CPS 제어 및 분석 알고리즘 특론

- 수업 소개 -

부산대학교

김호원

**부산대
정보보호 및 IoT 연구실,
사물인터넷연구센터
2018.9.3**

I. About this course

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Course name : CPS제어 및 분석 알고리즘 특론(EB74799)

- **Study the basics on CPS basics, digital twin and data analysis techniques for CPS environment**

  - In this course, we will study about the digital twin technology, which is important issues in CPS(Cyber Physical System).

    - Digital twin emulates the state and operation of physical equipment and services through modeled simulator. The digital twin simulator understands previous and current status and it predicts future states of modeled target.

  - Also, we will study about the basic technology such as security, IoT platform, data analysis techniques, which are important in CPS control & digital twin

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About this course…

About me…

- **Office : A06-6503**
- **Office hours： Monday & Wednesday, 12:00~13:20**
- **Email: howonkim@pusan.ac.kr**
- **Phone: 010-8540-6336**
- **http://infosec.pusan.ac.kr**

Current Major Interests

- 사물인터넷**(Internet of Things)** 연구
- 블록체인**(Blockchain)** 연구
- 딥러닝, **AI** 기술 연구
- 암호**(Cryptography),** 정보보호**(Information Security), IoT** 보안
- 암호 칩, 보안 칩 설계 연구, **TLS** 전용 칩 개발
- 국가보안기술연구소**, ETRI, KISA, IBM**과 공동연구
- 부산대학교 사물인터넷 연구센터 운영 중

About this course···
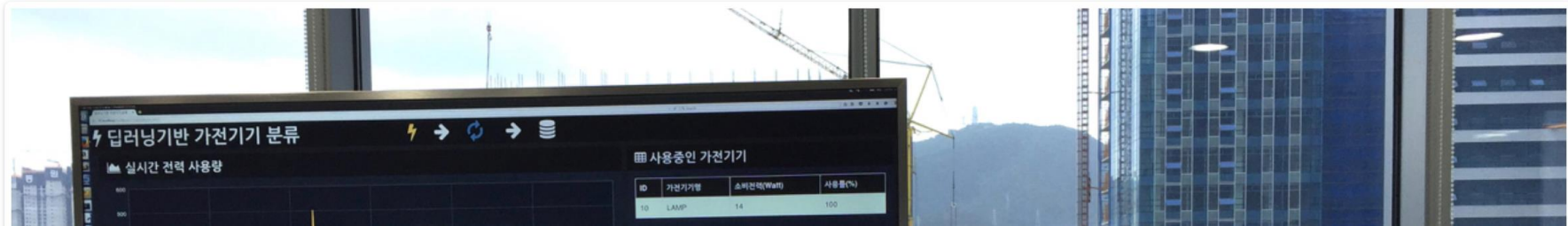
Course Materials
http://infosec.pusan.ac.kr

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정보보호 및 지능형 IoT 연구실
Information Security & Intelligent IoT

정보보호 및 지능형 IoT 연구실   대학원 진학   연구실 소개   연구 주제   연구실적   구성원 소개   수업강의

연구실 생활

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- ## Textbook
  - ### Digital twin:
    - Digital Twin, Possibilities of the new Digital twin technology by Anand Iyer, 2017
    - Materials from Internet
  - ### Security:
    - Cryptography, security (cryptography and network security by W. Stallings, http://williamstallings.com/Cryptography/)
  - ### Data analysis:
    - Cryptography
    - Introduction to Data Mining by Tan, Steinbach and Kumar

- ## Class time & Classroom
  - Monday, Wednesday : 18:10~21:00
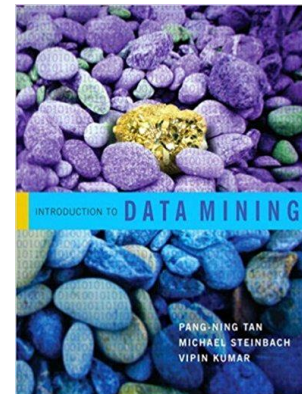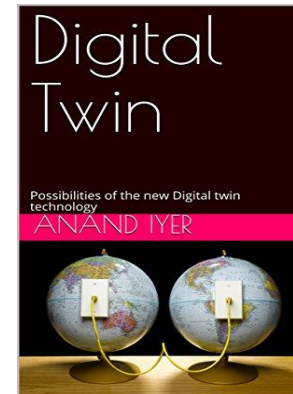
■ Assessment

항 목	점 수
출 석	5
중간고사	40
기말고사	40
과제물	15 (1 week delay: -20% penalty)
합 계	100

II. Introduction to Digital Twin

Ref) Digital Twin, Possibilities of the new Digital twin technology by Anand Iyer, 2017

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What is Digital Twin in an Industry?

