

# 52. IWK

Internationales Wissenschaftliches Kolloquium  
International Scientific Colloquium



**PROCEEDINGS**

| 10 - 13 September 2007

## **FACULTY OF COMPUTER SCIENCE AND AUTOMATION**



## **COMPUTER SCIENCE MEETS AUTOMATION**

### **VOLUME II**

**Session 6 - Environmental Systems: Management and Optimisation**

**Session 7 - New Methods and Technologies for Medicine and  
Biology**

**Session 8 - Embedded System Design and Application**

**Session 9 - Image Processing, Image Analysis and Computer Vision**

**Session 10 - Mobile Communications**

**Session 11 - Education in Computer Science and Automation**

**Bibliografische Information der Deutschen Bibliothek**  
Die Deutsche Bibliothek verzeichnet diese Publikation in der deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über <http://dnb.ddb.de> abrufbar.

**ISBN 978-3-939473-17-6**

## Impressum

- Herausgeber: Der Rektor der Technischen Universität Ilmenau  
Univ.-Prof. Dr. rer. nat. habil. Peter Scharff
- Redaktion: Referat Marketing und Studentische Angelegenheiten  
Kongressorganisation  
Andrea Schneider  
Tel.: +49 3677 69-2520  
Fax: +49 3677 69-1743  
e-mail: [kongressorganisation@tu-ilmenau.de](mailto:kongressorganisation@tu-ilmenau.de)
- Redaktionsschluss: Juli 2007
- Verlag:   
Technische Universität Ilmenau/Universitätsbibliothek  
Universitätsverlag Ilmenau  
Postfach 10 05 65  
98684 Ilmenau  
[www.tu-ilmenau.de/universitaetsverlag](http://www.tu-ilmenau.de/universitaetsverlag)
- Herstellung und Auslieferung: Verlagshaus Monsenstein und Vannerdat OHG  
Am Hawerkamp 31  
48155 Münster  
[www.mv-verlag.de](http://www.mv-verlag.de)
- Layout Cover: [www.cey-x.de](http://www.cey-x.de)
- Bezugsmöglichkeiten: Universitätsbibliothek der TU Ilmenau  
Tel.: +49 3677 69-4615  
Fax: +49 3677 69-4602

© Technische Universität Ilmenau (Thür.) 2007

Diese Publikationen und alle in ihr enthaltenen Beiträge und Abbildungen sind urheberrechtlich geschützt. Mit Ausnahme der gesetzlich zugelassenen Fälle ist eine Verwertung ohne Einwilligung der Redaktion strafbar.

## Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52<sup>nd</sup> International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.

I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.



Professor Peter Scharff  
Rector, TU Ilmenau



Professor Christoph Ament  
Head of Organisation



## Table of Contents



# CONTENTS

	Page
<b>6 Environmental Systems: Management and Optimisation</b>	
T. Bernard, H. Linke, O. Krol A Concept for the long term Optimization of regional Water Supply Systems as a Module of a Decision Support System	3
S. Röhl, S. Hopfgarten, P. Li A groundwater model for the area Darkhan in Kharaa river Th. Bernard, H. Linke, O. Krol basin	11
A. Khatanbaatar Altantuul The need designing integrated urban water management in cities of Mongolia	17
T. Rauschenbach, T. Pfützenreuter, Z. Tong Model based water allocation decision support system for Beijing	23
T. Pfützenreuter, T. Rauschenbach Surface Water Modelling with the Simulation Library ILM-River	29
D. Karimanzira, M. Jacobi Modelling yearly residential water demand using neural networks	35
Th. Westerhoff, B. Scharaw Model based management of the drinking water supply system of city Darkhan in Mongolia	41
N. Buyankhishig, N. Batsukh Pumping well optimi ation in the Shivee-Ovoo coal mine Mongolia	47
S. Holzmüller-Laue, B. Göde, K. Rimane, N. Stoll Data Management for Automated Life Science Applications	51
N. B. Chang, A. Gonzalez A Decision Support System for Sensor Deployment in Water Distribution Systems for Improving the Infrastructure Safety	57
P. Hamolka, I. Vrublevsky, V. Parkoun, V. Sokol New Film Temperature And Moisture Microsensors for Environmental Control Systems	63
N. Buyankhishig, M. Masumoto, M. Aley Parameter estimation of an unconfined aquifer of the Tuul River basin Mongolia	67

