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## Definition 2

An **Integer Linear Program** or **Integer Program** is a Linear Program in which all variables are required to be integral.

## Definition 3

A **Mixed Integer Program** is a Linear Program in which a subset of the variables are required to be integral.

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# Set Cover

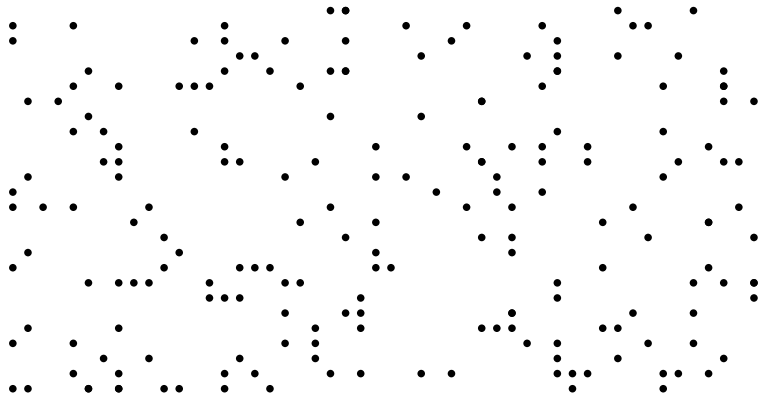
Given a ground set  $U$ , a collection of subsets  $S_1, \dots, S_k \subseteq U$ , where the  $i$ -th subset  $S_i$  has weight/cost  $w_i$ . Find a collection  $I \subseteq \{1, \dots, k\}$  such that

$$\forall u \in U \exists i \in I: u \in S_i \text{ (every element is covered)}$$

and

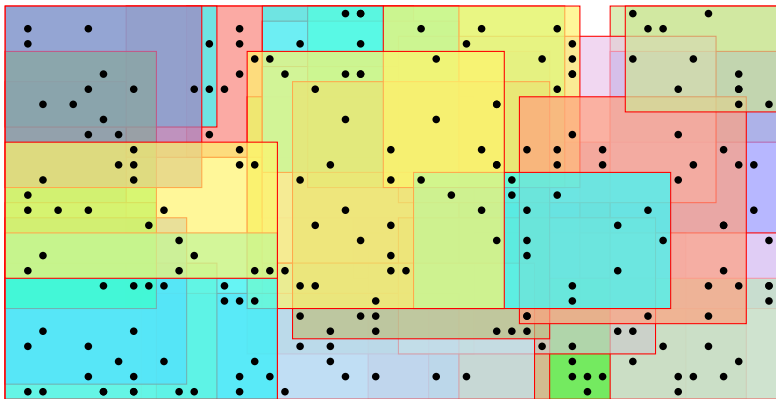
$$\sum_{i \in I} w_i \text{ is minimized.}$$

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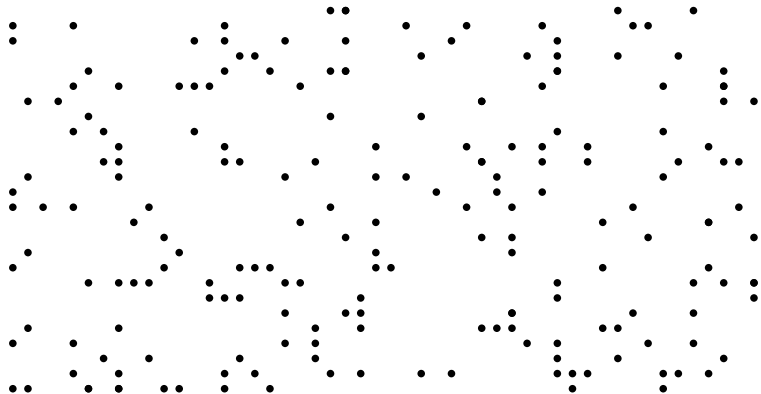




