Computer Vision I

Jannik Irmai, Jannik Presberger, Bjoern Andres

Machine Learning for Computer Vision
TU Dresden

https://mlcv.cs.tu-dresden.de/courses/24-winter/cv1/

Winter Term 2024/2025

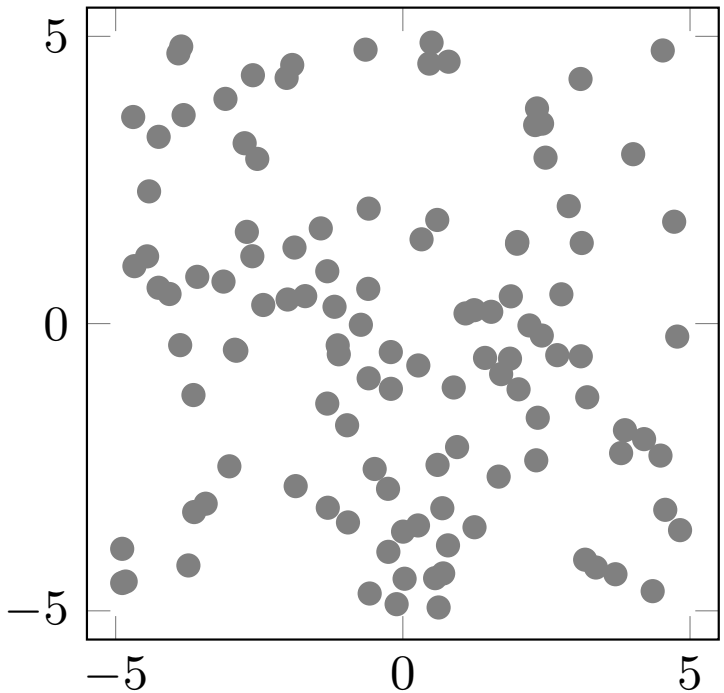
Object recognition

Object recognition is the task of finding any occurrences of an object in an image, given a **model** of the the geometry and appearance of the object.

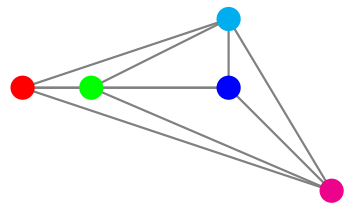
Object recognition

Pishchulin, Insafutdinov, Tang, A, Andriluka, Gehler, Schiele 2016.
Insafutdinov, Pishchulin, A, Andriluka, Schiele 2016.

