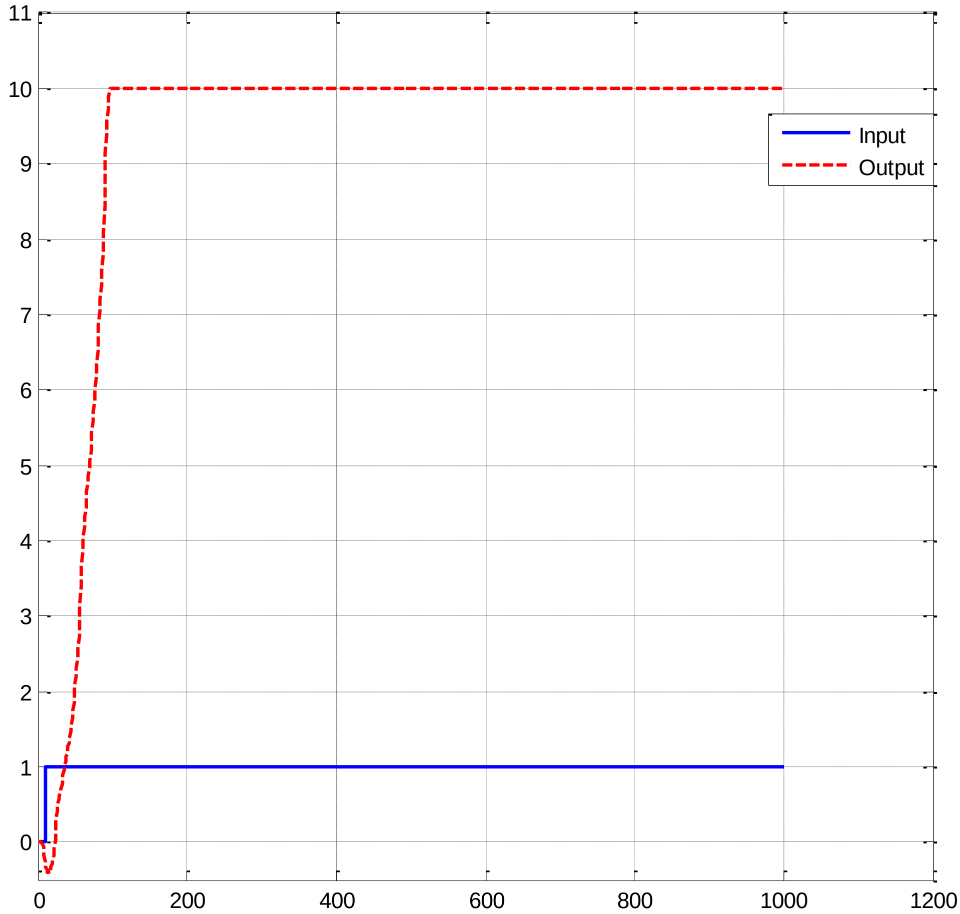

Figure 4. Input/Output Step Action

Figure 5 shows output/input action for Repeating Sequence Interpolated signals. Regarding to Figure 4 and 5, for these two inputs the output signals are the same and go towards saturation.

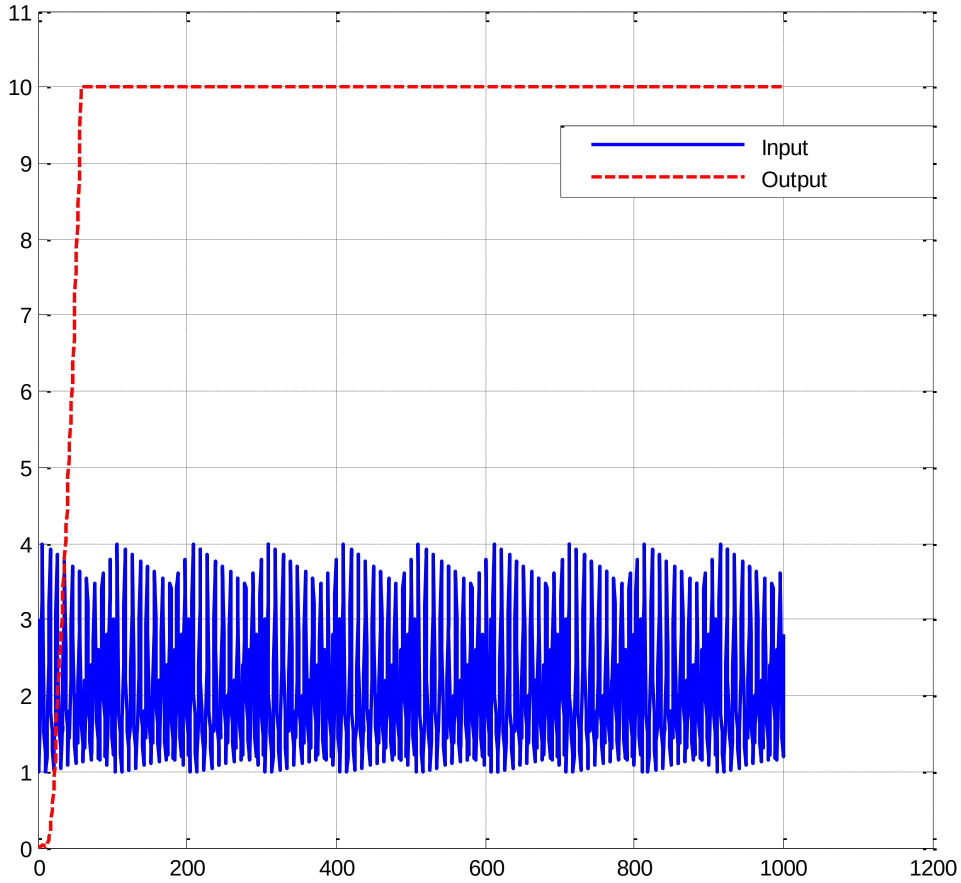

Figure 5. Input/Output Repeating Sequence Interpolated Action

2. Control

To control of multi degrees of freedom actuator, three purposes are very important:

- **Stability**: Stability is due to the proper functioning of the system. A system is called stable if for any bounded input signal the system's output will stay bounded. Therefore limitation of output deviation is very important for any design.
- **Robust**: Robust method is caused to achieve robust and stable performance in the presence of uncertainty and external disturbance. A system is robust when it would also work well under different conditions and external disturbance.
- **Reliability:** to control of nonlinear and uncertain systems, reliability play important role and most of model-base controller are reliable.

