Allen-Bradley

RSLogix 5000 Fuzzy Designer

User Manual

Rockwell Automation

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Important User Information

Solid state equipment has operational characteristics differing from those of electromechanical equipment. Safety Guidelines for the Application, Installation and Maintenance of Solid State Controls (publication SGI-1.1 available from your local Rockwell Automation sales office or online at http://literature.rockwellautomation.com) describes some important differences between solid state equipment and hard-wired electromechanical devices. Because of this difference, and also because of the wide variety of uses for solid state equipment, all persons responsible for applying this equipment must satisfy themselves that each intended application of this equipment is acceptable.

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Throughout this manual, when necessary, we use notes to make you aware of safety considerations.

WARNING	Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.
IMPORTANT	Identifies information that is critical for successful application and understanding of the product.
ATTENTION	Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard, and recognize the consequence
SHOCK HAZARD	Labels may be on or inside the equipment, for example, a drive or motor, to alert people that dangerous voltage may be present.
BURN HAZARD	Labels may be on or inside the equipment, for example, a drive or motor, to alert people that surfaces may reach dangerous temperatures.

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About This Publication

Use this manual to understand how to best use the features in RSLogix 5000 software version 16, FuzzyDesigner.

This manual describes the necessary tasks to:

- build fuzzy systems as block diagrams from components of the FuzzyDesigner Component Library and use FuzzyDesigner functions to complete the project.
- use, execute, and monitor the designed fuzzy system on Rockwell Automation Logix5000 controllers.
- understand the fuzzy project, and how you can export it to the XML format.

Who Should Use This Publication

This manual is for application and control engineers, to enhance functionality of control and decision making systems.

Conventions

Text that is	Identifies
Bold	A value that you must enter exactly as shown
Italic	A variable that you replace with your own text or value
`Courier`	Example programming code, shown in a monospace font so you can identify each character and space
Enclosed in brackets	A keyboard key

Notes:

Get Started with FuzzyDesigner

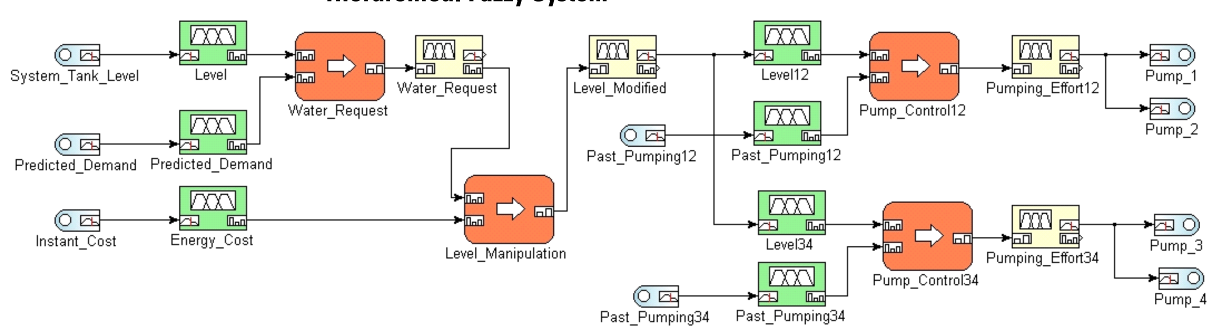
Introduction

Understanding FuzzyDesigner

FuzzyDesigner is a software package for designing a fuzzy system to be implemented as a Hierarchical Fuzzy System (HFS). Fuzzy systems can be used in the following applications:

- Industrial automation and control systems
- Process diagnostics and intelligent monitoring systems
- Artificial intelligence
- Decision-making and forecasting

Hierarchical Fuzzy System



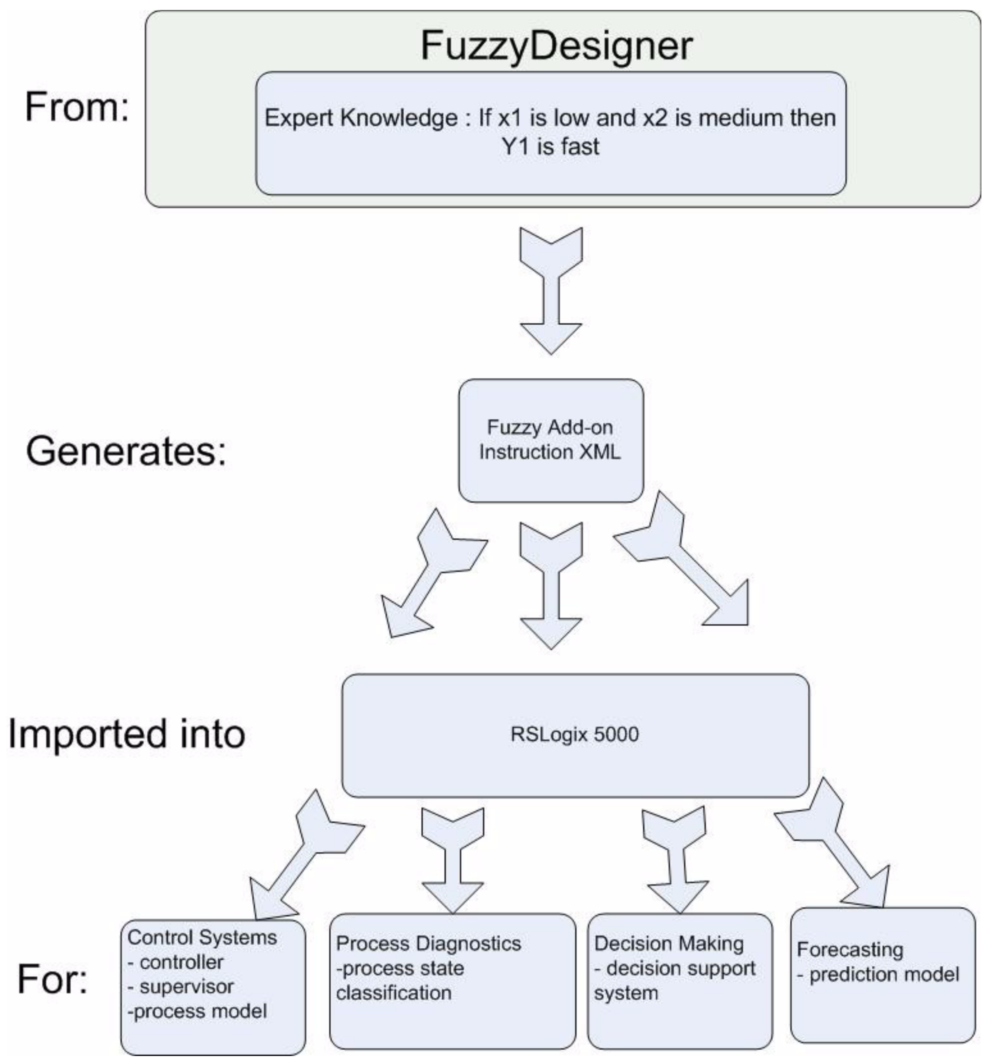
FuzzyDesigner enables application and control engineers to enhance the functionality of control and decision making systems in various branches of industry.

FuzzyDesigner includes a library of components you can use to design a fuzzy system that includes nonlinear input-output mapping. You can use a hierarchical structure to decompose a complex fuzzy system into smaller and simpler parts. This reduces the internal complexity of a fuzzy model and results in fewer fuzzy rules and provides easier insight into the system operation.

FuzzyDesigner is designed to work with Rockwell Automation's Logix5000 family of controllers. A fuzzy system designed in FuzzyDesigner can be exported to an L5X Add-On instruction (AOI) format. You can then import the fuzzy AOI into any of your projects as needed. Fuzzy AOIs can be used by any of the programming languages (Function Block Diagram, Ladder Logic, or Structured Text). With FuzzyDesigner, you can also monitor and update the selected fuzzy AOI online, directly in the running controller. This is made available through the RSLinx OPC Server.

The Intended Use of FuzzyDesigner figure shows the underlying idea and intended use of the FuzzyDesigner software package used in designing Fuzzy Add-On Instructions for Logix applications. You can build smart components, based on the expert knowledge encoded in fuzzy If-Then rules. You can use these components in the many applications listed above.

Intended Use of FuzzyDesigner



A Fuzzy Add-On instruction does not typically compete against standard controls found in Proportional-Integral-Derivative Controllers (PID). Fuzzy logic is a complementary tool, and fills functional gaps not addressed in standard controllers such as PIDs or Model Predictive Controllers.

A development cycle of fuzzy logic solutions for Logix applications consists of multiple steps.

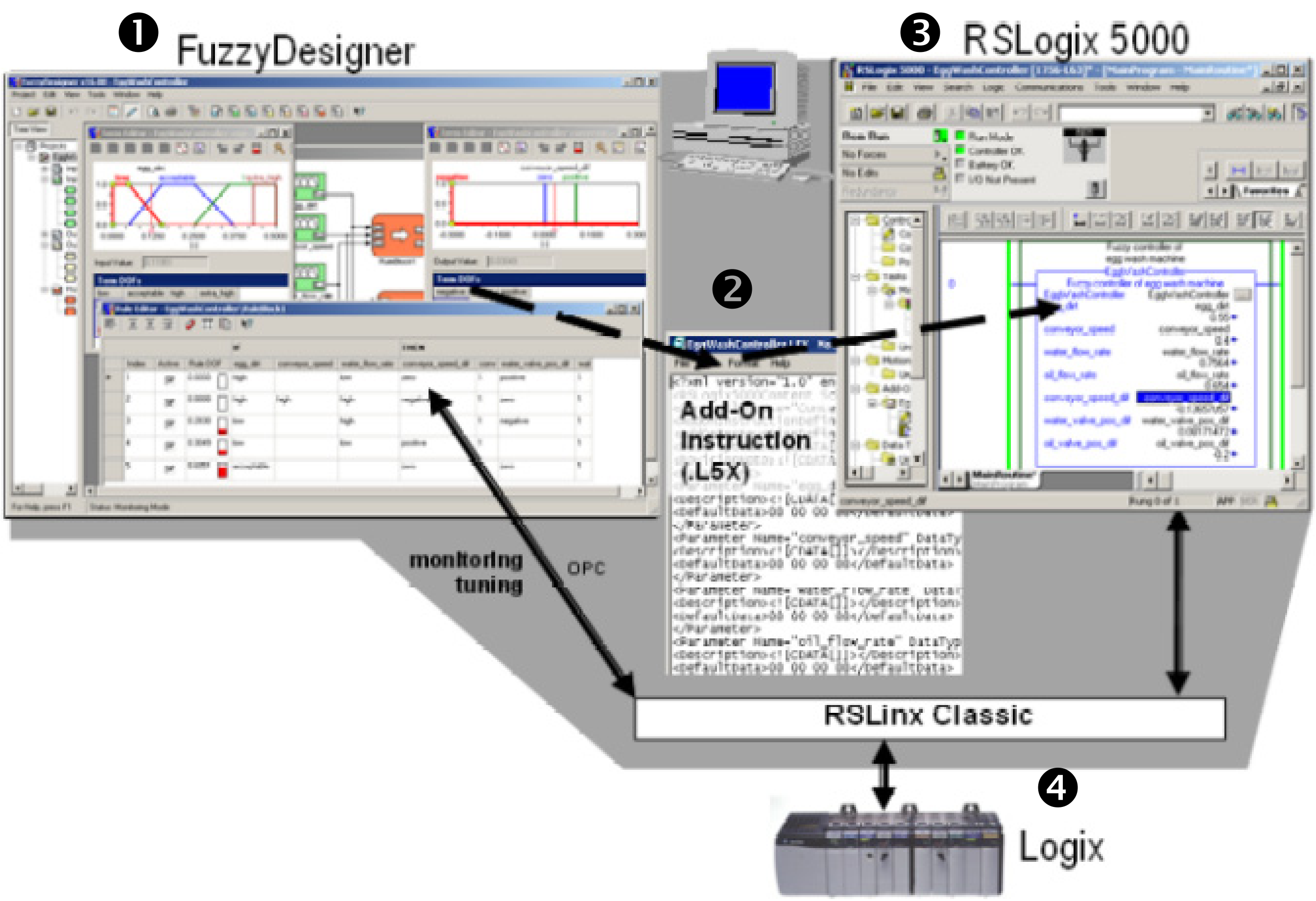
1. Design the fuzzy system in FuzzyDesigner.

2. Generate the fuzzy Add-On Instruction.

3. Integrate (import and instantiate) the fuzzy AOI to your RSLogix 5000 project.

4. Monitor and tune the fuzzy AOI running in Logix online by using FuzzyDesigner.

Using FuzzyDesigner with RSLogix 5000 Software



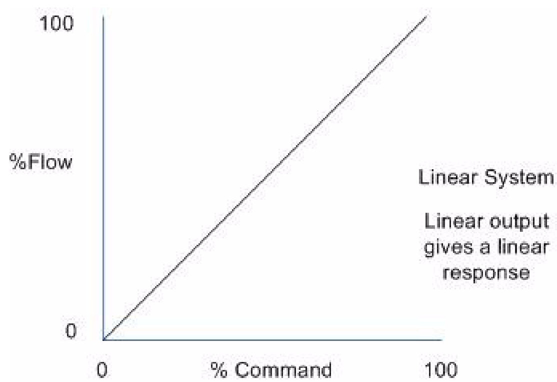
If you are unfamiliar with fuzzy logic, the next section introduces fuzzy logic terms and principles you might use in your fuzzy system.

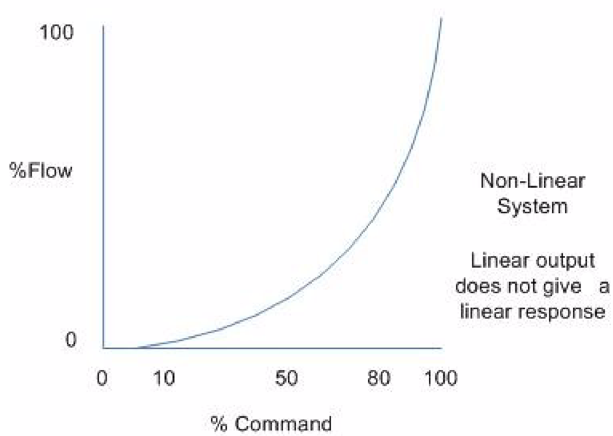
Fuzzy Logic and Fuzzy Control Essentials

This section introduces basic concepts used in a Fuzzy Add-On Instruction. The designer should know how to deal with an instruction's inputs, outputs, and fuzzy If-Then rules that will be used to define input-output mapping.

There are quite a number of systems or processes that are highly nonlinear, not well understood from the formal description point of view, or for which a mathematical model is not readily available. For these systems or processes, there is often an expert that is capable of supervising or controlling the process in a satisfactory manner. The figure Nonlinear System Example illustrates the difference between linear and nonlinear systems.

Nonlinear System Example





The decision making the expert uses in control system supervision can be expressed as a set of Fuzzy Logic If-Then rules.

An expert may be an operator, a maintenance person, or a control engineer, who knows what adjustments are needed during process instability. These adjustments may include defining setpoints for process variables, defining control action in feedforward or feedback contro,l or setting gains of conventional controllers, and may be as simple as turning a valve or knob.

Rockwell Automation is introducing a tool for building smart instructions that encode If-Then rules and use fuzzy logic internally to describe vague and incomplete knowledge in a natural way. Fuzzy Logic may serve in situations where:

- the process has not been automated and is running in Manual mode.
- a well-tuned PID controller does not provide the desired response, however, the expert knowledge is available to define the rules for a fuzzy algorithm.

Let's look at an example where we will discuss building a Heat, Ventilation and Air Conditioning (HVAC) system that manipulates the compressor speed based on room temperature and humidity. In HVAC systems, room comfort is often associated with vague (fuzzy) values of temperature and humidity that are more suitable for describing the problem than numerical (crisp) values.

Fuzzy rules used in this example might be as follows.

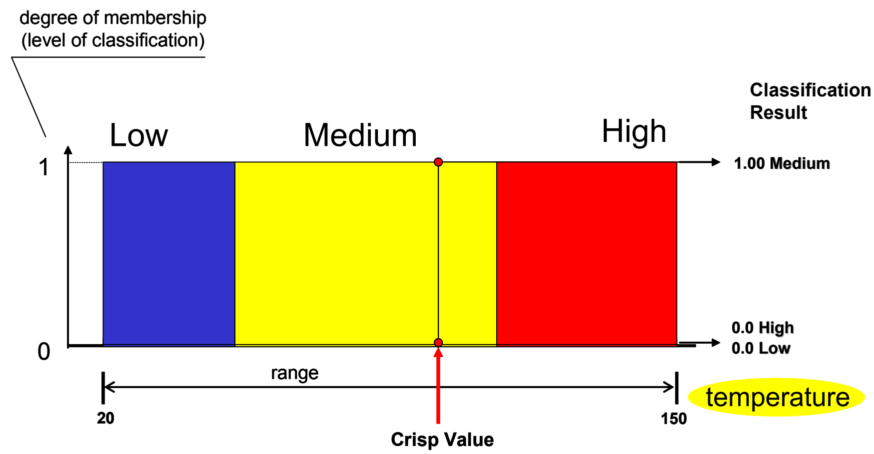
If	Then
Temperature is high and humidity is high	Speed is medium
Temperature is medium and humidity is very high	Speed is high

Consider these factors when developing fuzzy rules:

- How do I specify **High** and other fuzzy values in fuzzy rules?
- How do the rules process numerical inputs provided by tags associated with sensors?
- How do the rules derive outputs from inputs?
- If the output generated is vague (fuzzy), how do I get the numerical (crisp) value at the output when needed?

Crisp and Fuzzy

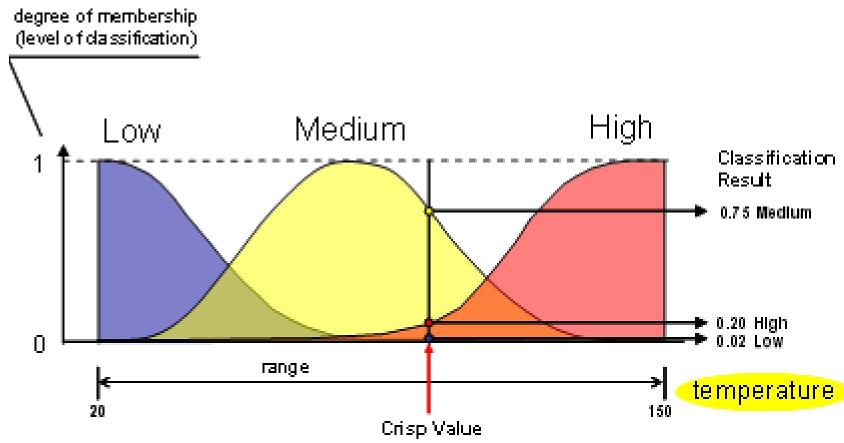
For temperature readings, you can classify a reading into three sets, Low, Medium and High. Each set contains values in a given interval, and the intervals do not overlap. This means that a single reading or value is uniquely classified into one set.



TIP — **Degree of membership** (DOM) is a value describing how well the particular value of the variable (in this case, temperature) fits the meaning of the label of the set, **Medium**. If the DOM is 1, the current temperature is understood as 100% Medium.

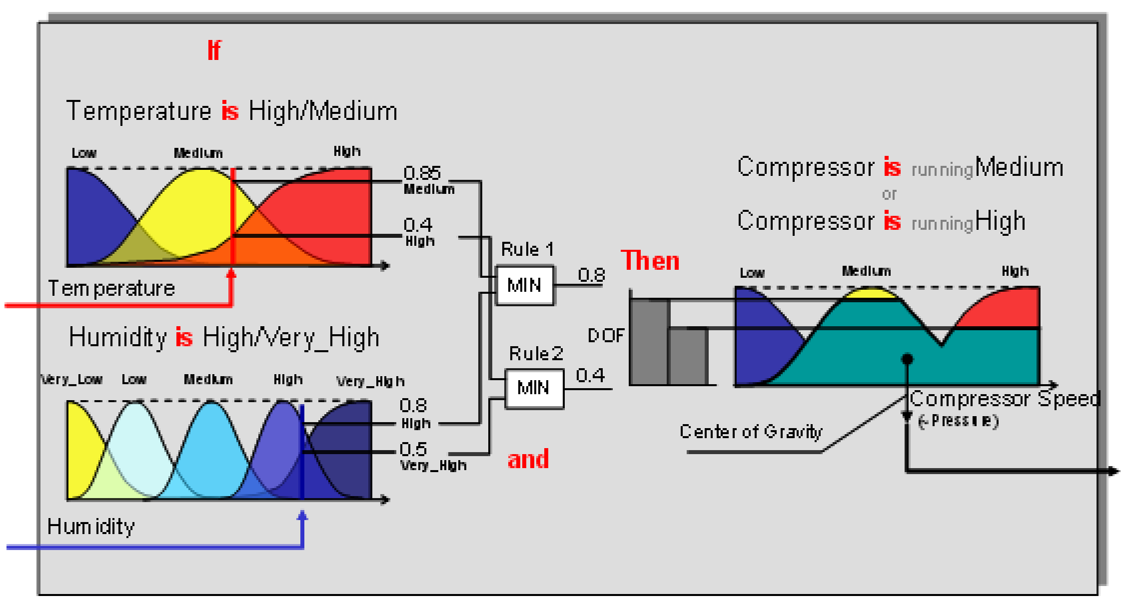
However, vague classifications are more realistic as there is usually no sharp border between Low, Medium, or High temperatures. In this situation, however, a single numerical value might fall into multiple categories. For example, it might be partially Medium, and partially High as shown in the following figure. A specification of how much the particular value of temperature fits into the meaning of the label of the category (fuzzy set) is described by the membership function, which becomes a design parameter of the fuzzy controller.

Similar fuzzy terms are designed for the output variables, that is, Low, Medium, and High for compressor speed in our example.



Fuzzy rules

The way in which the classified inputs are treated when passing through rules is shown in the following figure for our compressor control example.



First, the numerical values of Temperature and Humidity get their meaning. In our case, the current setting of the Temperature is such that it is both 85% Medium and 40% High. Humidity is both 80% High and 50% Very High. The first rule is thus 80% true for the current inputs while the second rule is 40% true when using **minimum** for the **and** operation. The first rule states that, if 100% satisfied, the compressor should run at Medium speed. Currently, the first rule is only 80% fulfilled, so one method of how to consider that the rule is only 80% fulfilled is to truncate the Medium fuzzy set for the output at the level 0.8.

A similar situation happens with the second rule where High compressor speed is only 40% fulfilled. As both rules are used at the same time, their conclusions must be combined to get a fuzzy value for the output, which is compressor speed. The partially-fulfilled Medium and High fuzzy sets are unified, and a single fuzzy value is assigned to Compressor Speed. As conventional control systems cannot deal with fuzzy values, the fuzzy instruction includes conversion from a fuzzy to a crisp value. For this case, the center of gravity for the green area is computed and used to represent the original fuzzy value.

To summarize, the designer has to:

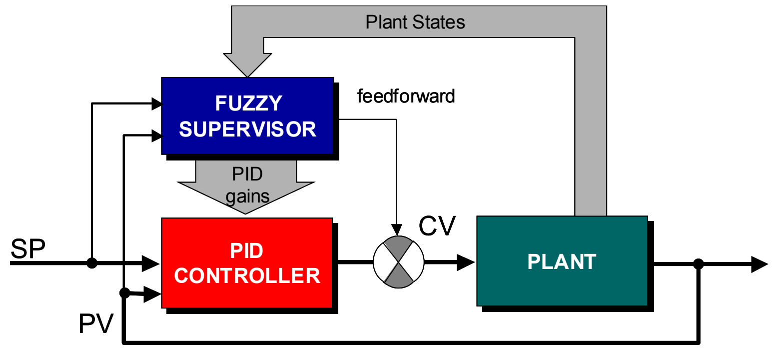
- define input and output variables.
- cover the interval of the respective variable by fuzzy sets (that is, membership functions).
- write if-then rules using labels of the fuzzy sets defined previously.

Potential Use of Fuzzy Logic

FuzzyDesigner enables you to enhance the functionality of existing or new control and decision making systems in various branches of industry.

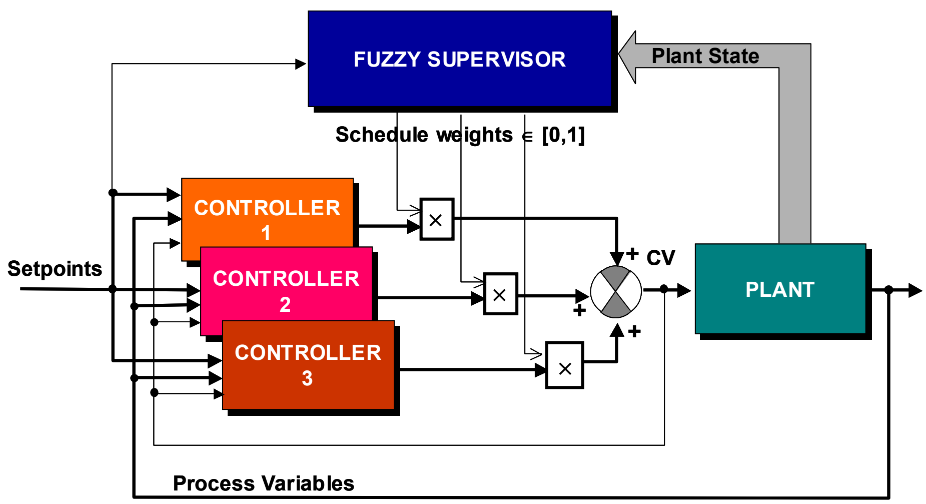
The fuzzy system designed and generated by FuzzyDesigner can be used in control systems, for example, as a direct nonlinear fuzzy-rule based controller, PID-feedback control system supervisor, or a process model in a Model Predictive Control scheme. Input and output filters are used for signal preprocessing such as filtering, deriving trends, and many other functions that might add dynamics to the static I/O map generated from fuzzy rules. Input filters can also be designed in FuzzyDesigner. Output filtering is an option and contains, for instance, a discrete integrator fed by the output of the Fuzzy Add-On Instruction.

Nonlinear, Fuzzy Rule Based Supervisor of a PID Controller



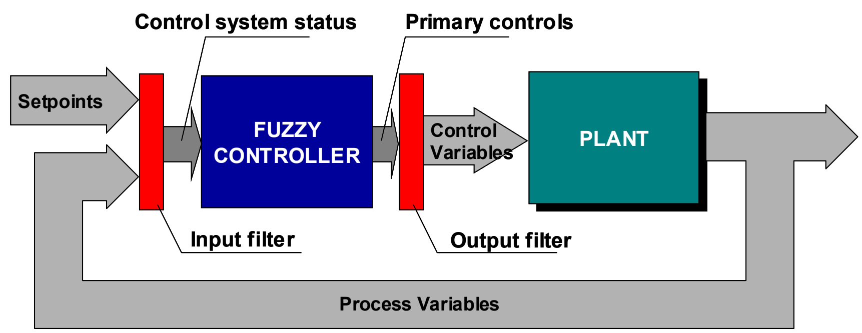
The great advantage of fuzzy supervision is that it can be applied to existing control and there is little danger of making errors in design. Most frequently used is a supervised PID controller where PID gains, feedforward action, or setpoints are being modified dynamically by rules depending on the process status and external conditions defined through setpoints.

Smart Switching Between Conventional Controllers, Takagi-Sugeno Controller



Another popular control structure with fuzzy logic is smart switching between local controllers. A local controller is an analytical controller designed to work around specific process operation conditions. Once the conditions change, the rule based supervisor decreases the influence of one controller and gives more weight to another controller that has been designed to work in the new conditions.

Feedback Control System with Direct Fuzzy Controller



A fuzzy controller with the above structure typically handles multiple inputs and generates multiple outputs. This system is recommended for experienced designers since control variables are direct functions of rules. The number of rules increases rapidly with the number of inputs and fuzzy terms for inputs. The problem of dimensionality can, however, be reduced by hierarchical structuring of the rule base of the controller, which is supported by FuzzyDesigner.

Specifications and Features

FuzzyDesigner features and specifications are summarized in the following tables.

For details, refer to the subsequent chapters.

Fuzzy System Components

Components are graphical objects, blocks you work with, to design a fuzzy system.

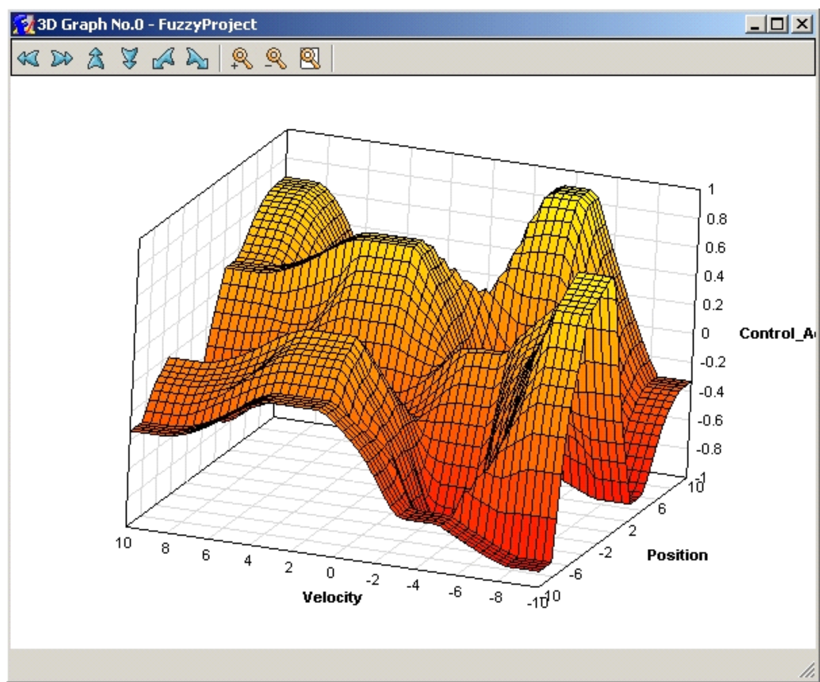
Component	Membership functions	AND	OR	Aggregation	Inference (Activation)	Defuzzification
	Type/method if applicable					
Input Port						
Input Linguistic Variable	Trapezoidal, S-shape, and their inverses					
Rule Block		Min/product t-norms	Max			
Output Linguistic Variable	Trapezoidal, singleton			Max s-norm	Mamdani/ Fuzzy Arithmetic	CA/MCA/ MOM/SOM/ LOM
Output Port						

Component	Membership functions	AND	OR	Aggregation	Inference (Activation)	Defuzzification
	Type/method if applicable					
Intermediate Linguistic Variable				Max s-norm		
Output T-S Variable				Max s-norm		
PID Controller						

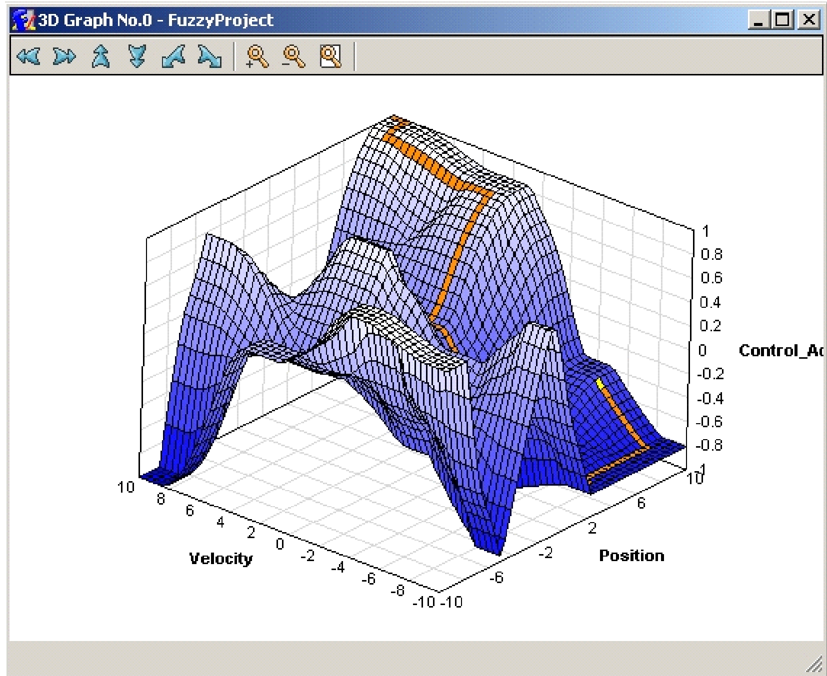
Fuzzy System Analysis Tools

Tool	Description
2D/3D mesh plots	Visualization of input-output static mappings generated by the fuzzy system or its specified subsystem
Interactive plot control	Color, grid, texture, zoom, and viewpoint management
Tracing fuzzy system evaluation	Marks output on the mesh when input is being changed

FuzzyDesigner Mesh Plot



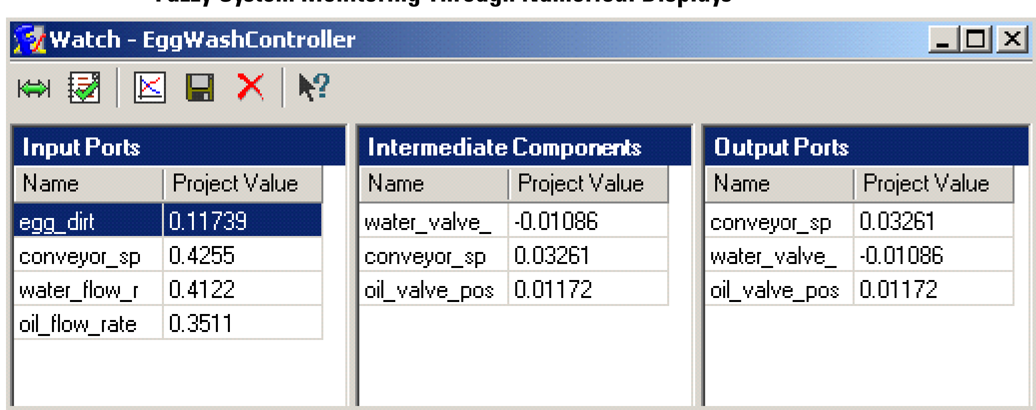
FuzzyDesigner Mesh Plot with Simulated Path



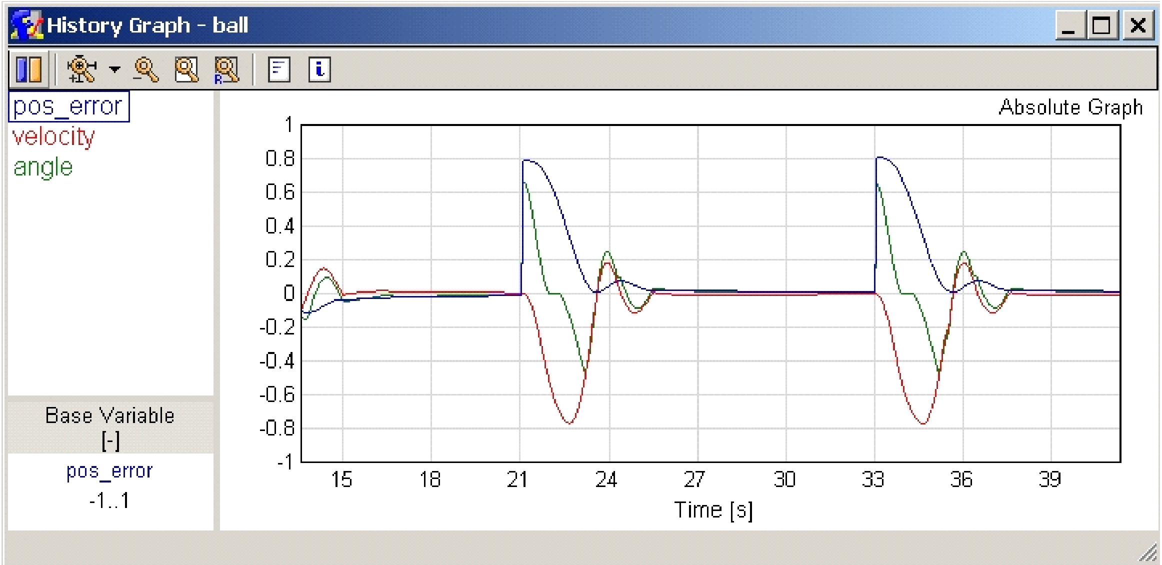
Fuzzy System Monitoring

Feature	Description
Numerical and graphical display	Monitoring of all internal variables
Archiving	Recording specified internal or external variables
History graph	Plotting history graph for on-line or off-line monitoring

Fuzzy System Monitoring Through Numerical Displays



Fuzzy System Monitoring Through Plotting Historical Recordings and On-Line Update



FuzzyDesigner Project Formats

File Format	Description
XML	.FSP – complete project file generated by FuzzyDesigner, .XML – user-supplied fuzzy system or project file

Direct Support of Logix5000 controllers

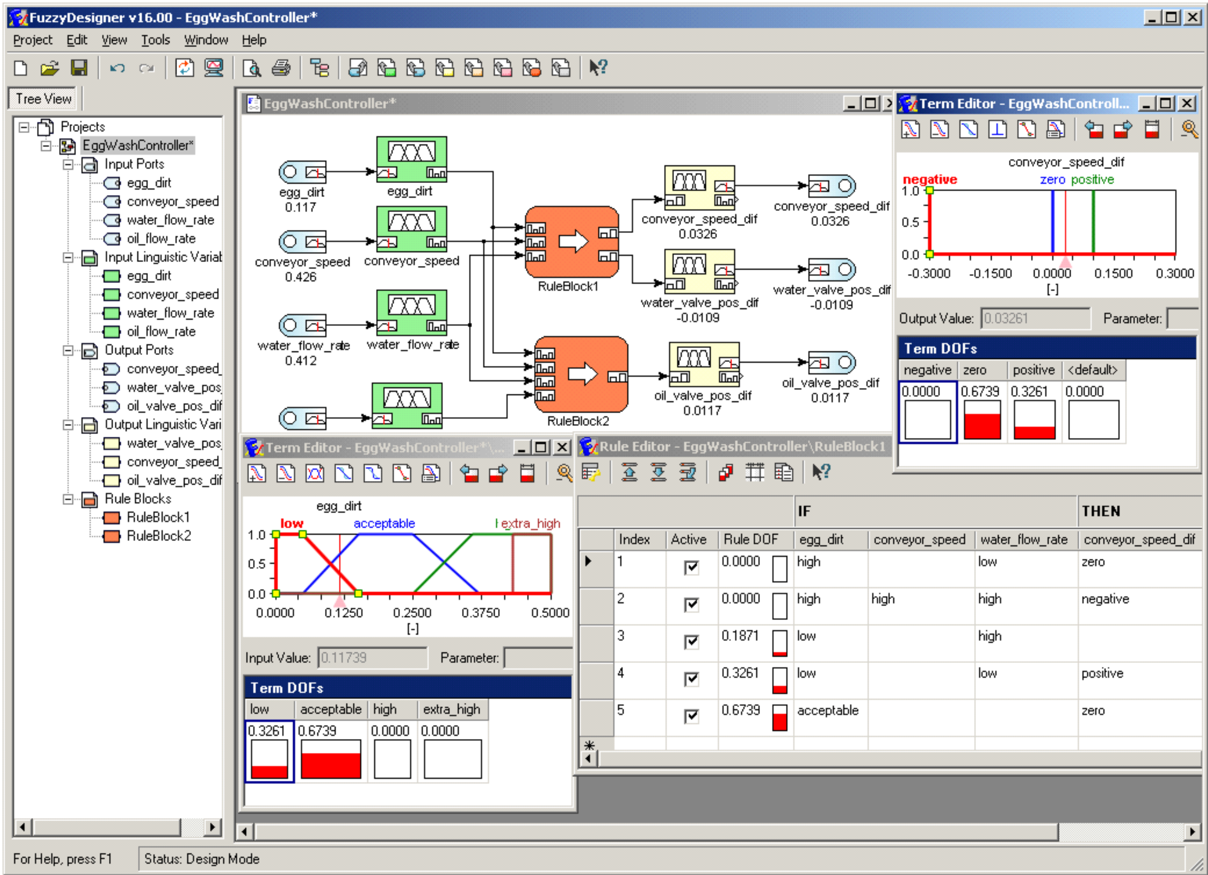
FuzzyDesigner, version 16.00 and later, supports Rockwell Automation's Logix5000 family of controllers. The fuzzy system designed using FuzzyDesigner can be exported to an RSLogix 5000 Add-On Instruction (AOI) XML import file. You can then import the fuzzy system into any of your projects as needed. Fuzzy AOI can be used by any of the programming languages (Function Block Diagram, Ladder Logic, or Structured Text). With FuzzyDesigner, you can also monitor and update the selected fuzzy AOI online, directly in the running controller. This is made available through RSLinx OPC Server.

