SWRL-F –
A Fuzzy Logic Extension of the Semantic Web Rule Language

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Plan

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- Design Choices
- SWRL-F ontology
- SWRL-F rules
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Related Work - DL

- Straccia, Holldobler, Hajek, Stoilos, Samou presented various extensions of DL in the direction of handling uncertainty and FL
- They focus on theoretical aspect of DL and FL and no implementation efforts are mentioned or presented by
- Loia, Senatore, Li, Pan mention implementations, but they are not publically available

Related Work - RL

- Lukasiewicz, Straccia, Wang, Agarwal, Hitzler, Damasio, Wulff, Sottaa, Stoilos propsed variouse rule languages to handle imprecision with no implementation
- Pan proposed f-SWRL
- Agarwal and Hitzler explained that syntax and semantics of f-SWRL actually offers no fuzziness
- Bobillo presented semantic fuzzy expert system based on FuzzyJess for a fuzzy balanced scorecard, but not based on SWRL

Contributions

- FL extension to SWRL
- based on standard OWL DL and SWRL
- SWRL-F ontology enables description of FL knowledge and its application in SWRL rules
- Implemented a test execution engine and development environment that is publically available.

Background

- Semantic Web Rule Language is a combination of the OWL DL and OWL Lite sublanguages with the Unary/Binary Datalog RuleML sublanguages of the Rule Markup Language
- Fuzzy Logic is a form of multi-valued logic, which derived from the fuzzy set theory introduced by Zadeh
    - extends binary set by adding a degree of membership
    - one can define several sets describing a variable
    - allows using linguistic variables
    - popular in fuzzy control systems

Design Choices

- connection between FL and SW/DL is a non-trivial problem
- leading idea was to follow fuzzy control systems scheme: fuzzification, inference, defuzzification
- make SWRL-F rules as simple as possible for the final user

Design Choices

- SWRL-F must be standard based
- anchoring in the well established fuzzy logic scheme
- SWRL-F can be fully expressed using OWL and SWRL
- fuzzy inference in SWRL-F is limited to the rules only
- SWRL-F does not create any inconsistencies with DL-reasoner

Design Choices

- Represent fuzzy assertions by
  - new built-in
  - object property
- Reuse already existing reasoner – FuzzyJess
- FuzzyJess is a superset of Jess
- Automatically compatibility with existing extensions and built-ins

SWRL-F ontology

- Class: FuzzyVariable
- Class: FuzzyTerm
- Class: FuzzyValue
- Class: FuzzySet
- ObjectProperty: hasFuzzySet
-   Domain: FuzzyTerm, FuzzyValue
-   Range: FuzzySet
- ObjectProperty: hasFuzzyTerm
-   Domain: FuzzyVariable
-   Range: FuzzyTerm
- ObjectProperty: hasFuzzyValue
-   Domain: FuzzyVariable
-   Range: FuzzyValue
- ObjectProperty: hasFuzzyVariable
-   Domain: FuzzyValue
-   Range: FuzzyVariable

SWRL-F ontology

For Project: ● FuzzySWRL

Class Hierarchy

● owl:Thing
  ● Curve (11)
  ▼ ● FuzzySet
    ▼ ● LFuzzySet
        ● LeftGaussianFuzzySet (1)
        ● LeftLinearFuzzySet (7)
        ● SFuzzySet
    ▼ ● LRFuzzySet
        ● GaussianFuzzySet
        ● PiFuzzySet
      ▼ ● TrapezoidFuzzySet (16)
          ● RectangleFuzzySet
        ▼ ● TriangleFuzzySet
            ● SingletonFuzzySet (6)
    ▼ ● RFuzzySet
        ● RightGaussianFuzzySet
        ● RightLinearFuzzySet (6)
        ● ZFuzzySet
  ● FuzzyTerm (25)
  ● FuzzyValue (9)
  ● FuzzyVariable (6)

SWRL-F ontology

Individual: CurveDelayDuration

  Types: FuzzyVariable

  Facts: hasCaption "period in which delay observed", hasUnit "minutes", hasRangeFinish 60.0, hasRangeStart 0.0, hasFuzzyTerm LongCurveDelayDuration, hasFuzzyTerm MediumCurveDelayDuration, ...

SWRL-F ontology

INDIVIDUAL EDITOR for CurveDelayDuration (instance of FuzzyVariable)

For Individual: http://www.owl-ontologies.com/FuzzySWRL.owl#CurveDelayDuration

Annotations

Property	Value	Lang
rdfs:comment		

hasCaption

period in which delay observed

hasUnit

minutes

hasRangeFinish

60.0

hasRangeStart

0.0

hasFuzzyTerm

◆ LongCurveDelayDuration
◆ MediumCurveDelayDuration
◆ ShortCurveDelayDuration
◆ VeryLongCurveDelayDuration
◆ VeryShortCurveDelayDuration

SWRL-F ontology

```
Individual: LongCurveDelayDuration
  Types: FuzzyTerm
  Facts: hasFuzzySet TrapezoidFuzzySet_16

Individual: TrapezoidFuzzySet_16
  Types: TrapezoidFuzzySet
  Facts: oneLeftX 12.0, oneRightX 30.0,
  zeroLeftX 10.0, zeroRightX 31.0
```

SWRL-F ontology

SWRL-F ontology

SWRL-F ontology

```
Individual: TestCurve3
  Types: Curve
  Facts: hasCurveDelay CurveDelay3,
  hasCurveValueDeviation
  CurveValueDeviation3,
  hasCurveDelayDuration CurveDelayDuration3,
  hasRisk CurveRisk3
```

SWRL-F ontology

SWRL-F ontology

```
Individual: hasCurveDelayDuration
  Types: FuzzyValue
  Facts: hasFuzzyVariable
  CurveDelayDuration, hasFuzzySet
  CurveDelayDurationFuzzySet3
```

SWRL-F ontology

SWRL-F rules

```
ObjectProperty: fuzzymatch
  Domain: FuzzyValue
  Range: FuzzyTerm
```

SWRL-F rules

Curve(?c) ∧ hasCurveDelayDuration(?c, ?d) ∧
  fuzzymatch(?d, ShortCurveDelayDuration) ∧
  hasRisk(?c, ?r) → fuzzymatch(?r, LowRisk)

SWRL-F rules

Discussion

- FuzzyVariable vs any numerical value
- SWRL-F relation to DL
- SWRL-F for expert knowledge representation
- SWRL-F indirectly allows disjunction

Conclusions

- extension to SWRL that allows constructing fuzzy rules in SWRL based on language variables described using OWL-based ontology
- general design is based on fuzzy control systems
- allows to avoid conflicts between FL and DL
- SWRL-F allows extending any SW application with FL capabilities basing on Protégé editor and modified SWRLJessTab

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