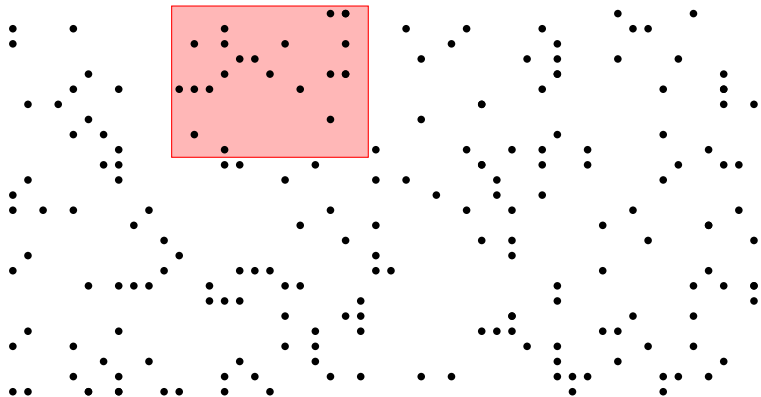
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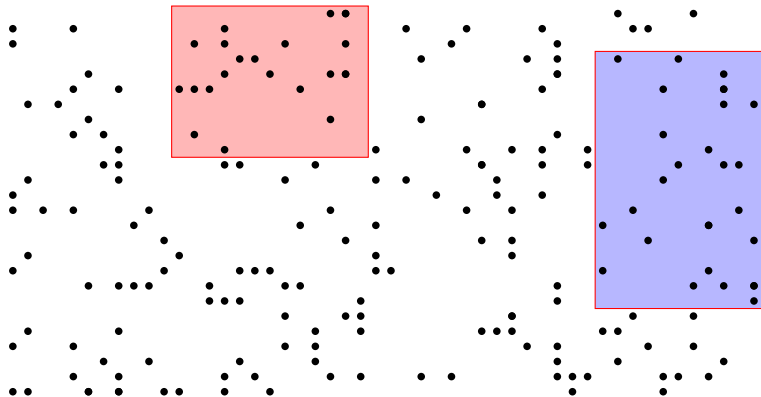
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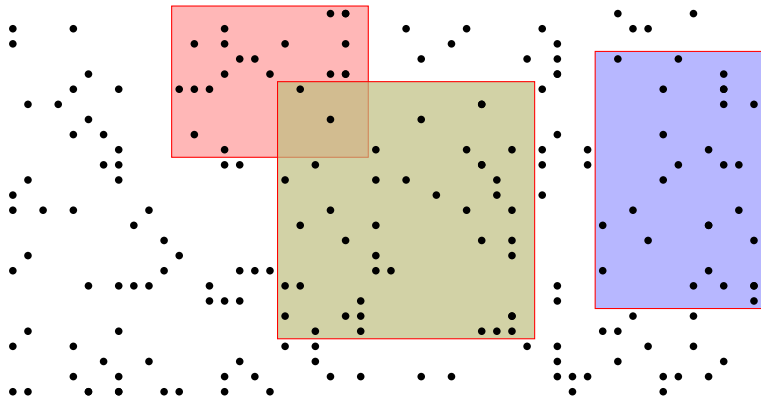
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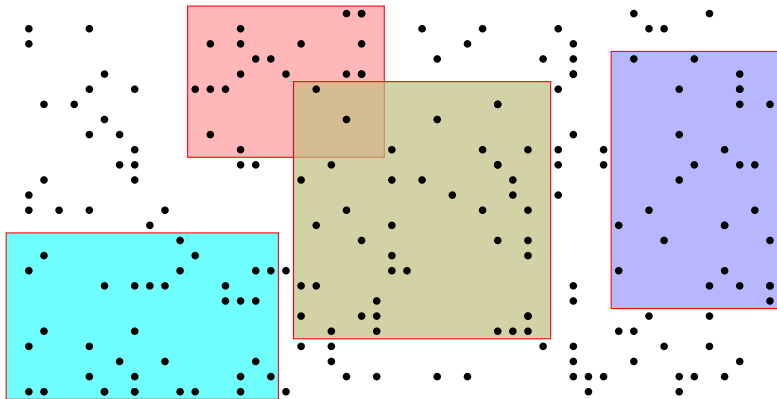
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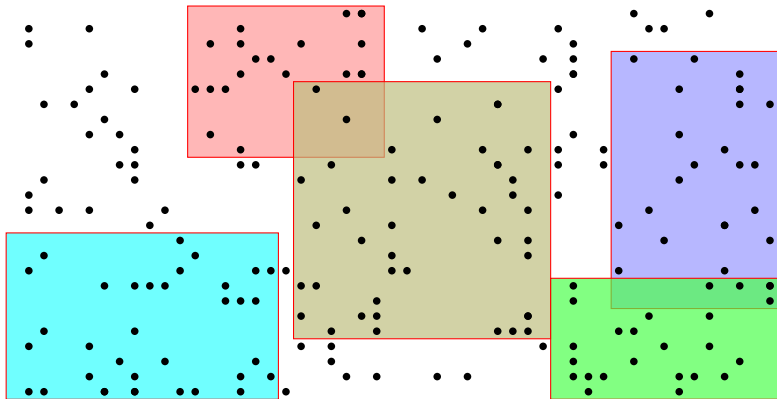
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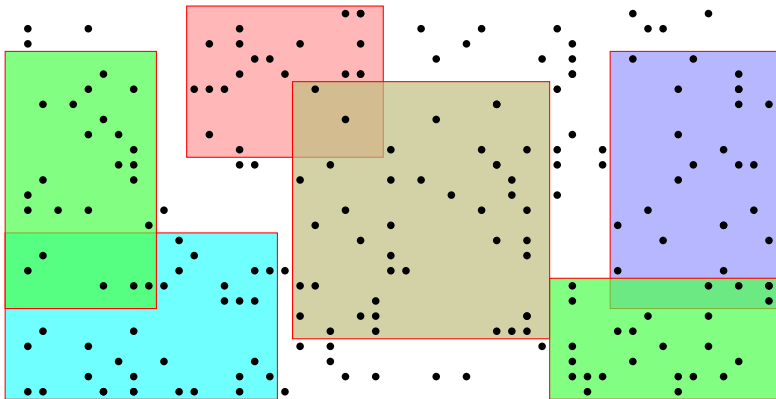
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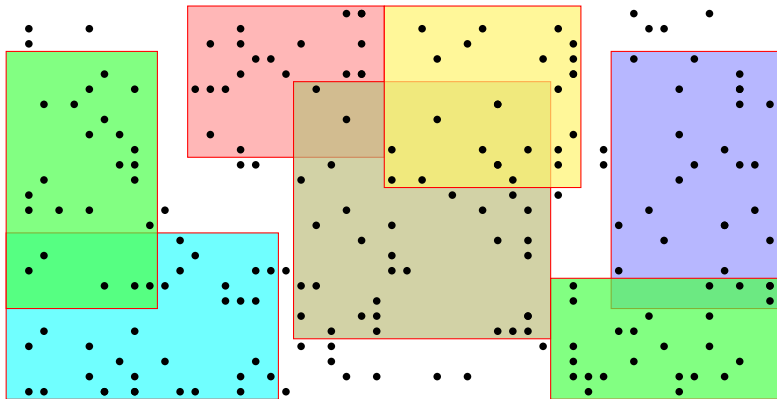