Features	Description
Export fuzzy AOI	Utility for export of designed fuzzy system into L5X file.
On-line parameter change	Changing parameters of a fuzzy system downloaded to the controller dynamically is enabled.
Real-time fuzzy system monitoring	Exact copy of the fuzzy system running on the PLC allows FuzzyDesigner to monitor all internal variables on the computer when both copies are fed with the identical inputs.

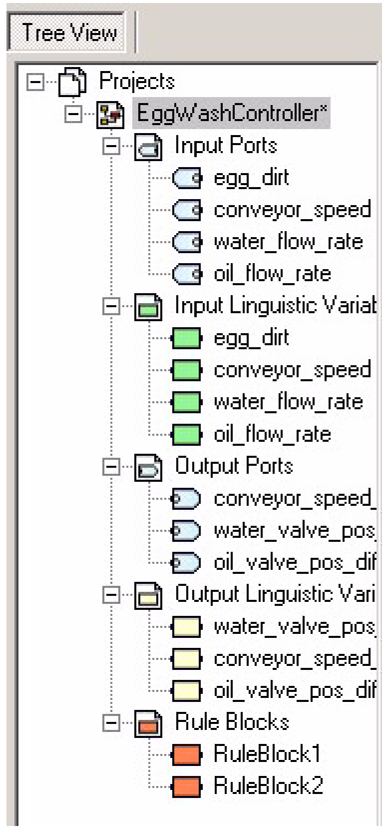
Integrated Design Environment (IDE) screen captures

Some of the FuzzyDesigner features, summarized in the preceding tables, are shown in this section.

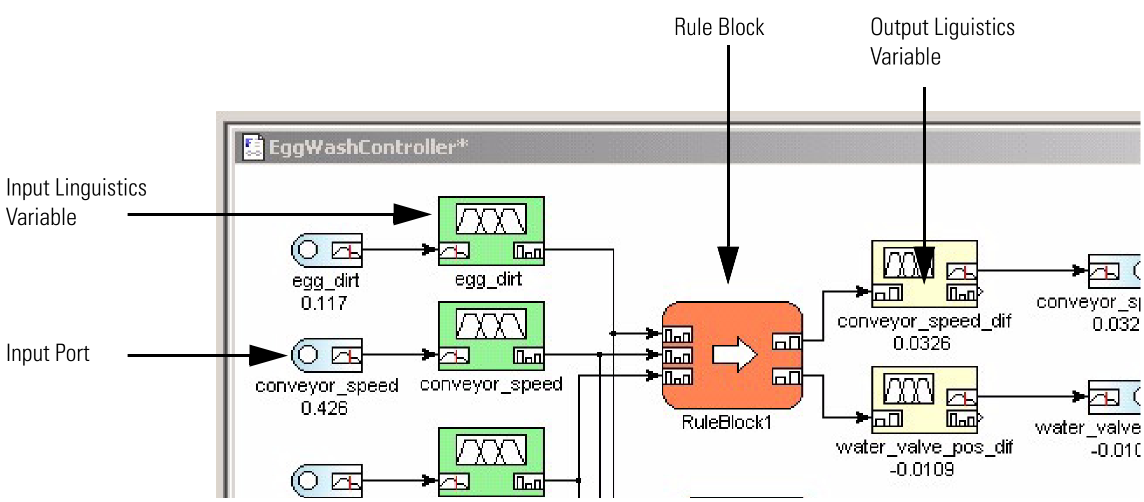
FuzzyDesigner Environment in Brief



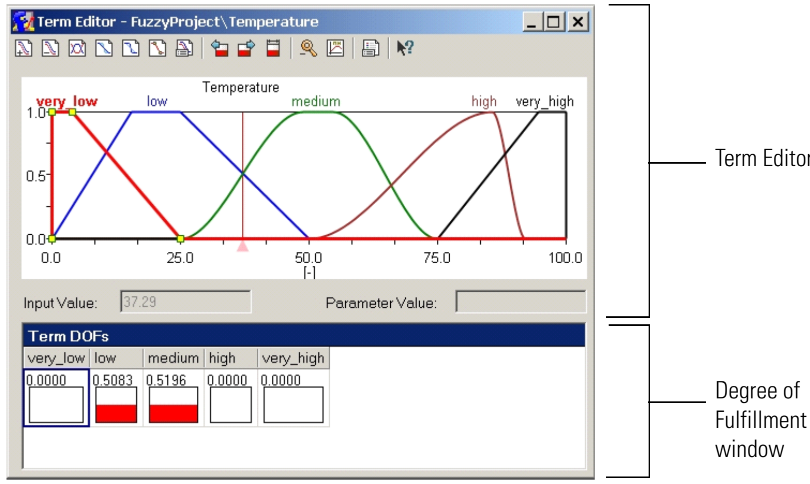
Project Tree view



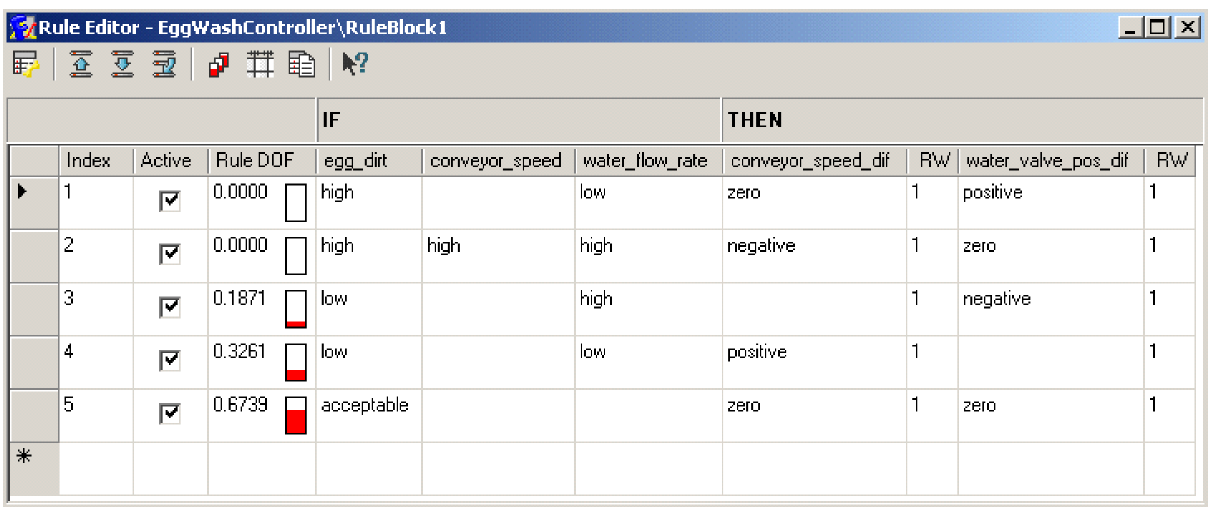
FuzzyDesigner Environment - Component examples



FuzzyDesigner Membership Functions

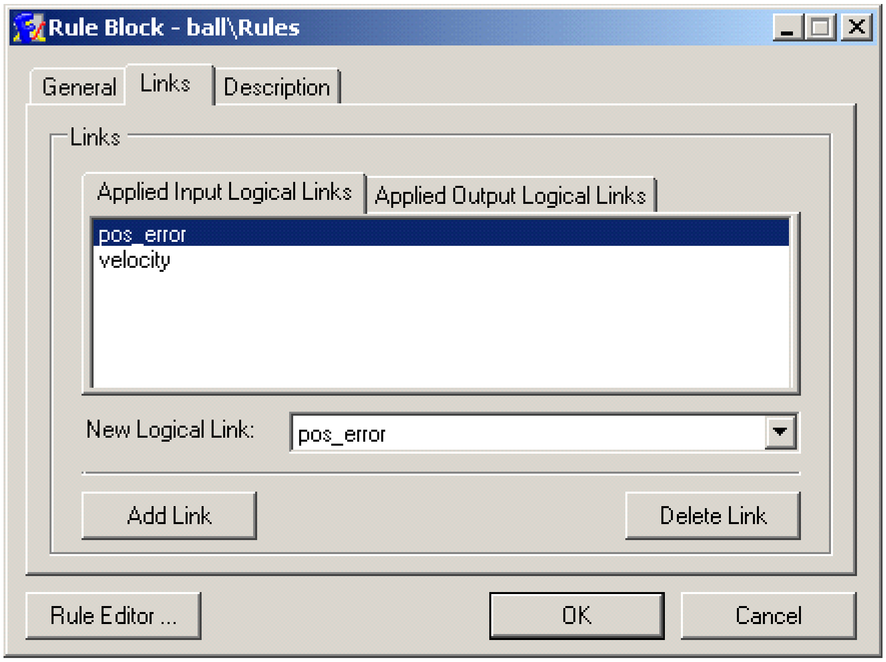


FuzzyDesigner Rule Base - Rule Editor

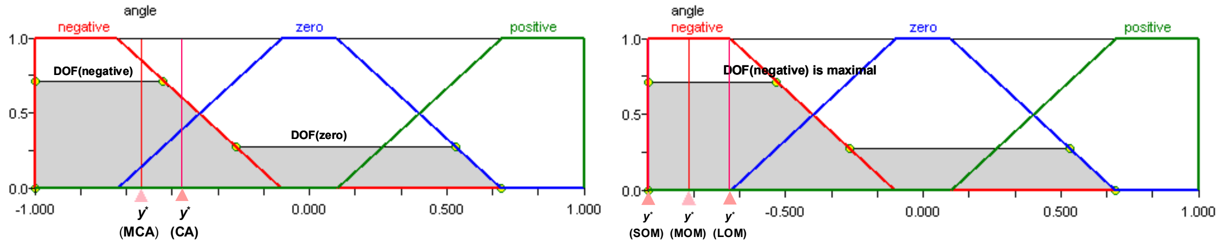


Index	Active	Rule DOF	egg_dirt	conveyor_speed	water_flow_rate	conveyor_speed_dif	RW	water_valve_pos_dif	RW
1	☑	0.0000	high		low	zero	1	positive	1
2	☑	0.0000	high	high	high	negative	1	zero	1
3	☑	0.1871	low		high		1	negative	1
4	☑	0.3261	low		low	positive	1		1
5	☑	0.6739	acceptable			zero	1	zero	1
*									

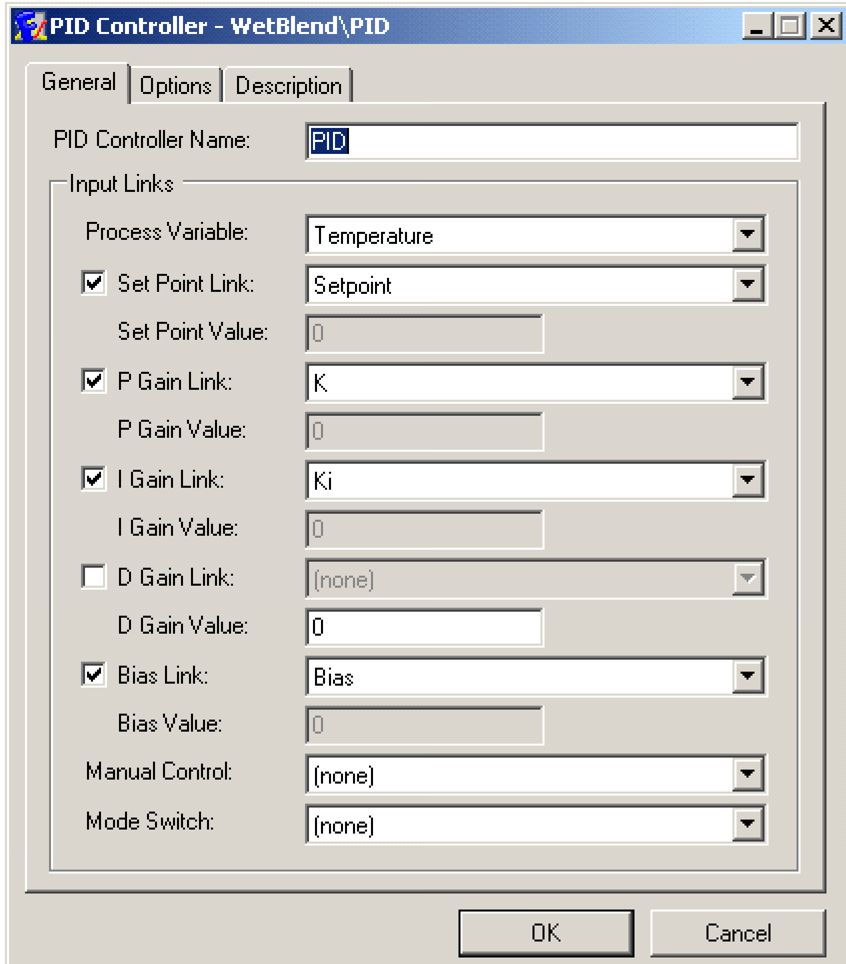
FuzzyDesigner Rule Interfacing



FuzzyDesigner Defuzzification Methods



FuzzyDesigner PID Controller



Notes:

FuzzyDesigner Component Library

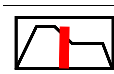
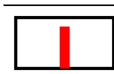
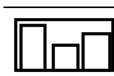
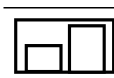
Introduction

The FuzzyDesigner Component Library offers eight components from which you can efficiently build distributed fuzzy systems.

Component Interface

The connection between components is called a **link**. Generally, a Hierarchical Fuzzy System (HFS) computes with data in the form of a crisp (real) value and/or a fuzzy set. Not all components enable both types of data to be transferred over the link. The data type on both ends of a link should match. FuzzyDesigner uses icons to define a link type as follows.

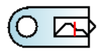
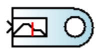
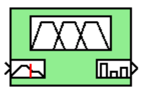
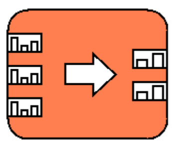
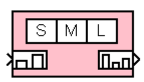
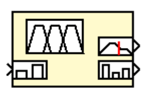
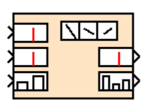
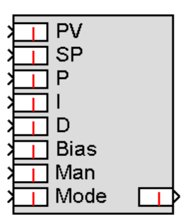
FuzzyDesigner Icons

Icon	Description
	Crisp value (input or output value link) – input crisp values and crisp values resulting from defuzzification are transferred over the link
	Crisp value (input or output value link) – crisp values are transferred over the link
	DOF value (input or output logical link) – degrees of fulfillment of fuzzy terms of a fuzzy variable are transferred over the link to a rule block
	DOF value (input or output logical link) – degrees of fulfillment of fuzzy terms resulting from rule block evaluation are transferred over the link to a fuzzy variable

Library of Components

The FuzzyDesigner Component Library offers the following components from which you can assemble fuzzy systems ranging from single input – single output systems to multiple input – multiple output systems with complex hierarchical structure of rules.

FuzzyDesinger Component Library Icons

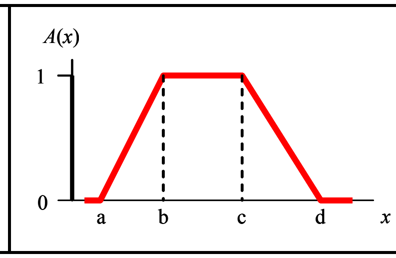
Icon	Name	Description
	Input Port	Preprocesses and stores values of a fuzzy system's input variables.
	Output Port	Stores values of a fuzzy system's output variables.
	Input Linguistic Variable	Stores linguistic terms and is used for classification of the actual component input, represented by a crisp value, into the fuzzy sets defined for the respective linguistic terms. In fuzzy control, the process where the input is converted from a crisp value is commonly called **fuzzification**.
	Rule Block	Stores rules and computes degree of fulfillment of rule conditions .
	Intermediate Linguistic Variable	Bridges logical chaining of rule blocks.
	Output Linguistic Variable	Stores linguistic terms and computes the output value from degrees of fulfillment of stored terms (defuzzification). It implements the process of **activation** of output linguistic terms defined as fuzzy sets.
	Output Takagi-Sugeno Variable	Stores parameters of functional terms and computes the output value from degrees of fulfillment of terms.
	PID Controller	Allows intelligent supervision of a built-in PID controller.

Supported Membership Functions

Library blocks let you work with fuzzy sets as defined by membership functions. Let *x* be the linguistic variable and A(*x*) be the degree of membership of *x* to the fuzzy set *A* defined by the sketched membership function. FuzzyDesigner works with the following types of membership functions.

Trapezoidal Membership Function with Parameters (vertices): (*a*,*b*,*c*,*d*)

$$A(x)=\begin{cases}0 & \text{if } x<a\\ (x-a)/(b-a) & \text{if } x\in[a,b)\\ 1 & \text{if } x\in[b,c]\\ (x-d)/(c-d) & \text{if } x\in(c,d]\\ 0 & \text{if } x>d\end{cases}$$

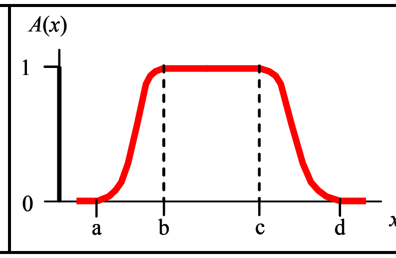


If $a = b$ then $A(a) = 1$. If $c = d$ then $A(c) = 1$.

Trapezoidal membership functions can be used in input and output linguistic variable components.

S-shape Membership Function (cubic spline) with Parameters: (*a*,*b*,*c*,*d*)

$$A(x)=\begin{cases}0 & \text{if } x<a\\ \dfrac{2}{(a-b)^3}(x-a)^2\left(x-\dfrac{3b-a}{2}\right) & \text{if } x\in[a,b)\\ 1 & \text{if } x\in[b,c]\\ \dfrac{2}{(d-c)^3}(x-d)^2\left(x-\dfrac{3c-d}{2}\right) & \text{if } x\in(c,d]\\ 0 & \text{if } x>d\end{cases}$$

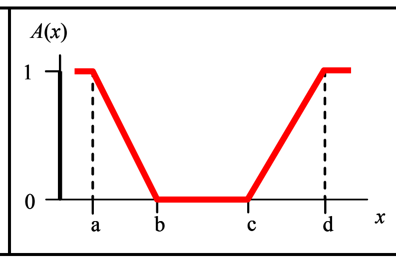


If $a = b$ then $A(a) = 1$. If $c = d$ then $A(c) = 1$.

S-shape membership functions can be used in input and output linguistic variable components.

Inverse Trapezoidal Membership Function with Parameters (vertices): (*a*,*b*,*c*,*d*)

$$A(x)=\begin{cases}1 & \text{if } x\le a\\ (x-b)/(a-b) & \text{if } x\in(a,b]\\ 0 & \text{if } x\in(b,c)\\ (x-c)/(d-c) & \text{if } x\in[c,d)\\ 1 & \text{if } x\ge d\end{cases}$$

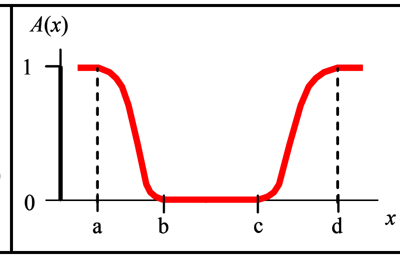


If $a = b$ then $A(a) = 1$. If $c = d$ then $A(c) = 1$.

Inverse trapezoidal membership functions can be used in an input linguistic variable component.

Inverse S-shaped Membership Function (cubic spline) with Parameters: (*a,b,c,d*)

$$A(x)=\begin{cases}1 & \text{if} \quad x\le a\\ \dfrac{2}{(b-a)^3}(x-b)^2\left(x-\dfrac{3a-b}{2}\right) & \text{if} \quad x\in(a,b]\\ 0 & \text{if} \quad x\in(b,c)\\ \dfrac{2}{(c-d)^3}(x-c)^2\left(x-\dfrac{3d-c}{2}\right) & \text{if} \quad x\in[c,d)\\ 1 & \text{if} \quad x\ge d\end{cases}$$

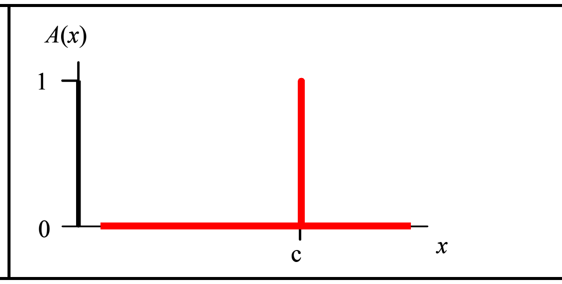


If $a = b$ then $A(a) = 1$. If $c = d$ then $A(c) = 1$.

Inverse S-shaped membership functions can be used in an input linguistic variable component.

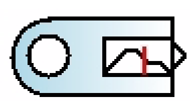
Singleton Membership Function with Parameter (position, center) *c*

$$A(x)=\begin{cases}1 & \text{if} \quad x=c\\ 0 & \text{otherwise}\end{cases}$$



Singleton membership functions can be used in an output linguistic variable component.

Input Port



The fuzzy system Input Port component stores an actual input value entering the HFS. Optionally, you can preprocess the input values by using the linear digital filter. This filter is defined by its pulse-transfer operator *H*, expressed in terms of the backward-shift operator *d*, or equivalently in time-domain as a difference equation, as follows.

$$H(d)=\frac{b(d)}{a(d)}=\frac{b_0+b_1d+\cdots+b_md^m}{1+a_1d+\cdots+a_nd^n}, \qquad y(d)=H(d)u(d)$$

$$y(t)=-a_1y(t-1)-\cdots-a_ny(t-n) \quad + \quad b_0u(t)+b_1u(t-1)+\cdots b_mu(t-m)$$

Filter numerator parameters : b_0, b_1, $\ldots b_m$; filter denominator parameters : a_1, $\ldots a_n$

There are two ways for designing the filter:

- user defined filter.
- butterworth low pass filter .

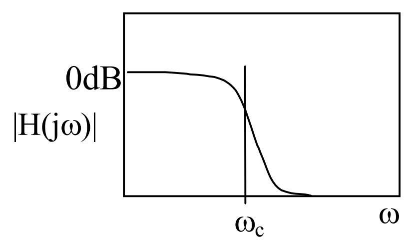
User Defined Filter

You set the numerator and denominator coefficients b_0, b_1, $\ldots b_m$ and a_1, $\ldots a_n$ directly (the parameters are entered in the specified order separated by the space character).

Butterworth Low Pass Filter

This filter can be created by specifying a normalized cutoff frequency q, taken from the interval [0.01, 1], and the order of the filter (1,2,3).

Bode Plot of the Butterworth Low-Pass Filter



This normalized frequency q corresponds to the absolute frequency $\omega_c = q\omega_n$, where $\omega_n = \pi / T_s$ is the Nyquist frequency for the sampling period T_s.

WARNING

All dynamical terms in a fuzzy system (filters, PID controllers) have to share the common sampling period Ts; otherwise the system will not work correctly.

Connections

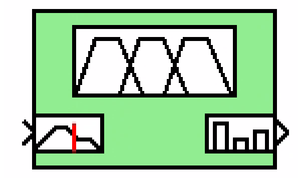
The output link of the input port is connectable to all components expecting a crisp value at the input. This includes the following components:

- Input Linguistic Variable
- Output Port
- Output Takagi-Sugeno Variable (accepts crisp values only)
- PID (accepts crisp values only)

Parameters

- Name of the component
- Vector b = $[b_0, b_1,, b_m]$, coefficients of the filter transfer function numerator $b(d)$– optional
- vector a = $[a_1, \ldots, a_n]$, coefficients of the filter transfer function denominator $a(d)$ – optional

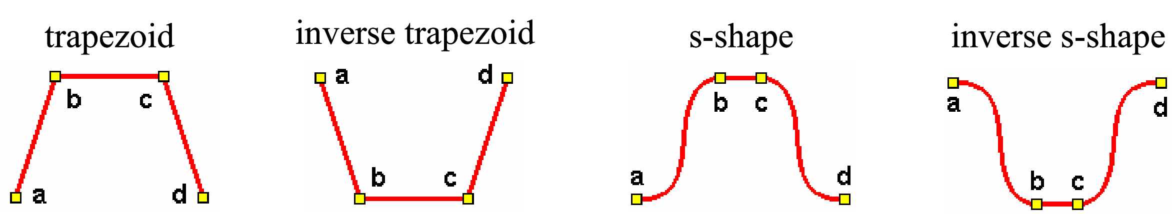
Input Linguistic Variable



The fuzzy system Input Linguistic Variable component stores membership functions (fuzzy sets) of terms and is used for fuzzification (classification) of the component input – a crisp value. The component output is a vector of degrees of fulfillment of all terms for the crisp input or degree of overlapping for the input fuzzy set.

An Input Linguistic Variable component consists of linguistic terms. Each linguistic term is defined by a fuzzy set, that is by the membership function and the name. There are four supported membership functions.

- Trapezoidal membership function
- S-shaped membership function
- Inverse trapezoidal membership function
- Inverse S-shaped membership function



Linguistic terms are defined on specified range $[x_{min}, x_{max}]$ (universe of discourse).

The component crisp input is fuzzified. The result of fuzzification of the crisp input value x^* is a **degree of fulfillment** (DOF) of the terms, which is computed for each term given by the membership function $A(x)$ as follows.

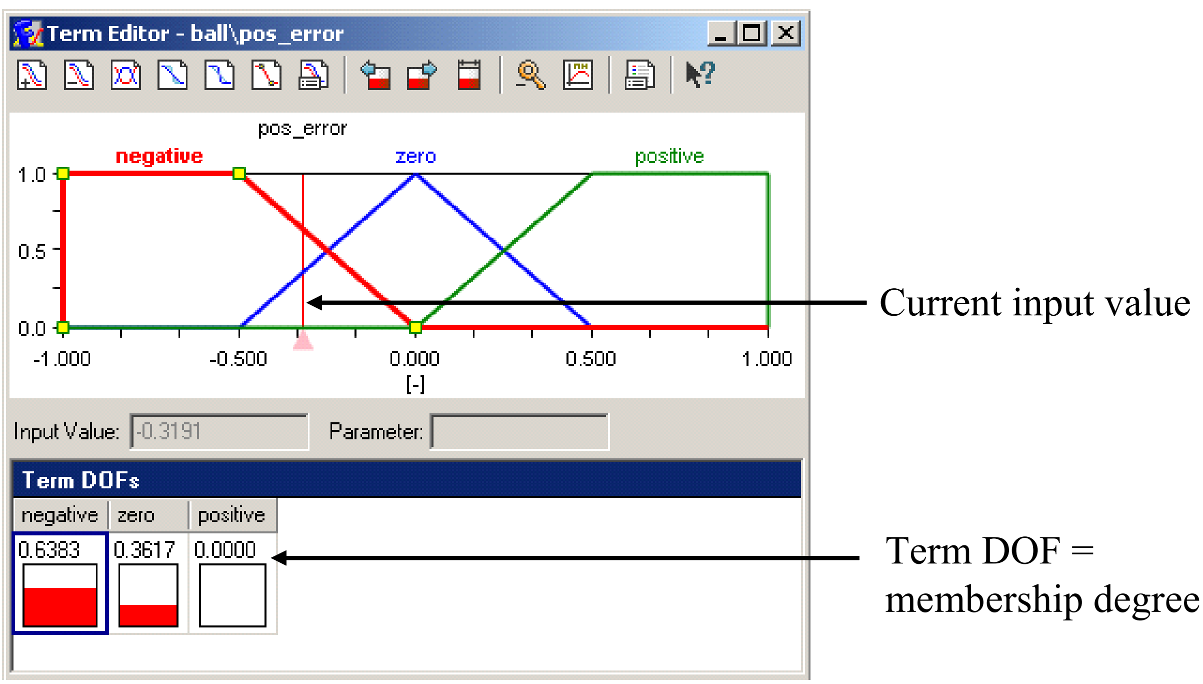
$$DOF(A) = \begin{cases} A(x^*) & if\ x^* \in [x_{\min}, x_{\max}] \\ A(x_{\min}) & if\ x^* < x_{\min} \\ A(x_{\max}) & if\ x^* > x_{\max} \end{cases}$$

This value is simply membership degree of value x^* to fuzzy set A and can be interpreted as a degree to which the proposition (x^* IS A) is true. An example of fuzzification of the crisp input value x^* is shown in the figure Process of Crisp Input Fuzzification. The component input value is -0.3191.

The component consists of three linguistic terms – negative, zero, and positive. The output of the component is the vector [0.6383, 0.3617, 0] – where 0.6383 is a degree of fulfillment of the term negative, 0.3617 is a degree of fulfillment of the term zero, and 0 is a degree of fulfillment of the term positive.

This value is simply membership degree of value x^* to fuzzy set A and can be interpreted as a degree to which the proposition (x^* IS A) is true.

Process of Crisp Input Fuzzification



DOFs of all terms are provided to connect rule blocks to complete the fuzzy logic inference.

Connections

The input link of the input linguistic variable is connectable to any of these components providing a crisp value:

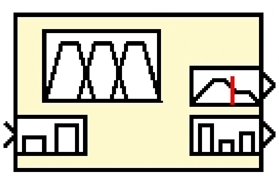
- input Port component.
- output Linguistic Variable component.
- output Takagi-Sugeno Variable component.
- PID component.

The output logical link of the input linguistic variable is connectable to components expecting a DOF value (as a result of fuzzification or defuzzification), such as the Rule Block component.

Parameters

- Name of the component
- Range of the input value of the component [x_{min}, x_{max}]
- List of terms described by
  - Name
  - Type of membership function
  - Vector of membership function parameters [a, b, c, d]

Output Linguistic Variable



The fuzzy system Output Linguistic Variable component stores output linguistic terms and is used for defuzzification. The component has a logical input link, degrees of fulfillment of all linguistic terms of the respective linguistic variable. The link can be multiple, meaning that the component can be connected to several rule blocks. The component has two output links – value and logical links. Depending on the selected inference algorithm and defuzzification method, the component computes a crisp value y^*. Such a result provides an output value link. The output logical link enables the connection of the component directly to another rule block. If the component input link is connected to a single rule block, the output degrees of fulfillment are the same as the input degrees of fulfillment. If the component is connected to several rule blocks, the output degrees of fulfillment of linguistic terms are computed as a maximum of the corresponding input degrees of fulfillment.

The Output Linguistic Variable component stores linguistic terms. Each linguistic term is defined by its fuzzy set, that is, the membership function and the name. The following membership functions are supported:

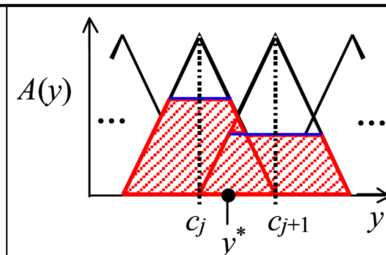
- Trapezoidal membership function
- Singleton membership function

Linguistic terms are defined on the specified range $[y_{min}, y_{max}]$ (universe of discourse).

Defuzzification

Defuzzification converts fuzzy sets to a crisp value, taking into account their degrees of fulfillment.

FuzzyDesigner supports the following defuzzification methods – Centroid Average, Maximum Center Average, Mean of Maximum, Smallest of Maximum, and Largest of Maximum.

y – output variable *Y* – universe of output variable, defined by an interval y^* – crisp output value (after defuzzification) A_i –membership function the output term *i*, that is, its fuzzy set *A* – fuzzy set, which is being defuzzified, obtained as a union of all “clipped” output membership functions. *A*(*y*) – membership degree of variable *y* in fuzzy set *A*	

Centroid Average – CA generally

An output value computed by this method is equal to the weighted average of the positions of the centroids of the output membership functions A_j weighted by their actual activation levels. The output value is computed as follows.

$$y^* = \frac{\sum_{j=1}^{M} A(c_j) \cdot c_j}{\sum_{j=1}^{M} A(c_j)}$$

where:

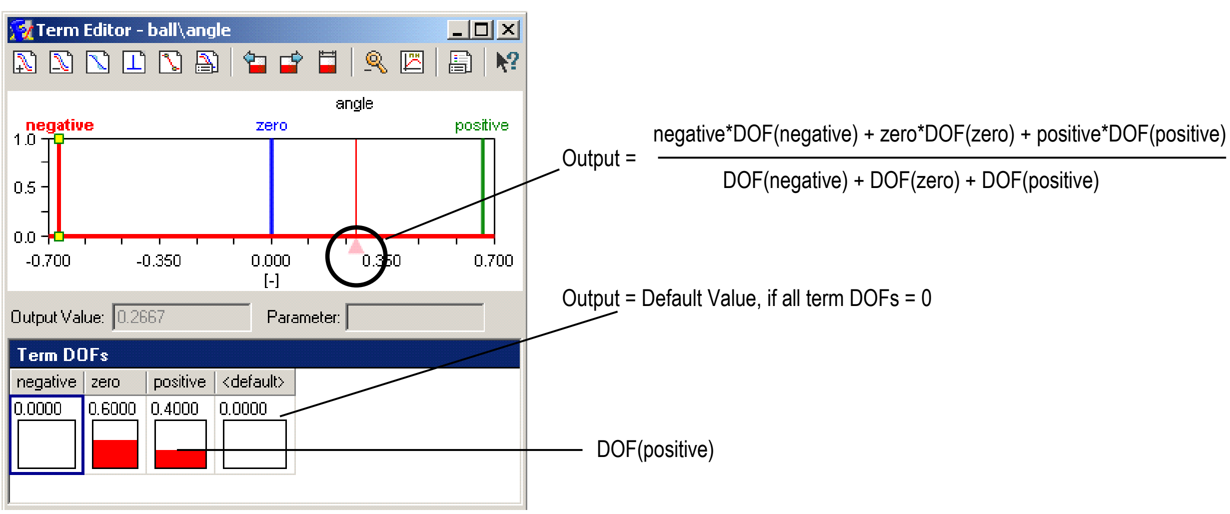
- $A(c_j)$ is the maximum of the degrees of fulfillment over all the rules with the consequent A_j
- c_j is a position of the centroid of the membership function A_j which is calculated in advance
- M is a number of fuzzy sets A_j

This method is used for applications when output is to be a continuous function of inputs for example, a control system

Maximum Center Average – MCA generally

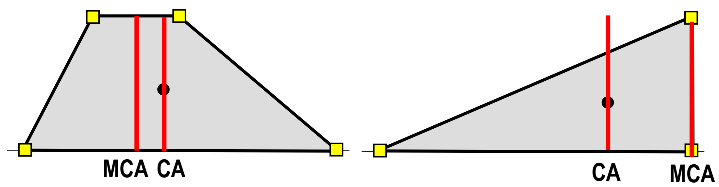
This method is similar to the Centroid Average method except that c_i , the center of maxima of B_i , is calculated in advance. This method is also continuous and allows the output value to reach the limits of the range.