M. Jacobi, D. Karimanzira 73  
Demand Forecasting of Water Usage based on Kalman Filtering

## **7 New Methods and Technologies for Medicine and Biology**

J. Meier, R. Bock, L. G. Nyúl, G. Michelson 81  
Eye Fundus Image Processing System for Automated Glaucoma Classification

L. Hellrung, M. Trost 85  
Automatic focus depending on an image processing algorithm for a non mydriatic fundus camera

M. Hamsch, C. H. Igney, M. Vauhkonen 91  
A Magnetic Induction Tomography System for Stroke Classification and Diagnosis

T. Neumuth, A. Pretschner, O. Burgert 97  
Surgical Workflow Monitoring with Generic Data Interfaces

M. Pfaff, D. Woetzel, D. Driesch, S. Toepfer, R. Huber, D. Pohlers, 103  
D. Koczan, H.-J. Thiesen, R. Guthke, R. W. Kinne  
Gene Expression Based Classification of Rheumatoid Arthritis and Osteoarthritis Patients using Fuzzy Cluster and Rule Based Method

S. Toepfer, S. Zellmer, D. Driesch, D. Woetzel, R. Guthke, R. Gebhardt, M. Pfaff 107  
A 2-Compartment Model of Glutamine and Ammonia Metabolism in Liver Tissue

J. C. Ferreira, A. A. Fernandes, A. D. Santos 113  
Modelling and Rapid Prototyping an Innovative Ankle-Foot Orthosis to Correct Children Gait Pathology

H. T. Shandiz, E. Zahedi 119  
Noninvasive Method in Diabetic Detection by Analyzing PPG Signals

S. V. Drobot, I. S. Asayenok, E. N. Zacepin, T. F. Sergiyenko, A. I. Svirnovskiy 123  
Effects of Mm-Wave Electromagnetic Radiation on Sensitivity of Human Lymphocytes to Ionizing Radiation and Chemical Agents in Vitro

## **8 Embedded System Design and Application**

B. Däne 131  
Modeling and Realization of DMA Based Serial Communication for a Multi Processor System



M. Müller, A. Pacholik, W. Fengler Tool Support for Formal System Verification	137
A. Pretschner, J. Alder, Ch. Meissner A Contribution to the Design of Embedded Control Systems	143
R. Ubar, G. Jervan, J. Raik, M. Jenihhin, P. Ellervee Dependability Evaluation in Fault Tolerant Systems with High-Level Decision Diagrams	147
A. Jutmann On LFSR Polynomial Calculation for Test Time Reduction	153
M. Rosenberger, M. J. Schaub, S. C. N. Töpfer, G. Linß Investigation of Efficient Strain Measurement at Smallest Areas Applying the Time to Digital (TDC) Principle	159
<b>9 Image Processing, Image Analysis and Computer Vision</b>	
J. Meyer, R. Espiritu, J. Earthman Virtual Bone Density Measurement for Dental Implants	167
F. Erfurth, W.-D. Schmidt, B. Nyuyki, A. Scheibe, P. Saluz, D. Faßler Spectral Imaging Technology for Microarray Scanners	173
T. Langner, D. Kollhoff Farbbasierte Druckbildinspektion an Rundkörpern	179
C. Lucht, F. Gaßmann, R. Jahn Inline-Fehlerdetektion auf freigeformten, texturierten Oberflächen im Produktionsprozess	185
H.-W. Lahmann, M. Stöckmann Optical Inspection of Cutting Tools by means of 2D- and 3D-Imaging Processing	191
A. Melitzki, G. Stanke, F. Weckend Bestimmung von Raumpositionen durch Kombination von 2D-Bildverarbeitung und Mehrfachlinienlasertriangulation - am Beispiel von PKW-Stabilisatoren	197
F. Boochs, Ch. Raab, R. Schütze, J. Traiser, H. Wirth 3D contour detection by means of a multi camera system	203

