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S1: Main Paper Session

Chair: Gregory Durgin (Georgia Tech, USA)

An FPGA Online Fault Location based on Bitstream Copy and Programmable LFSR.....1

Zhang Fan (National University of Defense Technology & Beijing Microelectronics Technology Institute, China); Shifeng Zhang (National University of Defense Technology, China); Qinqin Zeng (China Construction Science & Technology Group Co., Ltd., China)

In order to improve the reliability of SRAM-based field programmable gate array (FPGA) in various harsh environments, an FPGA online fault location method with high accuracy needs studying to support subsequent fault tolerance technologies. To achieve FPGA online fault location, it is necessary to overcome a series of limitations such as a lack of hardware resources and a lack of user design knowledge. Therefore, this paper proposes a black box fault location method based on meshed bitstream copy. Generally, the linear feedback shift register (LFSR) is used in application-dependent fault location to achieve exhaustive testing. As the scale of user design increases, the test complexity increases exponentially, and LFSR can only support small-scale application circuits. The method proposed in this paper divides the FPGA resources into small meshes, and copies the under-test mesh to adjacent areas by the bitstream copy. Apply the same test pattern to both meshes and compare the results to determine if there is a fault. This paper focuses on how to achieve the connection between the under-test mesh and the test structure, proposes a programmable universal linear feedback shift register, and presets a number of test routines connected to the under-test area in advance. By comparing the preset bitstream with the original under-test bitstream, we can find an available routine in preset bitstreams. The connection between the under-test mesh and the programmable linear feedback shift register is realized by modifying the corresponding bits of the under-test mesh. A ring oscillator with high resource utility is adopted for demonstration, by which fault injection and fault location experiments are carried out on current mainstream FPGAs.

Power Side-Channel Leakage Assessment of Reference Implementation of SABER Key Encapsulation Mechanism.....8

Leslie C Wang and Anupam Golder (Georgia Institute of Technology, USA); Yan Fang (Kennesaw State University, USA); Arijit Raychowdhury (Georgia Institute of Technology, USA)

Traditional public-key cryptographic schemes are soon going to be replaced with Post-Quantum Cryptographic (PQC) schemes to ensure security guarantees in a Quantum Computing-enabled world. While Quantum Computing will help solve many hard problems intractable by classical computing paradigm, it will also compromise the hard problems that traditional cryptographic schemes are built upon. Among the National Institute of Standards and Technology (NIST) finalist PQC schemes, SABER Key Encapsulation Mechanism (KEM) is the only one based on Module Learning With Rounding (LWR). In this work, we have investigated the decryption procedure of SABER KEM to identify leakages in power consumption traces for the reference implementation running on an ARM Cortex-M4 microcontroller by correlating the trace samples with the decrypted message bytes, and by performing a Test Vector Leakage Assessment (TVLA). Both assessment techniques indicate that the incremental-storage steps in the reference implementation might allow an adversary to reveal information about the message and/or secret key.

Robot Navigation Using Ultra-Wideband Indoor Localization and Dead Reckoning Algorithms.....12

Lycia Tran, Robert Huey, Haige Chen, Devaughn Menezes, James Root and Kate Blake (Georgia Institute of Technology, USA)

Indoor localization has become increasingly necessary for military and first response operations. However, since current GPS technology has rather low accuracy and reliability in indoor spaces, Ultra-Wideband (UWB) radio is a popular, more accurate alternative for indoor localization. This paper focuses on using UWB localization paired with inertial-based dead reckoning algorithms for more accurate and reliable tracking and navigation in indoor environments. Multiple UWB anchors are placed within a building and communicate within the anchor network, while the UWB tag on the robot overhears the communication and locates itself within the building using Time Difference of Arrival (TDoA) calculations. The robot is also equipped with an inertial measurement unit (IMU) that uses the accelerometer and gyroscope data in conjunction with dead reckoning algorithms and Kalman filtering to help the Roomba generate location estimates to achieve a higher update rate and reduce uncertainty in "dead zones" where the UWB signals are insufficient for the Roomba to use in its TDoA calculations. Together with a path planner module and feedback controller, the robot can generate and follow a certain trajectory. With the proposed solution, several experiments with different programmed paths will be performed. These experiments are expected to show that the robot navigates within 10 cm of its planned trajectory.

