Contents

- Bags of features
  - Textons for texture representation
  - Bags of words
  - ‘Dictionary learning’ (clustering)
  - Recognition
- Tracking
  - Meanshift and CAMshift
  - Other approaches

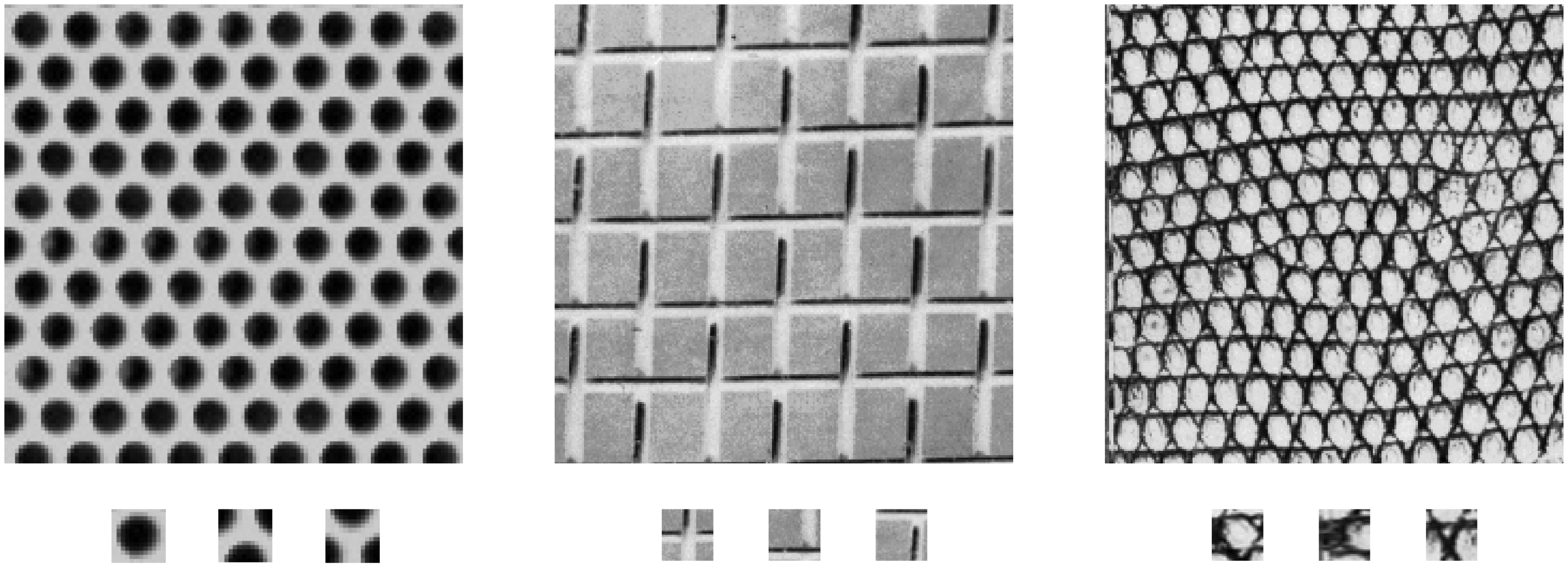
Bag of features models