Defuzzification CA=MCA for singletons.



Defuzzification CA and MCA for trapezoids.

Trapezoids are automatically transformed to singletons.



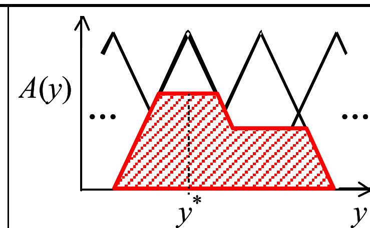
CA = centroid method

MCA = mean of maxima (to allow reaching limit values of the range)

The output value is then computed in the same way as for singletons.

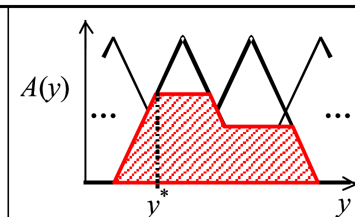
Mean of Maxima – MOM generally

This method computes the mean value of the interval at which the output fuzzy set reached the largest membership degree. It is defined as follows.

$y^* = \text{mean}\left\{ c_i \middle| A_i(c_i) = \max_j \left(A_j(c_j) \right) \right\}$	

Smallest of Maxima – SOM generally

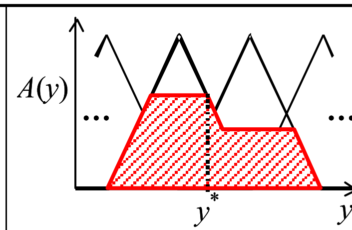
This method is similar to the previous one. Instead of mean value, the minimum value of the interval is chosen. The defuzzified output is computed as follows.

$y^* = \text{smallest}\left\{ c_i \middle| A_i(c_i) = \max_j \left(A_j(c_j) \right) \right\}$	

Largest of Maxima – LOM generally

The only difference to the previous method is that the maximum value of the interval is chosen. The defuzzified output is defined as follows.

$$y^* = \text{largest}\left\{c_i \middle| A_i(c_i) = \max_j \left(A_j(c_j)\right)\right\}$$



Mean of Maxima, Smallest of Maxima, and Largest of Maxima methods are not continuous and are mainly used in applications on decision-making and classification when the task is to choose from several alternatives.

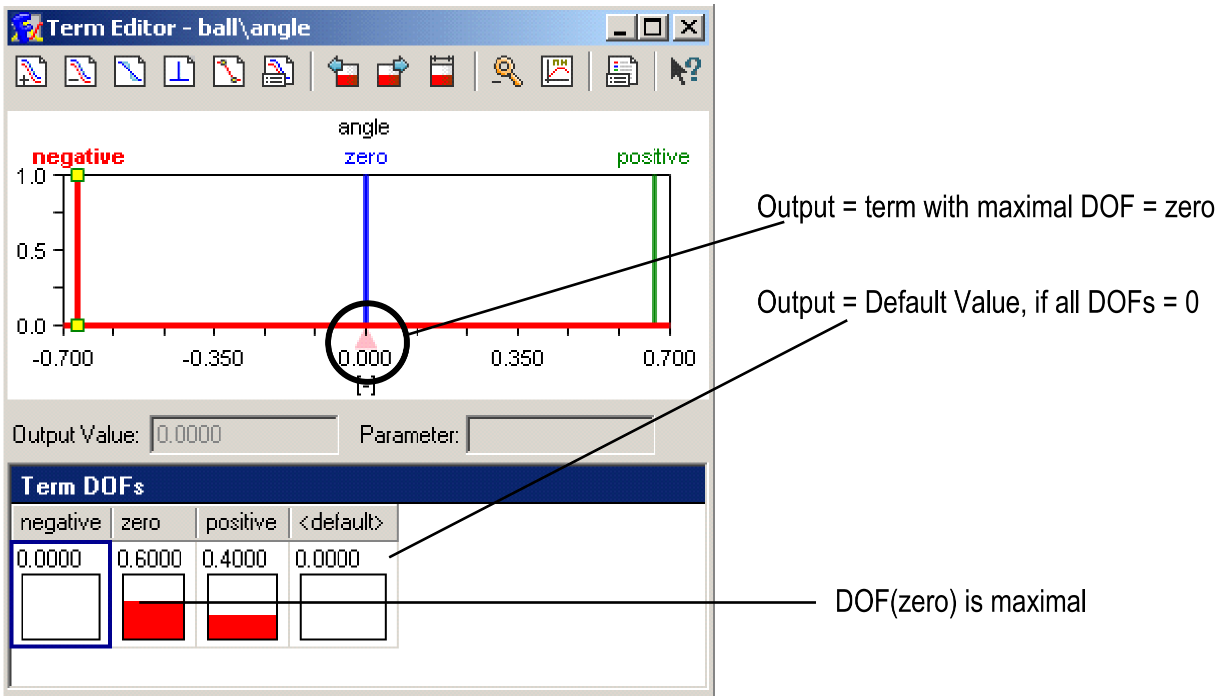
If no term is activated (*DOF* = 0) then the inference result is set to a user defined crisp **default value**.

Defuzzification SOM, MOM, LOM for singletons

Output value is computed as a reference singleton with maximal term DOF.

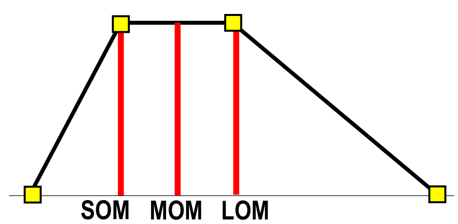
If more terms have the same maximal DOF>0, then:

- SOM: output = smallest of the singletons with maximal DOF.
- LOM: output = largest of the singletons with maximal DOF.
- MOM: output = mean of the singletons with maximal DOF.



Defuzzification SOM, MOM, LOM for trapezoids

Trapezoids are automatically transformed to singletons.



The output value is then computed in the same way as for singletons.

Recommendation

- Use singletons to have easier insight to the output inference mechanism
- No functionality is lost

Connections

The input link of the output linguistic variable can be connected to a component providing the DOF value (as a result of fuzzy inference), that is, the Rule Block component.

The output value link of the output linguistic variable can be connected to components expecting a crisp value, such as:

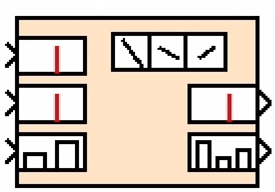
- Output Port component.
- Input Linguistic Variable component.
- Output Takagi-Sugeno Variable component (only crisp values are considered).
- PID component (only crisp values are considered).

The output logical link of the output linguistic variable can be connected to components expecting the DOF value (as a result of fuzzification or defuzzification), that is, the Rule Block component.

Parameters

- Name of the component
- Range of the output value of the component [y_{min}, y_{max}]
- List of terms described by
  - The name
  - The type of membership function
  - The vector of membership function parameters [*a*, *b*, *c*, *d*] for the trapezoidal membership function, [*c*] for the singleton membership function
- Type of fuzzy inference
- Type of defuzzification method
- Default output value

Output Takagi-Sugeno Variable



The classical model by Takagi-Sugeno offers a fuzzy rule based, smooth switching between analytical functions. The consequent is a crisp function of the antecedent variables rather than a fuzzy proposition. A general form of a Takagi-Sugeno model is:

R_i: IF x is A_i THEN $y_i = f_i(x)$

The consequent functions f_i are typically chosen as instances of a suitable parameterized function, whose structure remains equal in all the rules and only the parameters vary. Most often, these functions are linear combinations of antecedent variables. In control engineering, each rule usually represents local dynamics in different state space regions and the consequent is given in the form of a state-space or an ARX model. The overall model of the system is achieved by fuzzy **blending** of these linear models.

FuzzyDesigner supports Takagi-Sugeno fuzzy systems with linear functions in the rule consequents written in the following form.

$$R_i : \text{IF } x_1 \text{ is } A_{i1} \text{ and} \cdots \text{and } x_n \text{ is } A_{in} \text{ THEN } y = a_{i0} + a_{i1}x_1 + \ldots + a_{in}x_n$$

or

$$R_i : \text{IF } x_1 \text{ is } A_{i1} \text{ and} \cdots \text{and } x_n \text{ is } A_{in} \text{ THEN } y = a_{i0}$$

The Takagi-Sugeno fuzzy system with the constant value in the rule consequents can be also considered as a fuzzy system with singleton membership functions in the rule consequents. If the Centroid Average or Maximum Centroid Average defuzzification and Fuzzy Arithmetic Inference method is chosen, than the behavior of both fuzzy systems is the same.

The fuzzy system Output Takagi-Sugeno Variable component stores parameters of reference linear or constant consequent functions. The component has two input links – a logical input link (degrees of fulfillment of all reference functions) that can be multiple, meaning that the component can be connected to several rule blocks, and a value input link (connectable to components that produce crisp values), which can be multiple too. The number of links depends on the number of consequent variables.

The component has two output links:

- Value link
- Logical link

The output logical link enables the connection of the component directly to other rule blocks. If the component input link is connected to one rule block, the output degrees of fulfillment are the same as the input degrees of fulfillment. If the component is connected to several rule blocks, the output degrees of fulfillment of reference membership functions are computed as a maximum of the corresponding input degrees of fulfillment.

The output Takagi-Sugeno Variable component consists of functional terms. Each functional term is defined by its parameters (a_0, a_1, … a_n) and its name (the parameters are entered in the specified order separated by the space character). The type of every linguistic term can be different. There are two supported functions.

- Linear function: $f(x_1,x_2,...x_n) = a_0 + a_1\, x_1 + a_2\, x_2 + ... + a_n\, x_n$
- Constant function: $f(x_1,x_2,...x_n) = a_0$

Where $x_1,x_2,...x_n$ are outputs from preceding components providing crisp values.

The component calculates an inference result as a crisp value y^*

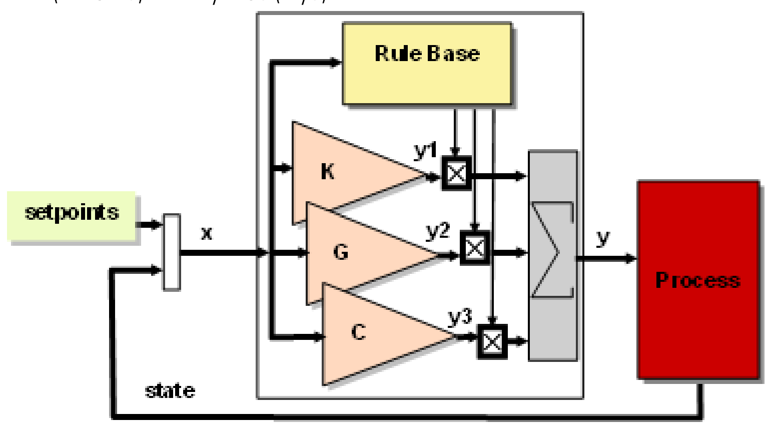
$$y^* = \frac{\sum_i dof_i \cdot f_i(x_1, x_2, \cdots, x_n)}{\sum_i dof_i}$$

where dof_i is *DOF* of *i*-th term. This value is finally limited to the range $[y_{min}, y_{max}]$. If no term is activated (*DOF* = 0) the inference result is a user-defined crisp **default value.**

EXAMPLE

Different linear-state feedback controllers are to be smoothly activated for different process states and setpoints – scheduling controller gains. There are three rules.

- IF (x1 IS A1) AND (x2 IS B1) THEN y = K0 + K1*x1 + K2*x2 (= y1)
- IF (x1 IS A2) AND (x2 IS B2) THEN y = G0 + G1*x1 + G2*x2 (= y2)
- IF (x1 IS A3) AND (x2 IS B3) THEN y = C0 (= y3)

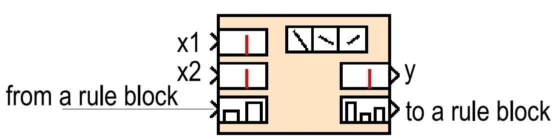


Defined (functional) terms:

K, type LINEAR, parameters = K0 K1 K2

G, type LINEAR, parameters = G0 G1 G2

C, type CONSTANT, parameters = C0



Evaluation (weighted average of functions):

$$y = \frac{y1*DOF(K) + y2*DOF(G) + y3*DOF(C)}{DOF(K) + DOF(G) + DOF(C)}$$

y = Default Value, if all DOFs = 0

Connections

The input logical link of the output Takagi-Sugeno variable can be connected to a component providing a DOF value (as result of fuzzy inference), that is, the Rule Block component.

The input value link of the output Takagi-Sugeno variable can be connected to components providing a crisp value, such as:

- Input Port component.
- Output Linguistic Variable component.
- PID component.
- Output Takagi-Sugeno Variable component.

The output value link of the output Takagi-Sugeno variable can be connected to components expecting a crisp value, such as:

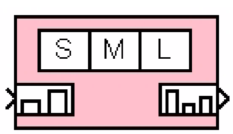
- Output Port component.
- Input Linguistic Variable component.
- Output Takagi-Sugeno Variable component (only crisp values are considered).
- PID component (only crisp values are considered).

The output logical link of the output Takagi-Sugeno variable can be connected to components expecting a DOF value (as result of fuzzification or defuzzification), such as the Rule Block component.

Parameters

- Name of the component
- Range of the input value of the component $[y_{\min}, y_{\max}]$
- List of functional terms described by
  - The name
  - The type of the function
  - The vector of the function parameters $[a_0, a_1, \dots, a_n]$ for the linear function, $[a_0]$ for the constant function
- Default value

Intermediate Linguistic Variable



The fuzzy system Intermediate Linguistic Variable component is used as a buffer allowing logical chaining of rule blocks.

The component consists of linguistic terms with symbolic meaning. Each linguistic term is defined by its name. Degrees of fulfillment of all terms are results of previous logic inference in preceding rule blocks connected to this component.

If the component input link is connected to a single rule block, the output degrees of fulfillment just copy inputs. If the component input is connected to several rule blocks, the output degrees of fulfillment of stored linguistic terms are computed as a maximum of the corresponding input degrees of fulfillment.

Connections

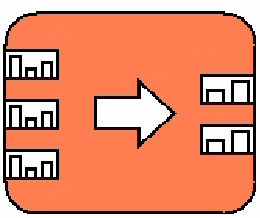
The input logical link of the Intermediate Linguistic Variable can be connected to a component providing a DOF value (as result of fuzzy inference in a rule block), that is, the Rule Block component.

The output logical link of the Intermediate Linguistic Variable can be connected to components expecting a DOF value (as result of fuzzification or fuzzy inference in a rule block), such as the Rule Block component.

Parameters

- Name of the component
- List of terms defined by their names

Rule Block



The fuzzy system Rule Block component stores rules, performs fuzzy logic inference based on fuzzy rules and computes degrees of fulfillment of linguistic terms for consequent variables (output logical links) from degrees of fulfillment of linguistic terms used in the rule for premise variables (input logical links).

Supported Format of Rules

Multiple notations are used in the explanation of the supported format of rules.

- $X_1, X_2, \ldots, X_n$ – premise variables
- $Y_1, Y_2, \ldots, Y_m$. – consequent variables
- $A_{i1}, A_{i2}, \ldots$ – terms defined for the premise variable X_i
- $B_{j1}, B_{j2}, \ldots$ – terms defined for the consequent variable Y_j

EXAMPLE

IF (X_1 IS A_{13}) AND (X_2 IS A_{21}) AND … AND (X_n IS A_{n1}) THEN (Y_1 IS B_{12}) [w_1] , (Y_2 IS B_{21}) [w_2], … (Y_n IS B_{n3}) [w_n]

where $w_k \in [0,1]$ is rule weight of the *k*-th consequent.

Schematically the rule can be rewritten as follows:

$(A_{13}, A_{21}, \ldots, A_{n1}) \rightarrow (B_{12}[w_1], B_{21}[w_2], \ldots, B_{n3}[w_n])$

This rule base format is very useful in manual design. It can be represented in the form of a table where every column corresponds to one variable and rows of the table are filled with appropriate terms or optionally with their inversions (applying the NOT operator).

FuzzyDesigner also supports the OR operator.

EXAMPLE

IF [(X_1 IS A_{11}) OR (X_1 IS A_{12}) OR ...] AND (X_2 IS A_{21}) AND … AND (X_n IS A_{n1}) THEN (Y_1 IS B_{12})

You define the number of terms in the OR expression.

The NOT operator can be applied to the whole OR expression.

IF [NOT [(X_1 IS A_{11}) OR (X_1 IS A_{12}) OR ...]] AND (X_2 IS A_{21}) AND … AND (X_n IS A_{n1}) THEN (Y_1 IS B_{12}) [w_1] , (Y_2 IS B_{21}) [w_2], …

The rule block component performs fuzzy logic inference based on fuzzy rules. In a simplified way, it computes degrees of fulfillment of consequent variables from degrees of fulfillment of premise variables by using fuzzy t-norms and s-norms (t-conorms).

FuzzyDesigner supports the following t-norms (fuzzy AND operators):

- Minimum: $T_{\min}(x, y) = \min(x, y)$
- Product: $T_{\text{prod}}(x, y) = x \cdot y$

FuzzyDesigner also supports this s-norm (fuzzy OR operator): maximum: $S_{max}(x, y) = \max(x, y)$

The evaluation of the Rule Block is completed in three steps.

1. DOFs of all rules are computed from DOFs of the rule premise by using the selected t-norm.
2. DOFs of all conseqent variables terms are computed for every rule.

   These DOFs are obtained from DOFs computed in step 1, multiplied by weights of consequent variables.
3. Total DOFs of all consequent variables are computed for the overall fuzzy system.

   Total DOF of one consequent variable is computed as maximum value of DOFs computed in step 2 for the appropriate consequent variable.

Assume a simple fuzzy system with these two premise variables (temperature, pressure) with terms:

- Temperature: (small, large)
- Pressure : (negative, zero, positive)

This system also has two consequent variables: (voltage, current) with terms:

- Voltage: (small, medium, large)
- Current : (zero, positive)

This system also has a minimum t-norm.

The rule base can be formulated as the following.

If	And	Then
Temperature is small	Oressure is negative	Voltage is medium [0.9] Current is positive [1.0]
Temperature is large	Pressure is negative	Voltage is small [0.8]
Pressure is positive		Voltage is small [1.0] Current is positive [1.0]

You can also formulate the rule base schematically:

- (small, negative) → (medium [0.9] , positive [1.0]).
- (large, negative) → (small [0.8] ,).
- (, positive) → (small [1.0] , positive [1.0]).

In the following example, some premise variable DOFs are supposed.

- Temperature: DOFtemp(small) = 0.4 , DOFtemp(large) = 0.8
- Pressure: DOFpress(negative) = 0.1 , DOFpress(zero) = 0.9 , DOFpress(positive) = 0.5

EXAMPLE

Step 1: DOFs of all rules are computed.

Rule 1: $DOF_{rule1} = \min(DOF_{temp}(small), DOF_{press}(negative)) = \min(0.4, 0.1) = 0.1$

Rule 2: $DOF_{rule2} = \min(DOF_{temp}(large), DOF_{press}(negative)) = \min(0.8, 0.1) = 0.1$

Rule 3: $DOF_{rule3} = \min(DOF_{press}(positive)) = \min(0.5) = 0.5$

Step 2: DOFs of all consequent variables for every rule terms are computed.

Rule 1: $DOF_{volt}(medium) = DOF_{rule1} \cdot Weight_{volt} = 0.1 \cdot 0.9 = 0.9$, $DOF_{curr}(positive) = DOF_{rule1} \cdot Weight_{curr} = 0.1 \cdot 1.0 = 0.1$

Rule 2: $DOF_{volt}(small) = DOF_{rule2} \cdot Weight_{volt} = 0.1 \cdot 0.8 = 0.8$

Rule 3: $DOF_{volt}(small) = DOF_{rule1} \cdot Weight_{volt} = 0.5 \cdot 1.0 = 0.5$

$DOF_{curr}(positive) = DOF_{rule1} \cdot Weight_{curr} = 0.5 \cdot 1.0 = 0.5$

Step 3: DOFs of all consequent variables terms for overall fuzzy system are computed.

$DOF_{volt}(small) = \max(DOF_{volt}(small)$ for all rules$) = \max(0.08, 0.5) = 0.5$

$DOF_{volt}(medium) = \max(DOF_{volt}(medium)$ for all rules$) = \max(0.09) = 0.09$

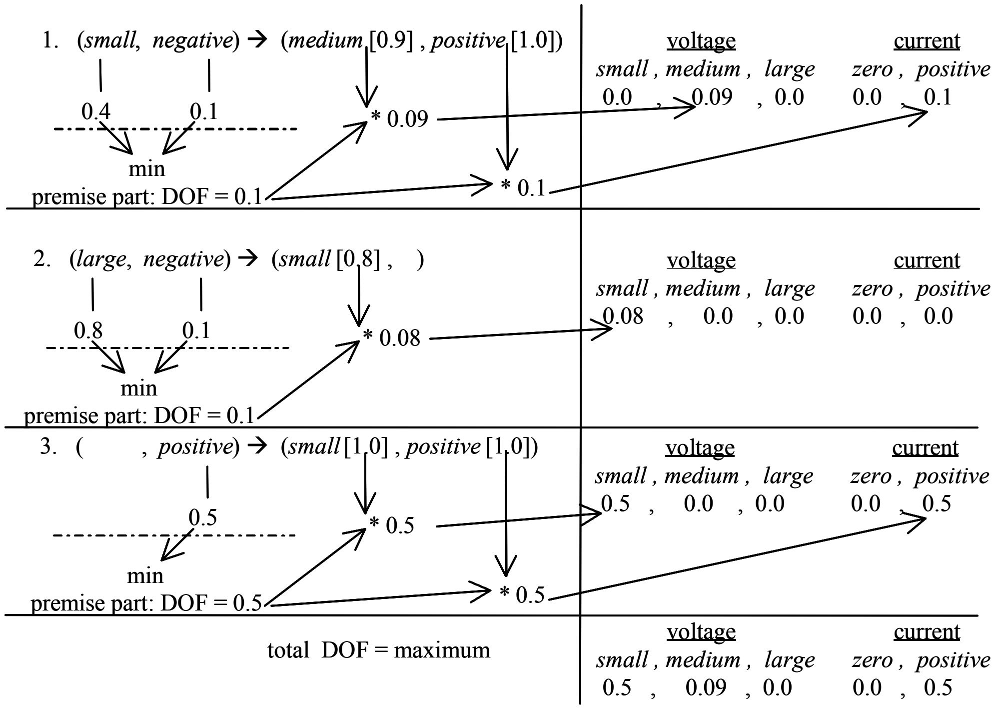
$DOF_{volt}(large) = 0$

$DOF_{curr}(zero) = 0$

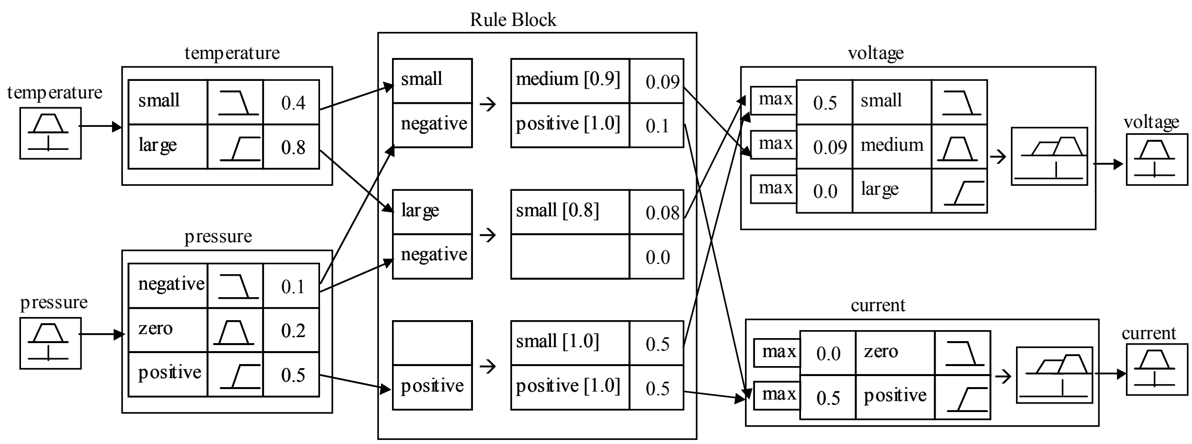
$DOF_{curr}(positive) = \max(DOF_{curr}(positive)$ for all rules$) = \max(0.1, 0.5) = 0.5$

These steps are schematically shown on the following figures.

Set of Rules Example Evaluation Procedure



Example of a Block Diagram of the Rule Block Evaluation



Connections

The input logical link of the Rule Block can be connected to a component providing a DOF value (as a result of fuzzification or defuzzification), such as the:

- Input Linguistic Variable component.
- Output Takagi-Sugeno Variable component.
- Output Linguistic Variable component.
- Intermediate Linguistic Variable component.

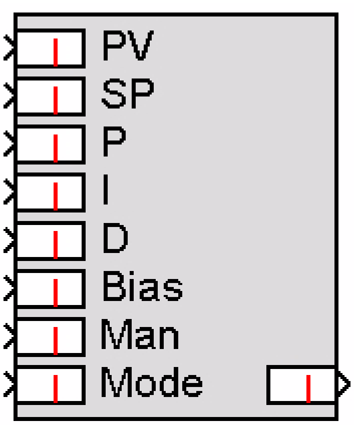
The output logical link of the Rule Block can be connected to components expecting a DOF value (as result of fuzzy inference), such as the:

- Output Takagi-Sugeno Variable component.
- Output Linguistic Variable component.
- Intermediate Linguistic Variable component.

Parameters

- Name of the component
- List of links to premise variables
- List of links to consequent variables
- Type of t-norm

PID Controller



The fuzzy system PID component enables you to design an intelligent supervision of a conventional PID controller.

The following symbols and terminology are used in description of the component:

- PV – process variable
- CV – control variable
- *SP* – set point
- E – error, *E* = *SP-PV*
- P- proportional gain,
- I- integral gain,
- D- derivative gain
- Man – manually set value of CV
- Mode – controller mode

The component can be used as a conventional PID controller with supervised parameters defined by component input links. The component output link provides a crisp value representing the control variable.

The component functionality is defined through the equation format with the option of using either independent gains or dependent gains. When the independent gains option is used, the proportional, integral and derivative gains affect only their specific proportional, integral or derivative terms respectively. When the dependent gains option is used, the proportional gain is replaced with a controller gain, which affects all three parts. Both formats are shown in the following equations.

$$CV = P\left(\left(b \cdot SP(t) - PV(t) \right) + \int_0^t I \cdot E(t)dt + D\frac{dO(t)}{dt} \right) + Bias$$

$$CV = P\left(b \cdot SP(t) - PV(t) \right) + \int_0^t I \cdot E(t)dt + D\frac{dO(t)}{dt} + Bias$$

Where parameter *b* can be defined by the user and has to be in interval [0,1]. The default value is 1. This parameter dampens the influence of the setpoint on the proportional action.

The component allows two formats of derivative term $O(t)$. Derivative input to the controller can be either the process variable $PV(t)$ or the error $E(t)$. Use of the process variable eliminates output spikes resulting from setpoint changes. Use of the error allows fast responses to setpoint changes when the algorithm can tolerate overshoots.

The algorithm is implemented in the discrete form.

Numerical integration is implemented as follows:

$$\int I \cdot Edt : \qquad Iterm_k = IE_k T_s + Iterm_{k-1}$$

where T_S is the loop update time.

Numerical derivation is implemented as follows:

$$\frac{dO}{dt} : \quad \Delta O_k = \frac{O_k - O_{k-1}}{T_s}$$

The calculation of the derivative term is enhanced by using a smoothing first order low pass digital filter. This filter eliminates large derivative term spikes caused by noise in the process variable.

$$\Delta O_k = (1-\alpha)\frac{O_k - O_{k-1}}{T_s} + \alpha\Delta O_{k-1}$$

where $$\alpha = \frac{1}{16\frac{T_s}{D}+1}.$$

Finally the control variable *CV* is computed in the following way:

$$CV_k = P\cdot(E_k + Iterm_k + D\cdot\Delta O_k) + Bias$$
$$CV_k = P\cdot E_k + Iterm_k + D\cdot\Delta O_k + Bias$$

in the case of dependent gains and independent gains respectively.

The controller can be used in two different modes – Manual mode and Automatic mode (default mode). During Manual mode the parameter *Mode*, which is defined by the input link, has to be set to 1. In this mode the controller calculates the user defined control variable, which is connected to the input link *Man*. During this mode the controller calculates the internal state of the integrator from the user defined control variable to achieve a bumpless transfer when the operator changes the control mode from manual to automatic. In the Automatic mode, when the parameter *Mode* is set to 0, the controller provides the computed value of the control variable. If input links *Man* and *Mode* are not fed, the default (automatic) mode is applied.

The component also provides the user additional features – output limiting with anti-reset windup, dead band control and gain forgetting factor.

Output limiting allows applies limits *CV_min* and *CV_max* to the control variable. If the output limiting is enabled, and the computed control variable exceeds the limits, the *CV* is saturated. When the value of the computed control variable reaches or exceeds limits, the integration is paused until the value of the computed control variable comes back into the range.

The adjustable dead band *DB* lets the user select an error interval *DBI* = [*SP-DB, SP+DB*] around the setpoint where the controller output does not change as long as the error remains within this range. This dead band lets you control how closely the process variable matches the setpoint without changing the value of *CV*. There are two choices of dead band type – zero crossing and no zero crossing dead band.

Zero crossing dead band control stops changing control variable ($\Delta CV = 0$) when the process variable crosses the setpoint. The control variable is not changed as long as the process variable remains within the dead band interval. Zero crossing dead band control can be written as follows:

Once PV reaches SP ($E = 0$) and as long as $PV \in DBI$, use $\Delta CV = 0$ (consider $E = 0$)

No zero crossing dead band control stops changing control variable immediately when approaching the setpoint and crossing the band limits. The control variable is not changed as long as the process variable remains in the dead band interval. No zero crossing dead band control can be written as follows:

IF ($PV \in DB$) THEN $\Delta CV = 0$ (consider $E = 0$)

When the gain parameters of the PID controller are supervised by fuzzy rules, rapid changes of premise rules variables may cause rapid changes of controller gains. To avoid these changes the gain forgetting factor g can be used. The value of g has to be in the interval [0.001 1]. Value $g = 1$ corresponds to exact parameter tracking (no forgetting factor is applied) and $g = 0.001$ corresponds to very slow parameter tracking. The default value is 1.

Connections

The Input links of the PID component can be connected to all components providing crisp values, such as:

- Input Port component.
- Output Takagi-Sugeno Variable component.
- Output Linguistic Variable component.
- PID component (theoretically).

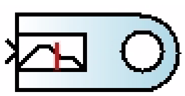
The output link of the PID component can be connected to all components expecting a crisp value, such as:

- Output Port component.
- Input Linguistic Variable component.
- Output Takagi-Sugeno Variable component (theoretically).
- PID component (theoretically).

Parameters

- Name of the component
- Controller Gain parameters (P, I, D), Bias – specified by links to components providing crisp values or by user defined constant values
- Setpoint value SP – specified by links to components providing crisp values or by user defined constant values
- Sampling period T_s
- Output limiting of control variable – YES or NO
- Output limits – $[CV_{\min}, CV_{\max}]$ (if YES)
- Equation format – dependent or independent gains
- Derivative input format – error or process variable
- Manual control (None or the link to component which defines the manual control variable)
- Mode – 0 (automatic) or 1 (manual)
- Parameter b - dampens the influence of the setpoint on the proportional action
- Dead band – YES or NO
- Dead Band Radius (if YES)
- Dead Band Type – Zero Crossing or No Zero Crossing (if YES)
- Gain forgetting factor

Output Port



The Output Port component stores an actual output value of the HFS provided by a preceding component. The output is a crisp value.

Connections

The input link of the output port can be connected to all components providing a crisp value, such as:

- Input Port component.
- Output Takagi-Sugeno Variable component.
- Output Linguistic Variable component.
- PID component.

Parameters

- Name of the component

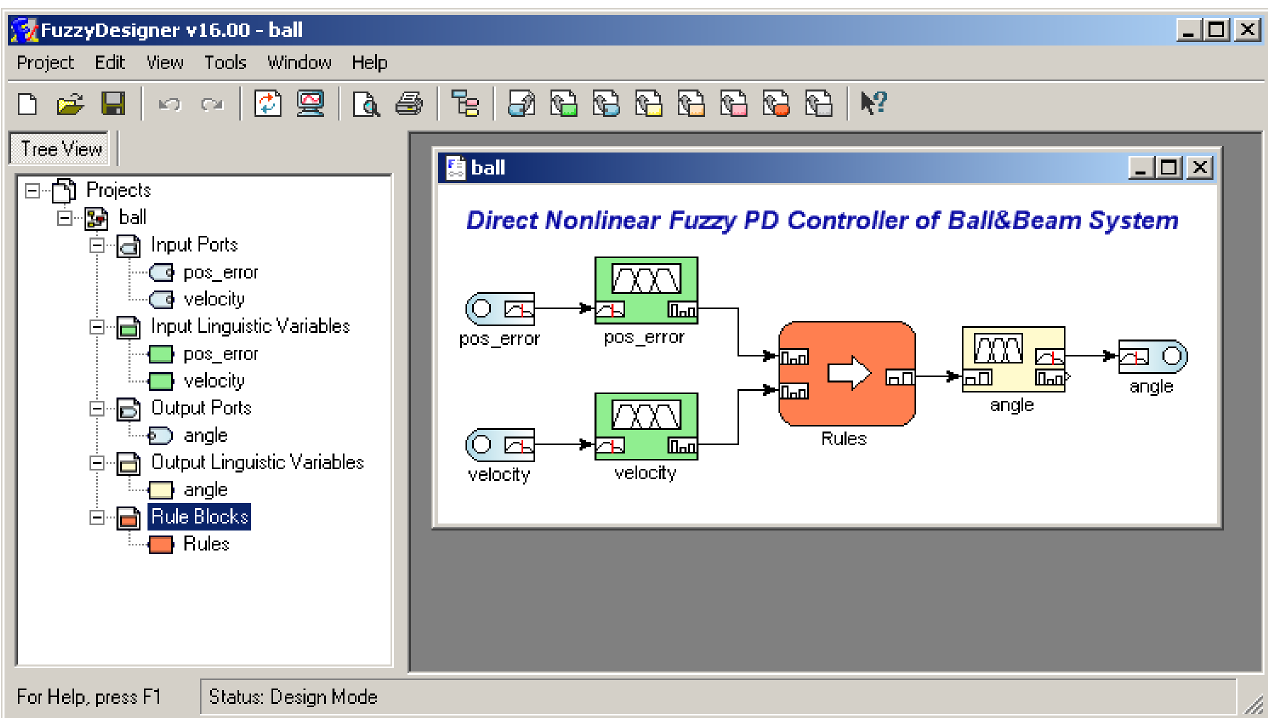
FuzzyDesigner Graphical User Interface

Introduction

The FuzzyDesigner graphical user interface (GUI) is illustrated by a simple academic **Ball and Beam** experiment provided as one of the sample projects when you install FuzzyDesigner.

The objective is to stabilize the ball at the desired position on the beam. The main screen of the FuzzyDesigner GUI with the opened project named **ball** (this is our **Ball and Beam** example), can be seen below.

Ball and Beam Project in FuzzyDesigner



Setting Options

There are some FuzzyDesigner features that can be configured according to personal preferences and for particular projects. You can access the customization options from the **View** and **Options** menu commands.

Tool Bar

The **Tool Bar** (see FuzzyDesigner Tool Bar) submenu on the **View** menu enables access to the commands for customizing the FuzzyDesigner tool bar. A tool bar button can be set as visible or invisible by clicking the appropriate Tool Bar submenu commands.

FuzzyDesigner Tool Bar

Status Bar

The **Status Bar** (see FuzzyDesigner Status Bar) menu command on the **View** menu enables you to set the status bar of FuzzyDesigner as visible or as invisible. The status bar shows FuzzyDesigner modes (see FuzzyDesigner Control Basics), and error messages.

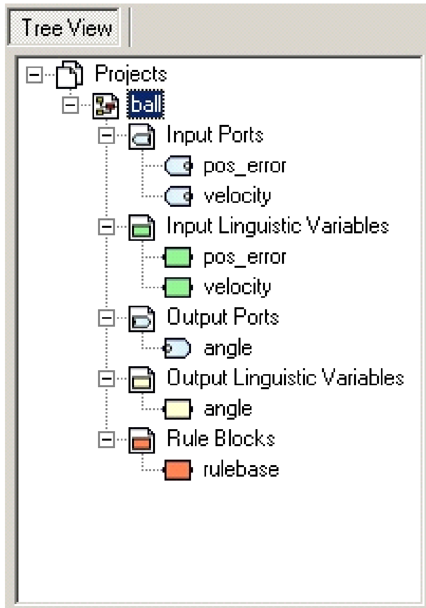
FuzzyDesigner Status Bar

Tree View

The **Tree View** (see FuzzyDesigner Tree View) menu command on the **View** menu enables you to set the Tree View tab control page visible or invisible (see Working with Projects). You can also do this by clicking the tool bar button with the same name (shown as a tool tip).

To resize the Tree View tab control page, use your mouse and drag the splitter on the right side of the tab control.

FuzzyDesigner Tree View



FuzzyDesigner Control Basics

The controls in FuzzyDesigner are very similar to other Microsoft Windows applications, and are easy to use.

FuzzyDesigner's functions can be accessed from the main menu or by clicking the tool bar button commands. By right-clicking the tree view item or in the FuzzyDesigner project window, a related pop-up menu appears. You can also control most of the functions using these pop-up menus. These menus are context-sensitive; they offer the most useful commands applicable to the current window.

