DIGIWATER

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R2.1.4 SYLLABI FOR COURSES

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1. INTRODUCTION

1.1. GENERAL

All types of industrial companies, those working in water industries included, must adapt their processes to advanced digital technologies driving Industry 4.0, such as: Internet of Things, Cloud computing, Artificial Intelligence and Machine Learning, Big Data and Cybersecurity.

Thus, there is a very high need for additional curricula items on those subjects with specific focus on the water sector and a need for an enhanced university-enterprise collaboration on the use of digital water models in research projects.

1.2. OBJECTIVES

One of the first goals of **DIGIWATER** project is the development of new, innovative, and multidisciplinary approaches to teaching and learning by using multidisciplinary curricula integrated with digital learning tools and virtual facilities with access in cloud systems and Problem Based Learning, to build IT skills to water professionals.

The objectives of the second work package **WP2: Digital Water Curriculum** are as follows:

- to design the curriculum relevant to the market and societal needs.
- to develop teaching and learning materials that can be used in university or lifelong learning courses both in-class and via eLearning.
- to design and develop the e-learning platform.
- to train teachers in academia and companies.
- to test an implement the upgraded curricula in partner universities.

Initial objectives must be achieved through the implementation of a number of tasks including analysis of partners' assets, best practices review, design and planning of curriculum, syllabi, practical activities and slides for classroom and e-learning, and harmonization of content.

This report presents the results of the implementation of **Task T2.1.4 – *Design and planning of syllabi***. The document includes a detailed syllabi specifying the content of the courses covering topics in (i) IoT & and Big Data and (ii) Cybersecurity in Critical Water infrastructure, based on the curriculum produced in Task T2.1.3. – *Digital Water curriculum design workshop*.

2. SYLLABI

2.1. GENERAL

In accordance with the results of Task T2.1.3. – *Digital Water curriculum design workshop*, the syllabi were conceived for two courses on ***Big Data & IoT*** and *Cybersecurity in water critical infrastructure*, aiming the development of two sets of teaching material of 7 and, respectively, 8 lectures, covered in 2-4 teaching hours.

A questionnaire (Table 1) was prepared and distributed among the partners. The detailed input for each item from the coordinator of each topic is presented in Annex.

Table 1: The template of the questionnaire

1. Topic name
2. Duration of the topic
3. Topic content
4. Learning outcome
5. Learning activities
6. Assignments
7. Assignments deadline
8. Standards and criteria for graded assignments
9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used
10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy
11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.
12. Reference literature

The syllabi include topics and readings to be covered in sequence with durations; important durations/milestones (e.g., assignment due, exam, and holidays); standards and criteria for graded assignments; description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used; policy on

late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy.

2.2. INTERNET OF THINGS (IOT)

This course presents the main topics concerning IoT, a system of interconnected physical and virtual objects with sensors, processing, and communication abilities, that can interact with each-other, with other devices and systems via the Internet or other types of networks[1].

The course consists of 7 units, each having a responsible partner assigned (Table 2).

Table 2: Responsible partners for *Internet of Things (IoT)* course

Unit	Content	Partner responsible
1	Introduction to IoT	UCY
2	Sensors in IoT	DOSCON
3	Instrumentation and SCADA	SmarTech
4	Cyber Security in IoT	UGAL
5	Standards & good practices (incl. Legal framework)	NMBU
6	Case studies based on simulations	SumAqua
7	Future trends	NMBU

The course starts with an introduction in protocols, architecture, and applications of IoT and a description of the next stage: Web of Things (WoT). Practical approaches to design, program and secure IoT devices are presented and aspects of data transfer to the cloud and between cloud providers are illustrated.

The second topic addresses, in a 2-hour lecture, different types of sensors used in IoT, the principles of sensor measurement, the process of sensor calibration and sensor communication protocols. The theoretical knowledge is then applied to append an IoT enabled transmitter to a water-quality measuring sensor.

A consistent overview of SCADA architecture, instrumentation, networks and servers, software and security threats is given in a 4-hour lecture. Besides introducing the basic concepts, this lecture presents the components of SCADA systems and different ways to choose them and to program the systems, creating applications for control and data transmission.

The fourth unit is about the world of cybersecurity, with all the facets of threats, vulnerabilities, cyberattacks, and countermeasures to reduce the exposure of our physical and informational assets. In addition to the general aspects of cybersecurity, specific IoT threats, IoT attack lifecycle, and challenges of securing IoT devices are addressed.

[1] "Internet of Things Global Standards Initiative". ITU. Retrieved 9 March 2023.

The subject of cybersecurity is continued in the fifth presentation, covering relevant standards and regulations, guidelines and best practices regarding IoT security and privacy. The EU cybersecurity act, NIS2 directive and GDPR are discussed.

The next lecture presents different case studies showing how Internet of Things can support water management. The applications discussed during the lecture are translated, if possible, into solution for some of the identified challenges in the water sector.

Internet of Things (IoT) course is ended with a presentation of recent and future trends in IoT advances using emerging technologies including 5G/6G, Edge and Fog computing, AIoT and Edge AIoT in cloud-based applications, predictive maintenance and blockchain. The IoT technology growth is appreciated within the context of Big Data, Cloud Computing and Data Analytics.

2.3. BIG DATA APPLICATIONS IN THE WATER SECTOR

Big Data is very vast domain dealing with collection, storage, organizing, analysis, transfer, visualization, protection of large or complex data that can't be processed using traditional data-processing software.[2] This course explores the Big Data applications in water sector focusing on data analytics, data visualization, data assessment, and data protections in different case studies. Table 3 gives the responsible partner for each unit of the course, who has developed the content of the designated lecture.

