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Design and Implementation of Fault Tolerant Soft Processors Inspired By Endocrine Cellular Communication

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ABSTRACT—In self repairing digital system, fault tolerance is a crucial operational aspect. Rerouting process followed by cell replacement is impractical. Moreover, efficiency cannot be achieved due to the addition of extra functional circuits. Endocrine cellular communication, a collection of cells and tissues of organisms that secrets hormone when an endocrine cell dies in a specific process.Its connections are maintained through blood vessels. Inspired by this communication system a system is proposed which reduces hardware overhead and minimizes unutilized hardware to maintain good fault coverage. In this paper, a fault unit recovering system was proposed by the use of genetic algorithm to increase the lifetime of circuits. Spare cells are used as a replacement in case failure occurs in working cells. Comparing with existing methods, the mechanism proposed is efficient for the real fault tolerant systems.

INDEX TERMS—Endocrine cellular communication, self-repair, genetic algorithm, Array multiplier, Stem cell.

I.INTRODUCTION

One important goal of the system is to increase the reliability. The key features involved in ensuring reliability are fault tolerance, detection and recovery. It is the source of inspiration for electronic fault tolerant system. During analysis, self-repairing system is found as most suitable technique which can resolve the faults occurred in fault tolerant systems.

Recent trends in microelectronics technology have gradually changed the strategies used in VLSI circuits. Establishing an efficient methodology is one of the key to design VLSI chip successfully. The design of microelectronics system is strongly influenced by the fact that transistor and featured size have continuously influenced, while density and frequency have increased. The products which are to be delivered to the customers must be thoroughly tested by the circuit manufacturers. The sources of circuit failure can be divided into two main categories: design errors and manufacturing defects

Design errors are caused by errors in the layout. Design errors are the errors which can be modified by eliminating the errors.Design errors are detected by simulating them and testing the simulation.

Simulation results cannot perfectly predict what a real circuit will do. Because most simulations cannot predict whether or not latch up will occur. Thus, it is indispensable to check a real circuit before we can be certain that all design errors have been fixed.

In the last 10 years, these conventional techniques have provento be relatively inefficient, and scientists have consequently turnedto biology to find motivation for a more appropriate self-repairingcircuit that can resolve the aforementioned crisis and faultswith fault-tolerant systems [1]–[11], [12], [13]–[21]

Embryonics is the new concept inspired from the biological cell to design digital circuits [3]. Genetic codes are carried by the biological cells through the whole system, building blocks with identical structures are organized,and an embryonic self-repairing circuit and the genetic code expressed in each block vary according to them [3]-[5].

By isolating the faulty block the self-repairing circuit can also recover from a fault. Also self-repair system can make better repair on fine grained scale rather than coarse grain scale of fault tolerant systems. So in this case, a little part of the system has to change and constant operation of spare (stem) blocks will not be enabled. Spare (stem) blocks can be any kind of logic, like biological stem cell (SC) is a special advantage.An adaptive hardware system with on-chip reprogramming dynamic routing, reconfiguration, and was used as a self-repairing system [7], [22] Even though self repairing systems had multiple advantages, it faces many obstacles to use in practical due to cell replacement and rerouting process. They are highly difficult and tricky to implement. A proper module must be allocated by the system to put back a faulty one and the neighboring modules are connected by the substitute module in the similar way as the faulty module was previously connected.

Therefore, such methods of self-repair involve both additional hardware for rerouting after the replacement of faulty cell (module) and inefficient arrangement of functioning modules as well as spare (stem) modules. The size of sparemodules and additional functional modules exponentially increases as the circuit size increases.

Considering the endocrine cellular communication as an inspiration, a new self repairing system was designed. In endocrine cellular communication, a specific hormone issecreted by a special endocrine cell when it receives a request from another specific hormone. Connections among endocrine cells are maintained by blood vessels.

