Blended Learning of IoT and AI for Business in Recurrent Education Program “Smart SE”

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Prof. Dr. Hironori Washizaki

- Professor and the Associate Dean of the Research Promotion Division at Waseda University in Tokyo
- Visiting Professor at the National Institute of Informatics
- Outside Directors of SYSTEM INFORMATION and eXmotion
- **Leading a large-scale grant at MEXT enPiT-Pro Smart SE**
- Leading projects on STEM education with a particular focus on introductory programming environments
- IEEE Computer Society Vice President for Professional and Educational Activities
- Associate Editor of IEEE Transactions on Emerging Topics in Computing
- Editorial Board Member of MDPI Education Sciences
- Steering Committee Member of the IEEE Conference on Software Engineering Education and Training (CSEE&T)
- Advisory Committee Member of the IEEE CS flagship conference COMPSAC
- Convener of ISO/IEC/JTC1 SC7/WG20
- [http://www.washi.cs.waseda.ac.jp/](http://www.washi.cs.waseda.ac.jp/)
Smart SE : Smart Systems and Services
innovative professional Education program

https://smartse.jp/en/

- Head: Waseda University
- 13 Partner universities: Ibaraki University; Gunma University; Tokyo Gakugei University; Tokyo Institute of Informatics; Osaka University; Kyushu University; Japan Advanced Institute of Science and Technology; Nara Advanced Institute of Science and Technology; Kougakuin University; Tokyo University of Technology; Toyo University; Tsurumi University; National Institute of Informatics
- 21 Partner companies and organizations: Toshiba; Fujitsu; NEC; Hitachi; e-Seikatsu; Yahoo; Whole Brain Architecture Initiative; Denso; Halex; Medical Information Company for Innovation; System Information; Mobile Computing Promotion Consortium; Japan Association of New Economy; Information Technology Federation of Japan; IT Verification Industry Association; Japan Society of Next Generation Sensor Technology; Japan Electronics and Information Technology Industries Association; Japan Embedded Systems Technology Association; Computer Software Association of Japan; Advanced IT Consortium to Evaluate, Apply and Drive; Weather Business Consortium
- 2 Supporters: Ritsumeikan University; The BigClouT Project (EU, NICT)

Ministry of Education, Culture, Sports, Science and Technology (MEXT)
2017-2021 enPiT-Pro
Agenda

• Overview of SmartSE
• Practical features in SmartSE
  • Comprehensive program sets
  • Quality assurance
  • Feedback loop of education and research
• Related activities in IEEE-CS PEAB
enPiT-Pro: Systematic, advanced, and short-term ICT practical recurrent education program with industry-academia network in Japan

**Background**
- Industry 4.0, uncertainty
- Work style reform, shortage of ICT professionals
- MEXT undergraduates and graduates education

**Features**
- MEXT enPiT-Pro ‘17-’21, recurrent education
- Industry-academia collaboration
- Practical, MOOC, project-based learning

**SmartSE**
*IoT, AI and Business*
- *Waseda University*, Ibaraki, Gunma, Tokyo Gakugei, Tokyo Tech., Osaka, Kyushu, JAIST, NAIST, Kogakuin, Tokyo Univ. Tech., Toyo, Tsurumi, NII

**enPiT-Pro Emb**
*Automotive, Embedding, IoT*
- *Nagoya University*, Shizuoka, Hiroshima, Ehime, Nanzan

**SI-IoTAiR**
*AI, IoT, Robotics*
- *U. Kitakyushu*, Kyushutech, Kumamoto, Miyazaki, Hiroshima City

**ProSec**
*Information Security*

**Open IoT**
*IoT, ICT*
- *Toyo University*, U. Tokyo, Yokohama National, Nagoya, Meijo
Background and related programs in Waseda University

Industrial needs
- Crucial needs of professional engineers in IoT, BigData and AI
- Difficulty in utilizing data and leading data-driven innovation

Vision of Japanese government
- Society 5.0: super smart society
- 4th industrial evolution

International situations
- Highly technology competitive environments
- Global human resource markets

Industrial engineers

Graduates and post-doctors

D-Data: data scientists program

EDGE-NEXT: innovation and entrepreneurship program

enPiT-Pro Smart SE

Data Science Research and Education Center

WASEDA VISION 150
Educating global leaders
Smart SE: Educating Professionals

Pl: Prof. Washizaki, 3M USD
14+ universities
16+ collaborators
16 classroom courses
13 Japanese online courses
1 English online course
37,000 learners online
IMS Japan, e-Learning award
Smart SE: Recurrent Education Program of IoT and AI for Business

AI, IoT and other advanced digital technologies

Business and value

Innovation

Process

Foundational technologies

Organization and society

AI

Data analytics

Feedback

Service

IoT

Data collection

BigData

Data-driven
Curriculum over different layers in digital transformation (DX) era

- Necessary viewpoint
- Data-driven and comprehensive approach
- Connection with Businesses and values
- Various objectives and contexts

