UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Advanced Data Management and Decision Support Systems

2627-1-F9103Q008

Aims

Module Data Management
The aim of the data management module is to introduce the main conceptual and theoretical tools to manage data. The aim is four-fold: Provide students with the practical and theoretical foundations of data management systems, including issues of data distribution; Illustrate and introduce the main paradigms to structure, store and manipulate data (including both relational and the most important noSQL paradigms); Provide a solid foundation to the basic concepts of large-scale data processing; Introduce the main concepts in modern data governance, data quality and engineering.
At the end of the course, students should have acquired and should be able to prove and communicate sufficient knowledge in the above mentioned topics, in particular (DdD1, DdD4):

- Data management systems' design principles
- Conceptual, logical and physical models for data management
- Data management principles in distributed settings (replication, sharding, distributed consensus solutions, transactions)
- Foundations of large-scale data processing (MapReduce/Hadoop, Spark)
- Foundations of data governance and data engineering

They should also have acquired the ability to apply the taught notions in practical contexts, in particular (DdD2):

- Ability to translate user requirements in data models and how to practically implement these latter
- Ability to practically manage data using different query and data models (SQL, Cipher)
- Ability to implement large-scale data processing pipeline, using tools such as Apache Spark

Finally, they should have reached a sufficient maturity enabling them to autonomously understand up-to-date development in data-management (DdD5), as well as the capacity to critically evaluate different data management solutions, their benefits and limitations (DdD3).

Module Decision Support Systems

The aim of the course is twofold: on the one hand, to introduce students to the main conceptual and theoretical tools to model rational choices in decision making; on the other hand, to provide students with models and tools to design usable (i.e., effective, efficient and easy-to-use) decision support systems and evaluate them in the real world.

At the end of the course, students should have acquired and should be able to prove sufficient knowledge in the above mentioned topics, in particular (DdD1, DdD4):
- Models and definitions of decision-making
- Theoretical foundations of decision making
- Automation of decision making processes
- Quality dimensions of decision support systems: usability, trust, dependence, compliance, reliance

They should also have acquired the ability to apply the taught notions in practical contexts, in particular (DdD2):
- Ability to formally define and analyze decision-making scenarios
- Ability to design decision support systems
- Ability to evaluate decision support systems

Finally, they should have reached a sufficient maturity enabling them to autonomously understand up-to-date developments in decision-making and related disciplines (DdD5), as well as the capacity to critically evaluate different decision support sytems, their benefits and limitations (DdD3)...

Contents

Module Data Management
Basics of modern data management
Relational and NoSQL data and query models
Distributed data management
Distributed data processing

Module Decision Support Systems
Decision Support Systems principles and design
Elements of formal decision theory: single agent, multi-agent, sequential.
Elements of behavioral decision theory: bounded rationality, heuristics, biases
Evaluation principles for Decision Support Systems

Detailed program

Module Data Management
Basics of Data Management systems (erogative lesson, 1h)
Data Management system design principles: reliability, scalability, maintainability (erogative lesson, 1h)
Data models (relational, key-value, document, graph) and query languages (erogative lesson, 2h)
- Conceptual data model (Entity Relationship model)
- Logical data models (relational, key-value, document, graph, vector embedding)
- Physical data models and storage formats
Practical usage of Relational DBMS and SQL (laboratory lesson, 4h)

Practical usage of NoSQL DBMS (Redis, MongoDB, Neo4J) (laboratory lesson, 4h)
Transactions and ACID properties (erogative lesson, 2h)
Distributed data management (replication, sharding, consensus) (erogative lesson, 4h)
Distributed data processing (MapReduce, Hadoop, Spark) (erogative lesson, 2h)
Practical usage of Apache Spark (laboratory lesson, 4h)
Principles of Data Governance, Data Security and Responsible Data Engineering (erogative lesson, 4h)

Module Decision Support Systems
All lessons are in erogative form.

- Foundations of Decision Support Systems (4h)
  Definitions of Decision Support Systems
  DSS Architectures
  DSS Design Principles
- Decision-Making and Expected Utility Theory (4h)
  Single-Agent Decision Theory (Decision under Ignorance, Decision under Risk)
  Computational Aspects of Decision-Making (Bayesian Networks, Decision Networks)
- Non-cooperative Game Theory (4h)
  Solution Concepts (Pareto optimality, Nash equilibria, Minimax/Maximin solutions, Correlated equilibria)
  Computational Aspects of Game Theory (Algorithms and Computational Complexity)
  Basics of Mechanism Design
- Sequential Decision-Making and Reinforcement Learning (4h)
  Markov Decision Processes and Dynamic Programming
  Basics of Reinforcement Learning (Exploration-Exploitation Trade-off, Q-learning)
  Search and Planning (Monte Carlo Tree Search)
- Foundations of Alternative DSS Approaches (4h)
  Knowledge-based DSS (Knowledge bases, Inference Engines)
  Conversational and Generative AI-based DSS
- Behavioural Decision Theory, Heuristics and Biases (4h)
  Bounded Rationality
  Heuristics
  Biases
  Ecological Rationality and Naturalistic Decision Making
  Prospect Theory
- Evaluation of Decision Support Systems (4h)
  Quantitative Evaluation Principles (Accuracy and Decision Quality Metrics, Experimental Design)
  Beyond Quantitative Metrics (Robustness, Fairness, Explainability)
  Human-DSS Interaction Quality

Prerequisites

Module Data Management
Basic notion of the relational model, SQL query language

Module Decision Support Systems
Basic notions of probability theory and artificial intelligence, mathematical maturity

Teaching form

Module Data Management
Class-room taught classes (16h), computer-based programming exercises (12h).
All lessons will be held in presence.