Therefore, design a controller based on above factors are the main challenge in many researches. Conventional control theory, intelligent control theory and hybrid control algorithm are three methods to control of highly nonlinear system, where, conventional control theories are work based on nonlinear dynamic parameters of system's dynamic, intelligent control theory is worked based on intelligent control theory and it is free of nonlinear dynamic parameters of system's dynamic and hybrid algorithm is designed based on the application of intelligent control theory in nonlinear system. Computed torque controller (CTC) is an effective nonlinear control methodology for highly nonlinear robot manipulator. The principles of this type of controller are based on feedback linearization and compute the required arm torques. Computed torque controller works based on behavior (dynamic formulation) of robot manipulator which caused to works very well when all dynamic and physical parameters are known. In uncertain dynamic parameters when the robot manipulator has variation computed torque controller has challenges[5]. In most of industrial applications, dynamic parameters of serial links robot manipulators have uncertain parameters or indefinite payload consequently design nonlinear conventional controllers based on dynamic formulation of robot manipulator (*e.g.,* computed torque controller) are the vital challenge. In recent years, much research has been done in the area of computed torque controller for nonlinear systems which has been reported in papers and textbooks [6-7]. The main idea to design computed torque controller is feedback linearization method. However CTC is a nonlinear controller which has an acceptable performance in certain condition but it has challenge in uncertainty. To reduce CTC's uncertainty challenge artificial intelligent theory (fuzzy logic) is introduced. In recent years, artificial intelligence theory has been used in control of nonlinear systems. Fuzzy logic controller (FLC) is one of the most important applications of fuzzy logic theory. This controller has been used to control of nonlinear, uncertain, and noisy systems. After the invention of fuzzy logic theory in 1965 by Zadeh, this theory was used in wide range applications such as control theory or system modeling. The nonlinear dynamic formulation problem in highly nonlinear system has been solved by fuzzy logic theorem. Fuzzy logic theory is used to estimate the system dynamics. This type of controller is free of mathematical dynamic parameters of plant. To solve the equivalent challenge in presence of uncertainty and external disturbance, two methods have been introduced:

- design fuzzy computed torque controller (FCTC)
- design computed torque fuzzy controller (CTFC)

Fuzzy computed torque controller (FCTC) is stable nonlinear intelligent controller. In this methodology, the main controller is computed torque controller and fuzzy logic controller is applied to it to estimate the nonlinear dynamic formulation in presence of uncertainty and external disturbance. In computed torque fuzzy controller the main controller is fuzzy logic controller and CTC is applied to fuzzy logic controller to reduce the fuzzy rules based on reduce the number of inputs and improve the stability of close loop system in fuzzy logic controller. In this paper hybrid controller, fuzzy computed torque controller, is introduced to control of high sensitive dental joint [8-9].

This paper is organized as follows; section two, is served as an introduction to the dynamic formulation of multi degrees of freedom joints, computed torque controller, and fuzzy logic algorithm. Part three, introduces and describes the methodology. Section four presents the simulation results and discussion of this algorithm and the final section is describing the conclusion.

Computed torque controller (CTC): Computed torque controller (CTC) is one of the effective nonlinear control methodologies for second order nonlinear system (*e.g.,* robot manipulator). Computed torque controller works based on behavior (dynamic formulation) of system, which caused to works very well when all dynamic and physical parameters are known. In uncertain dynamic parameters when the system has variation computed torque controller has challenges. In this type of controller, if the desired position trajectory for the manipulator defined as $\boldsymbol{q_d(t)}$, and the actual position trajectory defined as $\boldsymbol{q_a(t)}$, the tracking error calculated by;

$$\boldsymbol{e(t) = q_d(t) - q_a(t)} \qquad \textbf{(9)}$$

If state space equation is defined by;

$$\dot{x} = Ax + BU \tag{10}$$

According to the Brunousky canonical form $\boldsymbol{U}$ is the nonlinearity term and defined by;

$$U = \ddot{\boldsymbol{q}}_{\boldsymbol{d}} + \boldsymbol{A}^{-1}(\boldsymbol{q}).\{\boldsymbol{N}(\boldsymbol{q}.\dot{\boldsymbol{q}}) - \boldsymbol{\tau}\} \tag{11}$$

$$\dot{\boldsymbol{x}} = \begin{bmatrix} \mathbf{0} & \boldsymbol{I} \\ \mathbf{0} & \mathbf{0} \end{bmatrix} \boldsymbol{x} + \begin{bmatrix} \mathbf{0} \\ \boldsymbol{I} \end{bmatrix} \boldsymbol{U} \tag{12}$$

