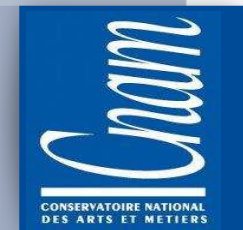


> *Introducing human reasoning within decision-making systems*



Presentation

NB: this presentation was originally written in French. I have translated it quickly so please don't get too upset if you encounter English mistakes. Instead, blame Gtranslate ;-) and drop me in email. Thanks! Franck.

Franck.Dernoncourt@gmail.com
26 Janvier 2011

1. Origins

2. Definitions

3. Application: fuzzy inference systems

4. Application: fuzzy queries

5. Conclusion

6. References

1. Origins

Observation:



Knowledge available to humans are virtually never perfect. These imperfections can be distinguished into two classes:

- **Uncertainties**, which refer to knowledge whose validity is subject to question. For example, if we know someone bumped his head on a ceiling, we can guess that he is likely to be very tall.
- **Inaccuracies**, which refer to knowledge that is not clearly perceived or defined. For example, instead of saying someone is 2 feet and 3 inches, we usually say that person is very tall.

1. Origins

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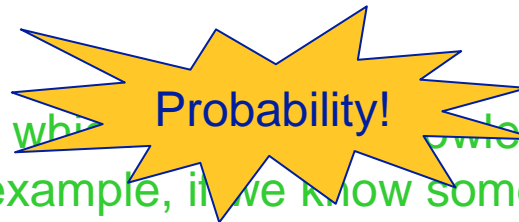
1. Origins

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1. Origins

Observation:



Knowledge available to humans are virtually never perfect. These imperfections can be distinguished into two classes:

Probability!

- ✓ Uncertainties, which refer to knowledge whose validity is subject to question. For example, if we know someone bumped his head on a ceiling, we can guess that he is likely to be very tall.
- ✗ Inaccuracies, which refer to knowledge that is not clearly perceived or defined. For example, instead of saying someone is 2 feet and 3 inches, we usually say that person is very tall.

1. Origins

Observation:



Knowledge available to humans are virtually never perfect. These imperfections can be distinguished into two classes:

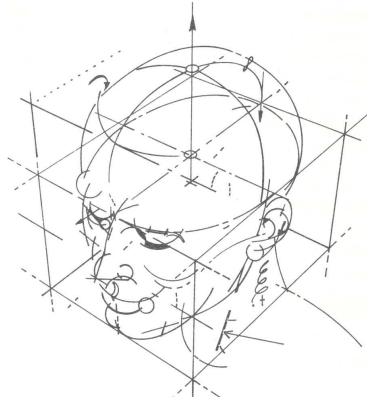
Probability!

- ✓ Uncertainties, which are knowledge whose validity is subject to question. For example, if we know someone bumped his head on a ceiling, we can guess that he is likely to be very tall.

Fuzzy logic!

- ✗ Inaccuracies, which are knowledge that is not clearly perceived or defined. For example, instead of saying someone is 2 feet and 3 inches, we usually say that person is very tall.

1. Origins



How to express these inaccuracies in logical terms?

Logic, a proposition is **true** or **false**.

Example: This person is tall. *True* or *false*?

→ Not flexible...

In **multivalued** logic, a proposition may have multiple values.

Example(ternary): This person is tall. *True*, *half true* ou *false*?

→ Slightly more flexible...

In fuzzy logic, a proposition can have as many values as one wants.

Example: This person is tall. This is 30% true.

→ Flexible!

1. Origins



Lofti Zadeh, researcher in systems theory, laid the foundations of fuzzy logic in an article in 1965.

Fuzzy logic is an **extension of the Boolean logic** based on the mathematical theory of fuzzy sets, which is a generalization of the classical set theory.

By introducing the notion of degree in the verification of a condition, thus enabling a condition of being in a state other than true or false, fuzzy logic provides a highly valuable flexibility to reasoning models, making it possible taking into account inaccuracies

1. Origins



Applications:

- Decision support system (e.g. in healthcare),
- Database (e.g. fuzzy queries),
- Fuzzy commands (e.g. subway line M14 in Paris),
- Data mining (e.g. clustering),
- Pattern recognition,
- ...

1. Origins

2. Definitions

3. Application: fuzzy inference systems

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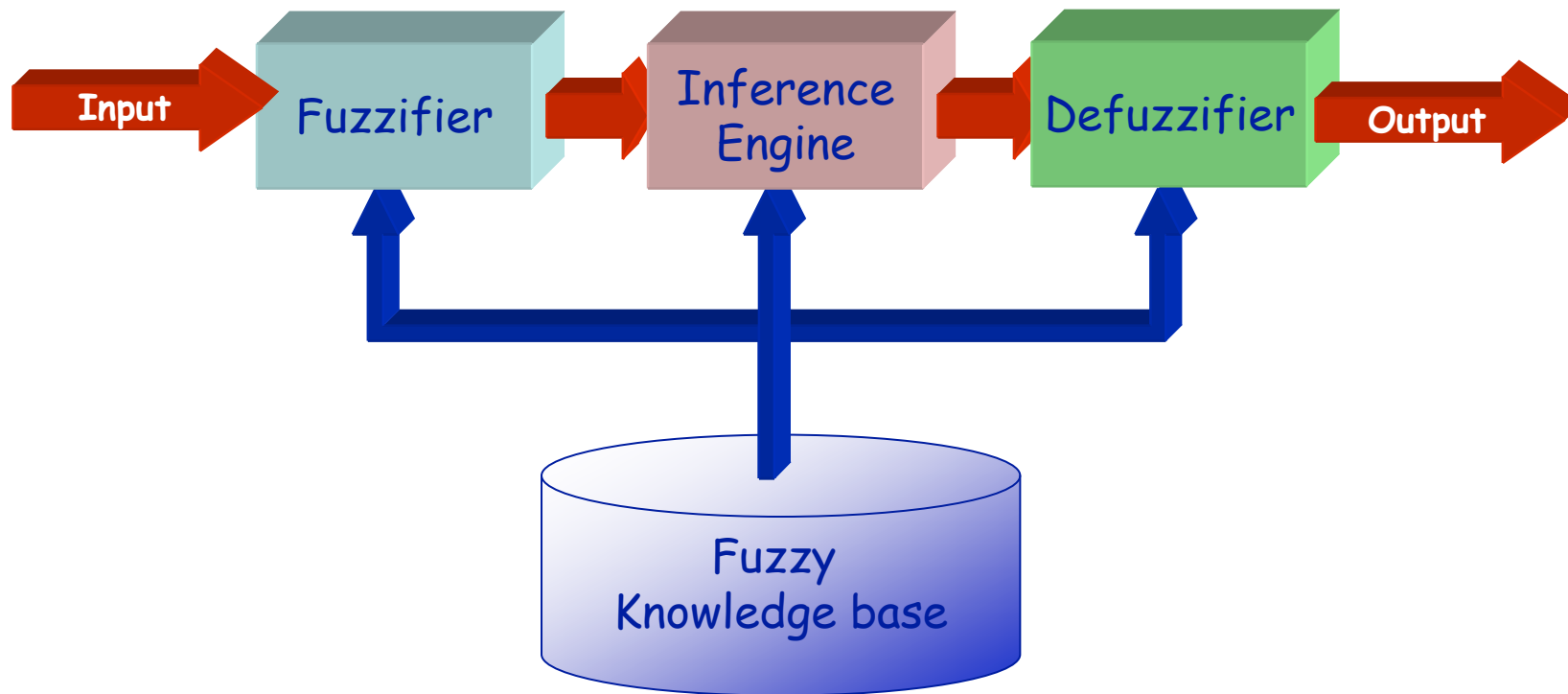
6. References

2. Definitions

Let's define the **key concepts of fuzzy logic** through an example of image processing: increasing the contrast of an image



