

Tutorial for

Introduction to Computational Intelligence in Winter 2015/16

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Lecture website: <https://tinyurl.com/CI-WS2015-16>

Sheet 4, Block II

10 December 2015

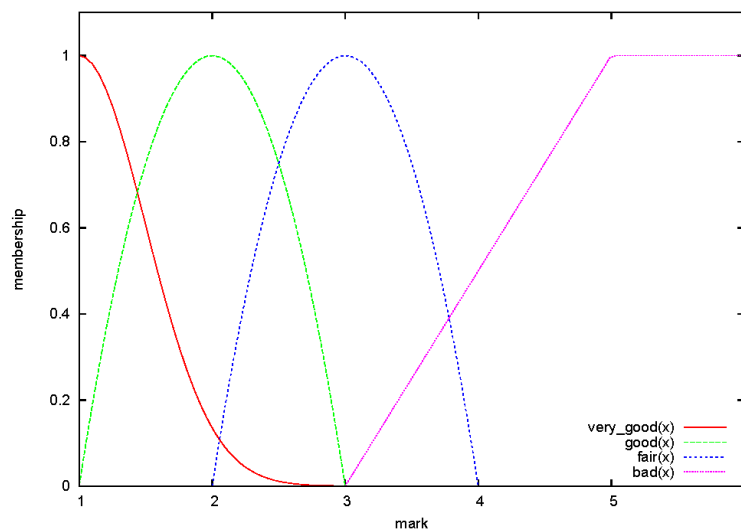
Due date: 13 January 2016, 2pm

Discussion: 14/15 January 2016

Exercise 4.1: Fuzzy Inference (5 Points)

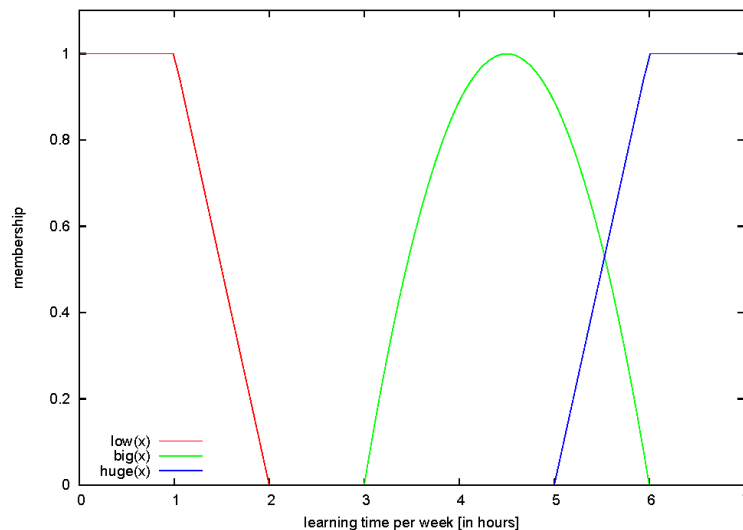
Consider the membership functions for the linguistic terms of the linguistic variable **mark**. Notice that outside the given range their values are zero!

$$\begin{aligned}\text{very_good}(x) &= \exp(-2(x-1)^2) \text{ for } x \geq 1 \\ \text{good}(x) &= -(x-1)(x-3) \text{ for } x \in (1,3) \\ \text{fair}(x) &= -(x-2)(x-4) \text{ for } x \in (2,4) \\ \text{bad}(x) &= \min\{1, \frac{1}{2}(x-3)\} \text{ for } x > 3\end{aligned}$$



Below you can find the membership functions for the linguistic terms of the linguistic variable **learning_time**. Again, outside the given range their values are zero!

$$\begin{aligned}\text{huge}(x) &= \min\{x-5, 1\} \text{ for } x \geq 5 \\ \text{big}(x) &= -\frac{4}{9}(x-3)(x-6) \text{ for } x \in (3,6) \\ \text{low}(x) &= \min\{2-x, 1\} \text{ for } x < 2\end{aligned}$$



Consider the fuzzy proposition

if `learning_time` is `big` then mark is `good`,

and the given fuzzy fact

`mark` is `fair`.

Deduce the resulting fuzzy set over learning time using the Łukaciewicz implication $\text{Imp}(a, b) = \min\{1, 1 - a + b\}$ and the max-prod composition.

Sketch the membership function. Hint: Discretize the function and use a table of values.

Exercise 4.2: Fuzzy Implication (5 Points)

- a) Use the increasing generator $g(x) = \sqrt{x}$ to derive a fuzzy implication. Does the resulting implication fulfill the axiom of contraposition? You are not allowed to use the theorem on slide 33 in lecture 7.
- b) Check for all fuzzy implications below if they fulfill the axiom of contraposition, again without using the theorem (lec 7, slide 33):
 - Reichenbach $\text{Imp}(a, b) = 1 - a + ab$
 - Łukaciewicz $\text{Imp}(a, b) = \min\{1, 1 - a + b\}$
 - Gödel $\text{Imp}(a, b) = \begin{cases} 1 & a \leq b \\ b & \text{otherwise} \end{cases}$

Exercise 4.3: Fuzzy Controller (10 Points)

Script `trainsim.R` contains a simple simulator for a train. The function `trainspeed(currentSpeed, force)` returns the speed on the following time step. The new speed is calculated based on the speed at the time and the applied force: negative values mean braking, positive values acceleration.

The value of the acceleration/braking force can be in the interval $[-200, 25]$. In combination with the other parameters, this means that the maximum speed of the train is 42.8 m/s (≈ 154 km/h) and the

braking distance is 697 m. The traveled distance in meter can be obtained by simply summing the returned speeds, because the unit is m/s and we use time steps of one second in the simulation.

Your task is to implement a Mamdani controller for the speed of a train in R that helps the train to travel a given distance as precisely and fast as possible (imagine that the train tracks end in a terminal station).

- a) Using your own perception, define membership functions for the linguistic variables *speed*, *remaining distance*, and *driving/braking force*.
- b) Define a comprehensible fuzzy rule system for the controller.
- c) Implement the control loop for the Mamdani controller using the center of gravity method for defuzzification.
- d) Comment your sourcecode.
- e) Start the train for a desired travel distance of 1000 m and 10 km with initial speeds of 0, 20, and 42.8 m/s. Report for each of the six settings the traveled distance and the required time. Plot the train's speed over time.