Solution
- Full-stack curriculum and common problems
- Business and design thinking, PBL, capstone
- Ease of course combinations, on-demand

Business
- IoT innovation
- IoT and systems approach
- IoT business model hypothesis verification

Application
- Architecture and quality engineering
- Embedded and realtime systems
- Security, privacy, and law

Information processing
- Machine learning
- Big data
- Knowledge processing and NLP

Embedding and IoT professional
- IoT communication
- And wireless sensor network
- Cloud computing foundation
- Sensor

Practical integration
- Cloud and business innovator
- Capstone project (solving actual problems)
- Global PBL
- Smart IoT PBL
- Smart IoT system business intro.
Human resources who will lead the creation of value through the provision of smart systems and services: Full-stack engineers with expertise (three types)

* Smart systems and services: Services that respond to specific and detailed needs, and systems that accommodate those services and deliver them efficiently

**Prerequisites**
- Applicants must pass an entrance test equivalent to the intermediate-level MCPC IoT technology certification exam (Students who are expected to pass will be admitted under the condition that they will take an introductory course)
- Actual work experience in information technology

**Human resource model (2)**
- System of systems and quality architects
  - Creating an integrated system out of a group of systems, performing multifaceted quality evaluations for systems including security, and making improvements through big data analysis

**Completion requirements**
- Knowledge level equivalent to the advanced-level MCPC IoT technology certification exam is evaluated at each subject category.
- Demonstrate the ability to create value with a course completion project

**Anticipated participants**
- Those who have a fundamental knowledge of information systems

**Human resource model (1)**
- Professionals of embedded systems and IoT
  - Design and build IoT systems that combine sensors and cloud computing, with a focus on business and innovation

**Cloud business innovator**
- Make future predictions by applying AI to analyze big data, and design and verify business models that offer adaptive services via cloud computing
Using the nation-wide network

- Developed teaching materials will be made available for use in each region, and will be used to train working adults
- Further expand the university network during the grant period (Ritsumeikan University, etc.)

Kitakyushu region
- Already established the Kitakyushu consortium with companies in the electronics industry
- Already running a working adult re-education program through a consortium with Waseda University (implemented ahead of enPIT-Pro efforts)
- Promoting education, graduate school enrollment, and collaborative research to regional companies that are part of the consortium

Waseda University (Kitakyushu Campus)
Kyushu University

Kansai region
- Osaka University
- Nara Institute of Science and Technology
- Ritsumeikan University (participating school)

Regional development
- Hokuriku district
- Gunma University
- Ibaraki University

Smart SE Tokyo Office

Kanto region

Corporate outreach
- Acquire participants by cooperating with companies from the initial stage of developing teaching materials
- Gain trust from companies by designing courses that meet actual needs and with high-quality teaching contents
- Promote strong cooperation that leads to collaborative research with local industries and companies in each region, and link it to graduate school enrollment
- Proactively conduct PR activities for online teaching materials

Corporate partners (Over 5,000 partners including member companies)
Agenda

• Overview of SmartSE
• Practical features in SmartSE
  • Comprehensive program sets
  • Quality assurance
  • Feedback loop of education and research
• Related activities in IEEE-CS PEAB
Practical features in Smart SE

1. Comprehensive program sets and blended learning
   • MOOC and on-demand lectures
   • Project-based learning (PBL)
2. Quality assurance in education
   • Course evaluation and interview
   • Review of entire program based on reference frameworks
3. Feedback loop of education and research
   • Individual subject (e.g., integrated modeling method)
   • Automated review of entire program
1. Blended learning

Remote lecture and class-room solo and team exercise (practice)

Group work without devices
- Breakout rooms in Zoom
- Online collaboration using Google documents

Individual work with devices
- Change to individual exercise by shipping devices
- On-demand videos and live-stream of lecturer’s instructions
MOOC and on-demand lectures

JMOOC/gacco
- 13 lecture courses
- 20,000-30,000 learners/year
- In Japanese

edX
- 1 lecturer
- 2,000-3,000 learners/year
- In English
Project-based learning (PBL)

Online group work
• Business model canvas
• Architecture design
• Cloud, AWS, Raspberry Pi
• Deep learning

