Ambient Intelligent Environments, Transparency and Fuzzy Logic

Christian Wagner
Overview

- My background.
- Fuzzy Logic – a brief overview.
- Type-2 Fuzzy Logic, Uncertainty and zSlices.
- ATRACO – a European Union FP7 Project.
- Light Level Adaptation in AIE – an example.
- Humans and the Requirement for Transparency.
- Conclusions and Future Work
My Background

- Pre - 2001: Luxembourg (Echternach)
- 2001-2004 BSc in Computer Science
  - Voice-controlled, fully functional bar-mixing robot
- 2004-2005 MSc in Robotics & Embedded System
  - Novel Sun SPOT technology implementation (I-wire)
- 2006-2009 PhD in Computer Science
  - “Towards Better Uncertainty Handling Based on zSlices and General Type-2 Fuzzy Logic Systems”
- 2008 – 2011 ATRACO (Adaptive and Trusted Ambient Ecologies)
  - Adaptation (human behaviour and device level)
  - Type-2 Fuzzy Logic
- 2011 Horizon Digital Economy Institute & School of Computer Science, UoN
My Background – Research Interests

- Computational intelligence, i.e. fuzzy logic, evolutionary computation, hybrid systems with a specific focus on uncertainty handling for example by developing and employing (type-2) fuzzy logic theory and applications.

- Real-world systems (robotics, ambient intelligence applications → high imprecision and “uncertainty”).

- Agent based systems, specifically in ubiquitous computing in the context of AIEs.

- Computational Intelligence ↔ Human interaction & acceptance / Social Sciences.
Fuzzy Logic in Brief

- Fuzzy Logic was introduced by Lotfi A. Zadeh in the 1960s in order to provide a mathematical framework enabling the reasoning with linguistically inspired concepts (fuzzy classes – fuzzy sets).

- Fuzzy Logic aims to mimic the human ability to reason in the face of uncertainty / imprecision (e.g. “it is warm”), often encapsulated in human language.
  - For example, we don’t say — If the temperature is above 24 degrees and the cloud cover is less than 10% and I have 3 hours time, I will go for a hike with a probability of 0.47.
  - We say — If the weather is nice and I have a little time, I will probably go for a walk.
    (H. Hagras)

- Fuzzy Logic sets attempt to provide a way of mathematically expressing the uncertainty of information while fuzzy systems attempt to reflect the reasoning with these “uncertain” concepts.

- Fuzzy Logic has been widely popular in control applications where fuzzy logic control can be employed as a way of converting linguistic control information to mathematical control information.
Fuzzy Logic in Brief

- A large number of control and commercial applications, from rice cookers, washing machines, VW’s automatic transmission,…
- Today – Computing With Words – a revitalized effort to imitate the human ability to reason and communicate with/on imprecise linguistic labels.
Fuzzy Logic in Brief

- What else?

- Fuzzy Logic Systems are rule-based systems. E.g.:
  
  IF LightSensor1 = Dark AND LightSensor2 = Moderate
  THEN CeilingLamp = Bright

- The “power” of fuzzy systems lies in the execution of MANY rules to different degrees.

- Fuzzy sets assign complex meaning to linguistic labels.

- Fuzzy systems’ rules are human-readable.
Type-2 Fuzzy Logic – why?

- Deal with imprecision in real world applications (device uncertainty, uncertainty about a human concept (e.g. tall))
- Aim to address uncertainty introduced by humans (changes in behaviour, preference, etc.)
- Employ human knowledge & experience (fuzzy rule bases)
- Creation of human interpretable systems → understanding → trust.
- Model human, (i.e. approximate) decision making in the face of uncertainty.
  - (Humans find it easy to reason about complex problems (e.g. “the weather is nice”), machines do not…)
  - Bring machine decision making closer to human decision making.
Consider the issue of adapting the heating conditions to a number of occupants in a house, for example, a family of four: Paul, Joan, Tom and Emily.
Example - continued

Using Interval Type-2 Fuzzy Logic:
Example – continued...

A 3D view of a zSlices based general type-2 fuzzy set
zSlices Based General Type-2 Fuzzy Sets
ATRACO (Adaptive and Trusted Ambient Ecologies)

The main project concepts:

- Activity Spheres
- 5 dimensions of adaptation:
  - User interaction adaptation
  - User behaviour adaptation
  - Sphere adaptation
  - Artefact adaptation
  - Network adaptation
- Social Evaluation & Driver
ATRACO continued...

- Dynamic, agent-based creation of “bubbles”, i.e. Activity Spheres relating to a specific user and a specific activity.
  - Employ pervasive software agents based around Activity Spheres, that “accompany” the user (locally, regionally and world-wide).

- Continuous adaptation to users and devices and to changes in their preferences/characteristics.
  - Learn from users (user is king paradigm) (vs programming…).

- Social Sciences & Computer Science / Engineering
  - work in a loop of gathering future user needs and determining feasibility
  - Achieve a balance between technology and the human.
  - Achieve a balance between long term research and economically viable, i.e. deployable (technically, socially acceptable & cost effective) research goals.

