Plant Simulation Assembly library

Reference manual

Siemens PLM Software

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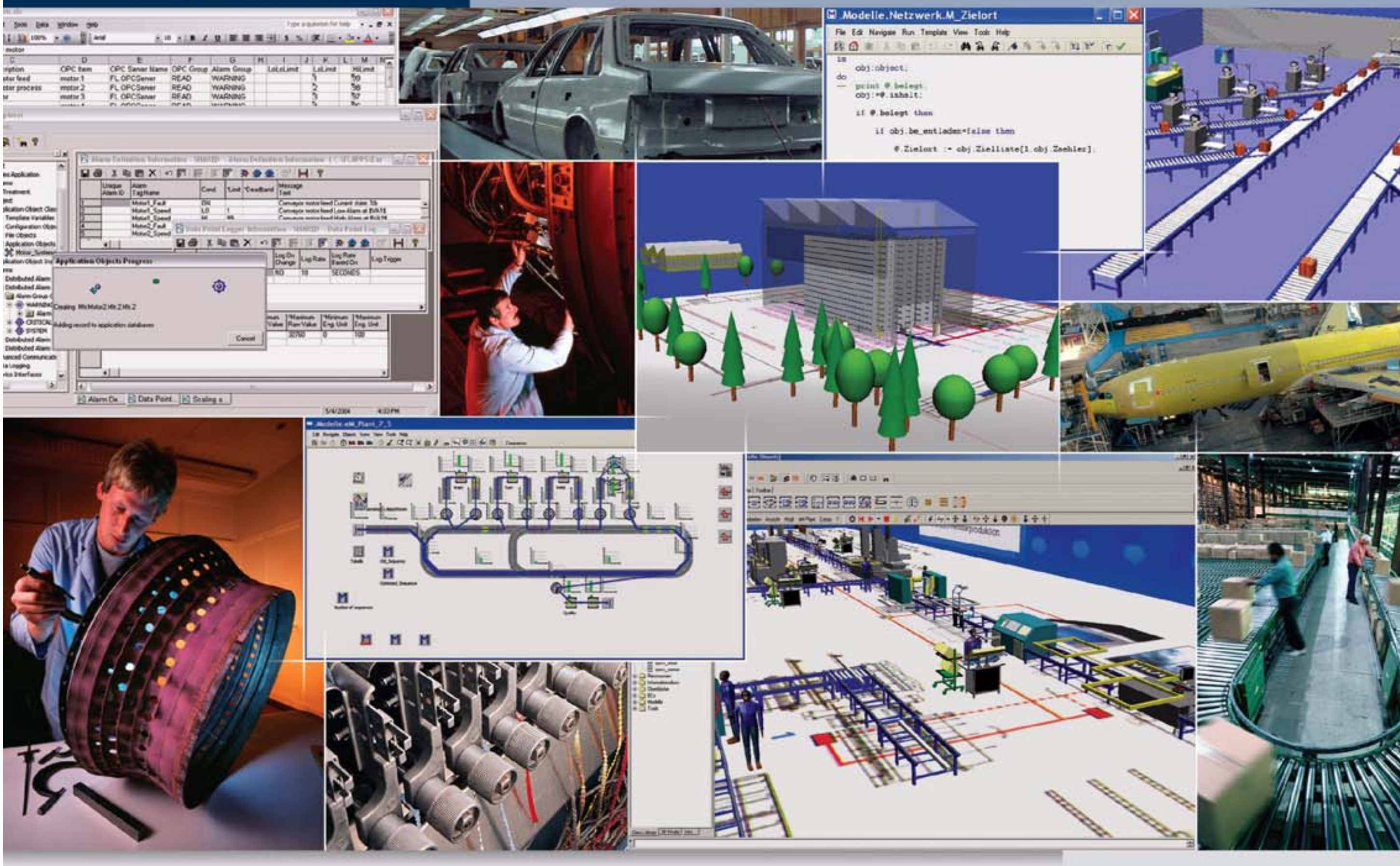

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Plant Simulation
Assembly Library
Fuzzy Logic

Version 9.0

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Fuzzy-Theory

In everyday situations there are many descriptions with which the truth value of a statement is dependent very subjectively and individually on the viewer. The boolean values cannot be often assigned, like true or wrong, unambiguously. That's why ZADEH in 1965 enlarged the classical set theory and founded the theory of the fuzzy sets. Based on the fuzzy sets he developed the fuzzy logic in extending of the classical bivalent (sharp) logic. In the Fuzzy-set theory the affiliation of-elements which comprises only of the values {0, 1} or {true, wrong}, is extended and is represented by the interval [0, 1]. Therefore it is possible that an element belongs only “to a part” to an set.