According to $\boldsymbol{x} = [\boldsymbol{e}^{\boldsymbol{T}}\ \dot{\boldsymbol{e}}^{\boldsymbol{T}}]^{\boldsymbol{T}}$

$$\frac{\boldsymbol{d}}{\boldsymbol{dt}} \begin{bmatrix} \boldsymbol{e} \\ \dot{\boldsymbol{e}} \end{bmatrix} = \begin{bmatrix} \mathbf{0} & \boldsymbol{I} \\ \mathbf{0} & \mathbf{0} \end{bmatrix} . \begin{bmatrix} \boldsymbol{e} \\ \dot{\boldsymbol{e}} \end{bmatrix} + \begin{bmatrix} \mathbf{0} \\ \boldsymbol{I} \end{bmatrix} \boldsymbol{U} \tag{13}$$

The requirement torque calculated by;

$$\boldsymbol{\tau} = \boldsymbol{A}(\boldsymbol{q})(\ddot{\boldsymbol{q}}_{\boldsymbol{d}} + \boldsymbol{U}) + \boldsymbol{N}(\dot{\boldsymbol{q}}, \boldsymbol{q}) \tag{14}$$

The formulation of PD computed torque controller is;

$$\boldsymbol{\tau} = \boldsymbol{A}(\boldsymbol{q})\left(\ddot{\boldsymbol{q}}_{\boldsymbol{d}} + \boldsymbol{K}_{\boldsymbol{v}}\dot{\boldsymbol{e}} + \boldsymbol{K}_{\boldsymbol{p}}\boldsymbol{e}\right) + \boldsymbol{N}(\boldsymbol{q}, \dot{\boldsymbol{q}}) \tag{15}$$

The PI computed torque controller formulation is;

$$\boldsymbol{\tau} = \boldsymbol{A}(\boldsymbol{q})\left(\ddot{\boldsymbol{q}}_{\boldsymbol{d}} + \boldsymbol{K}_{\boldsymbol{p}}\boldsymbol{e} + \boldsymbol{K}_{\boldsymbol{i}}\sum \boldsymbol{e}\right) + \boldsymbol{N}(\boldsymbol{q}, \dot{\boldsymbol{q}}) \tag{16}$$

The PID computed torque controller formulation is;

$$\boldsymbol{\tau} = \boldsymbol{A}(\boldsymbol{q})\left(\ddot{\boldsymbol{q}}_{\boldsymbol{d}} + \boldsymbol{K}_{\boldsymbol{p}}\boldsymbol{e} + \boldsymbol{K}_{\boldsymbol{v}}\dot{\boldsymbol{e}} + \boldsymbol{K}_{\boldsymbol{i}}\sum \boldsymbol{e}\right) + \boldsymbol{N}(\boldsymbol{q}, \dot{\boldsymbol{q}}) \tag{17}$$

Figure 6 shows the trajectory following in pure CTC in certain condition.

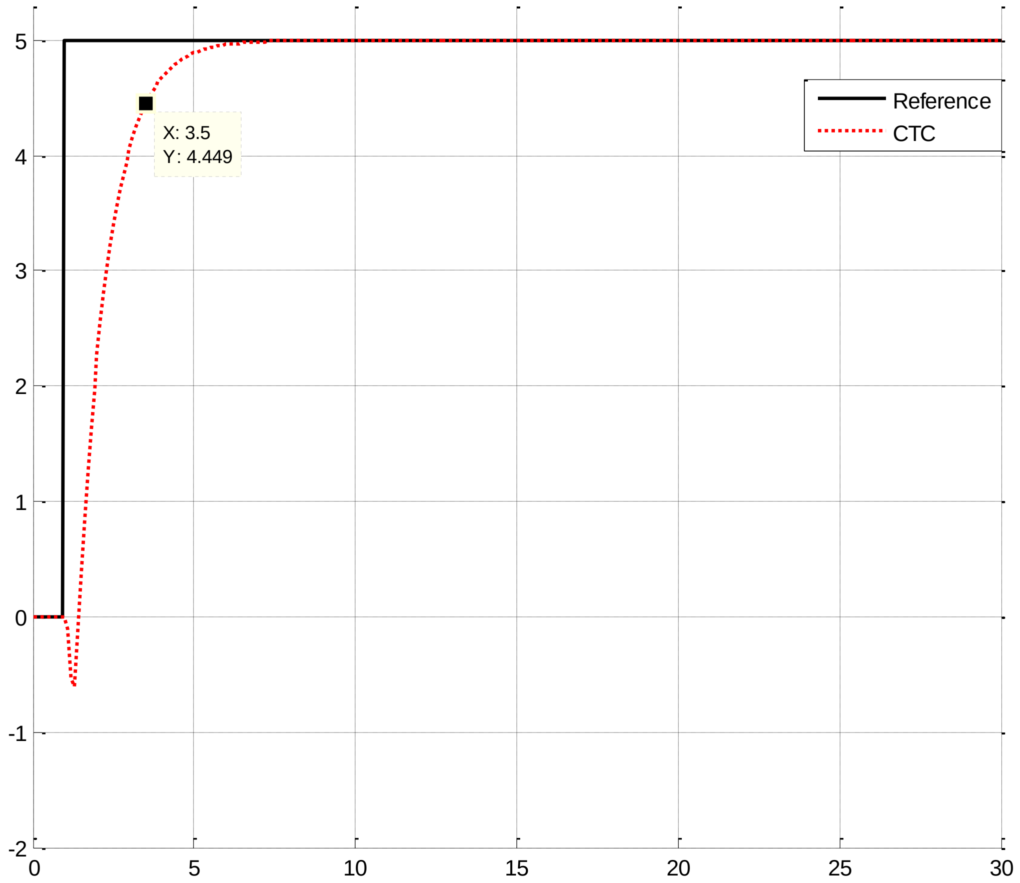

Figure 6. Trajectory Following for CTC in Certain Condition

According to Figure 6, from the rise-time point of view, the rise time is about 2.5 second. In certain condition, CTC has acceptable performance. Figure 7, shows the trajectory following for CTC in presence of uncertainty.

