Sugeno Fuzzy Inference

Sugeno Fuzzy Inference

- Difference between Mamdani and Sugeno is that Sugeno output membership functions are either linear or constant
- Mamdani-style inference, as we have just seen, requires us to find the centroid of a two-dimensional shape by integrating across a continuously varying function. In general, this process is not computationally efficient.
- Michio Sugeno suggested to use a single spike, a singleton, as the membership function of the rule consequent.
- A singleton, or more precisely a fuzzy singleton, is a fuzzy set with a membership function that is unity at a single particular point on the universe of discourse and zero everywhere else

Sugeno Fuzzy Inference

- Sugeno fuzzy model (also known as **TSK fuzzy model**) was proposed by Takagi, Sugeno and Kang
- Sugeno-style fuzzy inference is very similar to the Mamdani method.
- Sugeno changed only a rule consequent: instead of a fuzzy set, he used a mathematical function of the input variable.
- The format of the Sugeno-style fuzzy rule is

  IF x is A AND y is B THEN z is f(x, y)

  where:

  - x, y and z are linguistic variables;
  - A and B are fuzzy sets on universe of discourses X and Y, respectively;
  - f (x, y) is a mathematical function.

Sugeno Fuzzy Inference

- z= f(x, y)is a crisp function in the consequent.
- Usually f(x, y)is a polynomial of the input variables x and y. but it can be any function.
- When f(x, y)is a first-order polynomial, the resulting fuzzy inference system is called a first-order Sugeno fuzzy model, for example z=ax + by +c.
- When f is a constant, we then have a zero-order Sugeno fuzzy model,(z=ax+by+c where (a = b = 0)) which can be viewed either as a special case of the Mamdani Fuzzy inference system in which each rule's consequent is specified by a fuzzy singleton.

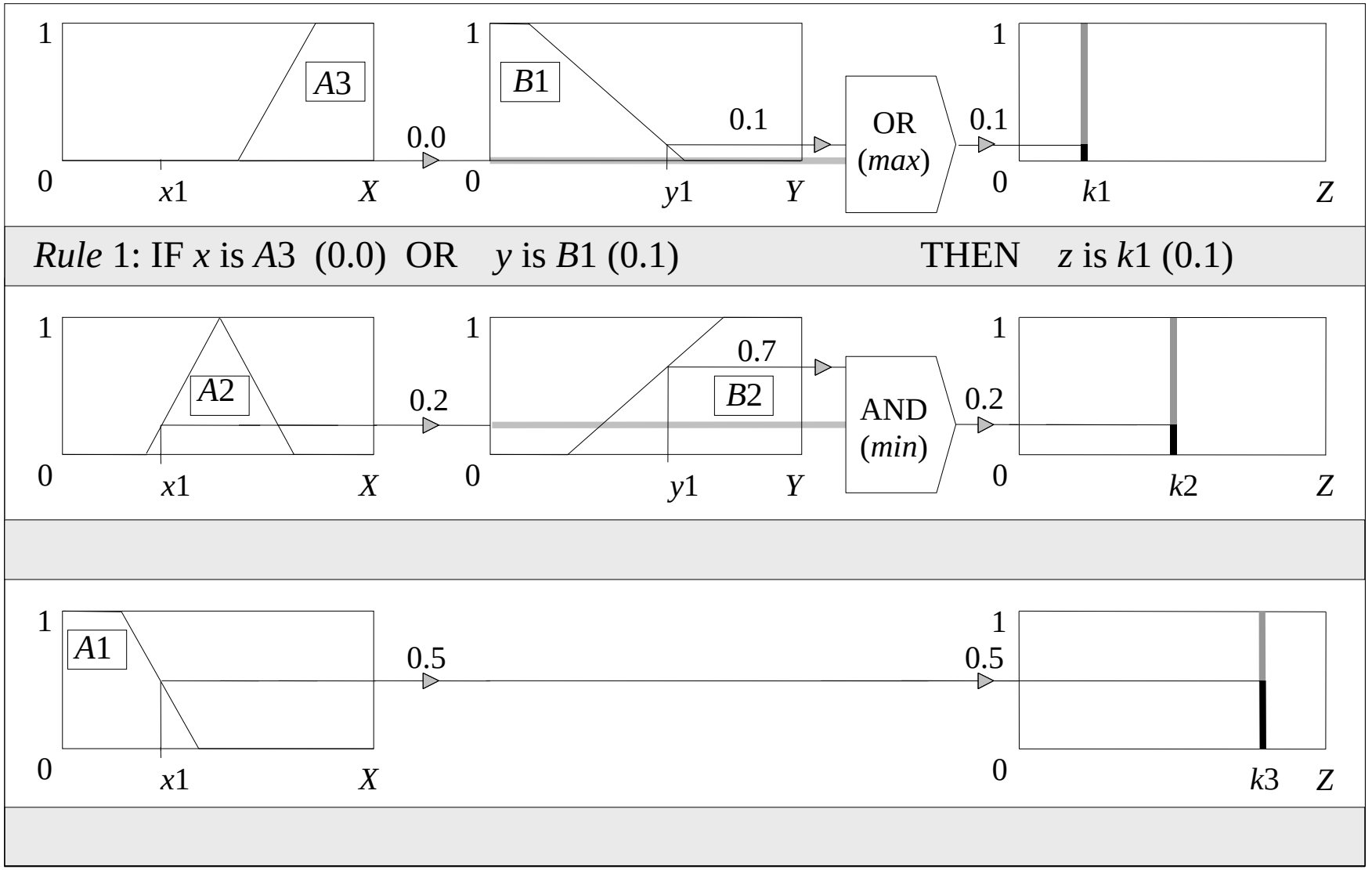
Sugeno Fuzzy Inference

- The most commonly used zero-order Sugeno fuzzy model applies fuzzy rules in the following form:

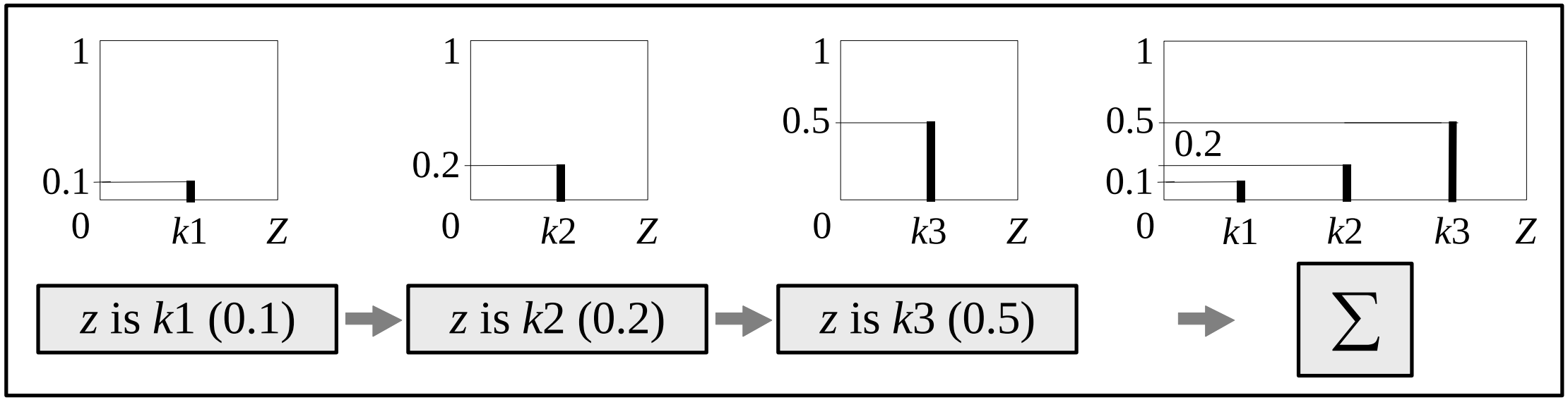
  IF x is A AND y is B THEN z is k

- where k is a constant.
- In this case, the output of each fuzzy rule is constant and all consequent membership functions are represented by singleton spikes.

Sugeno rule evaluation



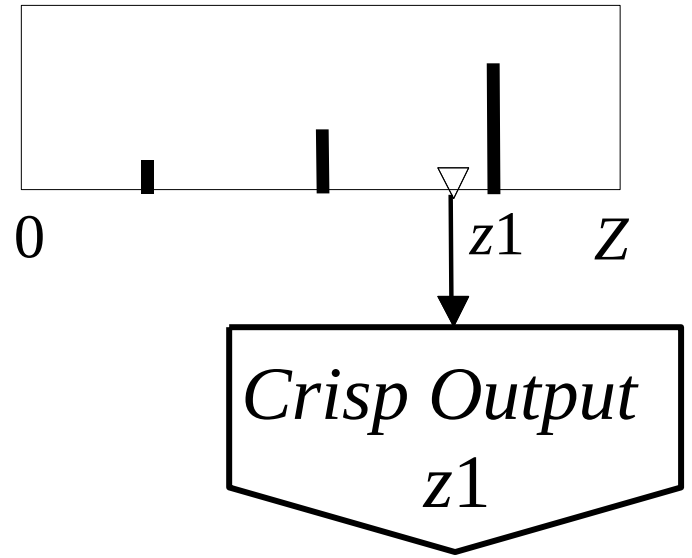
Sugeno Aggregation



Sugeno Defuzzification

Weighted Average (WA)

$$WA = \frac{\mu(k1) \times k1 + \mu(k2) \times k2 + \mu(k3) \times k3}{\mu(k1) + \mu(k2) + \mu(k3)} = \frac{0.1 \times 20 + 0.2 \times 50 + 0.5 \times 80}{0.1 + 0.2 + 0.5} = 65$$



How to make a decision on which method to apply – Mamdani or Sugeno?

- Mamdani method is widely accepted for capturing expert knowledge. It allows us to describe the expertise in more intuitive, more human-like manner. However, Mamdani-type fuzzy inference entails a substantial computational burden.

- On the other hand, Sugeno method is computationally effective and works well with optimization and adaptive techniques, which makes it very attractive in control problems, particularly for dynamic nonlinear systems.