Table 3: Responsible partners for *Big Data applications in the water sector* course

Unit	Content	Partner responsible
1	Introduction to Big Data	KU Leuven
2	Big data analytics (incl. Artificial Intelligence and machine learning tools)	UCY
3	Visualization of data	DOSCON
4	Cybersecurity in Critical Water Infrastructure	NMBU
5	Data safety and standardization (incl. Crash course on Open data)	DOSCON
6	Case studies	SumAqua
7	Data assessment exercises	TH OWL
8	Future trends	NMBU

An introductory 2-hour lecture is given in first unit, providing general knowledge and experience in the domain of Big Data. State-of-the-art Big Data applications related to water sector are identified and the basic terminology, data types and algorithms are presented, before taking the first steps in data science.

[2] "History of Big Data". SAS. Retrieved 9 March 2023.

The second 3-hour lecture goes deep into data processing and analytics, while introducing Artificial Intelligence and Machine Learning fields that provide the tools needed to find new insights and solve problems in the water sector.

Next unit develops a good understanding of data representation and visualization in 2-hour lecture. Also, examines different tools available in the market and discusses pros and cons using different web and app-based software instruments.

The need for Cybersecurity in critical water infrastructure is more than obvious. To defend against the typical threats to modern water systems, the knowledge about the risks and vulnerabilities is a must. The lecture describes the specific standards and regulatory frameworks required for compliance with critical water infrastructure requirements, too.

The subjects of data safety and standardization are examined during a 4-hour lecture. One the one hand, different database technologies, communications protocols and data structures are investigated. On the other hand, the issue of data restoring in case of breaches is discussed step by step, emphasizing the function and purpose of data encryption.

The sixth lecture presents different case studies showing how Big Data can support water management. The applications discussed during the lecture are translated, if possible, into solution for some of the identified challenges in the water sector.

Next topic is a more practical one, applying the basics to implement simple Big Data tools to visualize, correlate, and analyze data from public sources. The duration of this topic is 3 hours.

The last topic of the course describes applications, current research, and top industry trends of Big Data applications in the water sector, discussing aspects regarding the adoption of Machine Learning and other Artificial Intelligence technologies in this sector. Process optimization to create more accurate predictive models is addressed. Also, the strong need for security and privacy of data is highlighted.

3. CONCLUSION

Emerging technologies such as Internet of Things, Big Data, Artificial Intelligence and Cybersecurity work in harmony, transforming business, industries, healthcare, education and more, finally changing the world.

The content for the courses designed in Task T2.1.4 focuses on the above-mentioned technologies with case studies in the water sector, facilitating the understanding of the basics and focusing on the application in the water industry.

After the design of slides for lectures and e-learning (T2.2.1) and the development of practical assignments (T2.2.2), all the content will be harmonized following the syllabi (T2.2.2).

ANNEXES

A.1.1. INTRODUCTION TO IOT [UCY]

1. Topic name
• Introduction to IoT
2. Duration of the topic
• 3 hours
3. Topic content
• IoT - What is the IoT and why is it important? Elements of an IoT ecosystem, Technology drivers, Business drivers, Trends and implications, Overview of Governance, Privacy and Security Issues. • IoT Protocols - Protocol Standardization for IoT – Efforts – M2M and WSN Protocols – SCADA and RFIDProtocols – Issues with IoT Standardization – Unified Data Standards – Protocols – IEEE802.15.4–BACNet Protocol– Modbus – KNX – Zigbee– Network layer – APS layer – Security • IoT Architecture - IoT Open source architecture (OIC)- OIC Architecture & Design principles- IoT Devices and deployment models- IoTivity : An Open source IoT stack - Overview- IoTivity stack architecture- Resource model and Abstraction. • Web of Things - Web of Things versus Internet of Things – Two Pillars of the Web – Architecture Standardization for WoT– Platform Middleware for WoT – Unified Multitier WoT Architecture – WoT Portals and Business Intelligence. • IoT Applications - IoT applications for industry: Future Factory Concepts, Brownfield IoT, Smart Objects, Smart Applications. Study of existing IoT platforms /middleware, IoT- A, Hydra etc.
4. Learning outcomes
• Describe what IoT is and how it works today • Recognise the factors that contributed to the emergence of IoT • Design and program IoT devices • Use real IoT protocols for communication • Secure the elements of an IoT device • Design an IoT device to work with a Cloud Computing infrastructure. • Transfer IoT data to the cloud and in between cloud providers • Define the infrastructure for supporting IoT deployments
5. Learning activities
• Presentations - lecture • Practical sessions • Quizzes • Assignment – Project
6. Assignments
• **Assignment 1 (individual)** will focus on building a nightlight using a Raspberry Pi. This entails programming a light sensor and students becoming accustomed to a Raspberry Pi. • **Assignment 2 (group project)** will focus on bonding a Raspberry Pi with sensors and acting on the data that the sensor collects by using the Python programming language. The programming will be done in the Raspbian OS with Python since it is a well-supported programming language out of the box and has huge community support, making it the language of preference for developers.
7. Assignments deadline
• 3 hours for individual assignment • 3 hours for group assignment
8. Standards and criteria for graded assignments
• Class participation: 20% • Group project & presentation: 20% • Lab exercise/Assignment: 20%

• Individual Assessment (e.g. Test): 40%
9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used
• A (excellent work) 91–100 points • B (above average) 81–90 points • C (average)71–80points • D (below average) 50–70 points • F (failed) < 50 points
10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy.
• Students are expected to attend course regularly. In case of missing a course activity the student should perform additional work and submit it to the instructor.
11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.
• Active role in the classroom • Group work • Preparation of the assignments
12. Reference literature
• Misra, S., Mukherjee, A., & Roy, A. (2021). Introduction to IoT. Cambridge University Press. • Misra, S., Roy, C., & Mukherjee, A. (2021). Introduction to industrial Internet of Things and industry 4.0. CRC Press. • Singh, R., Gehlot, A., Gupta, L. R., Singh, B., & Swain, M. (2019). Internet of things with Raspberry Pi and Arduino. CRC Press. • Research Papers focus on the use of IoT in the water sector.

