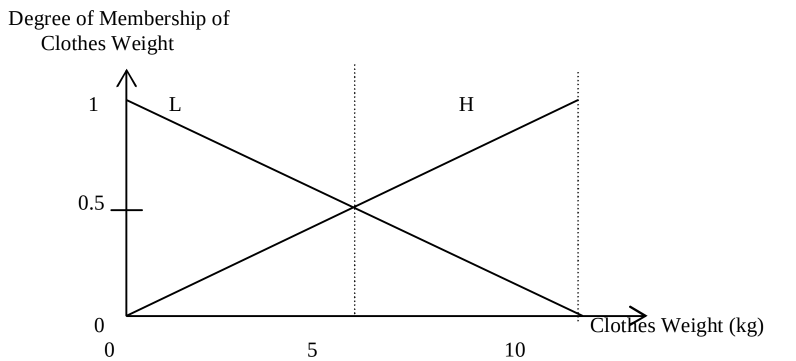
Final Examination AI and Neuro-Fuzzy Theory AT07.24 May 15, 2009

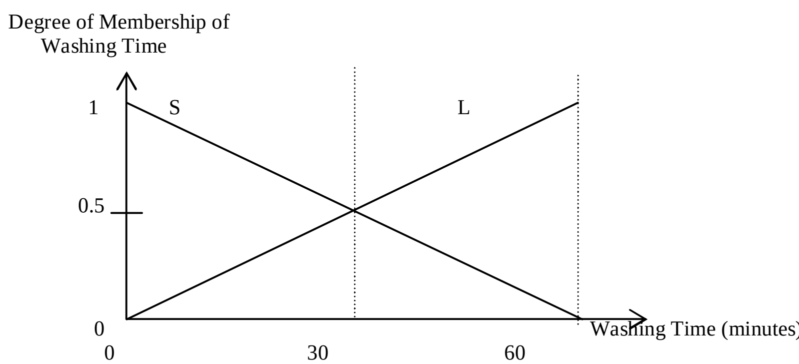
Time: 13:00-15:00 h. Open Book

Marks: 100

Attempt all questions.

Q.1 Fuzzy controller is applied to determine washing time, *t*, of a washing machine. The washing time depends only on clothes weight, *w*. If the clothes weight is categorized as Light (L), and Heavy (H), and the washing time is categorized as Short (S) and Long (L) as shown in the membership functions below.





Fuzzy inference rules of this washing machine is designed as

If the clothes weight is Light then washing time is Short.

If the clothes weight is Heavy then washing time is Long.

(a) Determine the washing time of this washing machine as a function of clothes weight by using center of gravity defuzzification method when the range of the clothes weight is between 0-10 kg. (20)

(b) Determine the washing time of this washing machine when the clothes weight is 8 kg. (5)

Solution

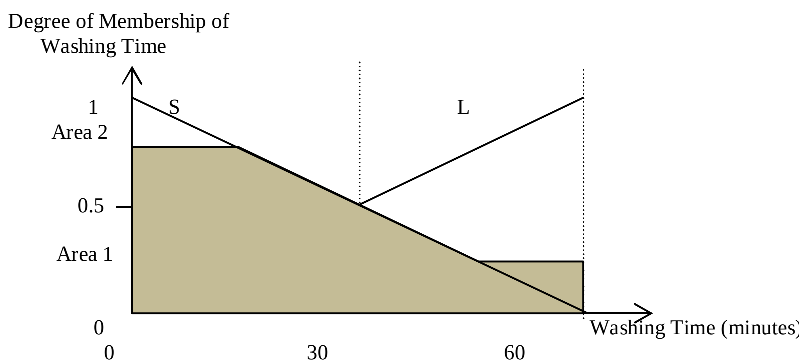
(a) Determine degrees of membership of clothes weight as a function of clothes weight, *w*.

$$L(w) = -\frac{w}{10} + 1 \quad (1)$$

$$H(w) = \frac{w}{10} \quad (2)$$

Degrees of membership of Light and Heavy are equal when the clothes weight is 5 kg.

When the clothes weight is less than 5 kg, the output before defuzzification looks like the below figure.



