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Method for Fuzzy Inference in a Fuzzy Control Loop

The invention relates to a method for fuzzy inference in a fuzzy control loop.

5 An article by Günter Trautzl entitled "Unscharfe Logik: Fuzzy Logik" ("Fuzzy Logic") appeared in "Der Elektroniker", No. 3, 1990 on pages 39-43.

10 The names rule-based-system, ambivalent logic and multi-valued logic are also used instead of the designation of fuzzy logic.

Fuzzy logic was developed as early as 1965 in order to be able to process even inaccurate and incomplete data records. Measured values are described by linguistic variables instead of by numbers. Fuzzy sets, for example positively large, positively
15 average, positively small, approximately zero, negatively small etc. are introduced for the linguistic variables. This fuzzy set is defined by its membership function.

The membership function specifies to what degree an element from the value range is contained in the set. A control
20 strategy is implemented by combining the linguistic variables in their fuzzy sets.

The actuating signal is generated with the aid of simple if-then rules. The following exemplary control strategy is used in the fuzzy control.

25 First Rule:

If the input variable of the controller is negatively small and at the same time the change in the input variable of the controller is positively small, then the manipulated variable is positively small.

30 Second Rule:

If the input variable of the controller is negatively small and the change in the input variable is positively large, then the manipulated variable is negatively small.

Third Rule:

35 If the input variable of the controller is approximately zero and the change in the input variable is positively small, then the manipulated variable is negatively small.

Fourth Rule:

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If the input variable of the controller is approximately zero and the change in the input variable is positively large, then the manipulated variable is negatively large.

5 A fuzzy linguistic manipulated variable which is to be transformed into a sharp physical variable is produced as a result of the combination. In accordance with the prior art, this purpose is served by determining the centre of gravity of fuzzy output variable, the calculation of which requires a comparatively long time, because many multiplications and a
10 division have to be carried out. The calculation of the value of the manipulated variable from the fuzzy set is also designated as defuzzification.

It is therefore the object of the invention to specify a method for a fuzzy control loop which renders the fuzzy control
15 loop substantially faster without a substantial negative effect on the remaining controller characteristics.

The invention achieves this object by providing only two fuzzy sets "positive" and "negative" for the manipulated variable of the fuzzy controller.

20 The invention proceeds from the idea of dividing the manipulated variable only into two states "positive" and "negative" and no longer, as in the prior art, into arbitrary states such as, positively small, negatively small and negatively large. This measure has the advantage that the
25 defuzzification can now be carried out only by subtraction and no longer by a series of multiplications and a division. Much time is saved as a result; the controller becomes substantially quicker because the computational outlay for subtractions is substantially less than for multiplications and divisions.
30 Nevertheless, the advantages of a fuzzy control loop are preserved.

Fig. 1 shows the membership functions of a known fuzzy control loop,

35 Fig. 2 shows membership functions of a control loop according to the invention,

Fig. 3 shows an exemplary embodiment of the invention.

Fig. 1 shows the membership functions of a first and a



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second input variable as well as of the output variables calculated therefrom. The defuzzification is performed by calculating the centres of gravity of the hatched areas in the diagrams.

5 The membership functions in accordance with the invention are illustrated in Fig. 2. The defuzzification is performed by subtraction of the maximum memberships of the two sets "positive" and "negative".

10 An exemplary embodiment of the invention is shown in Fig. 3.

 The first and the second input variables of the controller are fed to a group of blocks ZF, where the membership functions are filed. The outputs of these blocks ZF are connected to the inputs of a network U composed of comparators and multiplexers, where the minimum combinations are carried out in accordance with the rules. The outputs of the network U are connected to the inputs of a network 01 and a network 02. The maximum combinations in accordance with the rules are carried out in the two networks 01 and 02. However, in accordance with the invention a distinction is made only between "positive" and "negative" for the manipulated variable. Further states such as, for example, positively small, positively large, positively average, negatively small, negatively large, or negatively average are not provided. The outputs of the two networks 01 and 02 are connected to the inputs of a subtractor S at whose output the sharp manipulated variable SG can be tapped.

 In the case of the invention, the subtractor S is provided instead of multipliers and dividers. The runtime for calculating the manipulated variable is substantially reduced by this measure. Multipliers and dividers, which are provided in the prior art instead of the subtractor, require a substantially longer runtime for calculating centres of gravity.

 The fuzzy control loop according to the invention can easily be constructed from comparators, multiplexers and subtractors. By comparison with known fuzzy processors, the invention therefore represents a very simple and cost-effective implementation of a fuzzy control loop.

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Claims



1. Method for fuzzy inference for a fuzzy control loop, characterized in that only two fuzzy sets "positive" and
5 "negative" are provided for the manipulated variable of the fuzzy controller.
2. Method according to Claim 1, characterized in that the defuzzification is performed by subtracting the maximum membership of the two fuzzy sets "positive" and "negative".
- 10 3. Method according to Claim 1 or 2, characterized by the following if-then rules.
If the input variable of the controller is negatively small and the change in the input variable is positively small, then the manipulated variable is positive;
15 If the input variable of the controller is negatively small and the change in the input variable is positively large, then the manipulated variable is negative;
If the input variable of the controller is approximately zero and the change in the input variable is positively small, then
20 the manipulated variable is negative;
If the input variable of the controller is approximately zero and the change in the input variable is positively large, then the manipulated variable is negative.
- 25 4. Method according to Claim 1, 2 or 3, characterized in that the input variable and the change in the input variable are fed to a first network (ZF) where the membership functions are filed, in that the output variables of the upstream first network (ZF) are combined in an adjoining second network (U) composed of comparators and multiplexers, in that the output
30 signals of the second network (U) composed of comparators and multiplexers are combined in a third and a fourth network (01, 02), and in that the output signals of the third and fourth network (01, 02) are subtracted from one another in a subtractor (S) at whose output the actuating signal (SG) for an actuator
35 can be tapped.

