

FAULT DETECTION AND ISOLATION IN ROBOTIC MANIPULATOR VIA HYBRID NEURAL NETWORKS

Dev Anand, M.; Selvaraj, T. & Kumanan, S.

Department of Production Engineering,
National Institute of Technology, Tiruchirappalli-620 015, Tamilnadu, India
E-Mail: anandpmt@yahoo.co.in

Abstract

Fault diagnosis systems are important for industrial robots, especially those operated in remote and hazardous environment. Faults in robotic manipulator can cause economic and serious damages. So the Robots need the ability to independently as well as effectively detect and tolerate internal failures in order to continue performing their tasks without the need for immediate human intervention. This saves time and cost involved in repairing the robot. This type of autonomous fault tolerance is also useful for industrial robots in that it decreases down-time by tolerating failures, identifies faulty components or subsystems to speed up the repair process, and prevents the robot from damaging the products being manufactured. So an attempt is made to develop a robust fault detection system to identify and isolate the faults in robot manipulator. In this paper, two artificial neural networks are employed to identify and isolate the faults. A learning architecture, approximation of dynamic behavior of robot manipulator, is used to generate the residual vector, by comparing with actual measured values. First, A multi layer perceptron feed forward network, whose structure is characterized by layered graph, trained with back propagation algorithm is applied to reproduce the dynamic behavior, then counter propagation network which learns a near optimal look up-table approximation to the mapping being approximated. The counter propagation network has the ability to compress a huge amount of data in a few weights and parameters. Simulations employing a SCORBOT ER 5u plus five links robotic manipulator are showed demonstrating that the system can detect and isolate correctly faults that occur in non-trained trajectories. The main contribution of this work is the first application of fault detection and isolation to robot manipulator with non-additive fault.

(Received in January 2007, accepted in October 2007. This paper was with the authors 3 months for 2 revisions.)

Key Words: Robot Manipulators, Fault Isolation, Fault Detection, Hybrid Neural Networks

1. INTRODUCTION

Robots are often used in inaccessible or hazardous environments in order to alleviate time, cost and risk involved in preparing humans to endure these conditions. In order to perform their expected tasks, the robots are often quite complex, thus increasing their potential for failures. However, if people are frequently sent into these environments to repair every component failure in the robot, the advantages of using the robot are quickly lost. Fault tolerant robots are needed which can effectively detect and adapt to software or hardware failures in order to allow the robots to continue working until repairs can be realistically scheduled. Hence availability and reliability of these components are important for production environment. Hence, automated monitoring of the robotic manipulator for any faults and effective accommodation of such faults plays a crucial role in the use of robotic manipulators as autonomous systems [1]. Fault diagnosis and isolation methods are usually based on the residual generation and analysis concept. A mathematical model is used to reproduce the