Some slides adapted from Fei-Fei Li, Rob Fergus and Antonio Torralba

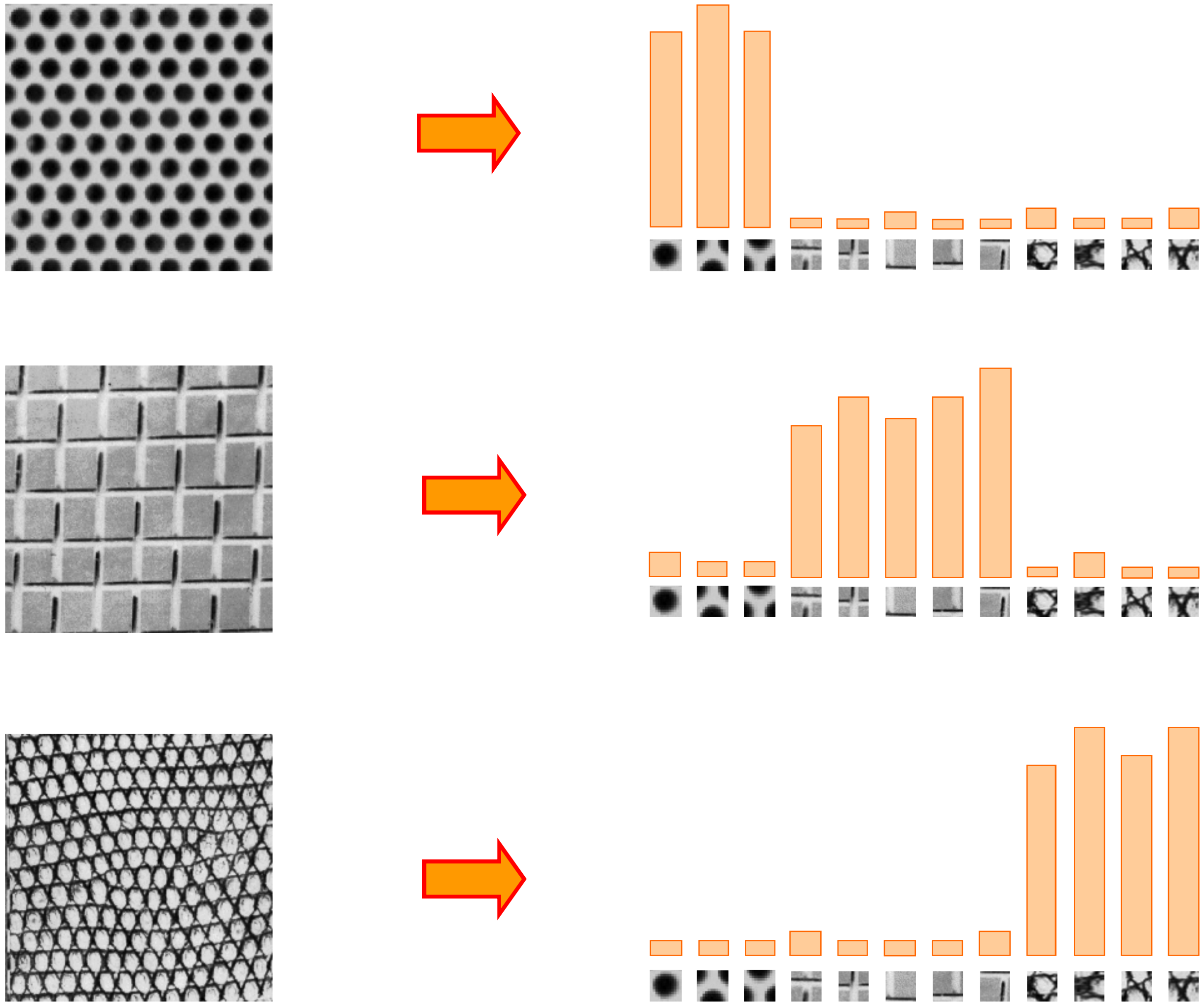
Origin 1: Texture recognition

Texture is characterized by the repetition of basic elements or *textons*.

Arguably, for stochastic textures, the identity of the textons matters more than their spatial arrangement.