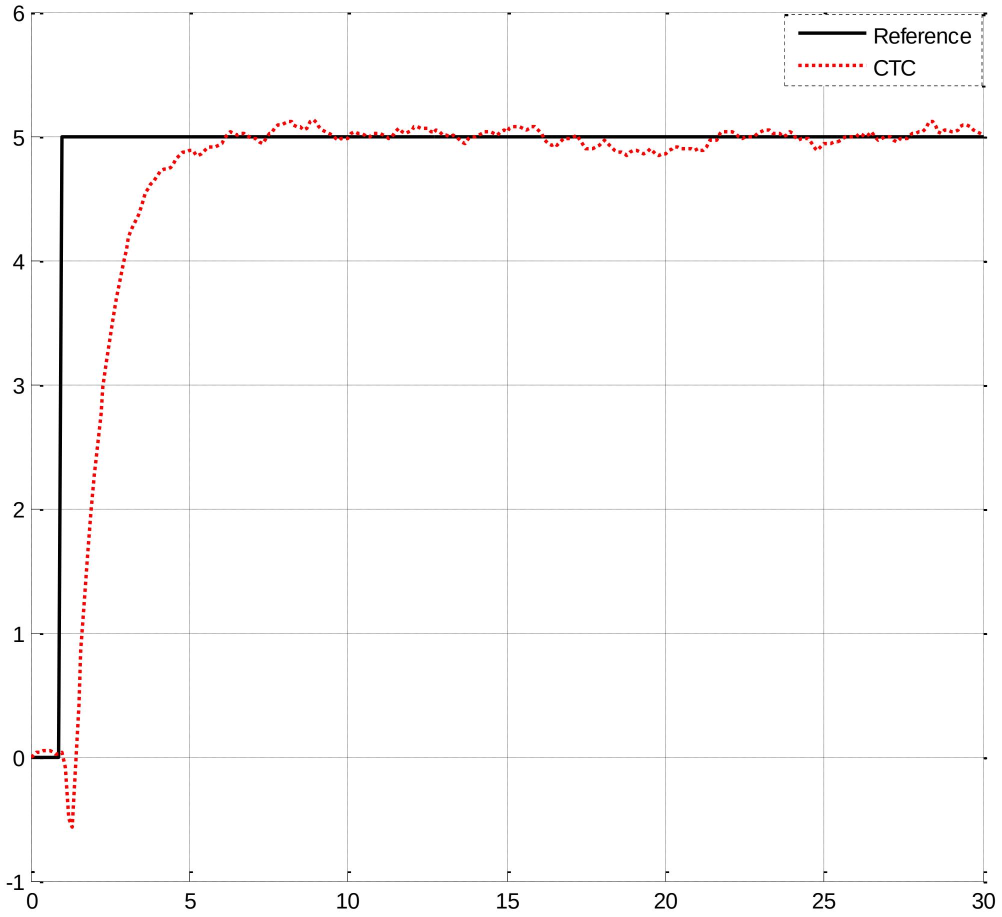

Figure 7. Trajectory Following for CTC in uncertainty

According to Figure 7, in uncertain condition CTC has moderate fluctuation and caused to instability. Regarding to Figure 6 and 7, CTC is used for certain condition but in uncertain condition it cannot guarantee the stability.

3. Design Adaptive Fuzzy Algorithm

According to above discussion, CTC has an important challenge in uncertainty. To solve this challenge PID fuzzy theory is add to CTC to tuning the CTC coefficients in uncertain condition as adaptive algorithm. To design fuzzy logic adaptive algorithm we used Gaussian membership function as follow formulation:

$$\mu_{F(x)} = e^{\frac{-(x-m)^2}{2K^2}} \quad \textbf{(18)}$$

To design PID like fuzzy algorithm with minimum rule base following formulation is introduced:

$$U_{PID} = U_{PD} + U_{PI} = \hat{f}(x|\lambda)_{PD} + \hat{f}(x|\lambda)_{PI} \quad \textbf{(19)}$$

The number of linguistic variables for each input is 5. Figure 8 shows the membership functions for inputs.