The statement whether a person at the age of 45 years is part of the amount “young people” is an example of a blurred amount allocation, because here neither (true) nor (wrong) is a suitable answer.

The Fuzzy technology was sped up in Japan in the 80s, in the middle of the 90s this technology was also used in Europe industrially.

Fuzzy-Set

In the classical set theory the element relationship is the basic concept describing whether an element α is included in a certain set A or not.

Besides, the set A is described by the enumeration of all elements or by defining properties which comes up exactly to the elements of the set.

By contrast an element can also be contained in a fuzzy set "a little". The degree of the relationship is described by an relationship function (membership function) which assigns a number between 0 and 1 to the elements of a basic set.

On fuzzy sets operations are defined as for example for intersection (AND), union (OR) and complement (NOT).

Application example

Today Fuzzy Logic is used in different areas. Mostly this technology is used when no mathematical, but only a verbal description is given. Out of linguistically formulated sentences and rules logic such a mathematical description can be won by means of Fuzzy logic. It is very interesting that with Fuzzy logic you can still control systems even if a mathematical relationssship cannot be found between the input and output values of a system, or only with very high expense that an automation is not realizable.

Fuzzy Functions

In general the values of a membership function can have any figure, as long as their functional values are in the interval [0,1]. The most frequent used forms of the membership function are the triangular function and the trapezoid function. However, Fuzzy functions can also be non-linear functions as for example the Sigmoid function:

$$S(x,\alpha,\delta) = \begin{cases} 0 & \text{für } x \leq \alpha - \delta \\ 1 - 2(\frac{x-\alpha+\delta}{2\delta})^2 & \alpha - \delta < x < \alpha \\ 1 - 2(\frac{\alpha-x+\delta}{2\delta})^2 & \alpha < x \leq \alpha + \delta \\ 1 & x \geq \alpha + \delta \end{cases}$$

The curve expresses by the form of a S. a increasing relationsship. The decreasing relationsship can be expressed by a suitable Z curve:

$$Z(x, \alpha, \delta) = 1 - S(x, \alpha, \delta)$$

The parametre α gives the turning point, δ determines the inclination of the curve, with larger δ the curve becomes more flat.

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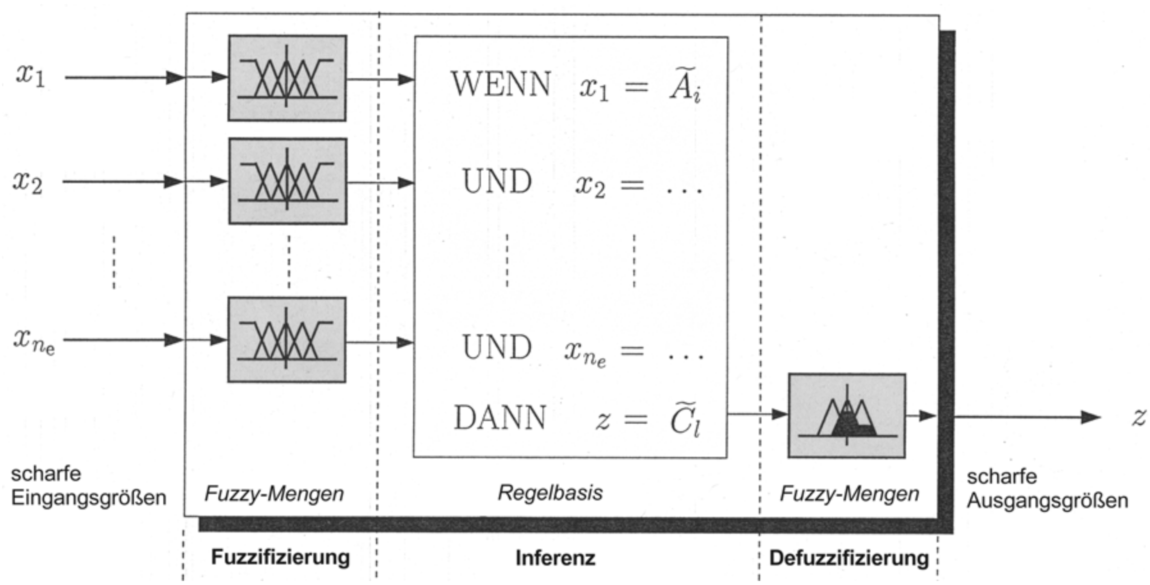
Fuzzy-Systems

Based on the basics of the Fuzzy logic, the construction of Fuzzy systems will be explained in the following chapter. Conventionally the mapping instructions of a system will be expressed mathematically. Fuzzy systems will be described by verbally formulated rules and fuzzy quantisation.



