ECE PhD Qualifying Exams

Presentation Schedule

Fall 2021
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Abstract:

Bearing faults account for a large majority of the faults in a machine, particularly for small-medium size machines. Therefore, their diagnosis is an intensively investigated field of research. Many research has focused on the diagnosis of bearing faults using one sensor including accelerometer, current, or temperature sensors. Although several diagnostic methods have been developed to detect bearing faults based on one sensor, the false alarm still results in losses. This research is going to introduce a multi-sensor fault diagnosis method for bearing fault detection to increase the reliability and accuracy of the fault diagnosis systems. For this purpose, a sensor module is designed and developed consisting of an accelerometer, flux, and temperature sensors. The signals are analyzed in the time domain and frequency domain to extract features. The performance and effectiveness of the method are demonstrated using an experimental setup with a set of realistic localized and generalized bearing faults.
This research proposes incorporating Machine Learning (ML) to improve the efficiency in the Internet of Things (IoT) domain, beginning from the fabrication of films to their deployment in automotive System-on-Chips (SoC) and adoption in Deep Neural Network (DNN) accelerators. Spectroscopic Ellipsometry (SE) is a powerful technique for in situ monitoring of Atomic Layer Deposition and thin film processes. However, the process followed to obtain film thickness from SE data is time intensive and involves complex ellipsometry hardware. Hence, to expedite the estimation of film thickness and simplify the associated hardware, we propose the use of ML to identify the most significant spectral range of SE data and subsequently train algorithms to predict thicknesses in the most efficient way, rapidly and with consistent accuracy.

Following this, we direct our attention to improving the reliability and functional safety of automotive SoCs by performing anomaly detection. With the evolution of safety-critical applications in the automotive domain, such as Advanced Driver-Assistance Systems and Autonomous Driving, it is imperative to assure Functional Safety (FuSa) of Electrical and/or Electronic (E/E) systems of in-road vehicles. Substantial reductions in semiconductor size have facilitated the enhancement of failure probabilities in Analog and Mixed-signal (AMS) components, which constitute a sizeable portion of modern automotive SoCs. Furthermore, challenges such as parametric variations and latent defects contribute to reliability issues in automotive SoCs, eventually resulting in hardware failure, thereby, subverting FuSa of the entire SoC. To address this issue, we propose an ML strategy that performs early anomaly detection, with the goal of preventing system failure.

The final aspect of our research involves facilitating low-power DNN inference in resource-constrained IoT edge devices. The ever-increasing computing requirements of DNNs have accentuated their deployment on hardware accelerators. However, inference execution of large DNNs often manifests as an energy bottleneck in such accelerators, especially when used in IoT edge devices. This can be primarily attributed to the massive energy incurred in accessing millions of trained parameters from the on-chip memory. To address this challenge, we propose a novel compression solution that facilitates low-power inference in commercial DNN accelerators.
Abstract:

Scanning Tunneling Microscopes (STMs) have long been used to obtain atomic-scale images of metal surfaces; though their ability to obtain high-resolution images is enticing, the use of STMs remains limited due to their slow scanning speed. By placing the z-axis actuation and tip of the STM in a small microelectromechanical system (MEMS), the STM tip-actuation assembly has a reduced footprint, higher bandwidth (leading to higher speeds), and is more suitable for batch fabrication. This MEMS approach also lends itself toward parallelism, meaning that multiple STM tips can scan the surface at the same time and further increase the throughput. This presentation expands on the idea of parallelism in STMs by proposing an array of MEMS tips to significantly increase scanning speeds.

PhD Advisor: Dr. Yiorgos Makris
Abstract:

Globalization and segmentation of the semiconductor manufacturing chain has left integrated circuit (IC) designs vulnerable to security threats such as intellectual property (IP) theft, counterfeiting, reverse engineering, and unwanted modification. This has raised interest in various obfuscation strategies to prevent unauthorized reproduction or usage of IC designs. This presentation covers a method of redacting sensitive logic within an IC and replacing it with an ambiguous TRAnsistor-level Programmable (TRAP) fabric. The logic can then be reinstated through post-fabrication programming by an authorized user. TRAP technology is capable of handling entire IC designs, or it can be used in conjunction with application-specific logic designs in a hybrid TRAP/ASIC format. These designs are produced using both specialized and commercially available CAD tools, which will be adapted along with existing TRAP fabric layouts as the technology is ported to Intel’s 22FFL semiconductor process.
Abstract:

It is well recognized that Global Navigation Satellite Systems (GNSS) provide signals of opportunity for studies of the Earth’s ionosphere. In fact, commercial monitors based on GNSS receivers are available for those interested in fundamental and applied observational studies of the ionosphere and space weather. These monitors, however, are relatively expensive making their use in remote areas and in distributed applications difficult.

