Designing a prototype for the multisensory system in the drive dynamics on a least square identification technique of a real-time uncertainty protocol for Humanoid Robotic Control System

Author: Dr. Ashok Kumar Ramadoss,

MCA, MBA, MSc. Mat Sc., Ph. D, (International Award winner and Senior Member of Robotics)

Associate Professor, Scientist, Software engineer, Senior Member in UACEE,New York and HongKong Society of robotics and automation and Member in Society of Robotics Surgery,Orlando,Florida,

Abstract

In this research an extensive description of the experimental manipulator has been provided. The Cartesian manipulator has been designed, built, and tested in the Industrial Automation Laboratory.

In the current work, only the DC motor/lead screw driven X-axis is used. The electro-mechanical system is operated through an open-architecture CNC control system; the *Open Real-Time CNC Operating System* (ORTS).The system architecture is designed following the *Encapsulated Logical Device* (ELD) framework, before being implemented across multiple computing platforms.

The real-time low level tasks are implemented on a *Digital Signal Processor* (DSP) under the ORTS operating system, while the event-driven high-level tasks are implemented under Windows NT operating system. This system configuration allows for an efficient and structured treatment of the information available in a multisensory system, as well as the management of control-oriented Processes.

Keywords: Ultrasonic Proximity Sensor, end-effectors, saturation zones, redundant data, Superior Electric synchronous stepper.

Introduction

To complete the description of the experimental platform, a model for the X-axis drive dynamics has been established. The model is based on a least-square identification technique.

A parametric model is first established and its parameters are identified from input/output data measured on the system itself.

This model of the X-axis drive dynamics is used in order to perform experimental testing of the proposed methodology and their corresponding policies. This is seen by the ultrasonic proximity sensor with the use of end effectors in the action of degree of freedom in the saturation zones thereby extracting the redundant data, using the collaborative and cognitive effort of superior electric synchronous stepper

1.0 Implementation

1.1 Preamble

In this research, a description of the experimental set-up is provided. This description is followed by an overview of the open-architecture control platform used in this application. The integration of the electromechanical experimental robot within the control system, as well as the implementation of the proposed policy, is then addressed. The system is implemented in an Encapsulated Logical Device Architecture, which provides an object- oriented approach to efficient and coherent treatment of information and control signals for multisensory robotics control system development Budenske [1]. Once the overall architecture of the system is established, the architecture is implemented in the control system. In order to generate good simulation results, an adequate model of the system is necessary. In the current work, the system is empirically identified based on a parametric model Elliott [2]. The identification procedure, as well as a brief overview of necessary theoretical background, is also provided Budenske Gini [3].

1.2 ExperimentalPlatform

The proposed policies are aimed at implementation on industrial automation and robotic systems. In order to simplify the problem Erol, N.A., Altintas, Y [5] at hand and limit the number of variables, as well as their effects Henderson [6] , a simple robotic device was designed and built in the Industrial Automation Laboratory for test purposes.
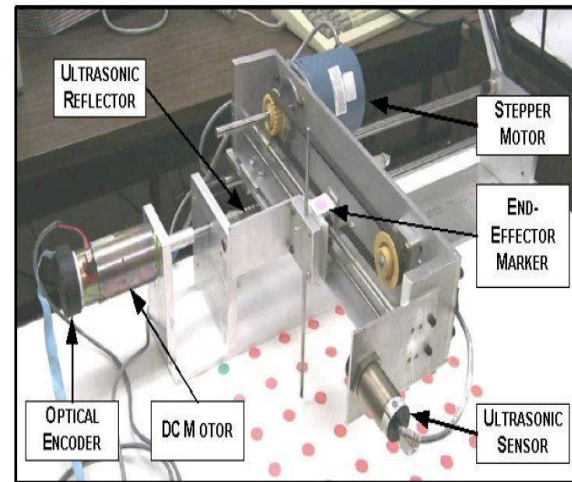

Figure .1. Experimental Cartesian Manipulator

The experimental manipulator, see Figure 1, is a Cartesian manipulator where both axes are actuated using a different mechanism.

The X-axis is actuated by a Pittman DC motor series 14- 204 connected to a double threaded lead screw of pitch 6.35 mm (0.250"). The X-axis has an active range of 180 mm and the position feedback is provided by an Agilent Technologies HEDS-6310 optical encoder presenting a resolution of 0.36° (1000 pulses per turn).