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Abstract

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1. Fuzzy control loop.

2.1. In a fuzzy control loop, the so-called defuzzification is performed by means of multipliers and dividers which require a comparatively long runtime to calculate the manipulated variable.

2.2. In order substantially to reduce the runtime for calculating the manipulated variable in a fuzzy control loop, only the two states "positive" and "negative" are taken for the manipulated variable. During the defuzzification, the calculation of the manipulated variable is performed by means of a subtractor instead of by means of multipliers and dividers. As a result, the runtime is substantially reduced; the controller becomes substantially quicker.

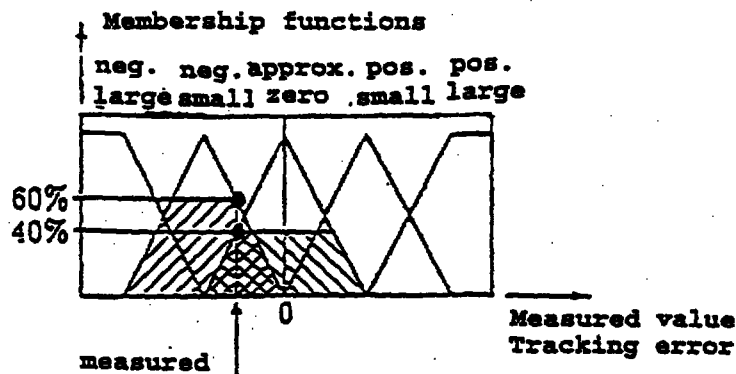
3. Fig. 3

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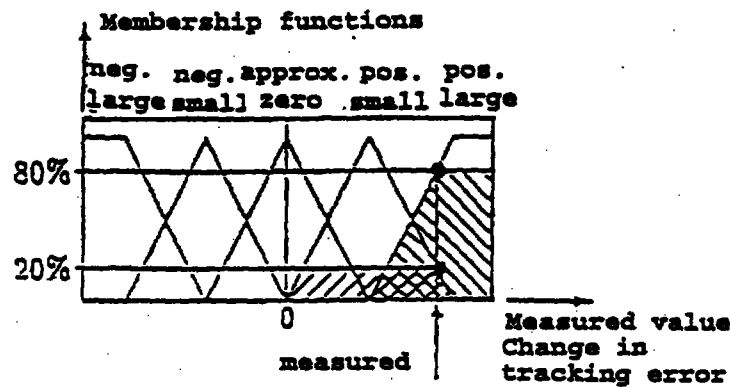
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1. Input variable



2. Input variable



Defuzzification by
calculating centres of gravity
of the hatched fuzzy
manipulated variable