Use the **Project****Recent Projects** menu command to reopen the most recent projects in FuzzyDesigner. Up to four projects are shown in the Recent Projects menu.

Detailed **Help** is accessible through the FuzzyDesigner main menu. The Help button can be used in the Term and the Rule Editor tool bars as well. Using this button, information about the particular editor can be displayed.

You can apply the **Edit****Undo** and **Edit****Redo** menu commands to a few changes made in the active project. The Undo menu command is always applied to the last change in the active project and the Redo menu command is always applied to the next change in the history of changes made in the active project.

FuzzyDesigner has two main modes, **Design mode** and **Monitoring mode**. FuzzyDesigner defaults to the Design mode, where you can design the project, set or reset options and use all application tools without any restriction. Use the Monitoring mode when you need to change the project parameters only, and leave the project design unchanged. Options and tools that can enable project design changes are restricted in the Monitoring mode. The current mode is indicated in the application Status Bar.

IMPORTANT

The Monitoring mode can be switched on or off directly from the Edit|Go to Design mode …/Go to Monitoring mode main menu item or the tool bar with the same name in the tool tip. The Monitoring mode is automatically enabled when the following dialoges are opened:

- Watch
- Simulation Watch
- Project Installation Wizard
- Online Connection Wizard Panel
- Monitoring Stand-Alone Component

After you close all of the open dialoges, FuzzyDesigner switches to the Design mode.

You can minimize, maximize or restore all windows opened in the FuzzyDesigner work area from the menu commands in the **Window** menu.

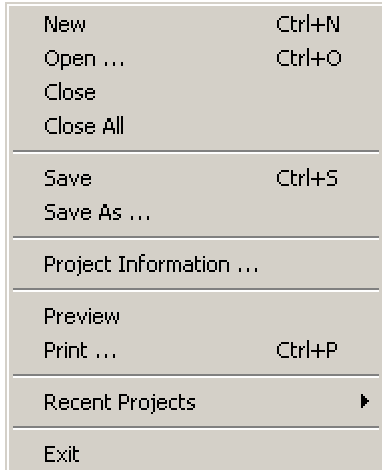
Main Menu

This section lists all menu items in the main menu bar of the FuzzyDesigner main window.

FuzzyDesigner Main Menu

Project

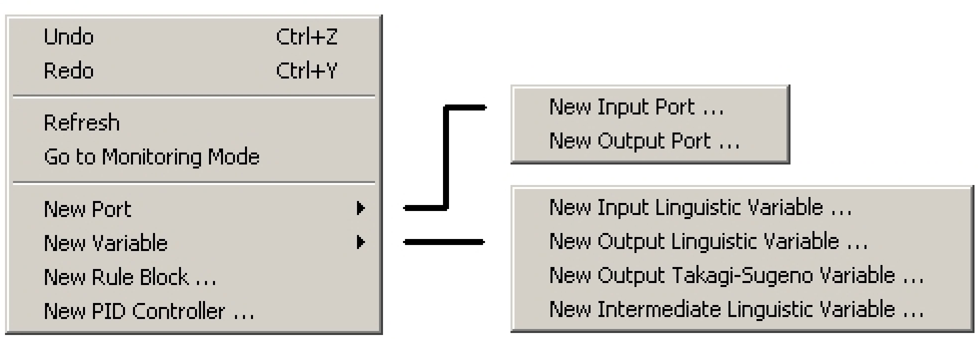
FuzzyDesigner Main Menu Project Structure



- New – creates a new project
- Open … – opens an existing project
- Close – closes the active project
- Close All – closes all open projects
- Save – saves the active project
- Save As … – save the active project with a different name
- Project Information … – displays the properties for the current project
- Preview – shows the preview of the currently active project
- Print … – prints the active project
- Recent Projects – shows the four most recent projects
- Exit – closes the FuzzyDesigner application

Edit

FuzzyDesigner Main Menu Edit Structure

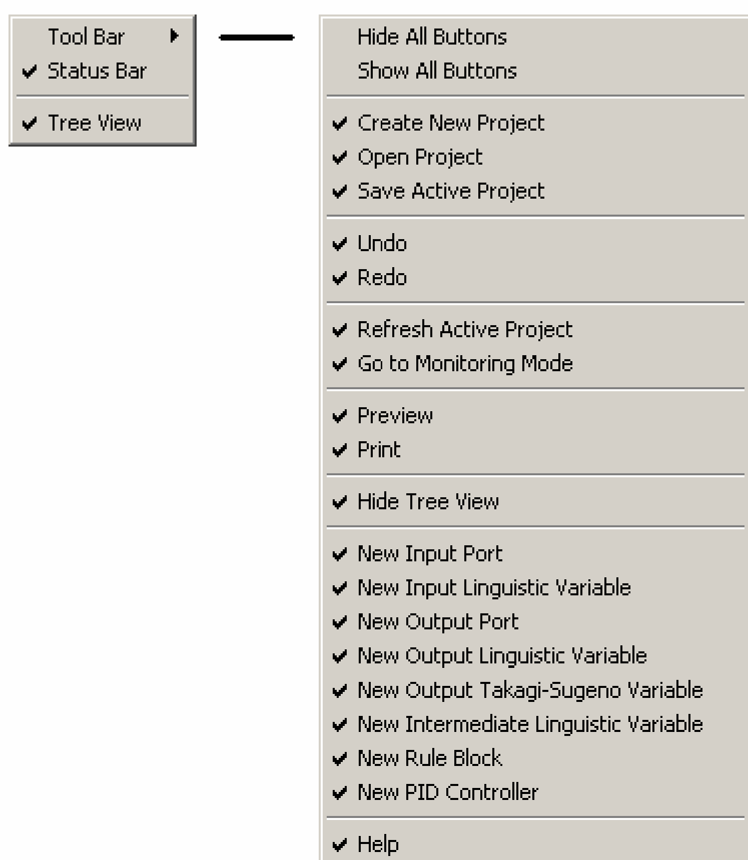


- Undo – see section FuzzyDesigner Control Basics
- Redo – see section FuzzyDesigner Control Basics
- Refresh – updates the display of the active project

- Go to Design mode .../Go to Monitoring mode – switches the project between the Design mode and Monitoring mode (see section FuzzyDesigner Control Basics)
- New Port
  - New Input Port ... – see section Input Port
  - New Output Port ... – see section Output Port
- New Variable
  - New Input Linguistic Variable ... – see section Input Linguistic Variable
  - New Output Linguistic Variable ... – see section Output Linguistic Variable
  - New Output Takagi-Sugeno Variable ... – see section Output Takagi-Sugeno Variable
  - New Intermediate Linguistic Variable ... – see section Intermediate Linguistic Variable
- New Rule Block ... – see section Rule Block
- New PID Controller ... – see section PID Controller

View

FuzzyDesigner Main Menu View Structure

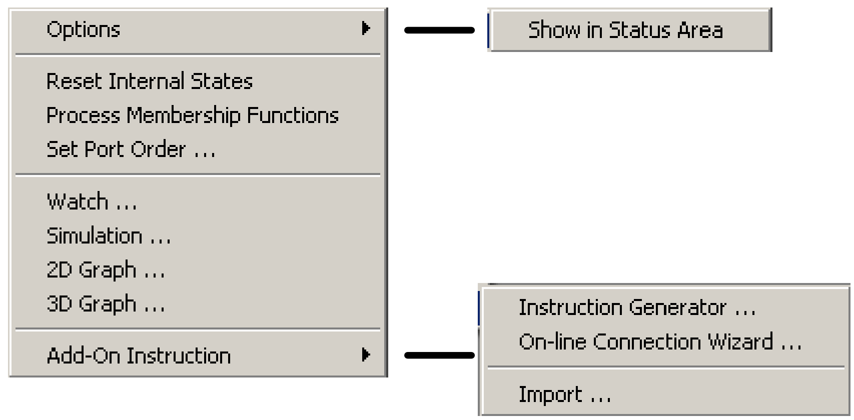


- Tool Bar
  - Hide All Buttons – hides all tool bar buttons of the application
  - Show All Buttons – shows all tool bar buttons of the application
  - Create New Project – shows or hides the Create New Project tool bar button of the application
  - Open Project – shows or hides the Open Project tool bar button of the application
  - Save Active Project – shows or hides the Save Active Project tool bar button of the application
  - Undo – shows or hides the Undo tool bar button of the application
  - Redo – shows or hides the Redo tool bar button of the application
  - Refresh Active Project – shows or hides the Refresh Active Project tool bar button of the application
  - Go to Design mode/Go to Monitoring mode – shows or hides the Go to Design mode …/Go to Monitoring mode tool bar button of the application
  - Preview – shows or hides the Preview tool bar button of the application
  - Print – shows or hides the Print tool bar button of the application
  - Hide Tree View/Show Tree View – shows or hides the Hide Tree View/Show Tree View tool bar button of the application
  - New Input Port – shows or hides the New Input Port tool bar button of the application
  - New Input Linguistic Variable – shows or hides the New Input Linguistic Variable tool bar button of the application
  - New Output Port – shows or hides the New Output Port tool bar button of the application
  - New Output Linguistic Variable – shows or hides the New Output Linguistic Variable tool bar button of the application
  - New Output Takagi-Sugeno Variable – shows or hides the New Output Takagi-Sugeno Variable tool bar button of the application
  - New Intermediate Linguistic Variable – shows or hides the New Intermediate Linguistic Variable tool bar button of the application
  - New Rule Block – shows or hides the New Rule Block tool bar button of the application
  - New PID Controller – shows or hides the New PID Controller tool bar button of the application
  - Help – shows or hides the Help tool bar button of the application

- Status Bar – shows or hides the status bar of the application
- Tree View – shows or hides the Tree View tab control page of the application

Tools

FuzzyDesigner Main Menu Tools Structure



- Options
  - Show in Status Area – check this menu item to set the FuzzyDesigner to the server mode. The FuzzyDesigner icon shows in the status area and the application should be closed only through the icon context menu.
- Reset Internal States – resets the internal states of all Input Port filters and PID Controllers in the just active project
- Process Membership Functions – appropriate output variables process according to fuzzy sets in the just active project
- Set Port Order … – see section Port Order Editor
- Watch … – see section Watch
- Simulation … – simulate your process by entering values for the variables defined on input ports (see Fuzzy System Simulation)
- 2D Graph … – see section 2D Graph
- 3D Graph … – see section 3D Graph
- Add-On Instruction … – create or monitor fuzzy Add-On Instructions (see RSLogix 5000 Add-On Instruction)

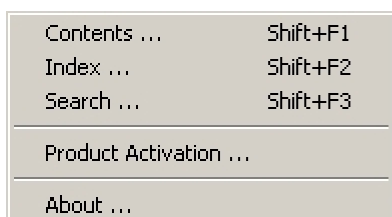
Window

FuzzyDesigner Main Menu Window

- Tile – tiles all open windows in the application workplace
- Cascade – cascades all open windows in the application workplace
- Arrange Icons – arranges icons in the application workplace
- Minimize All – minimizes all windows in the application workplace
- Maximize All – maximizes all windows in the application workplace
- Restore All – restores all windows to their normal size in the application workplace

Help

FuzzyDesigner Main Menu Help



- Contents … – shows the help contents
- Index … – shows the help index
- Search … – shows the help search dialog
- Product Activation … – shows the Product Activation dialog with the Computer ID. Send this together with the serial number to technical support to get the Activation Key to access the desired application features.
- About … – about the FuzzyDesigner

Tool Bar Menu

This section lists all menu buttons in the tool bar menu (see FuzzyDesigner Tool Bar) of the FuzzyDesigner main window.

- Create new project
- Open project
- Save active project
- Undo – see section FuzzyDesigner Control Basics
- Redo – see section FuzzyDesigner Control Basics
- Refresh – evaluates static the just active project
- Go to Design Mode…/Go to Monitoring Mode – switches FuzzyDesigner between the Design and Monitoring Mode (see section FuzzyDesigner Control Basics)
- Preview – shows the preview of the current project
- Print
- Hide Tree View – see section FuzzyDesigner Tree View
- New Input Port
- New Input Linguistic Variable
- New Output Port
- New Output Linguistic Variable
- New Output Takagi-Sugeno Variable
- New Intermediate Linguistic Variable
- New Rule Block
- New PID Controller
- Help – shows the FuzzyDesigner help

FuzzyDesigner Projects

Introduction

The basic working unit in the FuzzyDesigner is a project. This chapter describes the concept of a project.

A project is a set of data containing information related to a particular fuzzy system. Designing a fuzzy system involves several steps – definition of components and links between components, design of membership functions, and creating fuzzy rules.

Working with Projects

Most of the commands used for basic operations with projects can be found in the Project menu. This menu contains the following commands:

- New – creates a new project
- Open – opens an existing project
- Close – closes the currently active project
- Close All – closes all opened projects
- Save – saves the currently active project
- Save As – saves the currently active project to new file
- Project Information – shows the information about the currently active project
- Preview – shows the preview of the currently active project window

- Print – prints the project window of the currently active project
- Recent Projects – shows the four most recent projects
- Exit – closes FuzzyDesigner

All opened projects and their components are seen in the Tree View tab control page. When you right-click a tree view node, a context sensitive menu appears. When you right-click the **Projects** node, a context menu with the following commands appears (see Projects Tree View Node Context Menu):

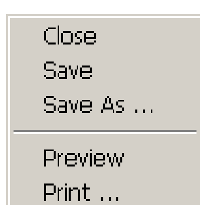
- New – creates a new project (see section Creating a Project)
- Open – opens an existing project (see section Opening an Existing Project)
- Close All – closes all opened projects (see section Closing a Project)

Projects Tree View Node Context Menu

When you right-click the opened project node, a context menu with the following commands appears (see Project Tree View Node Context Menu):

- Close – closes the project (see section Closing a Project)
- Save – saves the project (see section Saving a Project)
- Save As – saves the currently active project to new file (see section Saving a Project)
- Preview – shows the project preview
- Print – prints the project (see section Printing a Project)

Project Tree View Node Context Menu



There are project component type nodes of the applied components under the node of each opened project. When you right-click the component type node, a context menu with the following command appears (see Component Type Tree View Node Context Menu):

- Delete All – deletes all applied components with the appropriate type from the project.

Component Type Tree View Node Context Menu

There are component nodes of the applied components under the appropriate component type node of each opened project. When you right-click the component node, a context menu with the following commands appears (see Component Tree View Node Context Menu):

- Delete – deletes the selected component from the project

- Properties – shows the properties dialog of the selected component (see section Fuzzy System Components)

Component Tree View Node Context Menu

Creating a Project

Create a new project by using the Project\New main menu command or the New context menu command of the Projects tree view node. When a new project is created, the appropriate tree view node and project window will be added. A new project is not automatically saved. To save a recently created project, use the Save As command (see section Saving a Project) in the Project menu.

Opening an Existing Project

Follow these steps to open the existing project.

1. Select the Project\Open main menu command or the Open context menu command of the Projects tree view node.

2. From the Open dialog, choose the appropriate file type (fsp) and click or type the name of the project file.

3. When you select a fsp-file type, a file in the XML format with all project information will open.
   When the selected file has no information about the project graphical representation or about FuzzyDesigner GUI, the project will be opened with a default graphical representation and FuzzyDesigner GUI information (without the project description, for example).

4. Click Open.

   When the project opens successfully, the appropriate tree view node will be added to the Tree View tab control page and the project window will be opened in the application workplace with appropriate recently opened dialogs.

FuzzyDesigner is a Multi-Document Interface (MDI) application, so you can open more then one project at a time. Only one of the currently opened projects can be active, so all the tool bar button commands associated with a project are applied to this active project. The FuzzyDesigner active window does not automatically relate to the active project.

Changing the Active Project

You can switch between projects by clicking the appropriate project window or project tree view node. When a new or existing project is opened, it is automatically set as the active project. The name of the active project is shown in the title of the FuzzyDesigner main window.

Project Information

Use the Project\Project Information main menu command to open the Project Information dialog (see Project Information Dialog) for an active project.

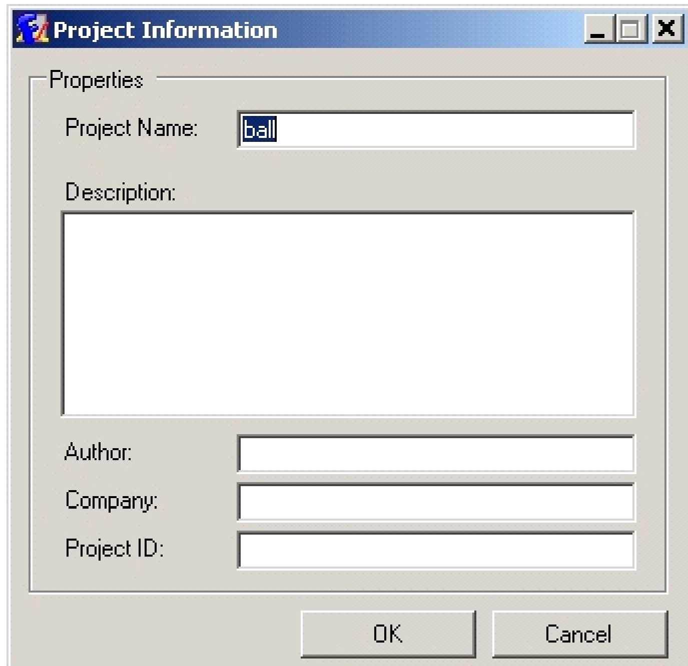
Properties group box – Specify additional information for the project, in the appropriate text boxes.

- Project Name
- Description
- Author
- Company
- Project ID – free-form project identification code

OK button - Accept the entered properties for the project.

Cancel button – Click the button if you do not want to apply the changes, but you want to close the dialog.

Project Information Dialog



Saving a Project

To save changes made in the active project, use the Project\Save main menu command. To save newly created projects, or to save to another project, use the Project\Save As main menu command. The standard Save As dialog appears immediately, so you may click the directory, where the project will be stored and type a new project name in the dialog.

The FuzzyDesigner project can be saved to the file with .fsp extension, where all the information about the project is stored in the XML format. This file can be opened in any XML editor.

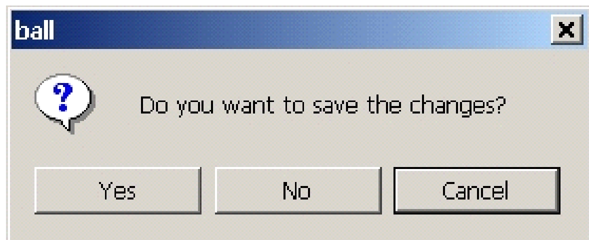
Closing a Project

You can close an active project using the Project\Close main menu command or directly close the active project by clicking Close in the top right corner of the project window.

To close all open projects, use the Project\Close All main menu command.

FuzzyDesigner may display a dialog, prompting you to save your project before closing it. To save the project's changes, click Yes. To close the project without saving the project's changes, click No. To return to the project without saving or closing the project, click Cancel.

Message Box of Closing an Unsaved Project



Designing a Project

The fuzzy system is designed in the project window, which is the main window for every project opened in FuzzyDesigner. There is a graphical representation of the designed hierarchical fuzzy system with applied project components and an additional text comment. A detailed description of how to work in the project window is available the section Designing a Fuzzy System.

Printing a Project

You can print the active project using the Print main menu command in the Project menu. You can also configure your printer from the Print dialog that appears.

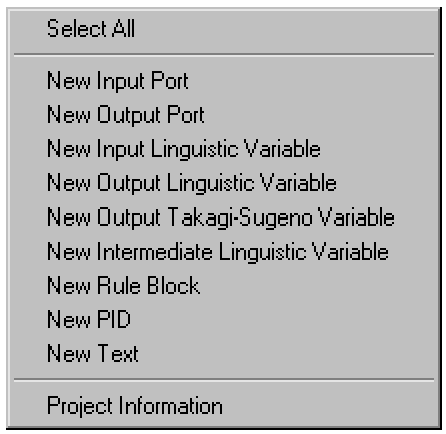
Designing a Fuzzy System

Having a graphical representation of a Fuzzy System speeds up the design, and also makes the internal architecture more transparent and interpretable. It also serves as natural project documentation. The graphics consist of three parts - the workspace of the project window, blocks, and text. These are explained in the following sections.

Fuzzy System Project Window

The fuzzy system project window enables the designer to create block diagrams of a fuzzy system by inserting and linking graphical objects, library components, and text. The window size is user defined, and accommodates any structure of a fuzzy system. Avoid moving any object outside of this area. If you right-click the empty Design Sheet window, the Design Sheet context menu (see Fuzzy System Project Window Context Menu) appears. The following menu items are available.

Fuzzy System Project Window Context Menu



- Select all – Selects all blocks and texts.
- New Input Port, New Output Port, – Adds a new block to the sheet.
- Project Information – Opens a window with project information.

Working with Blocks

There are eight types of Fuzzy System Components (see section Fuzzy System Components), referred to as blocks, which enable you to design the fuzzy system as a block diagram. Blocks are graphical objects.

Adding a Block

A new block can be added to the existing diagram in several ways. The first is by using context menu. This menu is described in the section Fuzzy System Project Window.

The other way to add a new block to the existing diagram is to use the Main Menu or the Tool Bar.

Selecting a Block

Click an existing block to select it. Other previously selected objects are automatically unselected.

To select multiple graphical objects, draw a bounding box around them with your mouse, or hold the CTRL key while clicking them.

To select all graphical objects (blocks and texts) use the Select All item from Fuzzy System Project Window Context Menu (see section Fuzzy System Project Window). You can also select a block through the Tree View.

Removing a Block

A block can be removed from the graphical model using the keyboard or the Tree View. Select a block and press the Delete key. Blocks are removed from the project completely.

Moving a Block

Graphical objects can be moved by using a drag and drop operation with your mouse or by using the CTRL and directional arrow keys on a selected object. The final position of the object must lie inside the working area. If one or more dragged objects are moved out of the permitted area then the objects are moved by default to the nearest permitted position.

Resizing a Block

Select an object and move your mouse over to any corner of object. Resize the object by clicking and dragging on a corner. You can resize only one block at a time.

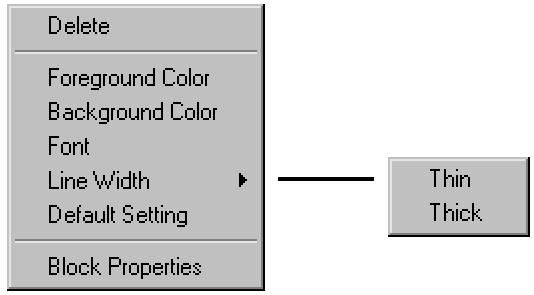
Block Properties

A block has two sets of parameters - the graphical and the internal parameters. All the parameters are accessible from the block context menu (see Blocks Context Menu). This menu appears if you right-click a block or a group of selected blocks.

You can change block appearance (graphical) parameters, foreground color (the color of the border), background color, font and line width.

You can change the internal parameters that define the block function by clicking the Block Properties menu item or by double-clicking the object. You can also modify internal parameters by using the Tree View.

Blocks Context Menu



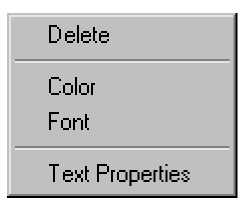
Working with Text

Use text to make comments in a fuzzy model. To insert text, select the Text Properties command in the Design Window context menu. If you enter only spaces or don't enter any text, the text object is not created.

Text objects are not selectable from the tree view.

To edit a text object, double-click the object, or right-click the text object and select the Text Properties command.

Texts Context Menu



Fuzzy System Components

There are eight fuzzy system component types:

- Input Port
- Input Linguistic Variable
- Output Port
- Output Linguistic Variable
- Output Takagi-Sugeno Variable
- Intermediate Linguistic Variable
- Rule Block

- PID Controller

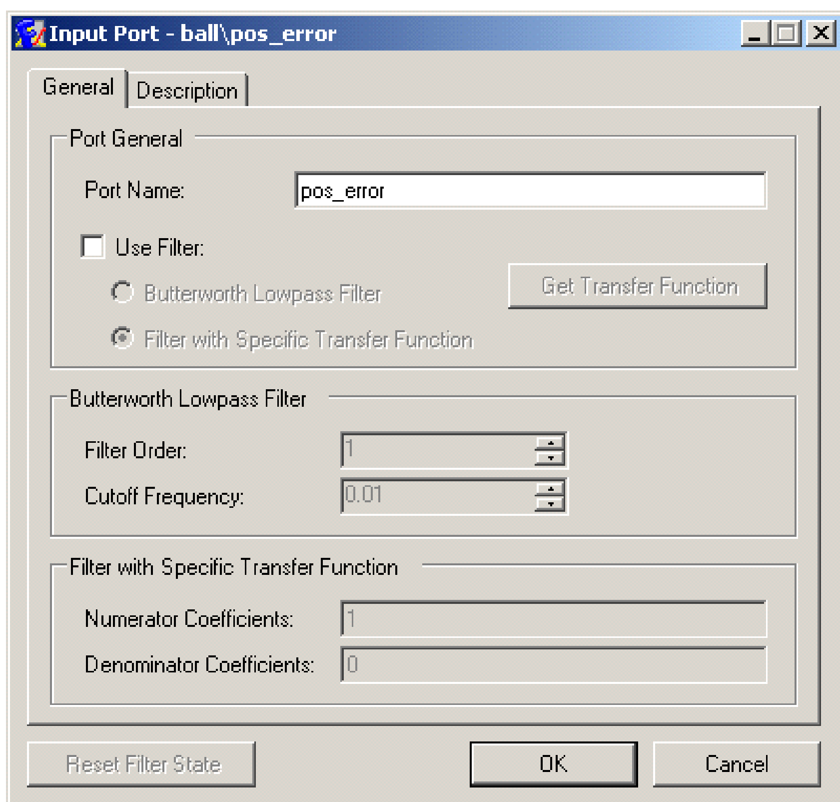
Components of the same type used more than once in the same project must have a unique name. The Input Port and the Input Linguistic Variable can share the same name. The name of the Input Linguistic Variable, Output Linguistic Variable, Output Takagi-Sugeno Variable and PID Controller used in the same project cannot be shared by the other components. The Output Port can share names with the Output Linguistic Variable.

Input Port

Use the Edit\New Port\New Input Port main menu command or the New Input Port tool bar button to add a new Input Port (IP) to the currently active project. Use the New Input Port project window context menu command to add a port. First, the Input Port properties dialog appears. A default name is assigned to a new component. Click OK to apply the component to the appropriate project. All names assigned to Input Ports belonging to a single project must be unique.

- General tab dialog – Specify the main properties of a new or existing IP.

Input Port Properties Dialog– General Tab Dialog



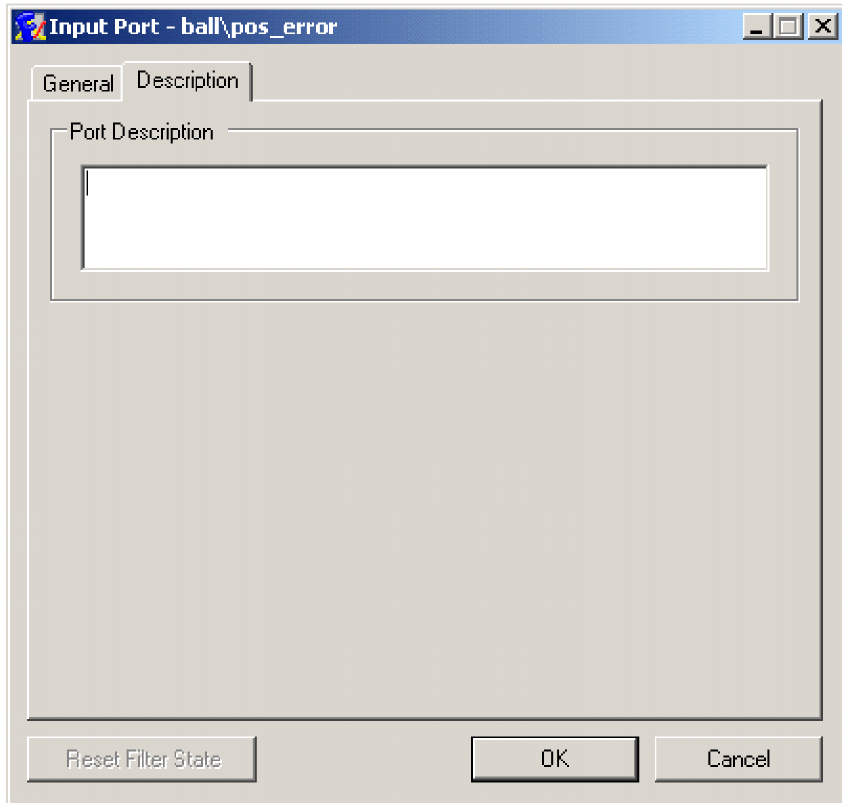
– Port General group box – Enter general parameters of a new or existing IP.
  - Port Name – Specify the IP name. This name will be used as the input parameter name when the fuzzy algorithm is compiled to an Add-On Instruction.
  - Use Filter – The IP input value can be filtered by a user-defined filter. Click the Use Filter check box to set up the Input Port filter.
  - Butterworth Lowpass Filter – Click this radio button to set the Butterworth Lowpass Filter parameters.
  - Filter with Specific Transfer Function – Click this radio button to set the user defined filter parameters.
  - Get Transfer Function– When you want to read the transfer function of the specified Butterworth Lowpass Filter (its numerator and denominator), click this button. The required numerator and denominator will be shown in the appropriate text boxes of the Filter with Specific Transfer Function group box.

– Butterworth Lowpass Filter group box – Specify parameters of a Butterworth Lowpass filter.
  - Filter Order – If you selected the Butterworth Lowpass Filter radio button, enter the required filter order here.
  - Cutoff Frequency – If you selected the Butterworth Lowpass Filter radio button, enter the cutoff frequency here.

– Filter with Specific Transfer Function group box – There are two text boxes, for you to specify the filter parameters.
  - Numerator Coefficients – If you selected the Filter with Specific Transfer Function radio button, enter the numerator coefficients here (see Input Port component description). Separate coefficients with a space: b_0 b_1 $\ldots b_m$.
  - Denominator Coefficients – If you selected the Filter with Specific Transfer Function radio button, enter the denominator coefficients here (see Input Port component description). Separate coefficients with a space: $a_1 \ldots a_n$.

- Description tab dialog – Specify the description of a new or existing IP.

Input Port Properties Dialog– Description Tab Dialog



  – Port Description – Enter the description of the IP. This description will be used as the input parameter description when the fuzzy algorithm is compiled to an Add-On Instruction.

- Reset Filter State button – Click this button to reset the internal state of the implemented filter.

- OK button – Accept the entered properties for the project.

- Cancel button – Click this button to close the IP properties dialog. Any changes made are not applied. You can also click Close, at the top right corner of the dialog.

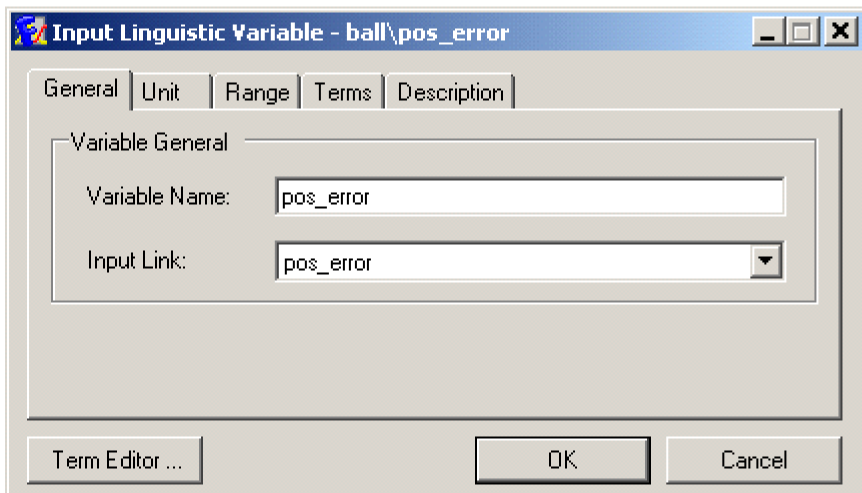
Input Linguistic Variable

Use the Edit\New Variable\New Input Linguistic Variable main menu command or the New Input Linguistic Variable tool bar button to add a new Input Linguistic Variable (ILV) to the currently active project. Use the New Input Linguistic Variable project window context menu command to add a variable.

First, the Input Linguistic Variable properties dialog appears. Click OK to add the component to the appropriate project. Input Linguistic Variable names must be unique in the same project.

- General tab dialog – Specify the main properties of a new or existing ILV.

Input Linguistic Variable Properties Dialog – General Tab Dialog

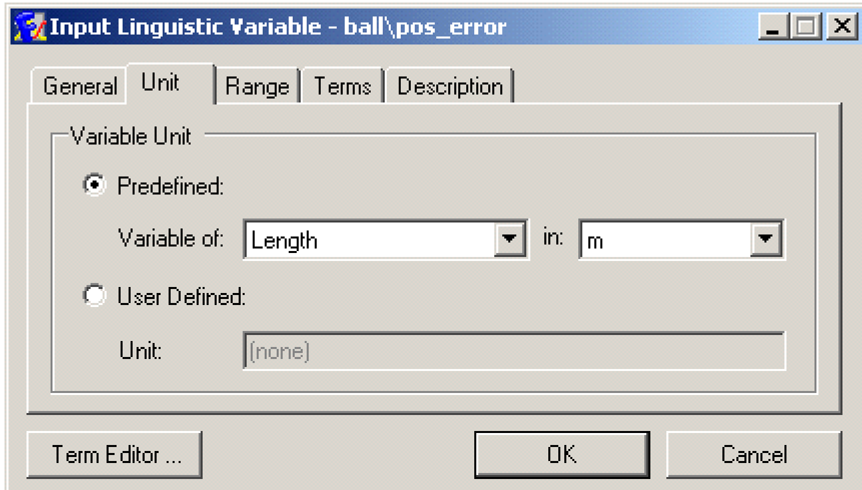


  – Variable Name – Specify the variable name.

  – Input Link – Select a feasible ILV input link from the drop-down list. The link can realize the connection between the ILV and an Input Port, Output Linguistic Variable, Output Takagi-Sugeno Variable or a PID Controller. When the dialog for a new unconnected ILV is opened, then all feasible input links are displayed.

- Unit tab dialog – Specify the unit of a new or existing ILV.

Input Linguistic Variable Properties Dialog – Unit Tab Dialog

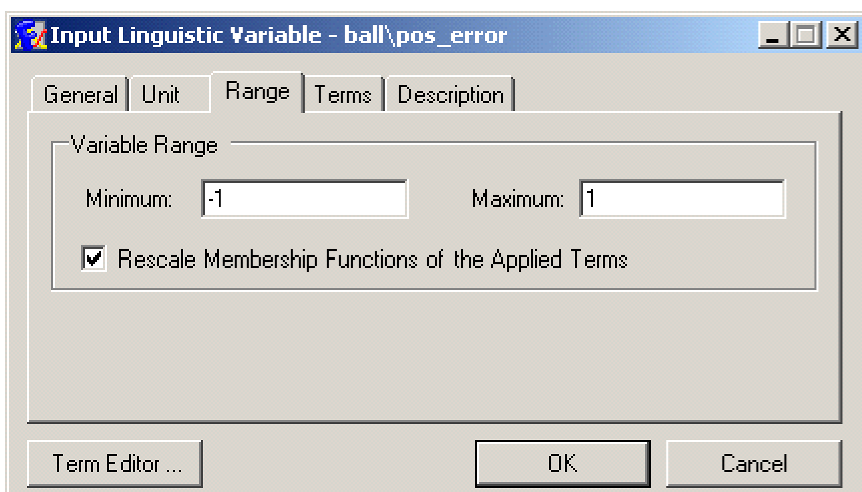


– Predefined – Click this radio button to select the variable unit from the list of predefined units.
  - Variable of – Select one of the predefined quantities, which has the same meaning as the ILV.
  - In – Select one of the predefined units as the requested unit of the ILV.

– User Defined – Click this radio button to select a user-defined variable unit.
  - Unit – Specify a unit of the ILV, up to 100 characters.

- Range tab dialog – Enter the operating range of the variable.

Input Linguistic Variable Properties Dialog – Range Tab Dialog



– Minimum – Specifies the lower limit of the variable.

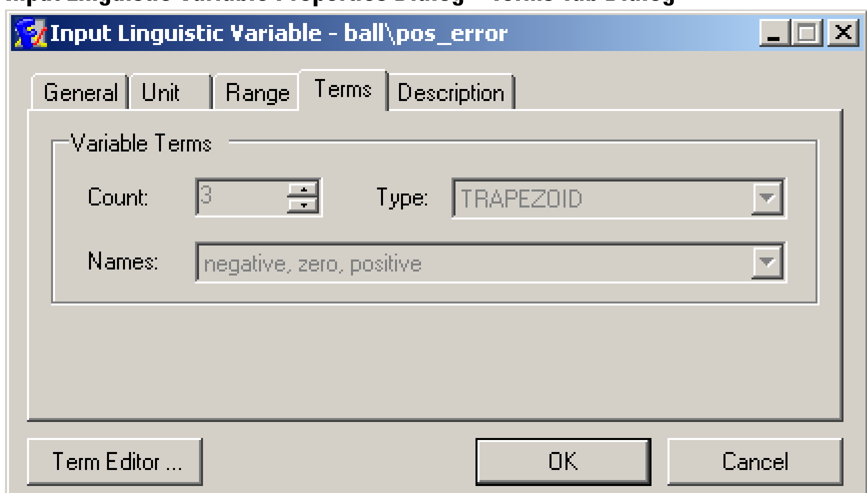
– Maximum – Specifies the upper limit of the variable.

