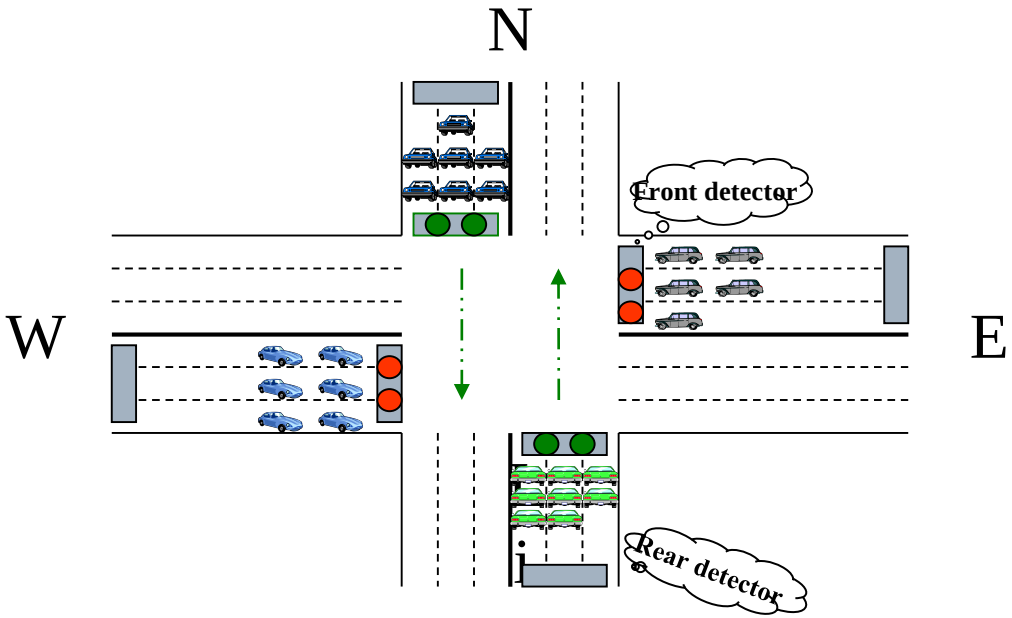
3.3 퍼지 이론을 이용한 제어 시스템의 개발 방법

– 설계 프로젝트 사례를 중심으로 –

1) 퍼지 기법을 이용한 신호등 제어 시스템 설계 프로젝트

- 개요



- 진입차량수 : 녹색 신호에 진입하는 차량 수
  - N (7대), Light (8대) = 15대
- 대기차량수 : 적색 신호에 대기하는 차량 수
  - W (6대), E (5대) = 11대
- 이상의 경우 직진을 위한 녹색 신호를 얼마나 더 연장하는 것이 합리적일까?

입출력 정보 및 시스템 구성도

- 입력 = {도착차량수(A), 대기차량수(Q)}
- Output = {직진신호연장시간(E)}
- 퍼지 신호등 제어 시스템

추론 기법

- 추론
  - 기본 정보
    - 직진신호시간 : 18초 (A=10, Q=10 일 경우)
  - 직진신호연장시간 : 직진신호시간 이외의 연장시간