Data's encoded in each module are developed with functional, connection data and a new wiring architecture. There are several devices available which can replace a faulty module by encoding data's (stem module) but they cannot maintain the function and connections properly. With some biological inspiration self-repairing systems changes the small part of the system and spare (stem) blocks are not operated constantly. Spare blocks are activated only if recovery block is disabled.

During the past few years genetic algorithm, neural networks and artificial brains has generated some remarkable results.The flow of the functional system is based on genetic algorithm. The process of evolution is based on alternation in genetic information occurring through two basic mechanisms: Cross over and mutation.

Crossover is directly related to the process of sexual reproduction when two organisms of the same species reproduce the offspring contains genetic material coming from both parents and thus becomes a unique individual different from either parent. Mutation consists of random alterations to the genome caused either by external phenomena (or) by chemical fault which occurs when the genomes merge [2].

The proposed system helps the circuit to maximize the efficiency of its hardware realization. The size of the hardware is reduced and it ensures good fault coverage.Even if several faults occur simultaneously in different modules, the system can recover them. Furthermore,it can preserve the state and function that existed just before the fault occurred in the sequential system.

II. Self Repairing System Influenced By Endocrine Cellular Communication

Self-repairing is a phrase applied to the process of recovery motivated by and directed by the patient, guided repeatedly only by instinct. Such a process encounters mixed fortunes due to its amateur nature, even if self-motivation is a major asset. The value of self-repairing lies in its ability to be tailored to the unique experience and requirements of the individual.

In a figurative sense, self-repairing properties can be described to systems or processes, which by nature or design be likely to correct any disturbances brought into them. Such as the rejuvenation of the skin after a cut or scrape, or of an entire limb. Or (in a more abstract sense) the setting of one's own broken bone, because once set, the bone will get develop back into itself and heal. In each case, the injured party (the living body) repairs the damaged part by itself.

Endocrine system is a radio-like communication system.It consists of endocrine glands and specialized collection of cells within organs of multi cellular organism. The endocrine glands sends its hormonal messages like a radio broadcast to essentially all cells of human body by secretion into the circulation of blood. Hormones are chemical messengers of endocrine communication. They are transported through the bloodstream and cells which have a receiver to take this message

A. Fault Tolerance

The development of a dependable computing system calls for the combined utilization of a set of methods that can be classified intofault prevention, fault removal, fault tolerance and fault forecasting.

Fault-tolerance is achieved through the introduction and the management of redundancy. A fault-tolerant computer may contain several forms of redundancy, depending on the types of faults it is designed to tolerate**.**Nowadays, fault-tolerance techniques are being employed as a means to protect critical computing systems not only from physical component failures, but also from faults in hardware and software design, operator faults during human-machine interaction, and even malicious faults perpetrated by felons.

From the inspiration of biological endocrine system, it depends on the efficient and flexible communication among the endocrine cells.Through apoptosis if an endocrine cell dies a new endocrine cell equipped with functions as that of the dead cell is produced and its overall communication network is recovered.Moreover, in theendocrine system, the hormones do not flow through a special path between endocrine cells but rather they are in contact with endocrine cells through a blood vessel.

III. Multipliers

Multipliers play avital role in today's digital signal processing and various other applications. Through advances in technology, many researchers have tried and are trying to design multipliers which suggests either of the following design targets – high speed, low power consumption, regularity of layout and hence less area or even combination of them in one multiplier thus making them suitable for various high speed, low power and compact VLSI implementation.The common multiplication method is “add and shift” algorithm.

A. Array Multiplier

Array multiplier, almost identical cells array is used for generation of the bit-products and accumulation. All bit-products are generated in parallel and collected through an array of full adders or any other type of adders and final adder. Array multiplier has a regular structure that simplifies the wiring and the layout.

Arrays are Compact and easy to layout, arrays performthis reduction in gate depth that is linear in the bit width. Using self-repairing concept, thefollowing system will proceeded by exhibiting it in array multiplier circuit.