The manipulator actuators and sensors are powered by a 24 VDC, 12 A power supply. The power for the X-axis actuator is managed by a custom made linear push-pull amplifier. The amplifier design, (see appendix A), uses a positive input signal [0-10 VDC] with an adjustable neutral point. Figure 6.3 provides both the exact and linearized characteristics of the amplifier.

The major difference between the exact and the linearized characteristics is the omission of the saturation zones at low and high input voltage.

2. Methodology

Motor Data – Pittman 14-204-B352

Parameter	Symbol	Units	Value
Continuous Motor Torque (Max.)	T_C	$N \cdot m$	183.6×10^{-3}
Peak Torque (Stall)	T_{PK}	$N \cdot m$	1.44
Motor Constant	K_M	$\frac{N \cdot m}{\sqrt{W}}$	60.9×10^{-3}
No-Load Speed	S_{NL}	rad/s	388
Friction Torque	T_F	$N \cdot m$	11.3×10^{-3}
Rotor Inertia	J_M	$kg \cdot m^2$	2.61×10^{-5}
Electrical Time Constant	τ_E	ms	1.58
Mechanical Time Constant	τ_M	ms	7.04
Torque Constant	K_T	$\frac{N \cdot m}{A}$	76.5×10^{-3}
Back-EMF Constant	K_B	$\frac{V}{rad/s}$	76.5×10^{-3}
Reference Voltage	E	V	30.3
Resistance	R_T	Ω	1.57
Inductance	L	mH	2.50
No-Load Current	I_{NL}	A	0.21
Peak Current (Stall)	I_P	A	19.2
Optical Encoder Data – Agilent Technologies HEDS-6310			
Cycles per Revolution	CPR	CPR	1000
Drive Data – Lead Screw			
Number of Threads	n		2
Thread Pitch	p	mm	6.35
Drive Range	X_R	mm	180

Table .1. Summary of X-Axis Drive Parameters

Table .1 presents a summary of the motor parameters, as well as the mechanical drive and the sensor parameters for this axis. The Y-axis is powered by a Superior Electric synchronous stepper Hutchinson [7], motor through a timing belt and sprockets (35 mm pitch diameter). The active range of motion for the axis is 160 mm and the position feedback is provided through a Daytronic Ultrasonic Proximity Sensor model D4900 Jörg [8] . The ultrasonic sensor has a sensing range of 4 to 30 inches, adjusted for the current application.

According to the manufacturer specifications, this analogy sensor provides a repeatability of ±1% of the full scale setting and approximately 5% hysteresis.

This sensor measures distance via the elapsed time of flight of the ultrasonic wave and, therefore, requires a reflective surface perpendicular to its axis to function properly Table 2. This surface is provided by adding an aluminium reflector on the end-effectors trolley, see Figure 1.

A summary of the Y-axis mechanical drive, actuator and sensor parameters are provided. An overhead camera is also used in the system Figure 3.

Motor Data – Superior Electric M092-FC-311C

Parameter	Symbol	Units	Value
Number of Steps per Revolution	S_{rev}	$\frac{s}{rev}$	200
Peak Torque (Stall)	T_{PK}	$N \cdot m$	1.4123
Residual Torque	T_R	$N \cdot m$	2.82×10^{-2}
Rotor Inertia	J_M	$kg \cdot m^2$	1.23×10^{-4}
Reference Voltage	E	V	22.5
Under-Load Current (Max.)	I_{MX}	A	0.61
Ultrasonic Proximity Sensor Data – Daytronic D4900			
Sensing Range (Min.)		mm	101.6
Sensing Range (Max.)		mm	762
Accuracy (% range setting)		%	±1
Hysteresis (% of set-point)		%	5
Response Speed		ms	50
Drive Data – Timing Belt			
Sprockets Pitch Diameter		mm	35
Drive Range	Y_R	mm	160

Table .2 Summaries of the Y-Axis Drive Parameters

Figure .2. Camera Location in the Work cell

See Figure 2 in order to provide information about the environment in which the system is operating (i.e., heteroceptive sensing), but it can also be used to provide redundant data about the system state. In this case, redundant data is generated for the end-effectors position. The position of the end-effectors is identified by the presence of a colour marker on the trolley, McCarragher, B.J., Asada, H., [9]

In Figure 1 the JVC CCD colour digital camera is interfaced to a PC running Windows NT through an Imaging Technologies IC2-COMP Mukai, T [10]. This combination of hardware generates a 640x480 pixel resolution colour digital image in approximately 30 ms. The whole acquisition sequence, including grabbing the image Nakamura [12] Nakamura. In Table 3 transferring it to the host memory, and processing the data, requires approximately 200 ms. A summary of the camera and lens parameters is provided