2. Definitions

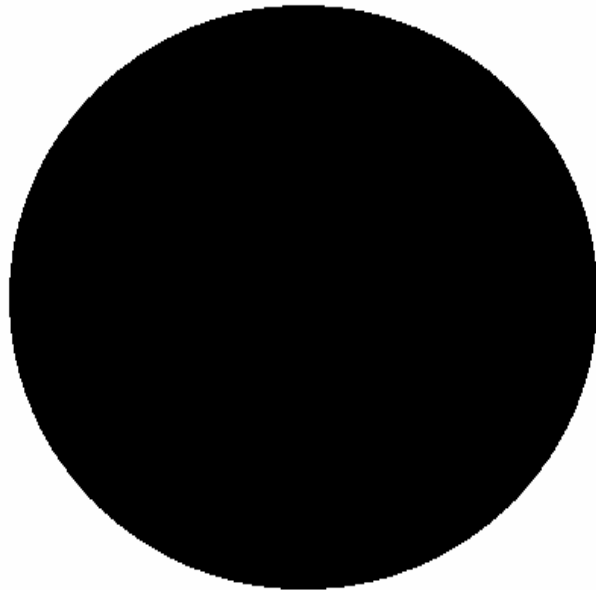


2. Definitions

Fuzzifier

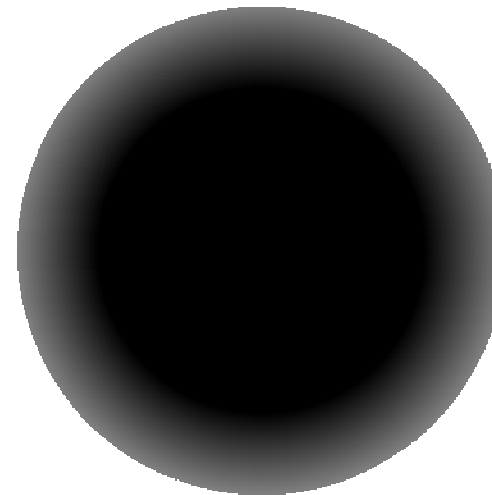
1) Fuzzy set and membership degree

Classical set



Indicator function: 0 or 1
→ **Binary** in classical logic

Fuzzy set



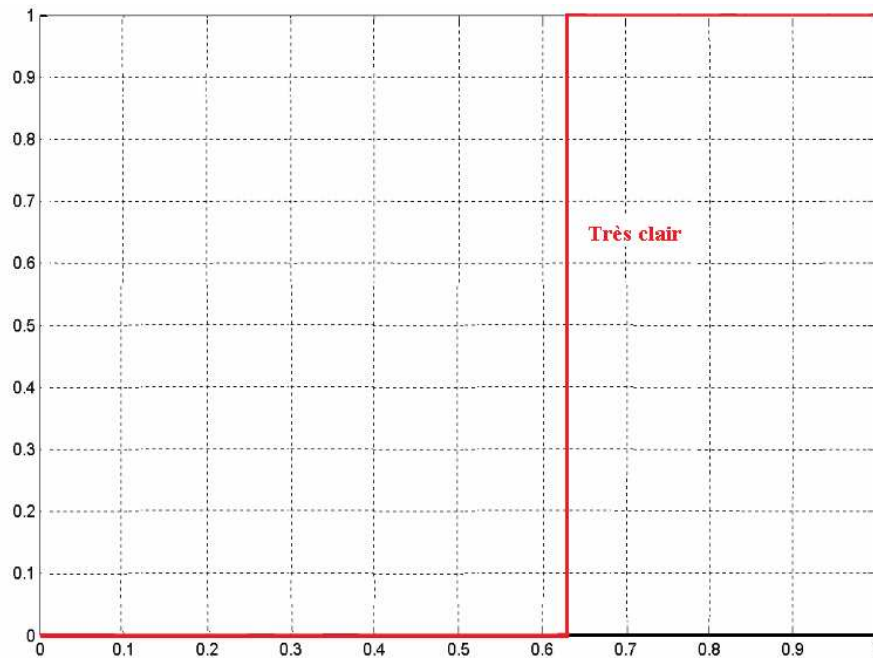
Membership degree: any real between 0 et 1
→ **Membership degree** in fuzzy logic
(eg 0.867)

2. Definitions

Fuzzifier

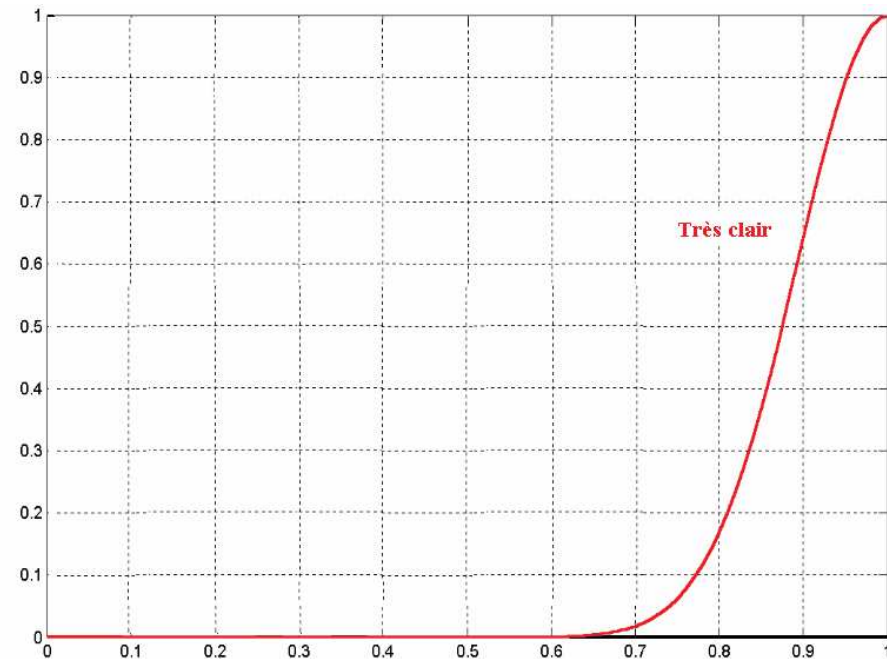
1) Fuzzy set and membership degree

Classical logic



Indicator function: 0 or 1
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Fuzzy logic

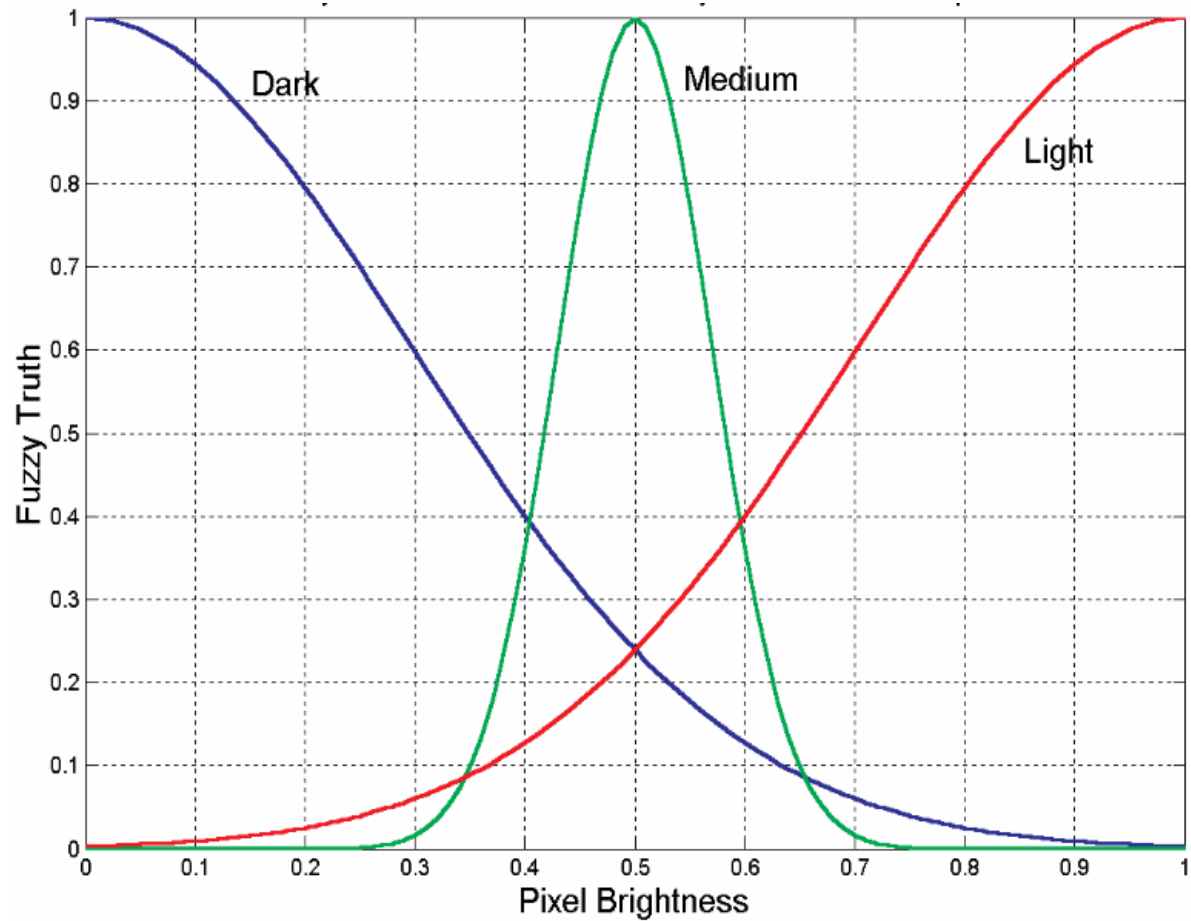


Membership degree: any real between 0 et 1
Membership degree in fuzzy logic
(eg 0.867)

2. Definitions

Fuzzifier

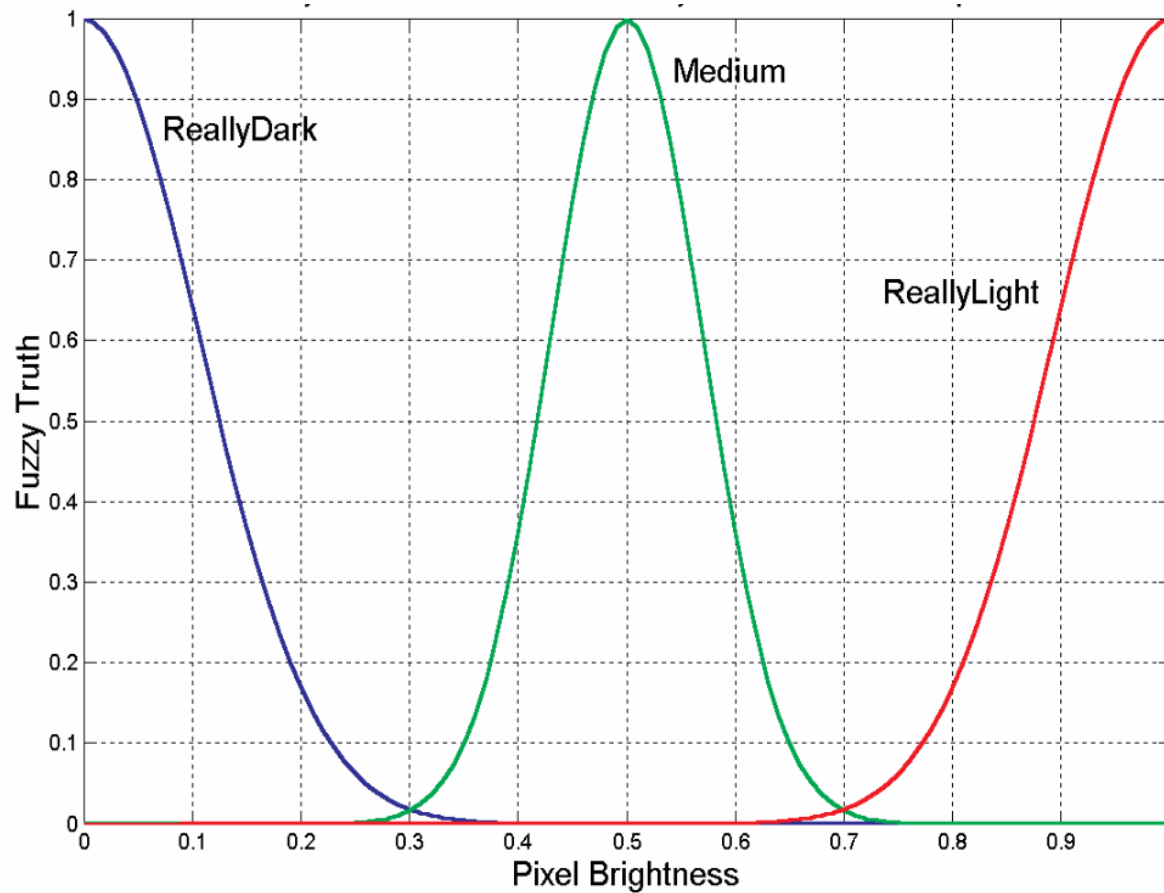
1) Membership functions (fuzzification step) in input



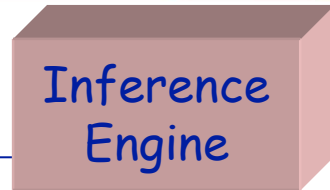
2. Definitions

Fuzzifier

1) Membership functions (defuzzification step) in **output**



2. Definitions



2) Redefinitions of basic operations

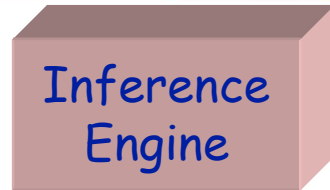
Classical logic

- Negation
- And
- Or

- Implication
- Modus ponens

Fuzzy logic

2. Definitions



3) Decision matrix

Input	Output
Light	Very light
Average	Average
Dark	Very dark

**Power of fuzzy logic!
A fuzzy system is expressed directly in
natural language**

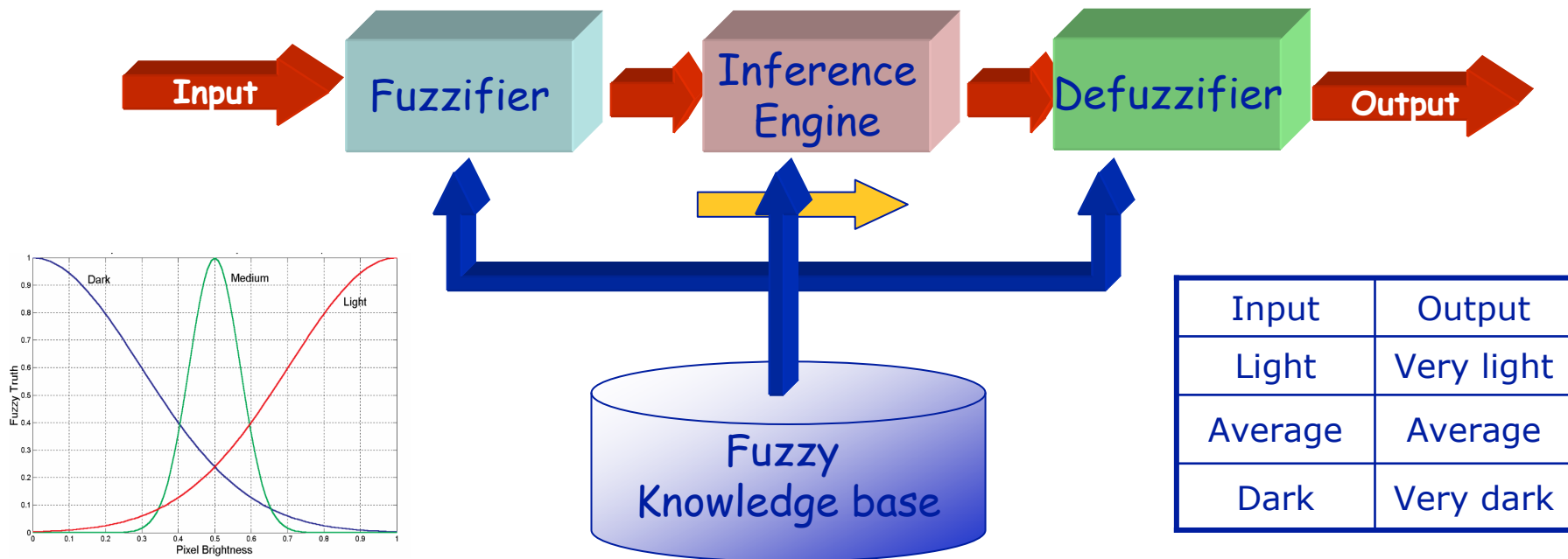
2. Definitions

4) Defuzzification !

Defuzzifier



2. Definitions



1. Origins

2. Definitions

3. Application: fuzzy inference systems

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6. References

3. Application: Decision Support Systems

Example of decision

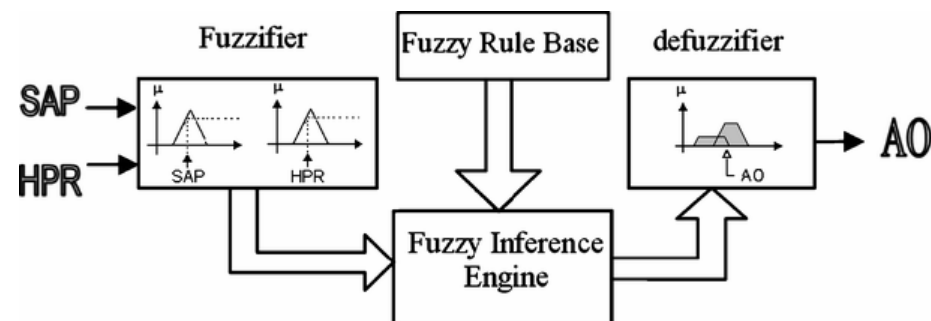
An anesthesiologist must decide on the content of the gas during surgery: the gas must be more or less anesthetic according to the patient's condition at a given time.

2 main criteria (input) :

- SAP: systolic arterial pressure
- HRP: heart pulse rate

1 decision (output) :

- AO: levels of anesthetic products in the gas



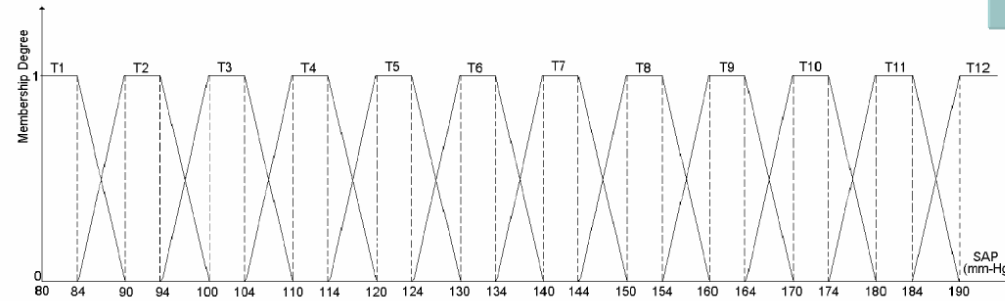
3. Application: Decision Support Systems



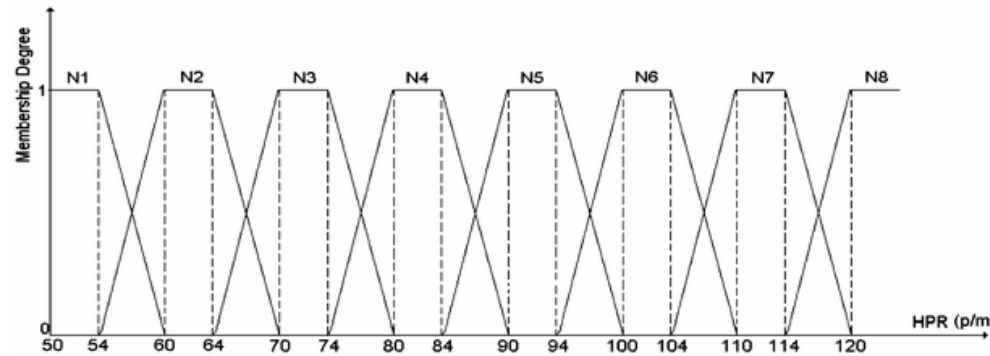
Fuzzifier

Membership functions

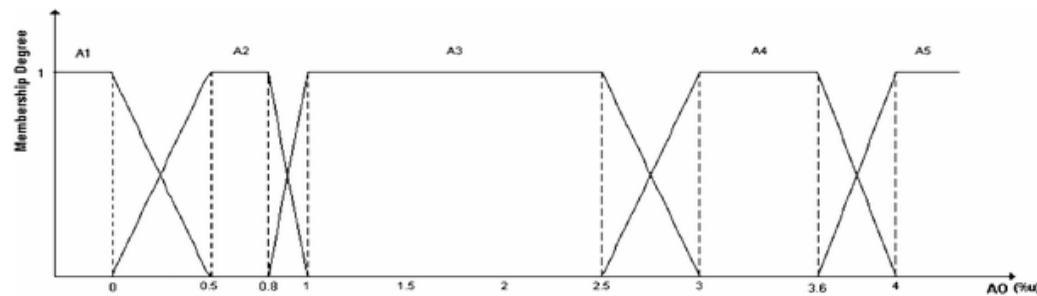
Input 1



Input 2



Output



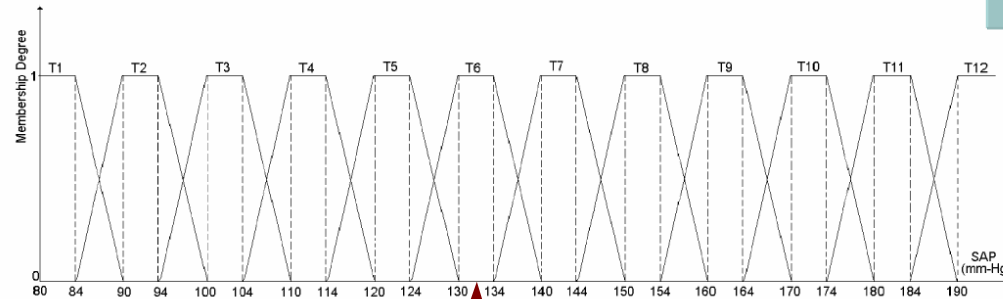
3. Application: Decision Support Systems



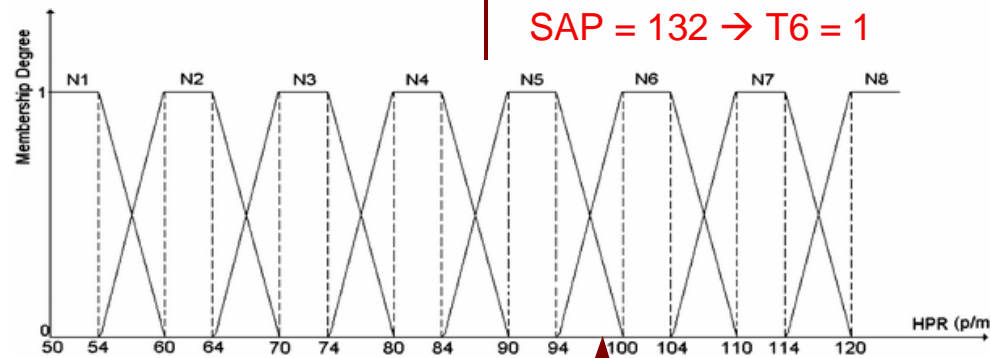
Fuzzifier

Membership functions

Input 1
SAP = 132



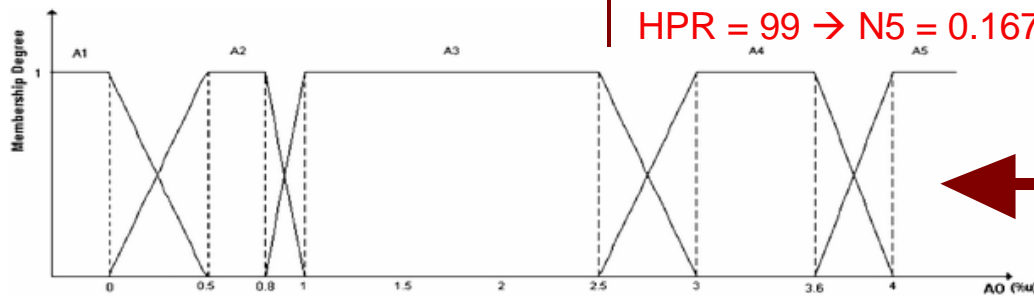
Input 2
HPR = 99



SAP = 132 → T6 = 1

HPR = 99 → N5 = 0.167, N6 = 0.834

Output



3. Application: Decision Support Systems



Decision matrix

	N1	N2	N3	N4	N5	N6	N7	N8
T1	A1	A1	A2	A2	A2	S	S	S
T2	A2	A2	A3	A3	A3	A4	A4	A4
T3	A2	A3	A3	A3	A3	A4	A4	A4
T4	A2	A3	A3	A3	A3	A4	A4	A4
T5	A2	A3	A3	A3	A3	A4	A4	A4
T6	A2	A3	A3	A3	A3	A4	A4	A4
T7	A2	A3	A3	A3	A3	A4	A4	A5
T8	S	A4	A4	A4	A4	A5	A5	A5
T9	S	A4	A4	A4	A4	A5	A5	A5
T10	S	A4	A4	A4	A4	A5	A5	A5
T11	S	A5	A5	A5	A5	A5	A5	A5
T12	S	A5	A5	A5	A5	A5	A5	A5

Read: If N5 and T10, then we decide A4

3. Application: Decision Support Systems



Decision matrix

HPR = 99, hence N5 = 0.167 and N6 = 0.834

	N1	N2	N3	N4	N5	N6	N7	N8
T1	A1	A1	A2	A2	A2	S	S	S
T2	A2	A2	A3	A3	A3	A4	A4	A4
T3	A2	A3	A3	A3	A3	A4	A4	A4
T4	A2	A3	A3	A3	A3	A4	A4	A4
T5	A2	A3	A3	A3	A3	A4	A4	A4
T6	A2	A3	A3	A3	A3	A4	A4	A4
T7	A2	A3	A3	A3	A3	A4	A4	A5
T8	S	A4	A4	A4	A4	A5	A5	A5
T9	S	A4	A4	A4	A4	A5	A5	A5
T10	S	A4	A4	A4	A4	A5	A5	A5
T11	S	A5	A5	A5	A5	A5	A5	A5
T12	S	A5	A5	A5	A5	A5	A5	A5

SAP = 132

Hence:

- T6 = 1*

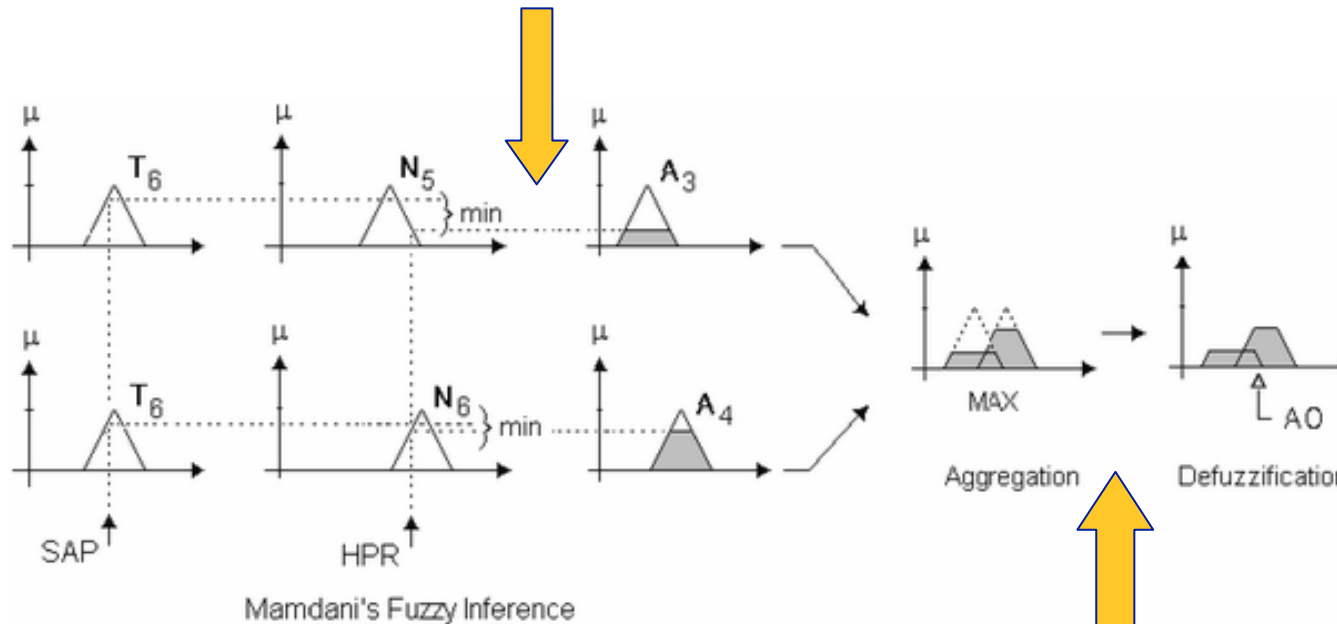
We therefore decide A3 and A4!

3. Application: Decision Support Systems

Input : HPR = 99 → N5 = 0.167, N6 = 0.834
 SAP = 132 → T6 = 1

Defuzzifier

T6 = 1	N5 = 0.167	=>	A3 = 0.167
T6 = 1	N6 = 0.834	=>	A4 = 0.5



A3 = 0.167 A4 = 0.5 => **Output = 3.368**

3. Application: Decision Support Systems



Anesthetist vs. fuzzy logic?

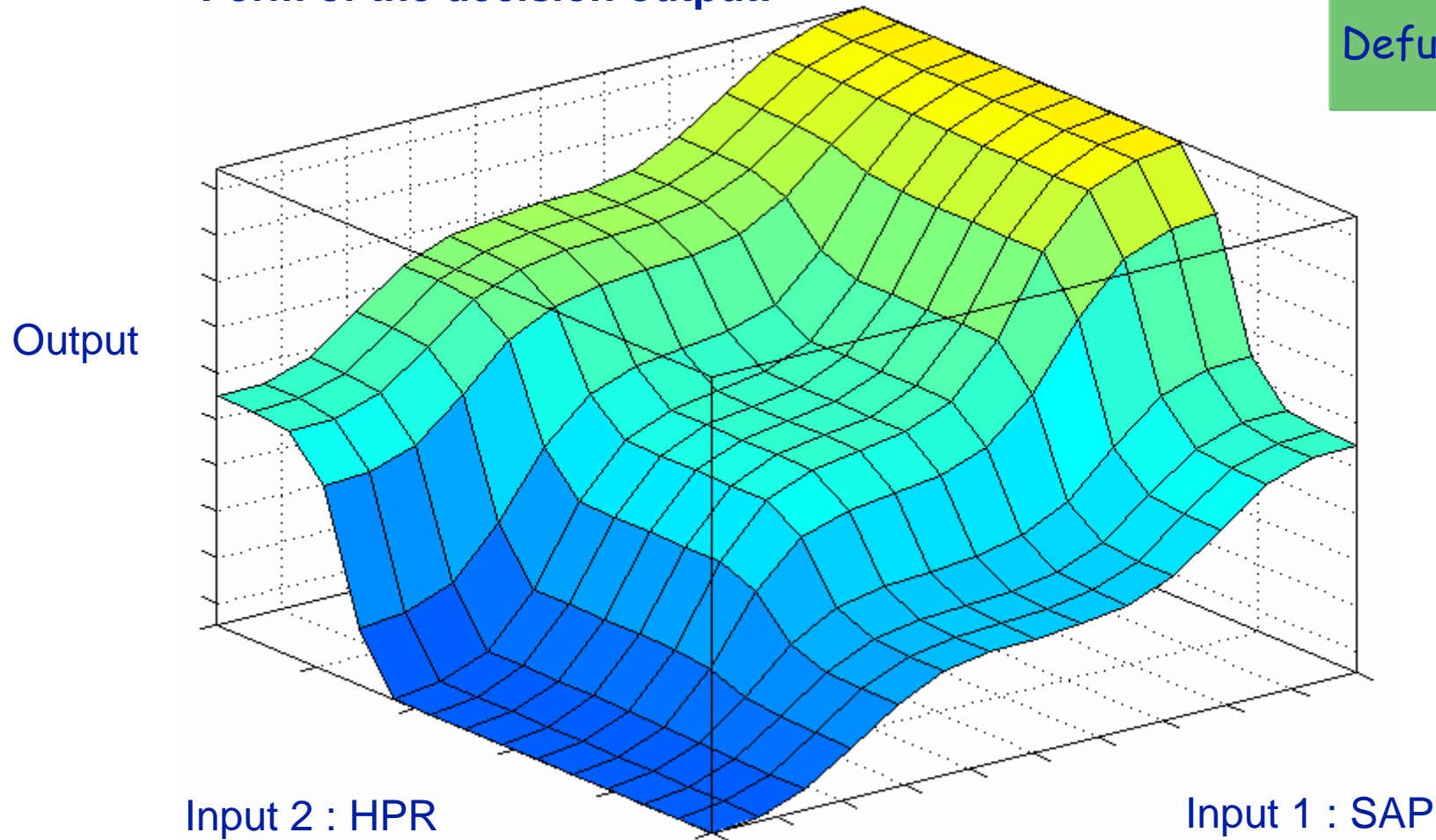
Table 5 Comparison of anesthetist prediction and Fuzzy Logic prediction

											Total		
Patient 1	SAP (mmHg)		164	161	192	156	172	161	152	157	154		
	HPR (p/m)		65	96	99	80	72	81	73	78	73		
	AO	Anesthetist	2	2.5	4	3	3.5	2.5	2.5	2.5	2.5	2.5	25
		Fuzzy Logic	3.25	3.29	3.88	2.18	3.27	3.27	1.83	2.38	1.83	25.2	
	Distance %												+1
Patient 2	SAP (mmHg)		149	184	139	182	163	158	158				
	HPR (p/m)		88	94	98	74	78	90	87				
	AO	Anesthetist	2	4	2	5	4	2	2				21
		Fuzzy Logic	1.85	3.27	2.61	3.27	3.27	2.61	2.52				19.4
	Distance %												-7.6
Patient 3	SAP (mmHg)		110	130	130	110	130	120	120				
	HPR (p/m)		90	70	70	68	72	75	76				
	AO	Anesthetist	2.5	2	2	2	2	1.5	1				12
		Fuzzy Logic	1.83	1.83	1.83	1.85	1.83	1.84	1.85				11.1
	Distance %												-7.5
Patient 4	SAP (mmHg)		150	110	115	110	110						
	HPR (p/m)		96	74	107	95	90						
	AO	Anesthetist	3	2	2	2	2						11
		Fuzzy Logic	2.18	1.83	3.26	2.00	1.83						11.1
	Distance %												+1

3. Application: Decision Support Systems

Form of the decision output:

Defuzzifier



1. Origins

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4. Application: fuzzy queries

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4. Application: fuzzy queries

XQuery : query language for XML databases

(XQuery plays over XML data a role similar to the SQL language vis-à-vis the relational data)



Example: a manager wants to give a bonus to all its vendors performance. He wants to make a query in the database to find them.

We will compare the results according to the logic on which the query is based : classical logic or fuzzy logic.

4. Application: fuzzy queries

Classical logic: Boolean test "Over € 4,000 in 10 days!"

Query :

```
<output>
{
  for $emp in doc("sale.xml")/salesman/emp
  let $eid := $emp/empid/text()
  let $en := $emp/ename/text()
  let $sa := $emp/sales/text()
  let $d:=$emp/days/text()
  return if ($sa >=4000 and $d <=10) then
    <emp>
    <empid> {$eid} </empid>
    <ename> {$en} </ename>
    <sales>{$sa}</sales>
    <days>{$d}</days>
    </emp>
  else ()
}</output>
```



4. Application: fuzzy queries

Classical logic: Boolean test "Over € 4,000 in 10 days!"

```
<output>
<emp>
<empid>1003</empid>
<ename>Joshua</ename>
<sales>5000</sales>
<days>10</days>
</emp>
<emp>
<empid>1004</empid>
<ename>Kevin</ename>
<sales>4998</sales>
<days>3</days>
</emp>
```



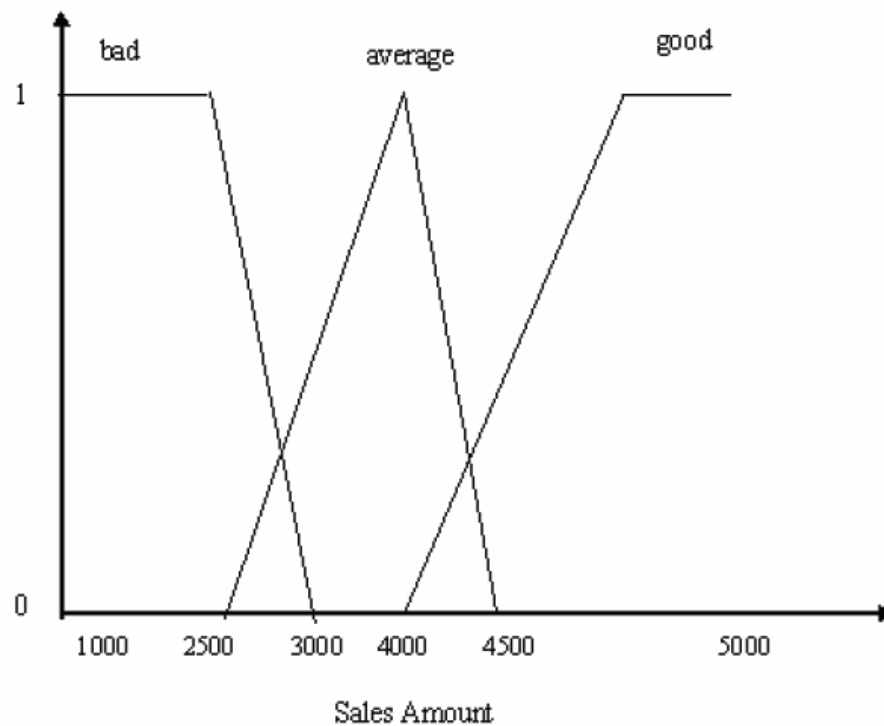
```
[...]
<emp>
<empid>1009</empid>
<ename>George</ename>
<sales>4100</sales>
<days>11</days>
</emp>
<emp>
<empid>1008</empid>
<ename>Henry</ename>
<sales>3999</sales>
<days>3</days>
</emp>
</output>
```



4. Application: fuzzy queries

Fuzzy logic: fuzzy criteria "Be good!"

Query:



4. Application: fuzzy queries

Fuzzy logic: fuzzy criteria "Be good!"

Query:

```
<output>
{
  for $emp in doc("salesman.xml")/salesman/emp
  let $eid := $emp/empid/text()
  let $en := $emp/ename/text()
  let $sa := $emp/sales/text()
  let $d:=$emp/days/text()
  return if {salesman=good } then
    <emp>
    <empid> {$eid} </empid>
    <ename> {$en} </ename>
    <sales>{$sa}</sales>
    <days>{$d}</days>
    </emp>
  else ()
}</output>
```



4. Application: fuzzy queries

Fuzzy logic: fuzzy criteria "Be good!"

```
<output>
<emp>
<empid>1003</empid>
<ename>Joshua</ename>
<sales>5000</sales>
<days>10</days>
</emp>
<emp>
<empid>1004</empid>
<ename>Kevin</ename>
<sales>4998</sales>
<days>3</days>
</emp>
```



[...]

```
<emp>
<empid>1009</empid>
<ename>George</ename>
<sales>4100</sales>
<days>11</days>
</emp>
<emp>
<empid>1008</empid>
<ename>Henry</ename>
<sales>3999</sales>
<days>3</days>
</emp>
</output>
```



4. Application: fuzzy queries



SQL: Query language for databases

SQL extensions incorporating fuzzy logic:

- SQLf [Bosc 1995] ;
- Summary SQL [Rasmussen 1996].

Classical query:

```
SELECT LName, Age, Expertise FROM Workers
WHERE Age < 40 AND Age >= 30 AND Expertise = 'AI';
```

Fuzzy query (SQLf_j):

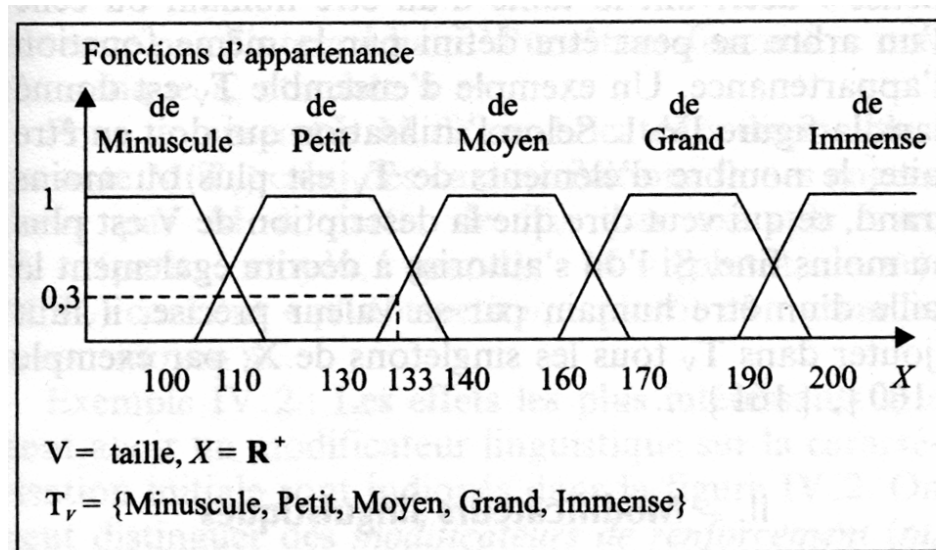
```
SELECT THRESHOLD 0.2 LName, Age, Expertise FROM Workers
WHERE ~Age IS 'Middle-aged' AND #Expertise IS 'AI';
```

4. Application: fuzzy queries

Concept of linguistic variable

Var_linguistique = (V, X, T_x) :

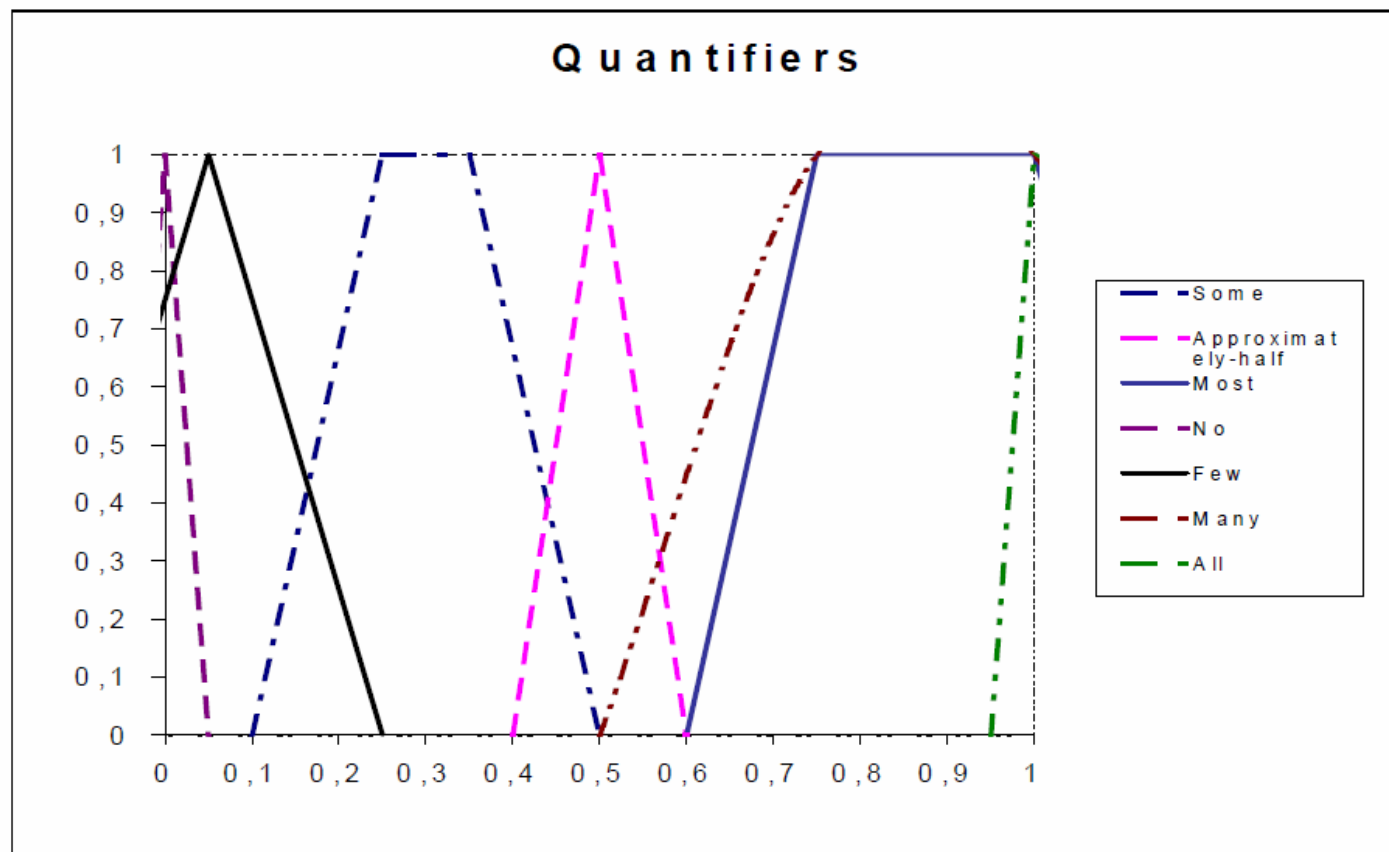
- V: variable (age, temperature, etc.) ;
- X: range of values of the variable;
- T_x: fuzzy set.



4. Application: fuzzy queries

Concept of quantifiers

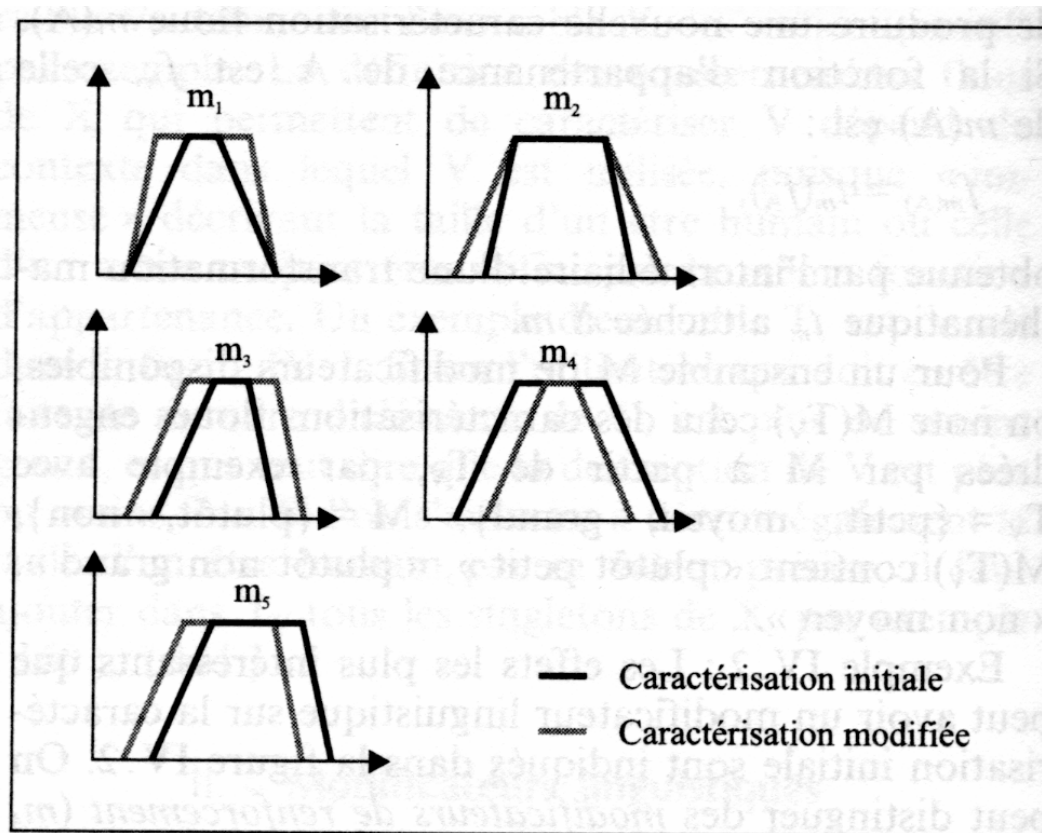
Example: "very, much, much, relatively ..."



4. Application: fuzzy queries

Concept of modifiers

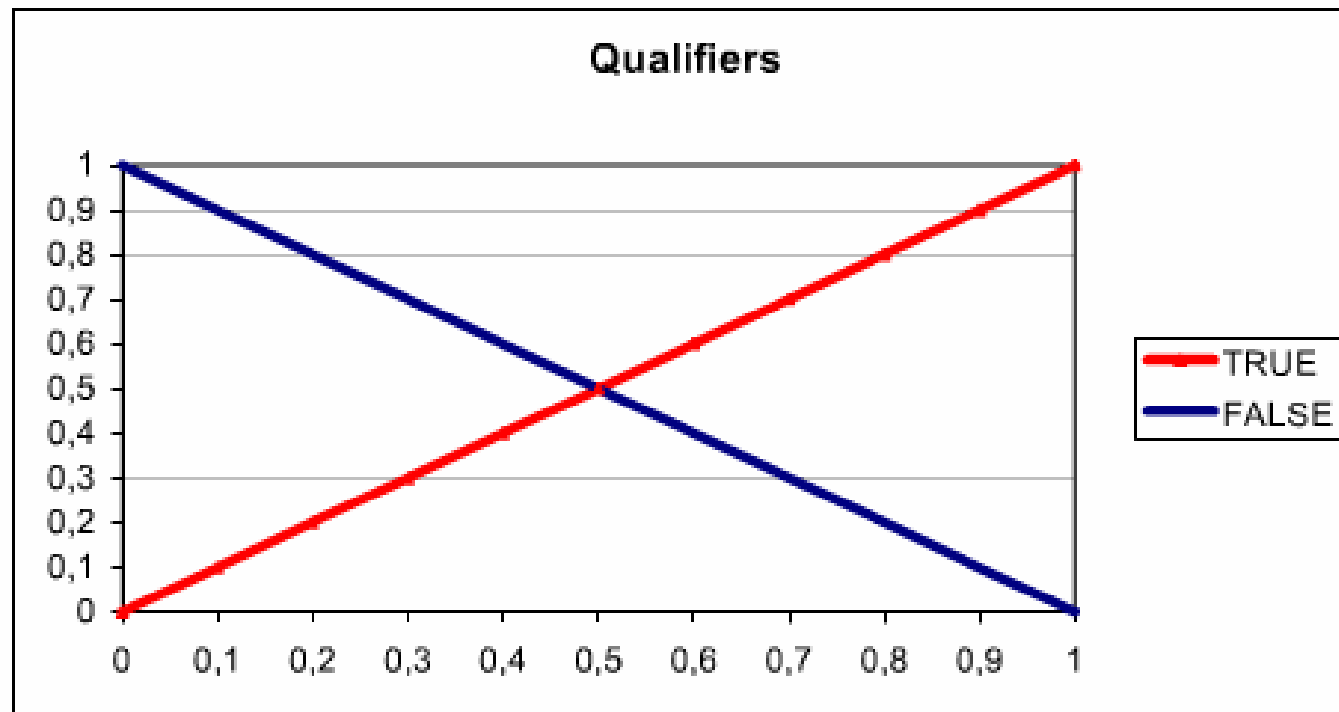
Example: "very, much, much, relatively ..."



