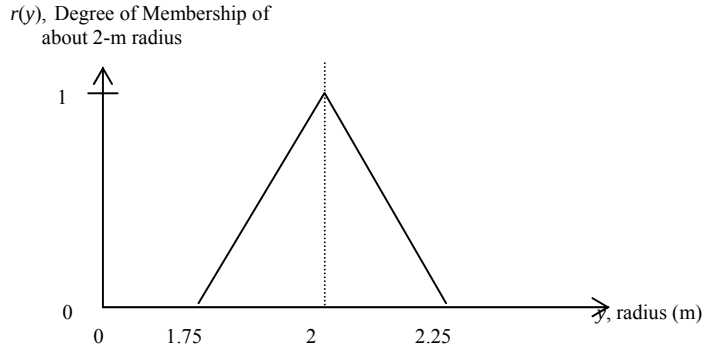
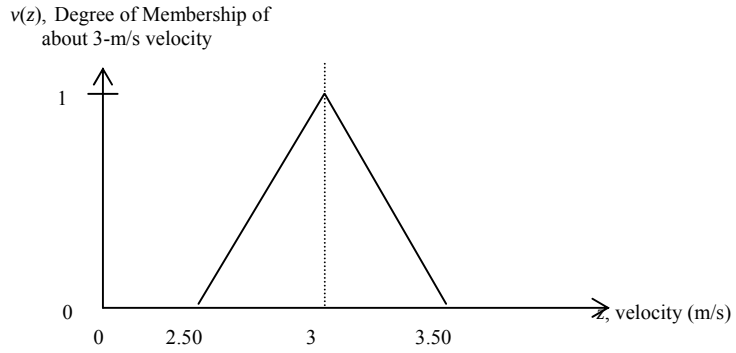
Final Examination AI and Neuro-Fuzzy Theory AT07.24 May 8, 2015

Time: 9:00-11:00 h. Open Book
Marks: 100

Attempt all questions.

Q.1 Determine membership function of the required centripetal force, $F(x) = \frac{mv^2}{r}$, used to make 5-kg mass, m, follow a curved path with about 2-m radius at about 3-m/s velocity. Membership functions for the fuzzy numbers of about 2-m radius, $r(y)$, and about 3-m/s velocity, $v(z)$ are given below. (25)





Solution

When $1.75 \leq y \leq 2$,

$$r(y) = 4y - 7 \tag{1}$$

When $2 \leq y \leq 2.25$,

$$r(y) = -4y + 9 \tag{2}$$

$$^{\alpha}r = \left[\frac{\alpha+7}{4}, \frac{9-\alpha}{4}\right] \tag{3}$$

When $2.5 \leq z \leq 3$,

$$v(z) = 2z - 5 \tag{4}$$

When $3 \leq z \leq 3.5$,

$$v(z) = -2z + 7 \tag{5}$$

$$^{\alpha}v = \left[\frac{\alpha+5}{2}, \frac{7-\alpha}{2}\right] \tag{6}$$

$$^{\alpha}(v^2) = \left[\frac{\alpha^2+10\alpha+25}{4} \quad \frac{\alpha^2-14\alpha+49}{4}\right] \tag{7}$$

$$^{\alpha}\left(\frac{v^2}{r}\right) = \left[\frac{\alpha^2+10\alpha+25}{9-\alpha} \quad \frac{\alpha^2-14\alpha+49}{\alpha+7}\right] \tag{8}$$

$$^{\alpha}\left(\frac{mv^2}{r}\right) = \left[\frac{5\alpha^2+50\alpha+125}{9-\alpha} \quad \frac{5\alpha^2-70\alpha+245}{\alpha+7}\right] \tag{9}$$

$$\frac{5\alpha^2+50\alpha+125}{9-\alpha} = x;\ 13.89 \leq x \leq 22.50 \tag{10}$$

$$\alpha = \frac{-50-x+\sqrt{x^2+280x}}{10};\ 13.89 \leq x \leq 22.50 \tag{11}$$

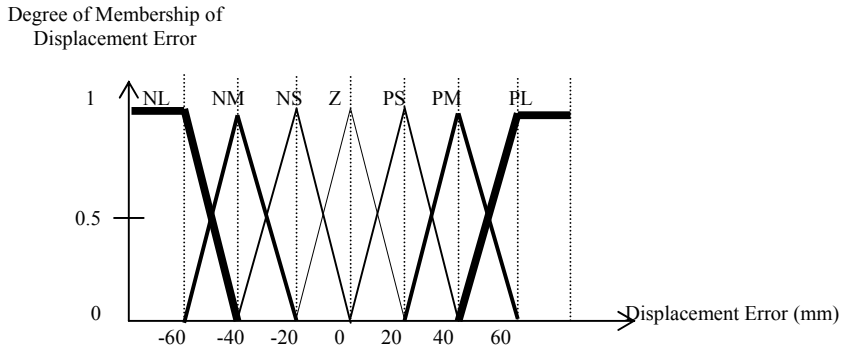
$$\frac{5\alpha^2-70\alpha+245}{\alpha+7} = x;\ 22.50 \leq x \leq 35 \tag{12}$$

