RAMS Seminar on 18th Dec. 2020

Advanced data-driven and machine learning techniques for safety, reliability, and autonomy of complex systems

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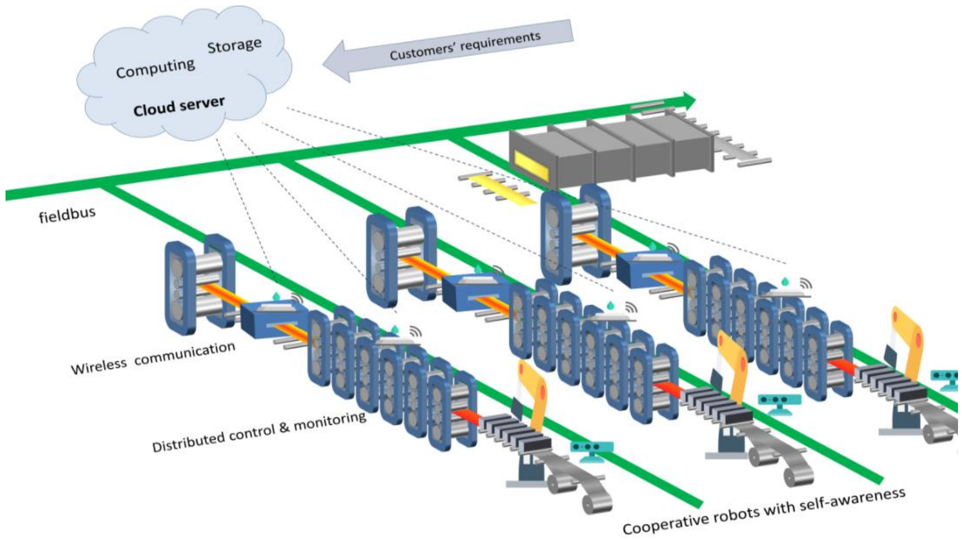
Previous research work

1. Automation in complex industrial process



Safety monitoring

- ➢ **Detect abnormalities**
- ➢ **Location: Sensor, actuator, process**
- ➢ **Fault-tolerant strategy**

- **Before fault occurrence:** **Online monitoring, RUL prediction, performance optimization, predictive maintenance.**
- **After fault occurrence:** **To ensure safety and reliability, information from the industrial big data is used for fault diagnosis, fault-tolerant control and resilient control.**

Previous research work

Driven by practical demand from industrial partners

- Reasonable important process measurements should be selected, which have **dominant influence to KPI** of the whole system.
- For further control, monitoring and optimization purposes from both the **efficiency and the safety/reliability** point of view.

- Developed a fault diagnosis system for automotive suspension system using a **data-driven diagnostic observer.**
- Only use available measurement to have a one-to-one relationship for key parameters of diagnostic observer for safety and reliability purposes.

- Control the KPI (steel thickness) to ensure product quality, in a condition that the mechanical model is not available, even in case of actuator fault.
- With available data from sensors, we proposed **data-driven predictive controller** to ensure KPI even after occurrence of abnormality/fault.

Previous research work

2. Advanced ML and machine vision aided health diagnosis

Huge amounts of medical data

- Electrocardiogram
- Image (X-ray, CT, etc.)
- Video (Ultrasonic Image)
- Audio (Patient's speech)

- It is important to develop reliable approaches for healthy monitoring and diagnosis based on available medical data.
- Get inspired from the medical domains and in turn benefit the industrial domains by developing novel learning methods and image processing methods, for different data like images, audio, video, lidar 3D point etc.