Output variable

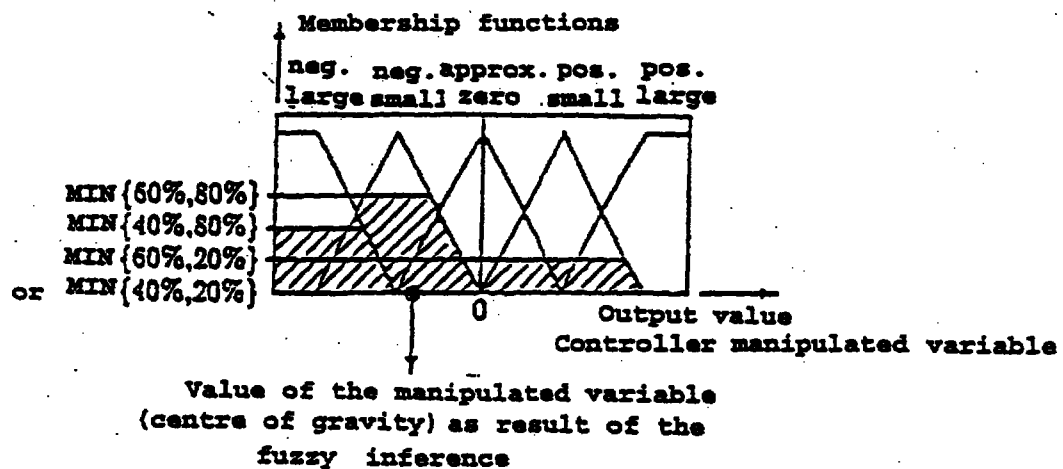


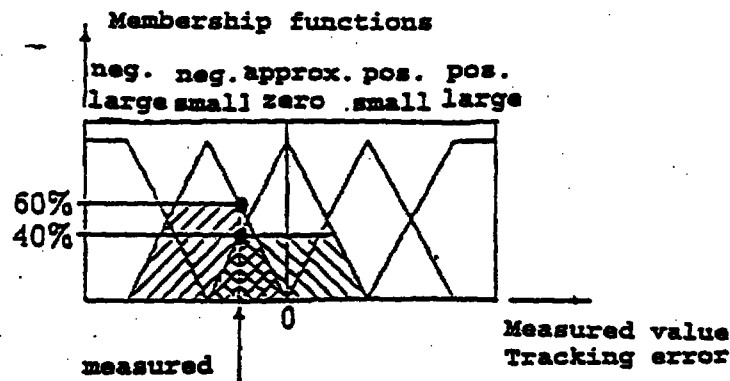
Fig. 1

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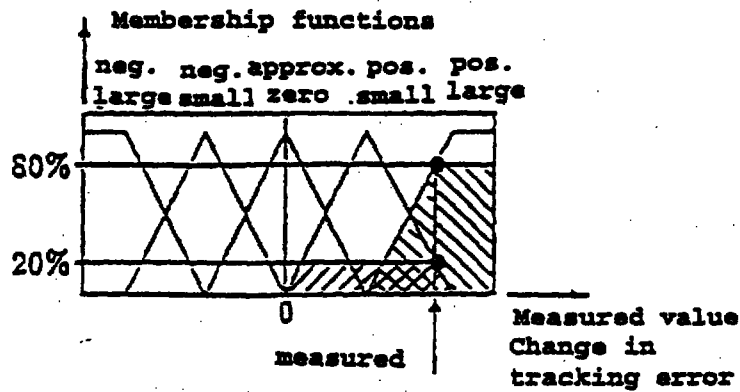
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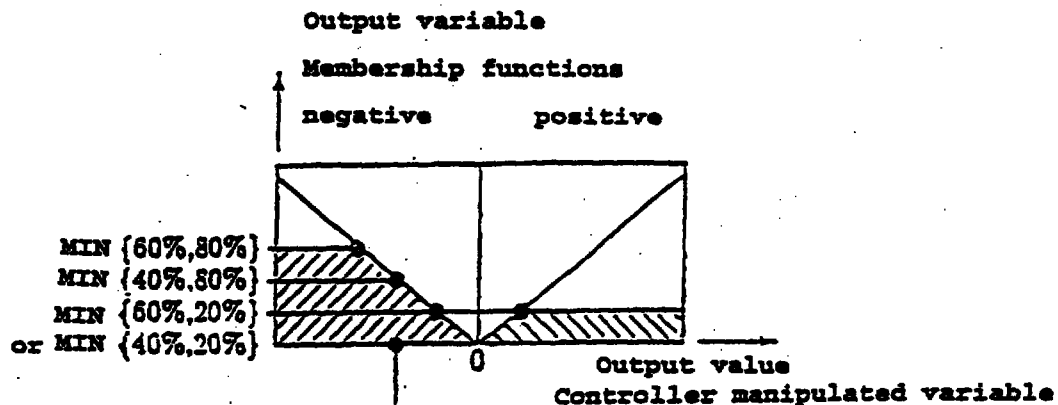
1. Input variable



2. Input variable



Defuzzification by subtracting
the maximum memberships of the
two fuzzy sets positive and negative



Value of the manipulated variable corresponds to 40 % of the negative
manipulating range (20 % positive - 60 % negative = -40 %)

Fig. 2

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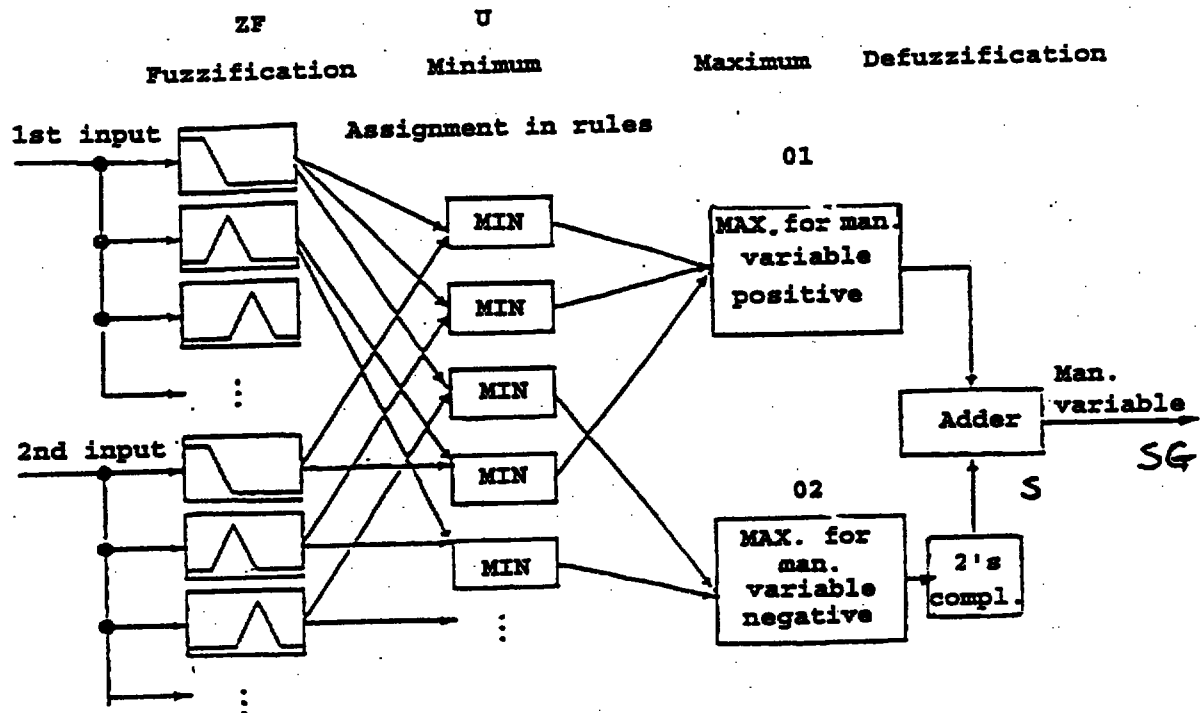


Fig. 3

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Method for Fuzzy Inference in a Fuzzy Control Loop

The invention relates to a method for fuzzy inference in a fuzzy control loop.

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The membership function specifies to what degree an element from the value range is contained in the set. A control strategy is implemented by combining the linguistic variables in their fuzzy sets.

The actuating signal is generated with the aid of simple if-then rules. The following exemplary control strategy is used in the fuzzy control.

First Rule:

If the input variable of the controller is negatively small and at the same time the change in the input variable of the controller is positively small, then the manipulated variable is positively small.

Second Rule:

If the input variable of the controller is negatively small and the change in the input variable is positively large, then the manipulated variable is negatively small.

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Third Rule:

If the input variable of the controller is approximately zero and the change in the input variable is positively small, then the manipulated variable is negatively small.