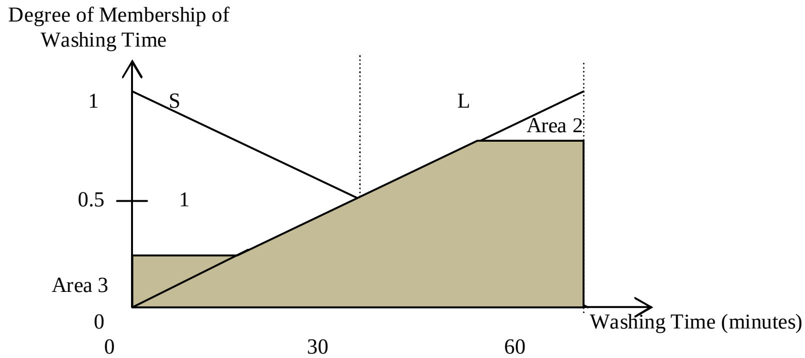
Define area 1 as the whole triangle of S, area 2 as the small triangle at the top of area 1 which will be removed from area 1, and area 3 as the small triangle at the right of area 1 which will be added to area 1. By COG defuzzification,

$$Washing\ time = \frac{\left[\frac{1}{2}60\times1\times20\right]-\left[\frac{1}{2}6w\times\frac{w}{10}\times2w\right]+\left[\frac{1}{2}6w\times\frac{w}{10}\times(60-2w)\right]}{\left[\frac{1}{2}60\times1\right]-\left[\frac{1}{2}6w\times\frac{w}{10}\right]+\left[\frac{1}{2}6w\times\frac{w}{10}\right]} \quad (3)$$

$$Washing\ time = \frac{[600]-[0.6w^3]+[18w^2-0.6w^3]}{[30]-[0.3w^2]+[0.3w^2]} \quad (4)$$

$$Washing\ time = -0.04w^3 + 0.6w^2 + 20 \quad (5)$$

When the clothes weight is more than 5 kg, the output before defuzzification looks like the below figure.



Define area 1 as the whole triangle of L, area 2 as the small triangle at the top of area 1 which will be removed from area 1, and area 3 as the small triangle at the left of area 1 which will be added to area 1. By COG defuzzification,

$$Washing\ time = \frac{\left[\frac{1}{2}60\times1\times40\right]-\left[\frac{1}{2}(60-6w)\times\left(1-\frac{w}{10}\right)\times(40+2w)\right]+\left[\frac{1}{2}(60-6w)\times(1-\frac{w}{10})\times(20-2w)\right]}{\left[\frac{1}{2}60\times1\right]-\left[\frac{1}{2}(60-6w)\times(1-\frac{w}{10})\right]+\left[\frac{1}{2}(60-6w)\times(1-\frac{w}{10})\right]} \qquad (6)$$

$$Washing\ time = \frac{[1200]-[0.6w^3-180w+1200]+[-0.6w^3+18w^2-180w+600]}{[30]-[0.3w^2-6w+30]+[0.3w^2-6w+30]} \qquad (7)$$

$$Washing\ time = -0.04w^3 + 0.6w^2 + 20 \qquad (8)$$

Since washing time of both cases are represented by the same equation, thus

$$Washing\ time = -0.04w^3 + 0.6w^2 + 20 \qquad \underline{(9)}$$

(b) When the clothes weight is 8 kg,

$$Washing\ time = -0.04(8)^3 + 0.6(8)^2 + 20 = 37.92 \text{ minutes} \qquad \underline{(10)}$$

Q.2 Determine membership function of an acceleration (m/s^2) of a car running with initial speed, $u(x)$, of about 25 km/h and the final speed, $v(x)$, of about 120 km/h within the duration, $t(y)$, of about 15 seconds. Assume the initial speed, the final speed and time are represented by the following membership functions. (25)

$$u(x) = \begin{cases} \frac{x}{5} - 4 & 20 \le x < 25 \\ -\frac{x}{5} + 6 & 25 \le x < 30 \\ 0 & \text{otherwise} \end{cases}$$

$$v(x)=\begin{cases}\frac{x}{20}-5 & 100\le x<120\\ -\frac{x}{20}+7 & 120\le x<140\\ 0 & \text{otherwise}\end{cases}$$

$$t(y)=\begin{cases}\frac{y}{3}-4 & 12\le y<15\\ -\frac{y}{3}+6 & 15\le y<18\\ 0 & \text{otherwise}\end{cases}$$