Exercise in assembly format
• Team work mixing engineers and university students
• AWS Deep racer
• Reinforcement learning

https://smartse.jp/information/2019/1105191102842/
## Comprehensive program sets

<table>
<thead>
<tr>
<th></th>
<th>Regular</th>
<th>Partial</th>
<th>JMOOC/gacco</th>
<th>edX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lecture courses</strong></td>
<td>15 courses and 3 projects</td>
<td>8 courses</td>
<td>13 courses</td>
<td>1 course</td>
</tr>
<tr>
<td><strong>Learning methods</strong></td>
<td>Live-stream, on-demand, assembly format</td>
<td>Live-stream, on-demand</td>
<td>On-demand only, no exercise</td>
<td>On-demand only, no exercise</td>
</tr>
<tr>
<td><strong>Duration</strong></td>
<td>6 hours/week</td>
<td>6 hours/week</td>
<td>3 hours/week</td>
<td>3-5 hours/week</td>
</tr>
<tr>
<td><strong>Course periods</strong></td>
<td>6 months</td>
<td>4 months</td>
<td>3 months</td>
<td>2 months</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>30 learners</td>
<td>50 learners</td>
<td>No limit</td>
<td>No limit</td>
</tr>
<tr>
<td><strong>Fee</strong></td>
<td>Approx. 5,000USD</td>
<td>Approx. 3,200USD</td>
<td>Free</td>
<td>Free (99USD for certificate)</td>
</tr>
</tbody>
</table>
2. Quality assurance in education

- Learners’ course evaluations to improve each course content
- Course text review by subject matter experts
  - E.g., a course division into multiple courses
- Learner interview one year after graduation to confirm and improve entire program
  - 2019: 60-80% respondents (N=10) answered the program was useful for developing and improving their businesses.
  - 2020: 85% respondents (N=13) answered the program was useful for developing and improving their businesses.

https://wasedaneo.jp/1692/
https://www.wasecom.jp/article/1294
Mapping course contents to knowledge/skill/competency frameworks

- Identifying strength and weakness (and potential extension) of the program
- Reference frameworks
  - Bodies of Knowledge: SWEBOK, INCOSE SE Handbook, PMBOK, …
  - Skill framework: SFIA framework, e-CF, …
  - Competency framework: i Competency Dictionary (iCD), SWECOM, …

<table>
<thead>
<tr>
<th></th>
<th>Skill a</th>
<th>Skill b</th>
<th>...</th>
<th>Competency x</th>
<th>Competency y</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course 1</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Course 2</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>…</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Course N</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
3. Feedback loop of education and research

**Education**
- Identifying potential problems
- E.g., IoT systems involving IoT business and systems modeling

**Research**
- Solving problems
- E.g., Integration of GQM+Strategies and SysML

- A case study of applying GQM+Strategies with SysML for IoT application system development, EAIS 2019
- Horizontal Relation Identification Method to Handle Misalignment of Goals and Strategies Across Organizational Units, IEEE Access 7(1), 2019
- Continuous modeling supports from business analysis to systems engineering in IoT development, EAIS 2020
- Systematical Alignment of Business Requirements and System Functions by Linking GQM+Strategies and SysML, Int. J. Service and Knowledge Management 5(1), 2021
Research: Automated course mapping by NLP and machine learning

Input

- Course materials (PDF and Power Point)
- iCD: Reference framework

Output

<table>
<thead>
<tr>
<th>Course</th>
<th>Skill a</th>
<th>Skill b</th>
<th>Competency x</th>
<th>Competency y</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course 1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Course 2</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>Course N</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Automated mapping

- Term extraction
- (i) Embeddings
  - (A) Bag of words
  - (B) Word2Vec
  - (C) Sentence BERT
- (ii) Automated determination
  - (A) Cosine similarity
  - (B) Random forest

Mapping result based on frameworks

“Automated educational program mapping on learning standards in computer science,” 45th IEEE Computer Society Signature Conference on Computers, Software and Applications (COMPSAC 2021), Fast Abstract
i. Embeddings

**Input**

- Text and slides
- List of skills and competencies

**Sentence extraction**

- “AI, BD, IoT are related … “

**Tokenization**

- [AI, BD, IoT, are, related, …]

(A) BoW

- [0 0 0 1 0 1 1 0 0 1 …]

or

(B) Word2Vec

- [-0.187 -0.003 0.314
  0.147 0.051
  -0.399 0.183 0.152],
- […]

Average

- [-0.126 0.220 0.104
  0.127 0.004
  -0.322 0.108 0.032],
ii. Automated determination of relation

(A) Cosine similarity

List of skills and competencies

(B) Random forest

Training data

Explanatory

Objective

Feature vector

Multi-label

Manual mapping results

Text and slides

Training

Predictor

“Automated educational program mapping on learning standards in computer science,” 45th IEEE Computer Society Signature Conference on Computers, Software and Applications (COMPSAC 2021), Fast Abstract
Experimental evaluation

- Targeting 30+ slide sets
- In terms of F-measure, combination of sentence distributed representation and supervised learning worked best.
- Need more improvement for practical usage