A.1.2. SENSORS IN IOT [DOSCON]

1. Topic name
• Sensors in IoT
2. Duration of the topic
• 2 hours
3. Topic content
• Types of online sensors • Sensor measurement principles • Sensor calibration • Communication protocols • Enabling IoT on sensors
4. Learning outcome
• Can develop a good knowledge of different types of online sensors used in water sector. • Be able to describe various measuring principles used by online sensors to detect variations in water-quality parameters. • Be able to describe the communication protocols used to read data from online sensors. • Can demonstrate an understanding of appending an IoT enabled transmitter to a water-quality measuring sensor.
5. Learning activities
6. Assignments
7. Assignments deadline

8. Standards and criteria for graded assignments
• https://www.nmbu.no/en/students/administration/grading-system
9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used
10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy.
• https://www.nmbu.no/en/students/administration/grading-system • https://www.nmbu.no/en/students/studentparliament/documents/node/31115
11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.
12. Reference literature
Online sensors for water quality monitoring • Review of sensors to monitor water quality https://publications.jrc.ec.europa.eu/repository/bitstream/JRC85442/lbna26325enn.pdf • Smart Sensors for Real-Time Water Quality Monitoring https://link.springer.com/book/10.1007/978-3-642-37006-9 • Ratnaweera, H.; Fettig, J. State of the Art of Online Monitoring and Control of the Coagulation Process. Water 2015, 7, 6574-6597. https://doi.org/10.3390/w7116574 **Communication protocol** • Communication protocols for wireless sensor networks https://www.sciencedirect.com/science/article/pii/S2405844018340192 • Sensor Network Protocols (Mahgoub, I., & Ilyas, M. (2006). Sensor Network Protocols (1st ed.). CRC Press. https://doi.org/10.1201/9781420006346 • R A Atmoko, R Riantini and M K Hasin 2017 IoT real time data acquisition using MQTT protocol. J. Phys. • M. B. Yassein, M. Q. Shatnawi, S. Aljwarneh and R. Al-Hatmi, "Internet of Things: Survey and open issues of MQTT protocol," 2017 International Conference on Engineering & MIS (ICEMIS), 2017, pp. 1-6, doi: https://doi.org/10.1109/ICEMIS.2017.8273112. **Enabling IoT on online sensors** • V.Lakshmikantha, A.Hiriyannagowda, A.Manjunath, A. Patted, J. Basavaiah, A. Anthony, IoT based smart water quality monitoring system, 2021, Global Transitions Proceedings, vol .2 (2), pp 181-186. https://doi.org/10.1016/j.gltp.2021.08.062 • N. A. Cloete, R. Malekian and L. Nair, "Design of Smart Sensors for Real-Time Water Quality Monitoring," in IEEE Access, vol. 4, pp. 3975-3990, 2016, doi: https://doi.org/10.1109/ACCESS.2016.2592958

A.1.3. INSTRUMENTATION AND SCADA [SMARTECH]

1. Topic name
• Instrumentation and SCADA
2. Duration of the topic
• 4 Hours
3. Topic content

• SCADA Overview
• SCADA Architecture
  ○ SCADA Hardware
  ○ Instrumentation

○ Networks ○ RTU and PLC ○ HMI ○ Servers • SCADA Software • SCADA Security
4. Learning outcome:
• What is a SCADA system, • Where these systems are used, • Component of SCADA systems, • How to choose system components, • How to program these systems, • Industrial communication networks within SCADA systems, • Security threats for SCADA systems • Ways to protect against these threats.
5. Learning activities:
• PLC / RTU programming: The CCW – Connected Components Workbench application developed by Rockwell Software will be used to create programs for the Micro800 series PLCs produced by Allen Bradley. • HMI interface programming – The CCW – Connected Components Workbench application developed by Rockwell Software will be used to create programs for the Panel View 800 series HMIs produced by Allen Bradley. • SCADA application programming – The IGNITION application developed by Inductive Automation will be used, which represents a modern WEB-based SCADA platform.
6. Assignments
• Topic1. creating a PLC application for control and data transmission for a simple raw water drilling system / simple waste water pumping system. • Topic2. making an HMI application for the operator interface for a simple raw water drilling system / simple waste water pumping system. • Topic3. creating a SCADA application using Ignition
7. Assignments deadline
• 3 weeks - one week for each topic.
8. Standards and criteria for graded assignments
9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used
10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy
• A second assessment is accepted for each topic
11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.
Understanding the topics presented. Realization of the proposed applications.
12. Reference literature
• Stuart G. McCrady, “Designing SCADA - Application Software - A Practical Approach”, Elsevier, 2013 • Ronald L. Krutz, “Securing SCADA Systems”, Wiley Publishing, Inc., 2006 • www.ab.com • https://www.rockwellautomation.com/en-us/support/product/product-selection-configuration/integrated-architecture-builder.html • https://inductiveautomation.com/ignition/platform

A.1.4. CYBER SECURITY IN IOT [UGAL]

1. Topic name

4. Cyber Security in IoT

2. Duration of the topic

5. 4 hours

3. Topic content

- Introduction in Cybersecurity
- Security goals
- Cybercriminal categories
- Common threats. IoT threats
- Cyberattack categories
- Security countermeasures.
  - Access Control
  - Physical security
  - Security services
  - Multi-factor authentication
  - Reduction IoT security threats
- Cyber kill chain. IoT attack lifecycle
- Cybersecurity best practices and guidelines
- Incident response
- Disaster recovery
- Risk management

