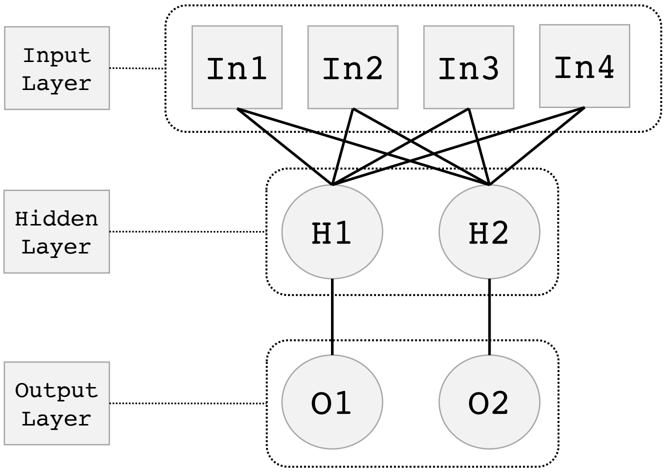
Neural Network Exercise

Instructions: We are going to implement the neural network seen below:



The network has 7 nodes. The four at the top produce input. The input is passed down to the two hidden-layer nodes in the middle. These nodes then do some computation, based upon the neural weights that connect them to the input layer, and send results to the two output nodes.

During the training of the network, the output nodes will check whether the output they receive is correct, and send signals back to the hidden layer accordingly. Depending upon whether or not the results were correct, the hidden-layer nodes will adjust the weights that they use in their calculations. Over time, error will be reduced, and the network will learn to recognize objects in images based upon their primary color.

1. **Setting Up**: Each node in the network will consist of a single person. Alternatively, each hidden-layer node can consist of two people, one for doing the feed-forward calculations, and one for doing backpropagation weight adjustments. Similarly, you may have one person doing the job of multiple input/output nodes. For instance, if you want all participants to do the simulation of hidden-layer nodes, then you can divide the class into two groups, one corresponding to `H1` and one corresponding to `H2`. The instructor can then read out the vector of inputs for each image, and then tell each group how to compute their error in each instance.

   Supplies are handed out as follows:

   - Each input neuron receives one of the 4 input (color) cards.
   - Each hidden-layer neuron receives a hidden-layer worksheet.
   - Each output neuron receives one of the 2 output (object class) cards.

   The hidden-layer neurons will fill out the first empty row of the worksheet. For each of the `Input` columns, enter a starting weight. These should be generated randomly by flipping a coin: if the coin comes up Heads, then enter weight 0.5; if the the coin comes up Tails, enter 0. (The right-most two columns are left empty.)

2. **Training**: In the training phase, we cycle through a set of images, and compute a response to each of them as follows:

    - Each input neuron should look at the image, and then pass on a response to each of the hidden-layer neurons. This response should be 1 if the image features the color for your neuron, and it should be 0 otherwise. The hidden-layer neurons should write the inputs in the next row, in the appropriate columns.
    - Each hidden-layer neuron should compute their response to the input. In each case, this will be the weighted sum:

      $$R = w_1 \cdot in_1 + w_2 \cdot in_2 + w_3 \cdot in_3 + w_4 \cdot in_4$$

      Write this result in the `Response` column, and communicate it to the single output neuron that is connected to the hidden-layer neuron.
    - Each output neuron should look at the image. If the image **does** contain an object to which it responds, then the output neuron computes the **error**: the difference between the correct answer and the response it received: $E = (1 - R)$. If the images **does not** contain an object to which it responds, the error computed is $E = (0 - R)$.
    - The error results computed by the output neurons are communicated back to their connect hidden-layer neurons. The neurons write this down in the `Error` column and then adjust their 4 input weights as follows, setting each weight as:

      $$w_i \leftarrow w_i + (in_i * E)$$

      These can be written down in the next row of the worksheet.

    This process repeats until the network is producing correct output on every input. The time that this takes can vary depending upon the randomness of the initial weights, but usually within 2–3 cycles through the (small) data-set, the network will have learned its functions, with one neuron detecting all apples in the images, and the other all non-apples.