M. Brandner Vision-Based Surface Inspection of Aeronautic Parts using Active Stereo	209
H. Lettenbauer, D. Weiss X-ray image acquisition, processing and evaluation for CT-based dimensional metrology	215
K. Sickel, V. Daum, J. Hornegger Shortest Path Search with Constraints on Surface Models of In-the-ear Hearing Aids	221
S. Husung, G. Höhne, C. Weber Efficient Use of Stereoscopic Projection for the Interactive Visualisation of Technical Products and Processes	227
N. Schuster Measurement with subpixel-accuracy: Requirements and reality	233
P. Brückner, S. C. N. Töpfer, M. Correns, J. Schnee Position- and colour-accurate probing of edges in colour images with subpixel resolution	239
E. Sparrer, T. Machleidt, R. Nestler, K.-H. Franke, M. Niebelschütz Deconvolution of atomic force microscopy data in a special measurement mode – methods and practice	245
T. Machleidt, D. Kapusi, T. Langner, K.-H. Franke Application of nonlinear equalization for characterizing AFM tip shape	251
D. Kapusi, T. Machleidt, R. Jahn, K.-H. Franke Measuring large areas by white light interferometry at the nanopositioning and nanomeasuring machine (NPM) (NPM)	257
R. Burdick, T. Lorenz, K. Bobey Characteristics of High Power LEDs and one example application in with-light-interferometry	263
T. Koch, K.-H. Franke Aspekte der strukturbasierten Fusion multimodaler Satellitendaten und der Segmentierung fusionierter Bilder	269
T. Riedel, C. Thiel, C. Schmallius A reliable and transferable classification approach towards operational land cover mapping combining optical and SAR data	275
B. Waske, V. Heinzl, M. Braun, G. Menz Classification of SAR and Multispectral Imagery using Support Vector Machines	281

V. Heinzl, J. Franke, G. Menz Assessment of differences in multisensoral remote sensing imageries caused by discrepancies in the relative spectral response functions	287
I. Aksit, K. Bunger, A. Fassbender, D. Frekers, Chr. Gotze, J. Kemenas An ultra-fast on-line microscopic optical quality assurance concept for small structures in an environment of man production	293
D. Hofmann, G. Linss Application of Innovative Image Sensors for Quality Control	297
A. Jablonski, K. Kohrt, M. Bohm Automatic quality grading of raw leather hides	303
M. Rosenberger, M. Schellhorn, P. Bruckner, G. Lin Uncompressed digital image data transfer for measurement techniques using a two wire signal line	309
R. Blaschek, B. Meffert Feature point matching for stereo image processing using nonlinear filters	315
A. Mitsiukhin, V. Pachynin, E. Petrovskaya Hartley Discrete Transform Image Coding	321
S. Hellbach, B. Lau, J. P. Eggert, E. Korner, H.-M. Gro Multi-Cue Motion Segmentation	327
R. R. Alavi, K. Brie Image Processing Algorithms for Using a Moon Camera as Secondary Sensor for a Satellite Attitude Control System	333
S. Bauer, T. Doring, F. Meysel, R. Reulke Traffic Surveillance using Video Image Detection Systems	341
M. A-Megeed Salem, B. Meffert Wavelet-based Image Segmentation for Traffic Monitoring Systems	347
E. Einhorn, C. Schroter, H.-J. Bohme, H.-M. Gro A Hybrid Kalman Filter Based Algorithm for Real-time Visual Obstacle Detection	353
U. Knauer, R. Stein, B. Meffert Detection of opened honeybee brood cells at an early stage	359

## 10 Mobile Communications

K. Ghanem, N. Zamin-Khan, M. A. A. Kalil, A. Mitschele-Thiel Dynamic Reconfiguration for Distributing the Traffic Load in the Mobile Networks	367
N. Z.-Khan, M. A. A. Kalil, K. Ghanem, A. Mitschele-Thiel Generic Autonomic Architecture for Self-Management in Future Heterogeneous Networks	373
N. Z.-Khan, K. Ghanem, St. Leistritz, F. Liers, M. A. A. Kalil, H. Kärst, R. Böringer Network Management of Future Access Networks	379
St. Schmidt, H. Kärst, A. Mitschele-Thiel Towards cost-effective Area-wide Wi-Fi Provisioning	385
A. Yousef, M. A. A. Kalil A New Algorithm for an Efficient Stateful Address Autoconfiguration Protocol in Ad hoc Networks	391
M. A. A. Kalil, N. Zamin-Khan, H. Al-Mahdi, A. Mitschele-Thiel Evaluation and Improvement of Queueing Management Schemes in Multihop Ad hoc Networks	397
M. Ritzmann Scientific visualisation on mobile devices with limited resources	403
R. Brecht, A. Kraus, H. Krömker Entwicklung von Produktionsrichtlinien von Sport-Live-Berichterstattung für Mobile TV Übertragungen	409
N. A. Tam RCS-M: A Rate Control Scheme to Transport Multimedia Traffic over Satellite Links	421
Ch. Kellner, A. Mitschele-Thiel, A. Diab Performance Evaluation of MIFA, HMIP and HAWAII	427
A. Diab, A. Mitschele-Thiel MIFAv6: A Fast and Smooth Mobility Protocol for IPv6	433
A. Diab, A. Mitschele-Thiel CAMP: A New Tool to Analyse Mobility Management Protocols	439