- Interdisciplinary research involving IT, people and companies.
  - Real world implementation & evaluation with lay users.
  - Real world cooperation through ATRACO (e.g. inAccess)
  - Collaborations with multiple academic partners to address wider issues (interaction etc.)
Focus on Light Level Adaptation

- Adaptation of light level in an AIE according to user preference.
- Real world evaluation & deployment in the iSpace at the University of Essex.
Light Level Adaptation – Phase 1

- Learning Phase:
  - User/device interaction capture
  - Interaction data clustering
  - Adaptive device model creation

- Light Sensor Model examples (light levels in lux):

Data $\rightarrow$ Light Sensor 1 $\rightarrow$ Light Sensor 2
Clustering algorithm employed: Fuzzy C-means

After fuzzy set based models of devices are created, fuzzy rules are extracted using the captured data and the fuzzy set models (based on Wang Mendel rule extraction algorithm).

Rules generated are of the format:

\[ IF \text{ living-above-sofa} = \text{Dark AND living-above-samsung} = \text{Moderate AND living-photoframe} = \text{Dark} \text{ AND ... THEN CeilingLights} = \text{Bright} \]
Light Level Adaptation – Phase 1 ctd.

- It works.
- Device models are adapted over time and rule bases are updated.
- Some problems (e.g. not enough labels to capture user preferences).

- Critical User feedback:
  - “I don’t like the system interfering with my choice.”
  - “I want to understand why stuff is happening!”
Phase 1 to Phase 2

- We aim to capture the human perception of the light level, learn the preferences/behaviour of the human user and adapt it for her/him…
- BUT – a user does not perceive the light level in a room as a series of individual values (sensors…).

- Can we use fuzzy sets to “model” this understanding of what indoor light level means to people?
- Fuzzy Logic sets aim to “model” the complex information underlying simple linguistic terms…
Light Level Adaptation – Phase 2

- A slightly different approach, 2 main goals:
  - More user-centric “model” of the ambient light level.
  - Continuous longer term adaptation.
Light Level Adaptation – Phase 2 ctd.

- Data is captured.
- The actual “ambient light level” value is associated with the mean of all sensors.
- The uncertainty as part of the AIE is associated with the variation of the individual sensor measurements at each measurement step.
  - A variety of sources of “uncertainty”, e.g.: weather changes (sun impact), wear & tear (dust), sensor obstruction (jumper on a sensor.), etc.
- Daily models of “ambient light level” are constructed.
- Daily models are amalgamated to create long term adaptive models in a sliding-window based approach.
Light Level Adaptation – Phase 2 ctd.

1. Living-photoframe-lux
2. Living-above-samsung-lux
3. Living-control-wall-lux
4. Living-fridge-lux
5. Living-plasma-lux
6. Kitchen-cupboard-left-lux
7. Kitchen-cupboard-centre-lux
8. Kitchen-cupboard-right-lux
Examples of data captured:
One day – interval type-2 fuzzy set based models.

- The uncertainty information is combined with prototype type-1 fuzzy sets and interval type-2 fuzzy sets are generated based on the data captured during the day.
- Here: example of the set “medium ambient light level”:
Over many days...

- Individual daily “models” are aggregated on a set-by-set basis through the computation of zSlices based agreement.
- Resulting in an increasing number of zLevels, e.g. for 2 days:
After 7 days:

- Sets have seven zSlices (levels in the third dimension).
- Sets capture the information on “medium ambient light level” as witnessed over 7 days.
- Sorry for the visualisations!
Sliding window based “model”...

Model based on data collected on Monday

Model based on the agreement between the data collected on Monday AND Tuesday

Model based on the agreement between the data collected on Monday AND Tuesday AND Wednesday

... and so forth for all days of the week until...

Model based on the agreement between the data collected from Monday until Sunday Inclusive.

Model slides

As new data (next Monday) becomes available, the agreement model which is set to model up to 7 days (a design decision) is updated to model the agreement of the last 7 days. I.e. the “new” Monday data is included into the agreement model, and the old Monday excluded.
The resulting sets are zSlices based general type-2 fuzzy sets.

Each set is still associated with one linguistic label. (in our example: medium)

However: much more information “under” each label.

All sensors are fused into one “model” of the Ambient Light Level, rules now take the format:

IF AmbientLightLevel = Dark

THEN CeilingLights = Bright
Light Level Adaptation: Conclusive Remarks and Future Work

- Rule transparency to the end user has greatly increased.
- Social evaluation currently ongoing.
- Ambient Light Level models adapt in a continuous fashion.

- zSlices based general type-2 fuzzy set “agreement” accepted for publication at the IEEE Symposium on Computational Intelligence in Paris.
- Full details are currently going into 2 further publications.

A lot more work:
- Establishment of full details on zSlices based agreement and publication.
- Evaluation of the accuracy of the models.
- Other applications and other sources of information.
- What is the actual uncertainty involved? We chose one interpretation…?
Conclusions and the bigger picture

- Humans employ simple labels to mean complicated things because it has clear advantages:
  - Ease of communication, memorization and reasoning.
- Capturing complex information (from sensor information to Tesco Club-card data) and representing it:
  - Human-readable.
  - Machine-readable and modifiable.
  - Accurately (with arbitrary and determinable degree of abstraction)
- has great promise for a large number of applications in the digital economy (privacy, third party applications, etc.)
- Fuzzy Logic, respectively general type-2 fuzzy sets can contribute to the creation of such “models”.
Future Work

- Continue the research in general type-2 fuzzy sets, their applications and underlying theory (e.g. zSlices based agreement for general type-2 fuzzy sets).

- Continue the research into the modelling of information related to humans (perceptions, behaviours) both using fuzzy logic and potentially other means.

- Hopefully collaborate with you as part of IMA, the School of Computer Science and the Horizon Digital Economy Institute.
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