

Exercises for Combinatorial and Computational Geometry

Series 1 — Convex sets

hints 25.10.2023, deadline 12:20 1.11.2023

Please choose a nickname that will be used in the list of scores on the webpage of the exercises. If you have already chosen a nickname, you can just sign your solutions with either your name or your nickname.

1. Find a set $M \subset \mathbb{R}^2$ that is a union of two convex sets such that $\mathbb{R}^2 \setminus M$ consists of five pairwise disjoint connected components. [2]
2. Prove Carathéodory's theorem (you may use Radon's theorem or a part of its proof). [2]
3. Let $M = \{x_1, y_1, x_2, y_2, \dots, x_{d+1}, y_{d+1}\}$ be a set of $2d + 2$ points in \mathbb{R}^d . Prove that M can be partitioned into two subsets A and B such that each of these subsets contains, for every $i = 1, 2, \dots, d + 1$, exactly one point from $\{x_i, y_i\}$, and the convex hulls of A and B have a nonempty intersection. (You may use the fact that the $(d + 1)$ -tuple of vectors $x_i - y_i$ is linearly dependent and then use an approach similar to the proof of Radon's theorem.) [2]
4. Let M be a finite set of at least four points in the plane such that each point is either red or blue. In addition, for every 4-tuple V of points of M there is a line strictly separating the red points of V from the blue points of V . Prove that there is a line strictly separating all the red points of M from all the blue points of M . [3]
5. Let X_1, X_2, \dots, X_{d+1} be finite point sets in \mathbb{R}^d such that for every $i \in \{1, 2, \dots, d + 1\}$ the origin lies in $\text{conv}(X_i)$. Prove that there exist $d + 1$ points x_1, x_2, \dots, x_{d+1} , with $x_i \in X_i$, such that $\text{conv}(\{x_1, x_2, \dots, x_{d+1}\})$ contains the origin. [4, hint]