Fourth Rule:

If the input variable of the controller is approximately zero and the change in the input variable is positively large, then the manipulated variable is negatively large.

A fuzzy linguistic manipulated variable which is to be transformed into a sharp physical variable is produced as a result of the combination. In accordance with the prior art, this purpose is served by determining the centre of gravity of fuzzy output variable, the calculation of which requires a comparatively long time, because many multiplications and a division have to be carried out. The calculation of the value of the manipulated variable from the fuzzy set is also designated as defuzzification.

It is therefore the object of the invention to specify a method for a fuzzy control loop which renders the fuzzy control loop substantially faster without a substantial negative effect on the remaining controller characteristics.

The invention achieves this object by providing only two fuzzy sets "positive" and "negative" for the manipulated variable of the fuzzy controller.

The invention proceeds from the idea of dividing the manipulated variable only into two states "positive" and "negative" and no longer, as in the prior art, into arbitrary states such as, positively small, negatively small and negatively large. This measure has the advantage that the defuzzification can now be carried out only by subtraction and no longer by a series of multiplications and a division. Much time is saved as a result; the controller becomes substantially quicker because the computational outlay for subtractions

- 3 -

is substantially less than for multiplications and divisions. Nevertheless, the advantages of a fuzzy control loop are preserved.

Fig. 1 shows the membership functions of a known fuzzy control loop,

Fig. 2 shows the membership functions of a control loop according to the invention,

Fig. 3 shows an exemplary embodiment of the invention.

Fig. 1 shows the membership functions of a first and a second input variable as well as of the output variables calculated therefrom. The defuzzification is performed by calculating the centres of gravity of the hatched areas in the diagrams.

The membership functions in accordance with the invention are illustrated in Fig. 2. The defuzzification is performed by subtraction of the maximum memberships of the two sets "positive" and "negative".

An exemplary embodiment of the invention is shown in Fig. 3.

The first and the second input variables of the controller are fed to a group of blocks ZF, where the membership functions are filed. The outputs of these blocks ZF are connected to the inputs of a network U composed of comparators and multiplexers, where the minimum combinations are carried out in accordance with the rules. The outputs of the network U are connected to the inputs of a network 01 and a network 02. The maximum combinations in accordance with the rules are carried out in the two networks 01 and 02. However, in accordance with the invention a distinction is made only between "positive" and "negative" for the manipulated variable. Further states such as, for example, positively small, positively large, positively average, negatively small, negatively large, or negatively average are not provided. The outputs of the networks 01 and 02 are connected to the inputs of a subtractor S at whose output the sharp manipulated variable SG can be tapped.

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In the case of the invention, the subtractor S is provided instead of multipliers and dividers. The runtime for calculating the manipulated variable is substantially reduced by this measure. Multipliers and dividers, which are provided in the prior art instead of the subtractor, require a substantially longer runtime for calculating centres of gravity.

The fuzzy control loop according to the invention can easily be constructed from comparators, multiplexers and subtractors. By comparison with known fuzzy processors, the invention therefore represents a very simple and cost-effective implementation of a fuzzy control loop.

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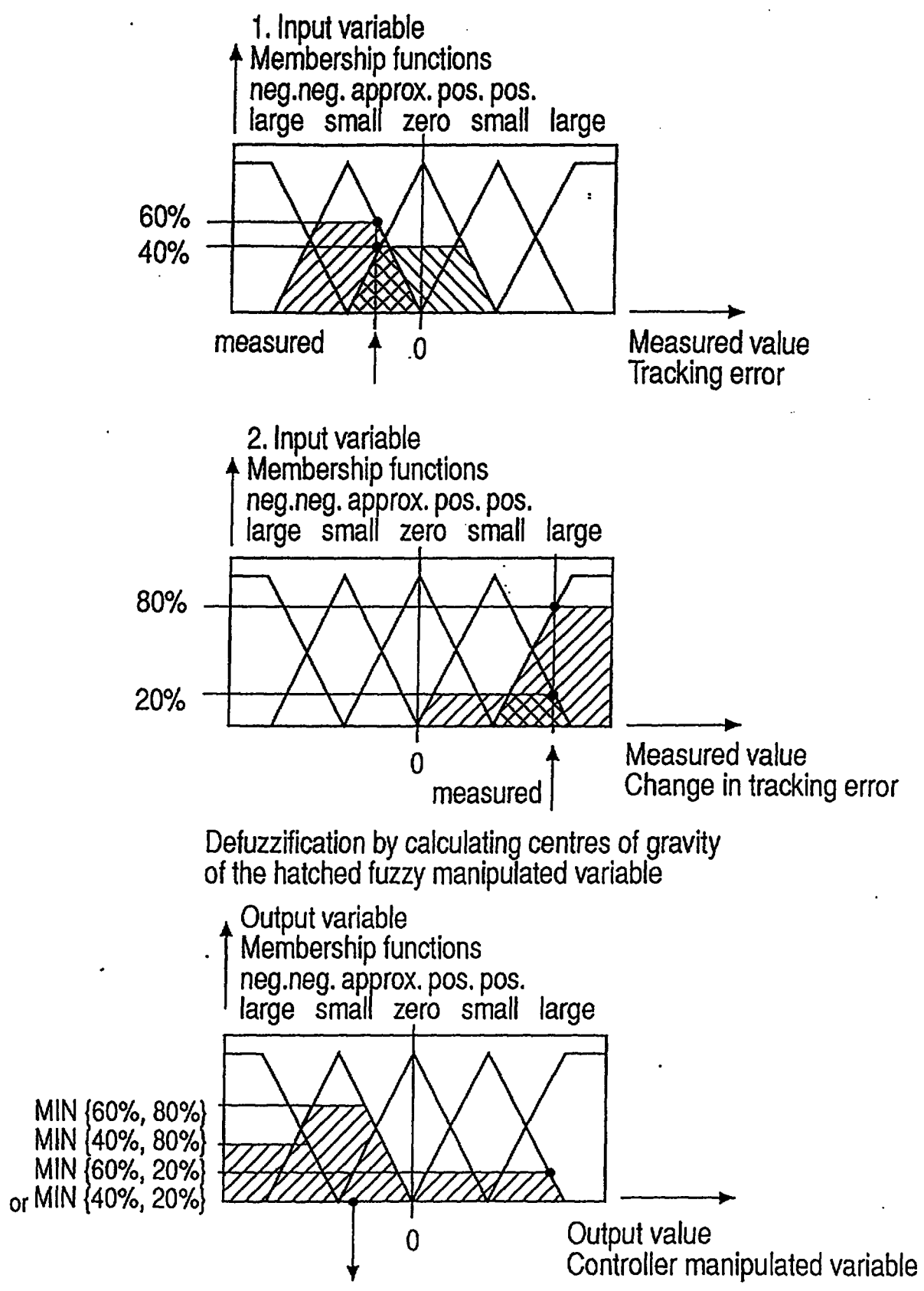
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Claims