– Rescale Membership Functions of the Applied Terms – Click this check box to rescale the membership functions of all terms of the ILV.

IMPORTANT The minimum value must be always lower then the maximum value. When the dialog for a new ILV is opened the default range is preset to –1 for minimum and 1 for maximum.

- Terms tab dialog – The ILV properties dialog defines the variable through the following terms.

Input Linguistic Variable Properties Dialog – Terms Tab Dialog



– Count – Specify number of terms, fuzzy sets, related to the variable.

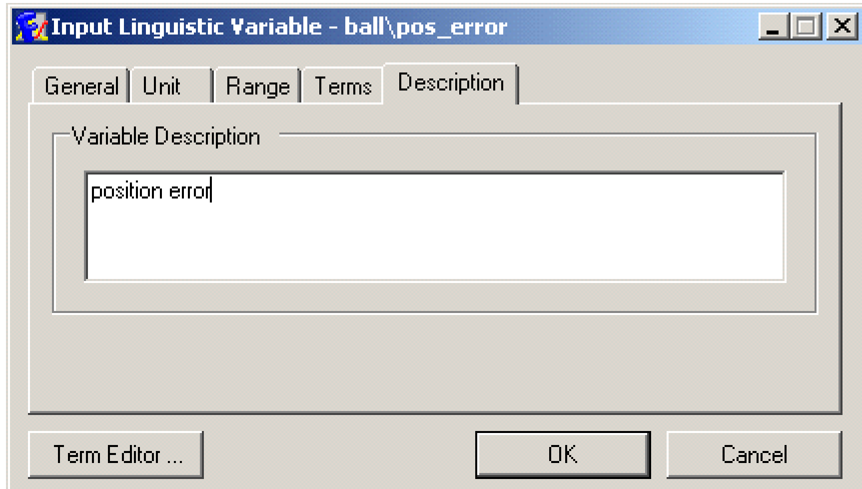
– Type – Select either the trapezoid or s-function ILV term type. When the ILV properties dialog is open for the existing variable, the term type of the applied variable terms is displayed. Other is displayed when term types for the selected variable differ.

– Names – Select default names of terms for the variable. When the ILV properties dialog is open for the existing variable, any applied terms are shown.

IMPORTANT When the ILV properties dialog is open for an existing variable, then the terms count, the type and the names are visible, but you cannot change them in the properties dialog.

- Description tab dialog – Specify the description of a new or existing ILV.

Input Linguistic Variable Properties Dialog – Description Tab Dialog



  – Variable Description – Enter the description of the ILV.

- Term Editor button – Click this button to open the Term Editor (see section Term Editor), where the predetermined variable terms can be changed (count, names).

- OK button – Accept the entered properties for the project.

- Cancel button – Click this button to close the ILV properties dialog. Any changes made are not applied. You can also click Close, at the top right corner of the dialog.

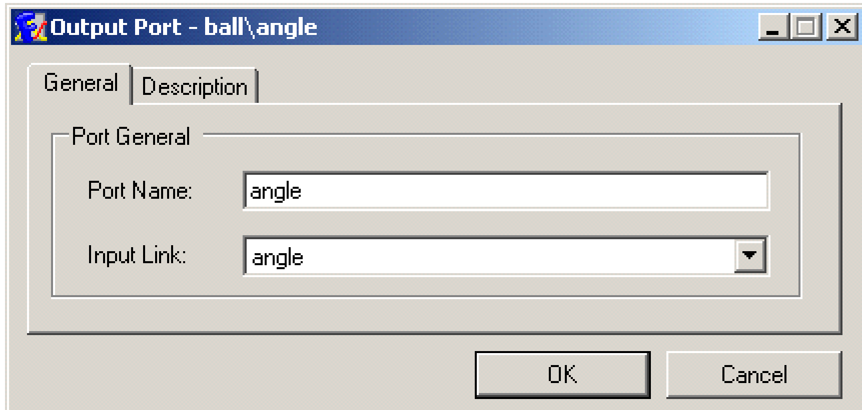
Output Port

Use the Edit\New Port\New Output Port main menu command or the New Output Port tool bar button to add a new Output Port (OP) to the appropriate fuzzy system project. Alternatively, use the New Output Port project window context menu command to add a port.

The Output Port properties dialog appears and a default name is assigned to the component. Click OK to add the component to the appropriate project. All Output Port names must be unique in the same project.

- General tab dialog – Specify all parameters of a new or existing OP.

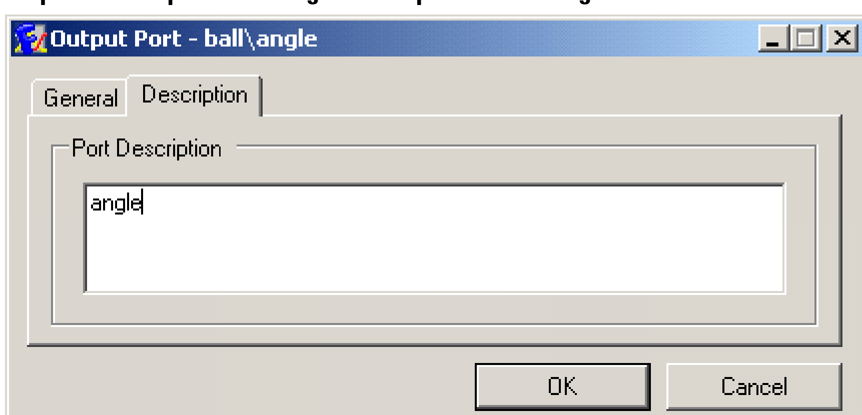
Output Port Properties Dialog – General Tab Dialog



  – Port Name – Specify the OP name. This name will be used as the output parameter name when the fuzzy algorithm is compiled to an Add-On Instruction.
  – Input Link – Set up the OP input link. The link can realize the connection between the OP and the Input Port, Output Linguistic Variable, Output Takagi-Sugeno Variable or the PID Controller.

- Description tab dialog – Specify the description of a new or existing OP.

Output Port Properties Dialog – Description Tab Dialog



  – Port Description – Enter the description of the OP. This description will be used as the output parameter description when the fuzzy algorithm is compiled to an Add-On Instruction.

- OK button – Accept the entered properties for the project.

- Cancel button – Click this button to leave the OP properties dialog. Any changes made are not applied. You can also click Close, at the top right corner of the dialog.

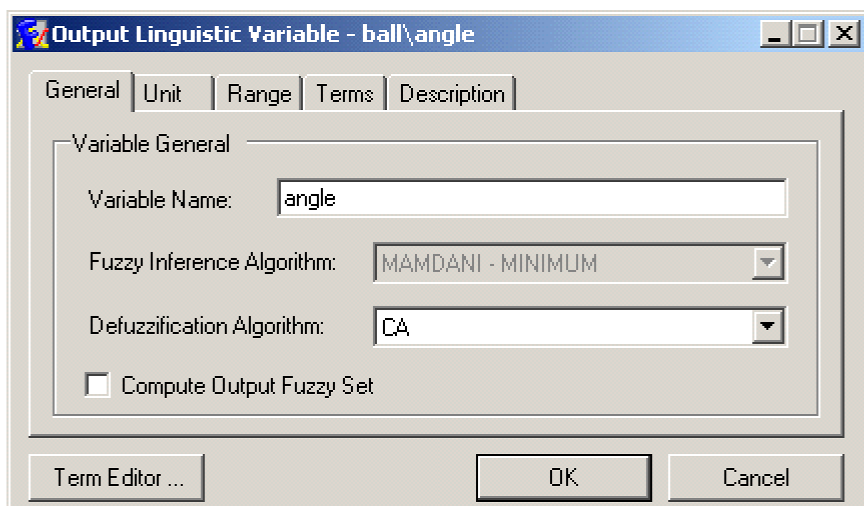
Output Linguistic Variable

Use the Edit\New Variable\New Output Linguistic Variable main menu command or the New Output Linguistic Variable tool bar button to add a new Output Linguistic Variable (OLV) to the appropriate fuzzy system project. Alternatively, use the New Output Linguistic Variable project window context menu command to add a variable.

The Output Linguistic Variable properties dialog appears and a default name is assigned to the component. Click the OK button to add the component to the appropriate project. All Output Linguistic Variable names must be unique in the same project.

- General tab dialog – Specify the main properties of a new or existing OLV.

Output Linguistic Variable Properties Dialog – General Tab Dialog



– Variable Name – Specify the variable name.

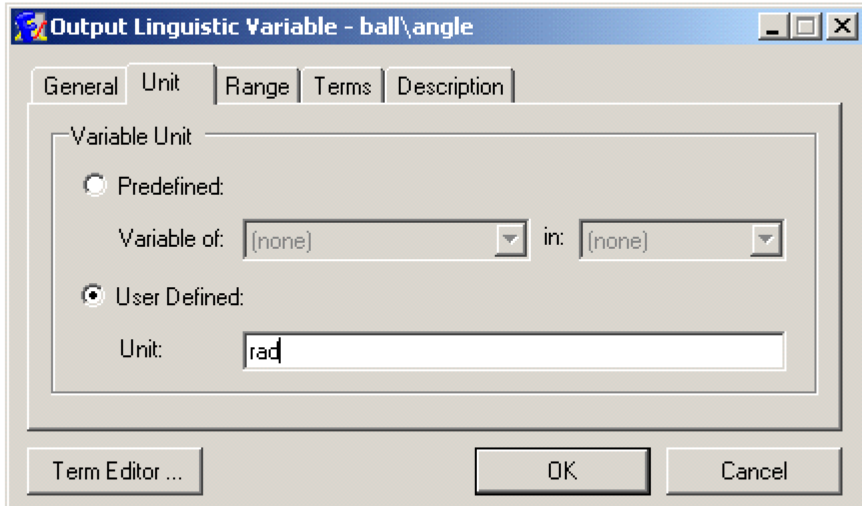
– Fuzzy Inference Algorithm – Specify the fuzzy inference algorithm to be applied.

– Defuzzification Algorithm – Select the Defuzzification algorithm.

– Compute Output Fuzzy Set – Click this check box to generate a fuzzy set as the component output.

- Unit tab dialog – Specify the unit of a new or existing OLV.

Output Linguistic Variable Properties Dialog – Unit Tab Dialog

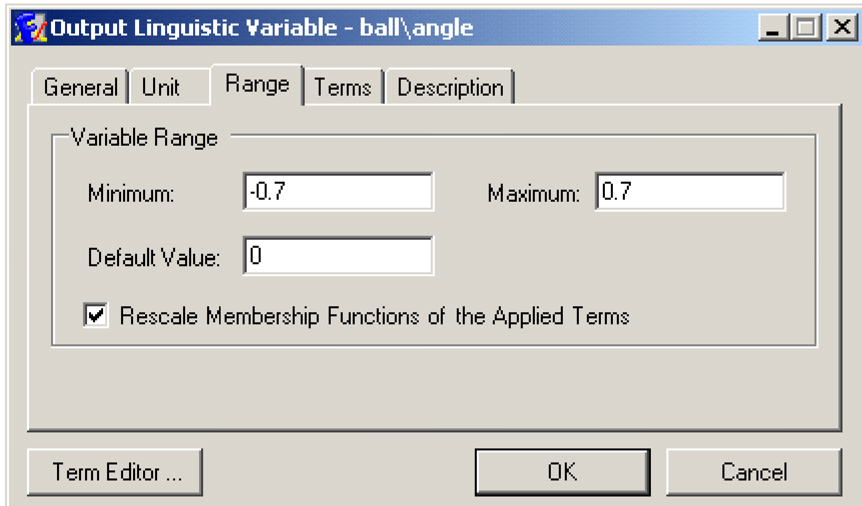


– Predefined – Click this radio button to select the unit of the variable from the list of predefined units
  - Variable of – Select one of the predefined quantities, which has the same meaning as the OLV.
  - In – Select one of the predefined units as the requested unit of the OLV.

– User Defined – Click this radio button to enter a user-defined variable unit.
  - Unit – Enter the unit name of the OLV, up to 100 characters.

- Range tab dialog – Specify the range of the variable and its default value.

Output Linguistic Variable Properties Dialog – Range Tab Dialog

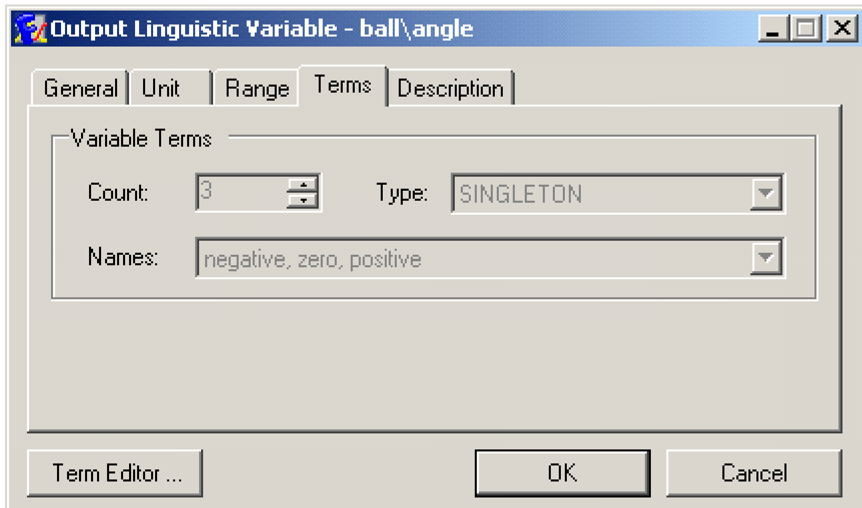


  – Minimum – Specify the lower limit of the variable.
  – Maximum – Specify the upper limit of the variable.
  – Default Value – Set up the default value of the variable. The default value must be within the specified range of the variable.
  – Rescale Membership Functions of the Applied Terms – Click this check box to rescale the membership functions of all applied terms of the OLV.

IMPORTANT	The minimum value must be always lower then the maximum value. When the dialog for a new OLV is open the default range is preset to –1 for minimum and 1 for maximum. The default value is set to the middle of this variable range.

- Terms tab dialog – When the OLV properties dialog is open for defining the variable, you can specify the variable terms in the same way as was explained for the Input Linguistic Variable.

Output Linguistic Variable Properties Dialog – Terms Tab Dialog



– Count – the number of terms.

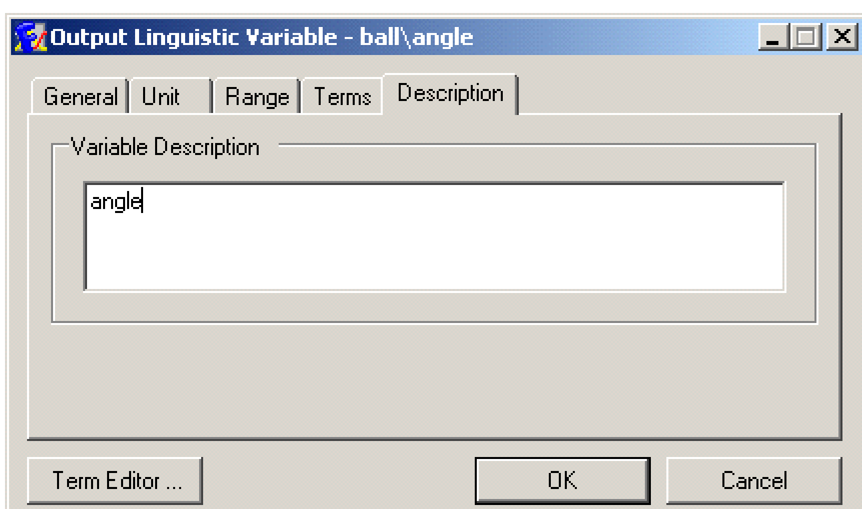
– Type – the type of terms.

– Names– predefined names of terms.

IMPORTANT When the OLV properties dialog is open for an existing variable, then the terms count, the type and the names are visible, but you cannot change them in the properties dialog.

- Description tab dialog – Specify the description of a new or existing OLV.

Output Linguistic Variable Properties Dialog – Description Tab Dialog



– Variable Description – Enter the description of the OLV.

- Term Editor button – Click this button to open the Term Editor (see section Term Editor), where the default variable terms can be changed, for example, count and names.

- OK button – Accept the entered properties for the project.

- Cancel button – Click this button to leave the OLV properties dialog. Any changes made are not applied. You can also click Close, at the top right corner of the dialog.

Output Takagi-Sugeno Variable

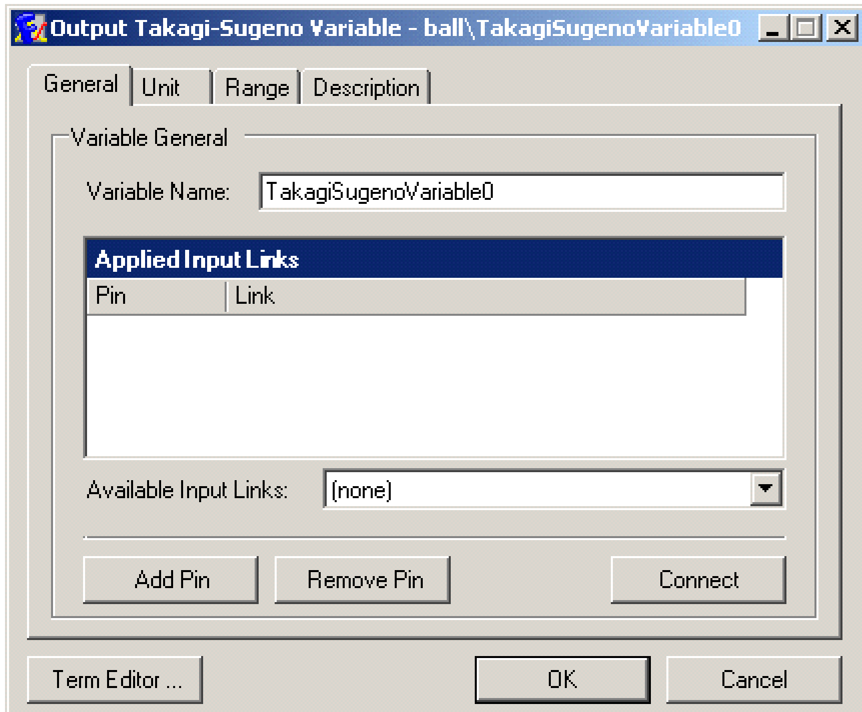
Use the Edit\New Variable\New Output Takagi-Sugeno Variable main menu command or the New Output Takagi-Sugeno Variable tool bar button to add a new Output Takagi-Sugeno Variable (OTSV) to the active project. Alternatively, use the New Output Takagi-Sugeno Variable project window context menu command to add a variable.

The Output Takagi-Sugeno Variable properties dialog appears and a default name is assigned to the component. Click OK to add the component to the appropriate project.

All Output Takagi-Sugeno Variable names must be unique in the same project.

- General tab dialog – Specify the main properties of a new or existing OTSV.

Output Takagi-Sugeno Variable Properties Dialog – General Tab Dialog



– Variable Name – Specify the variable name.

– Applied Input Links –All pins and applied input links of the OTSV are shown here. The component pins can be connected to the Input Ports, Output Linguistic Variables, Rule Blocks and the PID Controllers.

– Available Input Links – Select an available feasible input link for the variable.

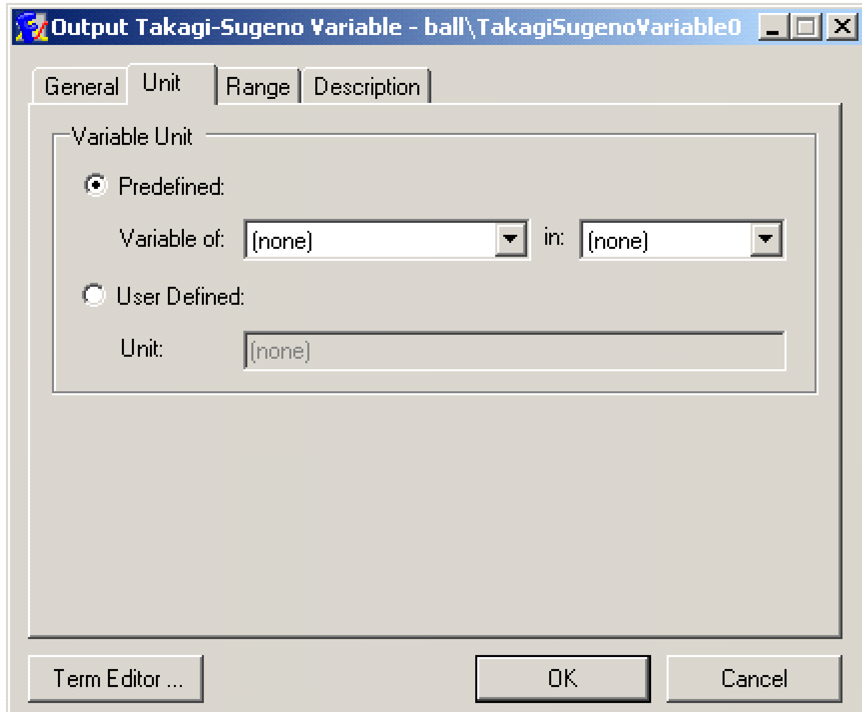
– Add Pin button – Click this button to add the pin to the Applied Input Links table related to the OTSV.

– Remove Pin button – Click this button to remove the pin selected in the Applied Input Links table.

– Connect button – Click this button to connect the link selected in the Available Input Links combo box with the pin selected in the Applied Input Links table.

- Unit tab dialog – Specify the unit of a new or existing OTSV.

Output Takagi-Sugeno Variable Properties Dialog – Unit Tab Dialog

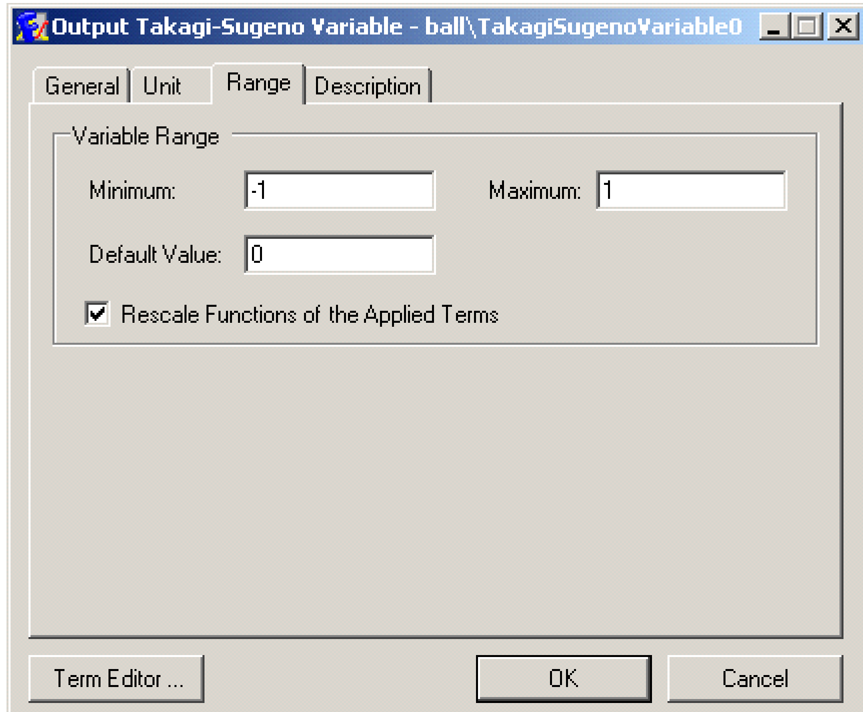


– Predefined – Click this radio button to select a predefined unit of the variable.
  - Variable of – Select one of the predefined quantities that has the same meaning as the OTSV.
  - In – Select one of the predefined units as the requested unit of the OTSV.

– User Defined – Click this radio button to insert a user-defined unit of the variable.
  - Unit – Specify a unit of the OTSV. The unit name can be up to 100 characters long.

- Range tab dialog – Specify the range of the variable including its default value.

Output Takagi-Sugeno Variable Properties Dialog – Range Tab Dialog



– Minimum – Specify the lower limit of the variable range.

– Maximum – Specify the upper limit of the variable range.

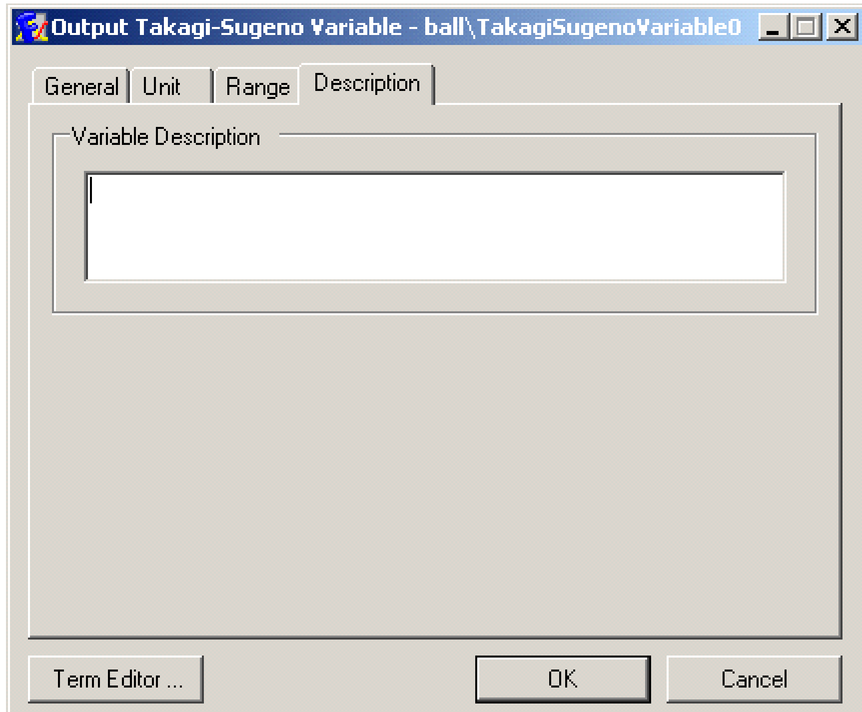
– Default Value – Specify the default value of the variable. The default value must be within the variable range.

– Rescale Functions of the Applied Terms – Click this check box to rescale functions of the all applied terms of the OTSV.

IMPORTANT	The minimum value must be always lower then the maximum value. When the dialog for a new OTSV is opened the default range is preset to –1 for minimum and 1 for maximum. The default value is set up to the middle of this variable range.

- Description tab dialog – Specify the description of a new or existing OTSV.

Output Takagi-Sugeno Variable Properties Dialog – Description Tab Dialog



– Variable Description – Enter the description of the OTSV.

- Term Editor button – Click this button to open the Term Editor (see section Term Editor), where you can chage the terms of the variable.

- OK button – Accept the entered properties for the project.

- Cancel button – Click this button to close the OTSV properties dialog. Any changes made are not applied. You can also click Close, at the top right corner of the dialog.

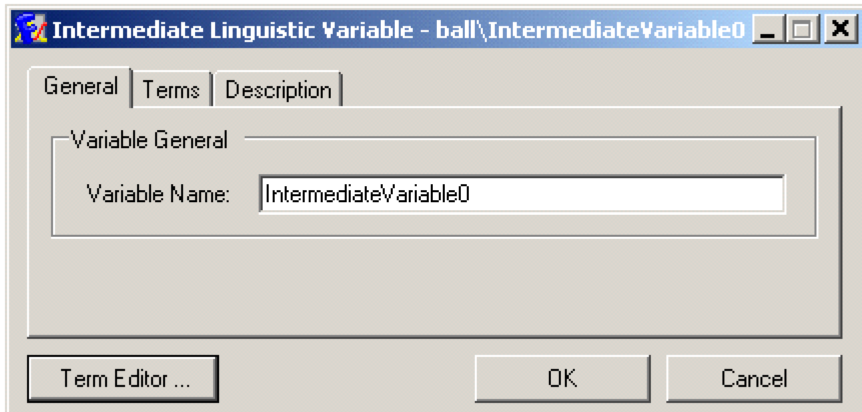
Intermediate Linguistic Variable

Use the Edit\New Variable\New Intermediate Linguistic Variable main menu command or the New Intermediate Linguistic Variable tool bar button to add a new Intermediate Linguistic Variable (IMLV) to the active project. Alternatively, use the New Intermediate Linguistic Variable project window context menu command to add a variable.

The Intermediate Linguistic Variable properties dialog appears and a default name is assigned to the component. Click OK to add the component to the appropriate project. All Intermediate Linguistic Variable names must be unique in the same project.

- General tab dialog – Specify the name of the IMLV.

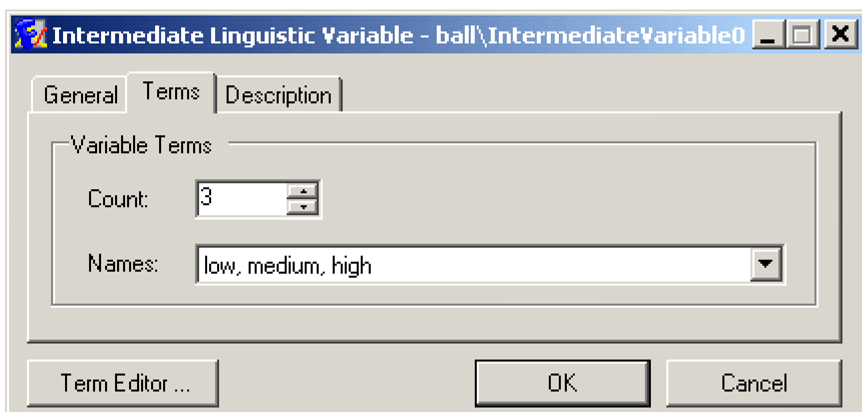
Intermediate Linguistic Variable Properties Dialog – General Tab Dialog



– Variable Name – Enter the name of the variable.

- Terms tab dialog – The IMLV properties dialog defines the variable through the following terms.

Intermediate Linguistic Variable Properties Dialog – Terms Tab Dialog



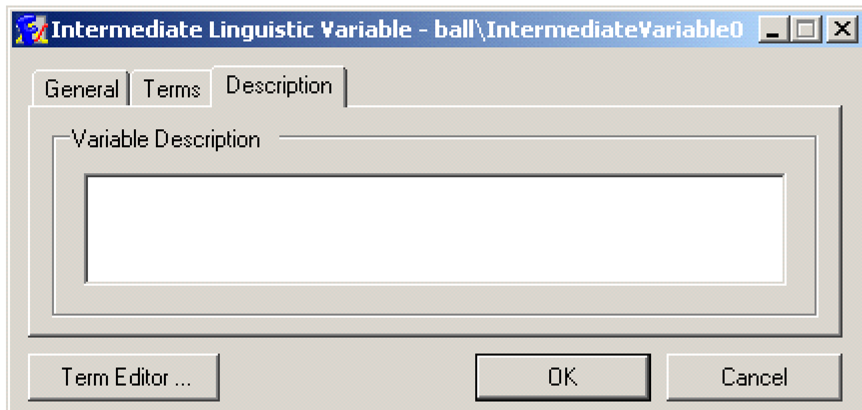
– Count – Specify the number of terms defined for the intermediate linguistic variable. When the IMLV properties dialog is open for an existing variable, the current number of terms is shown.

– Names – Change default names and specify names of terms for the newly created intermediate variable. When the IMLV properties dialog is open for the existing variable, the names of terms already applied are shown.

IMPORTANT	When the IMLV properties dialog is open for an existing variable, then the terms count and the term names are visible, but you cannot change them in the properties dialog.

- Description tab dialog – Specify the description of a new or existing IMLV.

Intermediate Linguistic Variable Properties Dialog – Description Tab Dialog



– Variable Description – Enter the description of the IMLV.

- Term Editor button – Click this button to open the Term Editor (see section Term Editor), where you can change the default terms of the variable (count, names).

- OK button – Accept the entered properties for the project.

- Cancel button – Click this button to close the IMLV properties dialog. Any changes made are not applied. You can also click Close, at the top right corner of the dialog.

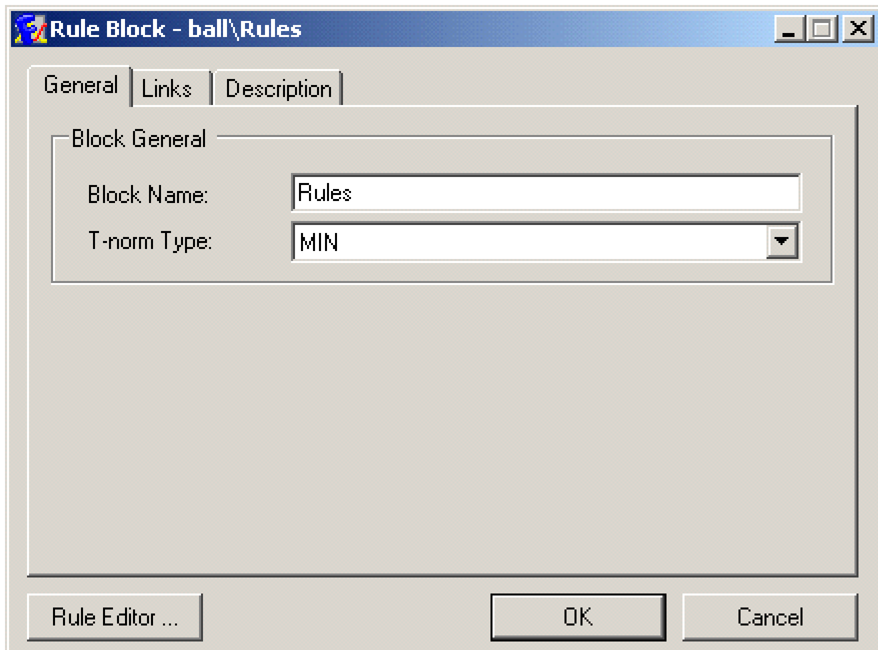
Rule Block

Use the Edit\New Rule Block main menu command or the New Rule Block tool bar button to add a new Rule Block (RB) to the active project. Use the New Rule Block project window context menu command to add a block.

The Rule Block properties dialog appears and a default name is assigned to the component. Click OK to add the component to the appropriate project. Rule Block names must be unique in the same project.

- General tab dialog – Specify the main properties of a new or existing RB.

Rule Block Properties Dialog – General Tab Dialog

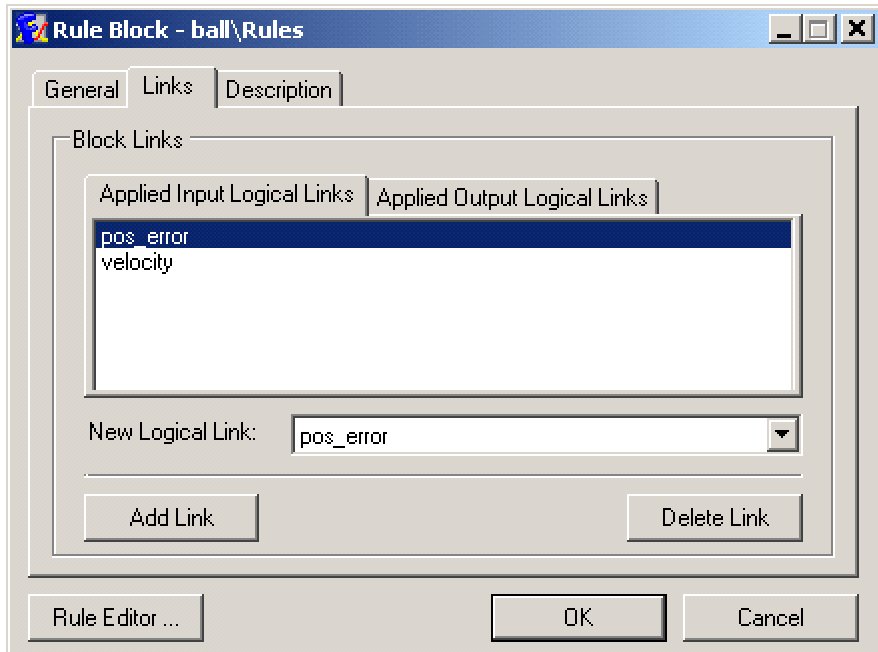


– Block Name – Enter the block name.

– T-norm Type – Set up the t-norm type for the block.

- Links tab dialog – Set up the RB input and output logical links.

Rule Block Properties Dialog – Links Tab Dialog



– Applied Input Logical Links Tab Dialog –The list box shows all applied input logical links of the block.

– Applied Output Logical Links Tab Dialog – The list box shows all applied output logical links of the block.

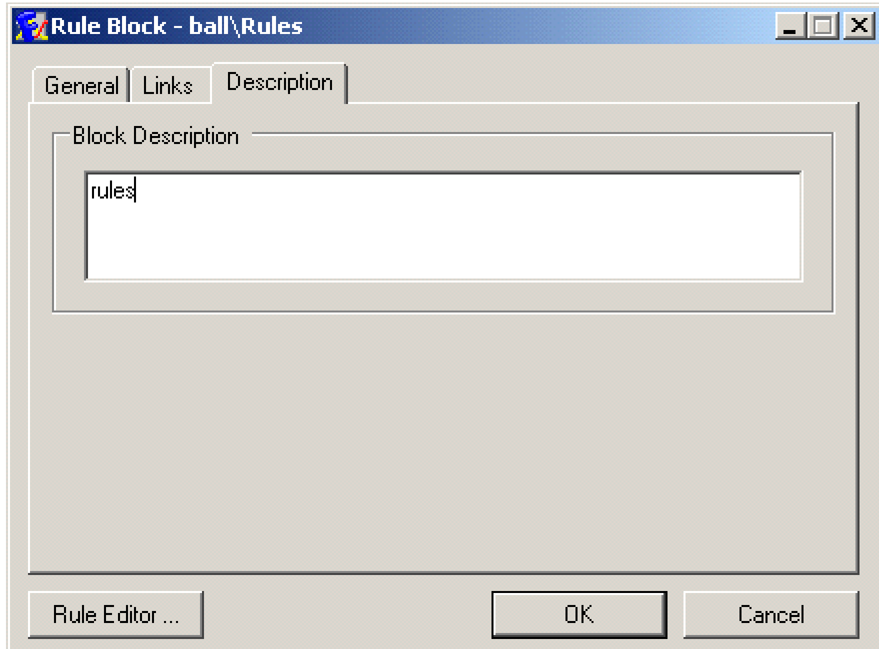
– New Logical Link combo box – Select one of the available input or output logical links that can be used for the block.

