Digital Twin Reliability （R）

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Session on

Digital Twin Reliability (R)

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Milan Time	Beijing Time	Agendas
15:00	21:00	**R-1 Digital Twins for Smart Firefighting and Evacuation** Xinyan HUANG
15:30	21:30	**R-2 Thermal and Thermal-Mechanical Oriented Reliability Co-design of SiC Power Device Panel-level Packaging** Jiajie FAN
16:00	22:00	**R-3 Multi-Robot Swarming: Cooperation and Competition** Shiyu ZHAO
16:30	22:30	**R-4 Digital Twin-Enabled Decision-Making for Multi-UAV Autonomous Recovery Oriented to Resilience** Xingsuo HAI
17:00	23:00	**R-5 Data-driven Stochastic Model Updating with Conditional Invertible Neural Networks (cINN)** Sifeng BI
17:30	23:30	**R-6 Electro-Thermal Digital Twin for Power Modules Temperature Characterization during Power Cycling Tests** Zhongchao SUN
18:00	24:00	**R-7 Data synchronization for reliable Digital Twins** Mama DIAKITÉ, Mamadou Kaba TRAORÉ

Digital Twin Reliability (R-1)

Xinyan HUANG

Associate Professor,
The Hong Kong Polytechnic University (China)

Title:
Digital Twins for Smart Firefighting and Evacuation

Abstract

Over the past decade, big data, Artificial Intelligence, and digital twin have enabled new approaches to improve fire safety. The emerging applications of AI and digital twins enable more intelligent fire detection, fire hazard assessment and real-time fire forecast. This talk will introduce the digital twin future framework for combining AI, sensor networks and intelligent robots to help forecast and fight fire, as well as safe evacuation in fire incidents. I will also talk about the guidelines for constructing a reliable fire database, propose new concepts for building Fire Digital Twin, and review deep learning algorithms that enable super real-time fire quantification, forecast of fire development, and robotic firefighting.

Digital Twin Reliability （R-2）

Jiajie FAN

Youth Professor,
Fudan University (China)

Title:
Thermal and Thermal-Mechanical Oriented Reliability Co-design of SiC Power Device Panel-level Packaging

Abstract

Silicon Carbide Metal Oxide Semiconductor Field Effect Transistor (SiC MOSFET) is mainly characterized by a higher electric breakdown field, higher thermal conductivity and lower switching loss enabling high breakdown voltage, high-temperature operation and high switching frequency. However, their performances are considerably limited by the high parasitic inductance and poor heat dissipation capabilities associated with existing wire-bonding packaging methods. A new panel-level SiC MOSFET power module is developed by using the Fan-Out and embedded chip technologies. To achieve the more effective thermal management and higher reliability under thermal cycling, some optimization methods, i.e. Ant colony optimization-Back Propagation neural network (ACO-BPNN), non-dominated sorting genetic algorithm (NSGA-II) and the improved multi-objective particle swarm optimization algorithm (MOPSO) will be introduced for optimizing the new design of SiC modules, and contrast it with the traditional Response Surface Method (RSM).

Digital Twin Reliability （R-3）

Shiyu ZHAO

Associate Professor,
Westlake University (China)

Title:
Multi-Robot Swarming: Cooperation and Competition

Abstract

Multi-robot swarming is a core research area in the field of robotics. It has also been recognized as one of the ten grand challenges in robotics. In this talk, I will introduce the research progress of the Intelligent Unmanned Systems Laboratory over the past few years. Multi-robot swarming tasks can be classified as cooperative or competitive. Regarding cooperative multi-robot swarming, I will talk about our recent research on a classic benchmark problem in multi-robot swarming: shape assembly. Regarding competitive multi-robot swarming, I will talk about our research work in the field of aerial target pursuit, particularly a series of vision-based motion estimation algorithms and systems.

Digital Twin Reliability （R-4）

Xingsuo HAI

Research Fellow,
Nanyang Technological University (Singapore)

Title:
Digital Twin-Enabled Decision-Making for Multi-UAV Autonomous Recovery Oriented to Resilience

Abstract

Real-time decision-making for multiple unmanned aerial vehicles (multi-UAV) mission planning is crucial but challenging due to unexpected disruptions. We propose a resilience-oriented decision-making framework that enables UAVs to generate autonomous recovery strategies in real time. A novel resilience metric is introduced, considering variances in mission completion rate and remaining resource inventory. On this basis, a resilience-oriented joint optimization model is formulated, incorporating maintenance and task reassignment as recovery strategies following accidental failures to UAVs. The optimization problem is formulated as a partially observable Markov decision process (POMDP) and solved using a modified multiagent deep Q network (MADQN) algorithm with enhanced learning efficiency. To leverage real-world experiences, digital twin-enabled technology is adopted for training, where each agent interacts with the DT environment using original and target networks to acquire an optimal assignment strategy. Simulations validate the effectiveness of the proposed methods.