4. Learning outcome

- Increase students' knowledge and readiness to defend themselves against cyber threats:
  - understanding the world of cybersecurity and its importance
  - understanding the most common cyber threats, attacks, and vulnerabilities and how they affect our data, network infrastructure, systems, and services
  - understanding security countermeasures to protect data, networks, systems, and services using authentication, access control, encryption, backup, etc.
  - understanding cybersecurity policies, procedures, and best practices for incident response, disaster recovery and risk management

5. Learning activities

- Course: 2 hours
- Hand-on activity using Cisco Packet Tracer network simulator: 2 hours

6. Assignments

- A written essay on one of the common cyber threats (opinion paper)

7. Assignments deadline

- One week after the end of the course

8. Standards and criteria for graded assignments

- Content organization and style
- Relevance and complexity of the argument
- Clarity of opinion and clarity of argument
- Use and documentation of sources

9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used

- Quiz to check knowledge, submitted online
  - percent of correct answered questions = 0 – 100%
- Essay score (four levels):
  - A (Excellent) = 80 – 100%

○ B (Good) = 70 – 79% ○ C (Acceptable) = 60 – 69% ○ F (Poor) = 0 – 59% • Final grade: 50% quiz + 50% essay • Letter grade ranges: ○ 95 – 100% = 10 = A (Excellent) ○ 85 – 94% = 9 = B (Very Good) ○ 75 – 84% = 8 = C (Good) ○ 65 – 74% = 7 = C (Good) ○ 55 – 64% = 6 = D (Satisfactory) ○ 50 – 54% = 5 = E (Sufficient) ○ 0 – 49% = 4 = F (Fail)
10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy
• Students are expected to attend all regularly scheduled classes for instruction and examinations. • Students should inform the instructor as soon as possible of any circumstances that may affect their academic performance or attendance so that alternative arrangements can be made. • Late assignments are not accepted after the deadline. • Academic integrity will be assessed according to the standards of academic conduct.
11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.
• Students should work in small groups to solve the hands-on activity and to identify the common cyber threats, attacks, and vulnerabilities. ○ problem-based learning ○ collaborative learning
12. Reference literature
• IoT Security – What is It and How Does It Protect Your IoT Devices - Palo Alto Networks https://www.paloaltonetworks.com/cyberpedia/what-is-iot-security • IoT Security Administrator's Guide (paloaltonetworks.com) https://docs.paloaltonetworks.com/content/dam/techdocs/en_US/pdf/iot/iot-security-admin/iot-security-admin.pdf • The 8 Stages of the IoT Attack Lifecycle - Palo Alto Networks https://www.paloaltonetworks.com/resources/infographics/the-8-stages-of-the-iot-attack-lifecycle • 4 Steps to Reducing IoT Threats (paloaltonetworks.com) https://www.paloaltonetworks.com/apps/pan/public/downloadResource?pagePath=/content/pan/en_US/resources/infographics/4-steps-to-reducing-iot-ot-security-threats-in-the-enterprise • Cisco Skills For All ○ Introduction to Internet of Things ○ Introduction to Cybersecurity ○ Cybersecurity Essentials https://skillsforall.com/catalog

A.1.5. STANDARDS & GOOD PRACTICES (INCL. LEGAL FRAMEWORK) [NMBU]

1. Topic name
• Standards & good practices (incl. Legal framework)
2. Duration of the topic
• 2 hours
3. Topic content
The course covers relevant standards, good practices, and regulations of IoT

• IEEE and ISO/IEC standards and guidelines for IoT -Architectural framework for IoT (IEEE P2413-2019), Harmonization and security of IoT (IEEE 1451-99), Sensor performance and quality (IEEE 2700, IEEE P2510) - IoT security and privacy guidelines (ISO/IEC 27402), IoT trustworthiness Principles (ISO/IEC 30149 ED1), Interoperability for IoT systems (ISO/IEC 21823-1) • Good practices for security of IoT • Global overview of IoT regulatory frameworks (ITU, BEREC, ETSI, etc.) • IoT security regulations (e.g., the EU cybersecurity act, the NIS2 directive) and IoT privacy regulations (e.g., GDPR)
4. Learning outcome
• Develop in-depth working knowledge of existing policies, standards, and guidelines • Outline and describe good practices related to the use of IoT • Examine guidelines and standards related to cybersecurity for IoT products • Develop a good knowledge of how the European Union (EU) regulates IoT cybersecurity and privacy • Participate in policy debates about emerging IoT standardization issues and their regulation at domestic, European, and international levels
5. Learning activities
• lecture(s), term paper, project work
6. Assignments: project work, reports, refection notes
• https://www.nmbu.no/en/employees/qae/courses/forms-of-assessment
7. Assignments deadline
8. Standards and criteria for graded assignments: letter grades
• https://www.nmbu.no/en/students/administration/grading-system
9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used
• A=5, B=4, C=3, D=2 and E=1 https://www.nmbu.no/en/students/administration/grading-system https://www.nmbu.no/en/students/studentparliament/documents/node/31115
10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy.
11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.
12. Reference literature
• IEEE and ISO/IEC standards for IoT (https://nordiciot.dk/ieee-and-iso-standards-for-iot/) • The IoT and the new EU cybersecurity regulatory landscape (https://www.tandfonline.com/doi/full/10.1080/13600869.2022.2060468) • Good Practices for Security of Internet of Things (https://www.enisa.europa.eu/publications/good-practices-for-security-of-iot-1 , https://www.enisa.europa.eu/publications/good-practices-for-security-of-iot) • Internet of Things (IoT) security best practices (https://standards.ieee.org/wp-content/uploads/import/documents/other/whitepaper-internet-of-things-2017-dh-v1.pdf) • IoT Cybersecurity: regulating the Internet of Things (https://www.thalesgroup.com/en/markets/digital-identity-and-security/iot/inspired/iot-regulations) • IoT Cybersecurity: 29 Security Laws, Regulations, Standards, and Best Practices (https://bgnetworks.com/the-state-of-iot-cyber-security/)