– Add Link button – Click the button to add a new logical link, selected by the New Logical Link combo box, to the appropriate list box of the selected tab dialog with applied logical links.

– Delete Link button – Click the button to delete a marked logical link from the appropriate list box of the selected tab dialog with applied logical links.

- Description tab dialog – Specify the description of a new or existing RB.

Rule Block Properties Dialog – Description Tab Dialog



  – Block Description – Enter the description of the RB.

- Rule Editor button – Click this button to open the Rule Editor (see section Rule Editor), where you can change the block rule base, for example, add or delete rules.

- OK button – Accept the entered properties for the project.

- Cancel button – Click this button to close the RB properties dialog. Any changes made are not applied. You can also click Close, at the top right corner of the dialog.

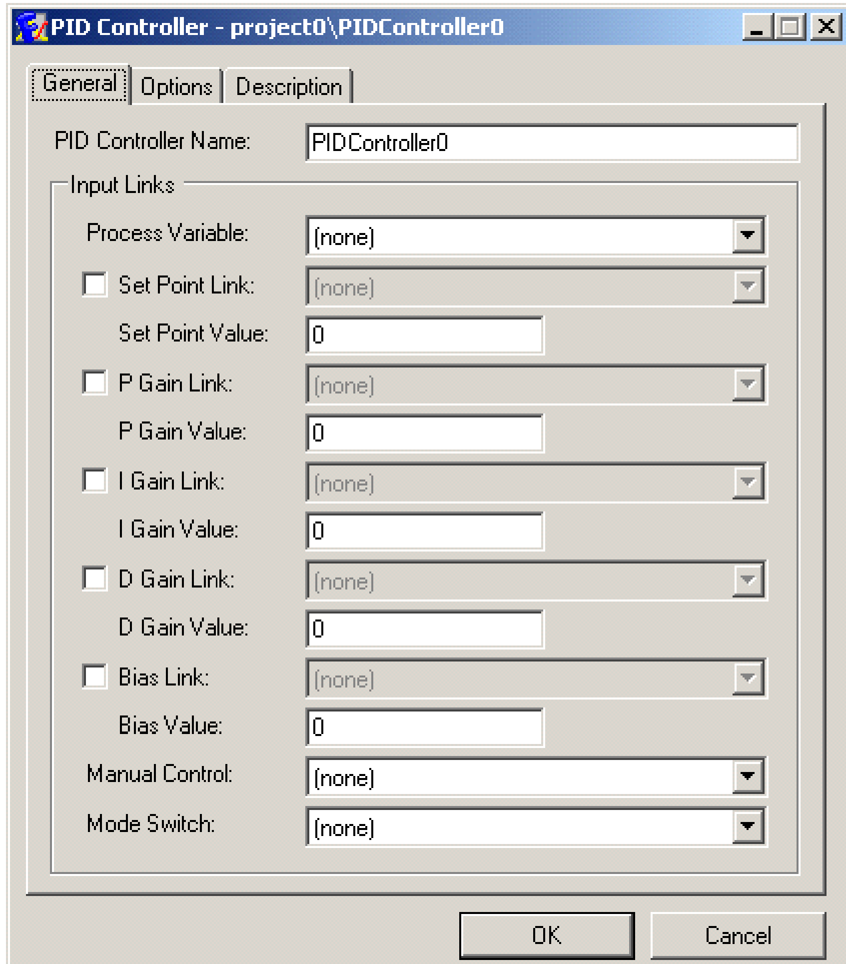
PID Controller

Use the Edit\New PID Controller main menu command or the New PID Controller tool bar button to add a new PID Controller (PIDC) to the active project. Alternatively, use the New PID Controller project window context menu command to add a controller.

The PID Controller properties dialog appears and a default name is assigned to the component. Click the OK button to add the component to the appropriate project. All PID Controller names must be unique in the same project.

- General tab control page – Specify the main properties of a new or existing PIDC.

PID Controller Properties Dialog – General Tab Dialog



– PID Controller Name – Specify the controller name.

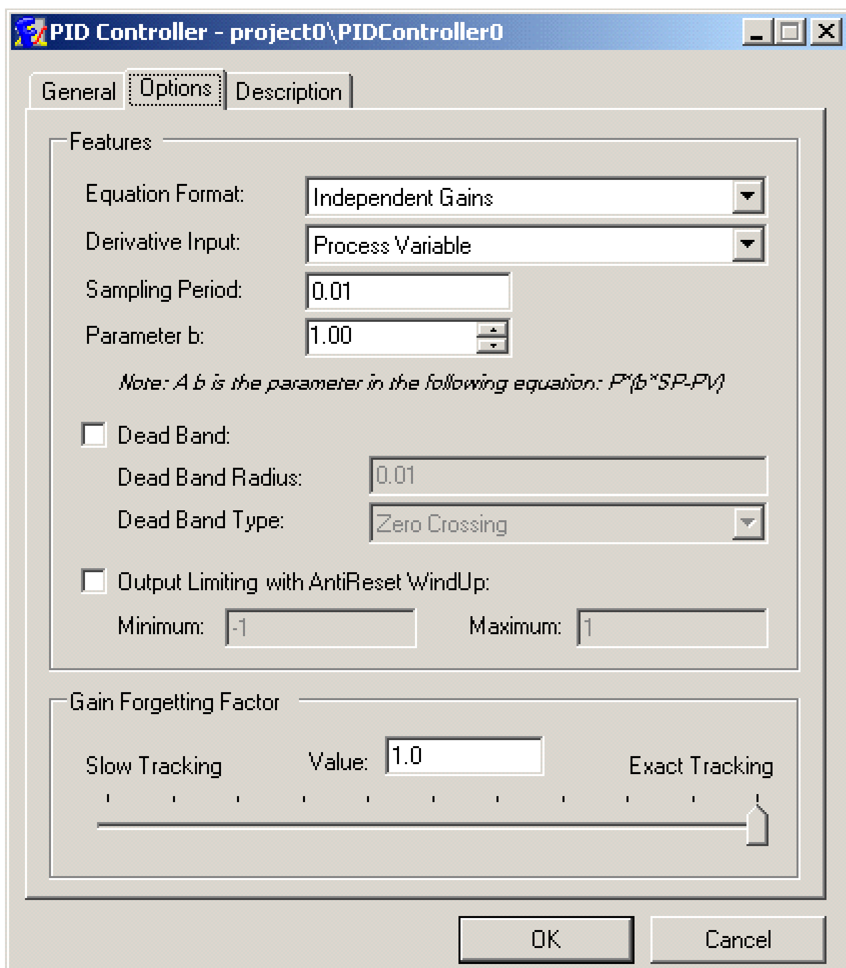
– Input Links group box – Set up all available input links or values.

- Process Variable – Set up required process variable link.
- Set Point Link – Click the check box and select the set point link.
- Set Point Value – When the Set Point Link check box is not checked, enter the set point value in the text box.
- P Gain Link – Click the check box and select the P gain link.
- P Gain Value – When the P Gain Link check box is not checked, enter the P gain constant value.
- I Gain Link – Click the check box and select the I gain link.

- I Gain Value – When the I Gain Link check box is not checked, enter the I gain constant value.
- D Gain Link – Click the check box and select the D gain link.
- D Gain Value – When the D Gain Link check box is not checked, enter the D gain constant value.
- Bias Link – Click the check box and select the bias link.
- Bias Value – When the Bias Link check box is not checked, enter the bias constant value.
- Manual Control – Select the manual control link.
- Mode Switch – Select the mode switch link.

- Options tab control page – Specify all remaining options of a new or already existing PIDC.

PID Controller Properties Dialog – Options Tab Dialog



– Features group box – Set up all features of a new or already existing PIDC.

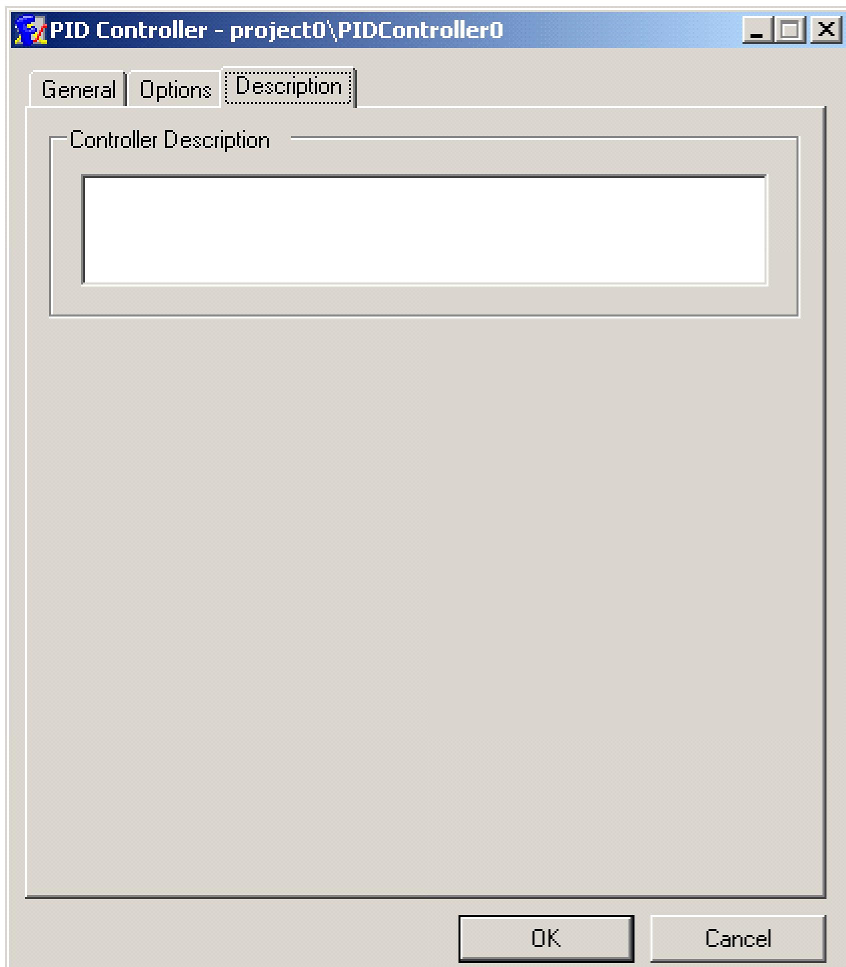
- Equation Format – Specify the equation format of the controller.
- Derivative Input – Specify the derivative input of the controller.
- Sampling Period – Specify the sampling period of the controller. The period must be greater then zero and is the same for all PIDs applied in the same project.
- Parameter b – Select the value of the parameter b entering the $P*(b*SP-PV)$ term of the PIDC equation. The value of the parameter ranges from 0 to 1.
- Dead Band – Click the check box to activate the dead band of the controller and specify the dead band radius and dead band type.
- Dead Band Radius – If the Dead Band check box is checked, enter the dead band radius of the controller. This value must be greater then zero.
- Dead Band Type – If the Dead Band check box is checked, enter the dead band type of the controller.
- Output Limiting with AntiReset WindUp – Click the check box to enable this function, and specify the upper and lower limits.
- Minimum – When the Output Limiting check box is checked, enter the lower saturation limit of the controller output.
- Maximum – When the Output Limiting check box is checked, enter the upper saturation limit of the controller output.

IMPORTANT The minimum value must be always lower then the maximum value.

- Gain Forgetting Factor group box – Specify the gain forgetting factor of a new or existing PIDC.
  - Value – Enter the controller gain forgetting factor value of the controller. The factor default value is set to 1 for a new PIDC.
  - Gain Forgetting Factor track bar – Specify the gain forgetting factor setting from slow tracking (minimum) to exact tracking (maximum).

- Description tab dialog – Specify the description of a new or existing PID controller.

PID Controller Properties Dialog – Description Tab Dialog



- Controller Description – Enter the description of the PID controller.

- OK button – Accept the entered properties for the project.

- Cancel button – Click this button to close the PIDC properties dialog. Any changes made are not applied. You can also click Close, at the top right corner of the dialog.

Term Editor

Default terms are defined for a variable when you add it to the project. The exception is the Output Takagi-Sugeno Variable. To change the default or to modify the existing terms setting you need to open the Term Editor dialog (see Input Term Editor for Input Linguistic Variable or Output Term Editor for The Output Linguistic Variable). Open the editor by clicking Term Editor, or double-clicking a variable in the project window or tree view.

The Term Editor consists of two main parts, the membership function editor and the table of term DOFs (DOF - degree of fulfillment). The membership function editor does not exist for the Output Takagi-Sugeno Variable and for the Intermediate Linguistic Variable.

- Term Editor tool bar – Use the buttons in the tool bar to create a new term, delete an existing term or change variable term properties.
  - Add Term – Add a term. The Term Properties dialog (see section Term Properties Dialog) appears. A complete set of term properties is accessible.
  - Delete Term – Delete a variable term. You can also use the Delete key.
  - Inverse Term – Add an inverse term for the currently selected variable term (Input linguistic Variable only).
  - Convert Terms To Trapezoids – Transfer all applied terms of the selected variable to trapezoids (except for Intermediate Linguistic Variable and Output Takagi-Sugeno Variable).
  - Convert Terms To S-Functions – Transfer all applied terms of the selected variable to s-functions (Input Linguistic Variable only).
  - Convert Terms To Singletons – Transfer all applied terms of the selected variable to the singletons (Output Linguistic Variable only).
  - Next Term – Selects the term adjacent to the current term.

TIP You can select a previous or next term from the currently selected one with the keyboard cursor keys. To select a term directly, click the term name area in the membership function editor.

– Term Properties – Show the Term Properties dialog (see section Term Properties Dialog) of the currently selected term.

IMPORTANT To show the Term Properties dialog of an already selected term, double-click anywhere in the membership function editor. To change the parameters of the selected term membership function only, right-click the term parameter and, in a click-and-drag operation, move it to the new position. Repeat as needed. This applies to the Input Linguistic Variable and Output Linguistic Variable only.

– Shift Selected Term Left – Shift the currently selected term to the left.
– Shift Selected Term Right – Shift the currently selected term to the right.
– Term DOFs Table Auto Arrange – Optimize the width of the Term DOFs table columns.
– Zoom Out – Restore the membership function editor window setting.

IMPORTANT To zoom in or out in the membership function editor, position the mouse cursor anywhere in the editor area. Hold down the right mouse button, and drag your mouse to the right (zoom in) or left (zoom out). Release the button when the scale is at the desired level.

When you want to zoom any part of membership function editor, click the begin point by the right mouse button and move the mouse right (the right mouse button is still pressed down) to the final point. Release the right mouse button to rescale the membership function editor. When the editor is zoomed, click the right mouse button and move the mouse left or right to slide the membership function editor zoom. To zoom out the editor, click the right mouse button, drag the mouse left and release the mouse button. Discussed mouse operation must be performed inside the editor axes area.

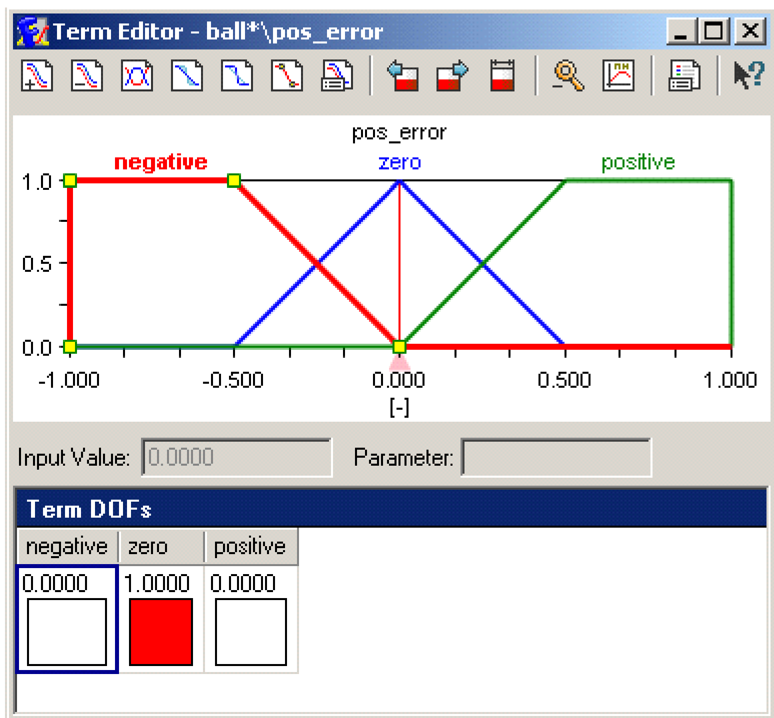
– Hide Term Names in Graph – Hide or show names of the applied variable terms seen in the membership function editor (except for Intermediate Linguistic Variable and Output Takagi-Sugeno Variable).
– Variable Properties – Show the appropriate variable properties dialog. The Term Editor dialog remains open.

– Help – Show information about the Term Editor.

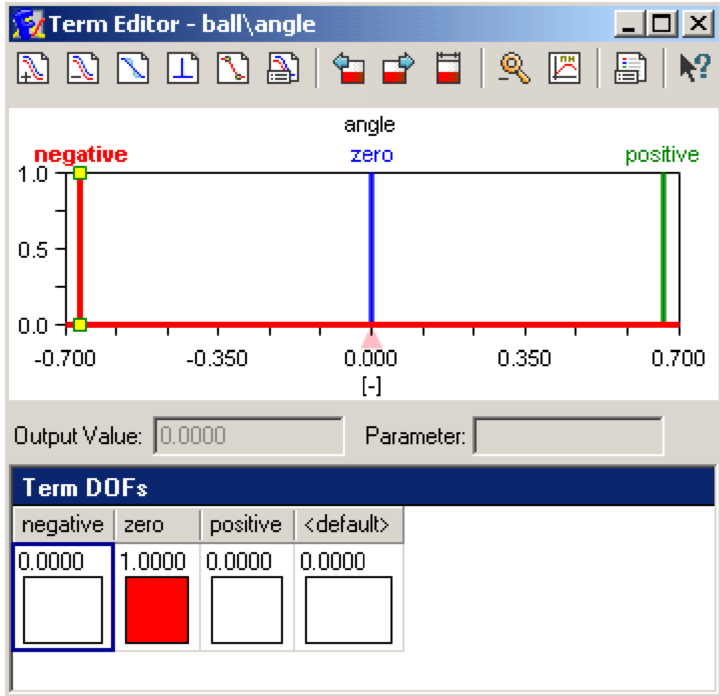
IMPORTANT When you want to specify input values of the Input Linguistic Variable, you can use the membership function editor slider. Position the mouse cursor above the slider, click the right mouse button and move the slider to the desired position, then release the right mouse button. The actual slider position of the Input Linguistic Variable is seen in the Input Value text box below the membership function editor. The input value is immediately stored in the appropriate project, which is then statically evaluated.

- Close button – Click this button to close the Term Editor dialog.

Input Term Editor for Input Linguistic Variable



Output Term Editor for The Output Linguistic Variable



Term Properties Dialog

When you click the Add Term tool bar button of a variable Term Editor dialog, the Term Properties dialog (see Input Term Properties Dialog or Output Term Properties Dialog) appears. A default name is assigned to a new term.

- General group box – Specify the main properties of the term.
  - Term Name – Enter the term name.
  - Term Type – Select the term type (except for the Intermediate Linguistic Variable).
- Parameters group box – Specify the term parameters (except for the Intermediate Linguistic Variable). For the Output Takagi-Sugeno Variable, parameters are separated by a space. Enter the linear term parameters in the order *a0 a1 … a*, where *a0* is a absolute term and *a1* corresponds to the signal connected to *pin1*. For more information, see the Output Takagi-Sugeno Variable component description.

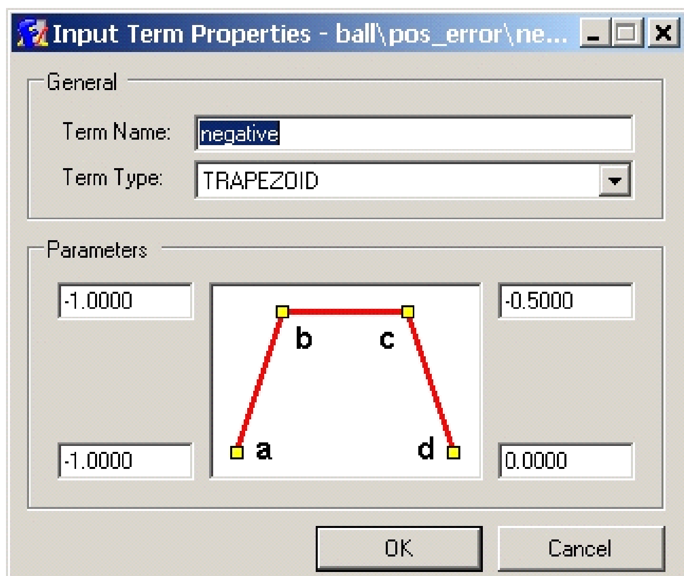
- OK button – Accept the entered properties for the project.
- Cancel button – Click this button to leave the Term Properties dialog. Any changes made are not applied. You can also click Close, at the top right corner of the dialog.

IMPORTANT

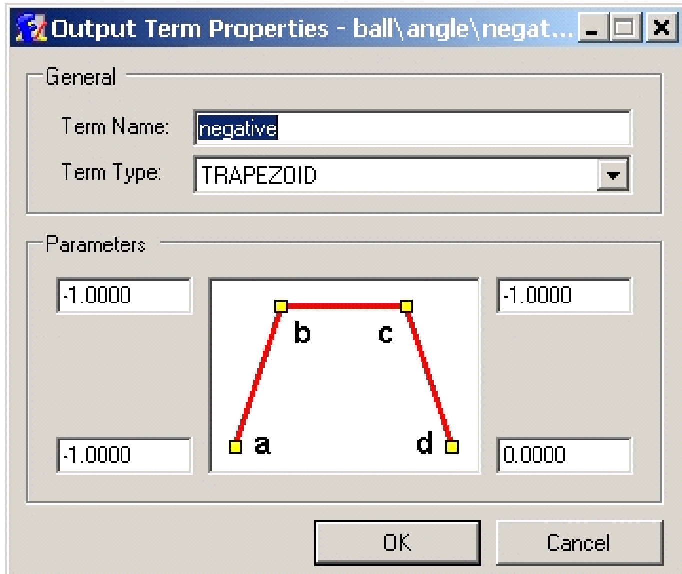
Open this dialog by double-clicking the right mouse button on the selected term in the Term Editor membership function editor, or from the table of term DOFs, or the Term Properties tool bar button of each Term Editor.

For the Intermediate Linguistic Variable and the Output Takagi-Sugeno Variable, the terms can be selected only from the table of term DOFs.

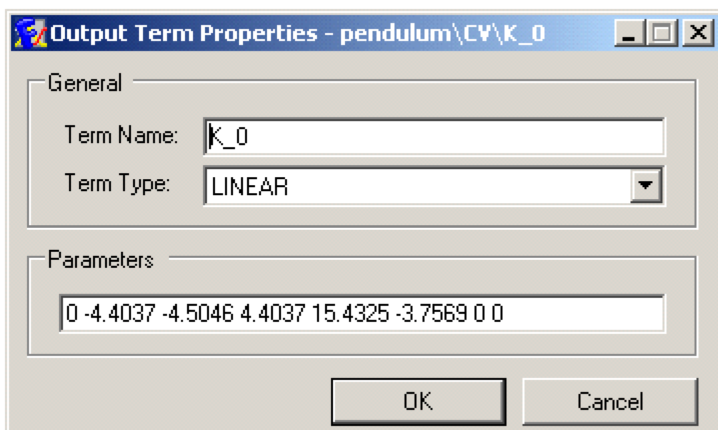
Input Term Properties Dialog



Output Term Properties Dialog



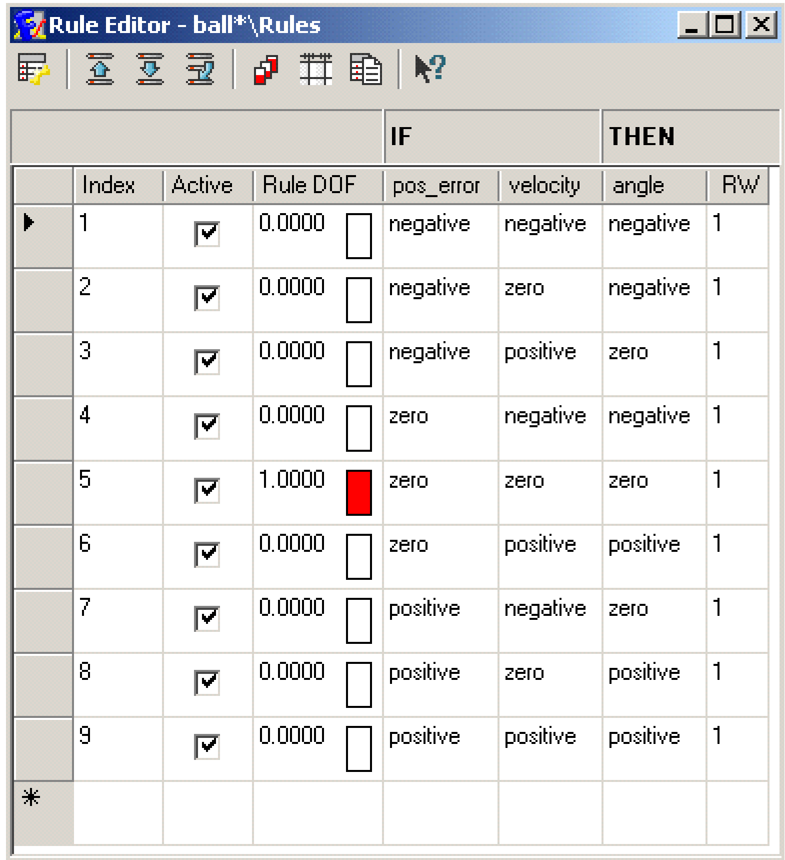
Output Term Properties Dialog for the Output Takagi-Sugeno Variable



Rule Editor

Click Rule Editor in the Rule Block properties dialog to open the Rule Editor dialog (see Rule Block Rule Editor with a Rule Base). You can also open the Rule Editor by double-clicking a Rule Block.

Rule Block Rule Editor with a Rule Base



		IF		THEN	
Index	Active	Rule DOF	pos_error	velocity	angle	RW
1	☑	0.0000	negative	negative	negative	1
2	☑	0.0000	negative	zero	negative	1
3	☑	0.0000	negative	positive	zero	1
4	☑	0.0000	zero	negative	negative	1
5	☑	1.0000	zero	zero	zero	1
6	☑	0.0000	zero	positive	positive	1
7	☑	0.0000	positive	negative	zero	1
8	☑	0.0000	positive	zero	positive	1
9	☑	0.0000	positive	positive	positive	1

The Rule Editor shows the following columns:

- Index – Shows the index of a rule of the selected Rule Block rule base.
- Active – Shows rule activity.
- Rule DOF – Shows current degree of fulfillment of every rule of the rule base.
- IF – Shows the premise variables of the selected Rule Block and the addressed terms which define the antecedent part of rules stored in the Rule Block.
- THEN – Shows the term of the consequent variables addressed by the rules of the selected Rule Block. Rule weights are also shown. The column with the weight of the consequent variable marked by the consequent variable name and RW (Rule Weight).

Operations with Rules

You can add, create, or delete rules.

Adding a Rule

To add a rule, click the first available blank row and a new rule with the correct index will be created. Repeat this if you want to add more rules.

Creating a Rule

With the Rule Editor, you can make or modify the rule base of the selected Rule Block. Each rule has the following assigned to it:

- Index - the position of the rule in the rule base, usually greater than zero
- Activity flag check box - if checked, the rule is enabled, otherwise it is disabled
- DOF

An active rule is evaluated during the inference process and might influence the fuzzy system output. Inactive rules remain in the database but are not evaluated.

Temporarily enabling and disabling rules can help you fine-tune your fuzzy system.

The rule specification contains the premise variables and weighted consequent variables. The rule base columns in the Rule Editor are arranged in the same order as the related variable links are applied.

If you want to create a rule, then use a mouse. Select the table cell you want to modify and choose the required parameter. By clicking on the cell with the rule activity, you can set the rule as active (checked) or inactive (unchecked). When you click the cell of the premise or consequent variable, choose the required term from the visualized combo box. All relevant terms of the respective variables are offered including their inverses. The rule base is the only place where you can apply the fuzzy logic NOT operator. Inversed terms are marked by NOT followed by the term name.

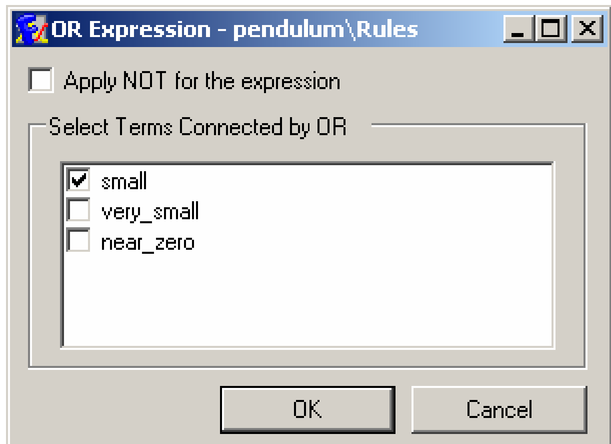
In the rule base table, the OR operator can also be used.

1. Select OR in the combo box, then check the terms that you want to use in the OR expression (see OR Expression Editor).

2. When you want to apply a NOT operator to the whole OR expression, check **Apply NOT for the expression**.

3. Click OK.

OR Expression Editor



When you set up a term in the consequent variable cell, you can select the weight of the consequent variable. All visible changes are stored in the appropriate Rule Block of the project immediately.

Deleting a Rule

When you click the first column, the appropriate rule will be marked as selected and the rule background will turn blue. You can also selection multiple rules. To delete the selection, press the Delete key on the keyboard.

Rule Editor Tool Bar

From this tool bar, you can access editor commands by right-clicking the tool bar buttons. The following buttons are available:

- Generate Possible Rules – Enables automatic generation of all rules resulting from the combination of terms and variables entering the rule premise. Negated terms, terms modified by NOT operator in the rule table, are not considered.

   a. Click the tool bar button and a dialog (see Generate Rules Dialog of Rule Editor) appears, where you can check the premise variables in the checked list box.
   The maximum number of generated rules of the selected premise variables is shown in the Maximum Number of Rules textbox.

b. Use the Number of Rules numeric control to decrease the number of rules you want to generate.

c. Click the Remove Just Applied Rules check box to remove all already applied rules of the selected Rule Block.

d. Click OK to generate the requested rules or click Cancel or Close (the top right dialog corner) to return to the appropriate Rule Editor dialog without any changes.

- Shift Selected Rule Up – Click this button to shift the selected rule one position up.

- Shift Selected Rule Down – Click this button to shift the selected rule one position down.

- Shift Selected Rule to Required Position – Click this button to shift the selected rule to the required position. A dialog (see Target Position Dialog of Rule Editor) opens and you can select the required final position for the selected rule in the Position No. box. Click OK, or click Cancel or Close to return to the Rule Editor dialog without making any changes.

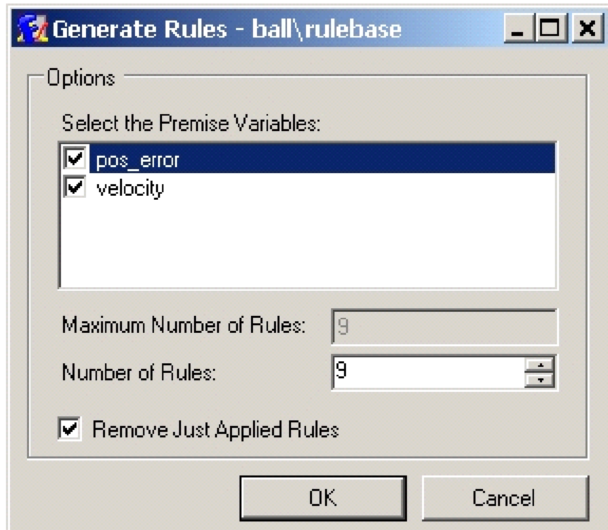
- Hide Column Bars – Click this button to hide or show the column bars with a graphic representation of the rule DOFs.

- Show Rules As Text – Click this button to see the rule base rules as text. A dialog (see Rules As Text Dialog of Rule Editor) with rules in the text format appears, and you can perform operations such as copy rules to another application through the clipboard.

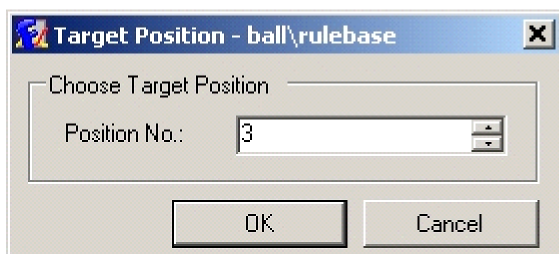
- Help – Click this button to show information about the Rule Editor.

- Close button – Click this button to close the Rule Editor dialog.

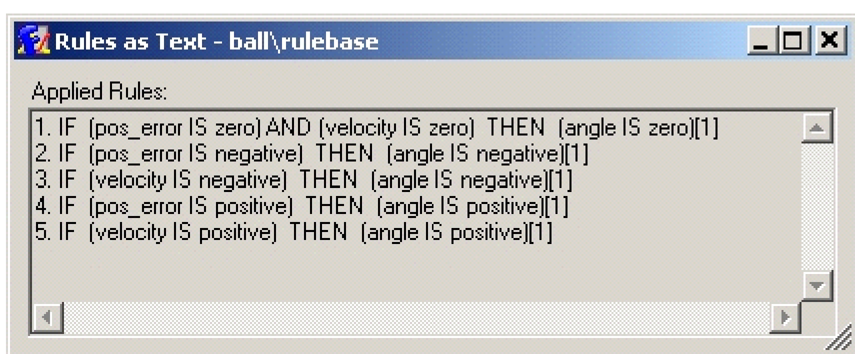
Generate Rules Dialog of Rule Editor



Target Position Dialog of Rule Editor



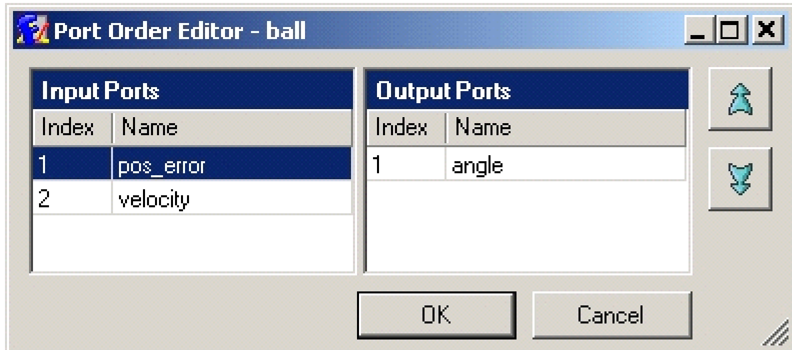
Rules As Text Dialog of Rule Editor



Port Order Editor

Use the Tools\Set Port Order main menu command to open the Port Order Editor dialog (see Port Order Editor Dialog), where you can change the order of the Input and Output Ports of the active project.

Port Order Editor Dialog



- Input Ports table – Select one of the applied Input Ports.
- Output Ports table – Select one of the applied Output Ports.
- Shift Port Up button – Click this button to shift any port up by one position. Select a port in the Input Ports table or the Output Ports table.
- Shift Port Down button – Click this button to shift any port down by one position. Select a port in the Input Ports table or the Output Ports table.
- OK button – Accept the entered properties for the project.
- Cancel button – Click this button to leave the Port Order Editor dialog. Any changes made are not applied. You can also click Close, at the top right corner of the dialog.

Watch

Use the Tools\Watch main menu command to open a dialog with all available component values of the active project (see Watch Dialog). The following buttons are available:

- Data History – Click this button to set up a history depth (see Watch Data History Dialog). The history depth is specified by number of samples, which are archived for user needs.
- History Data – Click this button to select components or choose one or more variables for archiving (see Watch Data History Dialog).

- History Graph – Click this button to show the history graph. When a dialog (see Watch History Graph Properties Dialog) with a check box lists appears, choose values for the history graph. To view the history graph (see History Graph), click the Show button at the bottom of the dialog.
  When the history is empty, the graph is shown immediately after you press the History Graph button. The ranges of the relevant component predefine the axis and grid of the history graph automatically, but you can change the range later. You can change the curve parameters, zoom of the graph, graph legend visibility and vertical axis information as well. The history samples are not interpolated, but joined by abscissa.