The evaluation of a Fuzzy system divides in three segments:

- Fuzzyfication
- inference
    - Aggregation
    - Implication
    - Accumulation
- Defuzzification

Fuzzification

Fuzzy sets serve as an interface between the rule base and the sharp values of the system environment. Real values from the system world are mapped on linguistic variables and their degree of relationsship.

Inference

The Inference engine will evaluate the rule base under inclusion of the results of the Fuzzification. The Inference engine maps the Fuzzy input sets on the Fuzzy output sets taking into account the rule base. The Inference engine splits itself in three functions: the Aggregation, the Implication and the Accumulation.

Aggregation

With the Aggregation the truth value *If* of part of every rule is determined. In addition the degree of fulfillment of the elementary statements of a rule will be conjunctiv combined.

Implication

With the implication the fuzzy conclusion will be done for all rules.The result of a rule will be a conclusion which is expressed by a Fuzzy set.

Accumulation

The accumulation generates the result out of the subsets of all rules.

Defuzzification

The result of the Inference is a fuzzy set a linguistic variable, which must become, in the last step, a sharp value. For this different methods are available, which are described with the object themselve.

Das Inferenz-Verfahren liefert eine unscharfe Menge einer linguistischen Ausgangsvariablen, welche im letzten Schritt in den scharfen Wertebereich zurücktransformiert werden muss. Hierzu bedient man sich unterschiedlicher Methoden, die bei dem Objekt selbst beschrieben sind.

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The Fuzzy Objects

Based on the basis of the Fuzzy theory three objects were implemented to realize Fuzzy controllers:

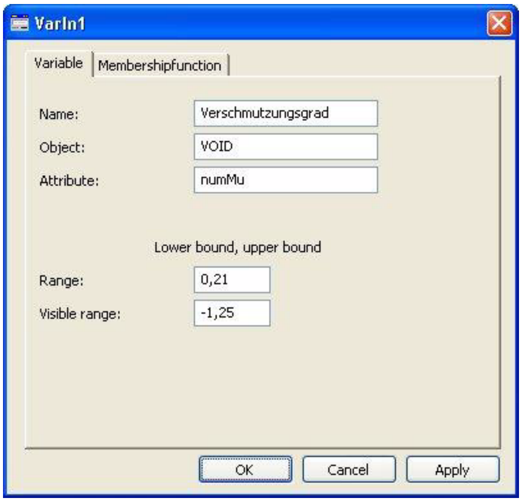
- VarIn,
- Rulebase,
- Varout

The objects are described in the following sections.

VarIn 

The object *VarIn* defines the interface to the model. Here the variable or the object as well as the interesting attribute are defined. They will be used as an input value for the rule base. Besides, the range of the value and the membership functions are defined.

Tab Variable



Name

Defines the name of the object *VarIn*.

Object

Enter the name of the object whose value should be used in the rule base.

Attribute

Enter the name of the attribute whose value should be used.

Range

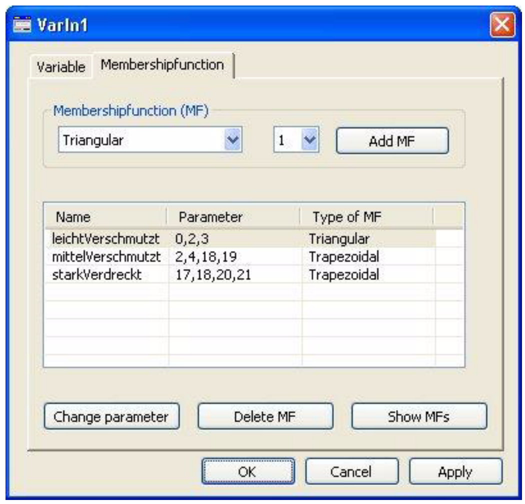
Enter the range of the attribute value can accept. Note: the membership function is calculated only on this range.