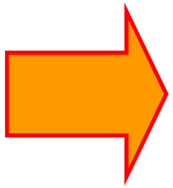
Origin 1: Texture recognition



Origin 2: Bag-of-words models

- Orderless document representation: frequencies of words from a dictionary Salton & McGill (1983)

Bags of features for object recognition

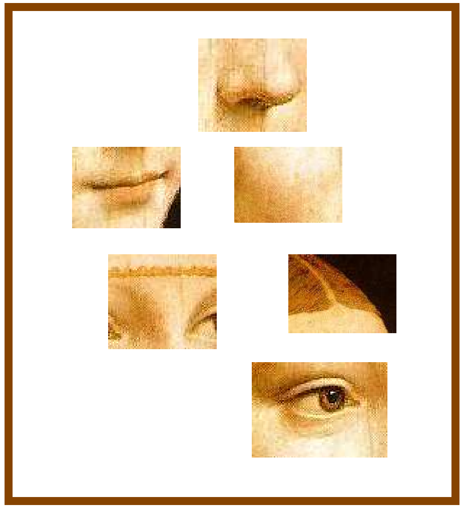


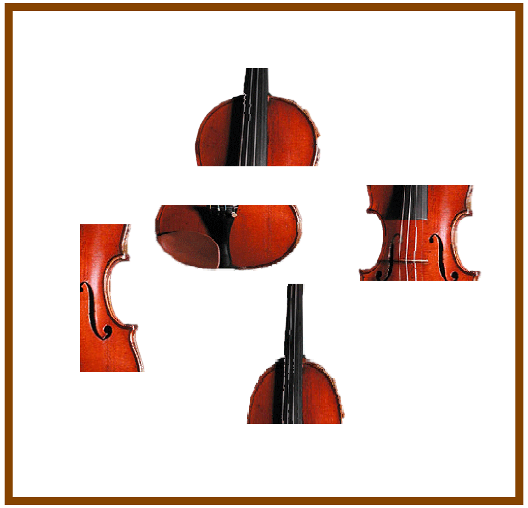
face, flowers, building

Quite effective for image-level classification