1. Method for fuzzy inference for a fuzzy control loop, characterized in that only two fuzzy sets "positive" and "negative" are provided for the manipulated variable of the fuzzy controller.
2. Method according to Claim 1, characterized in that the defuzzification is performed by subtracting the maximum membership of the two fuzzy sets "positive" and "negative".
3. Method according to Claim 1 or 2, characterized by the following if-then rules.
If the input variable of the controller is negatively small and the change in the input variable is positively small, then the manipulated variable is positive;
If the input variable of the controller is negatively small and the change in the input variable is positively large, then the manipulated variable is negative;
If the input variable of the controller is approximately zero and the change in the input variable is positively small, then the manipulated variable is negative;
If the input variable of the controller is approximately zero and the change in the input variable is positively large, then the manipulated variable is negative.
4. Method according to Claim 1, 2 or 3, characterized in that the input variable and the change in the input variable are fed to a first network (ZF) where the membership functions are filed, in that the output variables of the upstream first network (ZF) are combined in an adjoining second network (U) composed of comparators and multiplexers, in that the output signals of the second network (U) composed of comparators and multiplexers are combined in a third and a fourth network (01, 02), and in that the output signals of the third and fourth network (01,02) are subtracted from one another in a subtractor (S) at whose output the actuating signal (SG) for an actuator can be tapped.

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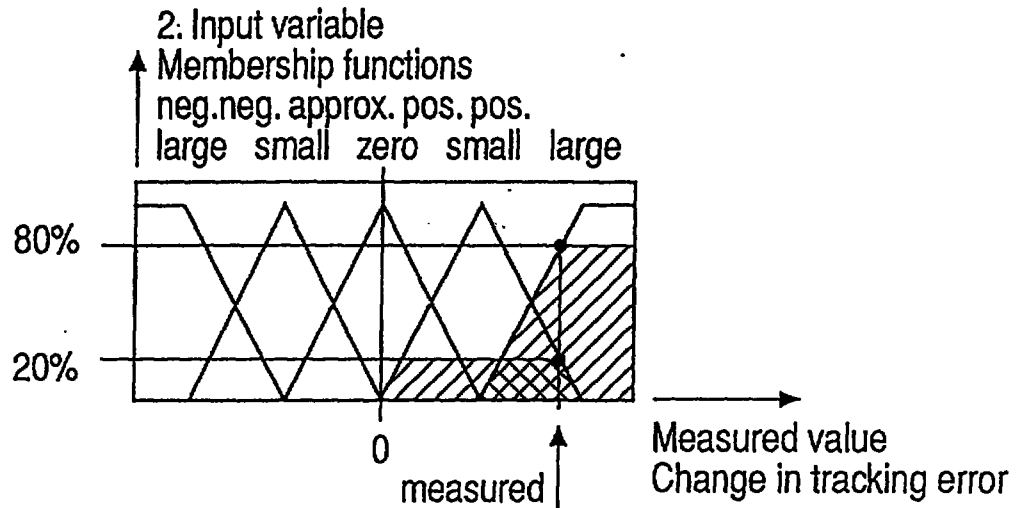
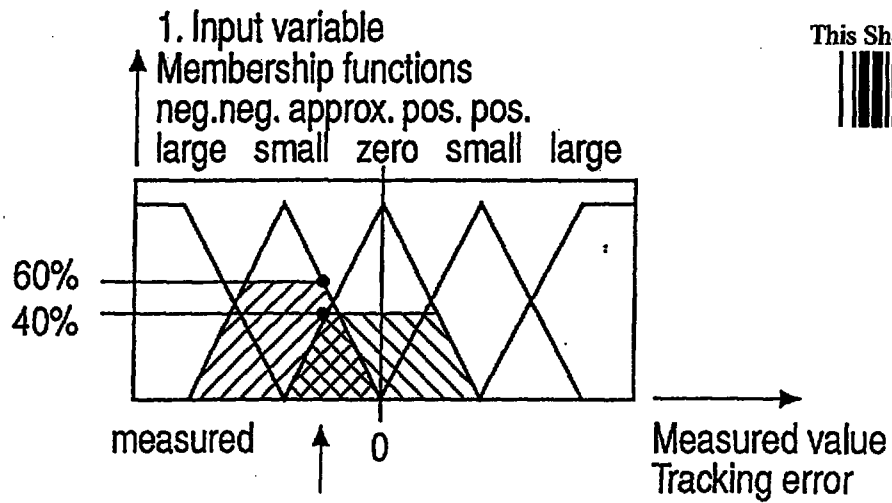


Value of the manipulated variable (centre of gravity) as result of the fuzzy inference