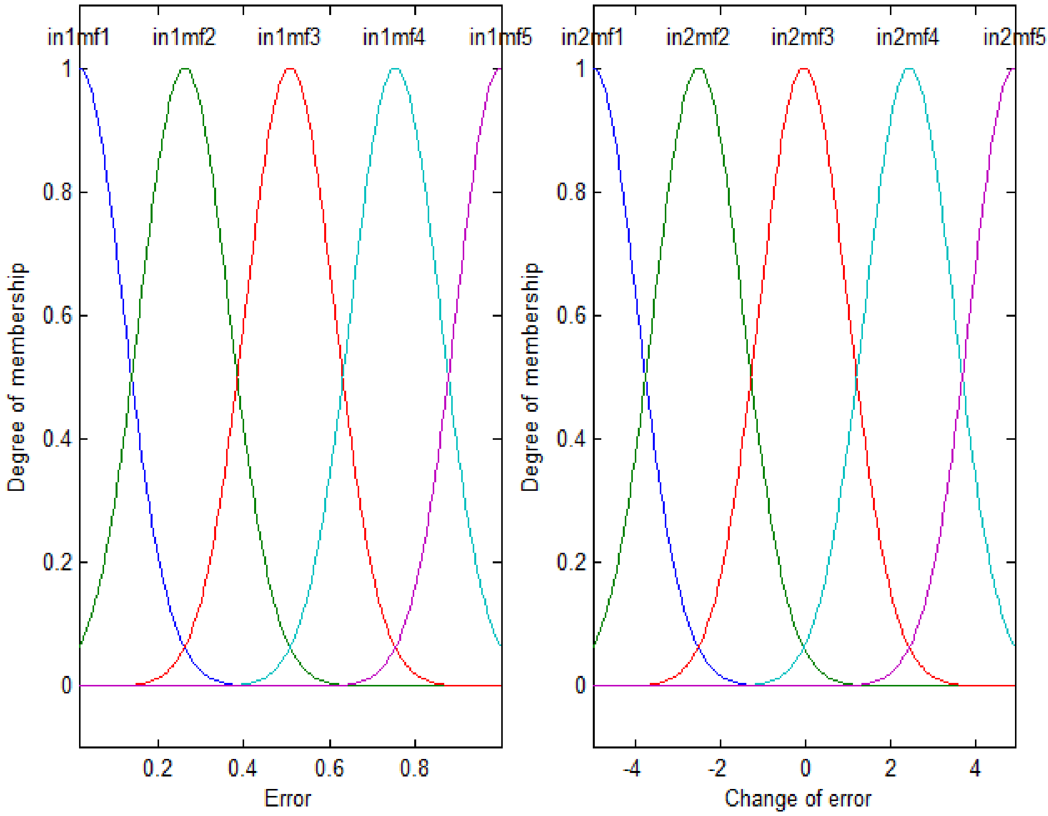

Figure 8. Degree of Membership for PD/PI Algorithm

The rate of error input is [0 to 1] and the rate of change of error is [-5 to 5]. The rule viewer of this design shows in Figure 9.

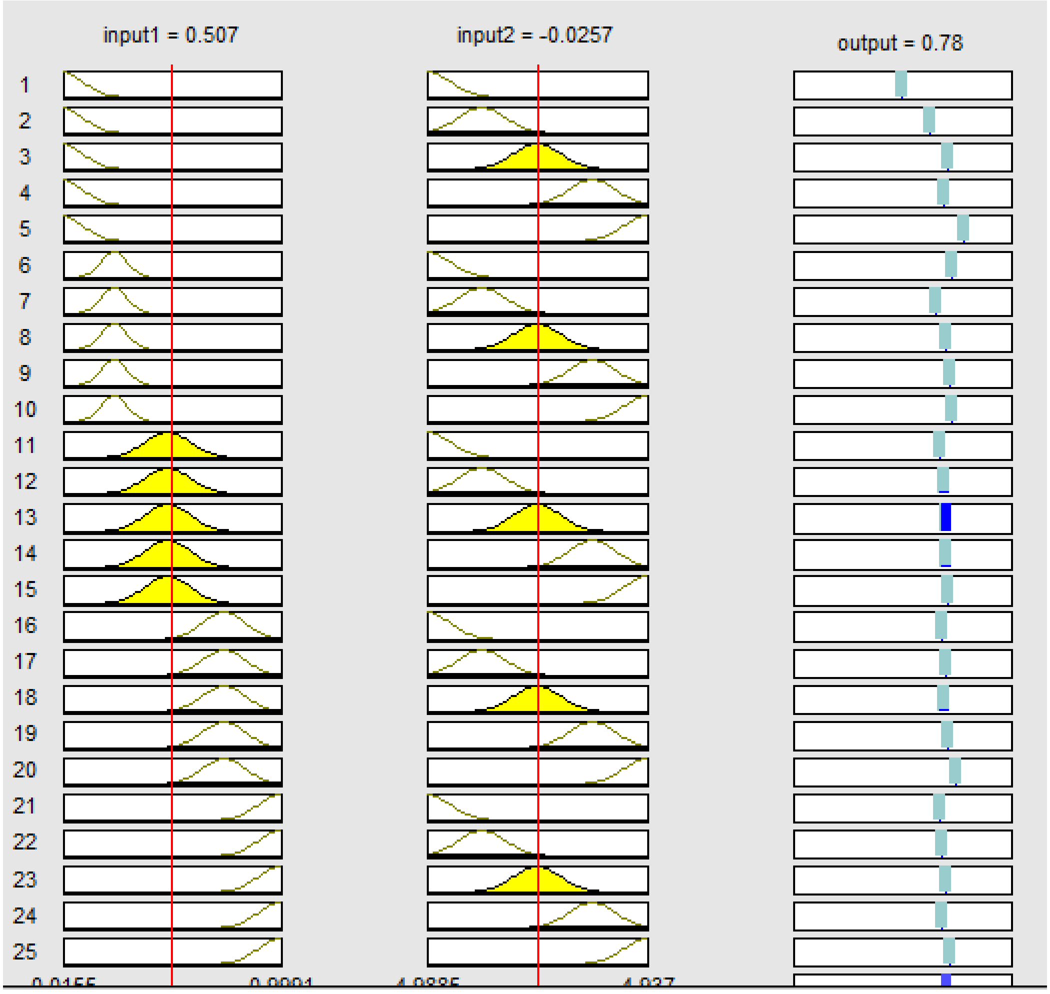

Figure 9. In/Out Rule Viewer for PD/PI Algorithm

After design rule base and membership function for PD and PI based PD algorithm, tuning the rate of are started. To tuning the rate of universe discourse, neuro-fuzzy is used. Figure 10 shows the testing data.