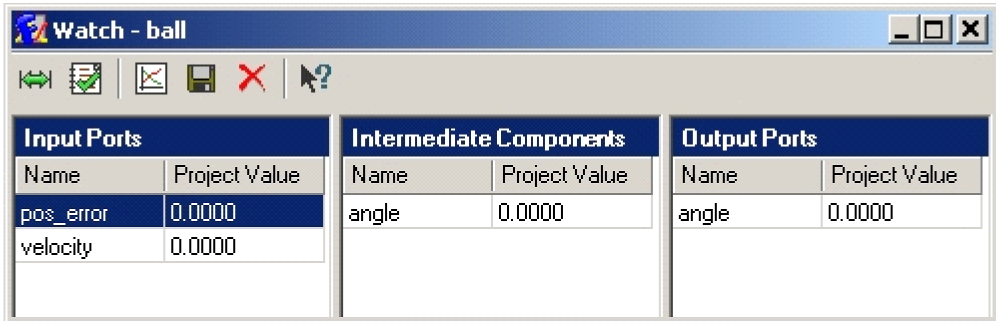
- Save History – Click this button to save the history into the specified file. When a dialog (see Watch Save History Data Dialog) appears, select the component values to be saved. Other than the selected component value, the time axis can also be stored. Two time formats are supported, relative and absolute time. Click Save As at the bottom of the dialog to confirm the choice and the standard Save As dialog appears. Select the file where you want to save the history and click Save.

- Clear History – Click this button to clear the memory.

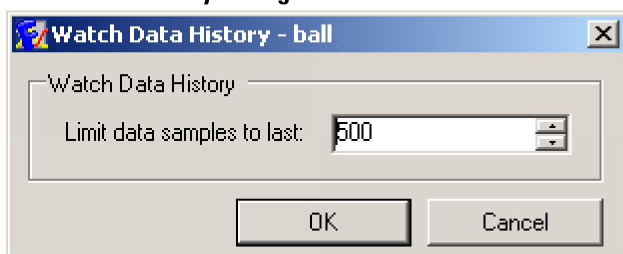
- Help – Click this button to show the information about the Watch dialog.

- Close button – Click this button to close the Watch dialog.

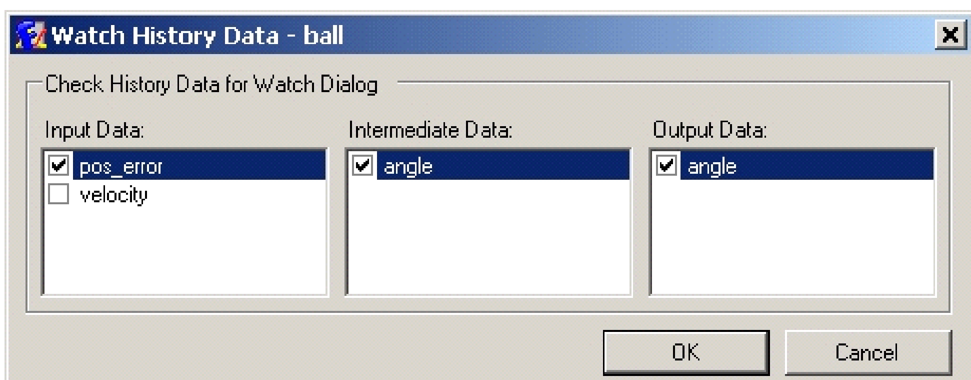
Watch Dialog



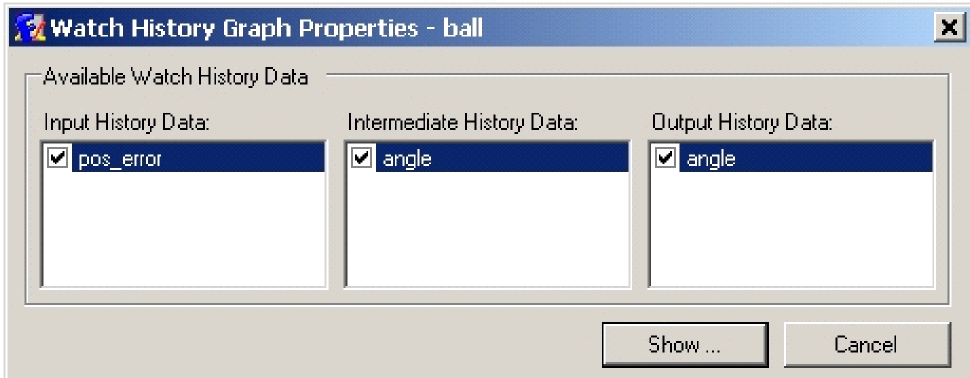
Watch Data History Dialog



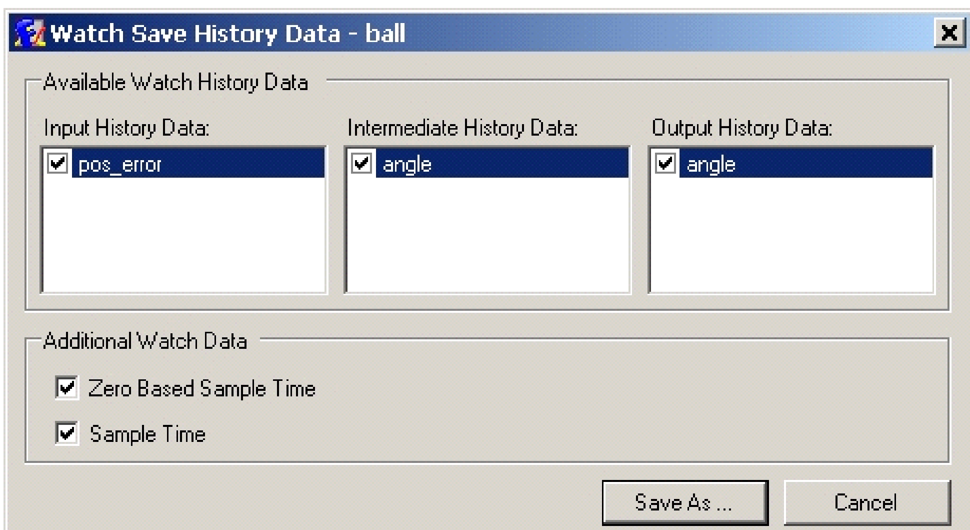
Watch History Data Dialog



Watch History Graph Properties Dialog



Watch Save History Data Dialog



Monitored data is saved in the ASCII format. The structure of the file is shown in the following table where:

- N_H is the history depth.
- T_s is the sampling period.
- $t_{elapsed}$ is the relative time elapsing from the monitoring start.
- t_{actual} is the absolute computer time.

Sample Time [ms]	Time	Input Name 1	Input Name 2	…	Output Name 1	…
$t_{elapsed} - (N_H-1)T_s$	$t_{actual} - (N_H-1)T_s$	$u_1(t_{elapsed} - (N_H-1)T_s)$	$u_2(t_{elapsed} - (N_H-1)T_s)$		$y_1(t_{elapsed} - (N_H-1)T_s)$	
⋮						
$t_{elapsed} - 2\ T_s$	$t_{actual} - 2\ T_s$					
$t_{elapsed} - T_s$	$t_{actual} - T_s$	$u_1(t_{elapsed} - T_s)$	$u_2(t_{elapsed} - T_s)$		$y_1(t_{elapsed} - T_s)$	
$t_{elapsed}$	t_{actual}	$u_1(t_{elapsed})$	$u_2(t_{elapsed})$		$y_1(t_{elapsed})$	

EXAMPLE

The monitored fuzzy system is the **Ball**. The data saved to the file are ball position error (pos_error), velocity of the ball (velocity), and the beam angle (angle). Every output variable has two columns – the first one stores values computed by FuzzyDesigner, the second one stores values loaded from the RSLogix 5000 project. Data was saved at 12:37:27.4, time elapsed from the monitoring start was 37 seconds. The defined history depth was 100 samples. The both Sample Time CheckBox and Zero Based Sample Time in milliseconds CheckBox were checked. Data was saved in the following form.

Sample Time [ms]	Time	Pos_error	Velocity	Angle	Angle (Controller)
17.2	12:37:07	-0.4569	0.756445	0.030031	0.030031
17.4	12:37:07	-0.30795	0.729367	0.158467	0.158467
36.8	12:37:27	-0.11491	0.475816	0.391279	0.391279
37.0	12:37:27	-0.05582	0.145594	0.107682	0.107682

History Graph

The History Graph is a Watch Tool component that displays measured or simulated data.

The creating and setting of initial parameters are explained in the section Watch.

The created graph can be either absolute or relative. You can select the graph type by clicking the first button on the history graph tool bar, and you can see this from a status bar at the top right corner of the graph window.

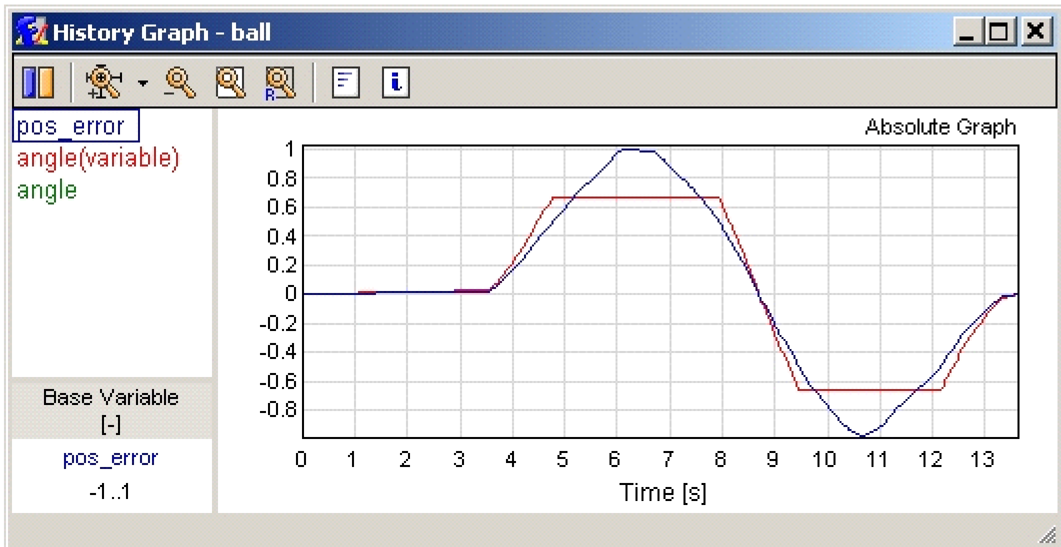
If the graph is absolute then the displayed scaling of vertical axis is valid for all curves, otherwise, the scaling is valid only for the labelled base curve. Its parameters are written in the separate window located in the left bottom corner of the graph main window. In the relative mode all curves are scaled to share the vertical range with the base curve. The vertical range of each curve can be changed in the legend context menu. This range is valid only for the current graph. It is not the same as the range defined in the Linguistic Variable Editor. Only the default range is the same. The main graph window consists of three parts (see History Graph), the Real graph window, the Legend and the Base Variable Property.

- Real graph window - This window is located on the right side of the graph main window, and it cannot be hidden. Measured historical samples are plotted here. Adjacent data points are linked by a line, no interpolation is applied. The number of curves displayed is limited to 1000. The grid of both axes is set automatically. Range of displayed data can be changed by zooming in and out. The units of the horizontal axis are written below the line. The units of vertical range are not displayed as the plotted variables might not share the same units. Right-click the legend to display the graph context menu (see History Graph Context Menu). You can change the graph size, or view the graph property window.

- Legend – This is located on the left top corner of the main graph window. You can hide it by using a graph toolbar button. The legend lists the displayed curves. Related text items and curves share the same color. If the curves overlap, the color of the first related item from the legend is applied. Use a drag-and-drop operation to reorder the list of items.
  The first item in the list is a base curve taken as a reference if the graph is relative in scale. Right-click the legend, and the legend context menu appears (see History Graph Legend Context Menu). From this menu, you can change the color or the vertical range tick marks related to a curve.

- Base Variable Property – This is located on the left bottom corner of the main graph window. You can hide it by using a graph toolbar button. The window displays the base curve information (the curve on top of the legend). Unit, name, color, and range are displayed.

History Graph

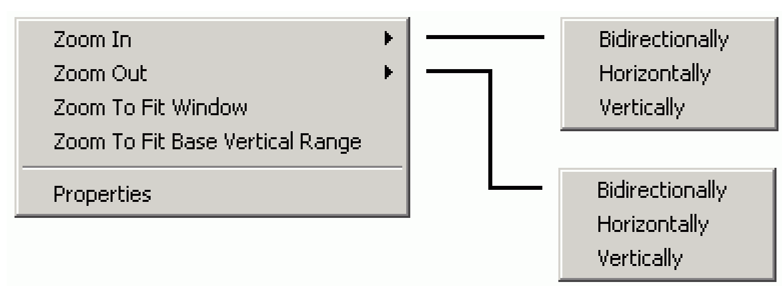


History Graph Control – Context Menu

Two context menus are available for history graph control.

The first menu, shown below, appears when you right-click the graph. The menu items are explained below.

History Graph Context Menu



- Zoom In – Zooms in on the graph. The maximum size depends on the base vertical range and maximum (on an absolute scale) real displayed value.

- Zoom out – Zooms out of the graph. The minimum size depends on maximum (on an absolute scale) value of all displayed curves.

- Zoom To Fit Window – Changes the graph size to best fit the window.

- Zoom To Fit Base Vertical Range – Changes the graph size to best fit the base vertical range in the window.

- Properties – Opens the dialog with graph properties (see Watch History Graph Properties Dialog).

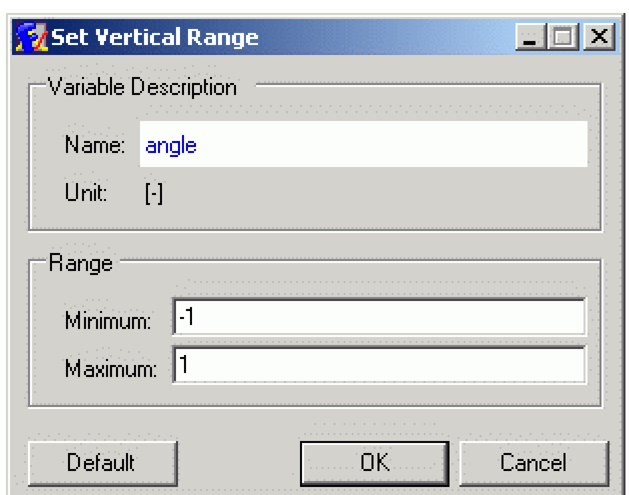
The second context menu appears you right-click the legend window. In this menu, you can change the parameters of the curve. The menu structure is shown in History Graph Legend Context Menu. The menu items are explained below.

History Graph Legend Context Menu

- Color – Change the color of the selected curve.

- Curve Vertical Range – Opens the dialog for changing the vertical range of the selected curve (see Curve Vertical Range Dialog). This range is used to map curves if the graph is relative, and is valid only for this graph.

Curve Vertical Range Dialog



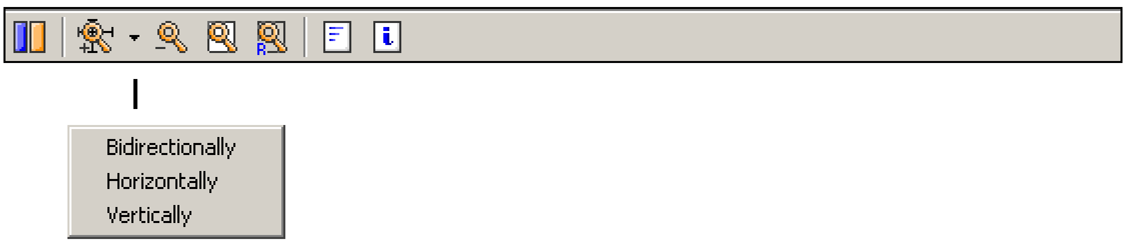
History Graph Control – Tool Bar

The tool bar (see History Graph Tool Bar) has these three categories of buttons:

- Changing the nature of graph range (relative or absolute)
- Zooming in and out of a graph
- Working with graph main window.

The buttons are explained below.

History Graph Tool Bar



- Relative/Absolute Graph – Switches the graph from relative to absolute and vice versa.

- Zoom In – Zooms in on the graph. You can select one of three zoom methods, Zoom Bidirectionally, Zoom Horizontally, and Zoom Vertically. The zoom method selected also applies to a zoom operation from dragging the mouse (see section History Graph Control – Mouse Dragging).

- Zoom Out – Zooms out the graph. See Zoom In for more details.

- Zoom To Fit Window – Changes the graph size to best fit the window.

- Zoom To Fit Base Vertical Range – Changes the graph size to best fit the base vertical range in the window.

- Show/Hide Legend – Shows or hides the legend window.

- Show/Hide Base Curve Parameters – Shows or hides the window with base window parameters.

History Graph Control – Mouse Dragging

You can change the size of the displayed graph by using your mouse. You can choose to zoom bidirectionally, horizontally, or vertically.

2D Graph

2D and 3D graphs are useful tools for off-line validation of a fuzzy system. Assume that the project deals with crisp inputs and outputs, which is the case in most control applications. The inference realized by the designed fuzzy system generates static input-output mapping. 2D graphs and 3D mesh plots are graphical representations of the mapping.

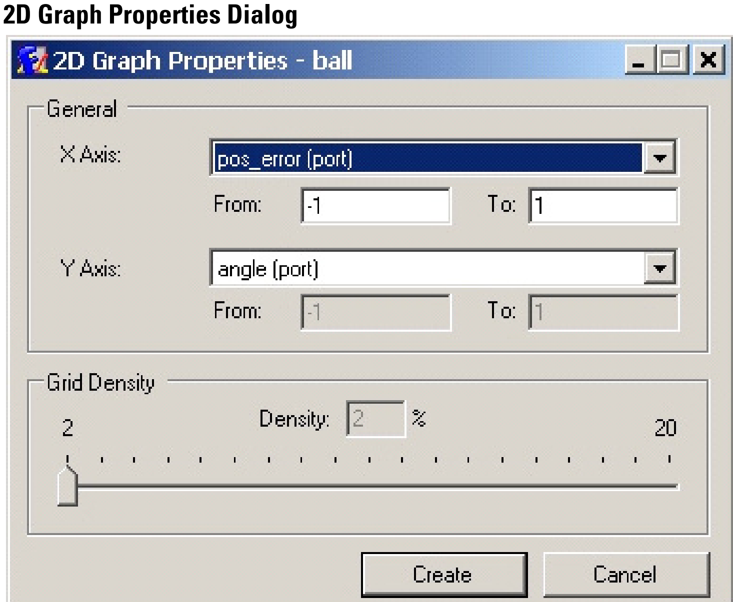
IMPORTANT Dynamic components such as input ports with filters and PID controllers, resulting in a dynamic fuzzy system, give 2D and 3D plots different meaning and use.

When the 2D(3D) Graph is opened and the related project is manually simulated, the system behavior is traced in yellow. To trace the system behavior for another simulated input, the 2D(3D) graph must be regenerated.

When you click the Tools\2D Graph main menu command, the 2D Graph Properties dialog (see 2D Graph Properties Dialog) appears and you can specify the 2D graph properties.

- General group box – Specify the general properties of the 2D graph.

2D Graph Properties Dialog



– X Axis – Select the Input Port or a disconnected Input Linguistic Variable as the x-axis of the 2D graph.
– From – Specify the lower limit of the x-axis range.
– To – Specify the upper limit of the x-axis range.
– Y Axis – Select the Output Port, the Output Linguistic Variable or the Output Takagi-Sugeno Variable as the y-axis of the 2D graph.
– From – Displays the lower limit of the y-axis range.
– To – Displays the upper limit of the y-axis range.

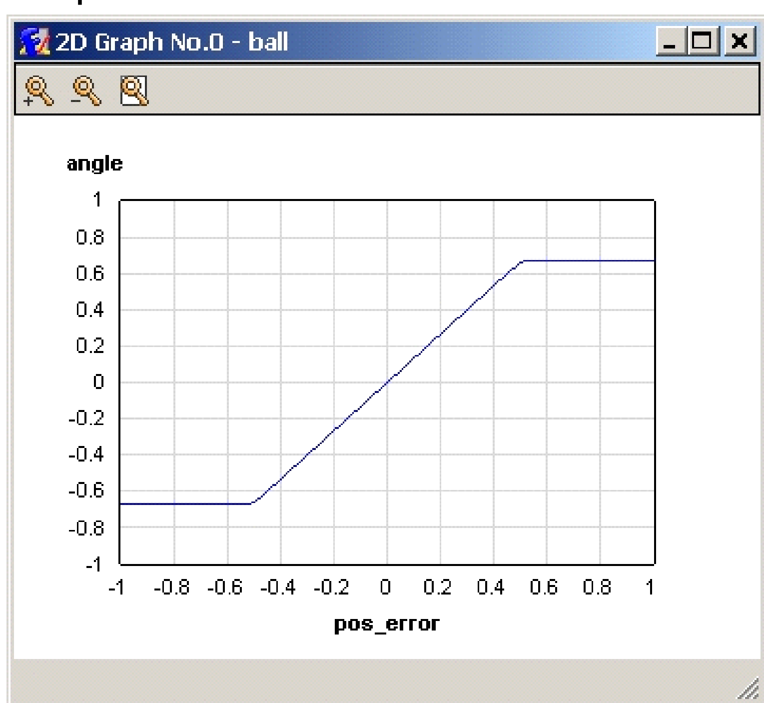
- Grid Density group box – Specify the grid density of the 2D graph.

  – Density – Displays the selected grid density of the graph. Select the density by clicking a point on the slider.

- Create button – Generate the 2D graph (see 2D Graph).

- Cancel button – Close the 2D Graph Properties dialog without creating a graph. You can also click Close, at the top right corner of the dialog.

2D Graph

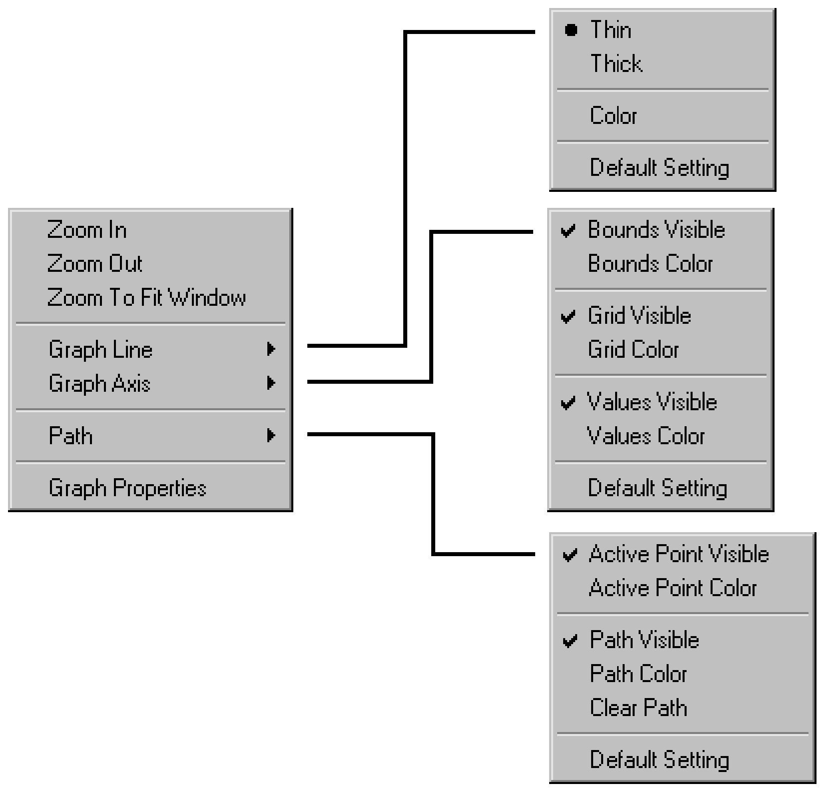


The 2D graph can be controlled from the context menu or tool bar buttons.

2D Graph Control – Context Menu

The context menu appears when you right-click the 2D graph and have the structure displayed in the 2D Graph Context Menu. The meaning of all menu items is explained as follows.

2D Graph Context Menu



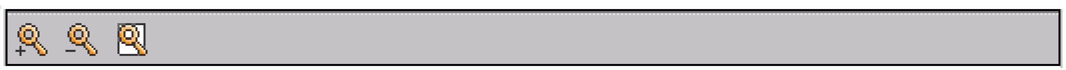
- Zoom In – Zoom in on the graph.
- Zoom Out – Zoom out of the graph.
- Zoom To Fit Window – Zoom in or out of the graph to best fit the window.
- Graph Line – Change the thickness and color of the graph line. Click the Default Setting option to restore the default settings.
- Graph Axis – Change the bounds, grid, and values parameters for the graph axis. If the bounds are not displayed, no other axis parameter is accessible. The grid step is automatic and is equal to 1/10 of the interval specified by bounds. The value item of the Graph Axis includes both values and names. Click the Default Setting option to restore the default settings.

- Path – Change the visibility and color of the path (trace), see section 2D Graph. You can also delete the complete path.
- Graph Properties – Open the 2D Graph Properties Dialog (see section 2D Graph).

2D Graph Control – Tool Bar

The tool bar (see 2D Graph Tool Bar) has three buttons: Zoom In, Zoom Out, and Zoom To Fit Window. All of them have the same function as the menu items with the same name.

2D Graph Tool Bar



3D Graph

When you click the Tools\3D Graph main menu command, then 3D Graph Properties dialog (see 3D Graph Properties Dialog) appears and you can set up the graph properties.

- General group box – Specify general properties of the required 3D graph.

3D Graph Properties Dialog

- X Axis – Link the selected Input Port or a disconnected Input Linguistic Variable to the x-axis of the 3D mesh plot.
- From – Sets the lower limit of the x-axis range.
- To – Sets the upper limit of the x-axis range.
- Y Axis – Links the selected Input Port or a disconnected Input Linguistic Variable to the y-axis of the 3D graph.
- From – Sets the lower limit of the y-axis range.
- To – Sets the upper limit of the y-axis range.
- Z Axis – Links the selected Output Port, Output Linguistic Variable or the Output Takagi-Sugeno Variable to the z-axis of the 3D graph.
- From – Displays the lower limit of the z-axis range.
- To – Displays the upper limit of the z-axis range.

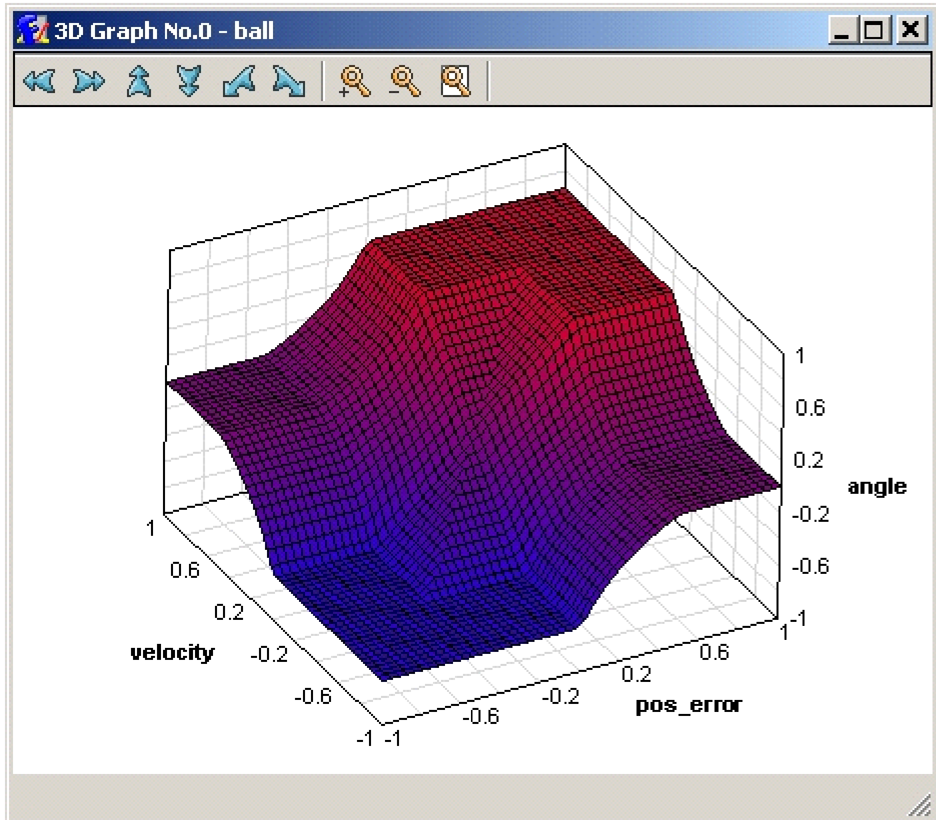
- Grid Density group box – Specify the grid density of the 3D graph.

  - Density – Displays the selected grid density of the graph. Select the density by clicking a point on the slider.

- Create button – Create the required 3D graph (see 3D Graph).

- Cancel button – Close the 3D Graph Properties dialog. No graph will be created. You can also click Close, at the top right corner of the dialog.

3D Graph

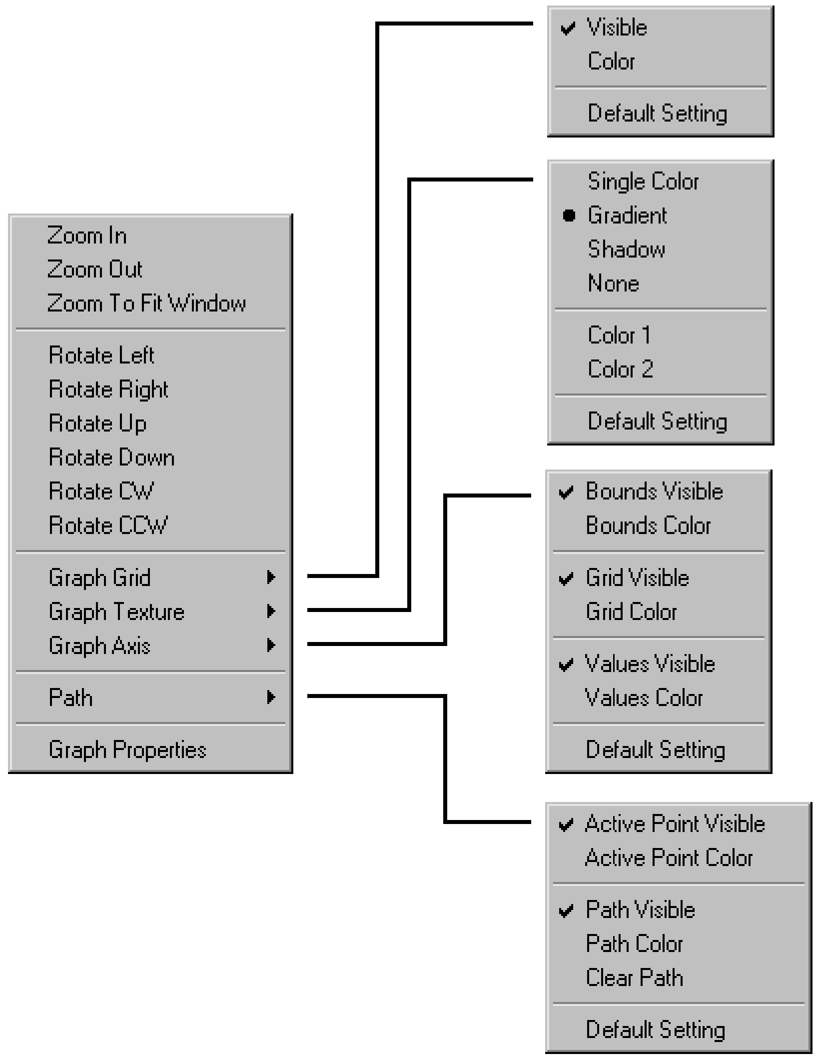


The 3D graph can be controlled either from the context menu or tool bar buttons. You can rotate the graph by using the mouse.

3D Graph Control – Context Menu

Right-click to display the context menu. The menu structure (see 3D Graph Context Menu) is explained below.

3D Graph Context Menu



- Zoom In – Zoom in on the graph.
- Zoom Out – Zoom out of the graph.
- Zoom To Fit Window – Zoom in or out of the graph to best fit the window.
- Rotate Left – Rotate the 3D graph to the left.
- Rotate Right – Rotate the 3D graph to the right.
- Rotate Up – Rotate the 3D graph up.
- Rotate Down – Rotate the 3D graph down.
- Rotate CW – Rotate the 3D graph clockwise.
- Rotate CCW – Rotate the 3D graph counter clockwise.

Graph Grid

Changes the graph grid visibility and color. Click the Default Setting option to restore the default settings.

Graph Texture

Changes the graph texture. There are four options.

- Single color texture – the graph has the texture defined as color 1.
- Gradient texture – the graph gets texture from gradient color. The lowest parts of the graph are assigned the color defined as color 2 and the highest parts of the graph, color 1.
- Shadow texture – the graph gets a shadowed texture. The base color for this is color 1.
- No texture – the graph is transparent.

Graph Axis

Changes the parameters of the graph axis. You can change the visibility and color of all three axes. Axis parameters are bounds, grid, and values.

Bounds are essential. If bounds are not visible then the other two parameters are not displayed. The grid distributes the interval defined by bounds into ten identical subintervals. The values item includes both values for all axis and their labels.

Click the Default Setting option to restore the default settings.

Path

Change the visibility and color of the path (trace), see section 3D Graph. You can change its visibility and color. You can also delete the complete path.

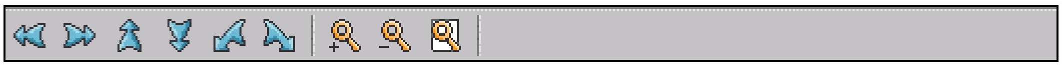
Graph Properties

Open the 3D Graph Properties Dialog (see section 3D Graph).

3D Graph Control – Tool Bar

The tool bar (see 3D Graph Tool Bar) has nine buttons: Rotate Left, Rotate Right, Rotate Up, Rotate Down, Rotate CCW, Rotate CW, Zoom In, Zoom Out and Zoom To Fit Window. All of them have the function identical to the menu items described previously.

3D Graph Tool Bar



3D Graph Control – Mouse Dragging

Drag the mouse to modify the 3D graph orientation. The graph is rotated in the left-right or up-down direction if you hold the left mouse button and drag horizontally or vertically. To rotate the graph CW and CCW, press the SHIFT key, the left mouse button and drag horizontally.

Fuzzy System Simulation

Introduction

FuzzyDesigner enables manual simulation of inputs and tracking of outputs generated by the fuzzy system. This feature serves as a basis for off-line tuning of a fuzzy system design parameters. All internal variables are also monitored and displayed during the input simulation run.

Use Tools\Simulation main menu command to start the monitoring. FuzzyDesigner switches to Monitoring mode and a Simulation Watch dialog appears.

Values of all component variables used in the fuzzy system project are displayed in three tables in the Simulation Watch dialog (see Simulation Watch Dialog). The first table displays Input Ports and the third, Output Ports. All the remaining **Intermediate Components** are displayed in the second table.

Input Value group box – Specify the range and input value of the Input Port selected from the Input Ports table.

- Minimum – Display or set the lower limit of the selected Input Port.
- Value – Display or set the value of the selected Input Port. The track bar is an alternative to the entry field.
- Maximum – Display or set the upper limit of the selected Input Port.

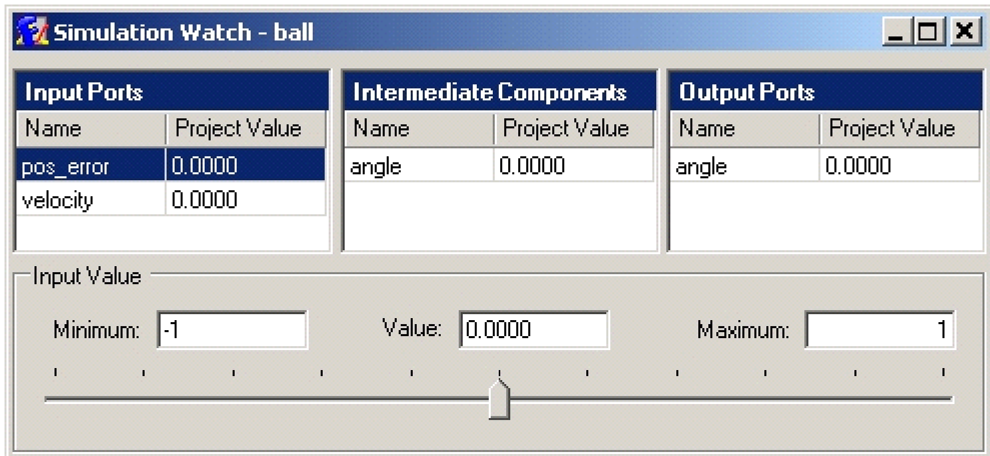
When you select the Input Port, the range and current value are shown in the Input Value group box. The Input Value group box is grayed out when you select a component from another table.

When you select an Input Port from the first table, you can change its input value by clicking the slider in the Input Value group box or by entering a value in the appropriate entry field.

When you change the input value of the selected Input Port, the fuzzy system project is statically evaluated, that is, the fuzzy system inference operation is computed. When you disconnect the Input Linguistic Variable you can use the related Term Editor to set up its input value by the membership function editor slider. You can use a variable as an additional input to the project.

Close button – Stops off-line simulation, and closes the Simulation Watch dialog. Returns FuzzyDesigner to Design mode.

Simulation Watch Dialog



RSLogix 5000 Add-On Instruction

Introduction

You can use Add-On Instructions (AOIs) to deploy your fuzzy logic algorithm created with FuzzyDesigner.