Definition of Digital Twin - Wikipedia

> • Digital twin refers to a digital replica of physical assets, processes and systems that can be used for various purposes.
>
> • The digital representation provides both the elements and the dynamics of how an Internet of Things device operates and lives throughout its life cycle.

– Digital twins integrate **artificial intelligence, machine learning and software analytics with data** **to create living digital simulation models** that update and change as their physical counterparts change.

– A digital twin continuously **learns and updates itself** from multiple sources to represent its near real-time status, working condition or position.

– **This learning system,** learns from itself, **using sensor data that conveys** **various aspects of its operating condition; from human experts**, such as engineers with deep and relevant industry domain knowledge; **from other similar machines; from other similar fleets of machines; and from the larger systems and environment in which it may be a part of.** A digital twin also integrates historical data from past machine usage to factor into its digital model.

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What is Digital Twin in an Industry?

Definition of Digital Twin - GE

- A digital twin is a <u>dynamic digital representation</u> of an industrial asset, that enables companies to better understand and predict the performance of their machines and find new revenue streams, and change the way their business operates.

Definition of Digital Twin - Forbes

– Digital twin is **a virtual model of a process, product or service**.

– This pairing of the virtual and physical worlds allows **analysis of data and monitoring of systems to head off problems before they even occur, prevent downtime, develop new opportunities and even plan for the future by using simulations.**

– Thomas Kaiser, SAP Senior Vice President of IoT, put it this way: "Digital twins are becoming a business imperative, covering the entire lifecycle of an asset or process and forming the foundation for connected products and services. Companies that fail to respond will be left behind."

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사물인터넷 기술 개요

■ 진화하는 사물인터넷 산업

- Digital transformation, Digital Twin 개념의 등장으로 인해, IT 뿐만 아니라, 전 산업에 있어서 IoT로의 변화/IoT에 의한 변화가 진행됨
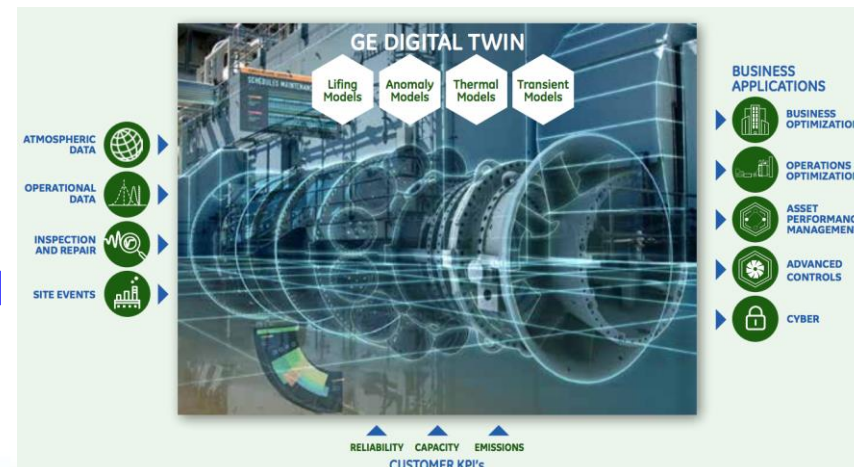
- **Digital Transformation:**
  - 기업이 새로운 비즈니스 모델, 제품 및 서비스를 창출하기 위해 디지털 역량을 활용함으로써 고객 및 시장(외부 생태계)의 파괴적인 변화에 적응하거나 이를 추진하는 지속적인 프로세스 (IDC)
  - 기업이 디지털과 물리적인 요소들을 통합하여 비즈니스 모델을 변화시키고, 산업에 새로운 방향을 정립하는 전략 (IBM)
  - 기업들이 최신의 디지털 기술을 활용하여 끊임없이 변화하는 환경에 적응하여 경쟁력을 확보하려는 노력

- **Digital Twin:**
  - 기존에는 주로 엔진, 기계 등, 제조 분야 적용에 많은 관심이 있었지만, 최근에는 헬스케어, 재난/재해, 교통, 스마트시티 등으로 그 개념이 확대되고 있음
  - Digital Twin은 물리적인 시스템의 특성과 기능을 완벽히 표현할 수 있는 사이버 복제물로서, 대상 물리 시스템의 상태 센싱, 제어, 고장 예측 등이 가능함

참고 : 제4차 산업 혁명과 디지털 트랜스포메이션 (Digital Transformation)의 이해, 김민식,   MNS Korea 2017 발표자료, 김호원
https://www.convergehub.com/blog/what-does-digital-transformation-mean-what-are-its-nine-core-elements
https://www.ge.com/digital/sites/default/files/Digital-Twin-for-the-digital-power-plant-.pdf

Interactions with Digital Twin

Interactions with Digital Twin

- In Industry, an equipment cannot work in isolation.

- **Example:** in a gas powerplant, where the gas turbine is a chief component, there are several ancillary systems that supply fuel, water and utilities to the turbine.