A.1.6. CASE STUDIES BASED ON SIMULATIONS [SUMAQUA]

1. Topic name
• Case studies using IoT and Big Data in the water sector
2. Duration of the topic
• 2 hours, in total
3. Topic content
• Different case studies showing how IoT (Internet of Things) and Big Data can support water management.
4. Learning outcome
• Insight in practical applications involving digitalization in the water sector.
5. Learning activities
• None
6. Assignments
• None
7. Assignments deadline
• None
8. Standards and criteria for graded assignments
• Not applicable
9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used
• Not applicable
10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy
• Not applicable
11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.
• During the lectures, other challenges in the water sector can be identified through interaction with students. Hereafter, a brainstorm can be done to translate the applications that are presented during the lecture into solutions for (some of the) identified challenges.
12. Reference literature
• Various publications made by the team of Sumaqua, as well as additional publications from different international scientific journals that leverage technologies for digitalization in the water sector (with a focus on IoT and Big Data)

A.1.7. FUTURE TRENDS [NMBU]

1. Topic name
• Future trends of IoT
2. Duration of the topic
• 2 hours
3. Topic content
This module will include recent trends in IoT advances/innovations utilizing emerging technologies • IoT Technology's growth • IoT connectivity – 5G/6G, WiFi 6, LPWAN, and Satellites • Empowered edge and fog computing in IoT • Recent advances and applications of AIoT and Edge AI in cloud-based applications • IoT-based smart cities • IoT empowered predictive maintenance

• Blockchain for IoT security
4. Learning outcome
• Explain current IoT applications, trends, and implications • Understand where the IoT concept fits within the water sector and possible future trends • Discuss IoT application usage in digital water and smart cities • Describe IoT connectivity and networks • Apply real-time and local analytics • Appreciate the role of big data, cloud computing, and data analytics in a typical IoT system
5. Learning activities
• lecture(s), term paper, project work
6. Assignments
• project work, reports, refection notes https://www.nmbu.no/en/employees/qae/courses/forms-of-assessment
7. Assignments deadline
8. Standards and criteria for graded assignments
• letter grades https://www.nmbu.no/en/students/administration/grading-system
9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used
• A=5, B=4, C=3, D=2 and E=1 https://www.nmbu.no/en/students/administration/grading-system https://www.nmbu.no/en/students/studentparliament/documents/node/31115
10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy
11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.
12. Reference literature
• Reliable Internet of Things: Challenges and Future Trends (https://www.mdpi.com/2079-9292/10/19/2377/htm) • Emerging Trends and Challenges in Fog and Edge Computing for the Internet of Things (https://www.mdpi.com/2624-831X/3/1/9) • Current-Trends-and-Future-Scope-for-the-Internet-of-Things (https://www.researchgate.net/profile/Faheem-Masoodi/publication/348448892_Current_Trends_and_Future_Scope_for_the_Internet_of_Things/links/6015789145851517ef275d22/Current-Trends-and-Future-Scope-for-the-Internet-of-Things.pdf) • Top Internet of Things (IoT) Trends for 2022: The Future of IoT (https://techreviewer.co/blog/top-iot-trends-in-2022-the-future-of-iot) • IoT, role, examples and trends for 2022 (https://www.spiceworks.com/tech/iot/articles/what-is-internet-of-things/) • Top 10 IoT trends that can guide your business decisions in 2022 (Top 20 Emerging IoT Trends That Will Shape Our Future Soon) https://www.ubuntupit.com/emerging-iot-trends/ • Future of IoT Technology: 8 Trends for Businesses to Watch in 2022 (https://www.iotforall.com/future-of-iot-technology-8-trends-for-businesses-to-watch-in-2022) • Major IoT Trends to Expect in 2022 (https://internetofbusiness.com/major-iot-trends-to-expect-in-2022/) • 10 IoT Trends for 2022/2023: Latest Predictions According To Experts (https://financesonline.com/iot-trends/)

A.2.1. INTRODUCTION TO BIG DATA [KU LEUVEN]

1. Topic name

- Introduction to Big Data

2. Duration of the topic

- 2 hours

3. Topic content

- Motivation of the course content. Teasers/Example cases of state-of-the-art Big Data applications related to water.
- General definition of Big Data, goals and content of the course.
- Basic terminology: instances, features (numeric/categorical)
- Introduction to data types: structured, unstructured
- Introduction to types of algorithms: unsupervised, supervised
- Introduction to the data science workflow: problem statement, data sources, data selection, data cleaning, data transformation, analysis, interpretation
- Exercise session: hands-on application of the above on a water related problem and related dataset

4. Learning outcome

- Understanding relevance and importance of Big Data for water applications
- Acquire general knowledge and experience in the domain of Big Data
- Grasping basic terminology and awareness
- First hands-on experience with real-life dataset

5. Learning activities

- Lecture
- Exercise session
- Student group work
  - Guided during exercise session
  - Guidance (email, in-person) on initiative of students after the session

6. Assignments

- 1 exercise session
- Assignment and exercise session should be coupled with the follow-up courses as well: big data analytics, visualization of data, ...