Visible Range

The Visible range is the range, for the representation of the membership function. It does not influence the membership function.

Tab Membership function

On this tab the membership functions and their parametres are defined.



Add MF

With this button you add a new membership function. An additional dilogue will be opened which supports you entering the input values.

Enter a name for the membership function. Select one of the available functions and enter the parameters. Below the input fileds a short tip about the expected values will be shown.

Change Parameter

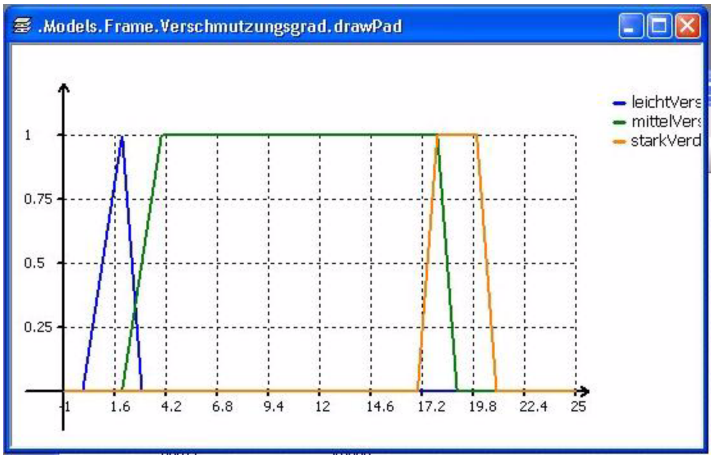
Press this button to open the input dialogue for the parameters of a membership function.

Delete MF

By pressing this button the marked membership function will be deleted.

Show MFs

Press this button to show the membership functions graphically. Depending on the definition you will see a similar chart, as shown below.

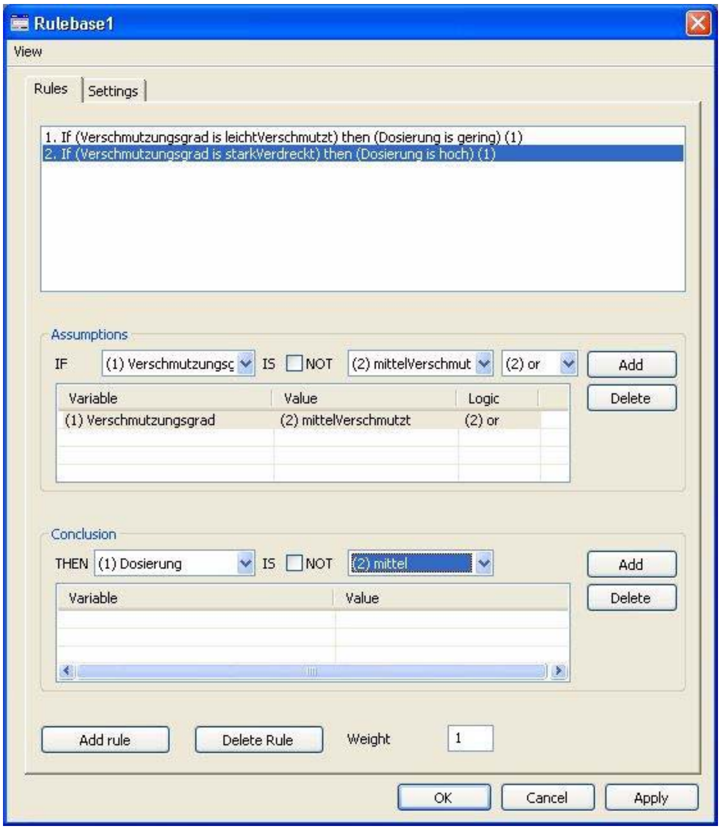


The visible area of the chart is fixed by the definition of the *Visible Range*.

Rulebase

In this object the rule base is defined. On tab *Rules* the defined rules will be shown, on tab *Settings* the settings are defined.