r1: A=10 & Q=20 then E=0초

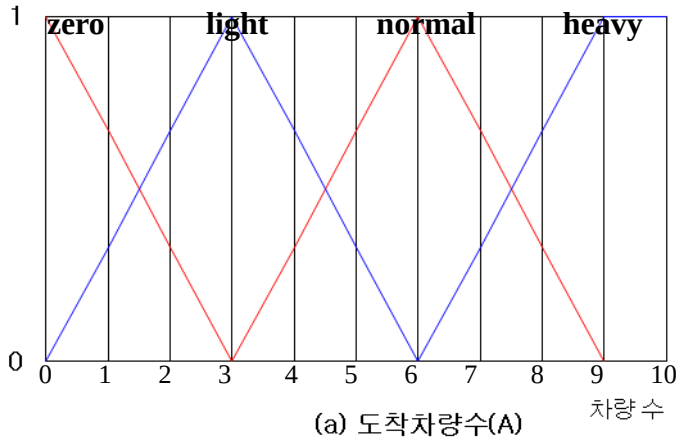
r2: A=20 & Q=5 then E=10초

r3: A=0 & Q=0 then E=?초

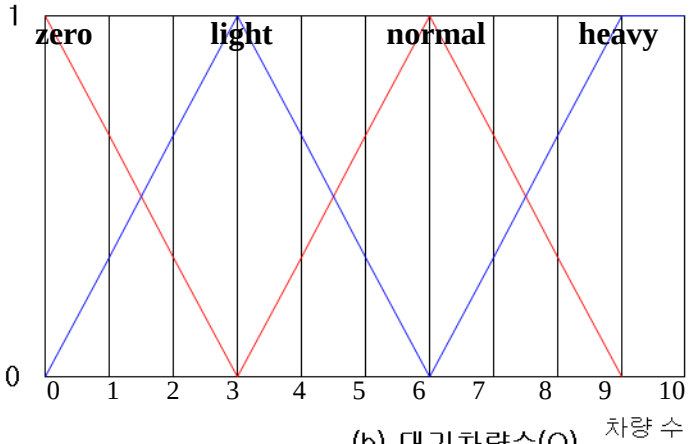
=> 이상의 규칙들에서 연장시간을 어떻게 산정할 것인가를 결정하기 위하여 퍼지 기법을 활용

퍼지 함수의 정의

- 입력 퍼지 함수의 정의

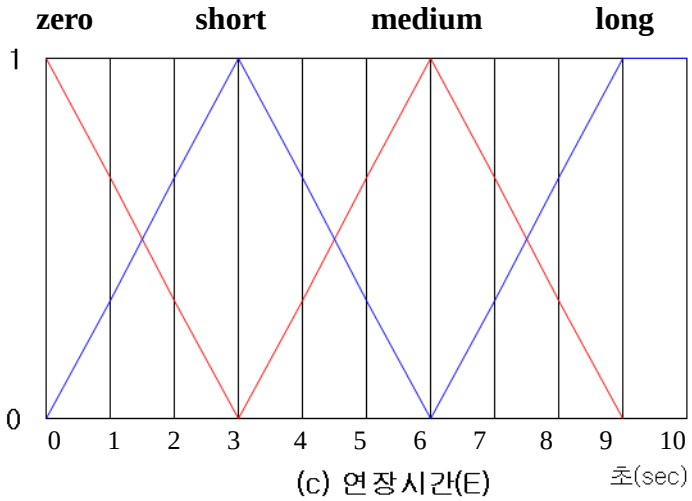


(a) 도착차량수(A)



(b) 대기차량수(Q)

- 출력 퍼지 함수의 정의



(c) 연장시간(E)

퍼지 제어 규칙

- 도표로 나타낸 퍼지 제어 규칙

A \ Q	ZERO	LIGHT	NORMAL	HEAVY
ZERO	ZERO	ZERO	ZERO	ZERO
LIGHT	SHORT	ZERO	ZERO	ZERO
NORMAL	MEDIUM	SHORT	ZERO	ZERO
HEAVY	LONG	MEDIUM	SHORT	ZERO

퍼지 제어 규칙

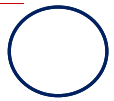
- if~then 구조로 나타낸 퍼지 제어 규칙

R1: if A = Zero and Q = Zero then E = Zero
R2: if A = Zero and Q = Light then E = Zero
R3: if A = Zero and Q = Normal then E = Zero
R4: if A = Zero and Q = Heavy then E = Zero
R5: if A = Light and Q = Zero then E = Short
R6: if A = Light and Q = Light then E = Zero
R7: if A = Light and Q = Normal then E = Zero
R8: if A = Light and Q = Heavy then E = Zero
R9: if A = Normal and Q = Zero then E = Medium
R10: if A = Normal and Q = Light then E = Short
R11: if A = Normal and Q = Normal then E = Zero
R12: if A = Normal and Q = Heavy then E = Zero
R13: if A = Heavy and Q = Zero then E = Long
R14: if A = Heavy and Q = Light then E = Medium
R15: if A = Heavy and Q = Normal then E = Short
R16: if A = Heavy and Q = Heavy then E = Zero

퍼지 제어 규칙의 적용 예

- A = 7 이고 Q = 5 일 때 E = ?

R1 : if A(Zero) = 0 and Q(Zero) = 0 then E(Zero) = 0초
R2 : if A(Zero) = 0 and Q(Light) = 0.2 then E(Zero) = 0초
R3 : if A(Zero) = 0 and Q(Normal) = 0.8 then E(Zero) = 0초
R4 : if A(Zero) = 0 and Q(Heavy) = 0 then E(Zero) = 0초
R5 : if A(Light) = 0 and Q(Zero) = 0 then E(Short) = 3초
R6 : if A(Light) = 0 and Q(Light) = 0.2 then E(Zero) = 0초
R7 : if A(Light) = 0 and Q(Normal) = 0.8 then E(Zero) = 0초
R8 : if A(Light) = 0 and Q(Heavy) = 0 then E(Zero) = 0초
R9 : if A(Normal) = 0.7 and Q(Zero) = 0 then E(Medium) = 6초
R10 : if A(Normal) = 0.7 and Q(Light) = 0.2 then E(Short) = 3초
R11 : if A(Normal) = 0.7 and Q(Normal) = 0.8 then E(Zero) = 0초
R12 : if A(Normal) = 0.7 and Q(Heavy) = 0 then E(Zero) = 0초
R13 : if A(Heavy) = 0.4 and Q(Zero) = 0 then E(Long) = 9초
R14 : if A(Heavy) = 0.4 and Q(Light) = 0.2 then E(Medium) = 6초
R15 : if A(Heavy) = 0.4 and Q(Normal) = 0.8 then E(Short) = 3초
R16 : if A(Heavy) = 0.4 and Q(Heavy) = 0 then E(Zero) = 0초