7. Assignments deadline

- Start of examination period

8. Standards and criteria for graded assignments

- Numerical (integer) score ranging between 0 and 20
- Passing score is set at 10

9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used

- Weighted sum of subscores on different parts of the assignment

10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy

- Missed deadline: no score (NA)
- Incomplete: subscore of 0 on missing part
- Revisions: allowed up to deadline
- Plagiarism: KU Leuven policy
- Attendance: not obligatory

11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.

- Lecture: presentation by lecturer, Q&A interaction with participants possible during the session

• Exercise: group work, assistance available for questions during the session
10. Reference literature

A.2.2. BIG DATA ANALYTICS (INCL. ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING TOOLS) [UCY]

1. Topic name
• Big Data analytics (incl. Artificial Intelligence (AI) and Machine Learning (ML) tools)
2. Duration of the topic
• 3 hours
3. Topic content
• Introduction to Big Data - What is Big Data • Introduction on Big Data processing and analytics and the challenges of Big Data mining • Big Data Management • Mining Data Streams & Streaming Analytics • Big Data pre-processing • Big Data Visualization • Introduction to ML, supervised, unsupervised, reinforcement learning, hypothesis (models) spaces, examples of ML applications • Introduction to AI, definitions and history of AI. Intelligent Agents: Problem formulation, goals, constraints environment and actors/agents.
4. Learning outcomes
• Acquire understanding of the sophisticated concepts and features of big data, ML and AI technologies and applications • Acquire understanding of big data models, AI models, and their technical features, as well as build deep insights about what kinds of applications they can support • Analyze the impact of advanced big data techniques for real-world business decisions and strategy applied in international companies. • Acquire a complete and in-depth landscape of the history, development and various applications of AI in various real-world business sectors • Master AI techniques, including knowledge representation and reasoning process techniques, and be able to apply them in business applications • Develop skills in ML, such as linear regression, decision tree induction, and artificial neural networks, and be able to devise new real-world solutions by applying the skills.
5. Learning activities
• The course will be offered in a mode that combines seminars, case study, team presentations, and group discussions.
6. Assignments

• **Assignment 1 (individual)** will be done in Jupyter (with Python) in the form of a small tutorial-assignment that includes some explanation and steps in the first cells of the notebook, leaving several implementation tasks for the end of the notebook that students will need to complete.
• **Assignment 2 (group project)** will focus on Big Data tools (in Python) that can also be shown and used with Jupyter. Options to be considered for the project include:
  ○ Pandas: Data manipulation and analysis Python library.
  ○ Vaex: High performance Python library for lazy Out-of-Core DataFrames (Big data version of Pandas).
  ○ Modin: Dataframe manipulation library that allows users to speed up their pandas workloads by acting as a drop-in replacement.

7. Assignments deadline
• 3 hours for individual assignment

• 3 hours for group assignment
8. Standards and criteria for graded assignments
• Class participation: 20% • Group project & presentation: 20% • Lab exercise/Assignment: 20% • Individual Assessment (e.g. Test): 40%
9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used
• A (excellent work) 91–100 points • B (above average) 81–90 points • C (average)71–80points • D (below average) 50–70 points • F (failed) < 50 points
10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy.
• Students are expected to attend course regularly. In case of missing a course activity, the student should perform additional work and submit to the instructor.
11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.
• Active role in the classroom • Group work • Preparation of the assignments
12. Reference literature
• Cohen, S., & Macek, J. (2021). Cyber-physical process monitoring systems, real-time big data analytics, and industrial artificial intelligence in sustainable smart manufacturing. Economics, Management and Financial Markets, 16(3), 55-67. • Fowdur, T. P., Beeharry, Y., Hurbungs, V., Bassoo, V., & Ramnarain-Seetohul, V. (2018). Big data analytics with machine learning tools. In Internet of things and big data analytics toward next-generation intelligence (pp. 49-97). Springer, Cham. • Big data, data analytics, artificial intelligence and machine learning, By: World Trade Organization, Source: The Role of Advanced Technologies in Cross-border Trade , pp 32-39 • Kibria, M. G., Nguyen, K., Villardi, G. P., Zhao, O., Ishizu, K., & Kojima, F. (2018). Big data analytics, machine learning, and artificial intelligence in next-generation wireless networks. IEEE access, 6, 32328-32338.

A.2.3. VISUALIZATION OF DATA [DOSCON]

1. Topic name
• Visualization of data
2. Duration of the topic
• 2 hours
3. Topic content
• Data representation • Dashboards • Tools for data visualization • 3-D visualization and Virtual reality • Web-based versus App-based
4. Learning outcome
• Develop a good understanding of different types of data sets and way of visualizing them. • Understanding the optimal dashboard layout for data representation.

- Analyze different visualization tools available in the market and identify the level of expertise required to use them.
- Understand the pros and cons of using a web-based visualization tool versus and app-based visualization tool.
- Demonstrate an ability to use tools to build basic dashboard layouts to visualize various datasets.

5. Learning activities

6. Assignments

7. Assignments deadline

8. Standards and criteria for graded assignments

- https://www.nmbu.no/en/students/administration/grading-system

9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used

10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy

- https://www.nmbu.no/en/students/administration/grading-system
- https://www.nmbu.no/en/students/studentparliament/documents/node/31115

11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.