## 11 Education in Computer Science and Automation

S. Bräunig, H.-U. Seidel Learning Signal and Pattern Recognition with Virtual Instruments	447
St. Lambeck Use of Rapid-Control-Prototyping Methods for the control of a nonlinear MIMO-System	453
R. Pittschellis Automatisierungstechnische Ausbildung an Gymnasien	459
A. Diab, H.-D. Wuttke, K. Henke, A. Mitschele-Thiel, M. Ruhwedel MAeLE: A Metadata-Driven Adaptive e-Learning Environment	465
V. Zöppig, O. Radler, M. Beier, T. Ströhla Modular smart systems for motion control teaching	471
N. Pranke, K. Froitzheim The Media Internet Streaming Toolbox	477
A. Fleischer, R. Andreev, Y. Pavlov, V. Terzieva An Approach to Personalized Learning: A Technique of Estimation of Learners Preferences	485
N. Tsyrelchuk, E. Ruchaevskaia Innovational pedagogical technologies and the Information educational medium in the training of the specialists	491
Ch. Noack, S. Schwintek, Ch. Ament Design of a modular mechanical demonstration system for control engineering lectures	497



R.Ubar / G.Jervan / J.Raik / M.Jenihhin / P.Ellervee

## **Dependability Evaluation in Fault-Tolerant Systems with High-Level Decision Diagrams**

### **INTRODUCTION**

To achieve high dependability, systems today are often designed with fault tolerance features to first detect errors and then to mask or recover from the effects of those errors. Thus, testing of these features is extremely important in understanding how dependable the systems are with the incorporated fault tolerance mechanisms and in gaining insight into the success of error detection and recovery. Fault injection is a means to effectively test and stress the error handling and fault tolerance mechanisms, so that the system behavior can be studied prior to their actual deployment.

Fault injection techniques can be classified in three main categories [1]: physical (or hardware Implemented fault injection), software implemented and simulation-based. Simulation-based fault injection is a useful experimental way to evaluate the dependability of a system during the design phase.

Recently many simulation based fault injection techniques have been proposed for system dependability evaluation [2-6]. They are targeted for execution-based models of working systems. Simulating faults in a system model (e.g. based on hardware description language VHDL, Verilog, System C etc) assures high flexibility.

However, there exists a problem of selecting faults to be injected. Erroneous responses in a system, in many cases, do not necessarily lead to a failure at the application level, even when the discrepancy with the nominal behavior has a long duration. An accurate but high-level fault analysis in the complete system is therefore required to discriminate real failure conditions from non-critical errors. Such an analysis is very difficult to carry out on the execution-based models using languages like VHDL, Verilog, System C. In this paper a method is proposed based on high-level modelling of systems with Decision Diagrams (DD) to select faults for injection targeting dependability evaluation.

## **MALICIOUS FAULTS AND FAULT INJECTION**

Traditionally in simulation-based fault injection techniques, the fault location, fault type and fault insertion time are typically selected at random. The drawback of randomly selected faults is the large probability that the injected fault will remain latent; that is, produce a no response fault injection experiment. This will reduce the quality of dependability evaluation procedure. Thus, there is a need to locate faults which do not belong to the no response category.

The goal of the fault injection experiment is to exercise the system's fault processing capabilities. Faults which fail a system in the absence of system fault detection capabilities are defined to be malicious [8,9]. Malicious faults systematically exercise the fault processing attributes of the system. A malicious fault if undetected will fail the system under test. Likewise, a malicious fault is guaranteed to produce an error which will produce a failure if it is not properly processed by the system. Thus, using malicious faults to estimate the dependability of the system eliminates the possibility of the no response fault injection experiment.

