EXPERIMENTING NON-SINGLETON TYPE-I AND TYPE-II FUZZY LOGIC SYSTEMS USING JUZZY EXTENSION

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Outline

• Uncertainty levels in FLSs
  • Crisp vs. Fuzzy
  • Type-I vs. Type-II (vs. Type-n)
  • Singleton vs. Non-singleton

• Tipping example demonstration
  • in Juzzy
  • in Juzzy+

• Current project (RITW) - brief introduction
Uncertainty in FLS

- Crisp vs. Fuzzy Sets

- Uncertainty in defining Fuzzy Sets
  - Type-II FLS
  - *Linguistic Variables and Approximate Reasoning* (Zadeh, 1975)
  - Interval type-I, General type-II, type-n
Uncertainty in FLS

- Uncertainty in input
  - Modeling the input uncertainties by fuzzy input sets
  - Not necessarily at linguistic level

- Singleton fuzzification

- Non-singleton fuzzification (Mouzouris & Mendel, 1997)

- Type-II non-singleton fuzzification (and beyond!)

Is the room temperature really $15^\circ$?
## Uncertainty in FLS (Mendel 2001)

<table>
<thead>
<tr>
<th>System</th>
<th>Uncertainty at Linguistic Level</th>
<th>Uncertainty at Technical Level (input)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Fuzzy</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Singleton Type-I FLS</td>
<td>Yes, type-I</td>
<td>No</td>
</tr>
<tr>
<td>Singleton type-II FLS</td>
<td>Yes, type-II</td>
<td>No</td>
</tr>
<tr>
<td>Non-Singleton Type-I FLS</td>
<td>Yes, type-I</td>
<td>Yes, type-I</td>
</tr>
<tr>
<td>Type-I Non-Singleton type-II FLS</td>
<td>Yes, type-II</td>
<td>Yes, type-I</td>
</tr>
<tr>
<td>Type-II Non-Singleton type-II FLS</td>
<td>Yes, type-II</td>
<td>Yes, type-II</td>
</tr>
</tbody>
</table>

...
Juzzy (Wagner, 2013)

- Java + Fuzzy
- Type-I, Interval Type-II and General Type-II Using $z$Slices (Wagner & Hagras, 2008)
- Used in:
  - JuzzyOnline (M. Pierfitte, 2013)
  - RitWeb (current project)
  - ...

- Juzzy+
  - including type-I and type-II non-singleton Inputs
Tipping Example

- Gaussian MFs (mean, sd) for [0,10]
  - Food: bad (0,3), great (10,3)
  - Service: unfriendly (0,2), ok (5,2), friendly (10,2)
  - Tip: low (0,2), medium (5,2), high (10,2)

- Defuzzification: Centroid, T-norm: Minimum

- Rule-base:

<table>
<thead>
<tr>
<th>IF FOOD IS</th>
<th>AND SERVICE IS</th>
<th>THEN TIP IS</th>
</tr>
</thead>
<tbody>
<tr>
<td>bad</td>
<td>unfriendly</td>
<td>low</td>
</tr>
<tr>
<td>bad</td>
<td>OK</td>
<td>low</td>
</tr>
<tr>
<td>bad</td>
<td>friendly</td>
<td>medium</td>
</tr>
<tr>
<td>great</td>
<td>unfriendly</td>
<td>low</td>
</tr>
<tr>
<td>great</td>
<td>OK</td>
<td>medium</td>
</tr>
<tr>
<td>great</td>
<td>friendly</td>
<td>high</td>
</tr>
</tbody>
</table>

http://gprs.olhbogspace.com/
Singleton Type-I FLS

Input food = new Input("Food Quality", new Tuple(0,10));
service = new Input("Service Level", new Tuple(0,10));
tip = new Output("Tip", new Tuple(0,10));

T1MF_Gaussian badFoodMF = new T1MF_Gaussian("bad food",0.0, 3.0);
T1MF_Gaussian greatFoodMF = new T1MF_Gaussian("great food",10.0, 3

Example for food=5, service=5: tip=£4.56
Singleton [Interval] Type-II FLS

- Bad Food Gaussian MF (mean, sd) → (mean, sd ± tol)

```
Input food = new Input("Food Quality", new Tuple(0,10));
...
T1MF_Gaussian badFoodUMF = new T1MF_Gaussian("UMF for bad food",0.0, 3+tol);
T1MF_Gaussian badFoodLMF = new T1MF_Gaussian("LMF for bad food",0.0, 3-tol);
IntervalT2MF_Gaussian badFoodMF = new IntervalT2MF_Gaussian("bad food",badFoodUMF,badFoodLMF);
...
```

- Example for food=5, service=5, tol=1.5: tip=£4.86
Type-I Non-Singleton Type-I FLS