Module Decision Support Systems
Class-room taught classes.
All lessons will be in erogative form.
Lessons will be held in presence.

Textbook and teaching resource

Module Data Management
Slides presented by the teachers.

(Suggested) Textbooks
Kleppmann, Martin. Designing Data-Intensive Applications: The Big Ideas Behind Reliable, Scalable, and Maintainable Systems. Sebastopol, CA: O'Reilly Media, 2017. ISBN: 978-1449373320.
Silberschatz, Abraham, Henry F. Korth, and S. Sudarshan. Database System Concepts. 7th ed. New York: McGraw-Hill Education, 2019. ISBN: 978-0078022159.
van Steen, Maarten, and Andrew S. Tanenbaum. Distributed Systems. 4th ed. CreateSpace Independent Publishing Platform, 2023. ISBN: 978-1718502642.
Karau, Holden, Andy Konwinski, Patrick Wendell, and Matei Zaharia. Learning Spark: Lightning-Fast Data Analytics. 2nd ed. Sebastopol, CA: O'Reilly Media, 2020. ISBN: 978-1492050049.
Redmond, Eric, and Jim R. Wilson. Seven Databases in Seven Weeks: A Guide to Modern Databases and the NoSQL Movement. 2nd ed. Raleigh, NC: Pragmatic Bookshelf, 2018. ISBN: 978-1680502534.

Additional materials, readings and resources will be available on the e-learning platform.

Module Decision Support Systems
Slides presented by the teachers.

(Suggested) Textbooks
Peterson, Martin. An Introduction to Decision Theory. 2nd ed. Cambridge: Cambridge University Press, 2017. ISBN: 978-1107151598.
Shoham, Yoav, and Kevin Leyton-Brown. Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations. Cambridge: Cambridge University Press, 2008. ISBN: 978-0521899437.
Kochenderfer, Mykel J., Tim A. Wheeler, and Kyle H. Wray. Algorithms for Decision Making. Cambridge, MA: MIT Press, 2022. ISBN: 978-0262047012.
Wickens, Christopher D., Justin G. Hollands, Simon Banbury, and Raja Parasuraman. Engineering Psychology and Human Performance. 5th ed. New York: Routledge, 2021. ISBN: 978-1138087514.
Gigerenzer, Gerd. Rationality for Mortals: How People Cope with Uncertainty. Oxford: Oxford University Press, 2008. ISBN: 978-0195171143.
Russell, Stuart. Human Compatible: Artificial Intelligence and the Problem of Control. New York: Viking, 2019. ISBN: 978-0525558613.

Additional materials, readings and resources will be available on the e-learning platform.

Semester

2nd semester

Assessment method

Module Data Management
The module has two different (exclusive) exam modalities, that can be selected by the student in accordance with the teacher:

Written exam (open questions) to ascertain understanding of the concepts taught in class.
The students will have to answer to 5 open questions on the contents of the course (all taught contents can be in the exam), where they will be asked to critically discuss different aspects of data management systems. Each question can be graded up to 6 points based on the following requirements: completeness (the student has exhaustively answered to all of the question elements), correctness (the student's answer is correct), communication (the student has demonstrated the ability to think critically about different aspects of the discussed topic).

OR

Project related to the topics of the module AND oral exam to ascertain understanding of the concepts taught in class.
The project can be performed in small groups (up to 2/3 persons, depending on the project) but the oral exam is individual.
The project can be graded up to 24 points based on the following requirements: completeness (the student(s) has exhaustively answered to all of aspects of the project assignment), correctness (the student(s) implementation is correct and exempt of errors), communication (the student(s) has demonstrated the ability to reason critically and report about the produced implementation).
The oral exam consists of three questions on the contents of the course (all taught contents can be in the exam), each of which can be graded up to 3 points.

The module does not have any in-progress tests.

Module Decision Support Systems
Written exam (open questions) to ascertain understanding of the basic concepts taught in class and their relationships (max. grade mark 30).
The students will have to answer to 5 open questions on the contents of the course (all taught contents can be in the exam), where they will be asked to critically discuss different aspects of data management systems. Each question can be graded up to 6 points based on the following requirements: completeness (the student has exhaustively answered to all of the question elements), correctness (the student's answer is correct), communication (the student has demonstrated the ability to think critically about different aspects of the discussed topic).

The course also offers the students the possibility to conduct an optional original essay for students with a written exam grade >= 18 (max. additional 4 points)

Office hours

Module Data Management
Available by appointment (email: andrea.campagner@unimib.it).
Module Decision Support Systems

Available by appointment (email: andrea.campagner@unimib.it).

Sustainable Development Goals

QUALITY EDUCATION