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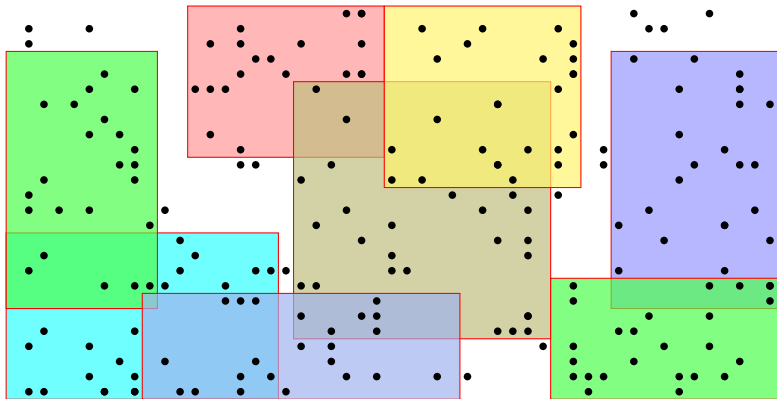




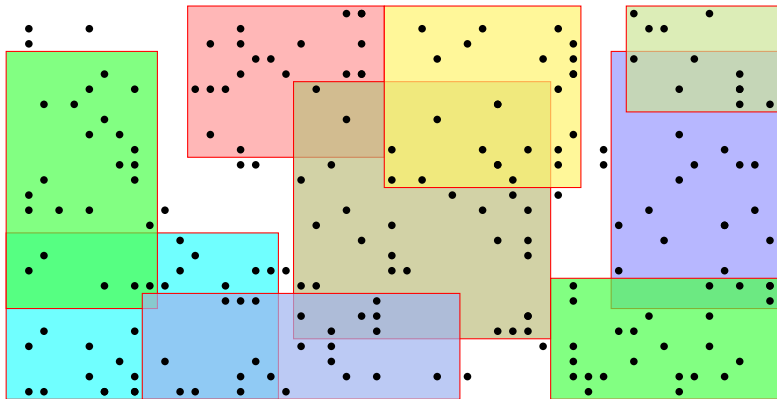
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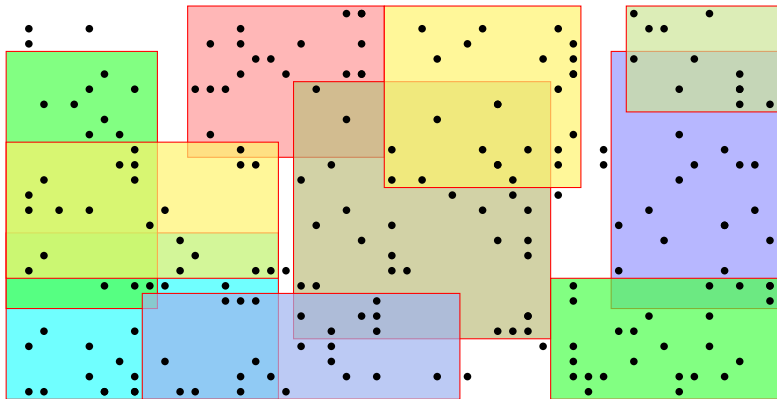
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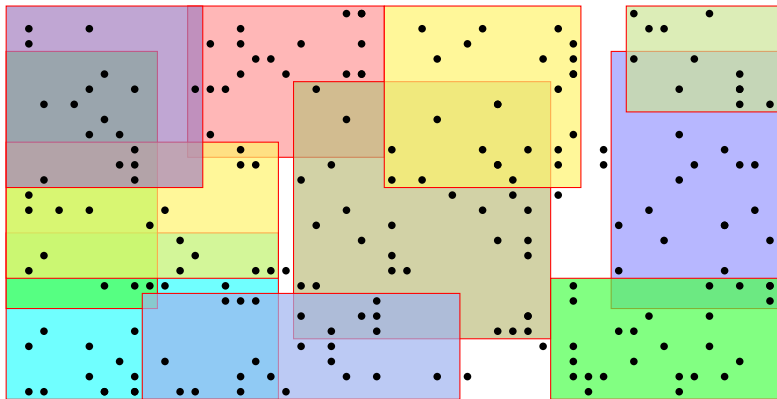
