Modelling Episodes with Generic Ontology Design Patterns

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Overview

- Motivation
  - Episodic Memories in Robotics
- Generic Ontology Design Patterns
  - Consistent Modelling: Structuring, Re-use, Semantic Constraints
  - Ontology Engineering: Generic DOL with Hets
- Episode: Sequence of Transitions between Scenes
  - Constraints on Transitions, Successful Episodes
- Safe Data Population, Scaling
  - Generation of Data + Axioms, Data Integrity Constraints
- Conclusion

Ontology and Domain Experts, End-Users

- Ontology Experts
  - Little Domain Knowledge, Rare ⇒ Ontology Expertise
- Domain Experts
  - Often Superficial Ontology Training, Needed ⇒ Domain Expertise
- Generic Ontology Design Patterns
  - Encapsulate Semantic Complexity ⇒ by Ontology Experts
  - Specialised Tool Box for Re-Use ⇒ by Domain Experts
  - Dedicated Data Patterns ⇒ for End-Users

⇒ Increased Consistency and Data Integrity

Motivation

- Episodes in Knowledge-Driven Service Robotics
  - CRC *Everyday Activity Science and Engineering*
  - Narratively Enabled Episodic Memories
    - Comprehensive Records of Events, Used for Teaching Robots
    - Performed by Robots or Demonstrated by Humans
    - Semantically Annotated by Humans
- NEEM Creator
  - Populate with Data Obeying Structural and Logical Constraints
- NEEM Consumer
  - Query Database of NEEMs

Objective: Consistent Modelling

- Episode as Foundational Pattern ⇒ by Ontology Experts
  - Successful, Logically Consistent Episodes
  - Special DUL Situation
  - Sequence of Transitions between Scenes
- Data Patterns ⇒ by Ontology Experts
- Tool Box of Configuration Patterns ⇒ by Domain Experts
  - Specialised to TableSetting
- Dedicated Data Patterns ⇒ for End-Users

Objective: Safe Data Population

- End-User Perspective

fetchFrom[CrockeryCupboard][DessertPlate], transportTo[front][Table], place[on][Table]

- Structured Menu of Tasks
  - Hierarchy of Vocabulary, Simple User Interface

```
transportTo
    transportTo[front]                      transportTo[back]
        transportTo[front][Table]               transportTo[back][Table]
```

- Substantial Scaling Embedded in GODPs
- Data Integrity Constraints via GODP Parameters

Modelling with Generic Ontology Design Patterns

Generic Ontology Design Patterns

- Generic DOL (Extension of OMG Standard)
  - Distributed Ontology, Modeling and Specification Language
- Heterogeneous Tool Set, Hets
  - Heterogeneous Specification and Verification Tools, Beyond OWL
- ODPs with Explicit Parameterization
  - Multiple Instantiations for Re-Use
- Beyond Macros
  - Ontology Parameters to Express Powerful Semantic Constraints
  - List Parameters, Recursion
  - Parameterized Names

Pattern DATA_Episode_TeaForOne

```
pattern DATA_Episode_TeaForOne
 [ Individual: e; Individual: a; Individual: env; Individual: s0;
   Individual: spr Types: SpatialRelation3D ] %% spatial position
 given EASE_Data_Task_TeaForTwo_log =
DATA_Episode_TableSetting [ e; a; env; s0;
 [fetchFrom[CrockeryCupboard][DessertPlate], transportTo[spr][Table],
                                             place[on][Table],
  fetchFrom[CrockeryCupboard][Saucer],       transportTo[spr][Table],
                                             place[topright][DessertPlate]
  fetchFrom[CrockeryCupboard][TeaCup],       transportTo[spr][Table],
                                             place[on][Saucer]          ] ]
```

- Lists of Dedicated Tasks
- Parameter for Spatial Position, Typing Constraint

Instantiations in Episode_TeaForTwo_log

```
ontology Episode_TeaForTwo_log = EASE_Data_Task_TeaForTwo_log
and DATA_Initial_TableSetting[BKBsTea_s0; BKB; EASE_Lab ]
and DATA_Episode_TeaForOne[BKBsTeaForOne_front;
     BKB; EASE_Lab; BKBsTea_s0;                front ]
and DATA_Episode_TeaForOne[BKBsTeaForOne_back;
     BKB; EASE_Lab; post[BKBsTeaForOne_front]; back  ]
and CONC_Episodes[TableSetting; Episode[TableSetting];
     BKBsTeaForOne_front; BKBsTeaForOne_back; BKBsTeaForTwo ]
```