<table>
<thead>
<tr>
<th></th>
<th>Cosine similarity</th>
<th>Supervised learning (BoW)</th>
<th>Supervised learning (distributed representation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precision</td>
<td>0.313</td>
<td>0.545</td>
<td>0.706</td>
</tr>
<tr>
<td>Recall</td>
<td>0.417</td>
<td>0.240</td>
<td>0.480</td>
</tr>
<tr>
<td>F-value</td>
<td>0.357</td>
<td>0.333</td>
<td>0.571</td>
</tr>
</tbody>
</table>

“Automated educational program mapping on learning standards in computer science,” 45th IEEE Computer Society Signature Conference on Computers, Software and Applications (COMPSAC 2021), Fast Abstract
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In ISO/IEC 17024 and ISO/IEC 24773-1, Competence and competency are defined as:

Ability to apply knowledge and skills to achieve intended results.

<table>
<thead>
<tr>
<th>Competency</th>
<th>Knowledge</th>
<th>Skill</th>
<th>Proficiency level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competency 1</td>
<td>List of knowledge required to demonstrate competency 1</td>
<td>List of skills required to demonstrate competency 1</td>
<td>Proficiency description level</td>
</tr>
<tr>
<td>Competency 2</td>
<td>List of knowledge required to demonstrate competency 2</td>
<td>List of skills required to demonstrate competency 2</td>
<td>Proficiency description level</td>
</tr>
<tr>
<td>:</td>
<td>:</td>
<td>:</td>
<td>:</td>
</tr>
</tbody>
</table>

ISO/IEC 24773-1: 2019
IEEE Computer Society PEAB - Professional & Educational Activities Board

- Vice President for Professional and Educational Activities: Hironori Washizaki
- Mission: Providing leadership in the Society for activities related to the professional activities of practitioners in computing disciplines
- SWEBOK V4 Evolution
  - Defining modern software engineering profession
  - Major release within 2021
- Curriculum Development and Accreditation Collaboration
  - Further development and related activities for CC2020, and related joint efforts including development of CS20XX
  - CSAB continues to operate the accreditation process
- Courses and Packages Development
  - Organizing existing training/education assets and certifications
  - Digitizing and developing training/education courses aligned with SWEBOK and other disciplines including Machine Learning
- Other BOKs and Adoption
  - Academia and industry adoption of SWEBOK
  - Further promotion and adoption of EITBOK

https://www.computer.org/volunteering/boards-and-committees/professional-educational-activities
Plan of SWEBOK evolution

  - Guiding learners, researchers and practitioners to have common understanding on “generally-accepted-knowledge” in SWE
  - Defining boundary of SWE and related disciplines
  - Providing foundations for certifications and educational curriculum
- SWEBOK Guide history
  - 1998 started by IEEE CS/ACM
- SWEBOK Guide V3: 15 Knowledge area (KA)
  - Software Requirements, Software Design, Software Construction, Software Testing
  - Software Maintenance, Configuration Management, Engineering Management, Engineering Process
  - Engineering Economics, Software Quality, Engineering Methods, Professional Practices
SWEBOK V3 → V4

- Requirements
- Design
- Construction
- Testing
- Maintenance
- Configuration Management
- Management
- Process
- Models
- Quality
- Professional Practice
- Economics
- Computing Foundations
- Mathematical Foundations
- Engineering Foundations

- Requirements
- Architecture
- Design
- Construction
- Testing
- Operation and Maintenance
- Configuration Management
- Management
- Process
- Models
- Quality
- Security
- Professional Practice
- Economics
- Foundations
SWEBOK V4 development

- **2020 Achievement**
  - Draft list of knowledge areas incl. new ones: Architecture KA and Security KA
  - Major enhancement areas: Economics KA (about value proposition), Maintenance KA (about operation), Engineering Models KA (about agile/DevOps)
  - Major reorganization areas: Computing/Mathematical/Engineering Foundation KAs (incl. connection with AI and IoT)
  - Policy of inclusion: “generally accepted” and “generally recognized”

- **2021 Plan (subject to change)**
  - Apr-June: Having revised guideline, Drafting list of topics, and recommended readings, identification of reviewers
  - July-Sep: Drafting topics, reference materials
  - Oct-Nov: Internal review and revising topics
  - Dec-Jan: Public review
  - Feb-Mar: Review comment disposition and release of V4

https://www.computer.org/volunteering/boards-and-committees/professional-educational-activities/software-engineering-committee/swebok-evolution
Summary

- Smart SE: Recurrent Education Program of IoT and AI for Business
  - Comprehensive program sets: MOOC and PBL
  - Quality assurance: course evaluation and mapping on reference frameworks
  - Feedback loop of education and research
- Related activities in IEEE-CS PEAB
  - SWEBOK evolution
  - Curriculum Development and Accreditation Collaboration
  - Courses and Packages Development
Further information

- Smart SE: [https://smartse.jp/en/](https://smartse.jp/en/)