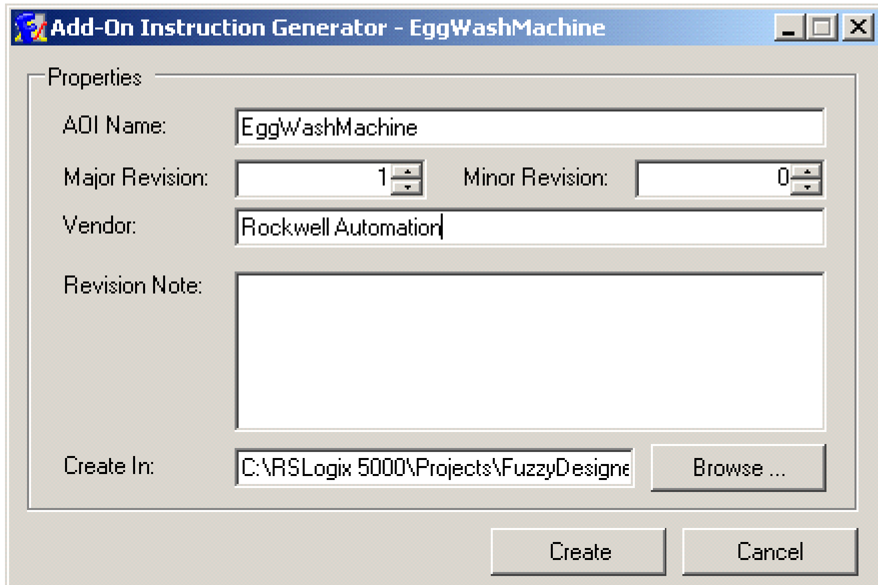
With FuzzyDesigner, you can use a fuzzy system in RSLogix 5000 software and run it on Rockwell Automation controllers (Logix5000 family). FuzzyDesigner enables you to export the designed fuzzy system to an Add-On Instruction XML import file (.L5X). You can then import the fuzzy system as a fuzzy instruction into any RSLogix 5000 projects. The fuzzy instruction can be used by any of the programming languages – Function Block Diagram, Ladder Logic, or Structured Text.

Generating a Fuzzy Add-On Instruction

You can export a fuzzy system to an Add-On Instruction XML import file (.L5X).

To generate the Add-On Instruction (AOI) for the active fuzzy project, click Tools>Add-On Instruction > Instruction Generator.

The following dialog appears.



The following conditions must be met to generate a fuzzy AOI:

- All blocks of the fuzzy system must be connected
- The fuzzy system must include at least one input port and one output port
- All rules must be complete (there is no rule with empty conditions or consequents)
- Each rule block must include at least one rule
- Each linguistic variable must include at least one term

The default file name of the Add-On Instruction is taken from the name of the fuzzy system in FuzzyDesigner, but you can change the name. The instruction name must follow to the Add-On Instruction naming rules. It must:

- Be no more than 40 characters long.
- Start with a letter or underscore (_). All other characters can be letters, numbers, or underscores.

In RSLogix 5000 software, the Add-On Instruction names are stored in the same namespace as all other built-in instructions and data types (system or user-defined). Therefore, the Add-On Instruction name must be unique. Otherwise, an error message will appear during the import of the fuzzy Add-On Instruction. When exporting the fuzzy Add-On Instruction, you can select the folder to which you want to save the L5X file. You can also enter these optional parameters:

- Add-On Instruction Major Revision
- Minor Revision
- Vendor
- Revision Note.

Add-On Instruction Parameters

The Add-On Instruction parameters correspond to the fuzzy system input and output ports. The ordering of parameters follows the order of the ports. Port order is determined, by default, by the order in which the ports are added to the project. The port order can also be set from the Tools > Set Port Order menu item. The following parameter attributes are set to default values:

- Name – The name of parameters are the same as the names of fuzzy system input and output ports.

- Usage – The usage is set to Input (for input ports) or Output (for output ports).

- DataType – The DataType of all input and output parameters is set to REAL.

- Required – The attribute Required is set to **true**, that is, the attribute requires an argument.

- Visible – The attribute Visible is set to **true**, that is, the attribute is visible on the RLL and FBD Instruction face when the AOI is invoked.

- Description – The description is taken from the Description field on the Project Information dialog (Project > Project Information menu item).

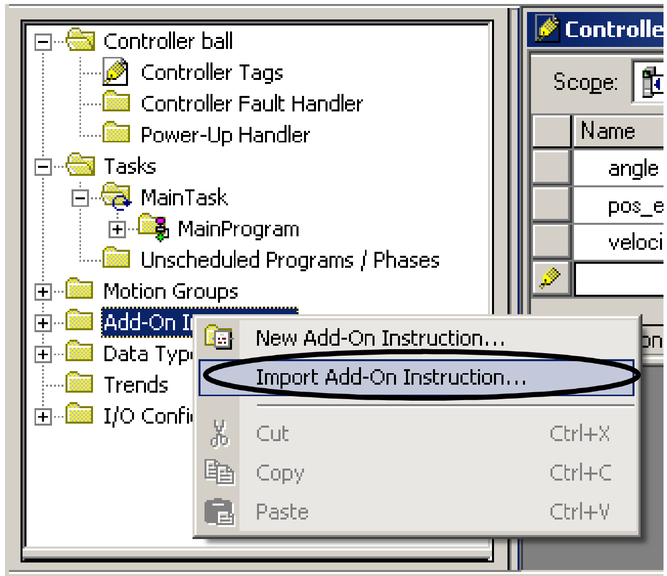
- Description of input and output parameters – The description is taken from the Description tab on the Input or Output Port properties dialog.

Importing Add-On Instructions to RSLogix 5000 Projects

You can use fuzzy Add-On Instructions in an RSLogix 5000 project.

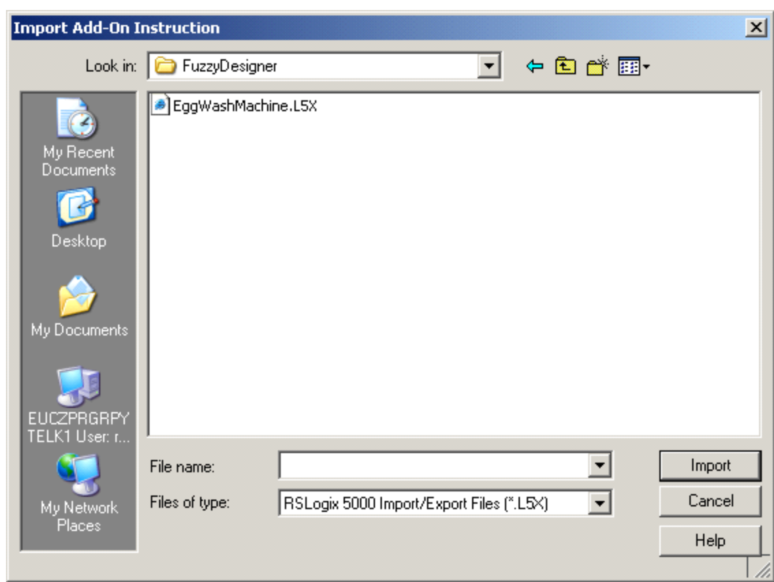
1. Open the RSLogix 5000 project to which you want to import a fuzzy system Add-On Instruction.

2. Right-click the Add-On Instructions folder in the Controller Organizer.



3. Choose Import Add-On Instruction.

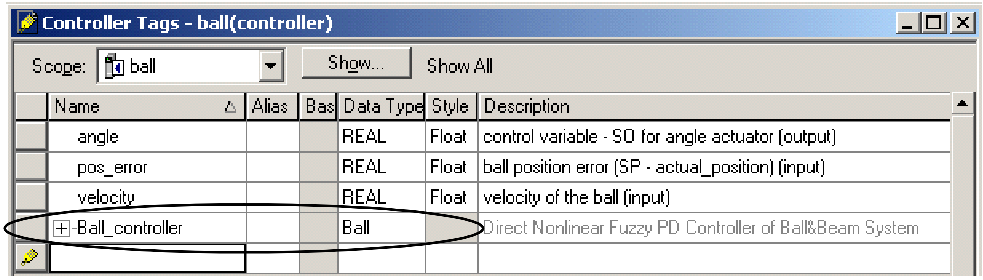
   The following dialog appears.



4. Select the Add-On Instruction (*.L5X file) you want to import to the RSLogix 5000 project.

5. Create an instance tag of the fuzzy Add-On Instruction.

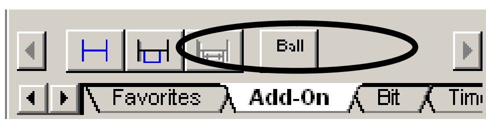
The type of the tag has to match the imported Add-On Instruction.

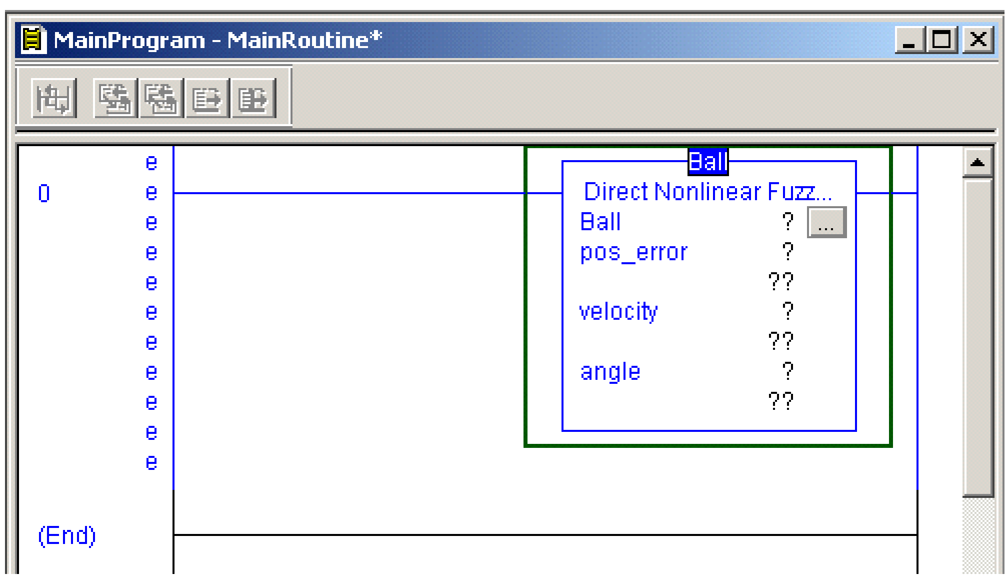


6. Create the tags (if not yet created) in which you want to store inputs and outputs of the fuzzy AOI.

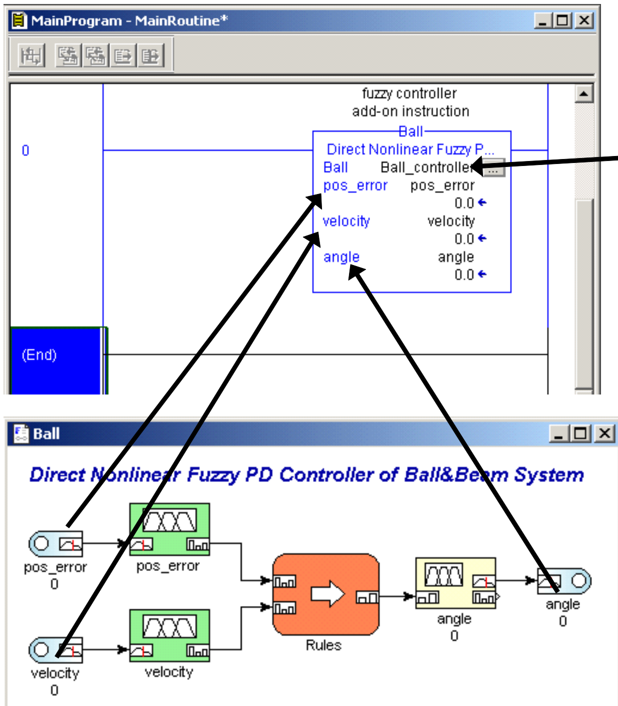
The type of these tags has to be REAL.

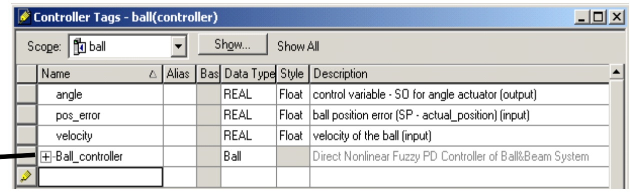
7. Add the fuzzy Add-On Instruction to code.





8. Enter parameters (operands) for the AOI.





- The order of parameters correspond to the port order of the fuzzy project
  - you can optionally set it by the **Tools > Set Port Order** menu item in FuzzyDesigner

Monitoring and Updating a Project Online

This section provides instructions on how to:

- establish online communication with a Logix controller to monitor and tune (modify parameters) the fuzzy AOI
- what to do if online communication is not working correctly. The communication with the Logix controller is via a RSLinx Classic OPC Server.

Before establishing online communication, certain conditions must be met.

- The fuzzy AOI is generated by FuzzyDesigner.
- The fuzzy AOI is imported to an RSLogix 5000 project.
- An instance of the fuzzy AOI is created in the RSLogix 5000 project.
- The RSLogix 5000 project is downloaded to a Logix controller.

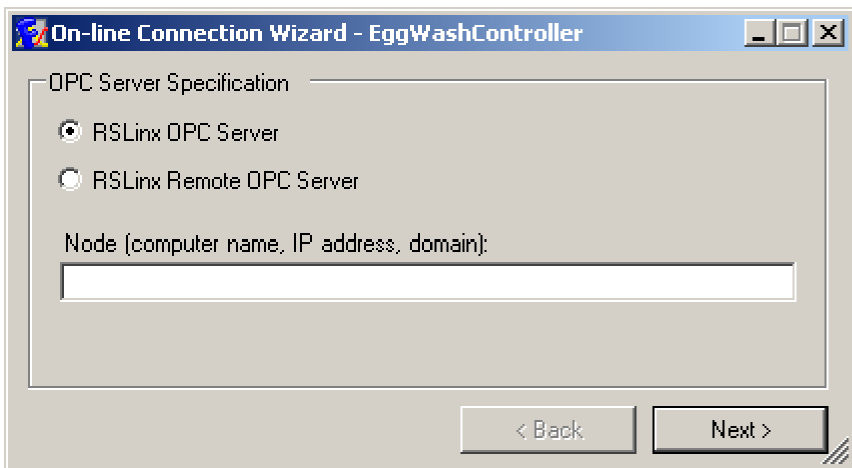
- An RSLinx Topic corresponding to the Logix controller is created (see section Configuring RSLinx OPC Server Topic). If an RSLogix 5000 project is saved, then a default RSLinx Topic is created with a default name that corresponds to the Controller Name.

- The fuzzy project used to generate the fuzzy AOI is open in FuzzyDesigner.

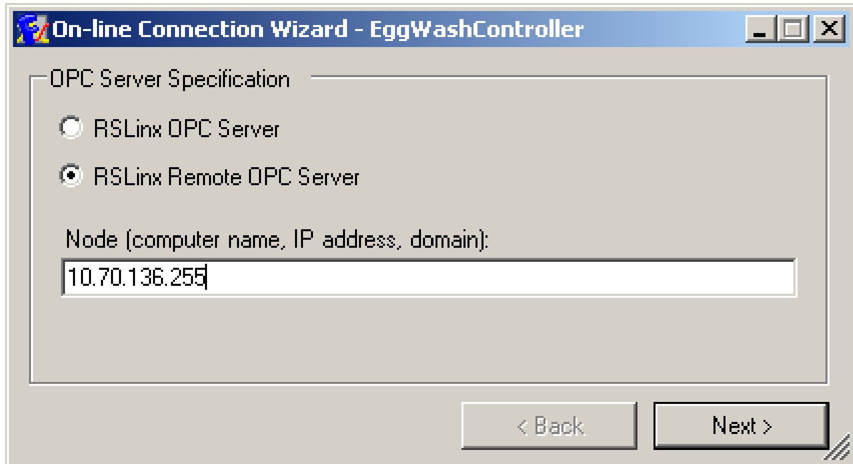
Follow these steps to establish online communication with a Logix controller.

1. In FuzzyDesigner, click Tools > Add-On Instruction > On-line Connection Wizard.

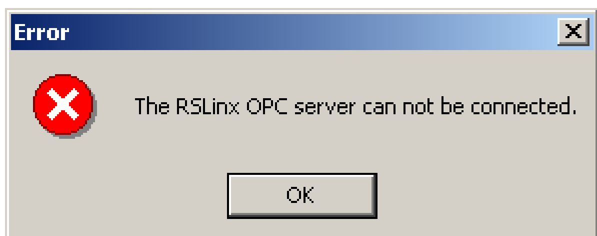
2. Specify the RSLinx OPC server.
   – If RSLinx software is installed on the same computer, select the RSLinx OPC Server option and click Next.



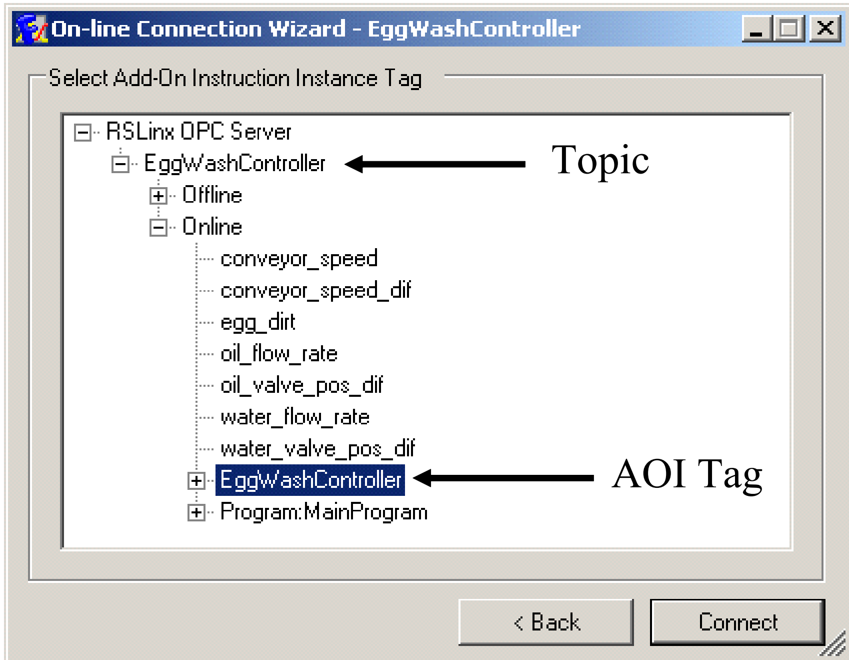
– If RSLinx software is installed on a remote computer, select the RSLinx Remote OPC Server option and specify a Node, then click Next.



If communication is not established, contact your network administrator to configure DCOM settings.



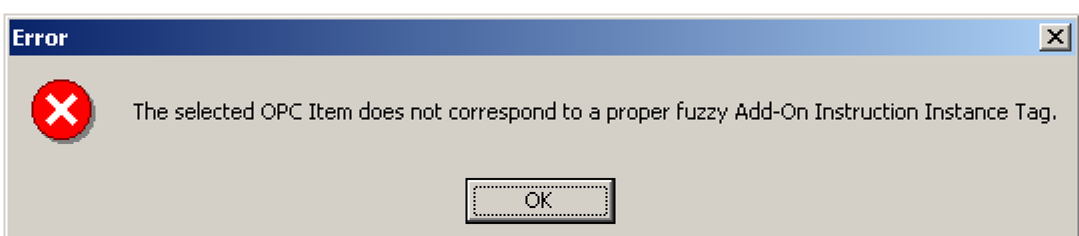
3. Select the Add-On Instruction instance Tag to monitor the OPC address space under a specific Topic (the first branch under the tree root RSLinx OPC Server) and click Connect.



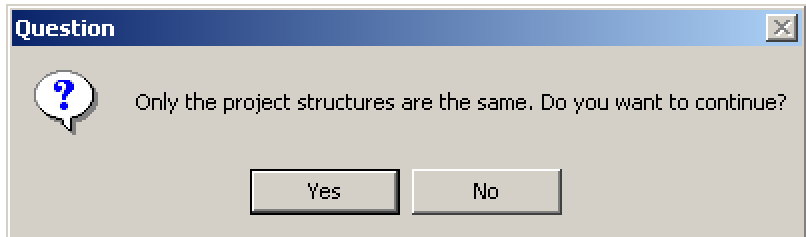
IMPORTANT The AOI instance Tag can be accessed through a Topic tied to corresponding Logix controller. If an RSLogix 5000 project is saved, then a default RSLinx Topic is created with a default name that corresponds to the Controller Name. To make sure that the selected RSLinx Topic corresponds to the correct controller or to reconfigure or create a new RSLinx topic, follow the steps described in the Appendix K – Configuring RSLinx OPC Server Topic.

If the AOI instance Tag cannot be found, then check if the RSLinx topic is correctly configured as explained above.

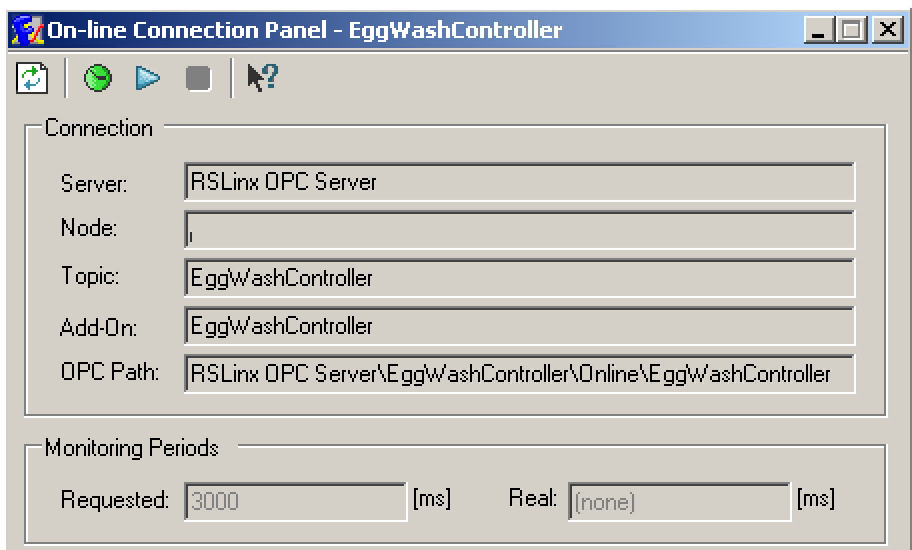
If the selected AOI instance tag does not correspond to the fuzzy project in FuzzyDesigner, the following message appears.



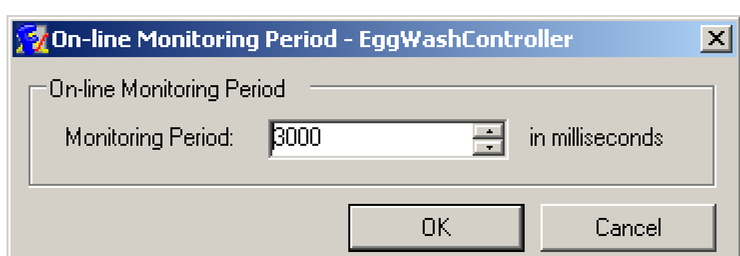
If the selected AOI instance tag does not have the same parameters as the fuzzy project in FuzzyDesigner and only the project structures are the same, the following dialog is shown. This can happen if you have changed some parameters off-line, for example, the membership function position.



If communication is successfully established, the following window appears.



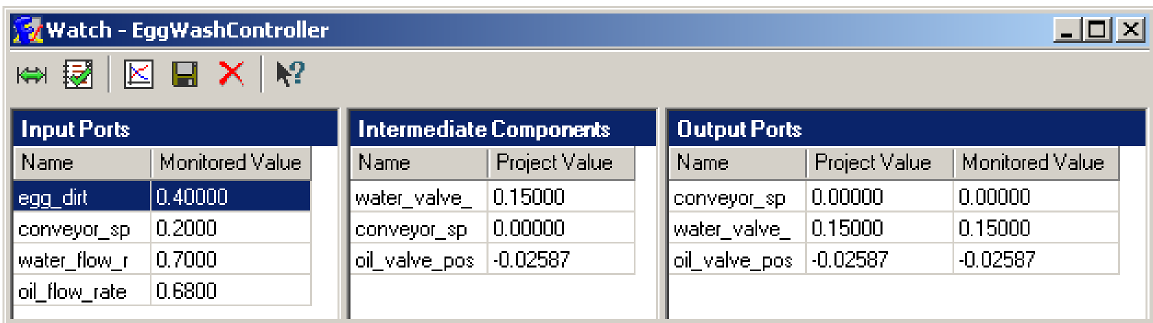
4. Start monitoring by clicking on the Run Monitoring icon. The On-line Connection Panel offers the following functionality:
   - If you want to change the monitoring period, click the Change Monitoring Period icon.



- If you make some changes, for example, changing membership function position in the fuzzy project in FuzzyDesigner and you want to apply the changes in Logix, click the Apply Changes to Logix icon on the On-line Connection Panel.

5. To stop monitoring click the Stop Monitoring icon.

The Watch window shows input and output values of the selected fuzzy system read from the selected controller (Monitored Value) as well as values computed in FuzzyDesigner (Project Value).



Configuring RSLinx OPC Server Topic

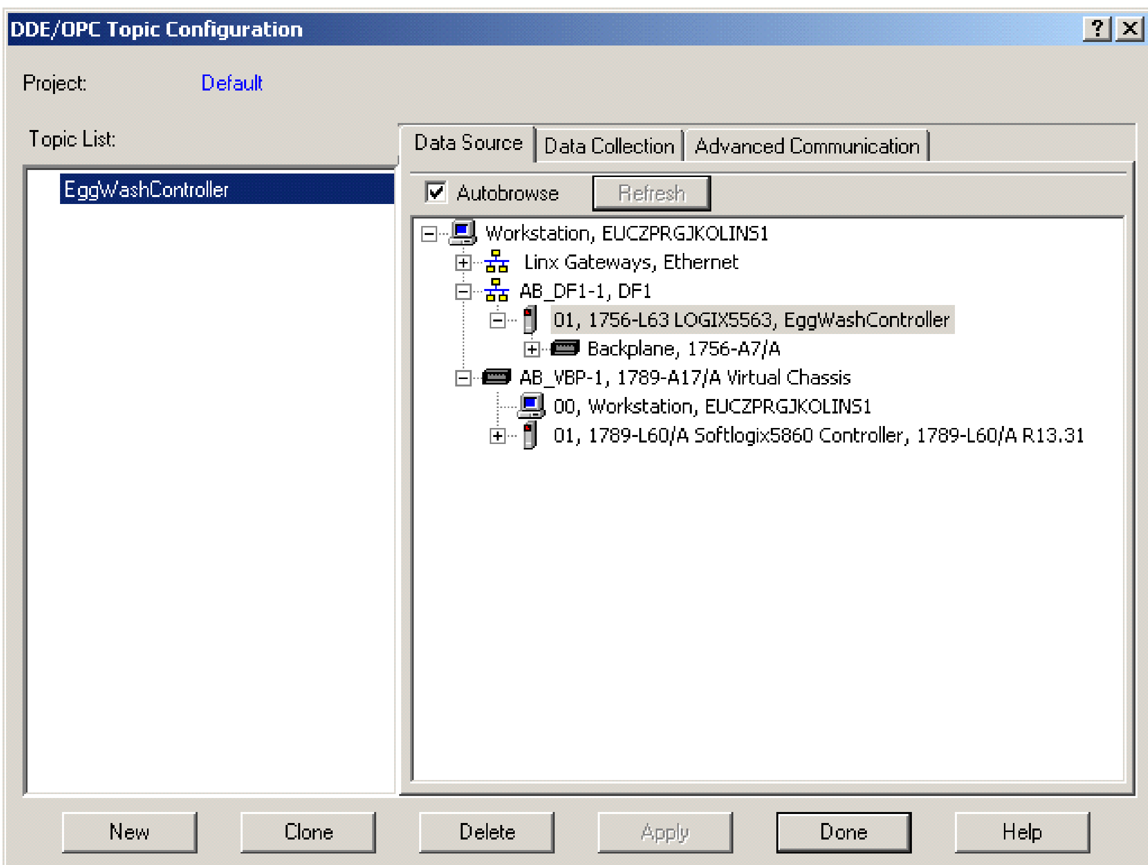
The OPC topic represents a specific path to a processor. If an RSLogix 5000 project is saved, then a default RSLinx topic is created with a default name that corresponds to the Controller Name.

To make sure that the selected RSLinx topic corresponds to the correct controller or to reconfigure or create a new RSLinx topic do the following steps.

1. Start RSLinx software by double-clicking the RSLinx icon on the desktop or by clicking the RSLinx Communication Service on the system Service Status toolbar .

2. In RSLinx software click the OPC/DDE menu, and choose Topic Configuration.

3. Select the topic in the Topic List.



The topic has to correspond to the correct controller path. If not, set the correct controller path in the communication path browser.

4. Click Done.

5. To create a new OPC topic, click New and enter a Topic name. Set a correct path to the controller in the browser.

6. Click Apply and then click Done.

Modifying Fuzzy System Parameters Online

When you modify fuzzy system parameters online, parameters are overwritten directly in the selected controller, that is, in the selected fuzzy system Add-On instruction tag.

The following conditions must be met:

- The number and the type of components have to be the same in both projects.

- The number of membership functions of every corresponding input linguistic variable, output linguistic variable and intermediate variable has to be the same (their names, types, and parameter values can vary).

- The number of consequent functions of every corresponding output Takagi-Sugeno variable has to be the same. The number of parameters of these functions have to be the same as well (their values can vary).

- The number and structure of rules of every corresponding rule block have to be the same. Weights of rules can vary.

- The names of fuzzy system input and output ports have to be the same as in the fuzzy system which was exported to the L5X file.

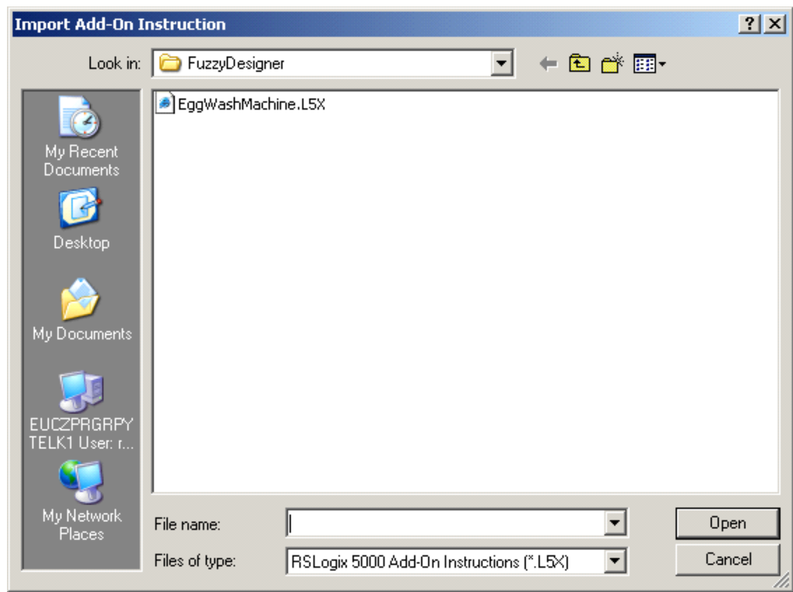
If these conditions are not met, the fuzzy system in the controller may not be updated online. Then you would have to export the fuzzy system to the L5X file and import it again to the RSLogix 5000 project.

If the fuzzy system parameters are successfully updated, the following message appears.

Modifying the fuzzy system parameters modifies a specific instance of the fuzzy Add-On Instruction, not the definition of the fuzzy Add-On Instruction. If you want to change the definition, you should create a new version of the fuzzy Add-On Instruction and import it onto your RSLogix 5000 project.

Importing an Add-On Instruction to FuzzyDesigner

FuzzyDesigner enables you to import the fuzzy Add-On Instruction XML file (.L5X) back to FuzzyDesigner. To import the fuzzy Add-On instruction, click the menu item: Tools > Add-On Instruction > Import. The following window appears.



Select the Add-On Instruction (*.L5X file) you want to import to FuzzyDesigner.

XML Format of a Fuzzy Project

FuzzyDesigner enables you to export and import the fuzzy project in the XML format. In this chapter, the basic structure of the XML document corresponding to the fuzzy project designed in FuzzyDesigner is shown.

An XML document consists of two main parts: the prolog and the document element (the root element).

Prolog

```
<?xml version="1.0"?>

<!--******************************************-->

<!--FuzzyDesigner Project Description in
XML format -->

<!--Version: 16.00.05-->

<!--Time: 07/13/2006 14:41:00-->

<!--******************************************-->
```

Document Element

```
<FUZZYDESIGNER_PROJECT SOFTWARE_VERSION="16.00.05"
PROJECT_VERSION="2.01.00">

    <FUZZY_SYSTEM NAME="FuzzyProject"
    VERSION="2.01">
        ⋮
        <INPUT_PORT NAME="velocity" />
        ⋮
        <INPUT_LINGUISTIC_VARIABLE NAME="velocity"
           PROCESS_FUZZY_INPUT="1">
           ⋮
        </INPUT_LINGUISTIC_VARIABLE>
        ⋮
        <OUTPUT_LINGUISTIC_VARIABLE NAME="angle">
           ⋮
        </OUTPUT_LINGUISTIC_VARIABLE>
        ⋮
    </FUZZY_SYSTEM>
```

```
    <GRAPHIC_MODEL VERSION="1.0">
        ⋮
    </GRAPHIC_MODEL>

    <GUI_PROPERTIES VERSION="2.01">
        ⋮
    </GUI_PROPERTIES>
```

</FUZZYDESIGNER_PROJECT>

The prolog contains the XML declaration, the XML description of the project designed in the FuzzyDesigner, the version of the Fuzzy Core implemented in the FuzzyDesigner and time and date when the fuzzy project was exported to the XML document.

The Document element (FUZZYDESIGNER_PROJECT) contains information concerning the fuzzy system components (element FUZZY_SYSTEM), graphical representation of the fuzzy system (element GRAPHIC_MODEL), and GUI properties (element GUI_PROPERTIES)

A more detailed description of the structure of the fuzzy system XML representation can be found in the FuzzyDesigner XML Project File Description document.

Glossary

Introduction

In this section, you can find brief explanations on terminology used in this document.

activation

A process by which the degree of fulfillment of a rule condition acts on an output fuzzy set

aggregation

An operation which combines several fuzzy sets to produce a single fuzzy set. In the context of fuzzy control, it is the method of activation when multiple rules share the same term of a linguistic variable in the rule conclusion.

application

A synonym for user programs

Centroid Average (CA)

A continuous defuzzification technique

client

An application that uses the services of an object

crisp set

A special case of a **fuzzy set**, in which the **membership function** only takes two values, commonly defined as 0 and 1

defuzzification

A conversion of a **fuzzy set** into a numerical value

Degree Of Activation (DOA)

The degree to which the **condition** part of a rule is satisfied and consequently the degree to which the terms in the rule **conclusion** will be activated.

Degree Of Fulfillment (DOF)

A general evaluation of the degree of truth of fuzzy logic expressions. DOF values range from 0 to 1. For example:

- Term DOF — the DOF for the expression "X is A", is the degree of membership of x in A.
- Rule DOF — the DOF of the condition part of a rule

extensible markup language (XML)

Class of data objects and definitions that define how programs should behave. XML documents are made up of parsed data, characters forming character data or markup. Markup defines the document's storage layout and logical structure. FuzzyDesigner uses XML to define the format in which FuzzyDesigner projects are kept.

fuzzification

Determination of **degrees of membership** of the crisp input value of the **linguistic terms** defined with each input **linguistic variable**

fuzzy number

A convex fuzzy set with maximum membership degree equaling 1

Hierarchical Fuzzy System (HFS)

A fuzzy system with chained rules and hierarchical structure of the rule base.

Inference

An application of **linguistic rules** on input values in order to generate output values

Input Linguistic Variable (ILV)

Stores linguistic terms and is used for classification of the actual component input, represented by a crisp value, into the fuzzy sets defined for the respective linguistic terms.

Input Port (IP)

Preprocesses and stores values of a fuzzy system's input variables

Intermediate Linguistic Variable (IMLV)

Bridges logical chaining of rule blocks

largest of maximum (LOM)

A discontinuous defuzzification technique

linguistic rule

IF-THEN rule with **condition** and ***conclusion***, one or both linguistic

linguistic term

In the context of fuzzy control, **linguistic terms** are defined by **fuzzy sets**

linguistic variable

A variable that takes values in the range of **linguistic terms**

link

A type of connection between fuzzy system components specifying format of data transferred

Maximum Center Average (MCA)

A continuous defuzzification technique

Mean of Maximum (MOM)

A discontinuous defuzzification technique

Membership Function (MF)

Function which defines the **degree of membership** over the universe of discourse for a given **fuzzy set**

Multiple Document Interface (MDI)

A Windows API for creating multiple window applications, allows FuzzyDesigner to show multiple fuzzy systems or projects at the same time.

OLE for Process Control (OPC)

An industrial standard allowing vendor-independent access to industrial communication networks, defined on OLE mechanism.

Output Port (OP)

Stores values of a fuzzy system's output variables

Output Takagi-Sugeno Variable (OTSV)

Stores parameters of functional terms and computes the output value from degrees of fulfillment of terms

Proportional-Integral-Derivative Controller (PIDC)

Allows intelligent supervision of a built-in PID controller

Rule Block (RB)

Stores rules and computes degree of fulfillment of rule conditions

Rule Weight, weighting factor (RW)

A value from the interval [0,1], that states the degree of importance, credibility, confidence of a **linguistic rule**

server

The object that provides services.

Smallest of Maximum (SOM)

A discontinuous defuzzification technique

s-norm

The class of mathematical operations realizing fuzzy union (OR)

t-norm

The class of mathematical operations realizing fuzzy intersection (AND)