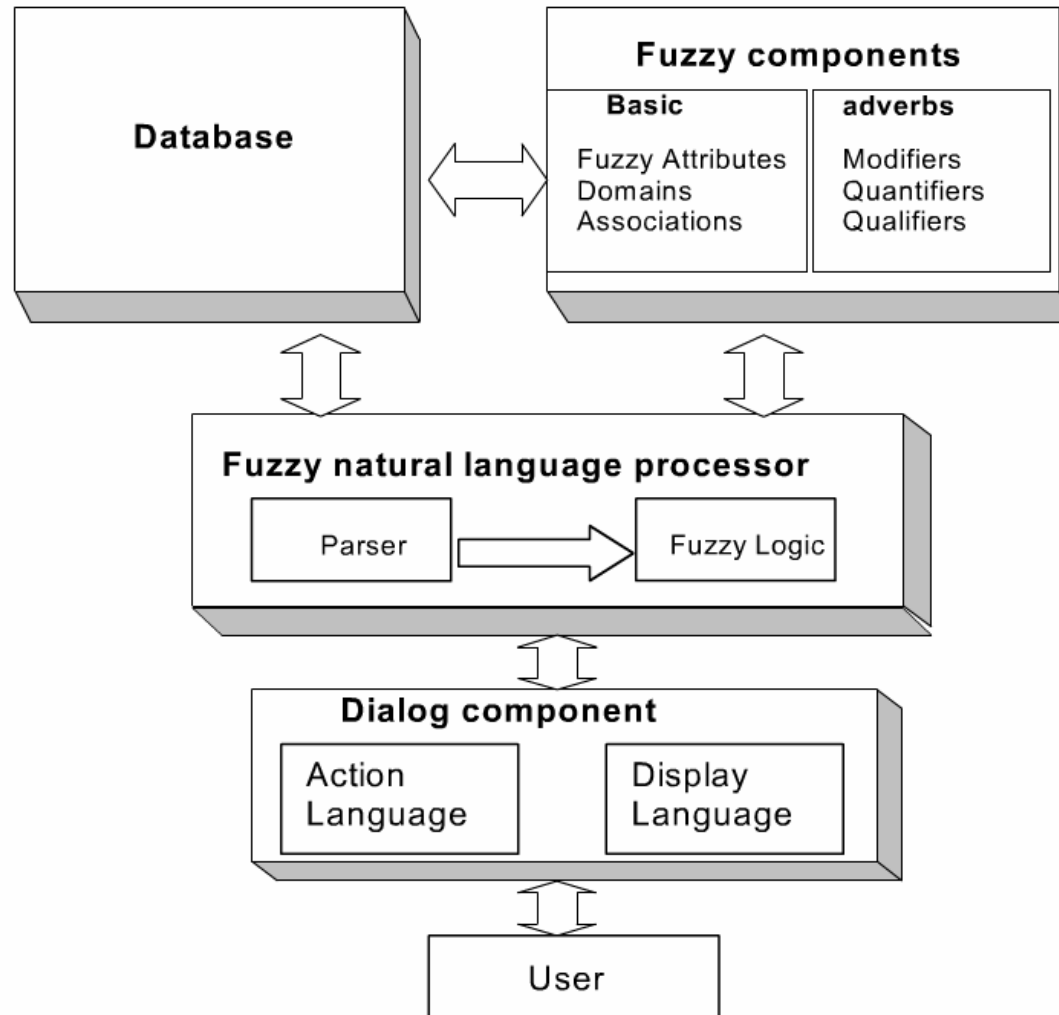
4. Application: fuzzy queries

Concept of **qualifiers**

Example: "true, false, probable, ..."



4. Application: fuzzy queries



1. Origins

2. Definitions

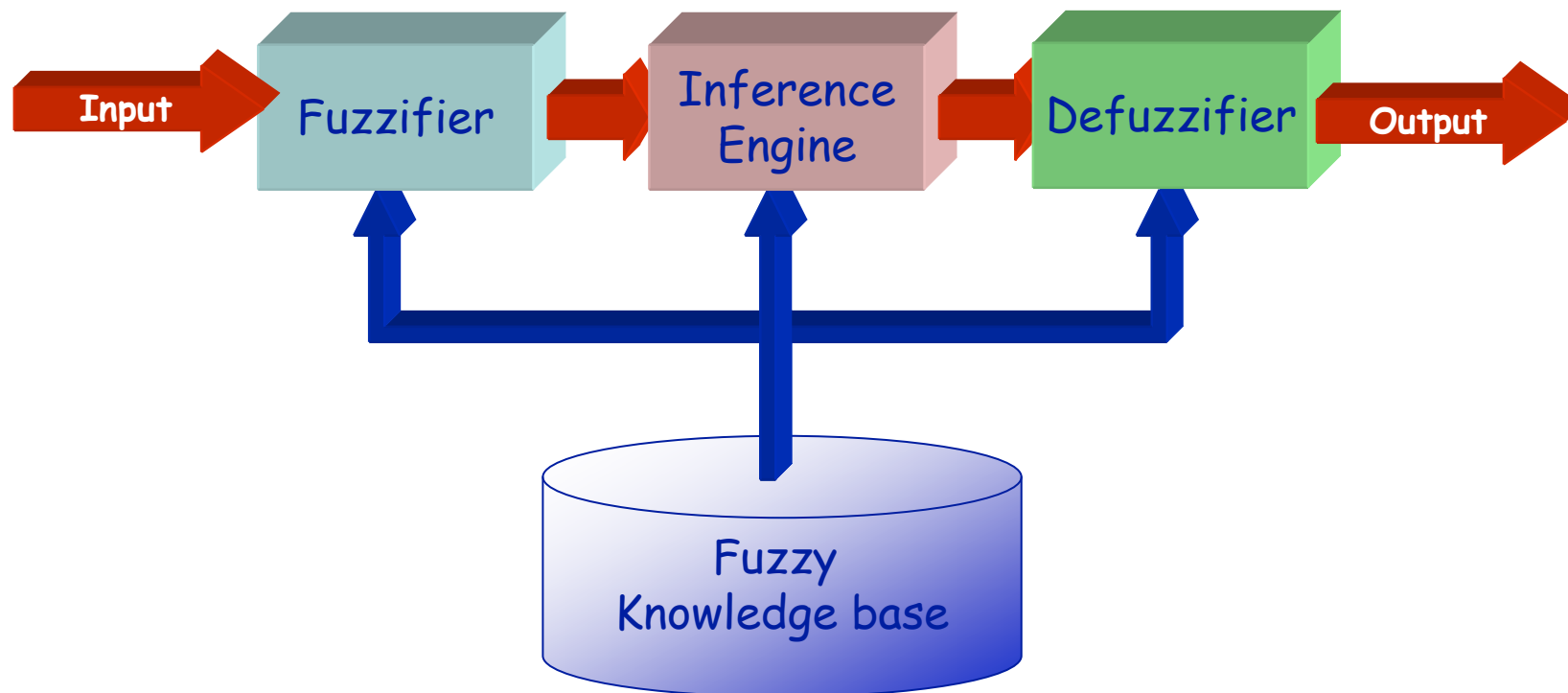
3. Application: fuzzy inference systems

4. Application: fuzzy queries

5. Conclusion

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Overview:



Future of fuzzy logic

- Link between human reasoning and artificial intelligence
- Accuracy vs. efficiency trade-off
- Possibility of coupling with other theories (neural networks, evolutionary algorithms, etc.).

1. Origins

2. Definitions

3. Application: fuzzy inference systems

4. Application: fuzzy queries

5. Conclusion

6. References

6. References



References:

- Bosc, P., Pivert, O.: SQLf: A Relational Database Language for Fuzzy Querying. IEEE Trans. on Fuzzy Systems 3 (1995) 1–17.
- Rasmussen, D. and Yager, R. R.: SummarySQL - A flexible fuzzy query language. Proceedings of the Second Workshop on Flexible Query-Answering Systems, Roskilde, Denmark (1996) 1–18
- Sanli S., Saraoglu H. M., (2007), A fuzzy logic-based decision support system on anesthetic depth control for helping anesthetists in surgeries. Journal of Medical Systems, 31 :511519.
- Zadeh L.A.: Fuzzy Sets. Inform. and Control 8 (1965) 338–353.

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