BASIC KNOWLEDGE

FUZZY CONTROL

Fuzzy control is nowadays an important branch of control engineering. Conventional approaches have not been displaced but have been enhanced considerably in some fields of application.
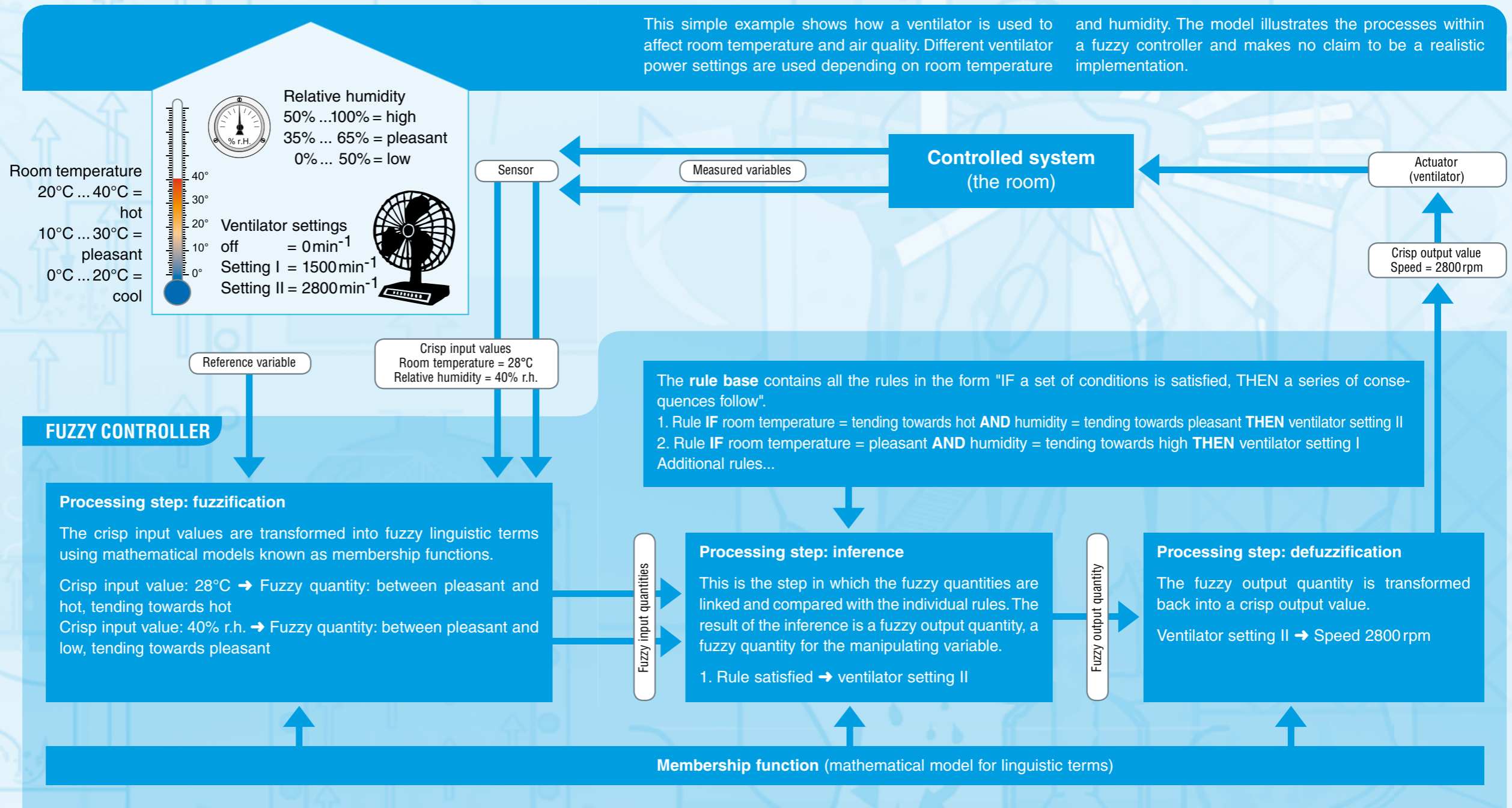
Until now, the fuzzy controller has achieved its greatest success in the industrial and commercial application of fuzzy methods.