Bag of features: overview

1. Extract features





Bag of features: overview

1. Extract features
2. Learn visual vocabulary ('dictionary' of visual 'words')

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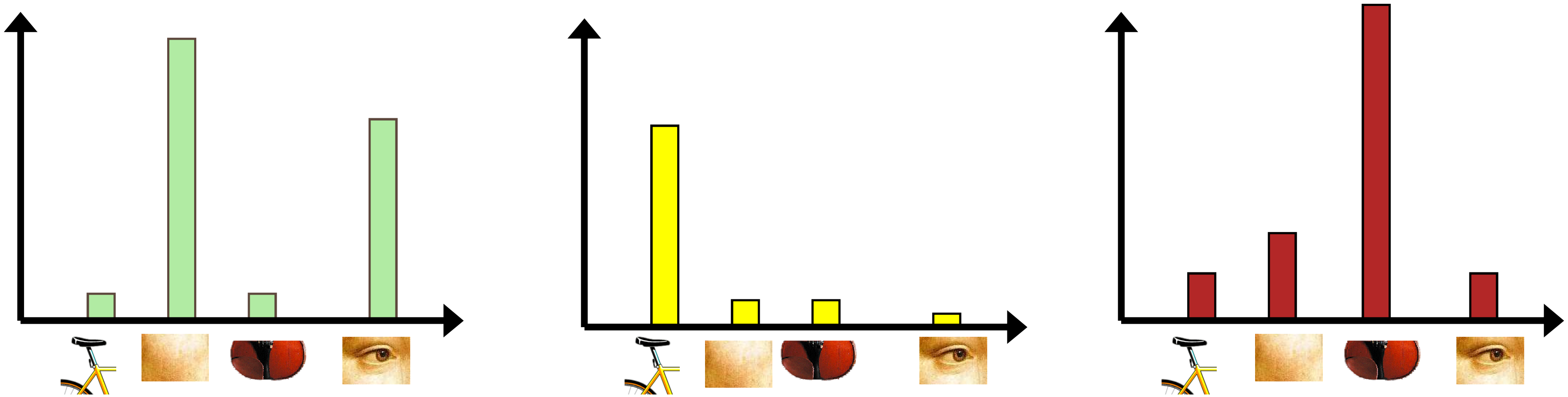
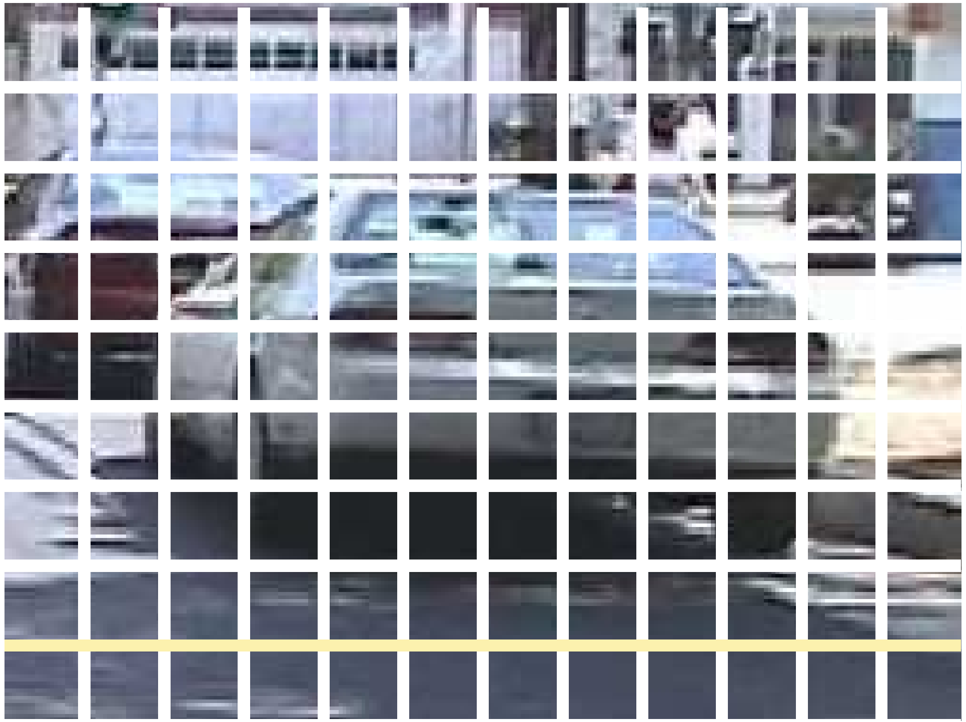
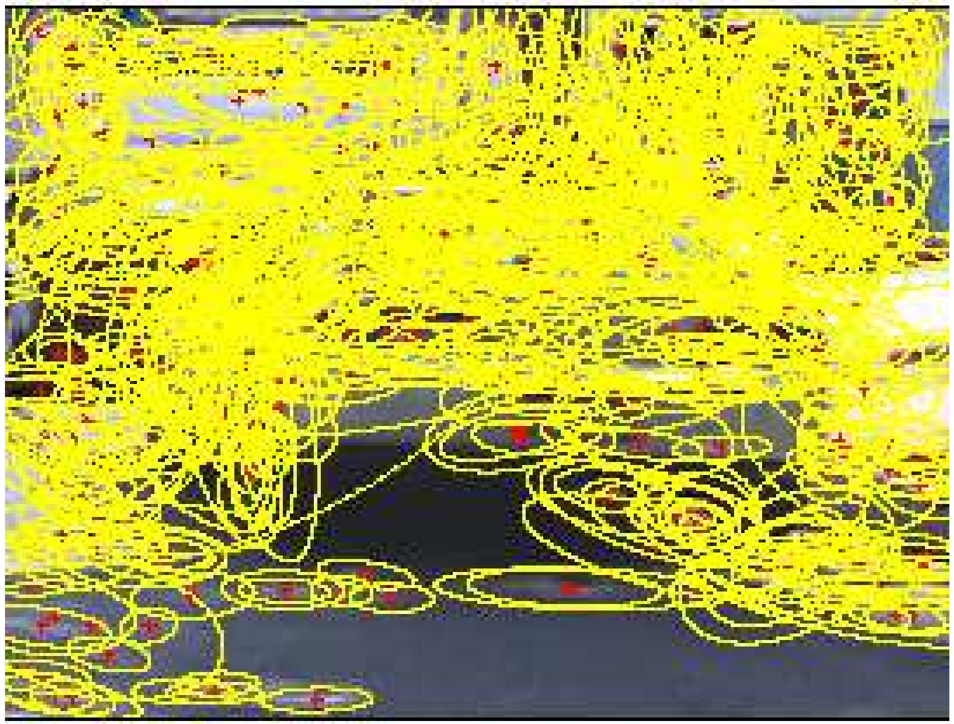
Bag of features: overview

