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Testing of Various Embedded System with Artificial Intelligence Approach

Swapnili P. Karmore, Dr. Anjali R. Mahajan

***Abstract*— Testing of Embedded System is a great challenge for software testers. Testing of embedded systems is most sophisticated and time consuming task because of its different infrastructure, organizations and techniques used for its development. Testing of application specific Embedded System is not similar to testing of another Embedded System. This paper gives a new artificial intelligent approach for testing of various Embedded Systems. It focuses on three different aspects. First is the efficient use of an Artificial Intelligence approach to test the Embedded System. Second is the development of one universal platform for testing. Third is development of safety critical character generator device.**

Safety critical characteristics are being monitored, tested and analyzed with an Artificial Intelligence Approach. An Artificial Intelligence approach uses Artificial Neural Network to train the neural network. Multiple embedded systems are successfully tested together in real time environment using the above approach.

***Index Terms*— Artificial Intelligent Approach, Black Box Testing, Embedded System Testing, Safety Critical Character Generator,**

I. Introduction

Now a day's use of Safety Critical software is rapidly increases. Safety critical characteristics are difficult to handle and difficult to measure. Testing of such Safety Critical characters in embedded system is very difficult task. Embedded Systems are becoming more and more important in today's life in many ways. Embedded Systems can be in general defined as special purpose information processing systems, containing both hardware and software development. Embedded systems are integrated in larger systems, which interact with environment for achieving a set of predefined tasks or applications. Testing of each Embedded Systems required separate tool or separate code .There is no such mechanism is presents in market, which is responsible to check number of Embedded Systems together.

As we are dealing with differential Embedded Systems each of Embedded System is developed as an application specific one and having different approaches for testing. These systems are characterized by Life cycles, Infrastructures, Techniques and Organization. These four cornerstones can be treated as basics for categorization of embedded systems and can be responsible for allocating techniques for performance sensitive devices, running in real-time applications. All too often, the available testing techniques are failed to run the performance and the space requirements, and the tester must program separate code for testing of each embedded system. In the drastic and changing environment, the rapid growth in the Embedded Systems marketplace demands efficient automated testing tool, which will be capable to solve testing problems of Embedded Systems. The resource, performance, and timing constraints of real time Embedded Systems suggest that significantly more powerful testing techniques should be required during the final stages of program development. The testing time provided from developers to tester is also very short for completing tests and covering faults.

Stronger and more costly techniques might become essential for the Embedded Systems testing process, which are affected by some issues important to the embedded world. First is the separation between the execution platforms and application developments. Embedded system testing is very difficult task because of large variety of execution platforms, cross-development environments, wide range of deployment architectures, and coexistence of various implementation paradigms, timing constraints and tight resources on the platform where they will be executed, lack of clear design models and emerging quality and certification standards.

Testing of various Embedded Systems are possible only when there is a possibility of categorize them on the basis of software, hardware used or on the basis of their type. Embedded Systems can be categorized as Technical scientific based Embedded Systems and the Safety Critical based Embedded Systems. On the basis of platform used Embedded System is again categorized as Target based Embedded System Testing and Host based Embedded System. This research work focuses on the testing of Embedded Systems Safety Critical characters. The Embedded System Testing process presents unusual challenges to a tester. Testing is carried out via black box.

For real time system, predictability, time constraints and resources awareness are of greater importance along with execution efficiency. For example, if a tester is not aware of the structure and complexity of Embedded System the testing of embedded system becomes very difficult. This research is aimed towards a new generation of testing real and virtual real time embedded systems. This work considers testing in several phases, including identification, categorization, static analysis, model checking, pattern generation and training. Major points of focus are Safety Critical character of Embedded Systems which makes them real time Embedded Systems.