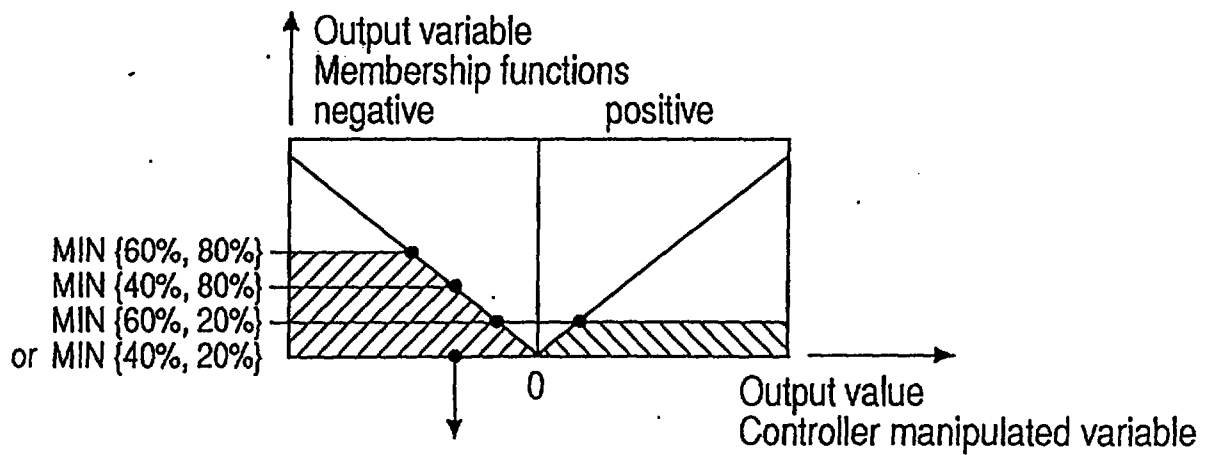
Fig.1

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Defuzzification by subtracting the maximum membership of the two fuzzy sets of positive and negative



Value of the manipulated variable corresponds to 40% of the negative manipulating range (20% positive - 60% negative = -40%)

Fig.2

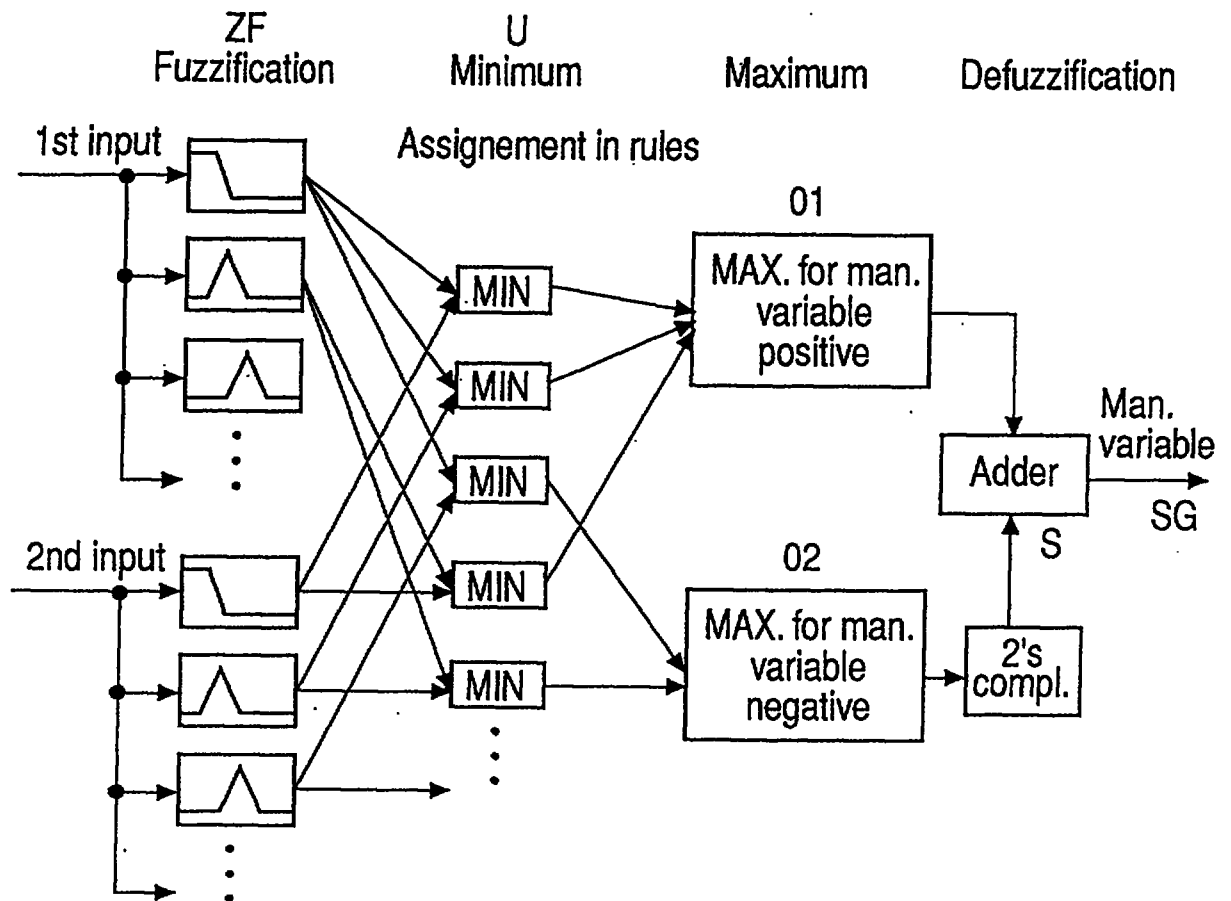
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Fig.3