Previous research work

Driven by challenge and open for methodology

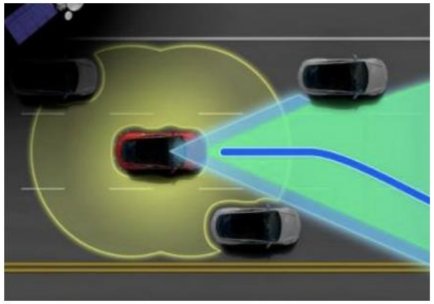
- Heart disease diagnosis using PPG data with a bracelet-like device: reliable diagnosis and long-term reliable working.
- Propose ML based feature reduction approach, compressed 1000 PPG data into 12 features to be stored in the device. Comparable diagnosis results with Medical certificate.

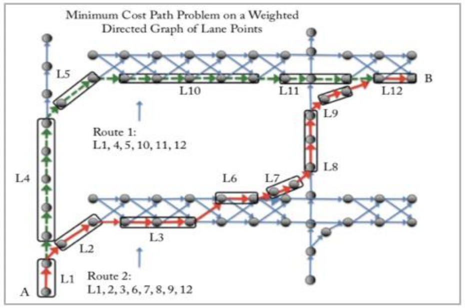
- Deep learning approaches for the automatic segmentation of the fundus images.
- Propose and implement a deep neural network structure based on the U-net and with dedicatedly-designed attention modules.

- Intelligent diagnosis of skeletal fluorosis and severity degree grading, using images of different parts of bones, and various sizes and orientations.
- Reduce the heavy workload of doctors and assist them to increase the diagnosis accuracy.

3. Autonomous vehicular system

Four "pillar technologies" for safety and reliability design





Sensor technology	Cognitive technology	Planning & Control	Cyber-physical system

- **Reliable data fusion approaches were proposed applicable for different working conditions and remain trustworthy in case of poor data quality.**
- **Cognitive and behavioral level prediction, planning and control were studied by combining deep learning and statistical learning.**
- **At the decision-making level, a cyber physical system framework for overall safety and efficiency guarantee was proposed.**

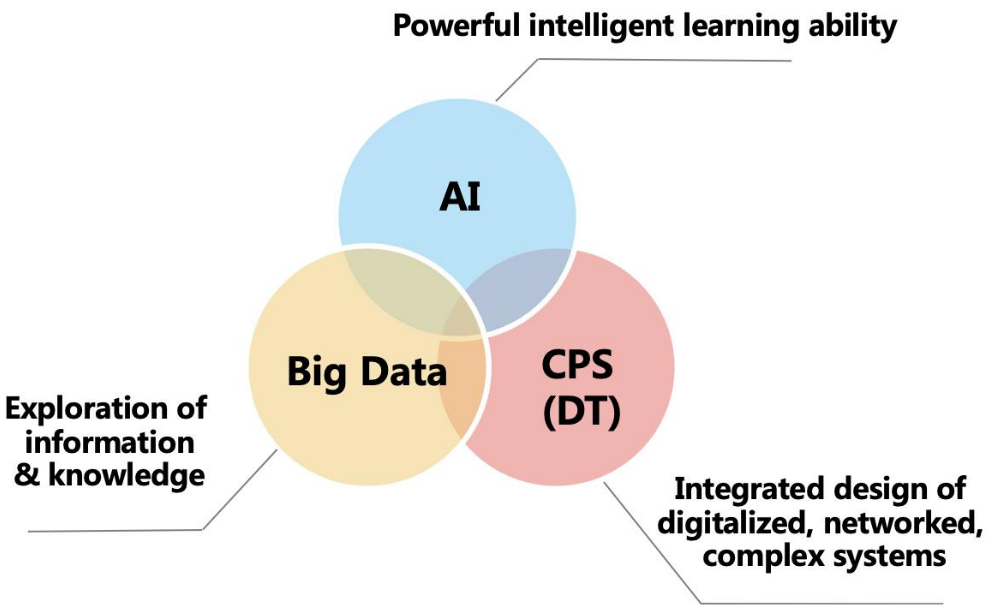
Research plan

Safety, reliability, and risk management under the SUBPRO framework

- System risk evaluation and management
- Fault prognosis and fault diagnosis
- Prediction and forecasting problems
- Adaptive soft sensing, perception, and identification