Characterization of a 60GHz Reader and mmID System for High Fidelity Real-time Tracking With On-chip Processing.....16

Marcus Chan, Ashley Goodnight, Aman Koul, Erin Ohm, Cynthia Wang, Charles A Lynch III and Emmanouil Tentzeris (Georgia Institute of Technology, USA)

In this work, a 60 GHz real-time tracking system utilizing an ultra-low-cost and compact mmID-enabled system is characterized. The characterized system consists of an ultra-low-cost and compact Antenna on Package (AoP) FMCW radar and mmID tag. The system leverages the use of on-chip processing and high-fidelity ranging enabled through the mm-Wave radar module providing a probability of detection greater than 0.9 at 35 cm from the radar module and bounded average ranging error and standard deviation of 1.36 cm and 2.01 cm, respectively. Additionally, the angular coverage of the mmID was characterized at 35 cm and displays an angular coverage of $\pm 15^\circ$ with a probability of detection greater than 80%. Thus, the survey of the system provides a framework for a potential future system centered around tracking multiple mmIDs for wearable applications such as gait analysis.

Stretchable Electronics Fabrication Techniques for Wearable Glove Sensors using Encapsulated Liquid Metal Paste.....20

Abigail Y Hasler, Callen Votzke, Calder Wilson, Shirley Lam, Jinyong Kim and Matthew L Johnston (Oregon State University, USA)

Stretchable electronic circuits and systems will be critical for future wearable devices and smart textiles, where existing fabrication approaches severely limit conformal deformation. This is especially true for wearable sensors and actuators for the Internet of Things and conformable electronic skins and textiles, all critical for emerging physical human-machine interfaces. From a packaging perspective, the basic structure and function of a rigid PCB has changed little in the last 50 years; advances such as flexible circuit boards allow deformation, but these do not provide stretch or fundamentally alter traditional 2D circuit topology. This study explores the fabrication of a silicone glove with encased liquid metal paste for future sensor and wearable device applications.

A Comparison of CNNs and LSTMs for EEG Signal Classification.....23

Albert S Ting, Johnathan Law and Ashwin Sanjay Lele (Georgia Institute of Technology, USA); Yan Fang (Kennesaw State University, USA); Arijit Raychowdhury (Georgia Institute of Technology, USA)

Non-invasive EEG devices have shown novel applications from neuro-biological exploration to robotic control. Controlling robotic movements using brain activity requires accurate processing of real time multi-channel data for classification into multiple classes for actuating the robot. Multiple networks ranging from convolutional and recurrent neural networks have been used to classify the time-encoded analog data stream. In this work, we study the classification of a 14 channel EEG device using convolutional neural networks (CNN) and long-short term memory (LSTM) for wrist motor response classification. Varying network structures suggested that CNNs consistently outperformed LSTMs in accuracy by approximately 10%. In the second step, we evaluated the relative importance of the channels where a subset of the EEG channels were provided as inputs to the classifier and the results showed that the CNN performance dropped quicker with reduced number of channels. We also identified a set of channels with the least effect on classification performance while comparing the individual contributions of the channels in the classification output.

Experimental Fault Rate Characterization and Protection in Embedded RRAM.....27

Connor Talley, Brian Crafton, Samuel Spetalnick, Muya Chang and Arijit Raychowdhury (Georgia Institute of Technology, USA)

Resistive Random Access Memory (RRAM) is a process and voltage compatible embedded nonvolatile memory- with high density. The interest in RRAM is increasing due to the growing impact of the von Neumann bottleneck on current memory technologies like DRAM and SRAM. RRAM's density is similar to that of DRAM, while only consuming a fraction of the power. However, as a developing technology, many of its features are uncharacterized, including its fault rate. In this paper, we characterize the factors influencing the initial fault rate of RRAM as well as an experimental method for its mitigation, and an overall fault rate reduction of 1516.4 times from previous literature.