Abstract**METHOD FOR FUZZY INFERENCE IN A FUZZY CONTROL LOOP**

1. Fuzzy control loop
- 2.1 In fuzzy control loop, the so-called defuzzification is performed by means of multipliers and dividers which require a comparatively long runtime to calculate the manipulated variable.
- 2.2 In order substantially to reduce the runtime for calculating the manipulated variable in a fuzzy control loop, only the two states "positive" and "negative" are taken for the manipulated variable. During the defuzzification, the calculation of the manipulated variable is performed by means of a subtractor instead of by means of multipliers and dividers. As a result, the runtime is substantially reduced; the controller becomes substantially quicker.
3. Fig. 3



Claims



1. Method for fuzzy inference for a fuzzy control loop, said control loop having at least two input variables and providing an output manipulated variable for an actuating signal, said control loop also having a plurality of linguistic expressions for each input variable and first membership functions each being assigned to one linguistic expression, said control loop also having a set of if-then rules, wherein the rules are declared to be "positive" or "negative" if-then rules dependent on their statement in the "then"-part of the rule whether the output manipulated variable has to be "positive" or "negative", the control loop also having second membership functions for each "positive" if-then rule and third membership functions for each "negative" if-then-rule comprising the steps of:
 - determining the relevant linguistic expressions for the measured value of each input variable based on the assigned first membership functions,
 - applying said if-then rules to the relevant linguistic expressions of the values of the input variables,
 - determining the membership values for each if-then-rule based on the second and third membership functions,
 - subtracting the maximum membership value of all "negative" if-then rules, from the maximum membership value of all "positive" if-then-rules,
 - determining the value for the output manipulated variable for said actuating signal based on the result of the subtracting step.
2. Method according to claim 1, wherein said set of if-then-rules include the following rules,
 - if said first input variable is "negatively small" and a change in said first input variable is "positively small", then said output manipulated variable is "positive",

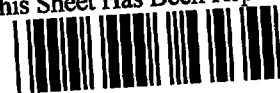
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- if said first input variable is "negatively small" and a change in said first input variable is "positively large", then said output manipulated variable is "negative",
 - if said first input variable is "approximately zero" and a change in said first input variable is "positively small", then said output manipulated variable is "negative", and
 - if said first input variable is "approximately zero" and a change in said first input variable is "positively large", then said output manipulated variable is "negative".
3. Method according to claim 1, wherein said output manipulated variable is an actuating signal and said step of determining the membership values for each if-then-rule includes the step of combining outputs derived by applying said first membership functions to said first and second input variables using comparators and multiplexers.
4. Method according to claim 1 to 3, wherein said second input variable is the change in said first input variable.

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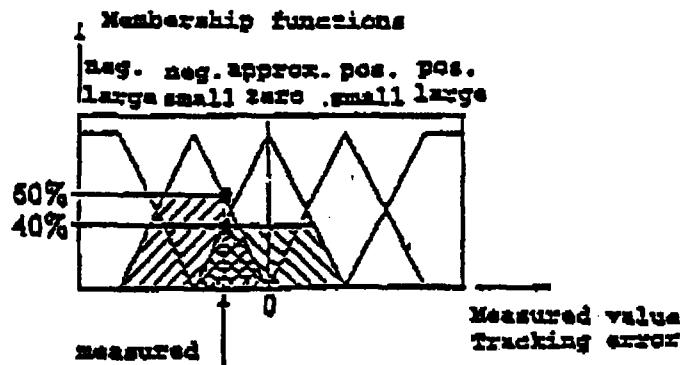
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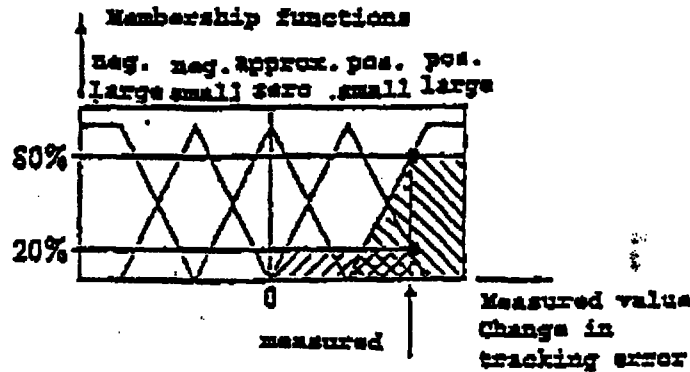


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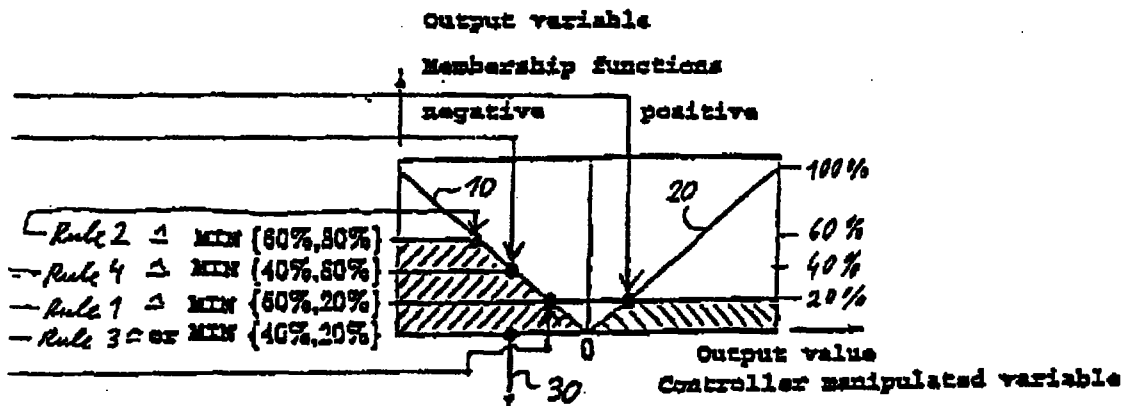
1. Input variable