- [4] Fabrizio, C.; Walker, D. I. (1997). Observer-based fault detection for robot manipulators, *Proceedings of the IEEE International Conference on Robotics and Automation*, Vol. 4, No. 3
- [5] Frank, P. M. (1990). Fault diagnosis in dynamic system using analytical and knowledge based redundancy-a survey and some new results, *Automatica*, Vol. 26, No. 3, 459-474
- [6] Michael, A. D.; Marios, M. P. (1998). Incipient fault diagnosis of dynamical systems using online approximations, *IEEE Transactions on Automation Control*, Vol. 43, No. 11
- [7] Isermann, R. (1984). Process fault detection based on modeling and estimation methods-a survey, *Automatica*, Vol. 20, No. 4, 387-404
- [8] Gertler, J. J. (1988). A Survey of model-based failure detection and isolation in complex plants, *IEEE Control Systems Magazine*, Vol. 8, No. 6, 3-11
- [9] Willsky, A. S. (1976). A survey of design methods for failure detection in dynamic systems, *Automatica*, Vol. 12, No. 6, 601-11
- [10] Patton, R.; Chen, J. (1991). Robust fault detection using eigen structure assignment: a tutorial consideration and some new results, *Proceedings of the 30th Conference on Decision and Control*, 2242-2247
- [11] Patton, R. (1994). Robust model-based fault diagnosis: the state of the art, *Proceedings of SAFEPRO-CESS'94*, Vol. 1, 1-10
- [12] Visinsky, M. L.; Walker Cavallaro, I. D. (1994). New dynamic model-based fault detection thresholds for robot manipulators, *IEEE International Conference Robotics and Automation*, Vol. 2, No. 8-13, 1388-1395
- [13] Wunnenberg, J.; Frank, P. M. (1990). Dynamic model based incipient fault detection concept for robots, *Proceedings of the 11th IEAC World Congress on Automatic Control*, Tallin, Estonia, 61-66
- [14] Carreras, C.; Walker, I. D. (2001). Interval methods for fault-tree analysis in robotics, *IEEE Transactions Robotics and Automation*, Vol. 50, No. 1, 3-11
- [15] Ting, Y.; Tosunoglu, S.; Tesar, D. (1999). A control structure for fault tolerant operation of robotic manipulators, *Proceedings IEEE International Conference on Robotics Automation*, Atlanta, GA, 684-690
- [16] Ralph, S. K.; Pai, D. K. (1999). Computing fault tolerant motions for a robot manipulator, *Proceedings IEEE International Conference on Robotics and Automation*, Detroit, MI, 486-493
- [17] Park, J.; Chung, W. K.; Youm, Y. (1996). Failure recovery by exploiting kinematic redundancy, *Proceedings 5th International Workshop Robot Human Communication*, Tsukuba, Japan, 298-305
- [18] Yi, Y.; Mcinroy, J. E.; Chen, Y. (2006). Fault tolerance of parallel manipulators using task space and kinematic redundancy, *IEEE Transactions and Robotics*, Vol. 22, No. 5, 1017-1021
- [19] Roberts, R. G. (2001). The dexterity and singularities of an under actuated robot, *Journal of Robotic System*, Vol. 18, No. 4, 159-169
- [20] Dailey, K. W. (2004). *The FMEA Handbook*, DW Publishing, New York
- [21] Winfield, A. F. T.; Nembrini, J. (2006). Safety in numbers: fault tolerance in robot swarms, *International Journal of Modeling, Identification and Control*, Vol. 1, No. 1, 30-37
- [22] Winfield, A. F. T.; Sa, J.; Gago, M. C.; Fisher, M. (2005). Using temporal logic to specify emergent behaviours in swarm robotic systems, *Proceedings of Towards Autonomous Robotic Systems (TAROS)*, London
- [23] Dixon, W. E.; Walker, I. D.; Dawson, D. M.; Hartranft, J. P. (2000). Fault detection for robot manipulators with parametric uncertainty: a prediction- error-based approach, *In IEEE Transactions Robotics. Automation*, Vol. 16, No. 6, 689-699
- [24] Balajee, K.; Lynne, E. P. (2007). *Fault tolerance based metrics for evaluating system performance in multi robot teams*, Distributed Intelligence Laboratory, The University of Tennessee, Knoxville, 54-61
- [25] Yavnai, A. (2000). Metrics for system autonomy. Part I: metrics definition, *Proceedings of Performance Metrics for Intelligent Systems (PerMIS)*, Vol. Part II.
- [26] Finkelstein, R. (2000). A Method for evaluating iq of intelligent systems, *Proceedings of Performance Metrics for Intelligent Systems (PerMIS)*, Vol. Part II.
- [27] Kohonen, T. (1995). *Self-Organizing Maps*, Springer-Verlag, Berlin
- [28] Leonard, J. A.; Kramer, M. A. (1991). Radial basis function networks for classifying process faults, *IEEE Control Systems*, Vol. 11, No. 3, 31-38