This research focuses on the challenges faced by testers for

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Swapnili P. Karmore *Research Scholar, Computer Science and engineering Department, G. H. Raisoni College of Engineering, Nagpur, India, 9823437807*

Dr. Anjali R. Mahajan Supervisor*, Computer Science and engineering Department,, P. I. E. T. College of Engineering, Nagpur, India*

embedded systems software. For real time system, predictability, time constraints and resources awareness are of greater importance along with execution efficiency. For example, if a tester is not aware of the structure and complexity of embedded system the testing of embedded system becomes very difficult. This research is aimed towards a new generation of testing real and virtual real time embedded systems. This work considers testing in several phases, including identification, categorization, static analysis, model checking, pattern generation and training. Major points of focus are safety critical character of embedded systems which makes them real time embedded systems.

Section I gives detailed description about aim and objective of research work. Section II gives literature survey whereas research work plan is focused in Section III and Section IV contains methodology Section V contains results and VI contains conclusion and the paper was concluded by references.

II. Literature Survey

A. The Ethics of Safety Critical Systems by Jonathan Bowen

Author has developed some ethics in order to solve the problems of testing of safety critical Embedded Systems. Developer has freedom to choose different techniques and methodologies to test and to develop the software. Aircraft as example for Safety Critical systems contains 10-9 accident per hours where software testing is not sufficient to solving of problems [2]. Software diversity likes, N-version programming and verification and validation of software can add some extra reliability and measurements on the effectiveness of such approaches are difficult to obtain. Computer program having change of single bit can lead unpredictable effect on its normal operation. Author explained some of the pitfalls and issues in choosing a suitable approach [1].

B. Neural-Network Based Test Cases Generation Using Genetic Algorithm by Ruilian Zhao & Shanshan Lv

In the paper Neural-Network based Test case Generation using Genetic Algorithm, Author focuses on major problem while performing Black Box Testing ,where Black box testing is how to select test cases from input domain on the basis of specification. In some software instead of input domain test cases are generated by output domains. Author presents a new approach for automated test case generation. Model developed via neural network and improved genetic algorithms. Here the classification is based on specification and the specification is responsible to select test cases [3].

C. Model- Based Test cases prioritization using Neural Network Classification by Nida Gökçe1& Mübariz Eminli

Running of test cases of differential Embedded Systems at a time may create large complexity and problems. If we consider Model based testing for real life software systems, we have to create a large number of tests and execution of test cases randomly will not give appropriate results. There is need of prioritization of tests before execution according to their importance or testers requirements. This paper solves the problem by providing classification approach to the results. Here parameter for classification is important index and frequency of events occurring. For approach classification Neural network is used and for all test cases classification is performed by multi layer perceptron neural network in artificial intelligence [4].

D. Automated Test case generation based on coverage analysis by Tim A.Majchrzak & Herbert Kuchen

Paper focuses on automated generations of unit tests. They have developed tool, which is symbolically executed java byte code for searching execution path through program, for searching choice-point generation, constraint solving and backtracking was used .They have proposes a novel way to reduce the test cases, which was based on their contribution to the global coverage of the data flow and control flow. Basic aim behind work is elimination of repeated and meaningless test cases. For example a method for handling AVL trees should only be tested by AVL trees rather than with arbitrary trees [5].

E. Testing Embedded Real Time Systems with TTCN-3by Juergen Grossmann, Diana Serbanescu.

In this paper author introduces a real time test technology and methodology for the automotive domain, based on a standardized test technology. These enable the exchange of test requirements, test cases, and test procedures between different parties involved in automotive systems development. Both methodology and technology are based on TTCN-3 and will contain several enhancements that adapt the already existing TTCN-3 standard to the needs of the automotive domain and especially to the emerging AUTOSAR standard. The paper started with the specification of real-time enhancements to TTCN-3 that provide systematic support for testing timing requirements of automotive software applications under real-time conditions. Author presented the real-time language features that were introduced to TTCN-3. They described their syntax and semantics and discussed their application by means of an example that reflects typical automotive timing requirements [6].

F. Parameter extraction and optimization using Levenberg –Marquardt algorithm by Le Due-Hung,Pham Cong-Kha.

Parameter extraction is use to determine the values of device model that minimize the difference between a set of measured characters and the result obtained by evaluation of device model characteristic to measure the data. A combination of a local optimization and the group device extraction strategy is adopted for parameter extraction. Here comparison between simulated and experimental data is carried out for the model fitting. In this paper author proposes the Levenberg-Marquardt algorithm for optimization and parameter extraction of EKV MOSFET model. This algorithm is the combination between the steepest gradient and the Gauss-Newton algorithms. Mat lab environment is used for design project implementation [7].