IV.OVERVIEW OF THE SELF-REPAIRABLE DIGITAL SYSTEM

In the system, explicit connections between a working module and spare modules are designed, so that the working module can be rerouted and connected to a spare module when the working module fails and is replaced with the spare module. The endocrine cellular communication is recovered by resuming the reception and secretion of the same hormones, which expression of the same genome as the dead endocrine cell.

Similarly, the system can recover the connection between modules using the same genome as the faulty module. In these ways, the existing system can maintain the connection between modules as well as the function of a module by module replacement existing self-repairing methods have a rerouting process that is separate from the replacement of the faulty module, which makes the system complex and has a high overhead.

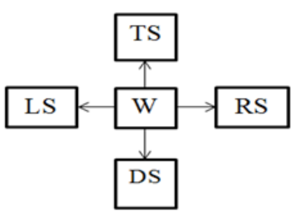

Fig .1 Cells for replacement instead of working cell
Stem cell: LS, DS, RS, TS

Fig. 1 represents all possible changes of index bits in W, LS, DS, RS, and TS cells after the receipt of a fault signal. On the other hand, the specificity of the endocrine cell that receives and secretes the unique hormone and the exact connection between endocrine cells is applied to develop our module structure and wiring structure, respectively.

Thus, the proposed system repairs a fault in a simple way, just as the recovery in the endocrine cellular communication is performed by simply expressing the same genome part of a dead cell in SC. As a result, our system has a low hardware overhead, even with large circuits, and has good fault coverage by reducing the unutilized hardware for fault recovery.

A.New Self-Repairing Mechanism: Endocrine cell Act as a Fault Detection unit

Fig. 2 represents the arrangement of SC and WC which implies there can be any number of WCs but a single WC must be allocated with only four SC.Every working cell (WC) has four neighboring SCs and the WCs can be replaced by any available SC among them in the event of fault occurrence.It chooses the proper candidate SC for the faulty WC without collision.

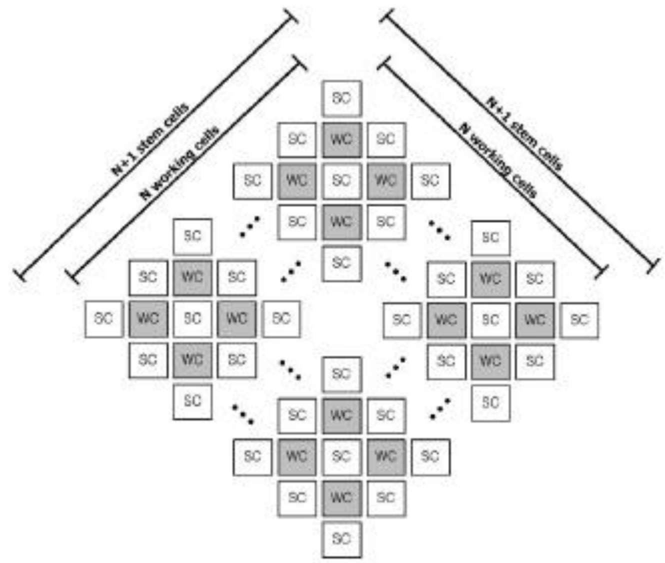

Fig .2 Cell arrangement of existing system

WCs in the Existing system can be expanded to any direction as far as every WC has four neighboring SCs. Because the SC can be used for four nearby WCs by exact control without collision. A WC can be recovered up to four times even though the number of SCs is similar to the number of WCs.

V. PROPOSED SELF-REPAIRING SYSTEM

Algorithms, commonly referred to as evolutionary algorithms such as genetic algorithms, evolutionary programming, and genetic are usually applied to problems which are too ill-defined or intractable by deterministic approaches, and whose solutions can be represented as a finite string of symbols.

An initial, random population of individuals (i.e., of genomes), each representing a possible solution to the problem, is iteratively “evolved” through the application of mutation (i.e., random alterations of a sequence) and crossover (i.e., random merges of two sequences).