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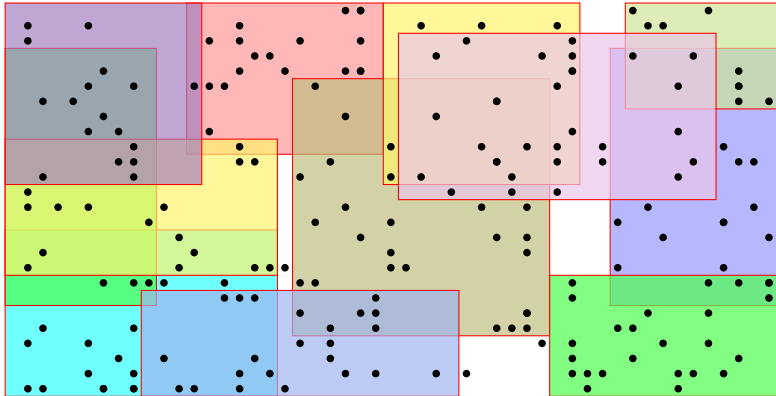
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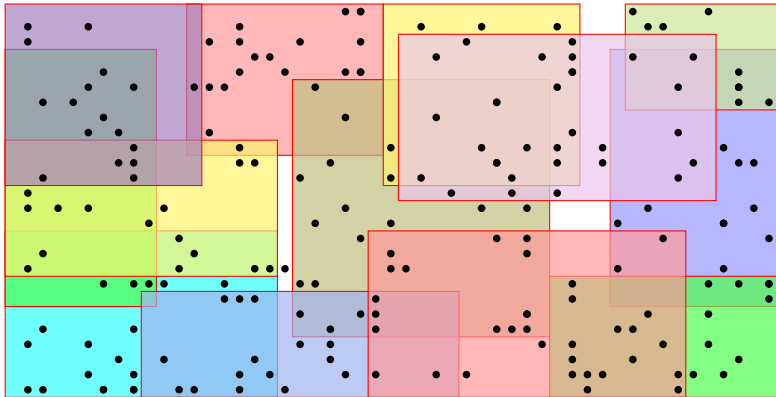
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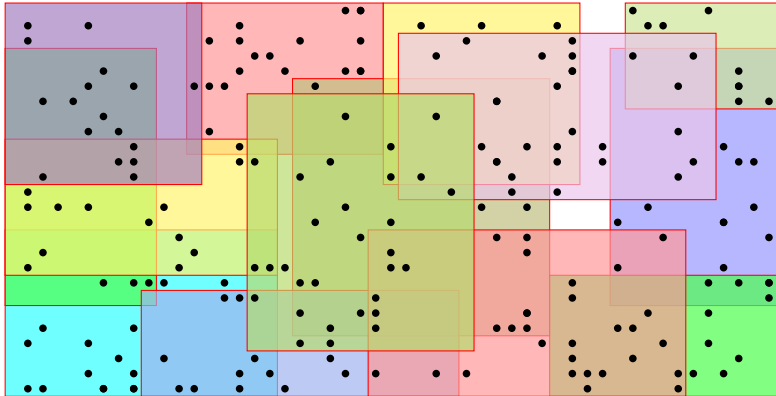
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# IP-Formulation of Set Cover