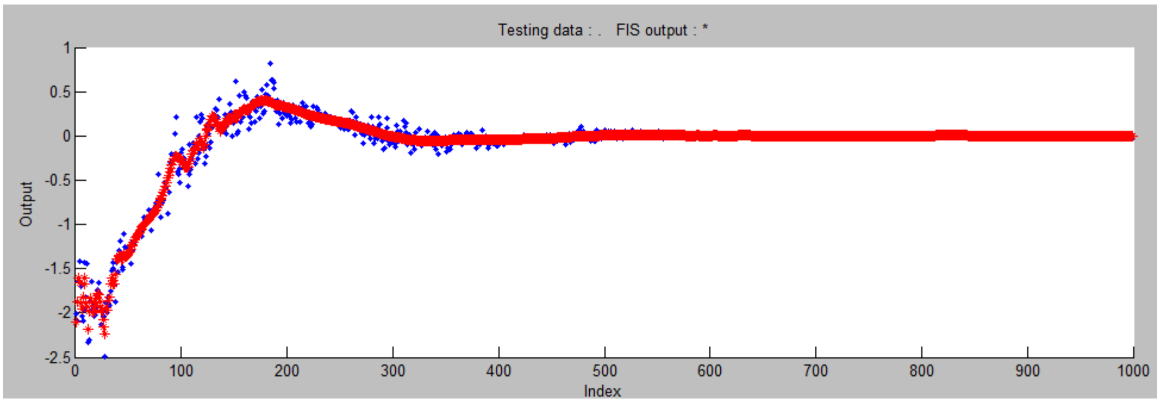

Figure 10. Neuro-Fuzzy Testing Data

Regarding to Neuro-fuzzy tuning the average testing error is about 0.075. To reduce the rate of error in this design two important parameters are play important roles: type of membership function and number of rule base however the number of training data is important. If we change, the linguistic variables from 5 to 7 the average testing error is reduce from 0.075 to 0.055.

To normalize the error and change of error scaling factors are applied (k_α and k_β) to e and $\dot{e}$ as bellows:

$$\boldsymbol{e_n = k_\alpha \times e} \tag{20}$$

$$\boldsymbol{\dot{e}_n = k_\beta \times \dot{e}} \tag{21}$$

Figure 11 shows the trajectory following in CTC and adaptive CTC. According to the following Figure, adaptive CTC has an important positive point in certain condition: the rise-time in adaptive CTC is better than CTC.

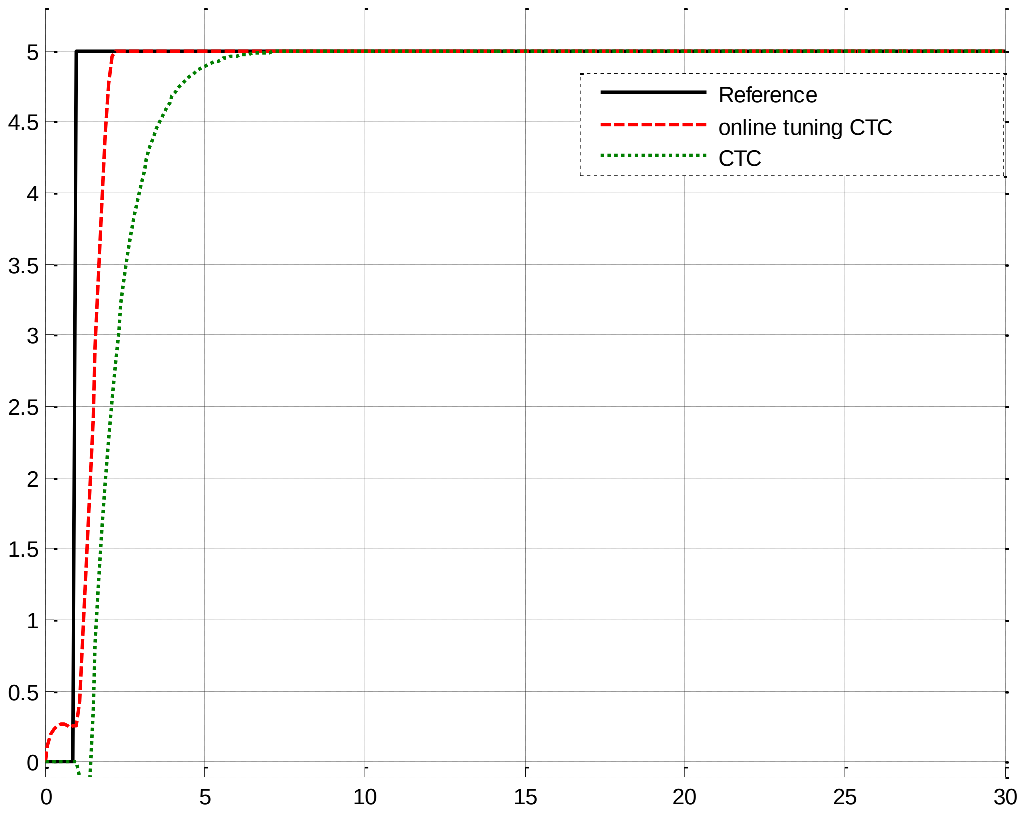

Figure 11. Trajectory Following for CTC and Adaptive CTC in Certain Condition

The power of disturbance rejection is very important to robust checking in any controllers. Figure 12 shows trajectory accuracy in CTC and adaptive CTC. Regarding to Figure 12, CTC has fluctuations in presence of uncertainty. Adaptive CTC improve the robustness and stability as well rise time.

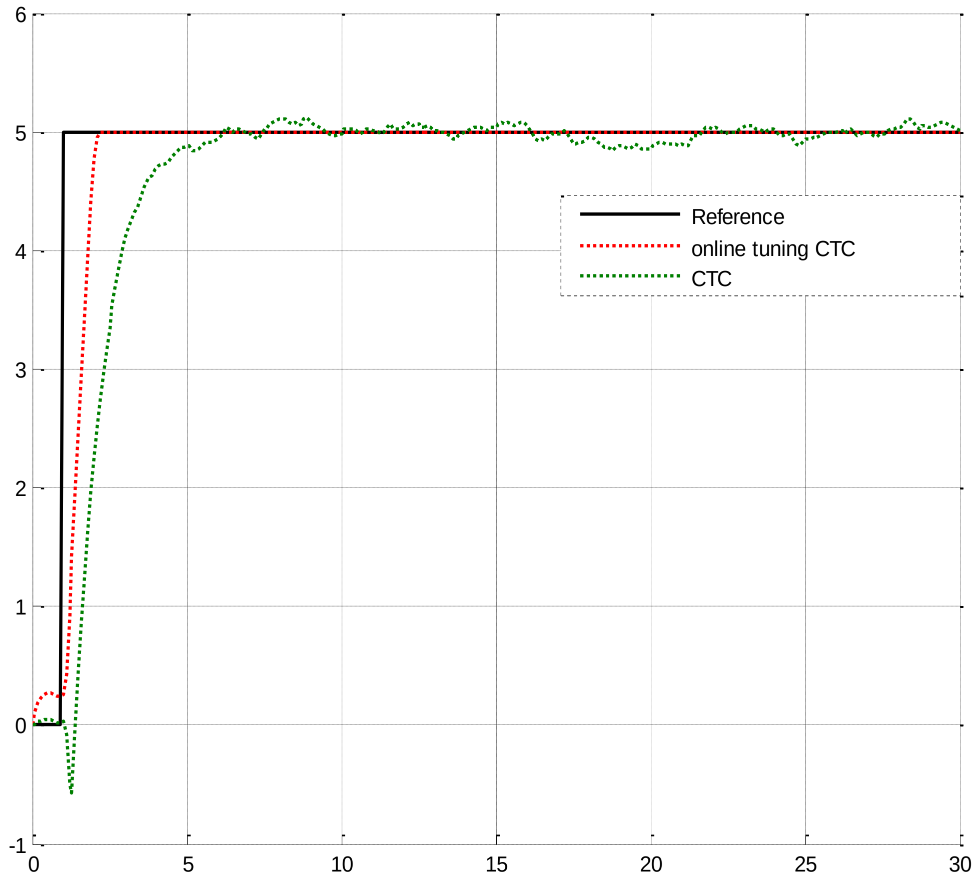

Figure 12. Trajectory Following for CTC and Adaptive CTC in Presence of Uncertainty

4. Conclusion

In this research, adaptive control of dental actuator is presented. According to this research, dental actuator works in saturation point in open loop. To solve this challenge feedback linearization controller is presented. This controller is nonlinear and works well in certain condition. However this type controller has acceptable performance in certain condition but the rise time is about 2.5 seconds. In uncertainty, this controller has fluctuations and it has not stability and robustness. To improve the stability and robustness, adaptive fuzzy algorithm is presented. To tuning the rate of error and change of error neuro-fuzzy algorithm is introduced. After evaluation fuzzy algorithm by neuro-fuzzy methodology, the rate of error is about 0.075. Adaptive fuzzy algorithm can solve two main challenges: stability and rise time.

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Project Title: “Design High Precision and Fast Dynamic Controller For Multi-Degrees Of Freedom Actuator”

Iranian center of Advance Science and Technology (IRAN SSP) is one of the independent research centers specializing in research and training across of Control and Automation, Electrical and Electronic Engineering, and Mechatronics & Robotics in Iran. At IRAN SSP research center, we are united and energized by one mission to discover and develop innovative engineering methodology that solve the most important challenges in field of advance science and technology. The IRAN SSP Center is instead to fill a long-standing void in applied engineering by linking the training a development function one side and policy research on the other. This center divided into two main units:

- Education unit
- Research and Development unit

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Ehsan Pouladi, he has been working at “Design High Precision and Fast Dynamic Controller for Multi-Degrees of Freedom Actuator for Experimental Research and Education” project at Iranian Institute of Advance Science and Technology, Sanaat Kade Sabz Passargad Research Center (IRAN SSP) as “research assistant“ of a research team composed of 21 researchers since Aug. 2013.

Farzin Piltan, he is an outstanding scientist in the field of Electronics and Control engineering with expertise in the areas of nonlinear systems, robotics, and microelectronic control. Mr. Piltan is an advanced degree holder in his field. Currently, Mr. Piltan is the Head of Mechatronics, Intelligent System, and Robotics Laboratory at the Iranian Institute of Advanced Science and Technology (IRAN SSP). Mr. Piltan led several high impact projects involving more than 150 researchers from countries around the world including Iran, Finland, Italy, Germany, South Korea, Australia, and the United States. Mr. Piltan has authored or co-authored more than 140 papers in academic journals, conference papers and book chapters. His papers have been cited at least 3900 times by independent and dependent researchers from around the world including Iran, Algeria, Pakistan, India, China, Malaysia, Egypt, Columbia, Canada, United Kingdom, Turkey, Taiwan, Japan, South Korea, Italy, France, Thailand, Brazil and more. Moreover, Mr. Piltan has peer-reviewed at least 23 manuscripts for respected international journals in his field. Mr. Piltan will also serve as a technical committee member of the upcoming EECSI 2015 Conference in Indonesia. Mr. Piltan has served as an editorial board member or journal reviewer of several international journals in his field as follows: International Journal Of Control And Automation (IJCA), Australia, ISSN: 2005-4297, International Journal of Intelligent System and Applications (IJISA), Hong Kong, ISSN:2074-9058, IAES International Journal Of Robotics And Automation, Malaysia, ISSN:2089-4856, International Journal of Reconfigurable and Embedded Systems, Malaysia, ISSN:2089-4864.

