Quantum logic and information processing

Academic Year: (2023 / 2024) **Review date: 24/04/2023 11:34:17**

Department assigned to the subject: Signal and Communications Theory Department

Coordinating teacher: BOUSOÑO CALZON, CARLOS

Type: Electives ECTS Credits : 3.0

Year : 2 Semester : 1

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

Introduction to Quantum Mechanics
Fundamentals of Machine Learning (desirable)

OBJECTIVES

To give the student a new perspective on data analysis (textbases, experiment results, questionnaires) that facilitates creativity for research in multidisciplinary fields.
To this end, a non-classical probabilistic model is introduced to explain phenomena considered "anomalous" or not "rational" in the traditional literature (e.g. Tversky and Shafir).
These mathematical models are non-Boolean logic-based, with a final structure that allows the use of conventional tools in quantum mechanics, which is why we usually call them "quantum-like."

DESCRIPTION OF CONTENTS: PROGRAMME

1. Why do we need non-classical probabilistic formalisms in data analysis and modelling? Paradoxes in experiments, main concepts in broader probabilistic paradigms, and research opportunities.

2. A first approximation into this subject: Experiments in cognition. Disjunction effect. Conjunction fallacy. Probability interference.

3. Some account of Mathematical tools: Lattices and Logic (Classical vs. Quantum). Hilbert space tools (States, Gleason's theorem, and non-unitary system evolution).

4. An interesting line: Concepts composition and vectorial text embedding in NLP (BERT, GPT4): Contexts, individual mental spaces, and collective spaces.

5. Some fun with Game Theory: Decision Making and Strategic games with incomplete information.

6. Some other possible excursions:
    6.1 Formal Concept Analysis
    6.2 Simplicial complex lattices: Chaotic dynamical attractors
    6.3 Second quantization -from scratch- in social applications
    6.4 Implementation on Quantum Computers

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LEARNING ACTIVITIES AND METHODOLOGY

- Focus on applying the introduced models in various multidisciplinary applications: finance, health, risk management, geostrategy, ecosystems, or conflict management, through the student's choice of their deliverables.

- Conducting experiments and games in the classroom to understand and evaluate the concepts.

- Use of mathematical models as simple as possible: the Hilbert spaces used are of finite dimension so that the spectra of the operators are eigenvalues, avoiding the introduction of projection valued sigma-measures and Finite Lattices.

- Different analytical perspectives are presented: probabilistic/algebraic to allow understanding of the subject.

- Links with other fields of knowledge will be established to allow the development of multidisciplinary research.
    - Text embedding (BERT. GPT4)
    - Formal Concept Analysis
    - Simplicial complexes in signal processing and chaotic dynamical attractors.

ASSESSMENT SYSTEM

% end-of-term-examination/test:	10
% of continuous assessment (assigments, laboratory, practicals…):	90

The main deliverable consists of a paper written by the student where he/she has to apply the models in this course to a subject of his/her choice. The format is that of a journal paper. (90%)
A final test at the end of the course will gauge the main concept of the course. (10%)

BASIC BIBLIOGRAPHY

- Busemeyer, J. R., & Bruza, P. D. Quantum models of cognition and decision., Cambridge University Press, 2012

- Khrennikov, A. Ubiquitous quantum structure., Springer., 2010

- Van Rijsbergen, C. J. The geometry of information retrieval, Cambridge University Press, 2004

ADDITIONAL BIBLIOGRAPHY

- Binmore, Ken Fun and Games. A text on game theory, DC Heath, 1992

- Cohen, D. W. An introduction to Hilbert space and quantum logic, Springer Science & Business Media., 2012

- Halmos, P. R. Introduction to Hilbert space and the theory of spectral multiplicity., Courier Dover Publications., 2017

- Haven, E., Khrennikov, A. Y., & Robinson, T. R. Quantum methods in social science: A first course, World Scientific Publishing Company, 2017

- Holevo, A. S. Statistical structure of quantum theory , Springer Science & Business Media, 2003

- Rédei, M. Quantum logic in algebraic approach, Springer Science & Business Media., 2013

BASIC ELECTRONIC RESOURCES

- Chris McCormick . BERT Word Embeddings Tutorial: https://mccormickml.com/2019/05/14/BERT-word-embeddings-tutorial/#what-is-bert