Solution

Convert the unit of speed from km/h to m/s,

$$u(x)=\begin{cases}\frac{x}{1.38}-4.03 & 5.56\le x<6.94\\ -\frac{x}{1.39}+5.99 & 6.94\le x<8.33\\ 0 & \text{otherwise}\end{cases} \tag{1}$$

$$v(x)=\begin{cases}\frac{x}{5.55}-5.01 & 27.78\le x<33.33\\ -\frac{x}{5.56}+6.90 & 33.33\le x<38.89\\ 0 & \text{otherwise}\end{cases} \tag{2}$$

$${}^{\alpha}u=[1.38(\alpha+4.03),1.39(5.99-\alpha)] \tag{3}$$

$${}^{\alpha}v=[5.55(\alpha+5.01),5.56(6.90-\alpha)] \tag{4}$$

$${}^{\alpha}t=[3(\alpha+4),3(6-\alpha)] \tag{5}$$

Acceleration is determined.

$$a=\frac{v-u}{t} \tag{6}$$

$${}^{\alpha}(v-u)=[5.55(\alpha+5.01),5.56(6.90-\alpha)]-[1.38(\alpha+4.03),1.39(5.99-\alpha)] \tag{7}$$

$${}^{\alpha}(v-u)=[6.94\alpha+19.48,32.80-6.94\alpha] \tag{8}$$

$$^{\alpha}\left(\frac{v-u}{t}\right)=[6.94\alpha+19.48,32.80-6.94\alpha]\cdot[\frac{1}{3(6-\alpha)},\frac{1}{3(\alpha+4)}] \qquad (9)$$

$$^{\alpha}\left(\frac{v-u}{t}\right)=[\frac{6.94\alpha+19.48}{18-3\alpha},\frac{32.80-6.94\alpha}{3\alpha+12}] \qquad (10)$$

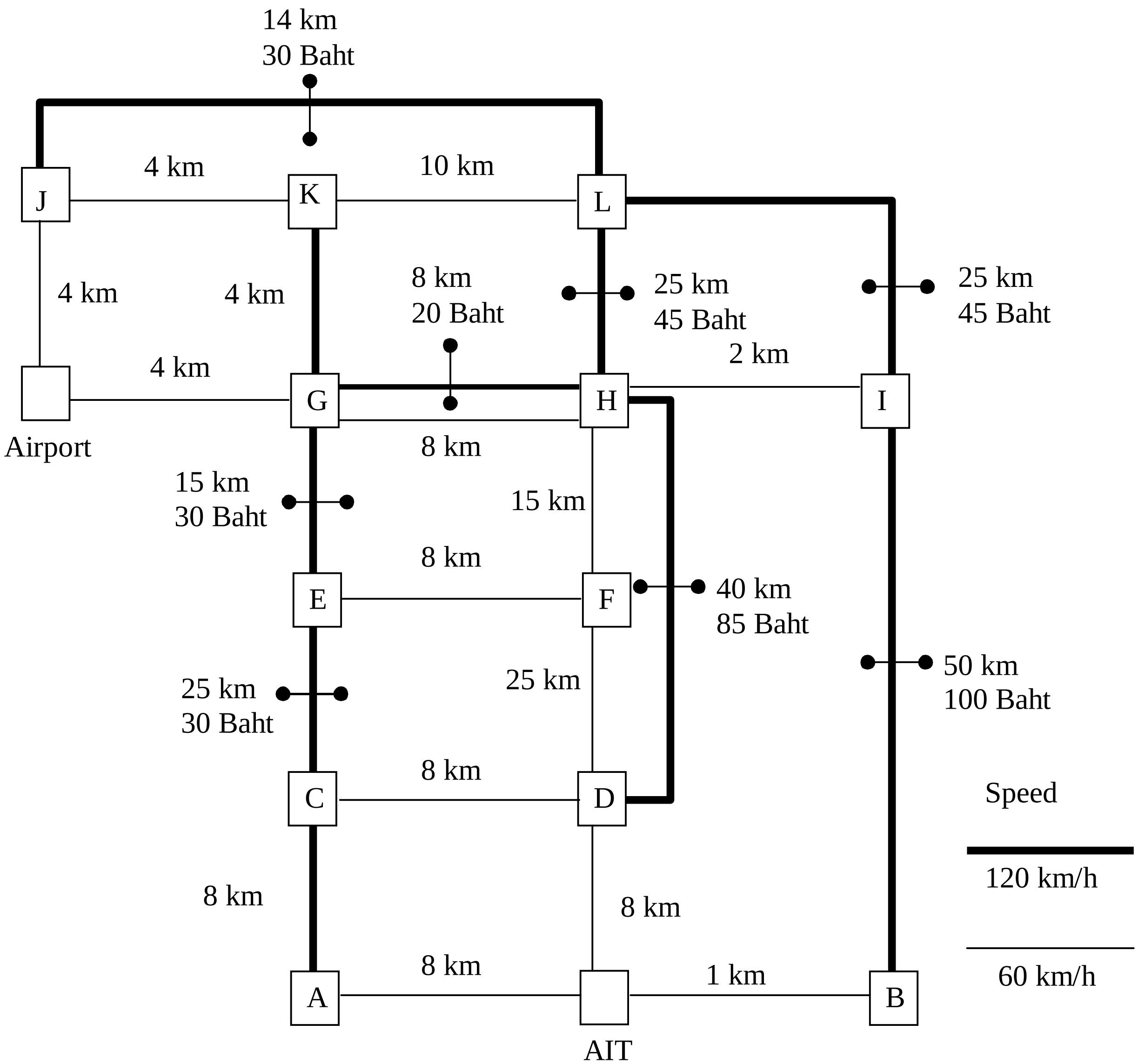
$$\alpha=\frac{18z-19.48}{3z+6.94} \quad \text{when } 1.08\le z<1.7 \qquad (11)$$