Key technologies

- Digital twin technology
- Data-driven and signal-based realization
- AI (e.g., deep learning)



Research plan

Potential applications (with industry)

- Offshore renewable energy
- Offshore petroleum industry (e.g., Oil and gas operation)
- Autonomous and cooperative underwater robots
- Other applicable scenarios … (Not limited to the above)

1. Construction of the digital twins

There are great benefits to build DT for offshore systems, such as wind turbines, oil drilling machines, underwater robots, to gain insights of the systems and strongly support real-time monitoring, control, and management.

Research plan

1. Construction of the digital twins

Different types of DTs are necessary at different system levels

- **Component twin** **Deliver an early warning about a problem and tell about the actual failure that is taking place.**
- **System twin** **Optimize over multiple KPIs and used to balance the key factors in the industrial practice.**

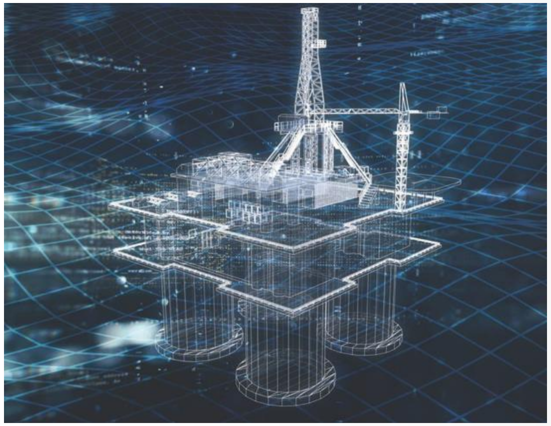
Key sub-topics

- **Data-driven modelling**
- **Model improvement using reinforcement learning**
- **Soft sensing based on deep learning**
- **How to make VERIFICATION of developed DT?!**

Research plan

2. Research on DT-enabled services

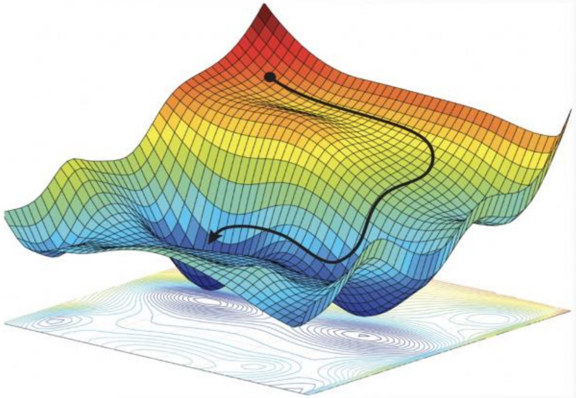
DT as an enabler of online monitoring



- To develop information fusion approaches for real-time performance degradation analysis, based on heterogeneous types of data.
- To perform data-driven and signal-based multi-level system monitoring and fault diagnosis (identification, classification, isolation, root-cause analysis, etc.)
- To establish risk models and propose risk management schemes.

2. Research on DT-enabled services

DT as an enabler of global optimization, fault-tolerance, and predictive maintenance



- To achieve global optimization by balancing the revenue against the remaining life against the maintenance cost.
- To achieve distributed implementation of the fault-tolerant control strategies.
- To predict the remaining useful life (RUL) of the devices, by learning from the colossal amount of historical.

Research plan

3. Full life-cycle management (LCM)

A comprehensive strategy that manage the system before and after the occurrence of faults.

In fault-free condition:

- **Big data and machine-vision based system monitoring**
- **Key performance indicator (KPI) prediction**
- **Performance optimization**
- **Data-driven construction of the digital twins**

In faulty condition:

- **KPI-oriented fault diagnosis**
- **Autonomous decision-making & automatic configuration**
- **Resilient control/fault-tolerant control**

Thank you!