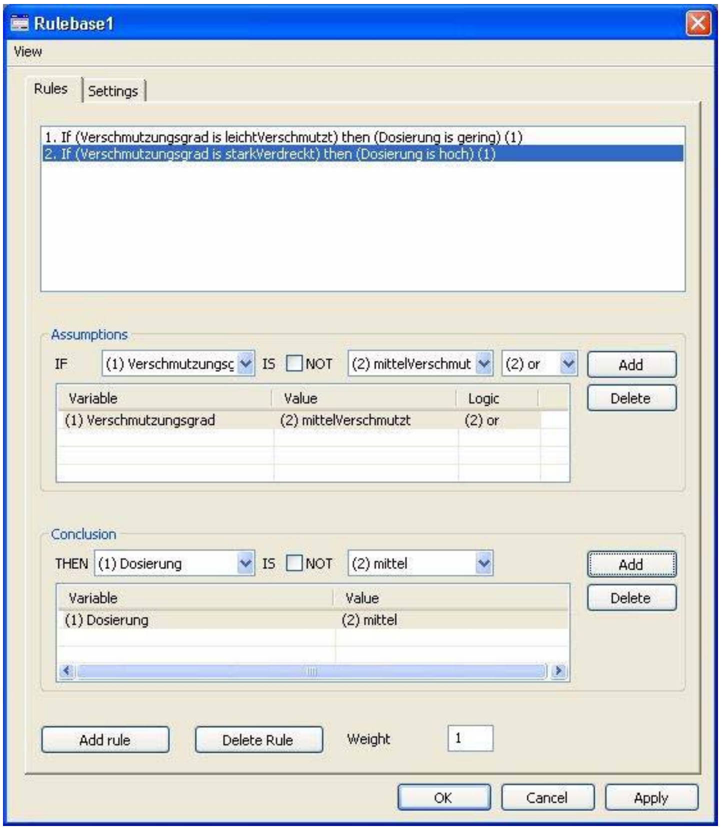
Tab Rules



The first area shows the already defined rules. Use the groups *Assumptions* and *Conclusions* to define new rules. Be sure that the objects *VarIn* and *VarOut* are connected with the rule base. Thereby the pulldown menus will be set with values.

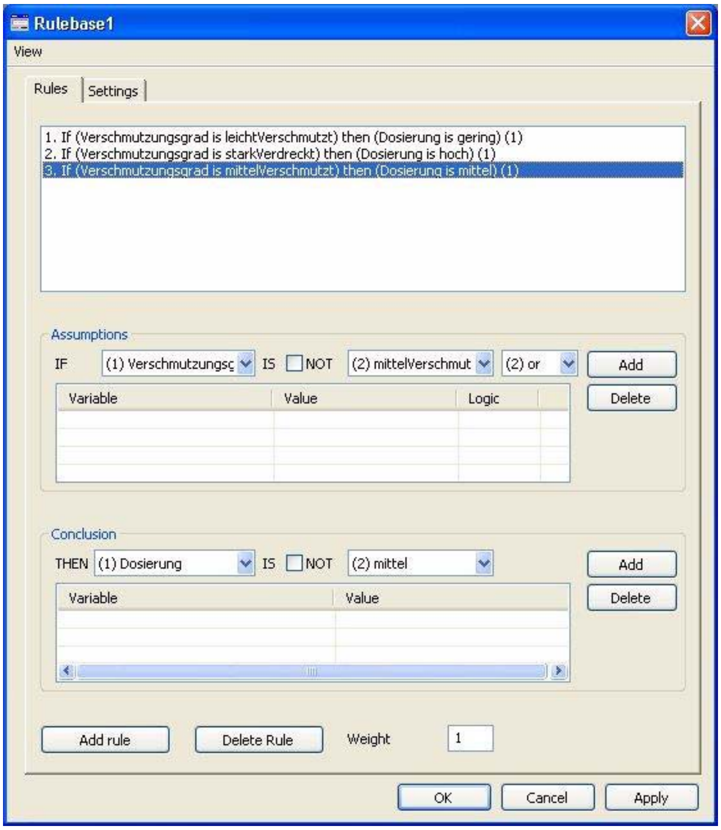
Entering a rule

Select a linguistic variable from the drop down list box near by *IF* . Select a value which the variable should accept. The value of the variables can be negated by checking the box near by *NOT* . By pressing the button Add the assumption will be entered in the list box below. Several assumptions can be combined by *AND* or *OR*.



In the input area *Conclusion* the *Then* part of the rule will be defined. Select a linguistic variable from the pulldown list box as well as a value this variable can accept. Mark the box near by NOT to negtiate the expression. The *Then* part of the rule is added by pressing the button *Add*.

