KRR - MOD2 - 2021-2022
Detailed Syllabus

A - Acronyms, remarks and evaluation

Acronyms and abbreviations

KRR = Knowledge Representation and Reasoning
KG = Knowledge Graph
RDF = Resource Description Framework
RDFS = RDF Schema
OWL = Ontology Web Language
DL = Description Logics
ASP = Answer Set Programming
NER = Named Entity Recognition
NEL = Named Entity Linking

Remarks

Some explanations about the syllabus:

- Topics: list all the topics that have been explained in the course;
  - some topics have been only introduced and can be considered more as extensions of the course material - of course you are not expected to be asked detailed questions around these topics (they are indicated with a tag "(pointers)"
  - some topics have been explained during the exercise lessons (they are indicated with a tag "[e]"
- Exercices: list of (types of) exercises made in class, which can all appear in the test
- Questions: list of more general questions that we expect you can answer; the list is not exhaustive but presents examples of soft knowledge that we hope you have acquired during the course. The test will contain an open question (2 points) that will be based on the reported or similar questions; because of how the scores are structured, you may interpret this as an "extra" question to get the maximum score in the test

Syllabus and evaluation

The evaluation is based on a written test and on project-based assignments, which are intended to replace the oral exam (not included in the evaluation) as a means to complement and increase the cold test scores. The final score is the result of the following score structure:

- Test: up to 31 points (31 = 30/30 with laude):

    - 29 points for exercises and technical questions (6, 2 for each technical session) - all of them can be answered based on main bibliographic references for the course
    - 2 points for an extra broad question that addresses soft knowledge - most of them can be better answered based on messages delivered during the lessons
- Assignments: up to 4 + 1 extra points, intended as substitute for oral test
    - 2 points for the ontology modeling assignment based on Protégé (mid-term evaluation - passed)
    - 2 points for the KG construction assignment + 1 more points for really outstanding projects (submission due to June 15th)

B - Syllabus

1. Introduction - AI and KRR

- ### Topics
    - The many facets of intelligence
    - Reasoning and inference
        - valid vs. justified inferences
    - Some challenges of AI today and the role of KRR (pointers)
- ### Excercises
    - NO

2. Knowledge Graphs & Data Management

- ### Topics
    - The KG abstraction
        - Factual information vs. documents on the web
        - Applications
        - Minimal KG definition
        - Dual interpretation (graph vs. statements)
        - Property graph vs directed edge-labeled graph models
    - RDF syntax and semantics
        - The Semantic Web stack
        - URI, URL, IRI
        - Turtle syntax
        - Blank nodes
        - Literal and typed literals
        - RDF semantics and entailment [e]
        - Reification [e]
    - SPARQL
        - Syntax and semantics
            - Query structure
            - ASK, SELECT, DESCRIBE, CONSTRUCT
            - Modifiers, optional values, union [e]
            - Path queries
- ### Exercises [2]
    - Modeling knowledge in RDF
        - Simple RDF semantics
            - Satisfiability (e.g., prove that every RDF graph is simply satisfiable)
            - Entailment
        - Statements in RDF from specifications
    - Querying data in RDF

        - SPARQL query writing: write queries based on specifications; compute results of input queries + graph
            - Basics and triple patterns
            - Modifiers
            - Optional values
            - Union
            - Path queries
            - Ask, describe and construct
- Questions
    - Essential requirements for KGs
    - Property graph vs directed edge-labeled graph models (pros vs cons)
    - Lexical ontologies vs. taxonomies vs. axiomatic ontologies
    - Difference between mereologies and is-a relations