- Then the exhaust of the turbine is generally connected to a waste heat boiler, where heat from the exhaust is recovered and converted to steam and there could be steam turbines. All these systems work in Tandem.

- **Therefore, We could have multiple Digital Twins or a seamless (Master) Digital Twin, that comprises of many Digital Twins.**

- 디지털 트윈은 기본적으로 multiple 디지털 트윈 특성을 가짐

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The concept of 'persona'

■ 'Persona' characteristics of Digital Twin

- 페르소나 는 사회 역할이나 배우에 의해 연기되는 등장인물이다. 이 단어는 원래 연극 탈을 뜻하는 라틴어에서 유래됨

- A **persona** is a social role or a character played by an actor. The word is derived from Latin.

- **즉, digital twin은 이를 사용하고자하는 사용자의 목적에따라 여러 기능을 제공해야 줘야 함**

- 사용자 **1 (**밸브 제어**/**모니터링 업무 수행자**):**
  - Assume that an operator is interacting with the Digital twin in a power plant. **His job is to open and close valves, ensure that operating parameters are kept at optimum. So, the Digital Twin has to inform him of what to do, open this valve a quarter turn or change flow setpoint, or drain the vacuum tank**, rather than keep rpm at so and so levels.

- 사용자 **2 (**가스터빈 **maintenance** 업무 수행자**)**
  - In the same plant, a maintenance person is looking at the turbine, **he now gets information as to what part is getting worn out, what is the routine maintenance that needs to be done, which specialist needs to be called and so on.** This maybe one of the many equipment's and he may get information on other requirements too.

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The concept of 'persona'

‘Persona’ characteristics of Digital Twin

- 사용자 3 (비즈니스 매너저):
  - A business manager wants to study the **comparative performance of different turbines across the spectrum and the Digital Twin sees the many Digital Twin of turbines in his company, at his site, across sites.**

- 사용자 4 (고객)
  - A customer wants to choose some features in their product and **wants to see the limits of the factory,** this can be done via a ‘persona’ of the Digital Twin that is configured solely for their convenience.

- **A persona(~Digital Twin) is a set of features or characteristics, that are unique to the functions of the organization and useful for a specific type of interaction.**

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Characteristics of digital twin

Digital Twin brings us to some realizations:

1. A Digital twin has multiple persona to interact with multiple people.

2. Digital Twins cannot live in Isolation and must essentially interact with other Digital Twins.

3. A master Digital Twin will comprise of many Digital Twins. This could be the typical use case.

4. The Master Digital Twin will have multiple Persona, to interact with different categories of people in day to day operations.

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Components of Digital Twin

Pre-Digital twin 주요 구성 요소

1. Simulation software
2. Operator Training Simulator(OTS)
3. Process Modelling
4. Equipment 3D models
5. 3D Plant Models

– To be a full-functioned Digital Twin, AI engine and IoT platform (with sensors) should be added

Components of pre-Digital Twin

Simulation software

– The earliest usage of DT has been in "aerospace"

– NASA used the DT concept for the first time. However, Soviet make their own systems wrapped in secrecy and have in parallel been running simulation software (that is, Digital Twin)

– DT has a component of simulation

Operator Training Simulator(OTS)

– In the process industry, the Operator training simulator have been popular

– The OTS provides a real time scenario training to the operator

– Simple example:

  • The OTS may have a heat exchanger, that could have built in thermodynamic heat exchanger calculations and by dynamically simulating the temperatures, the scenarios could be altered.

  • Operators have used these to simulate process runovers, reactor temperature over runs, and trained in various scenarios.

  • DT for process industries have simulation H/W, S/W, OTS as base components

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Components of pre-Digital Twin

Process modelling

- Process modelling has a very broad definition
- From supply chain processes, to operation process to equipment processes have an impact on the way of industry operates
- In any industry, Heat, Material balances, flow conditions(turbulent, vertices), motion conditions(moving robots, humans) all are part of the industry processes
- A good digital twin needs to incorporate these in its construction !

Equipment 3D models

- https://www.youtube.com/watch?v=2dCz3oL2rTw&feature=youtu.be
- The visualization of the Digital twin needs a CAD/3D model

3D plant models

- While equipment manufactures have one equipment to be modelled, a process plant has a lot of static equipment, many dynamic equipment, and some may have cranes, pokers.
- All these are today modelled in 3D using popular software's like PDS or AutoCAD 3D plant model or others
- These models are typically used in design, engineering and construction stages

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Digital Twin Building Blocks

Digital twin 주요 구성 요소

1. 3D representation
2. Motion parameters
3. Thermodynamic properties
4. Electrical characteristics
5. Flow characteristics, Hydrodynamics(fluid-), etc.
6. Component motion parameters
7. SOP(Standard Operating Procedure)
8. Basic AI tool or access to AI tools
9. (IoT platform, sensors, etc.)

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