We devoted efforts to an investigation aimed at developing an alternative low-cost GNSS-based sensor for ionospheric irregularity monitoring. The proposed effort consists of (P1) developing sensors that provide useful and adequate observations of ionospheric irregularities, (P2) carrying out field-tests to evaluate the performance of the sensors, and (P3) implementing a distributed array of sensors to study mid-latitude irregularities over the US.

Here, we will present and discuss the results of our effort including the design of proposed sensors, development of prototypes and data collection structure, deployment, and initial field-test results.

PhD Advisor: Dr. Fabiano Rodrigues
Emotion recognition using audiovisual features the same way it is done during human to human interaction is a challenging task for human-machine interaction systems. Under ideal conditions (perfect lighting, optimal speech capture, and smooth and unoccluded visual data) many systems are able to achieve reliable result; however, developing systems and training strategies to build systems that can perform well under non ideal conditions is not widely addressed in many models trained under ideal conditions. This study explores the use transformers to perform a dot product attention alignment to audiovisual features, concurrently fuse audiovisual features at the model level during training, and explore how the model performs under non-ideal to handle missing modalities mimicking real life interactions. Our experiments analyze how well this model perform in ideal conditions, modality missing conditions, and contrast this method against strong modality fusion baselines.
Abstract:
In this study, we construct an advanced driving behavior model that combines driving behavior, traffic conditions, and driver psychology which are expected to improve the understanding of driver behavior from both micro and macro views. We propose to expand the functionality to support in-the-fly driver/driving behavior measurement and modeling within an Android mobile platform. The UTDrive-MOBILE-App data capture, modeling and assessment/scoring strategies will be presented. Specifically, we discuss the formulation of an initial driver measurement solution and ways to provide viable feedback in the form of data visualization. We also conduct several experiments to verify and compare results under a range of driving field conditions. Finally, the potential for real-time driving behavior data capture and on-the-fly measurement solution is combined with machine learning as a means to explore richer multi-modal driver research.

PhD Advisor: Dr. John H.L. Hansen
Mirazul Haque

Evaluating Energy Robustness of Neural Networks

10/14/2021  1:00 PM

Abstract:

With the increasing number of layers and parameters in neural networks, the energy consumption of neural networks has become a great concern to society, especially to users of handheld or embedded devices. The fundamental problem of determining the robustness of a DNN with respect to its energy consumption (energy robustness) is relatively unexplored compared to accuracy-based robustness. My work has explored the evaluation of the energy robustness of energy-sensitive Adaptive Neural Networks (AdNNs) with respect to both attack and defense perspectives. For attacking AdNNs, I have developed two white-box techniques and a black-box technique. I have also created two defense mechanisms that can reduce the energy induced by energy-surging adversarial inputs.

PhD Advisor: Dr. Wei Yang
Abstract:

Active learning has proven to be useful for minimizing labeling costs by selecting the most informative samples. However, existing active learning methods do not work well in realistic scenarios such as imbalance or rare classes, out-of-distribution data in the unlabeled set, and redundancy. In this work, we propose SIMILAR (Submodular Information Measures based active Learning), a unified active learning framework using recently proposed submodular information measures (SIM) as acquisition functions. We argue that SIMILAR not only works in standard active learning, but also easily extends to the realistic settings considered above, and acts as a one-stop solution for active learning that is scalable to large real-world datasets. Empirically, we show that SIMILAR significantly outperforms existing active learning algorithms by as much as $\approx 5\% - 18\%$ in the case of rare classes and $\approx 5\% - 10\%$ in the case of out-of-distribution data on several image classification tasks like CIFAR-10, MNIST, and ImageNet.
Abstract:

At millimeter wave frequencies, antenna in package (AiP) integration is rapidly becoming an optimal approach for CMOS-based wireless systems. The losses on the silicon substrate prevent the on-chip antenna from being a viable solution. By using different packaging standards, the design and integration of antennas into the package allows for more flexibility in positioning ground planes and reflectors, and for improving antenna efficiency. Additional design optimization exists by using different mold compound materials (superstrates and substrates) and using feeding techniques to improve signal transmission performance and radiation characteristics. This work explores antennas that can be integrated into flip chip enhanced quad flat no lead (FC e-QFN) and embedded die enhanced quad flat no lead (ED e-QFN) packages to enable broadband performance in 90-140GHz and 140-220GHz frequency ranges.

PhD Advisor: Dr. Rashaunda Henderson
Personalized EEG Feature Selection for Low-Complexity Seizure Monitoring

Abstract:
Approximately one third of patients with epilepsy are refractory to medical therapy and thus can be at high risk of injuries and sudden unexpected death. A low-complexity EEG-based seizure monitoring algorithm is critically important for daily use, especially for wearable monitoring platforms. This work presents a personalized EEG feature selection approach that is the key to achieve a reliable seizure monitoring with a low computational cost. We advocate a two-step, personalized feature selection strategy to enhance monitoring performances for each patient. In the first step, linear discriminant analysis (LDA) is applied to find a few seizure-indicative channels. Then in the second step, least absolute shrinkage and selection operator (LASSO) method is employed to select a discriminative subset of both frequency and time domain features (spectral powers and entropy). A personalization strategy is further customized to find the best settings (number of channels and features) that yield the highest classification scores for each subject. Experimental results of analyzing 23 subjects in CHB-MIT database are quite promising. We have achieved an average F-1 score of 88% with excellent sensitivity and specificity using no more than 7 features extracted from at most 3 channels.

PhD Advisor: Dr. Mehrdad Nourani
Improving the Quality of Hardware Accelerators through automatic Behavioral Input Language Conversion in HLS

10/14/2021 10:30 AM

Abstract:

High-Level Synthesis (HLS) is now part of most standard VLSI design flows and there are numerous commercial HLS tools available. One persistent problem of HLS is that the quality of results (QoR) still heavily depends on minor things like how the code is written. One additional observation that we have made in this work is that the input language used for the same HLS tool affects the QoR. HLS tools (commercial and academic) are built in a modular way which typically include a separate front-end (parser) for each input language supported. These front-ends parse the untimed behavioral descriptions, perform numerous technology independent optimizations and output a common intermediate representation (IR) for all different input languages supported. These optimizations also heavily depend on the synthesis directives set by the designer. These directives in the form of pragmas allow to control how to synthesize arrays (register or RAM), loops (unroll or not or pipeline), and functions (inline or not). We have observed that two functional equivalent behavioral descriptions with the same set of synthesis directives often lead to circuits with different QoR for the same HLS tool. Thus, automated approaches are needed to help designers to generate the best possible circuit independently of the input language used. To address this, in this work we propose using Graph Convolutional Networks (GCN) to determine the best language for a given new behavioral description and present an automated language converter for HLS.
Abstract:

Silicon Carbide (SiC) switches compared to Silicon (Si) switches, have attracted more attention due to wider bandgap, higher breakdown field, and higher thermal conductivity. These merits allow the device to work in high switching frequency with low power losses. Despite of high performance, the reliability of SiC power semiconductor still is challenging and needs further investigation. In this study, the reliability of commercial SiC Schottky Barrier diode under high temperature reverse bias (HTRB) test has been investigated. Finally, to complete the evaluation, thermal resistance (Rth) of the device is measured during the aging for different diodes.
Abstract:

Magnetic gears (MG) are an important development to improve on the disadvantages of their mechanical counterparts. MGs have multiple topologies with each finding their suitable application. The triply excited magnetic gear (TEMG) is one such topology with interesting possibilities. This topology has an extra set of magnets in between the ferromagnetic modulators in addition to the permanent magnets (PMs) located in the inner and outer rotor. The TEMG topology has multiple variations with respect to magnet placements; the torque production in three such variations is studied and compared with the conventional MG. Different parameters are varied and the various topologies are optimized for maximum volumetric torque density (VTD) and permanent magnet specific torque (PM ST). The torque generated by these optimized models is compared, using the finite-element method (FEM), to verify the advantages and disadvantages of the TEMG topologies. The torque production due to the PMs located in between the modulators is minimal compared to the torque produced due to the PMs present in the other two rotors. To get the best torque production in the TEMG topologies, at least one of the rotor structures should have a consequent pole arrangement. The consequent pole arrangement in the outer rotor has better results than having them on the inner rotor.

PhD Advisor: Dr. Matthew Gardner
Abstract:

Nowadays, the popularity of social media platforms has increased dramatically. Unlike traditional media, such as television, newspaper, where content is usually created by professionals and subject to strict fact-checking, on a social media platform, anyone could be a content creator and distributor. The openness and lacking fact-checking lead to widespread rumors. To debunk rumors, many machine learning-based rumor detection approaches have been proposed. This presentation will go through the definitions, datasets, machine learning models, evaluation metrics, and future direction of rumor detection. Since in recent years, deep learning shows clear advantages for many machine learning problems. This presentation will focus more on the deep learning rumor detection approach. Compared with the former literature survey, this presentation will cover the graph neural network-based approach, which has gained increasing popularity in recent years.