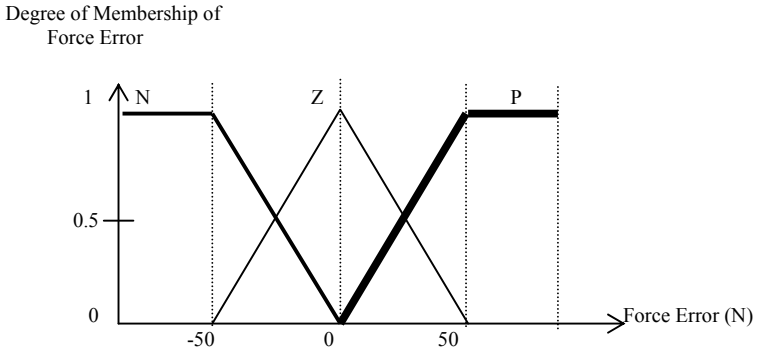
$$\alpha = \frac{70+x-\sqrt{x^2+280x}}{10};\ 22.50 \leq x \leq 35 \tag{13}$$

$$F(x) = \begin{cases} \frac{-50-x+\sqrt{x^2+280x}}{10} & 13.89 \leq x \leq 22.50 \\ \frac{70+x-\sqrt{x^2+280x}}{10} & 22.50 \leq x \leq 35 \\ 0 & otherwise \end{cases} \tag{14}$$

Q.2 In master-slave type haptics system, both displacement and force are controlled. Fuzzy control is applied to determine the required voltage, *v*, to drive a dc motor of the slave robot in a haptics system. The inputs of the fuzzy controller are position error, *p*, and force error, *f*, of the slave robot compared with the master robot.

Position error is categorized as Negative Large (NL), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM), Positive Large (PL). Force error is categorized as Negative (N), Zero (Z), Positive (P). All the membership functions are shown below.





Fuzzy Inference Rule with the output of the singleton-type required voltage is given below.

Force Error / Position Error	N	Z	P
NL	10	9	1
NM	7	6	1
NS	4	3	1
Z	1	0	-1
PS	-1	-3	-4
PM	-1	-6	-7
PL	-1	-9	-10

Determine the required voltage if the position error is detected -45 mm and the force error is detected -20 N. (25)