1. Extract features
2. Learn visual vocabulary ('dictionary' of visual 'words')
3. Quantize features using visual vocabulary
4. Represent images by frequencies of visual words



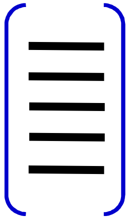
1. Feature extraction

- Extract features at locations on a regular grid, at random locations, at detected feature points, from superpixels…

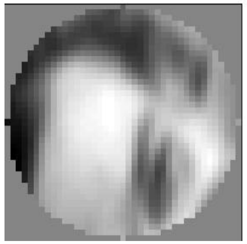
 

- Features: colour, texture, SIFT, SURF, etc.

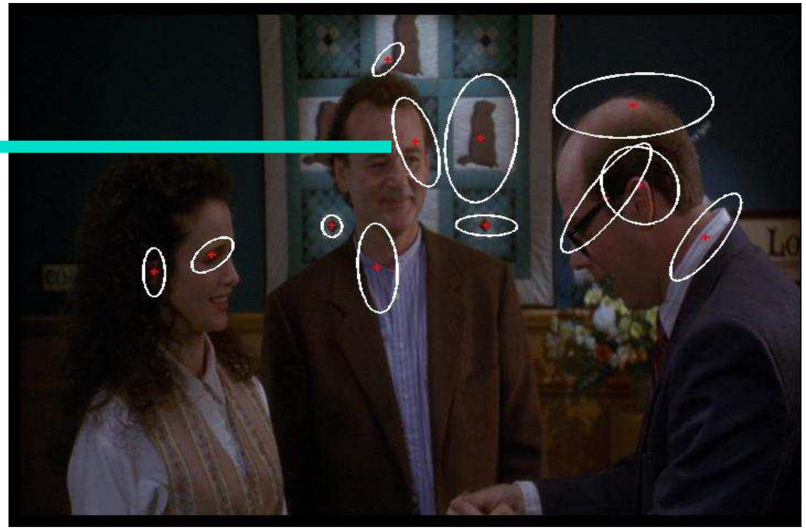
1. Feature extraction



SIFT descriptor

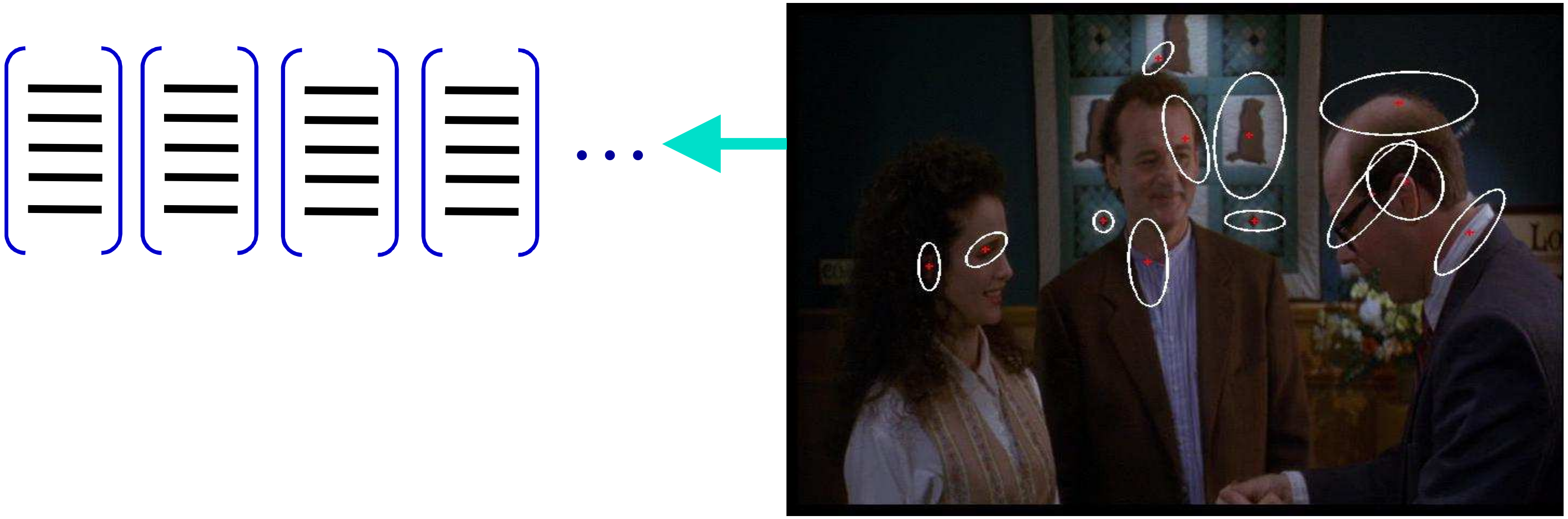


Normalized patch

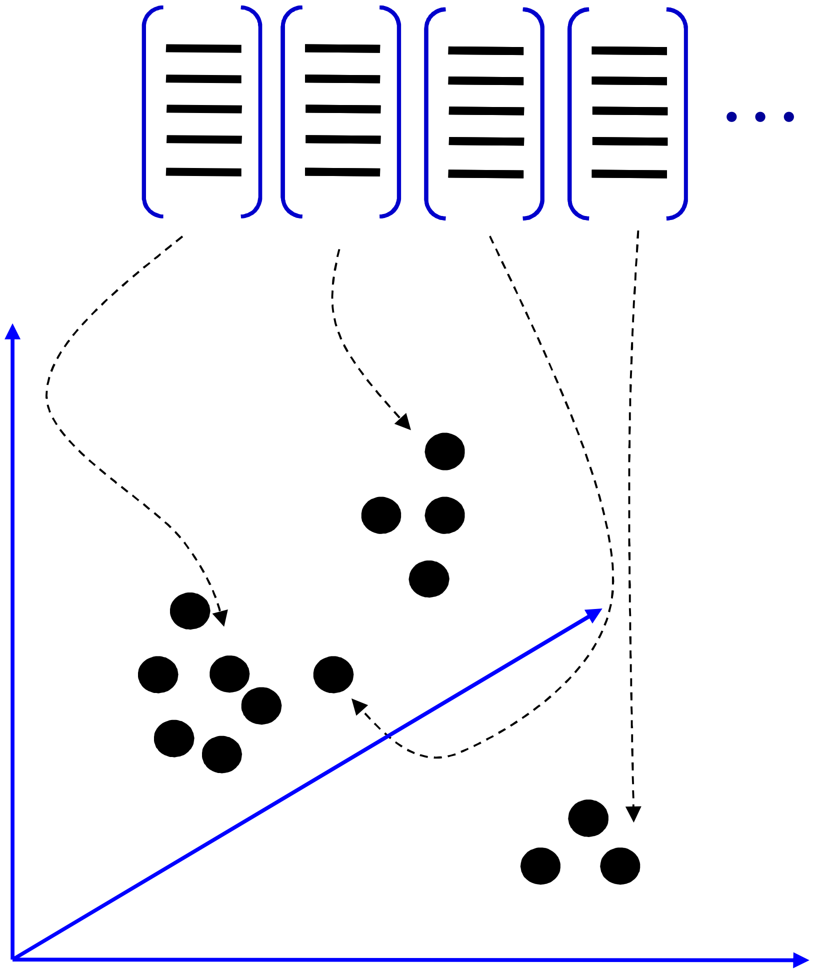


Patches (feature detection)