$$\alpha=\frac{32.80-12z}{3z+6.94} \quad \text{when } 1.7\le z<2.73 \qquad (12)$$

$$a(z)=\begin{cases}\frac{18z-19.48}{3z+6.94} & 1.08\le z<1.7\\ \frac{32.80-12z}{3z+6.94} & 1.7\le z<2.73\\ 0 & \text{otherwise}\end{cases} \qquad \underline{(13)}$$

The acceleration is about 1.7 m/s^2.

Q.3 Consider the routes from AIT to an Airport as shown below. Distance between each location (in km) is shown along the route. Each route accommodates different speed. Some routes require usage fee.



Determine the route from AIT to the airport according to the cost function defined by

Cost Function = [Distance (km) x 3 (Baht)] + [Travelling Time (hour) x 100 (Baht)] + [Usage Fee (Baht, if any)]

(a) hill climbing search (10)

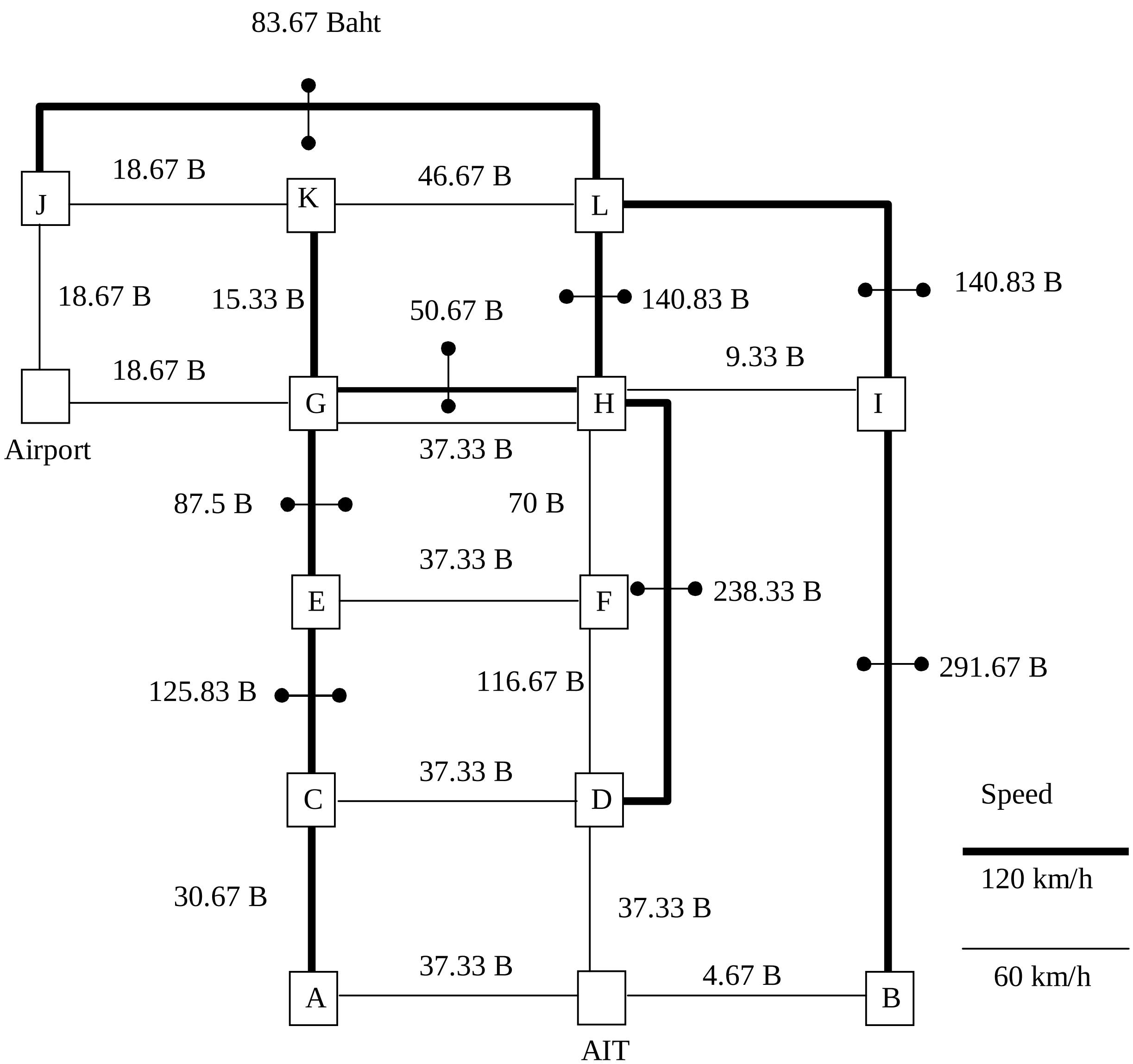
(b) best first search (10)

(c) dynamic programming search (10)

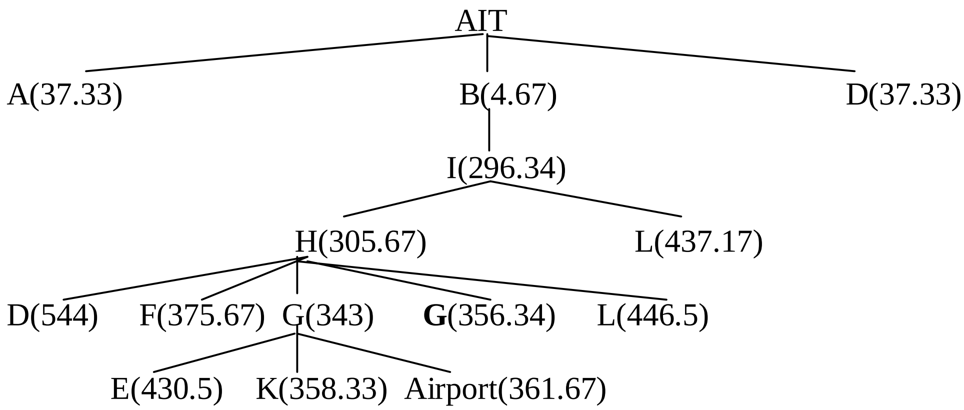
Show search tree, order of opened nodes, route, and total cost of all the methods in (a)-(e).

Solution

Determine cost between each location.