Mr. Piltan has acquired a formidable repertoire of knowledge and skills and established himself as one of the leading young scientists in his field. Specifically, he has accrued expertise in the design and implementation of intelligent controls in nonlinear systems. Mr. Piltan has employed his remarkable expertise in these areas to make outstanding contributions as detailed follows:Nonlinear control for industrial robot manipulator (2010-IRAN SSP), Intelligent Tuning The Rate Of Fuel Ratio In Internal Combustion Engine (2011-IRANSSP), Design High Precision and Fast Dynamic Controller For Multi-Degrees Of Freedom Actuator (2013-IRANSSP), Research on Full Digital Control for Nonlinear Systems (2011-IRANSSP), Micro-Electronic Based Intelligent Nonlinear Controller (2015-IRANSSP), Active Robot Controller for Dental Automation (2015-IRANSSP), Design a Micro-Electronic Based Nonlinear Controller for First Order Delay System (2015-IRANSSP).

The above original accomplishments clearly demonstrate that Mr. Piltan has performed original research and that he has gained a distinguished reputation as an outstanding scientist in the field of electronics and control engineering. Mr. Piltan has a tremendous and unique set of skills, knowledge and background for his current and future work. He possesses a rare combination of academic knowledge and practical skills that are highly valuable for his work. In 2011, he published 28 first author papers, which constitute about 30% of papers published by the Department of Electrical and Electronic Engineering at University Putra Malaysia. Additionally, his 28 papers represent about 6.25% and 4.13% of all control and system papers published in Malaysia and Iran, respectively, in 2011.

Narges Gholami Mozafari, she is currently working as a co researcher in Control and Robotic Lab at the institute of advance science and technology, IRAN SSP research and development Center. Her current research interests are in the area of nonlinear control, artificial control system and robotics.

Somayeh Jowkar, she is currently a research assistant at Institute of Advance Science and Technology, Research and Development Center, IRAN SSP. She has been working at “Design High Precision and Fast Dynamic Controller for Multi-Degrees-of Freedom Actuator for Experimental Research and Education” project at Iranian Institute of Advance Science and Technology, Sanaat Kade Sabz Passargad Research Center (IRAN SSP) as “Pre-PhD Student Researcher“ of a research team composed of 21 researchers since Aug. 2014 to Aug. 2015. She has had the main roles in initiation and development of this project which has resulted thus far in four scientific publications up to now. She has been working at “design Micro-electronic Based nonlinear controller for Four Degrees of Freedom Surgical Robot Manipulator” project at Iranian Institute of Advance Science and Technology, Sanaat Kade Sabz Passargad Research Center (IRAN SSP) as “research assistant scholar“ of a research team composed of 5 researchers since August 2015 to date. She has been working at “Industrial and Medical System Identification” project at Iranian Institute of Advance Science and Technology, Sanaat Kade Sabz Passargad Research Center (IRAN SSP) as “research assistant scholar“ of a research team composed of 3 researchers since May 2016 to date. Her current research interests are nonlinear control, artificial control system, system identification and design FPGA-based controller.

Ali Roshanzamir, he is currently Research Assistant at Energy Conversion System Lab at Hanyang University, South Korea. He was research assistant of team (8 researchers) to design a Micro-electronic Based nonlinear controller for first order delay system March, 2015-April, 2016, research student (45 researchers) to Nonlinear control of Industrial Robot Manipulator for Experimental Research and Education June 2010 to June 2011, and published 5 journal papers since 2011 to date. His current research interests are nonlinear control, artificial control system, Microelectronic Device, and HDL design.

Nasri Sulaiman, he is a Senior Lecturer in the Department Electrical and Electronic Engineering at the Universiti Purta Malaysia (UPM), which is one of the leading research universities in Malaysia. He is a supervisor and senior researcher at research and training center called, Iranian Institute of Advanced Science and technology (Iranssp) since 2012. He obtained his M.Sc. from the University of Southampton (UK), and Ph.D. in Microelectronics from the University of Edinburgh (UK). He has published more than 80 technical papers related to control and system engineering, including several co-authored papers with Mr. Piltan. He has been invited to present his research at numerous national and international conferences. He has supervised many graduate students at doctoral and masters level. He is an outstanding scientist in the field of Micro-Electronics.

Dr. Nasri Sulaiman advisor and supervisor of several high impact projects involving more than 150 researchers from countries around the world including Iran, Malaysia, Finland, Italy, Germany, South

Korea, Australia, and the United States. Dr. Nasri Sulaiman has authored or co-authored more than 80 papers in academic journals, conference papers and book chapters. His papers have been cited at least 3000 times by independent and dependent researchers from around the world including Iran, Algeria, Pakistan, India, China, Malaysia, Egypt, Columbia, Canada, United Kingdom, Turkey, Taiwan, Japan, South Korea, Italy, France, Thailand, Brazil and more.

Dr. Nasri Sulaiman has employed his remarkable expertise in these areas to make outstanding contributions as detailed below:

- Design of a reconfigurable Fast Fourier Transform (FFT) Processor using multi-objective Genetic Algorithms (2008-UPM)
- Power consumption investigation in reconfigurable Fast Fourier Transform (FFT) processor (2010-UPM)
- Crest factor reduction And digital predistortion Implementation in Orthogonal frequency Division multiplexing (ofdm) systems (2011-UPM)
- High Performance Hardware Implementation of a Multi-Objective Genetic Algorithm, (RUGS), Grant amount RM42,000.00, September (2012-UPM)
- Nonlinear control for industrial robot manipulator (2010-IRAN SSP)
- Intelligent Tuning The Rate Of Fuel Ratio In Internal Combustion Engine (2011-IRANSSP)
- Design High Precision and Fast Dynamic Controller For Multi-Degrees Of Freedom Actuator (2013-IRANSSP)
- Research on Full Digital Control for Nonlinear Systems (2011-IRANSSP)
- Micro-Electronic Based Intelligent Nonlinear Controller (2015-IRANSSP)
- Active Robot Controller for Dental Automation (2015-IRANSSP)
- Design a Micro-Electronic Based Nonlinear Controller for First Order Delay System (2015-IRANSSP)

