Week 2: Rough Sets, Information System, Decision Table

CS286: Topics in Intelligent Systems

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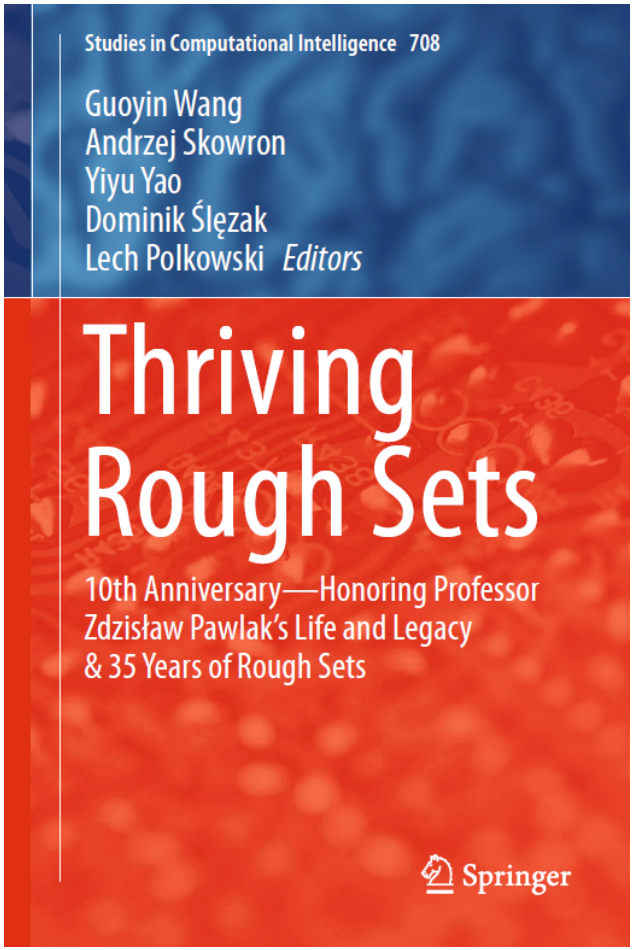
Agenda

1. Historical outline
   - Uncertainty
   - Logic
   - Zdzislaw Pawlak
2. Rough Set Theory
   - Background
   - Current Applications
   - Information System
3. Decision Table
   - Example
   - Knowledge Representation
   - Activity



Readings

- **Required**: Tarnowska17 - Chapter 4.1.1 (Informations Systems) - 4.1.2 (Decision Tables)
- Additional reading (optional)
  1. Lech Polkowski: "Zdzislaw Pawlak as I saw Him and Remember Him Now" in Thriving Rough Sets, Chapter 2, Springer, 2017.
  2. Lech Polkowski: "Rough Sets, Rough Mereology and Uncertainty" in Thriving Rough Sets, Chapter 4, Springer, 2017.
  3. Rafael Bello and Rafael Falcon: "Rough Sets in Machine Learning: A Review" in Thriving Rough Sets, Chapter 5, Springer, 2017.

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The Phenomenon of Uncertainty

Uncertainty

Inability to choose one optimal object in the given context from a set of more than one optional objects. (Polkowski, 2017)

Examples:

The Uncertainty Principle of Heisenberg (nature)

The precise values of position and energy of an electron cannot be known simultaneously

Goedel's incompleteness theorem (human-thinking)

There can be formulated statements formally correct about which one cannot decide whether they are true or false

Uncertainty in everyday life

The omnipresence of uncertainty in all venues of life:

- Making decisions at crossroads
- Investing on stock market
- Forecasting a political issue
- . . . When will coronavirus pandemic end???

Graded discussion

Discussion post: Uncertainty in everyday life (2 points)

- Describe in two sentences one situation within the last week when you dealt with uncertainty in decision-making
- Reply to at least one post that describes the same/similar experience as you had in the past.

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Logical systems to represent reasoning schemes with *uncertainty*

- Up to beginning of 20th century dealt solely with definite **binary–valued** statements, either true or false
- Jan Lukasiewicz in 1917 introduced **3-valued logic**, with the value of 2 for statements uncertain (labelled as 'don't know')
- Lotfi Asker Zadeh introduced the concept of **fuzzy set**
  - $\mu_A(x)$ in $(0, 1)$ is a **fuzzy membership function** that indicates the degree of uncertainty whether x is in A

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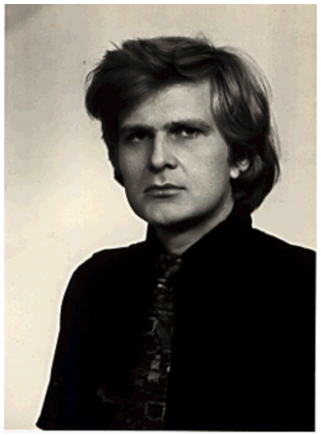
Zdzislaw Pawlak - my scientific grandfather

Zdzislaw Pawlak - PhD advisor of:

Zbigniw Ras - PhD advisor of:



Katarzyna Tarnowska (me)

- An enginner by education (graduated from Warsaw University of Technology, Department of Electrical Engineering)
- *"...but by intellectual composition he was close to theory in particular to mathematics and logic"* (Polkowski, 2017) - more in Reading 1 (Slide 3)

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The Pawlak Approach to Uncertainty

- Pawlak approached *knowledge* as ability to classify given objects into given categories
- *Uncertain knowledge* meant inability to classify certain objects into categories in a deterministic way.
- The notion of knowledge was a set of objects along with a partition of this set into categories, so–called *approximation space*.
- A specific implementation of this idea was using the notions of an *information system* and a *decision system*.

