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1.

1) Consider

$$W = \begin{bmatrix} 0 & 4 & 0 & 0 \\ 4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 4 \\ 0 & 0 & 4 & 0 \end{bmatrix}$$

Now if we calculate energy function for each pattern, the minimum values are 4 given patterns in the question.

$$E(o = [1, 1, 1, 1]) = -\sum_{i,j} W_{i,j} o_i o_j = -(4 + 4 + 4 + 4) = -16$$

$$E(o = [-1, -1, -1, -1]) = -\sum_{i,j} W_{i,j} o_i o_j = -(4 + 4 + 4 + 4) = -16$$

$$E(o = [-1, -1, 1, 1]) = -\sum_{i,j} W_{i,j} o_i o_j = -(4 + 4 + 4 + 4) = -16$$

$$E(o = [1, 1, -1, -1]) = -\sum_{i,j} W_{i,j} o_i o_j = -(4 + 4 + 4 + 4) = -16$$

$$E(o = [1, -1, 1, 1]) = -\sum_{i,j} W_{i,j} o_i o_j = -(-4 - 4 + 4 + 4) = 0$$

$$E(o = [1, -1, -1, 1]) = -\sum_{i,j} W_{i,j} o_i o_j = -(-4 - 4 - 4 - 4) = 16$$

As we see, four given vectors have lowest energy values by considering ‘W’ as above.

2) Same code used as in part1. Calculated weight matrix with given formula is:

$$W = \begin{bmatrix} 0 & 0 & 2 & -2 & 0 & -2 \\ 0 & 0 & 0 & 0 & -2 & 0 \\ 2 & 0 & 0 & -2 & 0 & -2 \\ -2 & 0 & -2 & 0 & 0 & 2 \\ 0 & -2 & 0 & 0 & 0 & 0 \\ -2 & 0 & -2 & 2 & 0 & 0 \end{bmatrix}$$

Now if we give pattern [1, 1, 1, -1, -1, -1] to the network we get the same pattern. By calculating energy value of this pattern we can find out all values are positive and negation outside of the sum, made it as small as possible, so energy value is at the smallest value too and this pattern is stable.

Now by giving pattern [-1, 1, 1, -1, -1, -1] to the network, we get the new stable pattern [1, 1, 1, -1, -1, -1].

3)

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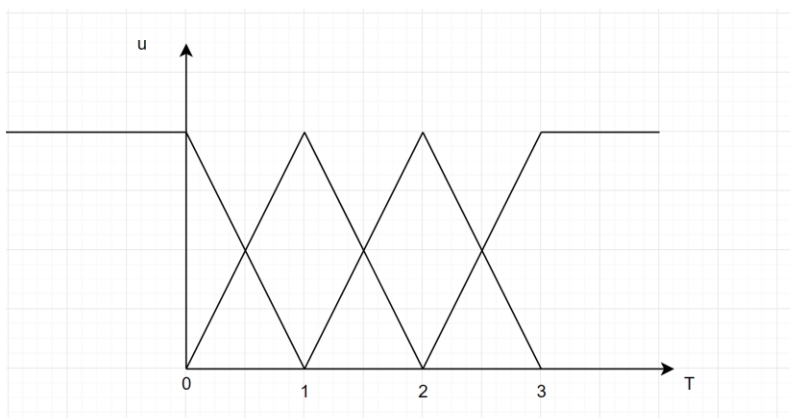
16	74.166	66.602	53.397
32	81.947	68.8	52.556
64	68.8	61.258	53.183

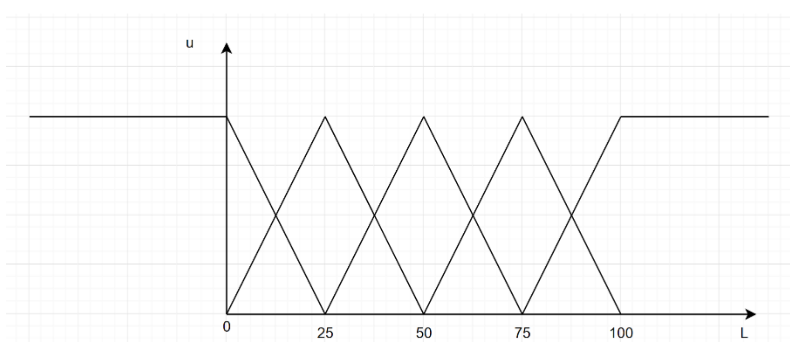
I used same functions in part 2.

