Lehrstuhl für STEUERUNGS- UND REGELUNGSTECHNIK	**MACHINE LEARNING IN ROBOTICS**
Technische Universität München	Exercises 4: Unsupervised Clustering
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Exercise 1

A team of three differential-drive mobile robots has to reach the three goal positions $g^{(1)} = (4, -0.5)$, $g^{(2)} = (7, 0.5)$, $g^{(3)} = (9, 1.5)$, starting from $x^{(1)} = (2, 2.5)$, $x^{(2)} = (3, 2)$, $x^{(3)} = (4, 2.5)$. The scenario is shown in Figure 1. Assign a goal position to each robot considering that:

i) Each robot can reach only one goal position.

ii) We want to minimize the total traveled distance $d_{trav} = \sum_{i=1}^{3} \|x^{(i)} - g^{(i)}\|$, where $g^{(i)}$ is the goal position assigned to the i$^{\text{th}}$ robot.

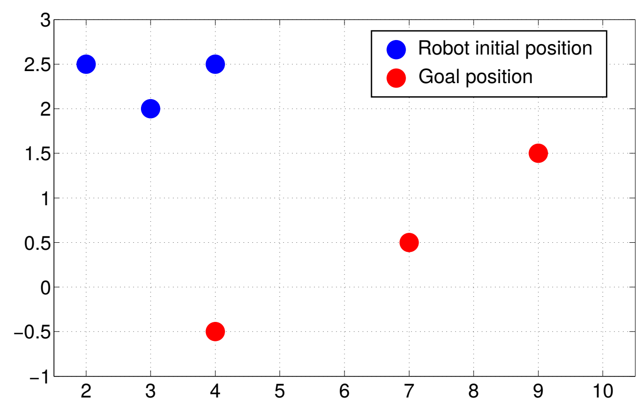

Figure 1: Robot and goal positions.

Exercise 2

Consider 5 companies that export products (x_1) to different countries (x_2). In this problem, for each company i, a 2D feature vector is defined as $\boldsymbol{x}^{(i)} = [x_1^{(i)} \; x_2^{(i)}]^T$. Some observations of $\boldsymbol{x}$ are summarized in the following table:

company i	product $x_1^{(i)}$	country $x_2^{(i)}$
1	1	1
2	2	3
3	5	7
4	6	5
5	6	7

Cluster those feature vectors using *agglomerative clustering*.

a) Calculate the matrix of the initial distances between the clusters (distance of each feature vector from the others) and merge the closest clusters. Use squared Euclidean distance $d(\boldsymbol{x}^{(i)}, \boldsymbol{x}^{(j)}) = \sum_k (x_k^{(i)} - x_k^{(j)})^2$ as metric.

b) Calculate the matrix of the distances between the clusters after the first merging using the *single-linkage* algorithm.

c) Draw the *Dendrogram* indicating the order in which the merging operations occur. Use the *single-linkage* algorithm.