Digital Twin Reliability （R-5)

Sifeng BI

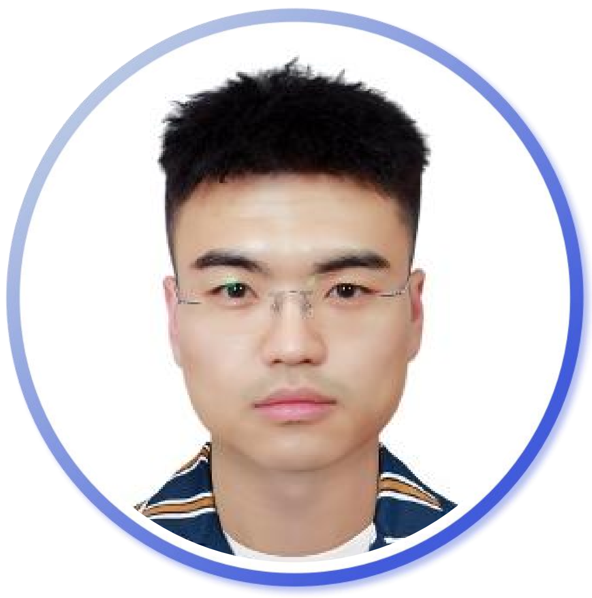
Assistant Professor,
University of Southampton (UK)

Title:
Data-driven Stochastic Model Updating with Conditional Invertible Neural Networks (cINN)

Abstract

This work focuses on a data-driven version of the model updating process. A recently developed conditional invertible neural networks (cINN)-based architecture has been adopted in this work to achieve the multilevel Bayesian updating. Unlike the conventional approaches that employ the artificial neural networks (ANN) solely as a forward surrogate during model updating, the cINN-based model updating is a framework that performs as a bidirectional network where the forward training and inverse calibration are integrated into a uniform structure. The cINN consists of two parts known as the conditional network and the invertible neural network (INN). Both networks are trained jointly in the forward direction and can operate inversely to offer rapid and accurate predictions by given observation data. The application of the cINN provides a more efficient and direct manner to solve model updating problems without calculating the likelihood function, compared to the conventional Bayesian model updating. The cINN is employed to establish the multilevel Bayesian interface, enabling the updating process to be conducted in a stochastic manner. Rather than directly calibrating physical parameters, this approach focuses on the calibration of their statistical moments, e.g. mean and variance, referred to as hyperparameters. The hyperparameters are then utilized to determine the Probability of Damage (PoD), which provides a confidence level about the structural condition, facilitating stochastic damage detection. Two case studies are proposed to demonstrate the multilevel cINN-based stochastic damage detection approach. The first involves a 3-degree-of-freedom (3-DOF) spring-mass simulation model, while the second case study employs an experimental rig testcase with practical measurements, each under various damage scenarios.

Digital Twin Reliability （R-6）



Zhongchao SUN

PhD candidate,
Aalborg University (Denmark)

Title:

Electro-Thermal Digital Twin for Power Modules Temperature Characterization during Power Cycling Tests

Abstract

The thermal behavior of power modules significantly impacts their power cycling lifetime by influencing power loss generation in the electrical domain and subsequently altering the temperature response. This study introduces a coupled electro-thermal digital twin designed to accurately predict the junction temperature during power cycling tests of wide band gap power modules and to provide detailed insights into the package's internal temperature distribution. The implementation was achieved through the integration of LTspice and COMSOL simulations governed by MATLAB scripts. Moreover, the proposed digital twin is compatible with enhanced electrical schematics by including parasitic and switch loss effects. It also supports the incorporation of innovative packaging patterns for comprehensive thermal analysis and extended thermo-mechanical analysis to identify the degradation mechanisms of critical packaging components.

Digital Twin Reliability （R-7）

Mama DIAKITÉ

PhD student,
the University of Bordeaux (France)

Title:
Data synchronization for reliable Digital Twins

Abstract

Data synchronization between a Digital Twin and its corresponding real system is a key feature of the Digital Twin concept, as it is what allows the Digital Twin model to be a faithful representation of the system of concern. However, no academic studies have been devoted to understanding the impact of such a synchronization on the quality and reliability of the Digital Twin's services. This presentation provides a conceptualization of the problem, and suggest, through a case study, how a sensitivity analysis approach can be formalized to address the issue.