Malicious fault list can be generated by creating fault trees using fault dependency analysis by reverse implication and providing fault collapsing. To cope with the complexity of fault analysis when carried out at plain low (logic) levels, we propose a hierarchical approach where the fault tree creation and fault collapsing will be carried out first at a higher level, thereafter to refine the fault injection points at a lower level. To carry out the fault dependency analysis and creation of malicious fault lists we propose to use the method of diagnostic modelling digital systems by decision diagrams (DD) [10-13].

## **MODELLING DIGITAL SYSTEMS WITH DECISION DIAGRAMS**

DD-s allow to investigate and solve the problems of fault dependency analysis at different abstraction levels of digital systems depending on the complexity of the system description. The well known Binary Decision Diagrams (BDD) [10] can be considered as a particular case of this model for using at logic level.

For lower (logic) level fault analysis we will use a special class of BDDs – structurally synthesized BDDs (SSBDD) [11] to represent the topology of digital circuits in terms of signal paths at the fanout free region (or macro) level. Macro level fault analysis can be carried out more efficiently than traditional gate level analysis [13].



In high-level architectural descriptions, we usually partition the system into high level components or subsystems where the descriptions of subsystems in general case can be modeled by control and data paths. These paths can be represented by a set of DDs where the nonterminal nodes in DDs correspond to the control variables (instruction codes, addresses, control words, logic or timing conditions etc), and the terminal nodes correspond to data variables, functional expressions or more complex behavioral or algorithmic descriptions of other subsystems. The terminal nodes will be represented again by a set of DDs to allow entering a lower hierarchical level for disclosing the label of the terminal node [12,13].

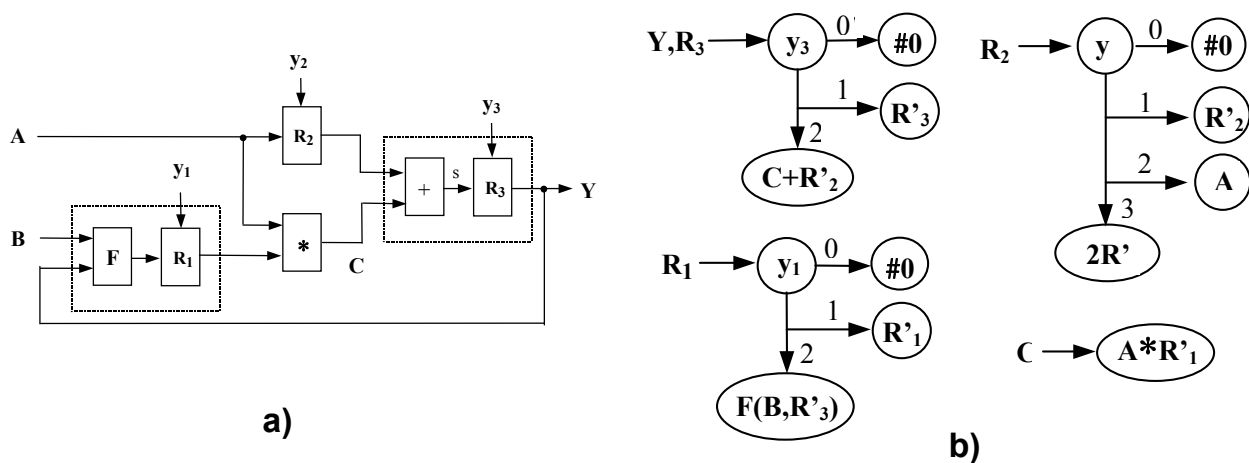


Fig.1. Simple data-path represented by DDs

In Fig.1 a simple register-transfer level data path consisting of 4 subcomponents (three registers with input logic and a multiplier) each represented by its DD is depicted. Each graph has a single nonterminal node labelled by a control variable whereas the terminal nodes are representing reset, hold, load and data manipulation (addition, shift, multiplication and a nondisclosed  $F(B,R'_3)$ ) functions. The values on edges correspond to the values of control signals. The apostroph shows that the value of the register variable is taken from the previous clock cycle.

Each path in a DD describes the behavior of the subsystem represented by DD in a specific mode of operation (working mode). For example, the path from the node  $y_3$  to the node  $C + R'_2$  in the graph  $R'_3$  represent the addition operation  $C + R'_2$  activated by the control signal  $y_3 = 2$ .

The faults having effect on the operation associated with activated path can be related to the nodes along the path. A fault may cause incorrect leaving of the

activated path. From this point of view we can introduce a very general fault model for DDs related to faulty behavior of nodes. In the case of SSBDDs the faults of a binary node are equivalent to the traditional logic level stuck-at-0(1) fault model.