The modified system of self repairing digital system contains working cell and spare cell. The working cell comprises of modules and their interconnections. In spare cell contains information about the function and the connection. Therefore, a faulty module can be replaced and the whole system's functions and connections are maintained by simply assigning the same encoded data to a spare module.

The main role of the gene-control layer is to assign the correct spare (stem) module to replace the faulty one. In addition, modules involved in this mechanism are distributed and operated in parallel. Fig. 3 provides the flow diagram of proposed system.

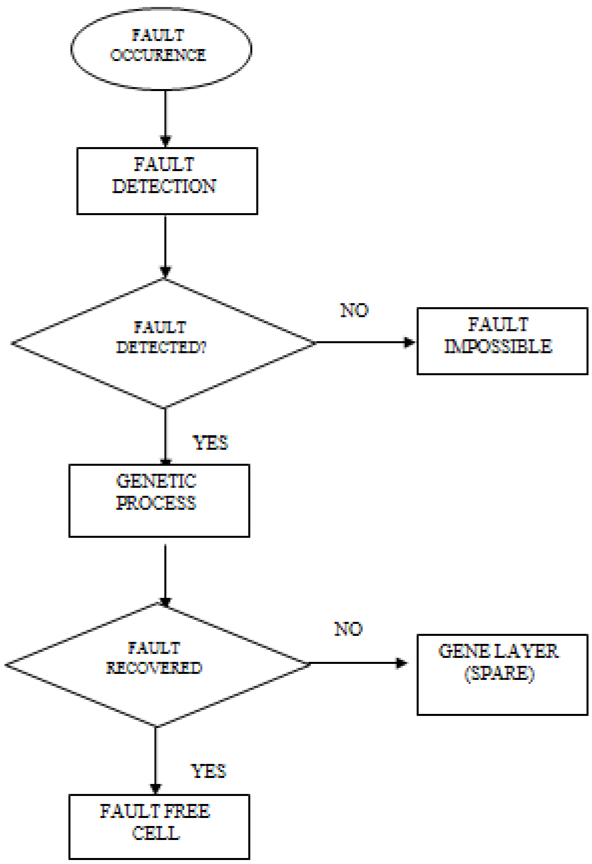

Fig .3 Fault detection and Correction

Fig.3 shows the overall flowchart of the fault detection unit, showing how it can recover a fault free working cell. If a fault is not detected then no possible faults could be found. Once a fault is detected the WCs will go through genetic process. A fault free WC will be obtained if the detected fault is recovered elsean apt SC will be replaced.

In Fig. 4 every WC is provided with only 2 SCs and its overall search problem is minimized. Even if several faults occur simultaneously in different modules, the system can recover them. Furthermore, the occurrence of fault is reduced by using genetic algorithm.

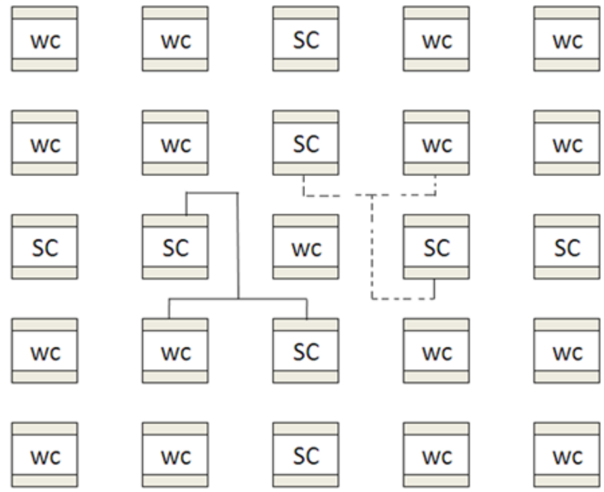

Fig .4 Cell arrangement of Proposed System

VI. Experimental Results

The performance of the system was analyzed by examining number of spare cells used. Our system improves the quality of working cell with minimum routing complexity.