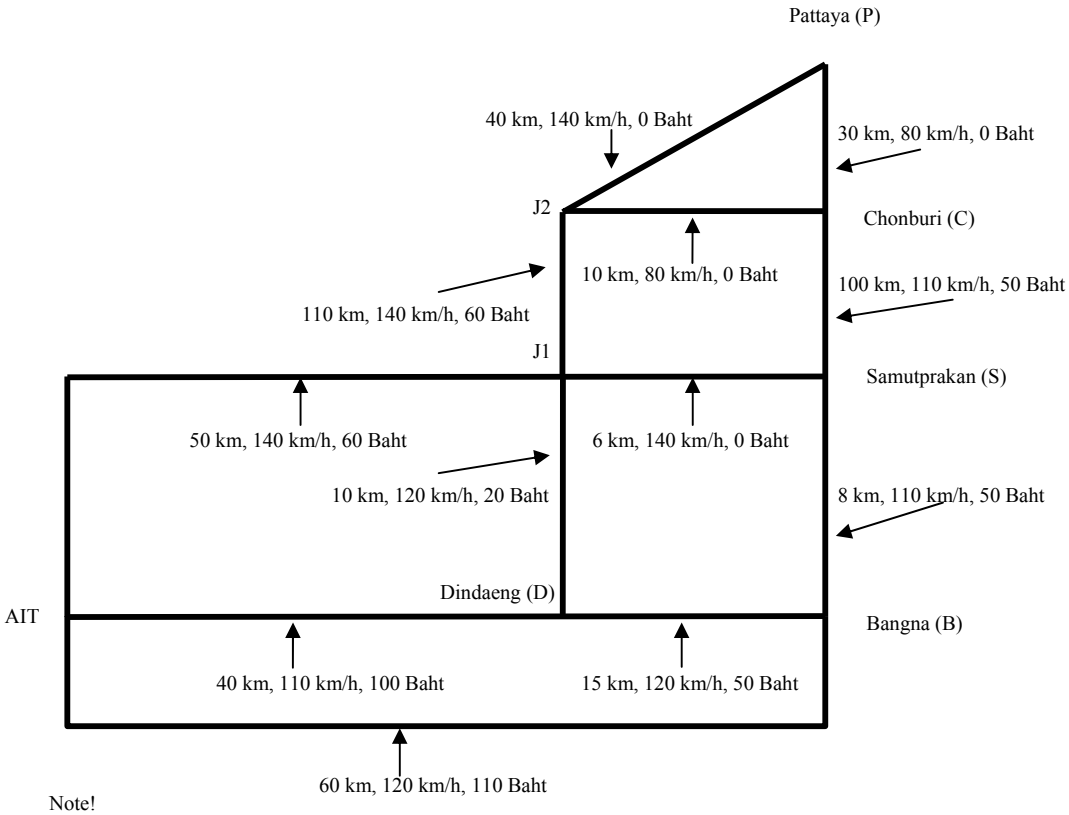
Solution

Force Error (-20N) / Position Error(-45)	N (0.4)	Z (0.6)	P (0)
NL (0.25)	10 (0.25)	9 (0.25)	1 (0)
NM (0.75)	7 (0.4)	6 (0.6)	1 (0)
NS (0)	4 (0)	3 (0)	1 (0)
Z (0)	1 (0)	0 (0)	-1 (0)
PS (0)	-1 (0)	-3 (0)	-4 (0)
PM (0)	-1 (0)	-6 (0)	-7 (0)
PL (0)	-1 (0)	-9 (0)	-10 (0)

Determine

$$v = \frac{[0.25\times10]+[0.25\times9]+[0.4\times7]+[0.6\times6]}{[0.25]+[0.25]+[0.4]+[0.6]} = 7.43\,V \qquad (1)$$

Q.3 AIT student union is organizing a trip from AIT to Pattaya city as shown in the below map. There are many routes to go to Pattaya depending upon the selected criteria; e.g. distance, time, cost, etc.