12. Reference literature

Tools and challenges

- S. M. Ali, N. Gupta, G. K. Nayak and R. K. Lenka, "Big data visualization: Tools and challenges," 2016 2nd International Conference on Contemporary Computing and Informatics (IC3I), 2016, pp. 656-660, doi: 10.1109/IC3I.2016.7918044.
- Manuela Aparicio and Carlos J. Costa. 2015. Data visualization. Commun. Des. Q. Rev 3, 1 (November 2014), 7–11. https://doi.org/10.1145/2721882.2721883
- Antonis Protopsaltis, Panagiotis Sarigiannidis, Dimitrios Margounakis, and Anastasios Lytos. 2020. Data visualization in internet of things: tools, methodologies, and challenges. In Proceedings of the 15th International Conference on Availability, Reliability and Security (ARES '20). Association for Computing Machinery, New York, NY, USA, Article 110, 1–11. https://doi.org/10.1145/3407023.3409228
- Rajeev Agrawal, Anirudh Kadadi, Xiangfeng Dai, and Frederic Andres. 2015. Challenges and opportunities with big data visualization. In Proceedings of the 7th International Conference on Management of computational and collective intElligence in Digital EcoSystems (MEDES '15). Association for Computing Machinery, New York, NY, USA, 169–173. https://doi.org/10.1145/2857218.2857256

Data Visualization tools

- https://www.techtarget.com/searchbusinessanalytics/definition/data-visualization
- https://www.dash.org/
- https://go2.grafana.com/

Virtual Reality

- Ma D, Fan X, Gausemeier J, Grafe M, Virtual Reality & Augmented Reality in Industry, 2011, SpringerLink, Berlin, 978-3-642-17376-9.
- Mirauda, D.; Capece, N.; Erra, U. Sustainable Water Management: Virtual Reality Training for Open-Channel Flow Monitoring. Sustainability 2020, 12, 757. https://doi.org/10.3390/su12030757.

- M. Chaudhry, "Creating Effective Virtual Reality Learning Experiences: Lessons Learned," in Education and Training in Optics & Photonics Conference 2021, A. Danner, A. Poulin-Girard, and N. Wong, eds., OSA Technical Digest (Optica Publishing Group, 2021), paper Th4A.1.
- Capece, N., Erra U.: StreamFlowVR: a tool for learning methodologies and measurement instruments for river flow through virtual reality. In: De Paolis (ed.) 6th International Conference AVR 2019, LNCS 11614. Springer, Italy (2019)

A.2.4. CYBERSECURITY IN CRITICAL WATER INFRUSTRUCTURE [NMBU]

1. Topic name

- Cybersecurity in Critical Water Infrustructure

2. Duration of the topic

- 2 hours

3. Topic content

- Critical water infrastructure
- ICS/SCADA system security
- Security threats and vulnerabilities
- Real-world cyber incidents /examples of cyberattacks
- Cybersecurity standards and regulations (e.g., NIST cybersecurity framework, EU NIS2 Directive)

4. Learning outcome

After completing this course, a learner/student will be able to:

- Develop a good knowledge of critical water infrastructure and its dependency
- Describe typical threats to modern water systems and outline techniques of defense against the threats
- Analyze critical water infrastructure and industrial control system security vulnerabilities and develop defensive measures
- Explain international cybersecurity standards and illustrate the context in which these are used to defend against cybersecurity threats
- Demonstrate an understanding of the specific regulatory and cybersecurity compliance requirements in the critical water infrastructure

5. Learning activities

- lecture(s), term paper, project work

6. Assignments

- project work, reports, refection notes
  https://www.nmbu.no/en/employees/qae/courses/forms-of-assessment

7. Assignments deadline

8. Standards and criteria for graded assignments

- letter grades
  https://www.nmbu.no/en/students/administration/grading-system

9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used

- A=5, B=4, C=3, D=2 and E=1
  https://www.nmbu.no/en/students/administration/grading-system
  https://www.nmbu.no/en/students/studentparliament/documents/node/31115

10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy

11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.

12. Reference literature
• Industrial Network Security https://www.sciencedirect.com/book/9780124201149/industrial-network-security • Guide to Industrial Control Systems (ICS) Security https://nvlpubs.nist.gov/nistpubs/specialpublications/nist.sp.800-82r2.pdf • Cyber Security for Cyber Physical Systems https://link.springer.com/content/pdf/10.1007/978-3-319-75880-0.pdf • Cyber Security for the Water Sector (https://wcwc.ca/cyber-security-for-the-water-sector/ • Infrastructure Cybersecurity: Water systems https://www.rpc.senate.gov/policy-papers/infrastructure-cybersecurity-water-systems • A Review of Cybersecurity Incidents in the Water Sector https://arxiv.org/pdf/2001.11144.pdf

A.2.5. DATA SAFETY AND STANDARDIZATION (INCL. CRASH COURSE ON OPEN DATA) [DOSCON]

1. Topic name
• Data safety and standardization
2. Duration of the topic
• 4 hours
3. Topic content
• Online databases and the communication protocols SQL NoSQL and hybridSQL • Threats to data and data sensitivity • Data security regulations • Security layers and remedies • Standardized data structures and formats
4. Learning outcome
• Can recall different database technologies and communication protocols • Can discuss different types of data, which threats they face and the damage these threats can cause • Know that there are different regulations that need to be followed for different types of data in different parts of the world • Describe steps to take for securing data and restoring data in case of data breaches • Be able to understand the function and purpose of encryption • Be able to discuss the need for standardized data structures • Be able to plan a data structure to store data and examine already existing data structures
5. Learning activities
• Lecture
6. Assignments
7. Assignments deadline
8. Standards and criteria for graded assignments
• https://www.nmbu.no/en/students/administration/grading-system
9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used
• A=5, B=4, C=3, D=2 and E=1 https://www.nmbu.no/en/students/administration/grading-system https://www.nmbu.no/en/students/studentparliament/documents/node/31115
10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy

11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.
12. Reference literature
• Data security threats https://www.sciencedirect.com/science/article/pii/S2214785322018855 • Data security regulations https://gdpr-info.eu/ https://oag.ca.gov/privacy/ccpa https://www.hhs.gov/hipaa • Data Security planning frameworks https://www.nist.gov/cyberframework https://www.iso.org/obp/ui/#iso:std:iso-iec:27000:ed-5:v1:en

A.2.6. CASE STUDIES [SUMAQUA]

1. Topic name
• Case studies using IoT and Big Data in the water sector
2. Duration of the topic
• 2 hours, in total
3. Topic content
• Different case studies showing how IoT (Internet of Things) and Big Data can support water management.
4. Learning outcome
• Insight in practical applications involving digitalization in the water sector.
5. Learning activities
• None
6. Assignments
• None
7. Assignments deadline
• None
8. Standards and criteria for graded assignments
• Not applicable
9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used
• Not applicable
10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy
• Not applicable
11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.
• During the lectures, other challenges in the water sector can be identified through interaction with students. Hereafter, a brainstorm can be done to translate the applications that are presented during the lecture into solutions for (some of the) identified challenges.
12. Reference literature
• Various publications made by the team of Sumaqua, as well as additional publications from different international scientific journals that leverage technologies for digitalization in the water sector (with a focus on IoT and Big Data)

A.2.7. DATA ASSESSMENT EXERCISES [TH OWL]

1. Topic name
• Data assessment exercises
2. Duration of the topic
• 3 teaching hours
3. Topic content
Interaction of water gauge and precipitation of different stations • Example data assessment with R (can be reproduced by the students after the lecture) • Procedure of data analysis - plausibility check - replacement of missing data by interpolation • Correlation analysis to other data - visualisation of two water gauges - correlation between data from two gauges - regression statistics for the correlation - quality check - possibility of prediction • Interaction with precipation data - scripting of data transfer from html-pages (public assess) - assessment of water gauge changes resulting from precipitation
4. Learning outcome
• Students identify access to public data • Students are able to implement simple data analysis tools • Students are able to assess data quality and interaction between data
5. Learning activities
• Application of programming language (e.g. R)
6. Assignments
• Self-learning of application of programming language
7. Assignments deadline
• Two weeks after lecture
8. Standards and criteria for graded assignments
• Working program procedure
9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used
10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy
• One repetition possible
11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.
• Understanding of lecture content • Application of lecture content to programming
12. Reference literature
• R-Handbook (open source)

A.2.8. FUTURE TRENDS [NMBU]

1. Topic name
• Future trends of big data applications in the water sector
2. Duration of the topic

• 2 hours
3. Topic content
• Adoption of advanced analytics, machine learning, and other AI technologies increase • Real-time big data analytics • Advanced predictive analytics in the water sector • Big data for improving monitoring performance and boosting efficiency • Better water quality forecasting, prediction of water demand and supply • Security and privacy for big data
4. Learning outcome
• Describe applications of big data in the water sector • Know about current research and industry trends of big data applications in the water sector • Describe how big data analytics can solve problems in the water sector and other disciplines • Optimize processes and create more accurate forecasting and predictive models • Develop a good knowledge of the security and privacy of big data
5. Learning activities
• lecture(s), term paper, project work
6. Assignments
• project work, reports, refection notes https://www.nmbu.no/en/employees/qae/courses/forms-of-assessment
7. Assignments deadline
8. Standards and criteria for graded assignments
• letter grades https://www.nmbu.no/en/students/administration/grading-system
9. Description of how the final grade will be computed with a breakdown of the ranges for each letter grade and whether or not pluses/minuses will be used
• A=5, B=4, C=3, D=2 and E=1 https://www.nmbu.no/en/students/administration/grading-system https://www.nmbu.no/en/students/studentparliament/documents/node/31115
10. Policy on late assignments, incomplete assignments, and revisions; academic integrity policy; attendance policy.
11. Expectations for classroom interaction: incorporation of active learning strategies throughout the semester in the form of group work, in-class writing assignments, etc.
12. Reference literature
• Top trends in big data for 2022 and beyond (https://www.techtarget.com/searchdatamanagement/feature/Top-trends-in-big-data-for-2021-and-beyond) • On big data, artificial intelligence, and smart cities (https://www.sciencedirect.com/science/article/abs/pii/S0264275118315968) • How can bid data and machine learning benefit environment and water management: a survey of methods, applications, and future directions (https://iopscience.iop.org/article/10.1088/1748-9326/ab1b7d) • Popular Big Data Technologies In 2022 (https://www.jigsawacademy.com/blog/data-science/popular-big-data-technologies-in-2022/) • Role of big data analytics in solving water problems (https://medium.com/@mynab247/role-of-big-data-analytics-in-solving-water-problems-728ccad41d78) • Big data in the water industry: How does it provide big value? (https://www.crayondata.com/big-data-in-the-water-industry-how-does-it-provide-big-value/#:~:text=The%20Benefits%20That%20Big%20Data%20Can%20Offer%20the%20Water%20Industr

y&text=Predictive%20maintenance%20strategies%20can%20leverage,costly%20downtime%20or%20machine%20failure.)

- Big data analysis for studying water supply and sanitation coverage in cities (Russia) (https://www.revistaespacios.com/a19v40n27/a19v40n27p21.pdf)
- Harnessing the Fourth Industrial Revolution for water (https://www.weforum.org/reports/harnessing-the-fourth-industrial-revolution-for-water/)
- An overview of bid data applications in water resources engineering (https://www.researchgate.net/publication/334710343_An_Overview_of_Big_Data_Applications_in_Water_Resources_Engineering)
- Security and privacy for big data (https://www.routledge.com/Trust-Security-and-Privacy-for-Big-Data/Alazab-Gupta/p/book/9781032047508#)