TABLE I

Comparison Of Delay And Area In Existing And Proposed System

System	Spare cell	Working cell	Area
Existing	4	1	1%
Proposed	2	1	0%

To evaluate the effectiveness of the approach, an experimental circuit based on an 8-bit multiplier was developed.Table I summarizes the comparison of two approaches.

Although the use of four spare cells eases the operation of the WCs in Existing system, it needs more space to establish itself soit is considered as overhead.

To overcome those drawbacks two SCs are only used in the place of Four SCs. It is achieved by using genetic algorithm and it is considered as an additional advantage because it reduces the area occupied by reducing the spare cells. It will recognize the occurrence of fault by observing the mismatches happened between the output bits. The above process will be carried out in crossover and mutation blocks to recover the working cell. While synthesizing, area overhead in proposed system was reduced to 0%. Delay occurred and power consumed are 4.26ns and 0.034 w respectively.

The proposed self repairing system, with two spare are simulated by using Xilinx ISE 12.1i ISE design suite and simulated by using Modelsim as shown in Fig. 5.

Implementation results will be carried out in Spartan 3E FPGA. The Spartan 3E family of Field-Programmable Gate Arrays (FPGAs) is specifically designed to meet the needs of high volume, cost-sensitive consumer electronic applications.

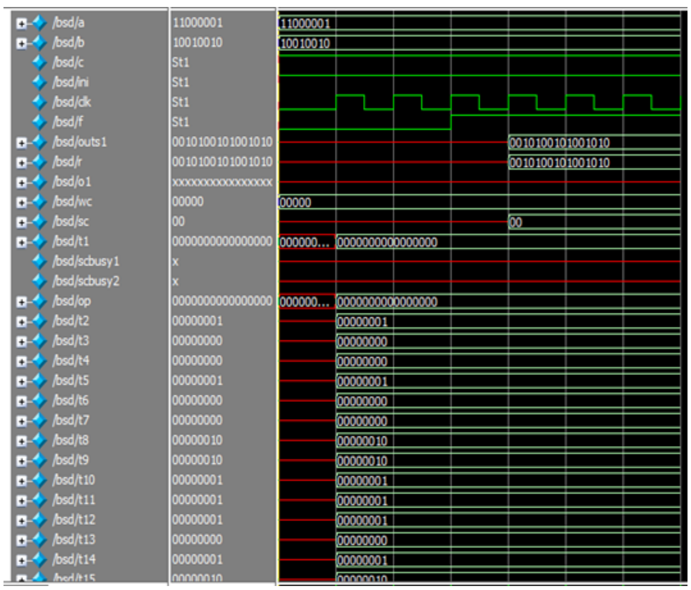

Fig .5 Simulation result

VII. CONCLUSION

The ubiquity of computer systems, the trend towards the development of more open andinterconnected systems, the increase in their complexity, their distribution and widely varyingin sizeare some of the new challenging targets for fault-tolerant computing.The primary goal of developing a fault tolerant or self-repairing system is to deal with faults that can occur in the target system. Other faults that might occur in additional hardware are not considered. However, faults might happen in any fragment of the circuits with the same possibility. Hence, the secondary faults that can occur in the additional functional hardware should be considered as well in the consideration of the cost and frequency.

However, if any other hardware is introduced to deal with such a fault in the additional functional hardware, then that hardware could also have other faults. Therefore, in the proposed system framework, we did not intend to implement such extra hardware for the possible secondary fault in the additional functional hardware, but rather focused on the faults that can occur in the application circuit. This means that addressing possible faults in the additional functional hardware remains as a topic for further study.In this paper, a new self-repairing digital system providing good scalability and fault coverage was proposed. As a result, all these make the system efficient.

The proposed system was compared with other major self-repair approaches and it was found that the proposed system has good fault coverage, low overhead, and no unutilized resources for fault recovery.The results obtained so far are encouraging to keep investigating on the application of biological concepts to the design of fault-tolerant engineering systems.

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