$$\begin{array}{llll} \min & & \sum_i w_i x_i & \\ \text{s.t.} & \forall u \in U & \sum_{i:u \in S_i} x_i & \geq 1 \\ & \forall i \in \{1, \dots, k\} & x_i & \geq 0 \\ & \forall i \in \{1, \dots, k\} & x_i & \text{integral} \end{array}$$

# Vertex Cover

Given a graph  $G = (V, E)$  and a weight  $w_v$  for every node. Find a vertex subset  $S \subseteq V$  of minimum weight such that every edge is incident to at least one vertex in  $S$ .

# IP-Formulation of Vertex Cover

$$\begin{array}{ll} \min & \sum_{v \in V} w_v x_v \\ \text{s.t.} & \forall e = (i, j) \in E \quad x_i + x_j \geq 1 \\ & \forall v \in V \quad x_v \in \{0, 1\} \end{array}$$

# Maximum Weighted Matching

Given a graph  $G = (V, E)$ , and a weight  $w_e$  for every edge  $e \in E$ . Find a subset of edges of maximum weight such that no vertex is incident to more than one edge.

$$\begin{array}{ll} \max & \sum_{e \in E} w_e x_e \\ \text{s.t.} & \forall v \in V \quad \sum_{e: v \in e} x_e \leq 1 \\ & \forall e \in E \quad x_e \in \{0, 1\} \end{array}$$

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# Maximum Independent Set

Given a graph  $G = (V, E)$ , and a weight  $w_v$  for every node  $v \in V$ . Find a subset  $S \subseteq V$  of nodes of maximum weight such that no two vertices in  $S$  are adjacent.

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# Knapsack

Given a set of items  $\{1, \dots, n\}$ , where the  $i$ -th item has weight  $w_i$  and profit  $p_i$ , and given a threshold  $K$ . Find a subset  $I \subseteq \{1, \dots, n\}$  of items of total weight at most  $K$  such that the profit is maximized.

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## Definition 4

A linear program LP is a **relaxation** of an integer program IP if any feasible solution for IP is also feasible for LP and if the objective values of these solutions are identical in both programs.

We obtain a relaxation for all examples by writing  $x_i \in [0, 1]$  instead of  $x_i \in \{0, 1\}$ .

## Definition 4

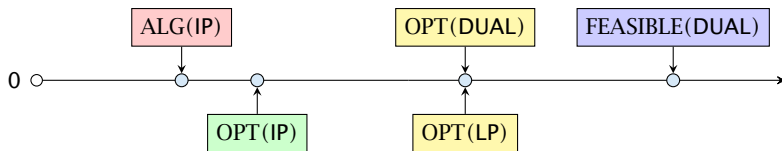
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By solving a relaxation we obtain an upper bound for a maximization problem and a lower bound for a minimization problem.

# Relations

## Maximization Problems:



## Minimization Problems:

