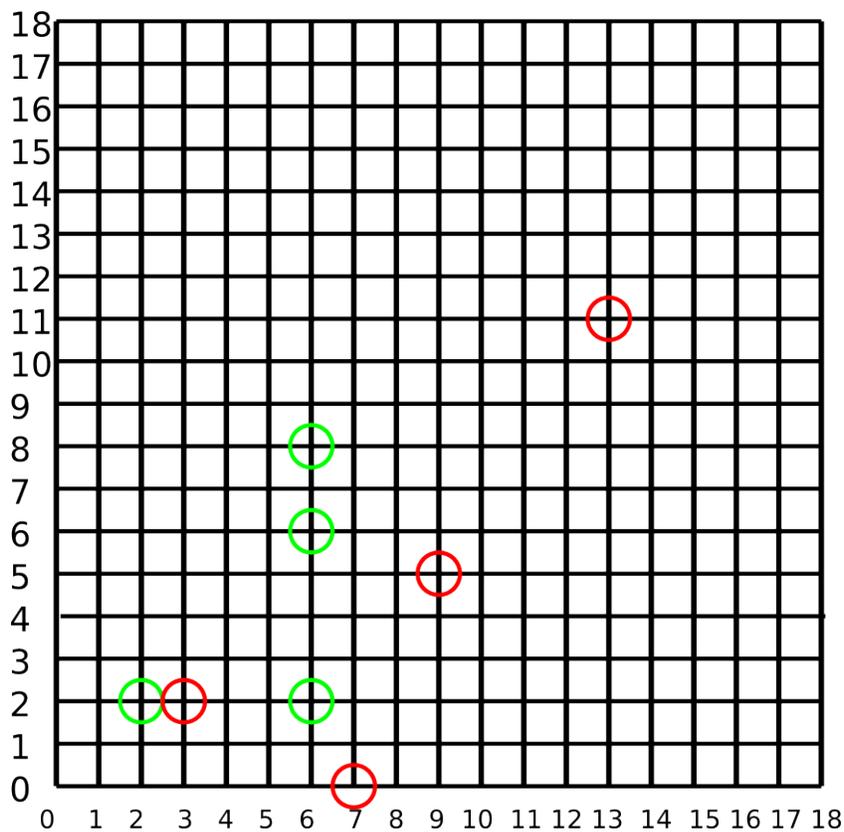


### Exercise 1: Iterative Closest Point (ICP) Algorithm

In this exercise you will use a standard ICP algorithm with the point-to-point distance metric to estimate the transform between the 2D datasets (model - red and target - green) depicted in the below figure. For the correspondence estimation please use the nearest neighbor search with the maximum radius set to 4 grid units. For the rotation estimation use an SVD library of your choice or calculate it yourself.

Recall the main steps in the ICP algorithm:

- find point pairs;
- estimate the translation vector  $t$ ;
- build the correlation matrix  $H$ ;
- estimate rotation matrix  $R$  using SVD;
- calculate the transform  $T$ ;
- transform dataset  $t$  using the transform  $T$ .



## Exercise 2: Generate Scale Invariant Feature Transform (SIFT) Feature

In this exercise you will generate the SIFT histogram from the below window in blue). We will assume that the scale spaces were already computed and the keypoint already found (in red). Your task is a) to calculate gradient magnitudes and orientations according to the following formulas:

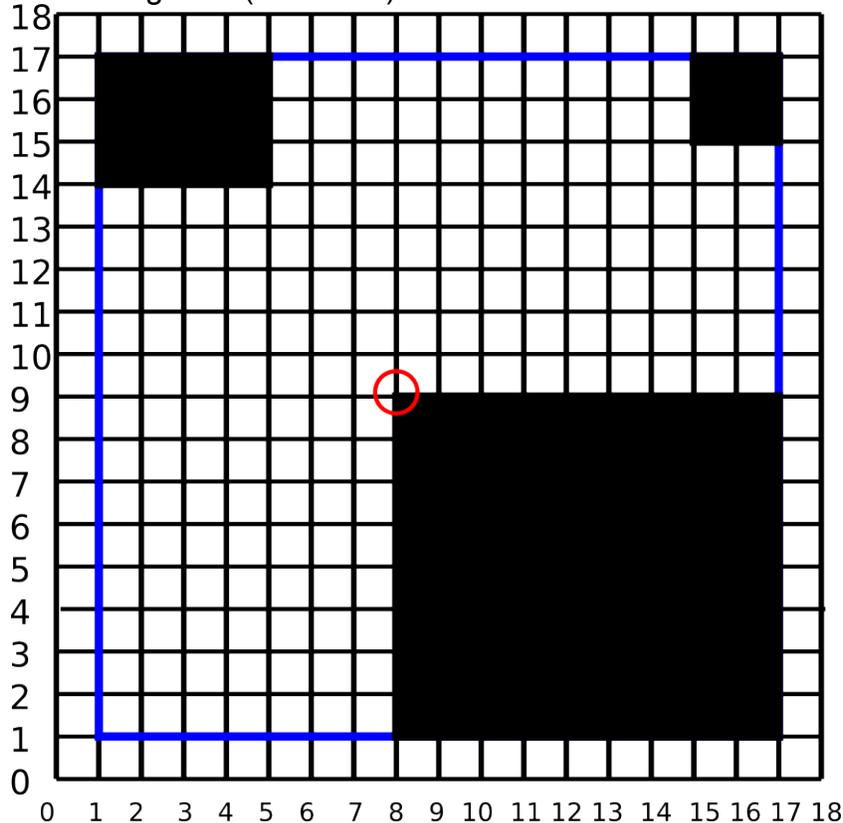
$$m(x, y) = \sqrt{(L(x + 1, y) - L(x - 1, y))^2 + (L(x, y + 1) - L(x, y - 1))^2}$$

$$\theta(x, y) = \tan^{-1}((L(x, y + 1) - L(x, y - 1))/(L(x + 1, y) - L(x - 1, y)))$$

and b) to generate the SIFT histogram for the found keypoint (in red below). Please use the atan2() function for the gradient orientation.

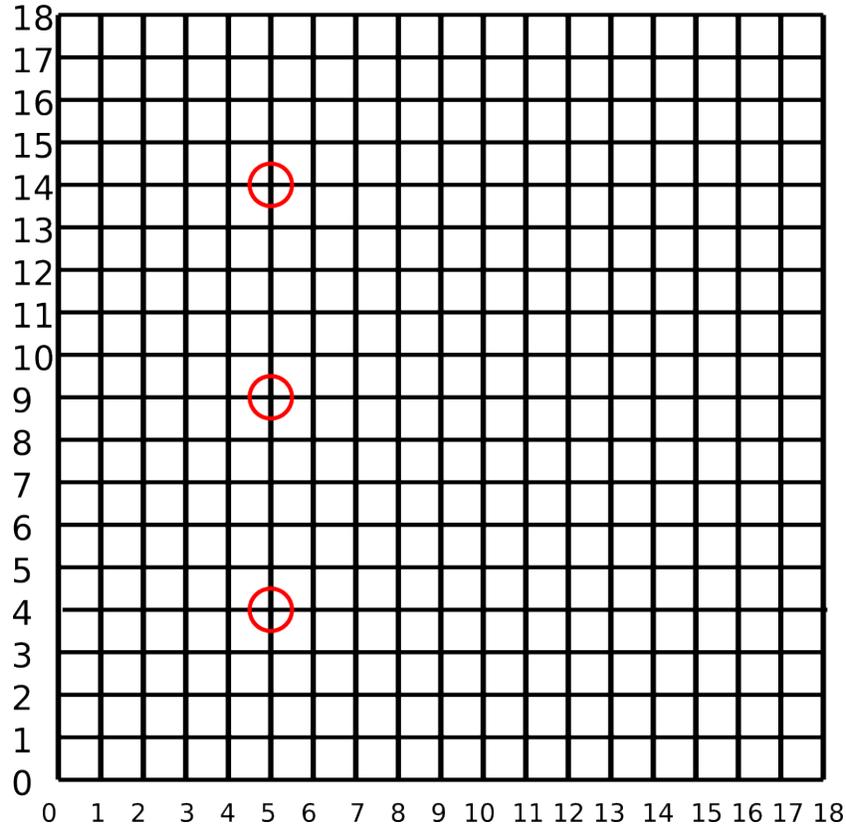
Recall the main steps in SIFT estimation:

- Construct a scale space (Done);
- Laplacian of Gaussian approximation (Done);
- Find keypoints (Done);
- Eliminate edges and low contrast regions (Done);
- Assign Keypoint Orientation (Your task);
- Generate SIFT histograms (Your task).



### Exercise 3: Hough Transform

Consider below 3 points in the image and using the Hough Transform cast the votes for them in the parameter space for finding the lines with the 0, 45, 90 and 135 degrees inclination angle. Select an appropriate parameter space which shall be a) uniquely defined for the given model and b) as low dimensional as possible. Which parameter space would be particularly bad for this example? Plot the Hough space graph and prove that the vertical line is the best fit.

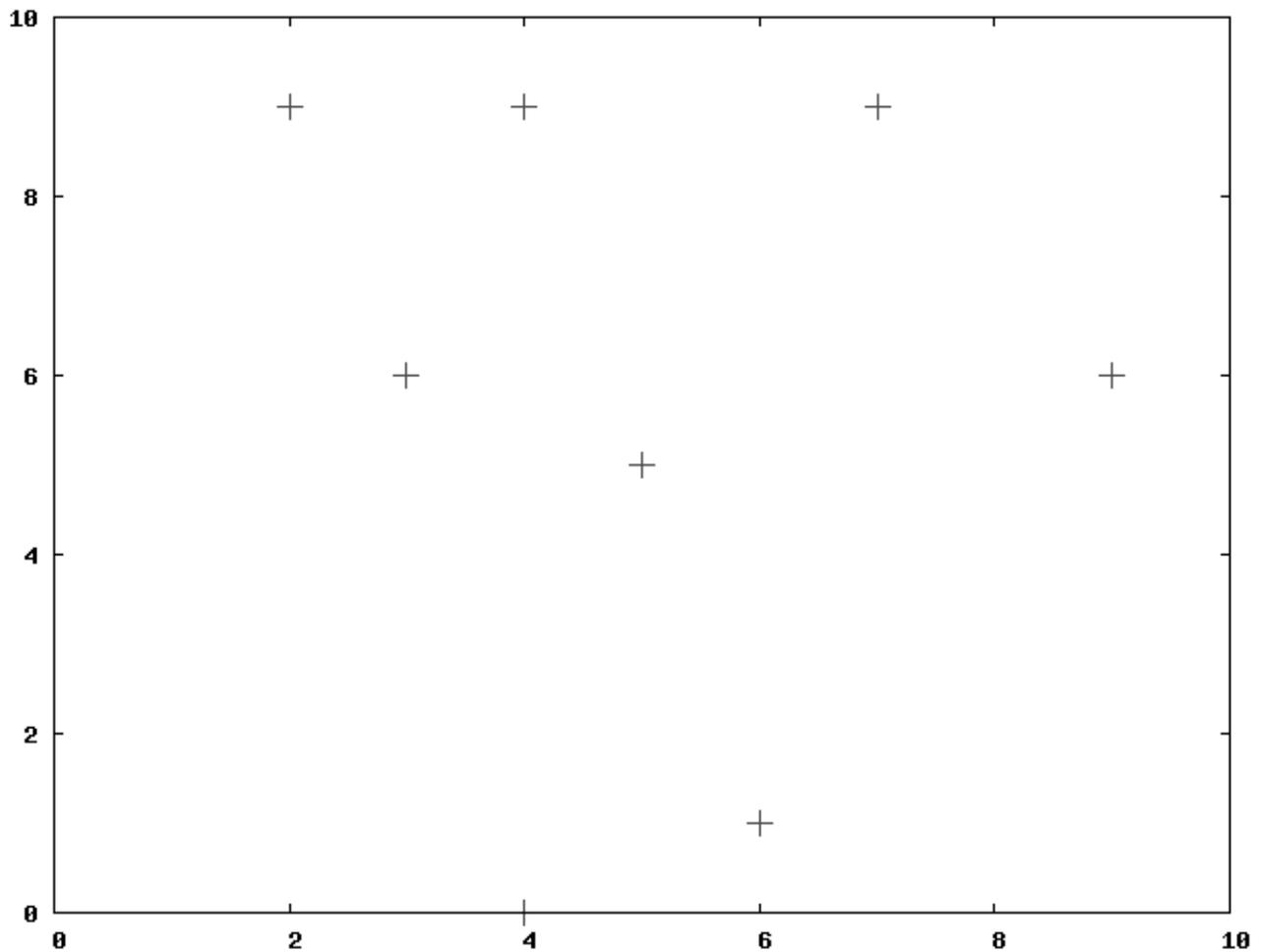


### Exercise 4: KD-Tree

Using a KD Tree algorithm decompose the below 2D dataset of 8 points into 3 steps or until the bucket size of 1. Provide the KD Tree decomposition in the below figure and the resulting KD Tree graph.

For the kd-tree construction follow the following heuristics:

- Start with x axis and then alternate between x and y axes.
- Points are inserted by selecting the median of the points being put into the subtree, with respect to their coordinates in the axis being used to create the splitting plane.
- What is the complexity of the search in O notation?



## Exercise 5: RANSAC

- How many points with normals need to be sampled to identify the equation of a cylinder?
- What is the effect of  $P_{success}$  set to 1? What about having a thousand samples?

## Exercise 6: Region Growing

Given a point belonging to a convex object,  $P(x,y,z)$ , segment this object from the scene using region growing.

- Check if a point belongs to the same convex object as the original point
- Don't grow from points that are near a boundary (given that you find a neighborhood that contains a point which does not satisfy convexity, make sure you don't grow further)
- Don't process the same point twice