(a) hill-climbing search

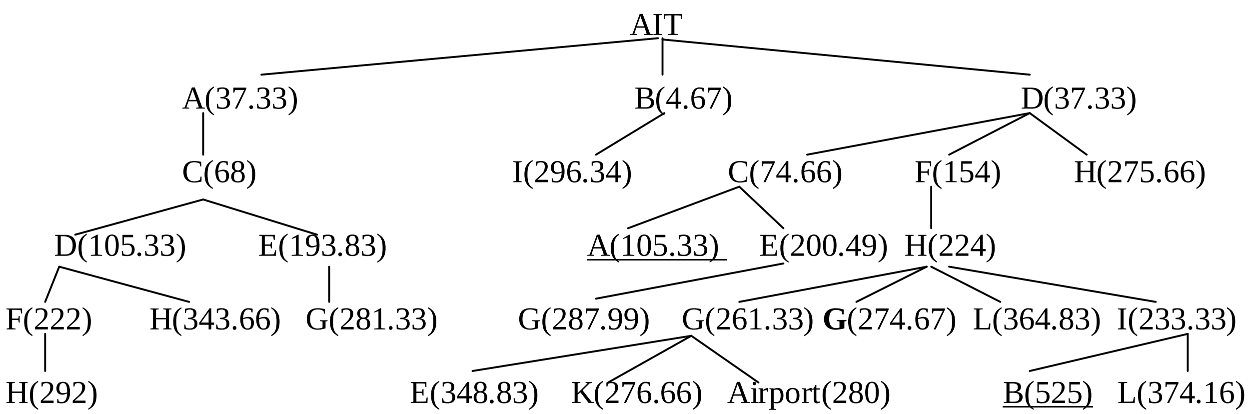


Order of the opened nodes: AIT, B, I, H, G

The route is AIT-> B-> I-> H-> G-> Airport

Total cost is 361.67 Baht

(b) best-first search

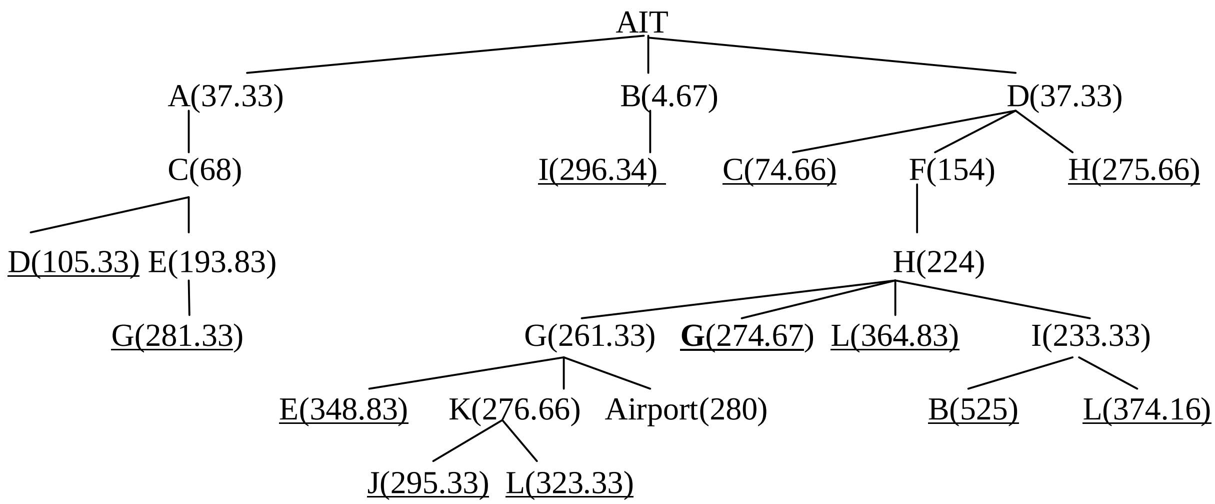


Order of the opened nodes: AIT, B(4.67), A(37.33), D(37.33), C(68), C(74.66), D(105.33), F(154), E(193.83), E(200.49), F(222), H(224), I(233.33), G(261.33)

The route is AIT-> D-> F-> H-> G-> Airport

Total cost is 280 Baht

(c) dynamic programming search



Order of the opened nodes: AIT, B(4.67), A(37.33), D(37.33), C(68), F(154), E(193.83), H(224), I(233.33), G(261.33), K(276.66)

The route is AIT-> D-> F-> H-> G-> Airport

Total cost is 280 Baht

Q.4 Determine how Particle Swarm Optimization can replace LMBP to determine weights and biases of a 1-10-1 Multi-Layer Perceptron network. Explain how each particle looks like, how to determine particle velocity, fitness function. (20)