- Crisp Input $x \rightarrow$ Gaussian ($x, xsd$)

$$T1NS\_Input \; food = \text{new} \; T1NS\_Input(\text{"Food Quality"}, \text{new Tuple}(0,10));$$

$$T1MF\_Gaussian \; badFoodMF = \text{new} \; T1MF\_Gaussian(\text{"bad food"},0.0, 3.0);$$

$$\text{food.setGaussianMF(new T1MF\_Gaussian(\text{"Food Quality MF"},5,xsd));}$$

- Example for $\text{food}=5, \text{service}=5, xsd=1.5$: $\text{tip}=£4.36$
Type-I Non-Singleton
[Interval] Type-II FLS

- Crisp Input $x \rightarrow$ Gaussian $(x, \text{xsd})$
- Bad Food Gaussian MF $(\text{mean}, \text{sd}) \rightarrow (\text{mean}, \text{SD} \pm \text{tol})$

T1NS_Input food = new T1NS_Input("Food Quality", new Tuple(0,10));
...
T1MF_Gaussian badFoodUMF = new T1MF_Gaussian("UMF for bad food",0.0, 3+tol);
T1MF_Gaussian badFoodLMF = new T1MF_Gaussian("LMF for bad food",0.0, 3-tol);
IntervalT2MF_Gaussian badFoodMF = new IntervalT2MF_Gaussian("bad food",badFoodUMF,badFoodLMF);
...
food.setGaussianMF(new T1MF_Gaussian("Food Quality MF",5,xsd));
...
- Example for food=5, service=5, tol=xsd=1.5: tip=£4.17
[Interval] Type-II Non-Singleton
[Interval] Type-II FLS

- Fuzzified Gaussian MF \((x, xsd) \rightarrow \text{Gaussian} (x, xsd \pm xtol)\)
- Bad Food Gaussian MF \((\text{mean}, sd) \rightarrow (\text{mean}, sd \pm tol)\)

T1NS_Input food = new IT2NS_Input("Food Quality", new Tuple(0,10));
...
T1MF_Gaussian badFoodUMF = new T1MF_Gaussian("UMF for bad food",0.0, 3+tol);
T1MF_Gaussian badFoodLMF = new T1MF_Gaussian("LMF for bad food",0.0, 3-tol);
IntervalT2MF_Gaussian badFoodMF = new IntervalT2MF_Gaussian("bad food",badFoodUMF,badFoodLMF);
...
T1MF_Gaussian foodQualityUMF = new T1MF_Gaussian("Food Quality UMF",5,tol+nsTol);
T1MF_Gaussian foodQualityLMF = new T1MF_Gaussian("Food Quality LMF",5,tol-nsTol);
food.setGaussianMF(new IntervalT2MF_Gaussian("Food Quality MF",foodQualityUMF,foodQualityLMF));
...

Example for food=5, service=5, tol=xsd=1.5, xtol=0.5: tip=£4.648
Type-n Non-Singleton
Type-n FLS

• !!!
RitWeb System

- Data-driven Environmental Policy Design using Fuzzy Logic
- Input: Properties of Elements, e.g., size of a particular lake
- Output: Deliveries of Human Values, e.g., productive use
  - Decision-making on management priorities
- MFs and Rulebase: designed by experts and stakeholders

- Using Juzzy
- Currently: Singleton type-I
  - Future work: non-singleton type-II
RitWeb System

### Value Delivery Results

#### Value delivery across all elements - sorted

<table>
<thead>
<tr>
<th>Name</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philosophical/Spiritual/Intrinsic</td>
<td>0.46294605413505</td>
</tr>
<tr>
<td>Knowledge and Education</td>
<td>0.3311565380021563</td>
</tr>
<tr>
<td>Productive Use</td>
<td>0.3072082166694062</td>
</tr>
</tbody>
</table>

#### Elements’ relative human value across all values - sorted

<table>
<thead>
<tr>
<th>Name</th>
<th>Relative human value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dulbin Nature Reserve woodland community</td>
<td>0.48748281759878664</td>
</tr>
<tr>
<td>Waterbirds</td>
<td>0.47451031977378233</td>
</tr>
<tr>
<td>Toolbin Lake Vegetation community</td>
<td>0.4721186367963366</td>
</tr>
<tr>
<td>Aquatic Invertebrate Community</td>
<td>0.46718086913665485</td>
</tr>
<tr>
<td>Dingerin Well Nature Reserve shrubland community</td>
<td>0.46089160897677955</td>
</tr>
<tr>
<td>Resident terrestrial birds</td>
<td>0.4546306602534958</td>
</tr>
<tr>
<td>Mammals</td>
<td>0.4504797051976033</td>
</tr>
<tr>
<td>Dulbin Nature Reserve (2) vegetation community</td>
<td>0.4153056872578238</td>
</tr>
<tr>
<td>Walbyring Lake vegetation community</td>
<td>0.403473525701828</td>
</tr>
</tbody>
</table>

#### Control Surface Plot

- Value: Productive Use
- for Element: Red Morrell woodland community
- According to Property (X-axis): Richness
- and Property (Y-axis): Size
References

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