추론 결과 도출 기법

- 비퍼지화(defuzzification) 방법

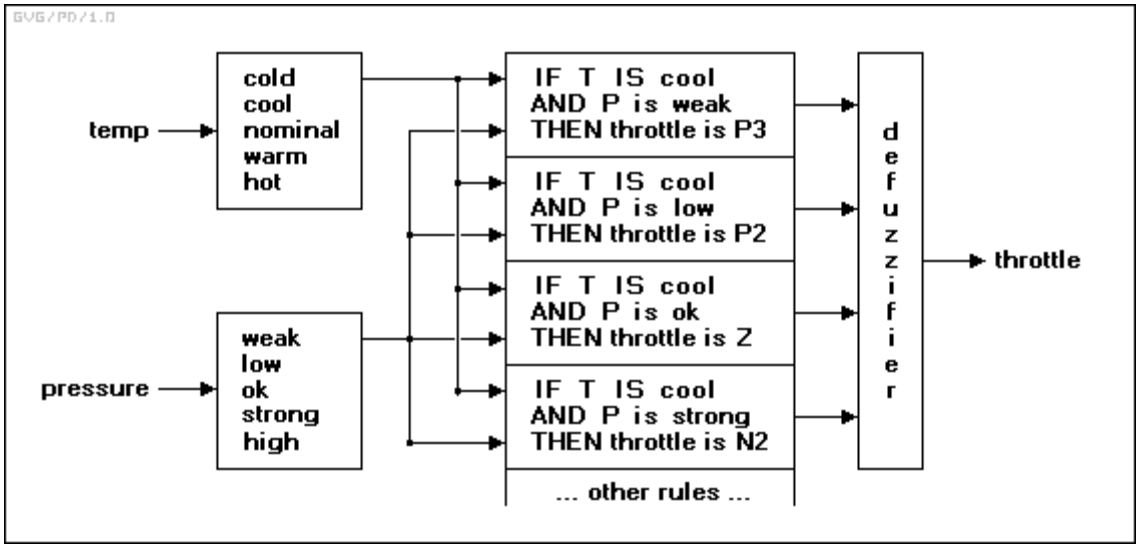
$$z^* = \frac{\sum \mu_C(\bar{z}) \cdot \bar{z}}{\sum \mu_C(\bar{z})} = \frac{0.2\times 3 + 0.7\times 0 + 0.2\times 6 + 0.4\times 3}{0.2 + 0.7 + 0.2 + 0.4} \approx 2\,\text{sec}$$

  - Where $\sum$ denotes the algebraic sum and $\bar{z}$ is the centroid of each symmetric membership functions

  - 따라서 앞의 예와 같은 상황에서는 직진 신호를 약 2초 정도 연장하는 것이 합리적인 결정이다.

2) 증기 터빈 제어 예

- As a general example, consider the design of a fuzzy controller for a steam turbine. The block diagram of this control system appears as follows:

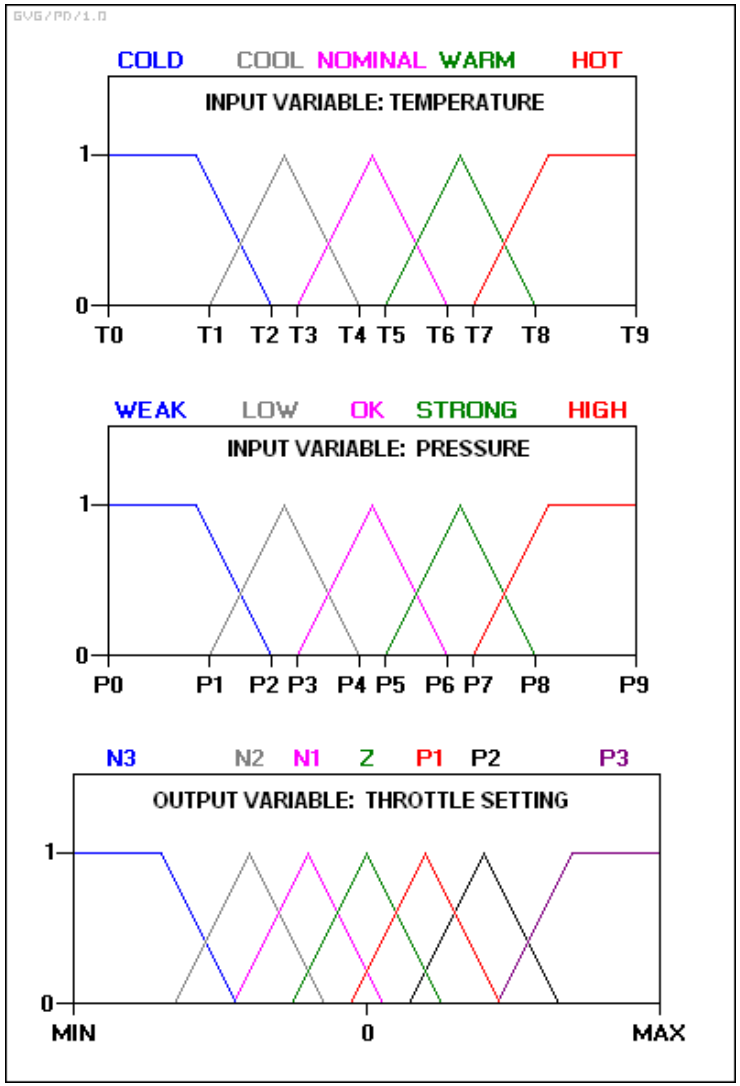


퍼지 함수 및 규칙의 정의

- There are two input variables, temperature and pressure, and a single output variable, the turbine throttle setting. The turbine's operation can be reversed, so the throttle setting can be positive or negative. The fuzzy set mappings are shown below:

- The throttle settings are defined as follows:
  N3: Large negative.
  N2: Medium negative.
  N1: Small negative.
  Z: Zero.
  P1: Small positive.
  P2: Medium positive.
  P3: Large positive.

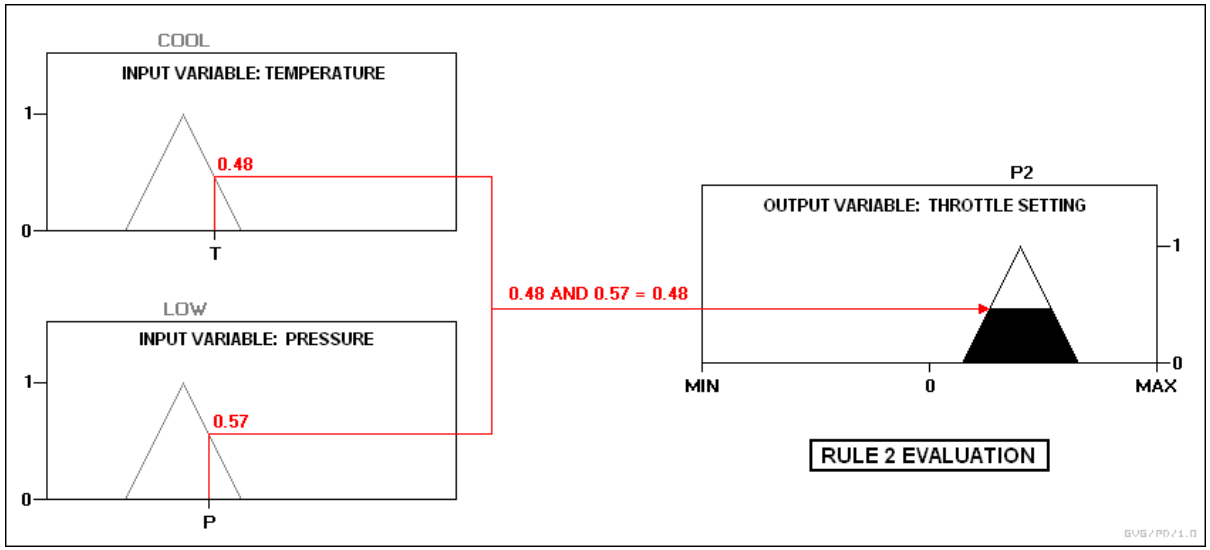
- The rule set includes such rules as:
  rule 1: IF temperature IS cool AND pressure IS weak, THEN throttle is P3.
  rule 2: IF temperature IS cool AND pressure IS low, THEN throttle is P2.
  rule 3: IF temperature IS cool AND pressure IS ok, THEN throttle is Z.
  rule 4: IF temperature IS cool AND pressure IS strong, THEN throttle is N2.