PhD Advisor: Dr. Weili Wu
Abstract:
Many of the signal processing application require us to extract the low dimensional subspace from a larger space. This process is usually classified as subspace decomposition. This process traditionally involves performing eigen decomposition. The eigen decomposition is computationally expensive requiring $O(M^3)$ flops for the $M$ by $M$ matrix. This high complexity makes it unfeasible for utilizing eigen decomposition for subspace decomposition specially for real-time applications. In this presentation, Fast Subspace Decomposition is presented which uses the special matrix structure of the signal subspace. The overall complexity in this case is $O(dM^2)$ where $d$ is the size of the signal subspace of interest and depending upon the application, is usually far less than $M$. Furthermore, the size of the subspace is not assumed to be known apriori and is estimated as part of the overall decomposition process.

PhD Advisor: Dr. Murat Torlak
Design patterns from sub-wavelength technology nodes may not be reliably printed on silicon even though they are Design Rule Check (DRC) clean and comply with Design For Manufacturability Guidelines (DFMGs). Such patterns are known as weak-points/hotspots and there is an imminent need to identify and fix them well-before fabrication. Since their inception, several hotspot detection solutions have been proposed, each of them with a premise of having better accuracy, lower false alarm rates or faster training times. As a part of such hotspot detection flows, the community has also proposed several novel feature extraction techniques customized for this application. In this work, we focus mainly on feature extraction techniques and survey all such methods, and also perform an experimental comparison between them to clearly understand the impact and importance of feature extraction in hotspot detection applications.
Abstract:
Large-scale satellite-based radio astronomy system is getting attention as it provides a wide range of spectrum access to both satellite communication systems and radio astronomy systems. Due to the limitations in radio astronomy observation (RAO) under sunlight, this investigation considers two types of space-based observations named Half-sphere (C1) and Earth blockage (C2) by medium earth orbit (MEO) communication satellites. In C1, MEO satellites in the opposite half-sphere of the sun can perform RAO, whereas those blocked by the earth's surface from the sun can perform RAO in C2. OneWeb’s MEO satellite constellation is divided into half and quarter parts to work as dual-purpose MEO (D-MEO) satellites that render both communication and RAO services. Then, eight different configurations of half D-MEO and fourteen different configurations of quarter D-MEO satellites have been proposed. The number of simultaneously observing D-MEO satellites and its relative (u, v) coverage region are investigated for all configurations in both types of RAOs. Further, the shading problem of astronomical objects is addressed, and to mitigate this problem, a new two-dimensional (2D) approach is presented to find the simultaneously observing D-MEO satellites, and maximum baseline distances specific to angular regions. These 2D performance metrics are analyzed for all suggested configurations. Under both C1 and C2 observations, the performances of all constellations are compared. The investigation finds suitable space-based telescope constellations specific to the RAO environment.
Abstract:

Decimeter-level ranging between computing devices is desirable for many IoT applications, but there are numerous challenges to overcome. Many existing positioning algorithms have been developed based on received signal strength indicator (RSSI) or channel state information (CSI) for accessible deployment. One of the main challenges of these existing approaches is lack of a common time reference between devices. However, recent developments in both Bluetooth and WiFi standards allow for new forms of two-way measurements which mitigate problems due to lack of a common time reference, opening new avenues for more advanced ranging algorithms. In this presentation, I will review existing ranging methods for Bluetooth and WiFi and propose possibilities for more advanced algorithms which utilize two-way channel frequency response measurements.

PhD Advisor: Dr. Murat Torlak
Abstract:
Spaceborne passive sensing (SPS) has been a crucial method for global earth observation, which obtains earth environmental and meteorological information. Therefore, it is important to protect the specific passive sensing spectrums from interferences of other transmission sources. Meanwhile, inter-satellite links (ISLs) play an important role in the traffic routing of satellite communication systems. Based on the characteristics of the passive sensors (PSs), we analyze the possibility of spectrum sharing between SPS and ISL. In this research, we explore the interference from higher altitude ISLs to PSs. Specifically, low earth orbit (LEO) satellites are considered as the potential candidates for PSs. In addition, the ISLs are set among medium earth orbit (MEO) communication satellites. The result of our research indicates that it is possible for MEO ISLs to utilize the passive sensing spectrum with several restrictions. The interference level of the received power for PSs does not exceed the threshold of International Telecommunication Union (ITU) regulations.

PhD Advisor: Dr. Hlaing Minn
Thank You!