Camera Data – JVC TK-1070U		
Parameter	**Units**	**Value**
CCD Chip Size	*in*	2/3
Effective Pixels (Horizontal)	*pixels*	768
Effective Pixels (Vertical)	*pixels*	493
Scanned Pixels (Horizontal)	*pixels*	640
Scanned Pixels (Vertical)	*pixels*	480
Scanning Line	*lines*	525
Interlacing Ratio		2
Acquisition Time	*ms*	30
Lens Data – Computar TV Zoom Lens 1:1.8/12,5-75		
Aperture Ratio (Max.)		1:1.8
Focal Length	*mm*	12.5-75
Focus	*m*	1- ∞

Table 3 Summary of Camera and Lens Parameters

3. Experimental Validation

The work cell is also equipped with a lighting system to provide uniform lighting of the workspace and facilitate the location of the end-effectors marker Pachter [13]. In order to avoid lighting variation problems related to the use of commercial fluorescent light tubes, high-frequency electronic ballasts have been substituted to the original magnetic ballasts. The high frequency signal generated by the electronic ballasts ($\square\square$15 kHz) is sufficiently higher than the camera sampling frequency (30 Hz) such that the camera is unaffected by the variations in the light signal Papanikolopoulos, N.P., [14] . Typical commercial magnetic ballasts running at AC power frequency (i.e., 60 Hz) are unsuitable for this purpose.

4. Implementation of Open-Architecture Control Platform

In order to commission the Cartesian manipulator described in the previous section, a real-time control system is necessary. Furthermore, to servo the position of the end-effectors and perform sensor integration in the lowest level of the control structure, an open-architecture control platform is necessary. An open-architecture control platform provide the basic functions of a CNC system (i.e., pre-emptive tasking, kernel functions, timing, I/O functions, etc.) while still allowing the user to define the control loops and processing functions. For the current application, Zheng, Y.F., [16] the *Open Real-Time CNC Operating System* (ORTS) [5, 8, 10, 14, 15, 17], developed by the Manufacturing Automation Laboratory of the University of British Columbia, has been selected to implement the real-time functions of the overall architecture. ORTS has been developed for CNC control of machine tools, mechatronics devices control, and process-control system designers.

5. Results

The manipulator actuators and sensors are powered by a 24 VDC, 12 A power supply. The power for the X-axis actuator is managed by a custom made linear push-pull amplifier. The amplifier design, (see appendix A), uses a positive input signal [0-10 VDC] with an adjustable neutral point. Figure .3 provides both the exact and linearized characteristics of the amplifier. The major difference between the exact and the linearized characteristics is the omission of the saturation zones at low and high input voltage Stover, J.A., [15]. The linear regression of the measured data omitting the saturation zones of the amplifier shows a perfect linear behaviour (i.e., the regression

coefficient R_2 is unity). Therefore, avoiding the use of extreme amplifier input signal regions justifies the assumption of a linear amplifier. Practically, the usable range of the amplifier can be limited by imposing, in software, lower and upper limits on the signal generated by the control algorithm.

The Y-axis stepper motor is driven through an Allegro Microsystems Unipolar Stepper-Motor Translator/Driver (#5804). This driver provides three excitation modes (i.e., one-phase drive, two-phase drive, and half-step drive) and requires as input enable and clock signals. The stepping mode can be modified on the fly, allowing for coarse/fine motion types. The clock signal frequency dictates the stepping speed and, therefore, provides an easy way to implement a PID-type control algorithm, while the three excitation modes enable the achievement of a sufficient level of positioning accuracy, or speed.
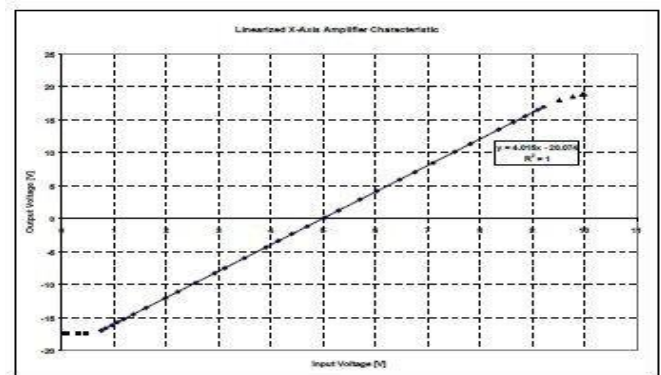

Figure 3. X-Axis Push-Pull Amplifier Characteristics

6 Discussions

Therefore, this package provides the flexibility and processing capacities required to implement the current application Smith, R.C., Cheeseman, P., [17]. The real-time operating system is composed of two major components, a real-time microkernel (ORTS-DSP) and a PC-based scripting

environment (ORTS-PC/NT). The real-time microkernel runs on one or more DSP boards plugged into a PC running an enhanced Windows NT operating system. The DSP handles all the real-time processing necessary to perform motion control, as well as I/O interfacing and communication with the PC through the ISA or PCI bus. The current application is developed on a Spectrum Signal Processing Indy F3 processor board [11, 16], equipped with the Texas Instrument TMS320C32 chip [12]. User defined processes are coded in ANSI C language [15], following ORTS specific guidelines and conventions, and registered in the kernel list of processes. The registration of the processes enables their compilation, their downloading on the DSP, and their use from the scripting interface. I/O is handled by the DSP board through a DSP~Link2 or DSP~Link3 interface. Various I/O boards are available for these interfaces and compatible with ORTS. For this particular application, a motion control oriented I/O board is selected, the Precision Micro Dynamics Inc. MFIO-3B [13]. A description of the ports provided by the multifunction I/O board is given by 6.3 Open-Architecture Control Platform. The ORTS-PC/NT component of the system consists of the scripting environment in which the User can organize the process specific tasks that are to be implemented in real-time on the DSP Platform. The ORTS scripting interface is shown in Figure 4.

Multifunction I/O board MFIO-3B	
Function	# of Channels
Quadrature Encoder Inputs	3
D/A (16 bits)	3
A/D (16 bits)	3
Digital I/O	24 bits

Table 4. MFIO-3B I/O Features

Table 4. Furthermore, to increase the flexibility of the hardware, screw terminal boards have been built to accommodate the MFIO-3B interfacing connectors in Table 4. Transparent communication between the ORTS-PC/NT application and other processes running on the same PC, or on a networked PC, is also available through the Microsoft Foundation Classes Libraries pipe classes.
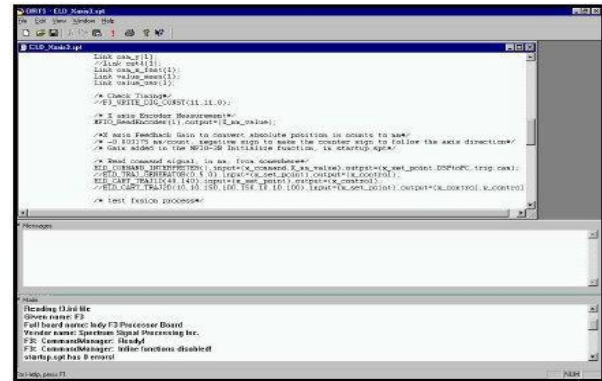

Figure 4.ORTS-PC Scripting environment.

The ORTS-PC/NT and ORTS-DSP applications provide a transparent communication protocol Inside of the real-time application itself, and also between the PC and DSP platforms.

7. Design

The system architecture is designed following the *Encapsulated Logical Device* (ELD) framework, before being implemented across multiple computing platforms. The real-time low-level tasks are implemented on a *Digital Signal Processor* (DSP) under the ORTS operating system, while the event-driven high-level tasks are implemented under Windows NT operating system. This system configuration allows for an efficient and structured treatment of the Information available in a multisensory system, as well as the management of control-oriented processes.

8. Conclusions

Based on a model of an experimental Cartesian manipulator designed, built, and tested in the Industrial Automation Laboratory, The system architecture is designed following the *Encapsulated Logical Device* (ELD) framework, before being implemented across multiple computing platforms. The real-time low-level tasks are implemented on a *Digital Signal Processor* (DSP) under the ORTS operating system, while the event-driven high-level tasks are implemented under Windows NT operating system. This system configuration allows for an efficient and structured treatment of the information available in a multisensory system, as well as the management of control-oriented processes.

8.1. Concurrence of Experimental results with Simulation work

Experimental Results concur with those obtained in simulation. The occurrence of a proprioceptive sensor failure is identified, leading to the sensing subsystem re-configuration and the faulty sensor data Rejection. The major contributions of this work to the field of industrial automation and robotic control Systems have been done following the research objectives stated at the beginning of this research.

The principal contributions are:

a. Development of a policy to integrate heteroceptive feedback in the position Servo-loops of robotic manipulators where this type of feedback is already available,

b. Development of a real-time uncertainty metric to enable the dynamic reconfiguration of the sensor subsystem on sensor fault or failure occurrence,

c. Establishment of heteroceptive sensor performance requirements in order to fulfil two different types of system performance requirements: namely, *Fault Tolerance* and

9. Fault Rejection.

Implementation of the sensor integration policy for robotic manipulator servo-loop in an experimental manipulator and testing of the policy behaviour in realistic condition The Cartesian manipulator has been designed, built, and tested in the Industrial Automation Laboratory. In the current work, only the DC motor/lead screw driven X-axis is used. The electro-mechanical system is operated through an open-architecture CNC control system, the *Open Real-Time CNC Operating System* (ORTS).

Finally, to complete the description of the experimental platform, a model for the X-axis drive dynamics has been established. The model is based on a least-square identification technique. A parametric model is first established and its parameters are identified from input/output data measured on the system itself. This model of the X-axis drive dynamics is used in order to perform experiment testing of the proposed methodology and their corresponding policies.

10.. Future Work

Furthermore, it would be necessary, in order to demonstrate the flexibility of the policies, to perform some testing based on another type of heteroceptive sensor, such as a 3D laser scanner. It would also be of interest to increase the number of heteroceptive, or proprioceptive, sensing sources, again to verify the behaviour of the integration and fusion schemes in such a context and the resulting overall robustness of the system in the presence of sensor fault or failure. Finally, the implementation of the policy in a real robotic work cell using a six degree of freedom robot, and the experimentation in real, pick-and-place operations would confirm the capacities of such a system and its industrial relevance.

References

[1] Budenske, J., Gini, M., "Achieving Goals Through Interaction with Sensors and Actuators", *Proceedings of the 1992 IEEE/RSJ International Conference on Intelligent Robots and Systems*, (1992): 903-908.

[2] Elliott, J.D., *Multisensory Fusion within an Encapsulated Logical Device Architecture*, M.A.Sc. Thesis, Department of Mechanical Engineering, University of British Columbia, (2001).

[3] Budenske, J., Gini, M., "Sensor Explication: Knowledge-Based Robotic Plan Execution through Logical Objects", *IEEE Transactions on Systems, Man, and Cybernetics – Part B: Cybernetics*, Vol. 27, (1997): 611-625.

[4] Erol, N.A., Altintas, Y., "Open Architecture Modular Tool Kit for Motion and Machining Process Control", *Proceedings of the ASME International Mechanical Engineering Congress and Exposition*, Vol.6, No.1, (1997):15-22.

[5] Erol, N.A., Altintas, Y., Ito, M.B., "Open System Architecture Modular Tool Kit for Motion and Machining Process Control", IEEE/ASME Transactions on Mechatronics, Vol.5, No.3, (2000):281-291.

[6] Henderson, T.C., Fai, W.S., Hansen, C., "MKS: A Multisensor Kernel System", *IEEE Transactions on Systems, Man, and Cybernetics*, Vol.SMC-14, No.5, (1984):784-791.

[7] Hutchinson, S., Hager, G.D., Corke, P.I., "A Tutorial on Visual Servo Control", *IEEE Transactions on Robotics and Automation*, Vol. 12, No. 5, (1996): 651-670.

[8] Jörg, S., Langwald, J., Stelter, J., Hirzinger, G., Natale, C., "Flexible Robot-Assembly using a Multi-Sensory Approach", *Proceedings of the 2000 IEEE International Conference on Robotics and Automation*, Vol. 4, (2000): 3687-3694.

[9] McCarragher, B.J., Asada, H., "The Discrete Event Control of Robotic Assembly Tasks", *Transactions of the ASME – Journal of Dynamic Systems, Measurement, and Control*, Vol.117, (September 1995):384-393.

[10]. Mukai, T., Ishikawa, M., "An Active Sensing Method Using Estimated Errors for Multisensor Fusion System", *IEEE Transactions on Industrial Electronics*, Vol.43, No.3, (1996):380-386.

[11] Musliner, D.J., Durfee, E.H., Shin, K.G., "World modelling for dynamic construction of real-time control plans", *Artificial Intelligence*, Vol.74, No.1, (1995):83-127.

[12] Nakamura, Y., Xu, Y., "Geometrical Fusion Method for Multi-sensor Robotic Systems", *Proceedings of the IEEE International Conference on Robotics and Automation*, Vol.2, (1989):668-673.

[13] Pachter, M., Chandler, P.R., "Challenges of Autonomous Control", *IEEE Control Systems Magazine*, Vol.18, No.4, (1998):92-97.

[14] Papanikolopoulos, N.P., Khosla, P.K., Kanade, T., "Visual Tracking of a Moving Target by a Camera Mounted on a Robot: A Combination of Control and Vision", *IEEE Transactions on Robotics and Automation*, Vol. 9, No. 1, (1993): 14-35.

[15] Stover, J.A., Hall, D.L., Gibson, R.E., Fuzzy-Logic Architecture for Autonomous Multisensor Data Fusion", *IEEE Transactions on Industrial Electronics*, Vol.43, No.3, (1996): 403-410.

[16] Zheng, Y.F., "Integration of Multiple Sensors into a Robotic System and its Performance Evaluation", *IEEE Transactions on Robotics and Automation*, Vol.5, No.5, (1989):658- 669.

[17]. Smith, R.C., Cheeseman, P., "On the Representation and Estimation of Spatial Uncertainty", *International Journal of Robotic Research*, Vol.5, No.4, (1986):56-68.

[18] Ashok Kumar R, Marimuthu K (2014) Prediction of stochastic cognitive neural schema with neural network paradigm of latent semantic nodes in autobot—humanoid robot using nonlinear regression of Gaussian sigmoidal curves in Boltzmann normalisation. International Information Institute, Tokyo, Japan. Inf Int Interdiscip J 17(8):3971–3984

[19] Ashok Kumar Ramadoss , Investigation of Data Concurrency of Sensory fusion in Humanoid Robot, IJAMAE - International jounal of advancement inmechanical and aeronautical engineering,vol 1, pp 45-49, IRED, Institute ofResearch engineers and Doctors, NEW YORK,USA..ISBN: 978-981-07- 6261- 2doi:10.3850/ 978- 981-07-6261-2_61: ISSN: 2372-4153, 2013

[20] Ashok Kumar Ramadoss & Marimuthu Krishnaswamy , Embedding inference engine in fuzzy expert robotic system shell in a humanoid robot platform for selecting stochastic appropriate fuzzy implications for approximate reasoning, Artif Life Robotics, Springer, SG Germany, vol. 20, no. 1, pp. 13-18.ISSN:14335298,2015
doi.org/10.1007/S10015-014-0189-2
https://link.springer.com/article/10.1007/s100 15-014-0189-2

[21] Ashok Kumar Ramadoss & Marimuthu Krishnaswamy, Cognitive Potential impact Minimization by Mitigating through the implementation of correction factor in the TED algorithm for the concurrency control in anticipation error during different movements in the Ramda Humanoid robot, International Journal of Digital content Technologies and its applications, Advanced Institute of Convergence Information Technology Research Center, South Korea, vol. 2, no. 4, pp. 16-21, ISSN :19759339 (ANNEXURE 2), Version 2. 1, 2015

[22] Dr.Ashok Kuma Ramadoss,Fuzzifing using Approximation with Fuzzy to Extract Structure and Motion Environments in Dynamic Humanoid Robotic System from the Opted and Uncertainty by Quantization in non monotone neural networks, International Journal of Universal association of computers and electronics engineers IJUACEE,VOL 1,

pp 5-9, Institute of Research Engineers and Doctors, Switzerland ISBN No. 978-1-63248-131-3, 2017

About Author

Dr.Ashok Kumar Ramadoss

*EX-Scientist and Specialist (SIV Industries Ltd.,),
*Project LEADER (Society Generalle' Software Asia French MNC ITPL Bangalore and LG soft Korean MNC)
*Senior Global Member Universal Association of Computers and Electronics Engineers, Sr.MUACEE (New York US- IRED).
*Best Paper Award Winner in Humanoid Robotics at International Conference - KL, Malaysia.
*Appreciation Award received at International conference in Neural Schema for Humanoid Robotics in Computing ,Communication and Information Technology ZURICH, SWITZERLAND.
*Invited Speaker on "Recent Cognitive trends and Activities on Humanoid Robots" TOKYO, JAPAN
*Editorial Board Member in journal "Technoarete Transactions on Industrial Robotics and Automation Systems"
*International Scientific and Technical Committee Member and Editorial Board Member in Information and Communication Engineering Committee, for International conferences and journals in World Academy of Science, Engineering and Technology, having i10-index:1775, headquarters at London UK.
*International Advisory Board Member Scope Database.
*Senior member in the HONG KONG Society of Robotics and Automation (HKSRA)
*Member in Robotics surgery Illinois, USA