Teleoperation of Semi-autonomous Robots Through Uncertain Environments.....31

Raymond Jia, Nathanael Koh, Nicholas Leone, Mohit Singh, Zixuan Wu and Patricio Vela (Georgia Institute of Technology, USA)

Robot navigation tasks are usually decomposed into sequential sub-tasks, thus requiring a hierarchical design of sub-systems governed by multiple decision and control loops. In practice, people are the experts in making high-level decisions based on environmental knowledge. However, obtaining the local, real-time environment information is difficult by ourselves, especially in unreachable or dangerous environments. On the contrary, robots are good at achieving lower-level tasks such as building a cost map and detecting nearby obstacles. Therefore, teleoperation is used to coordinate strategic human brains and faithful robot sensors and actuators, providing an information-sharing protocol that helps to build a human-in-loop system. In this paper, we design a set of interactive Robot Operating System (ROS) based teleoperation windows for the operators to supervise the robot's navigation through uncertain environments. Human operators will have the ability to modify the global cost map of the robot, which describes where obstacles are present in the robot's environment. Currently, the cost map is constructed by a static map of the environment and image data from the onboard depth camera and is used to formulate the robot's global path plan with Dijkstra's algorithm. With our enhancement, users can draw artificial walls around non-traversable areas and have the robot update its global path plan in real-time. The user can also switch to keyboard teleoperation mode to either stop the robot or adjust the robot's orientation. Finally, the user can specify waypoints and perform waypoint-based navigation, where the robot is given a set of smaller destinations rather than one final destination. This teleoperation stack is verified by a navigation task in a manually set complex Gazebo simulation environment.

Improving SRAM Performance With Different Interconnect Options at the 7nm Process Node.....38

Jacob Mack, Rudranshu Datta, Brandon Young, Zhuoqi Cai, Da Eun Shim and Azad Naeemi (Georgia Institute of Technology, USA)

Modern-day technology node scaling trends have exacerbated interconnect resistance and capacitance problems in chips. The ultra-narrowing wires that result in higher resistance and delays impact larger wire heavy circuits with memory components tremendously. As a result, performance enhancement is difficult at smaller technology nodes. To attempt a solution to this issue, we research alternative options that minimize interconnect and via resistances. This paper investigates how different back-end-of-the-line (BEOL) options in SRAM cells affect overall chip performance and power consumption. We found that swapping the interconnect material with Ruthenium yielded the greatest gains in performance, especially in read and write latency with a gain of up to 1.572x and 1.481x respectively over the current best known method. Thinning the metal barrier also provided an improvement of up to 1.425x and 1.408x in read and write latency over current methods.

Outdoor Perception Space Navigation Experimental Procedures.....41

Shao-Heng Chu, Amanda L Tang, Caleb Chang, Patricio Vela and Shiyu Feng (Georgia Institute of Technology, USA)

This paper proposes methods to compare two different navigation frameworks: move_base-Potential Gap and Global Path Follower-Potential Gap and examines how each of them behaves in different environment settings through simulated and real world experiments. Initially, we plan to utilize Gazebo and RViz to first run the test scripts in a simulated map. To assess TurtleBot's performances, we decide to use success rate, navigation time, trajectory length, and velocity smoothness as our evaluation metrics. Then we will move into real-world experiments. For outdoor testing, we decide to run trials on an open space platform and a narrow alleyway and plan to implementing Monte Carlo Localization to pinpoint the location of TurtleBot by combining GPS and robot odometry data. After completing all the trials, the final results will be analyzed and included in future works.

OwlBox: A Comparison of Processor Architecture and Software Runtime on Vehicle-to-Everything Communication for Intelligent Transportation Systems.....45

Prem Kurumpanai and Billy Kihei (Kennesaw State University, USA)

The Kennesaw State University OwlBox is an open-source Vehicle-to-Everything (V2X) transmitter/receiver based on a Linux Single Board Computer (SBC). The device can utilize popular programming languages to communicate on the licensed 5.9GHz spectrum. The packet reception and transmission speed for programs utilizing runtimes such as C, NodeJS, and Python \cite{cohda}\cite{commsignia} are compared to determine a preferred runtime for different smart transportation use cases. The runtimes are compared through Packet Reception Rate (PRR) and Packet Reception Speed (PRS) on ARM and x86 processors using the same Network Interface Chip (NIC) repurposed from older laptop Wi-Fi cards.