3. Knowledge Graphs & Reasoning

- Topics
    - From vocabularies to ontologies
        - Shared vocabularies
        - Social semantics and Schema.org
        - How to define a vocabulary (pointers)
        - Lexical ontologies, taxonomies and axiomatic ontologies
        - Is-a vs part-of relations
        - Axiomatic ontologies: axioms as constraints on the meaning of the terms in the vocabulary (ontological commitments)
    - RDFS
        - Main primitives introduced in RDFS
        - RDFS semantics via inference rules (main rules)
        - Reasoning with RDFS
        - Limitations of RDFS
        - Satisfiability and entailment for RDFS [e]
    - OWL 2
        - Main features of OWL 2
            - OWL 2 ontology structure and profiles
            - OWL 2 knowledge base definition from DL
            - Property axioms, disjointness
            - The concept and property lattices
            - Protégé Ontology Editor
        - The DL behind OWL 2: SROIQ
            - Complexity and families of DL languages
            - Syntax and semantics (full)
            - Inference tasks
            - Open World Assumption vs Closed World Assumption
            - Unique Name Assumption
            - Examples of reasonsers

- Exercises [2]
  - Modeling knowledge in RDFS [1]
    - RDFS Semantics:
      - Entailment
    - Statements in RDFS from specifications
  - Modeling knowledge in OWL [1]
    - Statements in OWL (DL syntax) from specifications
    - OWL inferences and OWA: give examples of what can and cannot be inferred from an OWL ontology
- Questions
  - Materialization vs. query-time inference
  - Impact of complexity of reasoning tasks in the choice of a DL (you are not asked to know the complexity map in its details, but you are expected to understand the rationale behind it)
  - Open World Assumption and real-world KGs

4. Declarative Problem Solving, Logic Programming & Nonmonotonic Reasoning

- Topics
  - Logic Programming and Non-monotonic Reasoning
    - Overview and syntax
    - Background: partial orders and extremals
  - Datalog:
    - Syntax and semantics
    - User's view vs computer's view of semantics
    - Queries and answers
    - Proof systems
      - Unification
      - Bottom-up & top-down procedures
      - Fixed points
    - Applications of datalog
  - Non-monotonic Reasoning:
    - Limitations of First Order Logic
    - Default reasoning
    - Closed World Assumption
    - Frame problem
    - Default logic and multiple extensions
  - ASP
    - Syntax
    - Normal logic programs and Non-monotonic reasoning

            - Semantics: grounding, Herbrand universe and Herbrand base
            - Stratification (pointers)
            - Gelfond-Lifschitz transformation
            - Semantics (full)
            - Recursion with negation
            - Brave and cautious reasoning
        - Extended logic programs and true negation
            - Semantics: Herbrand literal base
            - Semantics (full)
            - True negation vs classic negation
        - Disjunctive logic programs and constraints
            - Multiple answer sets: negation vs. disjunction
            - Constraints
            - Semantics (full)
            - Guess and check methodology
        - Extensions: (pointers)
            - Weak constraints
            - guess check optimize methodology
            - Summary of reasoning tasks and DLV architecture
            - Aggregate functions in DLV
- ## Exercises [2]
    - Datalog (with DLV):
        - Unification without function symbols
        - Bottom-up & top-down procedures
    - ASP + Disjunction and NAF:
        - Compute answer sets of given programs (herbrand/literal base, Gelfond-Lifschitz transformation, condition check)
        - Write a KB from specifications:
            - recursive rules
            - rules with disjunction
            - default reasoning
            - Guess & check from specifications
- ## Questions (not covered by exercises) [2]
    - Declarative problem solving
    - Guess, Check, Optimize

5. More on KRR for AI

- ## Topics
    - How to build a KB
        - Data linking
        - Mapping relational databases to RDF
        - Semantic table annotation

            - Natural language processing tasks: NER, NEL, relation extraction
        - KRR and AI challenge (reprise)
            - Distributional semantics
            - Representation learning (intuition)
                - Deep Neural Networks
            - Neuro-symbolic integration

- ## Exercises
    - NO

- ## Questions
    - NER, NEL, relation extraction for building KBs from texts
    - Differences between representation learning and knowledge representation approaches
    - Principles of distributional semantics as opposed to logic-based semantics