G. *A brief description of levenberg-Marquardt algorithm implemented by levmar by M.I.A.Lourakis*

This paper gives a brief description and deep knowledge about Levenberg-Marquardt algorithm and its implementation. Sometime this algorithm behaves like a steepest descent method, when the current solution is not closed from the correct one and behaves like Gauss-Newton method, when the current solution is close to the correct solution. It has become a regular technique for non-linear least-squares problems [8].

H. Risk based Testing of Safety –Critical Embedded Systems Driven by Fault Tree Analysis by Johhanes Kloos,Tanvir Hussain,Robert Eschbach,

In this paper author described an approach to use the results obtain from the Fault Tree Analysis during the constructions of test models in such a way that test cases can be, selected, prioritized and derived according to severity of the Risks which was identified and the number of basic events that cause it. In the context of software testing the risk based testing is very familiar term. Safety critical characteristics are used in risk estimation process of software development. Author proposes efficient method providing a significant increase in coverage of safety critical functions, compared to regular model based testing [9].

III. RESEARCH WORK PLAN

Research plan begins with embedded system's testing life cycle, were all of testing requirements are analyzed, test plans are designed and coded. The verification and validation techniques are used.

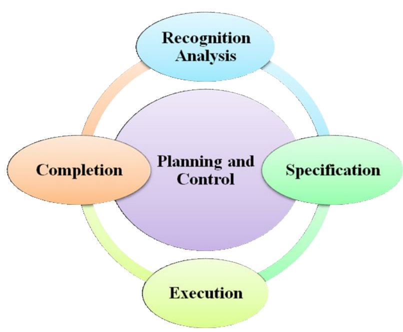

Fig. 1. Life cycle of Testing embedded system

Testing is performed in all of development processes of embedded systems. Planning and control is provided to Recognition analysis, Specification, and Execution and completion phase. Different embedded systems are identified before considering under test. If we will take ten numbers of Embedded Systems and we have to test them under one platform, first we have to identify their type. In order to test them via one tool as it is a very difficult task. Embedded System is the application specific one and each embedded system contains its specific testing tool. It contains hardware as well as software, so there is a need to test hardware as well as software.

Categorization of Embedded System is required before testing. On the basic of categorization, techniques can be used for testing of embedded systems [10]. Here we are performing the black box testing, where we are going to check inputs and outputs of embedded systems in order to compare the safety critical character of Embedded System.

Research plans begins with smaller experiments on small size embedded systems. Mobile phone, Printer laptops are considered device under test. While perform testing so many issues and challenges are identified. Memory mapping, online and offline printer testing was successfully performed .Host based and target based testing was performed to test various Embedded Systems. Another experiment contains testing via randomized algorithms and Hit and jump algorithm. For all these experiments there is need to develop different environment and different techniques before testing.

The main aim and objective behind research work is development of universal environment were all devices can be tested successfully under one roof. In the second phase of research work artificial intelligence approach is used which solves problem of testing of differential embedded system together. Two case studies are taken under consideration to understand and solve the problem of testing of embedded system under one platform. Case Studies are used to understand development and testing of Embedded Systems.

Let us take an example of Safety critical systems that is pacemaker. Pacemaker needs to guarantee important properties like deadlock-free, safety, etc. which worry human lives. It is used for temporary intensive care simulation of the human heart. Pacemaker's stimulation frequency and amplitude can always be set in wide ranges to match the current therapeutic necessities. The sensing of the heart's own action and the emission of stimulation impulses is indicated optically by LED. In addition, acoustic signals for sensing and stimulation can be switched on and off as per requirement. So switch on or off pacemaker and blinking of LED is the indicator or a factor which derives it's as a safety critical system.