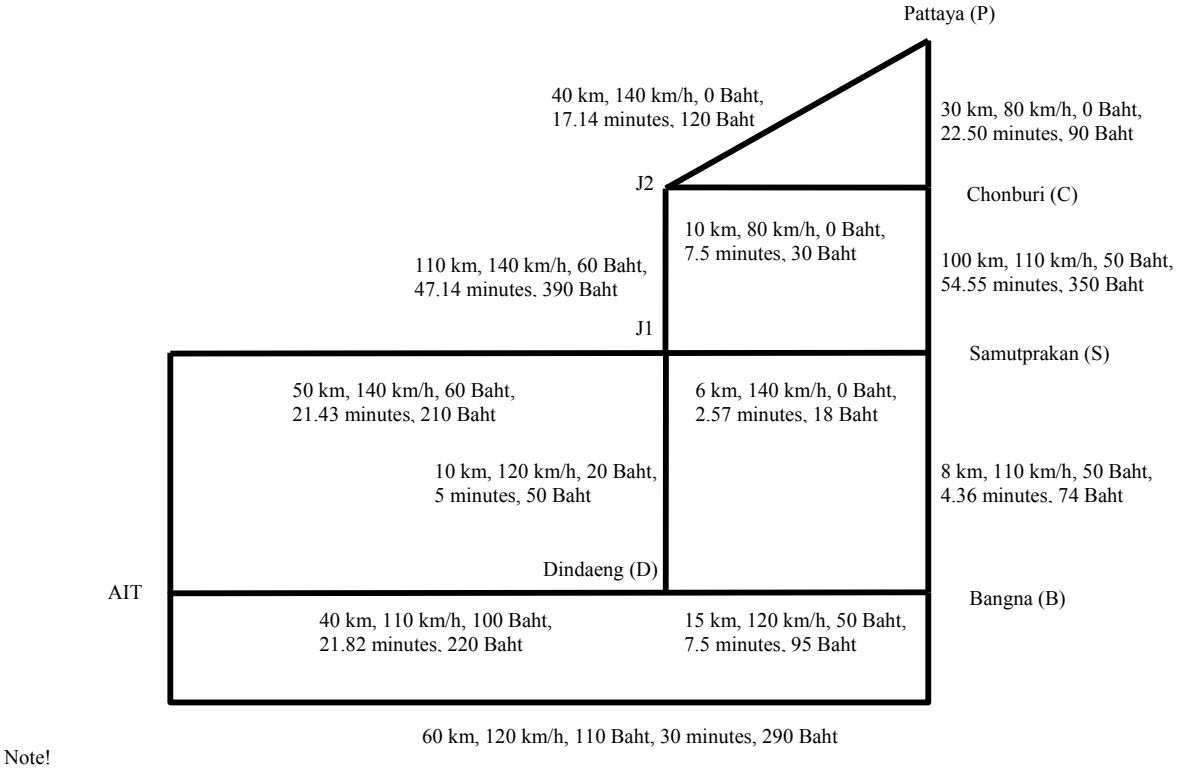


Note!
10 km, 120 km/h, 60 Baht: distance = 10 km, speed limit = 120 km/h, toll fee = 60 Baht

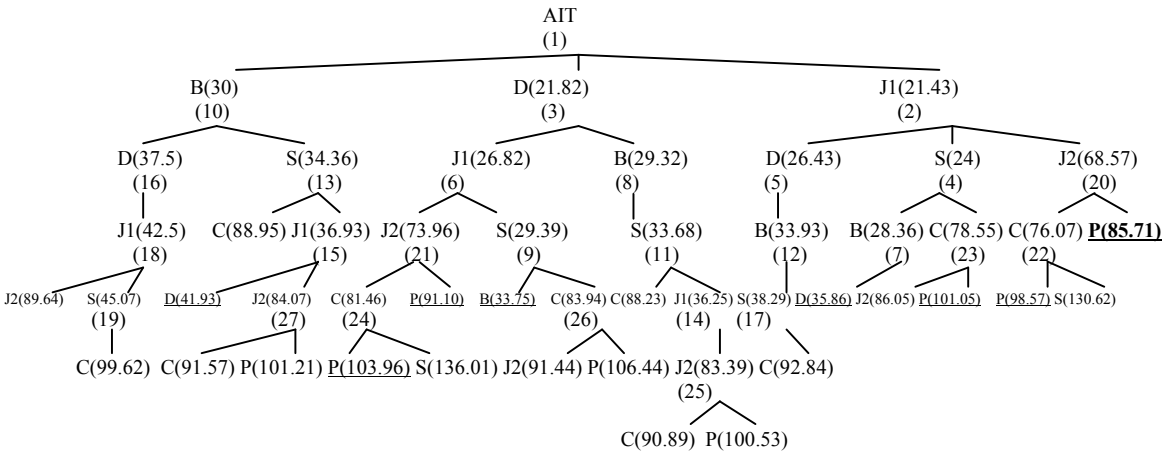
(a) Determine the best route by branch-and-bound method using short travelling time as the criteria. Draw the search tree and label the order of node opening. (25)

Solution

(a) Determine travelling time using distance/speed limit.



Note!
10 km, 120 km/h, 60 Baht, 5 minutes, 90 Baht:
distance = 10 km, speed limit = 120 km/h, toll fee = 60 Baht, travelling time = 5 minutes, travelling cost = 90 Baht

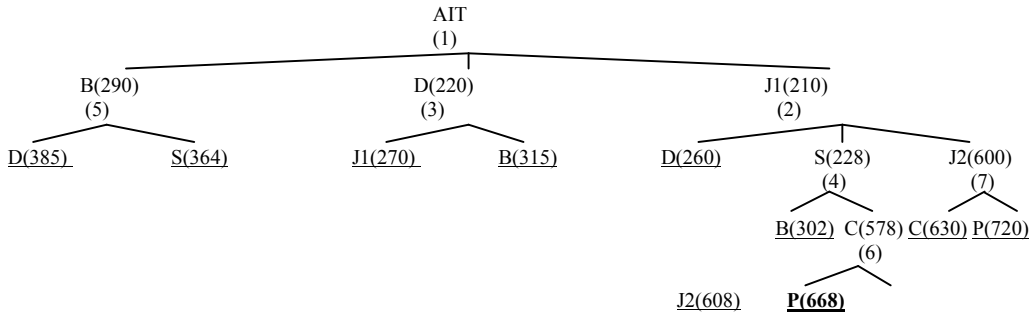


The best route is AIT-J1-J2-P

(b) Determine the best route by dynamic programming method using cheap travelling cost as the criteria. When the travelling cost is the summation of toll fee and gasoline cost. Use gasoline cost of 3 Baht per one kilometer. Draw the search tree and label the order of node opening. (25)

Solution

(b) Determine travelling cost using summation of toll fee and 3xdistance.



The best route is AIT-J1-S-C-P