Fuzzy controllers are non-linear controllers. Any non-linearity in the controlled system can be compensated for by an appropriate choice of membership functions and by establishing a rule base. Membership functions are the mathematical models for linguistic terms, such as triangular function, trapezoidal function or Gaussian function.

Like a conventional controller, the fuzzy controller transforms input variables into output variables that then act upon the process or the controlled system. Various input and output variables are linked together to allow complex systems to be easily controlled. The input and output values are crisp values in the form of signals. The fuzzy values that are typical of fuzzy methods only play a role within the controller.

Three processing steps take place within a fuzzy controller: fuzzification, inference and defuzzification.

The design of a fuzzy controller involves the selection of the input/output variables, the determination of the membership functions and the establishment of a rule base.

This simple example shows how a ventilator is used to affect room temperature and air quality. Different ventilator power settings are used depending on room temperature and humidity. The model illustrates the processes within a fuzzy controller and makes no claim to be a realistic implementation.

Relative humidity
50% ...100% = high
35% ... 65% = pleasant
0% ... 50% = low

Room temperature
20°C ... 40°C = hot
10°C ... 30°C = pleasant
0°C ... 20°C = cool

Ventilator settings
off = $0\,min^{-1}$
Setting I = $1500\,min^{-1}$
Setting II = $2800\,min^{-1}$

Sensor

Measured variables

Controlled system
(the room)

Actuator
(ventilator)

Crisp output value
Speed = 2800 rpm

Reference variable

Crisp input values
Room temperature = 28°C
Relative humidity = 40% r.h.

FUZZY CONTROLLER

The **rule base** contains all the rules in the form "IF a set of conditions is satisfied, THEN a series of consequences follow".
1. Rule **IF** room temperature = tending towards hot **AND** humidity = tending towards pleasant **THEN** ventilator setting II
2. Rule **IF** room temperature = pleasant **AND** humidity = tending towards high **THEN** ventilator setting I
Additional rules...

Processing step: fuzzification

The crisp input values are transformed into fuzzy linguistic terms using mathematical models known as membership functions.

Crisp input value: 28°C ➜ Fuzzy quantity: between pleasant and hot, tending towards hot
Crisp input value: 40% r.h. ➜ Fuzzy quantity: between pleasant and low, tending towards pleasant

Fuzzy input quantities

Processing step: inference

This is the step in which the fuzzy quantities are linked and compared with the individual rules. The result of the inference is a fuzzy output quantity, a fuzzy quantity for the manipulating variable.

1. Rule satisfied ➜ ventilator setting II

Fuzzy output quantity

Processing step: defuzzification

The fuzzy output quantity is transformed back into a crisp output value.

Ventilator setting II ➜ Speed 2800 rpm

Membership function (mathematical model for linguistic terms)

Advantages of fuzzy controllers
- Multivariable control systems can be realised quickly, problem-oriented and comprehensible. This is particularly true if there is no model of the controlled system, or if the model displays an unfavourable non-linear structure.
- The response of a system is described in linguistically defined terms and is therefore simpler to understand than a mathematical one.
- The rule base and the definition of the fuzzy quantity can be added to or modified retrospectively.

Limits of fuzzy controllers
- In conventional control engineering, the controlled system is first modelled. This model is then used to design the controller. By contrast, a fuzzy controller is designed directly from the experiences gained from existing controllers or human input. Errors made during the creation phase are therefore very difficult to correct later.
- As the complexity of the system increases, the amount of work required to develop a fuzzy controller increases superproportionately.
- It's very difficult to find the right defuzzification method. The calculation of the crisp output value is either:
  a) complicated, slow and good
  or
  b) fast, but with a poor result