Another case study is of Antilock Breaking system. Traditional anti lock brake control system includes a central electronic control unit, four wheel speed sensors and two hydraulic valves within the brake hydraulics. Antilock Breaking system's electronic control unit constantly monitors the rotational speed of each wheel. The Modern electronic stability control systems are an advanced evolution of the Antilock Breaking system concept. Its uses two sensors for system work; these are a steering wheel angle sensor and a gyroscopic sensor. Gyroscopic sensor is used to detect the direction taken by the car. The ESC software will break the necessary individual wheels. The steering wheel sensor is used to help in the operation of Cornering Brake Control, which informs the ABS that wheels on the inner side of the curve should break more than wheels on the outer side.

So sensor activities and signal proves the indicator or a factor, which derives it's as safety critical system. Failure of it will fail the overall system. We will consider these two Embedded Systems as a device under test, we can test there inputs and outputs together whether they are generating safety critical characteristics or not. Safety Critical Character is responsible for making Embedded System as Safety Critical Embedded System and also responsible for failure or success of the system.

Research plan begins with different smaller experiments to study how Embedded Systems Testing is different than other system and how an Artificial Intelligence Approach is used to test embedded systems. The main difference is instead of using real different embedded system the characteristics which make them Safety Critical are generated first. It is monitored, analyzed and tested via Artificial Intelligent approach.

We can handle these two embedded systems separately in order to test their inputs, outputs, desired outputs and functioning. If some more embedded devices are included then it is not possible to perform testing of all embedded systems together. But this is possible via artificial intelligent approach. The idea behind the research work is we are considering only that factors which makes our system safety critical one. The device which is responsible to generate such characters, which makes embedded systems safety critical is generated first. Hardware is responsible to generate number of safety critical characters under one roof, which are tested, analyzed and monitored via an Artificial Intelligent Approach. An AI approach used is ANN here [11].

On the basis of hundred samples collected from the Embedded System under test through the interface card, which communicated using serial port PC and the USART of ATMEGA16 of interface card. The Embedded System is designed around PIC16F877 which is performing four different tasks and the changes on IO's are detected by the interface card on parallel ports. The system scan maximum of twelve input pins and six output pins and four critical inputs around 1us and the changes on IOs are detected and transfer to the neural network. The sequential samples are creating different patterns for different applications. These patterns are used to train neural network.

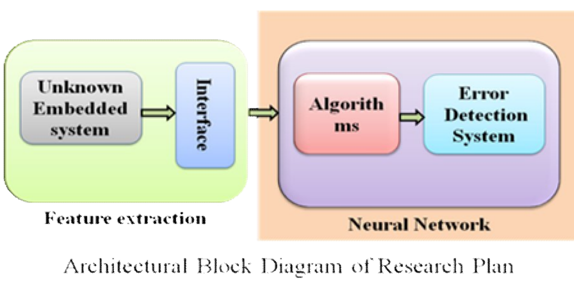

Fig. 2. Architectural Block Diagram of Research plan work

An Artificial Intelligence approach uses Levenberg-Marquardt algorithm to train the neural network. The Levenberg–Marquardt algorithm gives numeric calculations for solving the problem of minimizing a nonlinear function. Levenberg-Marquardt algorithm is alternative to the Gauss-Newton method. Gauss –Newton method is used to find the minimum of a function. The training problem can be treated as a general function optimization problem; Gauss-Newton method adjusts parameters being the weights and biases of the network.

Neural network is used to map between a set of numeric targets and data sets of numeric inputs. The Neural Network Fitting Tool is used for selecting data, creating and training a network [12], and use to evaluate performance using mean square error and regression analysis. After selecting data for input and target, we get three kinds of samples first is training which are presented to the network during training and the network is further adjusted according to its error, second is validation which is used to measure network stops improving and last is testing which is used for testing and have no effect on training. It provides an independent measure of network performance during and after training.

IV. Results

Experiment setup is used for demonstration of actual verses virtual testing of Embedded Systems. Some results are obtained. First set of outputs are obtained via hardware developed for Safety Critical Characteristics Generator.