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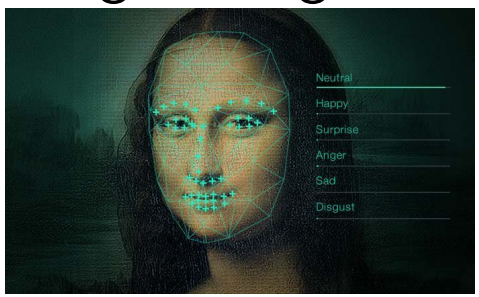
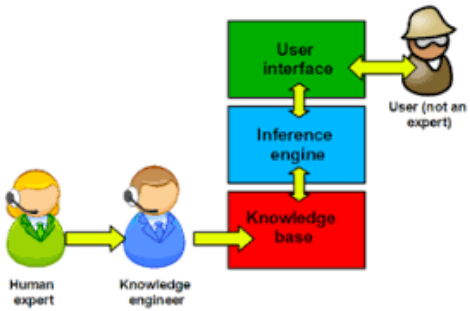
Rough Sets in Machine Learning

Machine Learning

Image Recognition



Expert Systems



Graded discussion

Discussion post: Roungh Set Theory in Machine Learning

- Read or skim "Rough Sets in Machine Learning: A Review" by R.Bello and R.Falcon (see Slide 3 Reading 3)
- Discuss one chosen implementation of rough sets in machine learning and explain why you think it is important (in around 100 words).

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Definition

An **Information System** is a tuple $S = (X, A, V, \rho)$ where X is a finite set of **objects**, A is a finite set of **attributes**, $V = U_{a \in A} V_a$ where V_a is the set of values of attribute a (called the domain of a) and $|V_a| > 1$, ρ is a function mapping objects and attributes to values, $\rho : X \times A \rightarrow V$.

A special case of Information Systems is called a *Decision Table*.

Definition

A **Decision System** (U, A, V, ρ, d) is augmented by an additional attribute, the **decision** d. The other attributes are called **conditions**.

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Decision Table - Example

Example

A decision table with 8 **objects** describing patients with 3 **attributes**: *Headache*, *Muscle pain*, and *Temperature*. A **decision** is a binary attribute *Flu* specifying if a patient has a flu or not.

U	Headache	Muscle pain	Temp.	Flu
p1	Yes	Yes	Normal	No
p2	Yes	Yes	High	Yes
p3	Yes	Yes	Very-high	Yes
p4	No	Yes	Normal	No
p5	No	No	High	No
p6	No	Yes	Very-high	Yes
p7	No	Yes	High	Yes
p8	No	No	Very-high	No

Graded Lab

Lab 2 activity: describing a decision table

Working with the dataset you chosen in Lab 1 answer the following questions:

- How many *objects* does the *decision table* describe?
- What does the *object* represent? (i.e. patient, log entry)
- How many *attributes* describe the objects?
- What are the *conditional* and what attribute(s) is the *decision*?

Decision Table - Practical Setting

In practical settings, **decision tables** are created from ordinary tables, datasets or database, by specifying conditions and decisions.

- **Conditional attributes** are characteristics that are easily available, for example measurements, parameters, personal data, etc.
- **Decision** is a feature related to not commonly known knowledge, for example given by an expert (i.e. physician) or based on later observations (i.e. stock exchange rating).

A sample dataset interpreted as a *decision table* with a *binary* **decision attribute** "Sick", specifying —whether a person is sick or not:

Patient	Age	Sex	Chol.	Resting ECG	Heart rate	Sick
p_1	53	M	203	hyp	155	yes
p_2	60	M	185	hyp	155	yes
p_3	40	M	199	norm	178	no
p_4	46	F	243	norm	144	no
p_5	62	F	294	norm	162	no
p_6	43	M	177	hyp	120	yes
p_7	76	F	197	abnorm	116	no
p_8	62	M	267	norm	99	yes
p_9	57	M	274	norm	88	yes
p_{10}	72	M	200	abnorm	100	no

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Decision Table as Knowledge Representation

- Decision table (DT) represents **knowledge** and allows to simulate decision-making processes.
- Knowledge in a DT is represented by associating or identifying *decision* values with certain values of *conditional* attributes.
- Decision is known only for the objects from the *training* table.
- The goal is to use it for establishing a decision for *new* objects, based on their attributes.

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Graded Lab

Lab 2 activity: knowledge representation

Working with the dataset you chosen in Lab 1 answer the following questions:

- What *knowledge* is represented by the chosen decision table?
- Who is the *expert* involved? (i.e. physician)
- What *decision-making process* does it simulate? (i.e. diagnosis, treatment)

Self-check

Try to answer the following questions:

1. What are the reasoning schemes to incorporate uncertainty?
2. What is the Pawlak's approach to uncertainty in rough set theory?
3. List three current influences of rough set theory in machine learning.
4. What is a Decision Table? Give one example and explain concepts of *object*, *attributes*, *conditions*, and *decisions*.
5. How is decision table used to represent *knowledge*?