Fuzzy Inference Models For Discrete Event Systems

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Research themes of the computer sciences team
- Modeling and Simulation
- Wireless Sensor Networks

Application field

- Renewables
- Fires

Water management
Modeling method for systems with imperfect parameters

Classical approach

- Assumptions
- Model
- Simulator
- Results

Taking into account the imperfections describing the system

Multi modeling Framework

Interpretation of fuzzy results

Approach

Fuzzy Logic

DEVS Formalism

Applications
Outline

- FIS: Fuzzy Inference Systems
- Discrete EVent System Specification
- iDEVS: inaccurate DEVS
- DEVFIS: DEVS + FIS
- Case of Study
- Conclusion
FIS allows an intuitive way to represent the behaviour of complex systems. They are used in robotics, control, decision support, etc.

- Inputs and Outputs based on Fuzzy Sets Theory
- Inference engine based on rules (IF A Then B)
DEVS is a multi-formalism, generic and adaptable based on Discrete Event System Theory.

- Modular and hierarchical:
  - Atomic model
  - Coupled model
- Separation between the modeling and simulation.
- Automatic generation of simulation algorithms based on models.
- Time management at the level of events.
Our approach

Fuzzy Logic

- Development of the Fuzzy Sets Theory (inaccurate data)
- Development of the Possibilities Theory (Uncertain data)
- Extending classical logic for approximate reasoning about imperfect knowledge (incomplete data)

DEVS

- Multi-formalism, generic and adaptable
- Modular and hierarchical
- Implementation following the object-oriented properties
- DEVSimPy: implementation of DEVS in python

iDEVS (DEVS+FST)
uDEVS (DEVS+PT)
DEVFIS (DEVS+FIS)

Multi-formalism, generic and adaptable
Modular and hierarchical
Implementation following the object-oriented properties
DEVSimPy: implementation of DEVS in python
Outline

- FIS: Fuzzy Inference Systems
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iDEVS is an extension of DEVS for the simulation of systems with inaccurate parameters

- Based on FuzzySet class to describe inaccuracy
- Evolving set of operators and manipulation functions
- New atomic model
- Complies with the DEVS formalism specifications
- Does not change the simulation algorithms
- Possibility of coupling between DEVS and iDEVS models
// FuzzySet class
String label // linguistic label
real a, b // kernel
real ψ, ω // support

A fuzzy number is a fuzzy interval if \( a = b \)
A crisp number is a fuzzy interval if \( a = b = ω = ψ \)

// Characteristic functions
function \( μ^{-}(λ) = αλ+ψ \) // left front
function \( μ^{+}(λ) = -βλ + ω \) // right front

// Overloading operators \{+,-,×,/,<,>, etc.\}
FuzzySet operator×(FuzzySet) // multiplication function
FuzzySet operator×(Real) // multiplication function

// Manipulation functions
FuzzySet sin(FuzzySet) // multiplication function
DEVFIS is an extension of DEVS for the simulation of Fuzzy Inference Systems

- based on FuzzySets class: FuzzySet list
- provides a set of tools to represent Fuzzy Inference Systems as DEVS models
- applications: control, learning, optimization, decision-making, etc.
Following the iDEVS approach, the class FuzzySets has been developed for the DEVFIS method.

- It allows representing the inputs and outputs of FIS.
- It includes, a fuzzy sets: a list of FuzzySet objects.
- Several functions that allow the use of inference methods have been developed.
  - method to associate a linguistic label to FuzzySets of the list
  - methods of learning and optimization,
  - Mamdani and Takagi-Sugeno methods
The role of the input model (Ip and Io) is to associate the input value to a linguistic label and to a membership degree.
The aim of inference model is to apply the rules and calculate the overall membership degree.
The output model determines the result according to one or more membership degrees and rules conclusion.
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Case of Study

**System**: A mixer must blend 2 water flows, one at a temperature of 80 and other at a temperature of 10. It is controlled by the opening of 2 valves, \( vh \) (valve hot) for hot water and \( vc \) (valve cold) for cold water. \( vh \) and \( vc \) take all values from 0 (closed) to 1.

A FIS is responsible for changing the opening of valves for temperature and streamflow setpoint (\( Ts \) and \( Ss \)). It takes as input temperature error (\( Te \)) and Streamflow error (\( Se \)).
Case of Study

The field errors for temperature (Te) and streamflow (Se) is divided into three fuzzy sets:
- Negative : NG (Negative Great) - NP
- Zero : ZR
- Positive : PP (Positive Small) - PG

These tables are easy to interpret:
- If Te is N and Se is N then Δvh is PG and Δvc is ZR.

This rule corresponds to the situation:
- the temperature is too cold (TE=N) and the streamflow too low (SE=N), increasing the streamflow of hot water (Δvh=PG) without touching the streamflow of cold water (Δvc=ZR), we simultaneously increasing the streamflow and temperature
The errors of temperature $TE$ and streamflow $SE$ are represented by the membership function.

The inference system chosen corresponds to a zero order FIS (type Takagi-Sugeno), there is no fuzzy output.

The controller settings are numerical values, we have set to “Grand (Big)” = 0.1 and “Petit (little)” = 0.05. We therefore, $NG = -0.1$, $NP = -0.05$, $PP = 0.05$ and $PG = 0.1$.
C0 and C1 send the temperature and streamflow setpoint (37 and 1.4)
M describes the mixer, it calculates the temperature and streamflow
S0 and S1 calculate temperature (TE) and streamflow (SE) error
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DEVS is a multi modeling formalism

Fuzzy Logic can represent and manipulate imperfect knowledge expressed in natural language

iDEVS is an extension of DEVS for the simulation of systems with inaccurate parameters

based on FuzzySet class

DEVFIS is an extension of DEVS for the simulation of Fuzzy Inference Systems

based on FuzzySets class: FuzzySet list
### Prospect

Taking into account imperfect information

<table>
<thead>
<tr>
<th>inaccurate</th>
<th>uncertain</th>
<th>incomplete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuzzy Sets Theory</td>
<td>Possibilities Theory</td>
<td>Approximate Reasoning</td>
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**Fuzz-iDEVS : fuzzy toolbox for the DEVS formalism**
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