퍼지 추론 방법

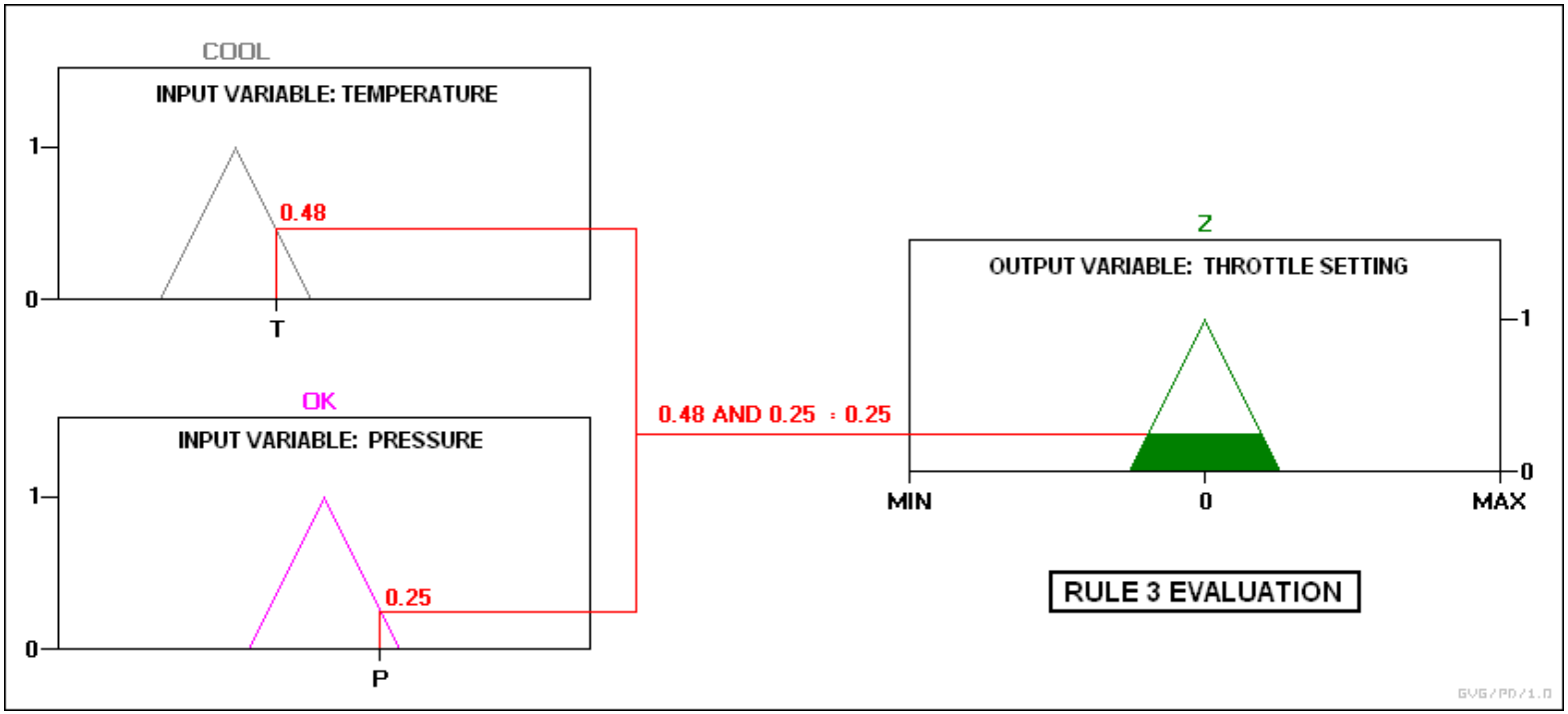
- In practice, the controller accepts the inputs and maps them into their membership functions and truth values. These mappings are then fed into the rules. If the rule specifies an AND relationship between the mappings of the two input variables, as the examples above do, the minimum of the two is used as the combined truth value; if an OR is specified, the maximum is used. The appropriate output state is selected and assigned a membership value at the truth level of the premise. The truth values are then defuzzified.

- For an example, assume the temperature is in the "cool" state, and the pressure is in the "low" and "ok" states. The pressure values ensure that only rules 2 and 3 fire. Rule 2 is evaluated as follows:



퍼지 추론 방법

- Rule 3 is evaluated as follows:



퍼지 추론 방법

- The two outputs are then combined: