Problem 177: Synaptic Server

Difficulty: Hard

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Problem Background

Lockheed Martin has been contracted by the United States Army to build a new self-driving troop transport. Your team has been assigned to build a street sign identification system for the transport. Your system is required to take a low-resolution photograph of a street sign and output a string indicating the type of sign in the picture; one of:

- STOP_SIGN
- YIELD
- LANE_ENDS
- SPEED_LIMIT
- CROSSWALK

This is harder than it sounds, because no two pictures will be the same. The position of the transport, the time of day, poor weather, or even graffiti on the sign can prevent an accurate identification. However, your algorithm must be able to overcome these problems, because a wrong answer could be disastrous!

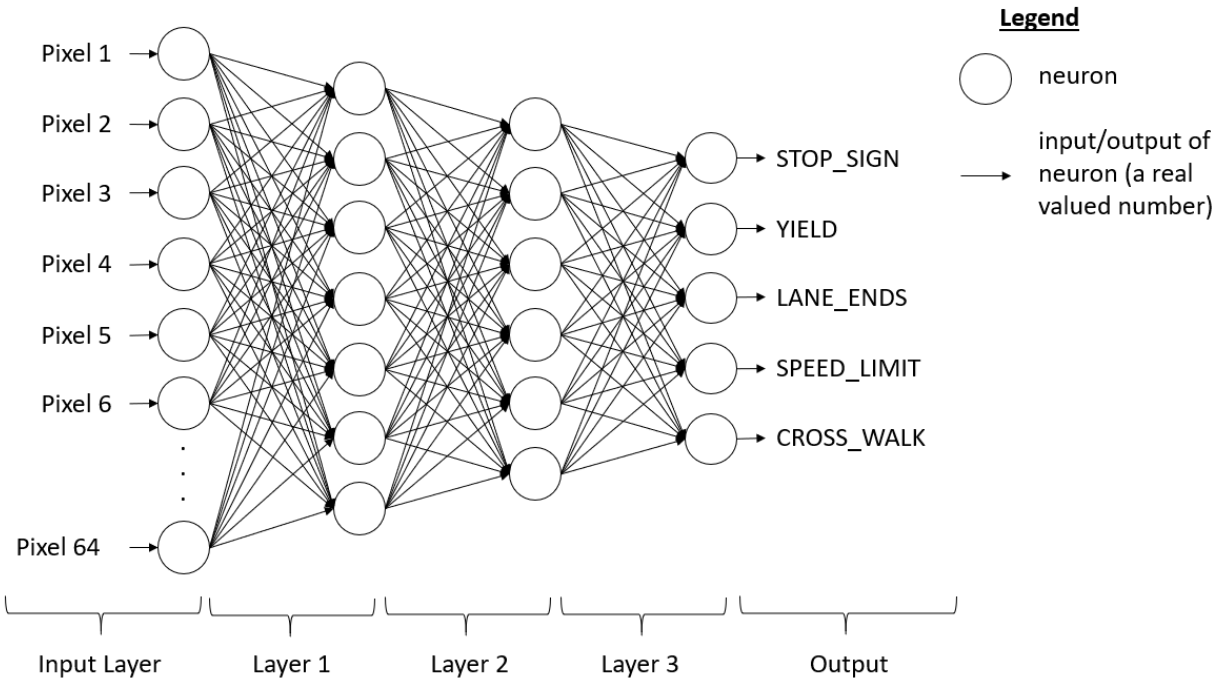
Writing a traditional function to solve this problem would be nearly impossible, but you know a team of humans could identify signs very easily. This creates an ideal setup for a class of algorithms called supervised machine learning, where a computer "learns" an unknown function using a large amount of known sample data.

Problem Description

Your lead engineer suggests using a neural network to solve this problem. A neural network is a machine learning algorithm loosely based on the structure of the brain. There are two main components to a neural network: neurons and layers. Neurons are the fundamental computing unit within a neural network, and are grouped into a series of many layers.

Each neuron in a neural network contains a list of weights ($\vec{w}$) and a single bias value (b). These numbers make neurons configurable, allowing the computer or engineer to adjust those values as the computer learns from existing data. Each neuron is responsible for producing a single "real valued number" (any positive, negative, or zero number); the outputs from all neurons in a layer are then collected into a single list and sent as the inputs to each neuron in the next layer. The image on the

next page illustrates the layout of a neural network and how these inputs and outputs are passed between layers.



Each neuron uses the following formula to calculate its output value.

$$y = \max\left(0, b + \sum_{i=0}^{N} x_i w_i\right)$$

In this formula:

- y is the neuron's output value
- $\max(\quad)$ is a function that returns the larger of the two numbers given to it
- b is the neuron's bias value (different for every neuron)
- Σ is a summation operator; it indicates that the portion of the equation after it must be repeated for each value of i from 0 through N inclusive, and that all of those values must then be added together to form a single number.
- N is the number of inputs for the neuron; this is equal to the number of neurons in the previous layer
- $\vec{x}$ is a list (containing $x_0, x_1, \ldots, x_N$) with the input values for the neuron (the outputs from all neurons in the previous layer, in order)
- $\vec{w}$ is a list (containing $w_0, w_1, \ldots, w_N$) with the neuron's weights for each input (different for every neuron)

This formula could also be written as:

$$y = \max(0, b + x_0 w_0 + x_1 w_1 + \cdots + x_N w_N)$$

All neurons in the same layer share the same set of inputs; however, their unique weight and bias values ensure that every neuron produces a different output.

For the troop transport's neural network, each neuron in the first layer will receive as input a list of 64 numbers between 0.0 and 1.0 inclusive; each number in the list represents the grayscale value of a pixel in an 8-by-8 pixel image of a street sign. These neurons will produce outputs to be passed to the next layer, which will produce outputs to be passed to the next layer, and so on. The final layer will contain only five neurons, representing the five types of street sign to be identified, as follows:

1. STOP_SIGN
2. YIELD
3. LANE_ENDS
4. SPEED_LIMIT
5. CROSSWALK

The outputs produced by each of these five neurons represent how confident the network is that the corresponding sign is the correct answer. Your system needs to determine which output value is the highest and return that string as the final answer.

Fortunately, your lead engineer was able to locate data from several pre-trained neural networks; your team has to test all of these networks to see how well they perform.

Sample Input

The first line of your program's input, received from the standard input channel, will contain a positive integer representing the number of test cases. Each test case will include:

- A line containing a positive integer greater than or equal to 3, L, representing the number of layers in the neural network.
- A line containing L positive integers, separated by spaces, representing the number of neurons in each layer of the network. The last integer in this list, representing the output layer, will always be 5. Other integers may range from 6 to 128, inclusive.
- L lines containing the decimal bias and weight values of each neuron in the layer. Values will be separated by spaces. For each neuron in the layer, one weight value will be provided for each input, followed by the neuron's bias value. For example, a layer with five neurons that receives six inputs would list values as follows:

  $$w_{0,0}\ w_{0,1}\ w_{0,2}\ w_{0,3}\ w_{0,4}\ w_{0,5}\ b_0\ w_{1,0}\ w_{1,1} w_{1,2}\ w_{1,3}\ w_{1,4}\ w_{1,5}\ b_1 \ldots\ w_{4,4}\ w_{4,5}\ b_4$$
- A line containing 64 decimal numbers between 0.0 and 1.0 inclusive and separated by spaces, representing the pixel values to be given as the inputs to all neurons in the first layer.

The sample input for this problem is too large to publish in this description. Please download the sample input from the Code Quest Academy website.

Sample Output

For each test case, your program must print a line containing the name of the street sign with the highest confidence level calculated by the neural network. Street signs should be printed exactly as shown in the description above.

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SPEED_LIMIT
YIELD
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