Object recognition



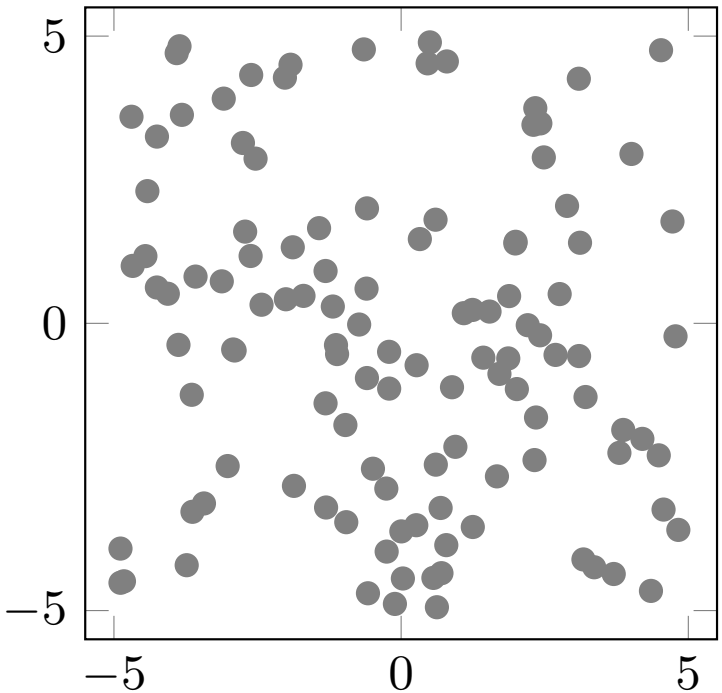
Set D of **image points**



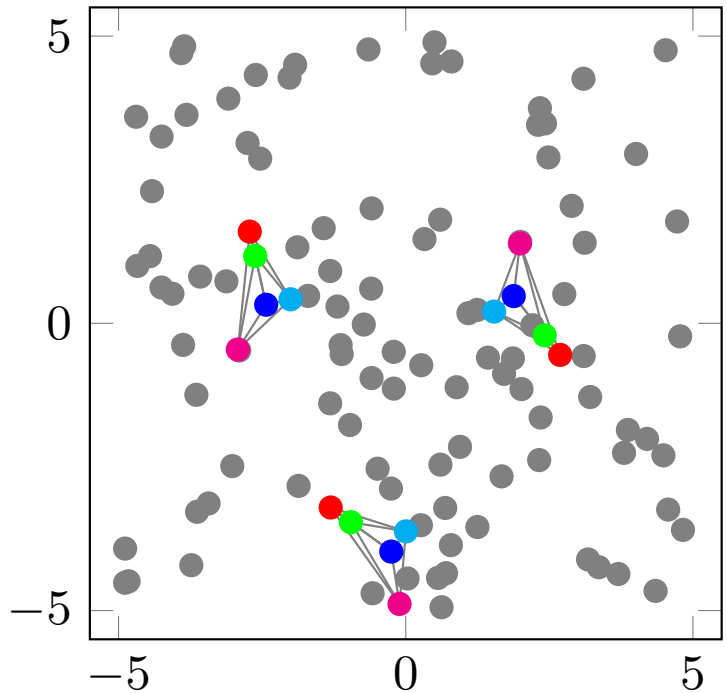
ϵ (not part of object)

Set V of **object points**

Object recognition



Set D of **image points**



Recognition

Decisions at points

- For any **image point** $d \in D$ and any **object point** $v \in V$, let $z_{dv} \in \{0, 1\}$ indicate whether d is an occurrence of v.
- We constrain each image point to be an occurrence of precisely one object point, possibly ϵ. Hence, we consider the feasible set

$$Z_{DV} = \left\{ z \colon D \times V \to \{0,1\} \;\middle|\; \forall d \in D \colon \sum_{v \in V} z_{dv} = 1 \right\} .$$

Costs at points

- For any image point $d \in D$ and any object point $v \in V$, let $c_{dv} \in \mathbb{R}$ a cost associated with the decision $y_{dv} = 1$
- This cost typically depends on the contents of the image at the point d.
- It can be estimated from examples by the machine learning techniques discussed earlier.

Decisions for pairs of points

- For any pair $\{d, d'\} \in \binom{D}{2}$ of image points, let $y_{\{d,d'\}} \in \{0, 1\}$ indicate whether d and d' belong to the same occurrence of an object in the image
- We require these decisions to be transitive, i.e.

$$\forall d \in D \; \forall d' \in D \setminus \{d\} \; \forall d'' \in D \setminus \{d, d'\}: \\ y_{\{d,d'\}} + y_{\{d',d''\}} - 1 \leq y_{\{d,d''\}} \qquad (1)$$

  Hence, we consider the feasible set

$$Y_D = \left\{ y \colon \binom{D}{2} \to \{0, 1\} \;\middle|\; (1) \right\}$$

Costs for pairs of points

- For any pair $(d, d') \in D^2$ of image points such that $d \neq d'$ and any pair $(v, w) \in V^2$ of object points, let
  - $c'_{dd'vw} \in \mathbb{R}$ a cost associated with the decision $z_{dv}\, z_{d'w}\, y_{\{d,d'\}} = 1$
  - $c''_{dd'vw} \in \mathbb{R}$ a cost associated with the decision $z_{dv}\, z_{d'w}\, (1 - y_{\{d,d'\}}) = 1$
- These costs can depend, e.g., on the distance between d and d' in the image plane.
- They can be estimated from examples by the machine learning techniques discussed earlier.

Optimization problem

- The task of object recognition can now be stated as the optimization problem

$$\begin{aligned}\min_{(y,z)\in Y_D\times Z_{DV}} & \sum_{d\in D}\sum_{v\in V} c_{dv}\, z_{dv} \\ & + \sum_{d\in D}\sum_{d'\in D\setminus\{d\}}\sum_{(v,w)\in V^2} c'_{dd'vw}\, z_{dv}\, z_{d'w}\, y_{\{d,d'\}} \\ & + \sum_{d\in D}\sum_{d'\in D\setminus\{d\}}\sum_{(v,w)\in V^2} c''_{dd'vw}\, z_{dv}\, z_{d'w}\, (1-y_{\{d,d'\}})\end{aligned}$$

- This is a joint graph decomposition and node labeling problem.
- The same local search algorithms we have considered for the task of semantic segmentation can be applied.