In more general case of DDs the faults of the nonterminal nodes can be interpreted as the addressing fault model of microprocessor cores [13]: output edge is either always activated (stuck) or always broken, or instead of the given edge, another edge or a set of edges is activated. This is a very general fault model that allows to represent most of control errors in the case of microprocessor cores.

It is easy to extend the described fault model of a DD node to model complex faults like shorts, delays, crosstalks etc. All of these faults can be represented by a checkpoint where the error manifests at certain conditions i.e. by a pair (fault site; fault condition). Since the nodes of DDs can be regarded as checkpoints the fault model on DDs can be represented as a pair (node; fault condition). In such a way the fault model on DDs can be seen as a very powerful model able to cover a very wide class of faults in digital systems.

The formalism of DDs allows to implement simple algorithms to analyze the cause-effect and fault dependency relationships which would be impossible in case of descriptions written in languages like VHDL, Verilog, System C.

### **MALICIOUS FAULT LIST GENERATION WITH DECISION DIAGRAMS**

Malicious faults will be generated for a given set of test sequences. A test activates a process in a system consisting of a sequence of iterations. Each iteration (clock cycle, microinstruction or instruction cycle, transaction etc.) activates paths in DDs of the corresponding DD-model of the system. The faults having effect on the behavior of the system at a given iteration can be related to the nodes of the activated path.

For each observable checkpoint  $C_i$  of a test sequence, a Fault Tree (FT) with a root  $N_i$  will be created. Assuming an erroneous signal is detected at  $C_i$ , a set of candidate faulty checkpoints  $C_k$  explaining the misbehavior in  $C_i$  is created by tracing the activated path on the corresponding DD for  $C_i$ . This set of checkpoints  $C_k$  will be included into FT as successors of  $N_k$ . For each node  $N_k$  in FT, a list of malicious faults associated with  $C_k$  is determined. For all leaf nodes in FT to be constructed the same procedure is repeated until the input events for the test sequence are reached. If  $C_k$  represents stored data (register variables), we will continue fault dependency analysis in the previous test iteration. Each node in FT characterised with a list of

malicious faults and the number of iteration can be used as a point for fault injection. To reduce the number of malicious faults, the FT can be compressed (collapsed) by using fault equivalence and fault dominance relationships. The fault model is not restricted by the approach. In general, arbitrary changes  $R + \epsilon$  of the values of a variable  $R$  can be accepted. The set of accepted values of  $\epsilon$  can be given by a fault list.

An example of FT created for the data path in Fig.1 and for the test sequence in Table 1 is shown in Fig. 2. The malicious fault list selected from FT is depicted in Table 2.

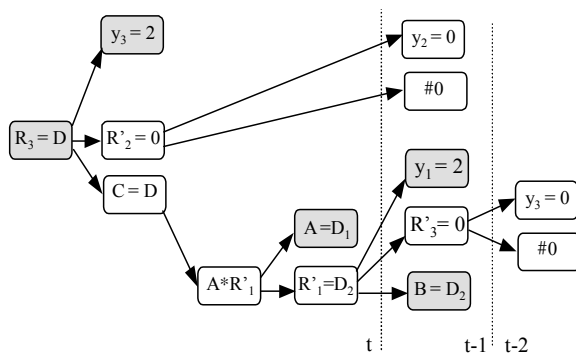


Fig.2. Fault tree

t	y <sub>1</sub>	y <sub>2</sub>	y <sub>3</sub>	A	B	C	R <sub>1</sub>	R <sub>2</sub>	R <sub>3</sub>	Y
1			0						0	
2	2	0			D <sub>2</sub>		D <sub>2</sub>	0		
3			2	D <sub>1</sub>		D			D	D

Table 1. Test sequence

t	y <sub>1</sub>	y <sub>3</sub>	A	B	R <sub>2</sub>	Y
2	0			D <sub>2</sub> + ε <sub>2</sub>	ε <sub>3</sub> ≠ 0	
3		0,1	D <sub>1</sub> + ε <sub>1</sub>			D = ε

Table 2. Malicious fault list

## CONCLUSIONS

A new approach based on fault dependency analysis with Decision Diagrams is proposed for selecting faults to be injected targeting fault tolerance evaluation in digital systems. Such a fault analysis is impossible when the execution-based models written in VHDL, Verilog or System C are used. The proposed method allows to avoid no response fault injection experiments and as the result to increase the quality of dependability evaluation.

