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Lecture 13
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Exercise 13.1: Population Codes

1. $a = r + e$

2. See fig. 1. In a population, neurons usually do not only respond to their preferred stimulus, but also with decaying strength to close ones. Therefore, not only exactly one neuron gets stimulated, but several, with a peak in activity at the actual stimulus.

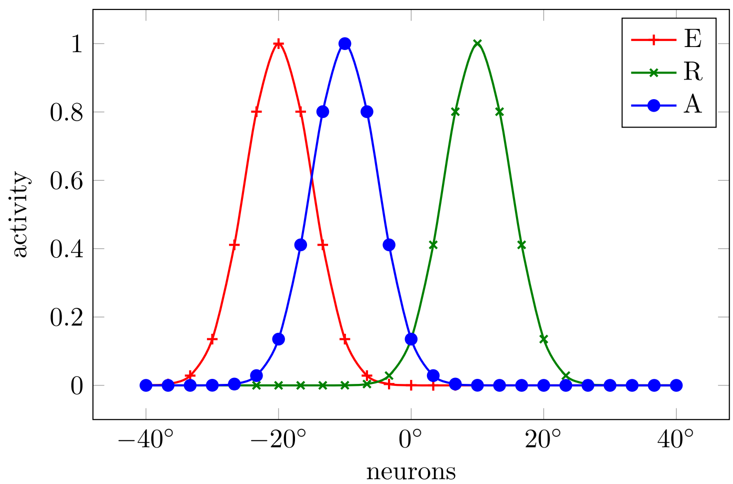

Figure 1: Activity of the input populations E, R, and A

3. We want the system to infer the value of a given the values of e and r, *i.e.*, we want to implement a two-dimensional function. Since we have a two-dimensional layer of neurons (the intermediate layer I) we can use it to hard-wire this function. For that, we give each neuron a meaning based on its position in the layer: the x-coordinate encodes the values of e from $-40°$ to $40°$ and the y-coordinate the values of r from $-40°$ to $40°$. Now, we set up the connections to the input populations. Each neuron in E represents one possible value of e. We connect it to all neurons in I. The weight of the connection is chosen to be high if the difference between e and the encoded e value of the neuron in I is small. The same is done for the population R and values r. Each neuron of population A representing a value a is connected in a similar fashion to all neurons in I who's e and r values add up to a.

   Now, whenever a neuron is active in one of the populations E, R, or A, a whole line of neurons will be active in I: for E and R these lines will be axis-parallel and for A the line will be a diagonal.

   If only input e and r is provided to the system, the highest activity in I will be where both lines meet. This in turn activates the corresponding neurons in A, with a peak at $a = r + e$. In the cited paper, this is calles 'function approximation'.

4. See fig. 2. As explained above, the input creates a peak of activity in the intermediate layer I where the two lines are meeting. The resulting activation of neurons in A also activates neurons in I on the diagonal.

5. Not only a, the relative position of the object to your head, is changing, but also r, the retinal position of the object. In the activity pattern of fig. 2 we would observe that the point of peak activity would move in the direction of the r-axis towards $r = -20°$. The diagonal and the line caused by R in the activity pattern would move such that the point of peak activity remains their point of intersection.

6. See fig. 3. The recordings correspond to a cut through the activity pattern in fig. 2.

7. It is possible by following the same procedure as described above. In fact, any function can be implemented since the intermediate layer serves as a lookup table for the results.

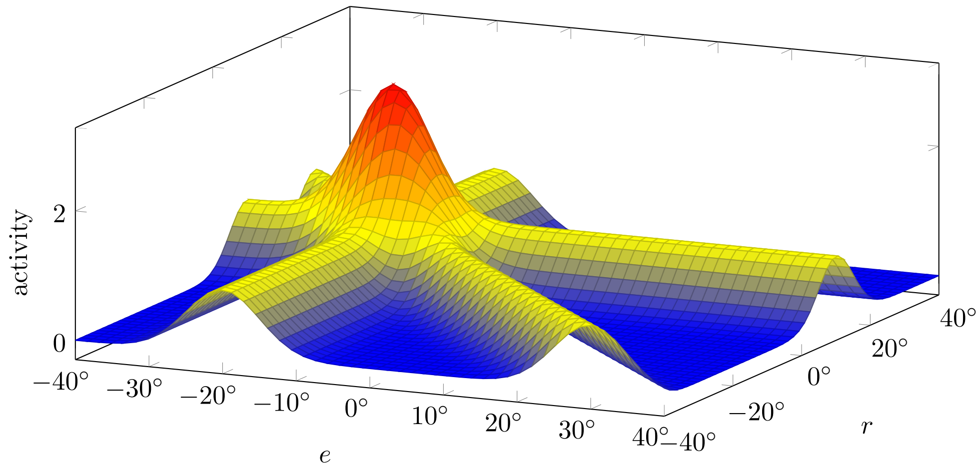

Figure 2: Activity profile of the intermediate layer I when receiving input from E and R.

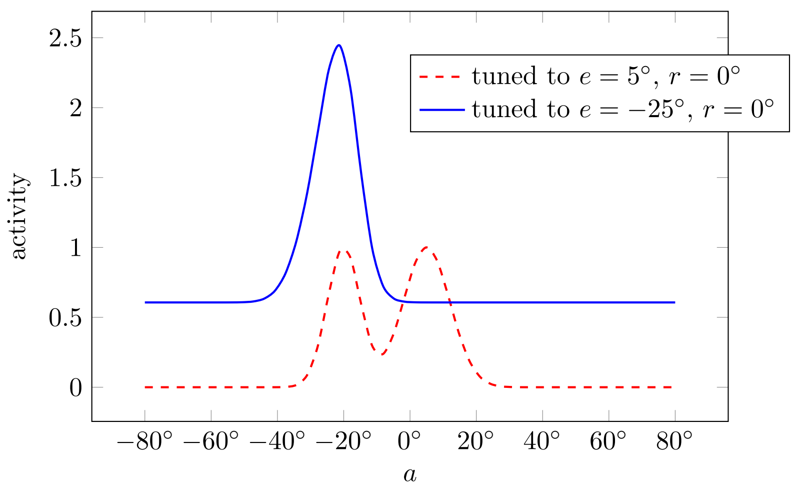

Figure 3: Activity of two neurons in I as the object is moving from $-80°$ to $80°$.