2. Input variable



Defuzzification by subtracting
the maximum memberships of the
two fuzzy sets positive and negative



Value of the manipulated variable corresponds to 40 % of the negative
manipulating range (20 % positive - 60 % negative = -40 %)

Fig.. 2



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Claims

1. Method for fuzzy inference for a fuzzy control loop, said control loop having at least two input variables and providing an output manipulated variable for an actuating signal, said control loop also having a plurality of linguistic expressions for each input variable and first membership functions each being assigned to one linguistic expression, said control loop also having a set of if-then rules, wherein the rules are declared to be "positive" or "negative" if-then rules dependent on their statement in the "then"-part of the rule whether the output manipulated variable has to be "positive" or "negative", the control loop also having second membership functions for each "positive" if-then rule and third membership functions for each "negative" if-then-rule comprising the steps of:
 - determining the relevant linguistic expressions for the measured value of each input variable based on the assigned first membership functions,
 - applying said if-then rules to the relevant linguistic expressions of the values of the input variables,
 - determining the membership values for each if-then-rule based on the second and third membership functions,
 - subtracting the maximum membership value of all "negative" if-then rules, from the maximum membership value of all "positive" if-then-rules,
 - determining the value for the output manipulated variable for said actuating signal based on the result of the subtracting step.
2. Method according to claim 1, wherein said set of if-then-rules include the following rules,
 - if said first input variable is "negatively small" and a change in said first input variable is "positively small", then said output manipulated variable is "positive",

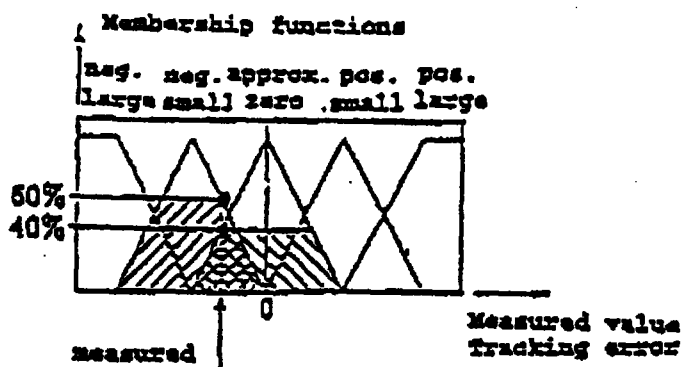
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- if said first input variable is "negatively small" and a change in said first input variable is "positively large", then said output manipulated variable is "negative",
 - if said first input variable is "approximately zero" and a change in said first input variable is "positively small", then said output manipulated variable is "negative", and
 - if said first input variable is "approximately zero" and a change in said first input variable is "positively large", then said output manipulated variable is "negative".
3. Method according to claim 1, wherein said output manipulated variable is an actuating signal and said step of determining the membership values for each if-then-rule includes the step of combining outputs derived by applying said first membership functions to said first and second input variables using comparators and multiplexers.
4. Method according to claim 1 to 3, wherein said second input variable is the change in said first input variable.

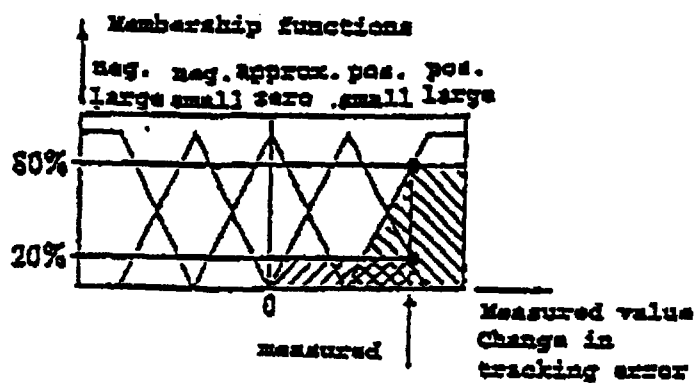
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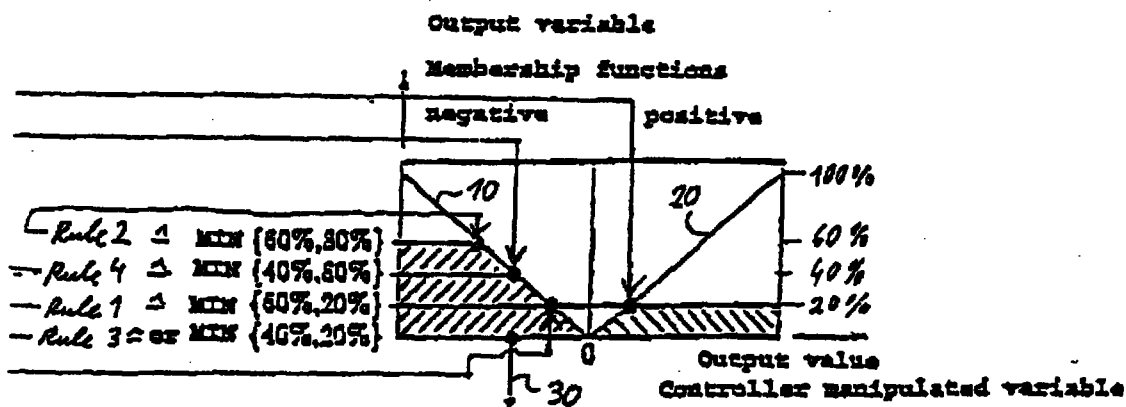
1. Input variable



2. Input variable



Defuzzification by subtracting the maximum memberships of the two fuzzy sets positive and negative



Value of the manipulated variable corresponds to 40 % of the negative manipulating range (20 % positive - 40 % negative = -40 %)

Fig. 2