Uncertainty Representations and Reasoning

A course on uncertainty modeling beyond probability theory

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Thanks go to Cassio de Campos and Vu-Linh Nguyen for their support during the development and running of the course

EINDHOVEN UNIVERSITY OF TECHNOLOGY

Course overview

Goal

Introduction to uncertainty modeling approaches
that go beyond classical probability theory

General information

- Elective in TU/e's Data Science & Artificial Intelligence Master program
- Study load: circa 140 hours (5 ECTS)
- First edition in 2022–2023 Q1 (Sep–Nov)
- Students: circa 40, all familiar only with classical probability and statistics

Learning activities

Theory
- Lectures
- Practice exercises

Assignment
- Literature study (report)
- Poster presentations

'Instructions'
- Explanation course organization
- Q&A lectures, exercises, assignment

Schedule overview

- Quartile = 8 contact session weeks + 2 exam weeks
- Contact sessions:
  - 16 sessions total: 2/week, each 2 blocks of 45 minutes (3 hours/week)
  - lectures (18 blocks); instructions (6 blocks); poster presentations (8 blocks)

Sessions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Blocks	L	L	L	L	L	L	P	P	L	L	L	L	L	P	P	I
	I	L	I	L	L	I	P	P	L	L	L	L	I	P	P	I

- Exam: 3 hours; resit possibility during exam week of next quartile

Grade composition

50/50 for assignment/exam

Support options

- Q&A sessions and lecture breaks
- Online Forum
- Direct message to lecturer

Assignment

Goal

Understand and explain to fellow students how different uncertainty modeling approaches each can deal with a specific application topic

Application topics

- Classification
- Clustering
- Decision trees
- Markov chains
- Graphical models

Organization

Setup
- Done in pairs
- In parallel to lectures

Deliverables
- Report
- Poster

Literature to digest
- Provided: 4–7 papers/topic (1+/approach)
- Other texts also allowed

Report template summary

Title
Authors
Abstract
Data+code availability
Contributions
Acknowledgements

Introduction
introduce topic, context, motivation, report overview

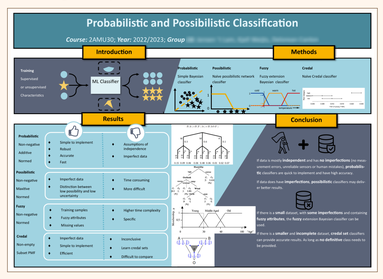
Literature discussion
conceptual discussion, key contributions, relevance

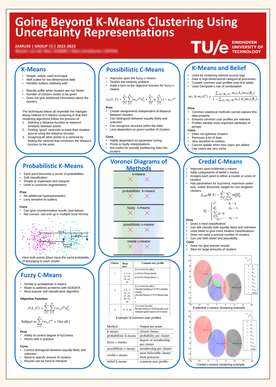
Theory
unified presentation, math, illustration, examples

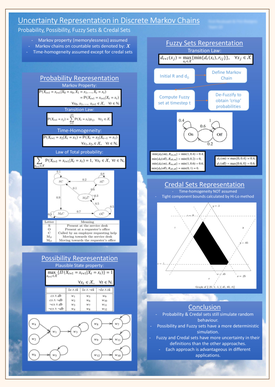
Conclusions
advantages, limitations, recommendations

Poster examples

Thanks go to the students that gave permission to use their poster







Assessment

- Formative: Midterm (session 7–8)
- Summative: Final (session 14–15)
- Peer review by fellow students using rubrics
- Good participation was important (24%)

Rubrics summary

Scale			Problematic 0 points	Insufficient 2 points	Sufficient 3 points	Good 4 points	Excellent 5 points
Report	Structure	7.5%	presence and quality of structure and structuring elements (sectioning, paragraphs, lists, tables, figures)				
	Clarity	20%	degree to which the content is explainable by the reader based on a reading (argumentation steps, examples, illustrations)				
	Language	5%	quality of grammar, spelling, and formulation				
	Notation	5%	introduction and appropriate choice/use of formal notation				
	Mathematics	7.5%	presence, clarity, and integration of math expressions in the text				
	Referencing	5%	degree text is supported by sufficient on-topic references; completeness of entries				
Poster	Balance	6.5%	balance between text/math and illustrations/examples; suitability for live explanation (storyline, key takeaways)				
	Presentation	6.5%	degree of preparation and capability to answer questions				
#Approaches		13%	number and coverage of unc. modeling approaches (aim = 4)				

Observations

- Participation was generally enthusiastic
- Most pairs kept to the literature provided
- Pairs often struggled to integrate material from papers using approaches discussed towards the end of the lecture series

Lectures, Exercises, and Exam

Goal

For each of the uncertainty modelling approaches discussed:
- know and understand the foundations & interpretations
- obtain the skills to solve basic inference and decision problems

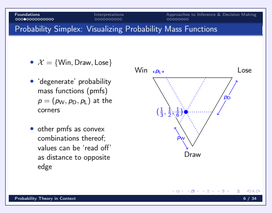
Lecturing approach

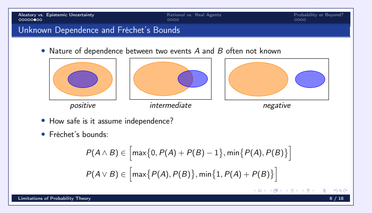
- Theory lectures in classical style
- Illustrative examples mixed in
- Successful opportunities for interaction
  - Students were encouraged to interrupt
  - Activating questions from lecturer