- Instantiations of GODPs, Joined by **and** (Union)
- Arguments: Initial Scene, Agent, Environment, Position
- Concatenation of Episodes to Result

Instantiations, Parameterised Names

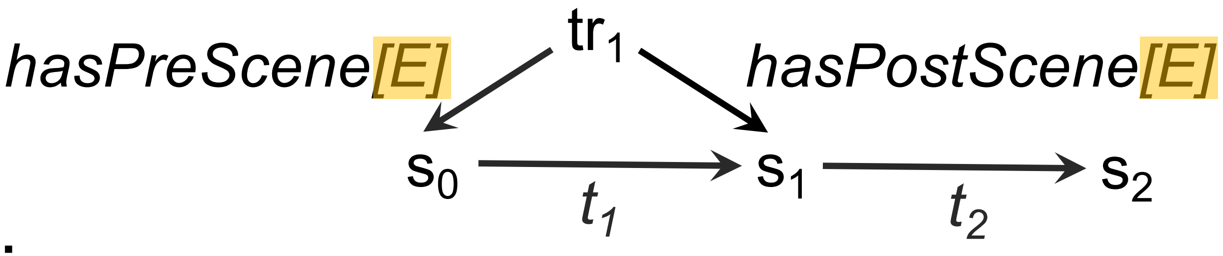
```
pattern FUNCTION_INVERSE
 [ObjectProperty: f; Class: D; Class: R; ObjectProperty: finv] =
ObjectProperty: f Domain: D Range: R %% Characteristics Functional
ObjectProperty: finv Domain: R Range: D InverseOf: f

pattern SEQUENCE [Class: E] %% kind of sequence elements
=    FUNCTION_INVERSE[hasLast[E];     Seq[E]; E; isLastOf[E]  ]
 and FUNCTION_INVERSE[hasFirst[E];    Seq[E]; E; isFirstOf[E] ]
 and FUNCTION_INVERSE[isSeqElemOf[E]; E; Seq[E]; hasSeqElem[E]]
 and FUNCTION_INVERSE[succ[E];        E;       E; prec[E]      ]
```

- Semantics Encapsulated in Body
- Parameters, Instantiations with Different Arguments, Reuse
- Parameterised Names for Distinct Name Spaces

Episode, Transition, Scene

- Episode of Kind E, e.g. TableSetting
- Linear Sequence of Transitions, “Unrolling” of a Plan
- Transitions tr_1, …
- Scenes s_0, s_1, s_2 , …
- Task Relations t_1, t_2 , …
- PreScene s_0, PostScene s_1 of tr_1



DATA GODPS

Data GODPs

- Safe Data Population
  - Generation of Data + Axioms
- Data Integrity Constraints via GODP Parameters
  - Typing Constraints
  - Constraints for Facts
- Substantial Scaling Embedded in GODPs
  - Factor: ca. 50 Generated Axioms per Task

CONCLUSION

Consistent Modelling in Ontology Engineering

- Body Abstracts from Semantic Complexity
  - Localization, Confinement of Revisions
- Repository of GODPs Adapted to Development Task
  - Users Have No Extraneous Impact
  - See https://ontohub.org/repositories/neem-godps
- Parameters Comprise Powerful Constraints
  - Users Focus on Appropriate Arguments
- Reuse in Multiple Instantiations
  - OWL-DL Constraints on Arguments are Verified Automatically
- Explicit Design Decisions, Development Log

Implementation in the Heterogeneous Tool Set

- Expansion of Instantiations
  - Stratification of Parameterised Names to OWL
- Generation of Proof Obligations for the Generated Ontology
- Proof of Consistency and Data Integrity Constraints
- Classification by Standard DL Reasoners

Ongoing Work

- Failures in Episodes
- Repositories for Foundational GODPs, Application Domains
  - DUL, EASE Robotics Ontology, Food and Cooking, ROS …
- Data Integrity Constraints
  - “Static” Check at DOL Expansion Time
- Semantic Relations Between Patterns in DOL
  - Refinement, Conservative Extension, …
- Change Management
  - Logs of Instantiations as Development Objects
  - Replay, Reordering, Abstraction, …

THANK YOU
FOR YOUR ATTENTION!