Luminaire for Connected Lighting System that Mimics Natural Light Spectrum.....49

Lindsey M Lubin, Ikenna Nwokedi, Bernard Kippelen, Yashodhan Diwan and Oliver Moreno (Georgia Institute of Technology, USA)

With the rise of smart lighting, there is more flexibility than ever. Currently, buildings around the world are being equipped with occupancy sensors and HVAC controls to save energy and reduce costs. Recent

discoveries of a third photoreceptor in the eye have shown a need for a new application in smart lighting called circadian lighting. Years of not delivering adequate light energy to this circadian photoreceptor have shown connections to fatigue, tiredness, depression, and disruption of one's circadian rhythm. However, the lack of standardization in the lighting industry has made it both difficult and expensive for current companies to make the change to this new developing lighting system.

This research aims to develop a lighting system that can increase the health effects of today's lighting while continuing to increase efficiency and adjustability in a cost-effective manner. Utilizing the low-cost option of 3D printing for the hardware allows for rapid testing during the development phase and easy customization for the end users' needs after deployment. In addition, creating open-source software with already existing systems like the Arduino IDE makes upgrading one's current lighting systems possible without running into proprietary issues.

Moving the state of lighting to one that is highly customizable and open source allows for democratized technology. This way lighting is more accessible to the user and their needs as each end user will likely have different needs. Studies have found that individuals working under their preferred lighting conditions had increases in mood and ratings in terms of lighting and environmental satisfaction.

3D Micro-solenoid for High Sensitivity Antibody Detection for Infection Testing.....53

Hoseon Lee, Nick Garber, Sravani Ambadapudi, Michael Nolan and Joseph Lee (Kennesaw State University, USA); Fang-Chen Lin (Aimtec, USA); Peter Hesketh (Georgia Institute of Technology, USA)

This paper is on developing three-dimensional micro-solenoids with channels through which magnetically tagged antibodies can flow through for the purposes of antibody detection for viral infections. A COMSOL simulation study has been conducted and a 3D-printed micro-coil winding apparatus has been designed and fabricated for automating the coil-winding process. An ultra low-noise amplifier circuit is simulated, prototyped and tested for the purpose of amplifying the induced voltages from the micro-solenoid when a magnetically tagged antibody passes through.

Finite Element Modeling of the Infant Heart to Determine the Relationship between Single Ventricle Disease and the Seismocardiogram.....57

Sahil J Mithani and Juntao Wang (Georgia Institute of Technology, USA); Zeinabou Diarra and David Lin (Georgia Tech, USA); Omer T Inan (Georgia Institute of Technology, USA)

Treatments for Single Ventricle Diseases (SVD) involve risky surgeries and can still result in hospital readmission, making continuous wearable monitoring systems to detect clinical deterioration and improve patient outcomes extremely valuable. The seismocardiogram (SCG), a non-invasively acquired cardiomechanical signal, contains features that provide critical heart mechanic insights and can be used in conjunction with existing wearable signal modalities to improve SVD patient outcomes. However, the exact relationship between SCG features and cardiac behavior has not been thoroughly studied. While modeling heart movements has increased SCG understanding, much of the previous work has only used canine and adult human hearts. As such modeling, the hearts of patients with SVD are not well understood. In this work, we created 3D models of the infant's heart and developed a modeling pipeline to compare the acquired SCG signals to those created by simulation models. The result indicates accurate segmentations of the aortic root, ventricles, and atria, and a FEM analysis on a ventricle heart model is established to be a useful starting point for hydraulic forces analysis on heart models. Modeling heart movement for SVD patients can provide a deeper understanding of SCG signals in identifying specific SCG characteristics in SVD patients for monitoring applications.