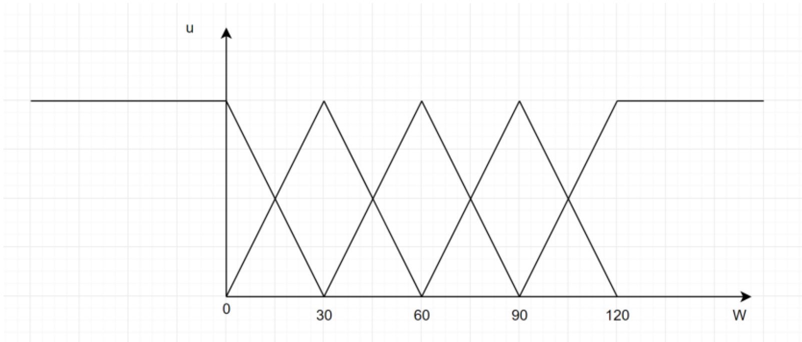
2.

1) First let's define the parameters. Two input values are type of dirt (T) and dirtiness level (L). Suppose we have three types of dirt {soil, Ink, oil} and value of T differs from 0 to 3 and maps {no_dirt: 0, soil: 1, Ink: 2, oil: 3} to numbers, and L varies from 0 to 100. If L is very low, then we have fast wash. If T is under 0 we consider no dirt and higher than 3, we consider oil. Wash time (W) varies between 0 to 120 minutes. Now let's define relations:
   - If we have no dirt, we have fast wash.
   - If we have soil and dirt level is low, we should wash very short
   - If we have Ink and dirt level is low, we should wash short
   - If we have oil and dirt level is low, we should wash short
   - If we have soil and dirt level is medium, we should wash short
   - If we have Ink and dirt level is medium, we should wash long
   - If we have oil and dirt level is medium, we should wash long
   - If we have soil and dirt level is high, we should wash long
   - If we have Ink and dirt level is high, we should wash very long
   - If we have oil and dirt level is high, we should wash very long
   - If we have soil and dirt level is very high, we should wash very long
   - If we have Ink and dirt level is very high, we should wash very long
   - If we have oil and dirt level is very high, we should wash very long

   Values of L are : very low, low, medium, high, very high
   Values of T are: no dirt, soil, Ink, oil
   Values of W are: fast wash, very short, short, long, very long
   Now we need to draw the fuzzy values for each parameter.







Now with given input and a proper defuzzification method, we can control the washing time.

2) As the GMP says:

$$B'(y) = \sup_{x \in X} \min\{A'(x), (A \to B)(x, y)\}, y \in Y$$

Now if we apply the Larsen rule, we have:

$$B'(y) = \sup_{x \in X} \min\{A'(x), A(x)B(y)\}, y \in Y$$

Domain X is $\{3\}$ and Y is $\{-5, -4, -3, -2, -1, 0\}$.

$$B'(-1) = \min\{A'(3), A(3)B(-1)\} = \min\{1, 0.165\} = 0.165$$
$$B'(-2) = \min\{A'(3), A(3)B(-2)\} = \min\{1, 0.335\} = 0.335$$
$$B'(-3) = \min\{A'(3), A(3)B(-3)\} = \min\{1, 0.5\} = 0.5$$
$$B'(-4) = \min\{A'(3), A(3)B(-4)\} = \min\{1, 0.25\} = 0.25$$

Actually $B'(y) = 0.5B(y)$

3) We have three states. 1 is when the pendulum is between 90 and -90. At this point we should make changes to speed up the pendulum to move it upside. When it reached the degrees near the 180, we should keep the balance there. My code is not very efficient but works for a while and loose the balance and again tries to reach the stable state again.