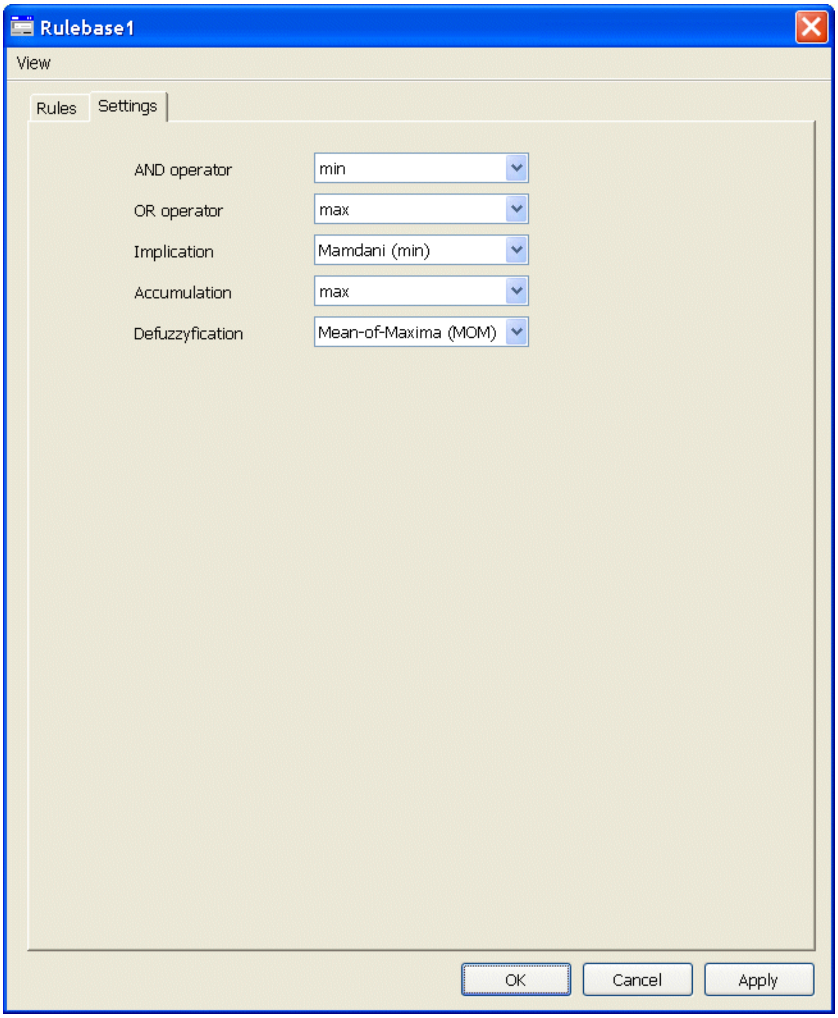
Press button *Add Rule* to add the whole rule. The rule will be shown in the window at the top of the dialogue.



Delete Rule

Use this button to delete a marked rule.

Tab Settings



On this tab the functions which are used for the logical operations are selected. The results of the evaluation of every single rule will be combined by AND. For this operation the min. operator is mostly used.

Also the implication will be done for each rule separately. Define in which way the results will be aggregated with the exit membership function. Two functions are available for the implication:

- Mamdani: The aggregated values and the exit fuzzy sets Ausgangsfuzzymenge are combined by the max operation.
- Larson: The product will be calculated using the aggregated values and the exit fuzzy set.

By the accumulation the intersection of the sets are combined. For this the max operation is available. The result will be a accumulated set.

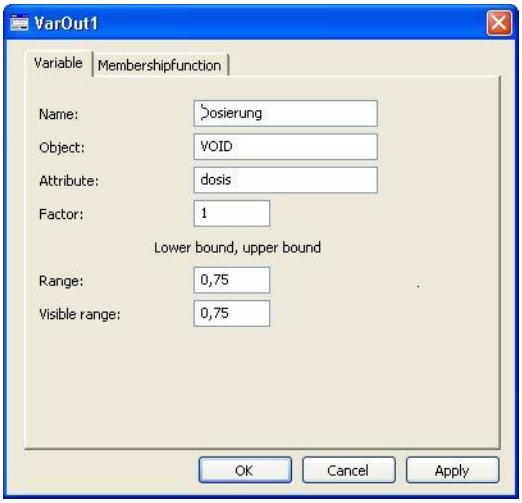
Defuzzification

The resulting fuzzy sets are converted again into "sharp" values. For this only the method *COA* is currently available. This function calculates the center of gravity of the area and gives the value x-coordinate as a result.

