Representing and Reasoning about Unknown Environments

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Outline

- Introduction
  - *WP3 Goals*
  - *WP3 Tasks & Deliverables*

- Part I: Phoenix Knowledge Base (D3.1, 3.2)
  - *Knowledge Representation in Phoenix*

- Part II: Human Interface Layer (D3.4, 3.5)

- Part III: Methodologies
  - *Knowledge Elicitation (D3.1)*
  - *Knowledge Representation (D3.2)*
  - *Knowledge Representation Techniques (D3.3)*
  - *Ontologies (D3.2, 3.1)*
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WP3 Goals

- The goal of WP3 is to develop a *knowledge base* that will include a body of knowledge needed for exploration tasks in Phoenix
- An exploration task starts with the user question that may include their *initial knowledge* and *objective*
- The initial knowledge and the objective are extracted from the question via the *Human Interface Layer (HIL)*, and updated during the ongoing user interaction and exploration task
- The knowledge base includes the procedural knowledge of the experiments that is used to achieve the objective
- If such procedural knowledge is unavailable, it is possible to use an *Artificial Intelligence (AI) planner* that can generate possible experiments starting from the initial knowledge to achieve the objective using the knowledge base

WP3 Tasks

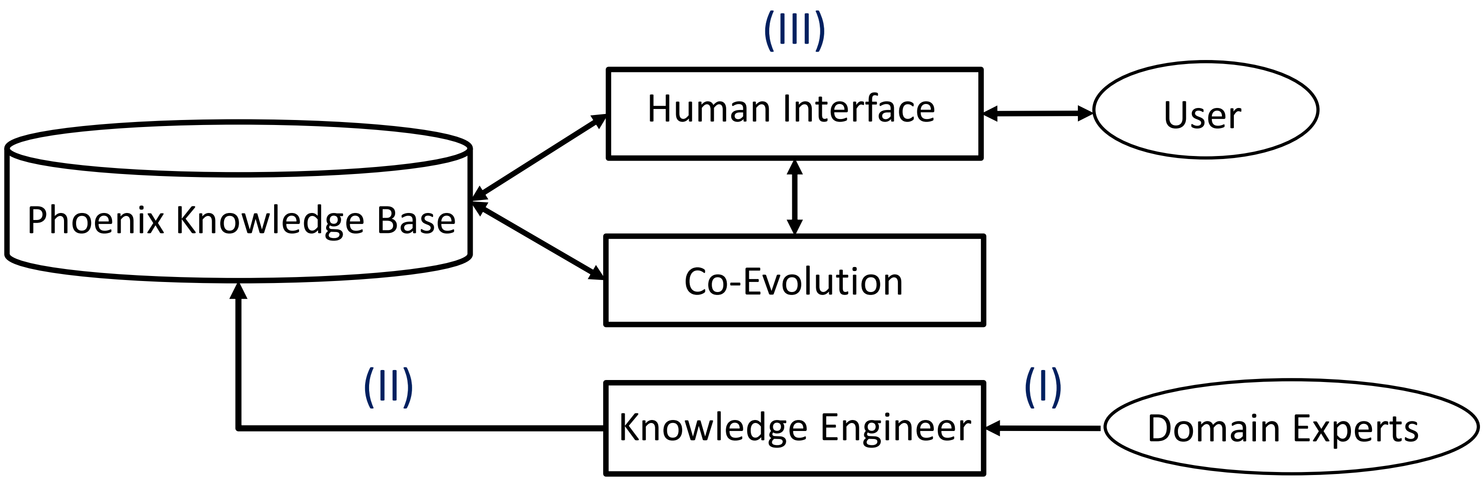

Figure 1: Main tasks in WP3 (I), (II) and (III) are illustrated.

(I) Knowledge Elicitation (3.1) is the process for acquiring the knowledge from the domain experts. This process is performed by the knowledge engineers using a number of methods (detailed in #12).

(II) Knowledge Representation (3.2) is the process for structuring and representing the acquired knowledge in a machine-processible format. The representation describes the world and provides intelligent reasoning (detailed in #13).

(III) Human Interface Layer (3.4, 3.5) is a medium between the user and the Phoenix that allows the knowldge exchange (detailed in #9).

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Knowledge Representation in Phoenix

- The Phoenix knowledge base consists of concepts, individuals, relations, properties, and rules
  - Concepts refer to the classes of things that exist in a domain
  - Individuals are instances of the classes
  - Relations describe how classes relate to one another (e.g. 'isa' relation defines subsumption relation between different classes, WaterChannel is a subclass of Environment)
  - Properties define the attributes of the classes
  - Rules if-then statements that define the logical inferences can be drawn
- In **Figure 2** shows only the concepts, properties and their relations:
  - Environment, WaterChannel are concepts that represent entities in real world
  - 'isa' relation indicates subsumption (e.g. WaterChannel subclass of Environment)
  - Length is a property that defines certain aspects of the concept WaterChannel
  - All other relations are used in their intensional meanings

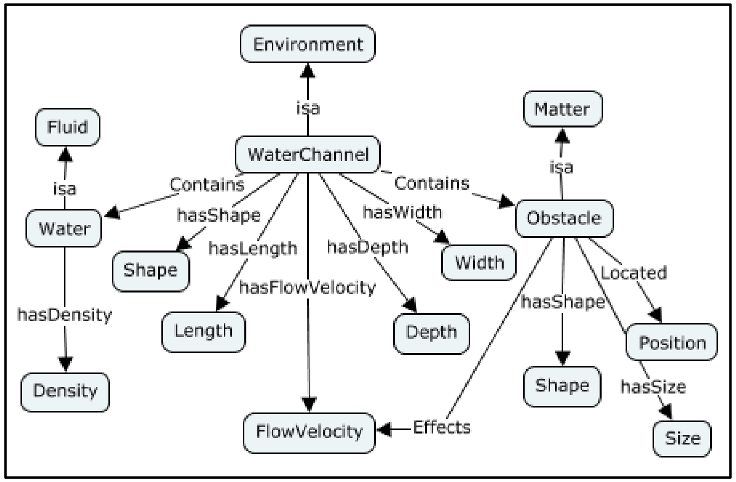

Figure 2: An example graph representation of the knowledge about the water channel environment

The Key Roles of the Phoenix Knowledge Base

The knowledge base is key for the following:

- Parsing the user input, and recognizing the initial knowledge and objectives of the user:
  - Used the concept in the knowledge base and concept matching algorithms in Human Interface Layer
- Deducing experiments that can achieve the user's objective starting from the initial knowledge:
  - Used the procedural knowledge stored in the knowledge base
- Identifying the additional knowledge that is required to perform an experiment:
  - Procedural knowledge includes domain concepts and their properties which requested from the user taht is specified in a procedural knowledge
- Suggesting agents that can be used for the exploration task:
  - Knowledge base specifies the relations between the agent and environment concepts; thus, selection from one influences another in co-evolution phase
- Deducing the unknown parameters of the environment based on experiment results:
  - The result of an experiment provides information about some of the agent and environment properties in post processing phase

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Human Interface Layer (HIL)

- Human Interface Layer (HIL) is a medium for the knowledge exchange between the user and the Phoenix system
- The interaction starts with the user's question which is processed with string matching algorithms to recognize the concepts that match to the knowledge base
- The concepts recognized in the user's question constitute the initial knowledge and objective that the user may possess
- The goal is to identify experiments that achieve the objective of the user starting from the initial knowledge. These experiments are specified in the knowledge base
  - Based on the user's question, we hypothesize about the objectives of the user and suggest procedures that can achieve these objectives
  - Selecting a suggested experimental procedure may require additional input from the user, thus provide more information for a correct experiment design
  - As the suggested procedures are performed, the knowledge about the exploration task is modified
  - Complex objectives may be decomposed into sub-objectives that can be achieved by performing multiple experiments depending on the feedback loops between the experiment results

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Part III: Methodologies

- This section describes the methods that are used in each task involved in WP3
- We discuss knowledge elicitation methods, knowledge representation techniques, and a challenging aspect of WP3 that is to include uncertainty in the knowledge elicitation, representation and reasoning

Knowledge Elicitation

- Knowledge elicitation is the process of acquiring the required knowledge for an exploration task
- Various techniques have been developed based on the types of the knowledge required elicited, namely, *interviews, protocol analysis, concept sorting, grids, concept and process mapping*[1]
- Expert disagreements, or probabilistic expert elicitation introduces uncertainties in knowledge
- Automatic knowledge extraction methods are increasingly being adopted for building knowledge bases[2]; these methods cause uncertainties in knowledge due to the limitations in knowledge extraction tools

[1]*Shadbolt, N. R., & Smart, P. R. (2015). Knowledge Elicitation : Methods , Tools and Techniques. Evaluation of Human Work.*

[2]*Dong, X. L., Gabrilovich, E., Heitz, G., Horn, W., Lao, N., Murphy, K., … Zhang, W. (2014). Knowledge Vault : A Web-Scale Approach to Probabilistic Knowledge Fusion, 601–610.*

Knowledge Representation

- Roles of Knowledge Representation[1]:
  - *substitutes the objects and concepts in real word*
  - *requires ontological commitments that focus on certain aspects and ignore the others*
  - *is a mean to draw inferences; thus, provides intelligent reasoning*
  - *provides environment for efficient computation that reasoning is performed*
  - *is a medium of human expression*

[1]Davis, R., Shrobe, H., & Szolovits, P. (1993). What is a knowledge representation? AI Magazine, 14(1), 17–33.

Knowledge Representation Techniques

- *Semantic Networks:* used for propositional information. They are represented as directed graph consisting of nodes, edges and edge labels defining concepts, relations and relation semantics
- *Frames[1] & Scripts[2]:* convenient structures for representing objects that are typical to a stereotypical situation. Useful for representing common sense knowledge. An object is defined by a set of slots (properties). A value of a slot may be another frame.
- *Logic:* formal language that is defined by the syntax and semantics; it allows reasoning
- *Production Systems:* condition-action pairs (IF <condition> THEN <action> clauses) that define a condition, if it is satisfied, the production rule "fires", and the action is carried out. Suitable for representing procedural knowledge
- *Ontologies:* define formal terminologies of concepts and their relations that exist in a domain (detailed in #15)

[1]*Minsky, Marvin (1974), A Framework for Representing Knowledge, MIT-AI Laboratory Memo 306.*

[2]*Schank, R. C., & Abelson, R. P. (1975). Scripts, Plans, and Knowledge. Proceedings of the 4th International Joint Conference on Artificial Intelligence, 151–157.*

Ontologies

- Define semantically enriched information in a domain
- Consist of concepts, properties, relations, rules and logical axioms
- Can be represented as a graph structure
- Represented using an ontology language (e.g. OWL)

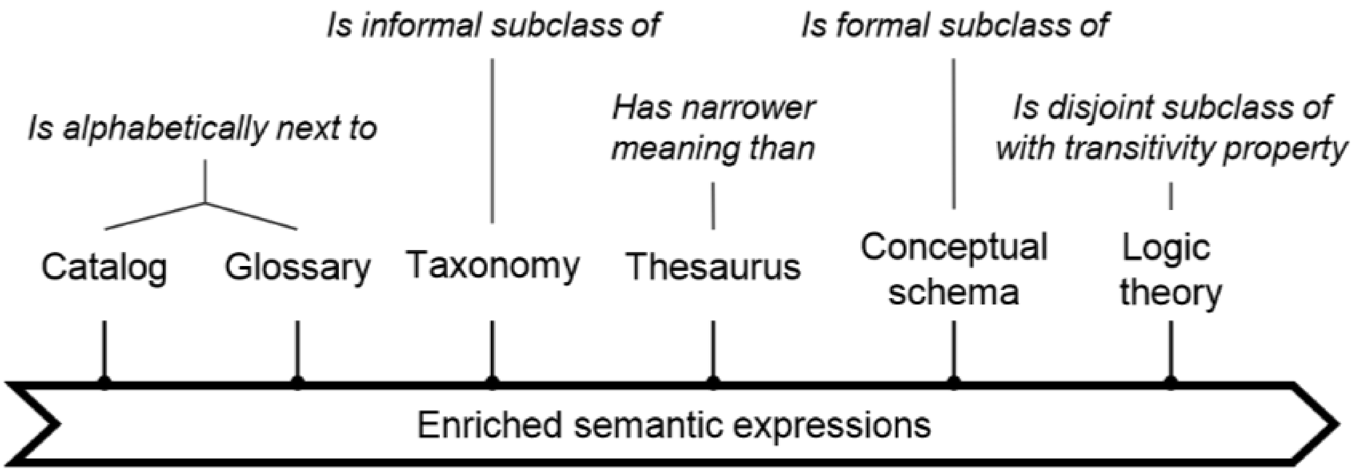

Figure 11: Ranking of ontologies from least formal to most formal

Uncertainties in Knowledge

- Uncertainties are inherent in knowledge elicitation, representation and reasoning in most of the applications[1]
  - Knowledge elicitation includes uncertainties stem from *collaborative knowledge acquisition and expert elicitation*
  - Knowledge representation involves uncertainties due to the *information extraction, data integration*
  - Reasoning involves uncertainties due to the *unknown parameters, default values with range or probabilities, and noisy measurements*
- In Phoenix, most of the environmental parameters may be unknown, guessed or may have a probability distribution
- Therefore, the knowledge representation includes uncertainty representation, reasoning deals with uncertainty, and the planner (if used) takes into account of the probability of success of the suggested plans

[1]*Aggarwal, C. C., & Yu, P. S. (2009). A survey of uncertain data algorithms and applications. IEEE Transactions on Knowledge and Data Engineering, 21(5), 609–623.*

Uncertainty in Representation and Reasoning

- Uncertain knowledge representation and reasoning is very active topic in the Artificial Intelligence (AI) community[1]
- There are a number of methods suggested for uncertainty representation and reasoning:
  - Uncertain knowledge graphs and probabilistic query matching[2]
  - Probabilistic logic programming[3]
  - Markov logic networks[4]

[1]Brachman, R., & Levesque, H. (2004). Knowledge Representation and Reasoning. The Morgan Kaufmann Series in Artificial Intelligence (Vol. 1).

[2]Huang, H., & Liu, C. (2009). Query evaluation on probabilistic RDF databases. Lect. Notes in Comp. Sci., 307–320.

[3]Raedt, L. De, & Kimmig, A. (n.d.). Probabilistic (Logic) Programming Concepts.

[4]Richardson, M., & Domingos, P. (2006). Markov logic networks. Machine Learning, 62(1-2), 107–136.

Conclusion

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