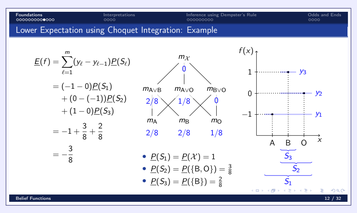
Lecture topics & Uncertainty modeling approaches

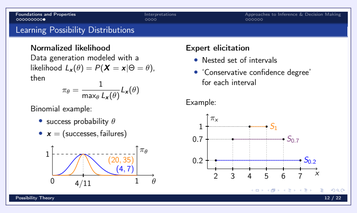
1. Probability (classical)
2. Limitations of probability (arguments to go beyond)
3. Belief functions
4. Possibility
5. Fuzzy sets
6. 2-Monotone capacities
7. Probability intervals
8. Credal sets
9. Interval expectation ('prevision' mentioned)

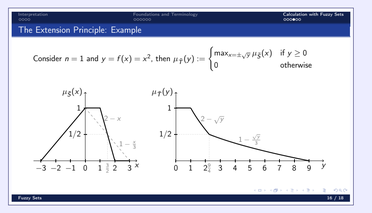
An example slide from each of the lectures

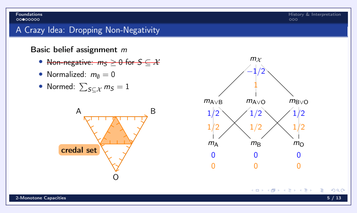


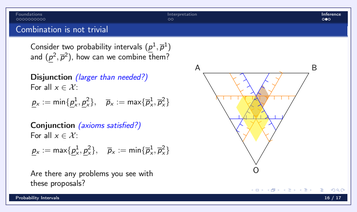


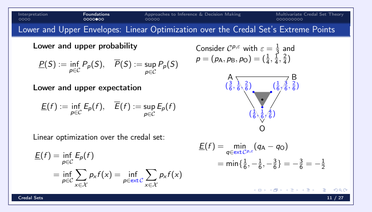


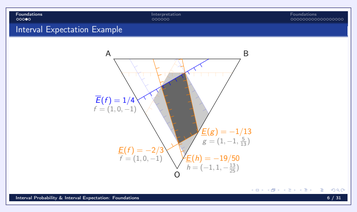










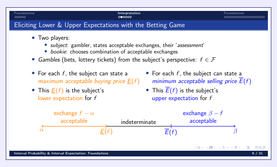


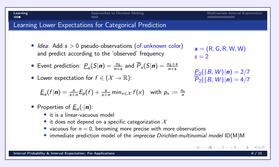
Much of the actual content was inspired by materials from the SIPTA Schools

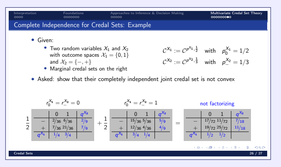
Focus areas

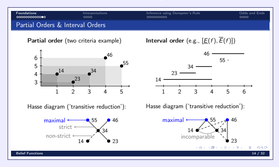
Each approach is discussed in generally the same way:
- Foundations: basic concepts & axioms
- Interpretation
- Inference: obtaining values/bounds
- Learning models from data (sometimes)
- Multivariate models (often)
- Decision making (often)

Some focus area example slides









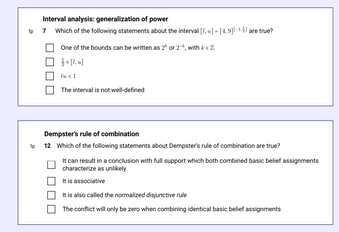
Practice exercises

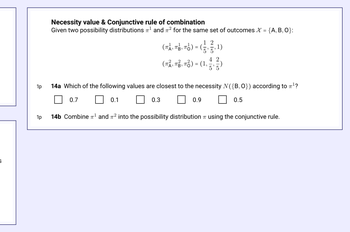
- On-line quiz per lecture (ungraded, repeatable)
- Automated feedback and model answers
- Students generally did not participate in a timely manner
- Multiple-choice and open questions
- Theory and calculation questions

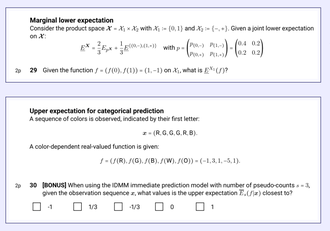
Exam

- 30 questions (multiple-choice and open)
- Practice exercises were mostly representative of exam questions
- Level of attainment expected on beforehand was not achieved in general

A few exam questions







Problems, Challenges, and Plans

Goal (*for us teachers, this time*)

Get feedback to improve the course in the coming years

More attention to practice exercises

Problem Exam results showed a lower-than-aimed-for proficiency solving exercises

Challenge How do we get students to make the practice exercises in a timely manner?

Plan Make the practice exercises a more integrated part:
- Incentivize by making them count for the grade
- Create dedicated practice exercise Q&A blocks
- Create time by removing content
  But which content?

Providing more didactic literature

Problem Reports & poster presentations showed that many students encountered difficulties understanding the content of a good deal of the provided literature

Plan Improve the list of provided literature

Challenge Where do we find a sufficiently broad set of *didactically written* papers?