VarOut

The object *VarOut* owns the same dialogue elements like the object *VarIn*.

Tab Variable



Name

Enter the name of the *VarOut* object.

Object

Enter the name of the object in the simulation model.

Attribute

Enter the name of the attribute whose value should be used.

Range

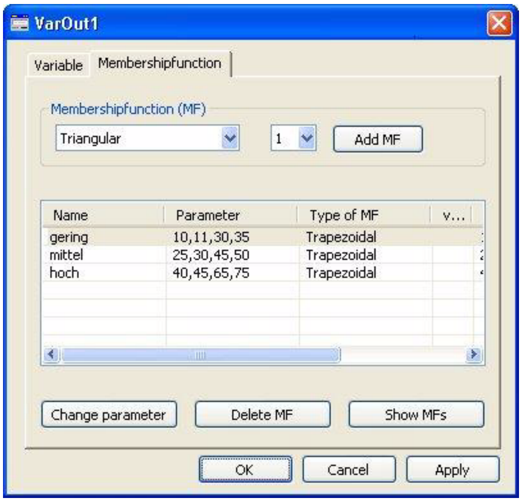
Enter the range the attribbute value can accept. Note: the membership function will only be calculated for this range.

Visible Range

The Visible range defines the visible area which will be used for showing the membership function. This values does not influence the membership function.

Tab membership function

On this tab the membership functions and their parametres are defined.



Add MF

Use this button to add a new membership functions. Another dialogue will be opened for entering the parameters of the function.

Enter a name for the membership function. Select a function out of the drop down list box and enter the parameters in the input field. Below this input field you see a short tip which values are expected.

Change Parameter

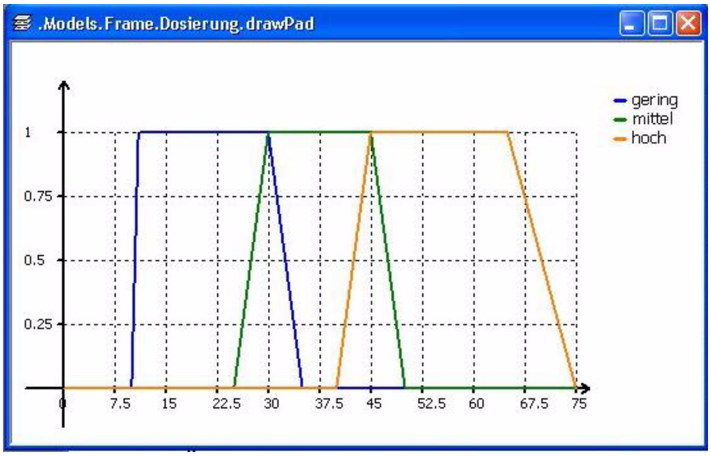
Use this function to open the input dialog of the membership function.

Delete MF

By pressing the button *Delete MF*, the marked memebrship function will be deleted.

Show MFs

By pressing the button Show MFs the membership functions will be shown graphically. Depending on the definition a similar chart like the one below will be shown.



Description of the used methods

Mean-of-Maxima (MOM) - Method

Here the functional value corresponds to the arithmetic average value of each single value with maximum affinity.

Center of area method (COA)

The result value of this method is the x coordinate of the center point of the area between the z-axes and the function value of the graph.

High method

This method first calculates the center of the area for each exit fuzzy set.

During the real evaluation of the Fuzzy system, these center points are weighted by the "heights" of the surfaces.

Reduced High method

This method simplifies the height method. The center of area of each single exit fuzzy set will be calculated like as in the height method. The implication and accumulation is cancelled and the center of areras are weighted with the result values of every rule.

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SIEMENS

Division headquarters

United States
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
972 987 3000
Fax 972 987 3398

Regions

Americas
Granite Park One
5800 Granite Parkway
Suite 600
Plano, TX 75024
800 498 5351
Fax 972 987 3398

Europe
Norwich House Knoll Road
Camberley, Surrey
GU15 3SY
United Kingdom
44 1276 702000
Fax 44 1276 705150

Asia-Pacific
Suites 6804-8, 68/F., Central Plaza
18 Harbour Road, WanChai
Hong Kong
852 2230 3333
Fax 852 2230 3210

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