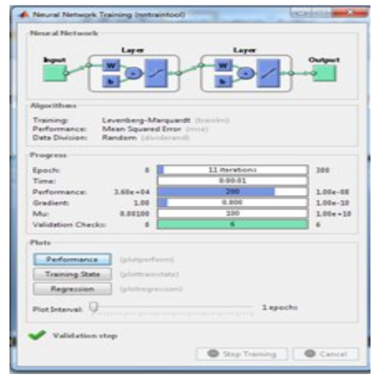

Fig. 3. Neural Network for training Samples

Training is performed via Levenberg-Marquardt back propagation algorithm. When the network does not perform well after training then we have to change the number of neurons. Training automatically stops when generalization stops improving, as indicated by an increase in the mean square error of the validation samples.

Figure three shows neural network for training the samples. It shows neural network training results, were levenberg algorithm is used. Figure four is for set of inputs, figure five is for set of outputs and figure six is for training set. Experimental set up for second pattern gives similar results . In second case set of saved inputs and outputs are used. They are trained via neural network fitting tool.

Figure four, five and six is for set of inputs and outputs generated via safety critical character generator hardware device. Figure four shows real time input and output drawn out from Safety Critical Character Generator device,which is the great achievment of research work. Figure seven gives graphical diagram for training sets. Neural network is used to compare the desired and generated input outputs.nftool is used to train the network.

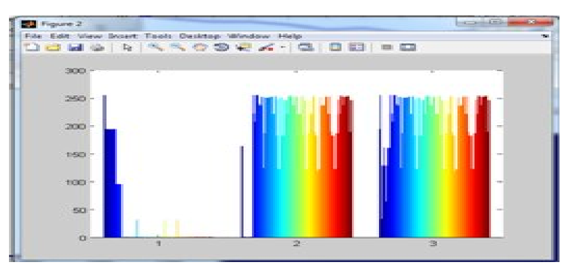

Fig. 4. Set of inputs from Safety Critical Character Generator

Mean Squared Error is used to calculate the average squared difference between outputs and targets. We got Lower values and lower values are always better. Zero means no error.

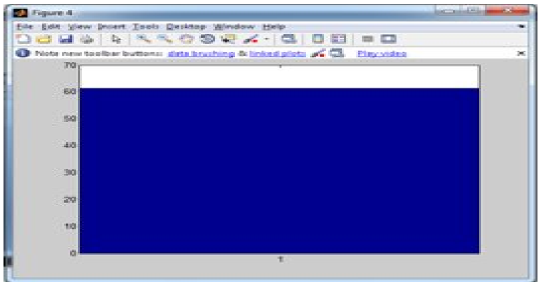

Fig. 5. Set of outputs drawn from Safety Critical Character Generator.

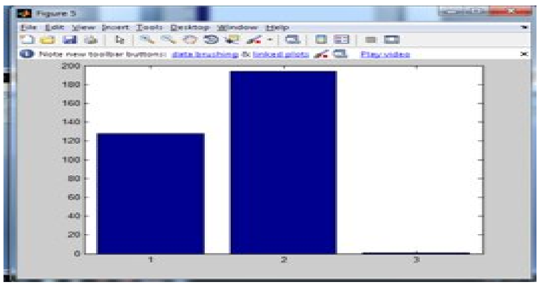

Fig. 6. Set of compared input and outputs.

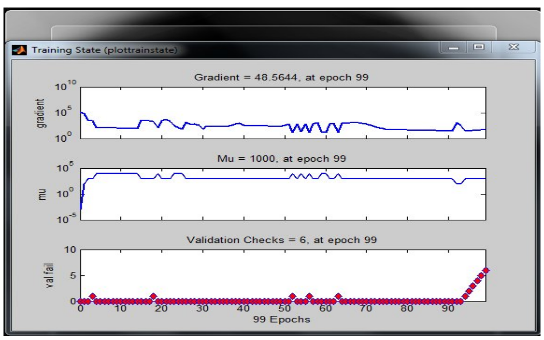

Fig. 7. The graphical output for Training set.