**Acknowledgement:** The work has been supported by Estonian Science Foundation grants 5910, 6717, 6829 7068, EC 6th framework IST project VERTIGO, Estonian Information Technology Foundation (EITSA) and Enterprise Estonia.

## References:

- [1] A.Benso and P.Prinetto, eds. Fault Injection Techniques and Tools for VLSI reliability evaluation. Kluwer Academic Publishers, 2003.
- [2] E.Jenn, J.Arlat, M.Rimén, J.Ohlsso, J.Karlsson, "Fault injection into VHDL models: the MEFISTO tool", in Proceedings 24th International Symposium on Fault-Tolerant Computing (FTCS-24), pp. 356-363, Austin, TX, USA, 1994.
- [3] V.Sieh, O.Tschäche, F.Balbach, "VERIFY: Evaluation of Reliability Using VHDL-Models with Embedded Fault Descriptions", in Proceedings 27th International Symposium on Fault Tolerant Computing (FTCS-27), pp. 32-36, Seattle, WA, USA, 1997

- [4] D.Gil, J.Gracia, J.C.Baraza, P.J.Gil, "A Study of the effects of Transient Fault Injection into the VHDL Model of a Fault-Tolerant Microcomputer System", in Proceedings 6th IEEE International On- Line Testing Workshop (IOLTW'2000), pp. 73-79, Palma de Mallorca, Spain, 2000.
- [5] R. Leveugle and K. Hadjiat, "Multi-Level Fault Injections in VHDL Descriptions: Alternative Approaches and Experiments," J. Electronic Testing: Theory and Applications (JETTA), vol. 19, no. 5, pp. 559-575, Oct. 2003.
- [6] J.C. Baraza, J. Gracia, D. Gil and P.J. Gil. Improvement of Fault Injection Techniques Based on VHDL Code Modification. 10th IEEE International High-Level Design Validation and Test Workshop, 30 Nov.-2 Dec. 2005 Page(s):19 – 26.
- [7] J.Sosnowski, P.Gawkowski, P.Zygulski, A.Tymoczko. Enhancing Fault Injection Testbench. Proceedings of the International Conference on Dependability of Computer Systems (DEPCOS-RELCOMEX'06), May 2006 Page(s):76 – 83.
- [8] D.T.Smith, B.W.Johnson, J.A.Profeta. System Dependability Evaluation via a Fault List Generation Algorithm. IEEE TRANSACTIONS ON COMPUTERS, VOL. 45, NO. 8, AUGUST 1996, pp.974-979.
- [9] A.Benso, P.Prinetto, M.Rebaudengo, M.Sonza, R.Ubar. A New Approach to Build a Low-Level Malicious Fault List Starting from High-Level Description and Alternative Graphs. Proc. IEEE European Design & Test Conference, Paris, March 17-20, 1997, pp.560-565.
- [10] R.E.Bryant. Graph-based algorithms for Boolean function manipulation. IEEE Trans. on Computers, Vol.C-35, No8, 1986, pp.667-690.
- [11] A.Jutman, A.Peder, J.Raik, M.Tombak, R.Ubar. Structurally Synthesized Binary Decision Diagrams. 6th International Workshop on Boolean Problems, Freiberg, Germany, Sept. 2004, pp.271-278.
- [12] G.Jervan, R.Ubar, Z.Peng, P.Eles. Test Generation: A Hierarchical Approach. In "System-level Test and Validation of Hardware/Software Systems" by M.Sonza Reorda, Z.Peng, M.Violante. Springer Series in Advanced Microelectronics, Vol.17, 2005, pp. 63-77.
- [13] O.Novak, E.Gramatova, R.Ubar. Handbook of Electronic Testing. CTU Printhouse, Prague, 2005, 400 p.

**Authors:**

Prof. Raimund Ubar

Dr. Gert Jervan

Dr. Jaan Raik

Mr. Maksim Jenihhin

Prof. Peeter Ellervee

Tallinn University of Technology, Raja 15

12617, Tallinn, ESTONIA

Phone: +372 6202252

Fax: +372 6202253

E-mail: {raiub, gerje, jaan, maksim}@pld.ttu.ee, lrv@cc.ttu.ee