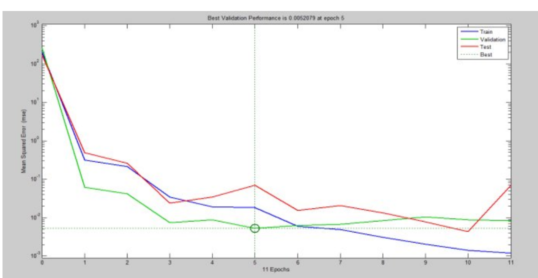

Fig. 8. Performance Analysis of training validation and testing.

Regression R values is used to measure the correlation between outputs and targets. A Regression value one means a close relationship, Zero means a random relationship and we get 0.999 means equivalent to one. Training stops when any of these conditions occurs:

- When the number of epochs is reached to maximum.
- When the maximum amount of time is exceeded.
- When the Performance is minimized to the goal.
- When the performance gradient falls below.
- When the mu exceeds mu_max.
- When the performance has increased more.

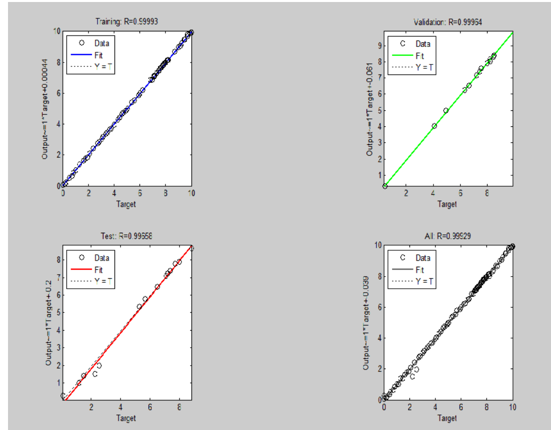

Fig. 9. The graphical output of Regression.

Experimental setup for saved input output gives following result, where Figure eight is for Performance Analysis of training validation and testing. Performance graph was plotted against training validation and testing. Figure nine is for Regressions.

V. Conclusion

In this paper, we have demonstrated an Artificial Intelligent approach to test the inputs and outputs of Safety Critical Embedded Systems. The Safety Critical characteristics are generated via hardware; Safety Critical Character Generator device. Research work gives a new approach for testing of embedded systems .Testing of heterogeneous embedded system is not possible over a one tool, as testing of pace maker is not similar to testing of ABS. Each of application specific embedded system requires its own specific tool. Inputs of Embedded systems which are responsible to generate safety critical characteristics are tested here via neural network means via an Artificial Intelligent Approach.

The process of Training Validation and Testing is performed. This is the universal methodology for Embedded System Testing. This approach is capable to test ten or more number of Embedded Systems together. Experimental result shows that this method is promising for solving testing problems of embedded systems. This paper describes the testing framework that is black box based and capable of testing several Embedded Systems over on single platform in real time . LM method has been proposed for reserch work which gives less error faster computation time and moderate complexity and has been implemented successfully.

Future scope will be the modification of testing tool for heterogeneous Embedded Systems, where the number of device under test can be increased.

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Mrs. Swapnili P. Karmore is pursuing her PhD in computer Science and Engineering. She is Assistant Professor and Course coordinator of M.E., Embedded System and Computing in G. H. Raisoni College of engineering. She has published several papers in international conferences and journal as first and second author. She has completed her diploma in Electronics and Telecommunication, BE in Computer Engineering and M.E in Embedded System and Computing in Rashtrasanta Tukdoji Maharaj Nagpur University. Her research interest includes Embedded System Testing, Artificial Neural Networks, and Software Engineering.

Dr. Anjali R. Mahajan is Professor and Head of Department of Computer Science and Engineering, Priyadarshini Institute of Engineering &.Technology, Nagpur. She has eighteen and more years of academic experience. She has received her PhD Degree from Sant Gadge Baba Amravati University in 2010. Dr (Mrs) Anjali Mahajan was worked as Technical Committee Member, Session Chair, board of studies and she is member of different professional societies. She has arranged so many workshop and trainings for faculty. She has published more than fifty papers in reputed international journals and conferences.