1. Feature extraction



2. Learning the visual vocabulary



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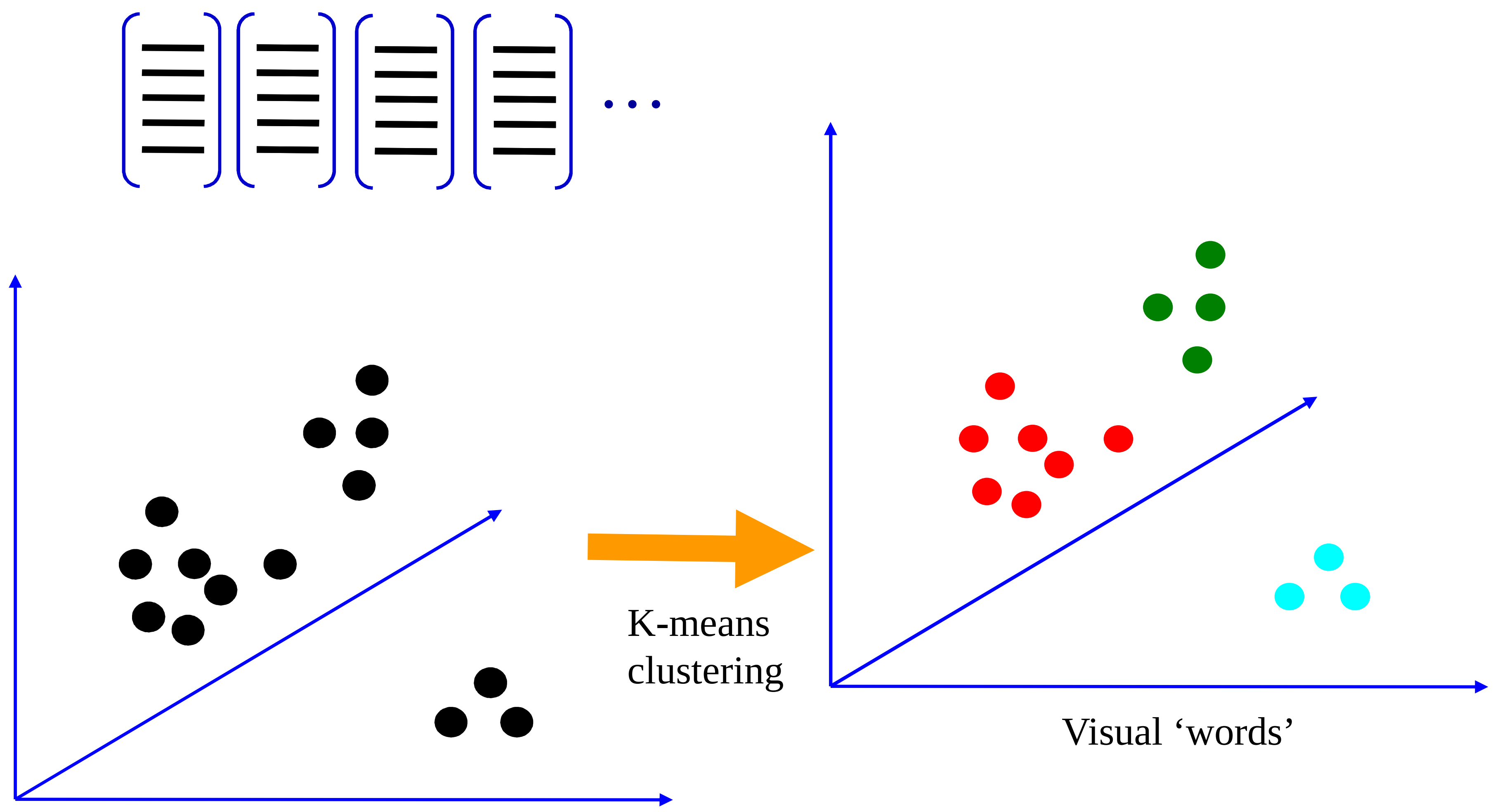
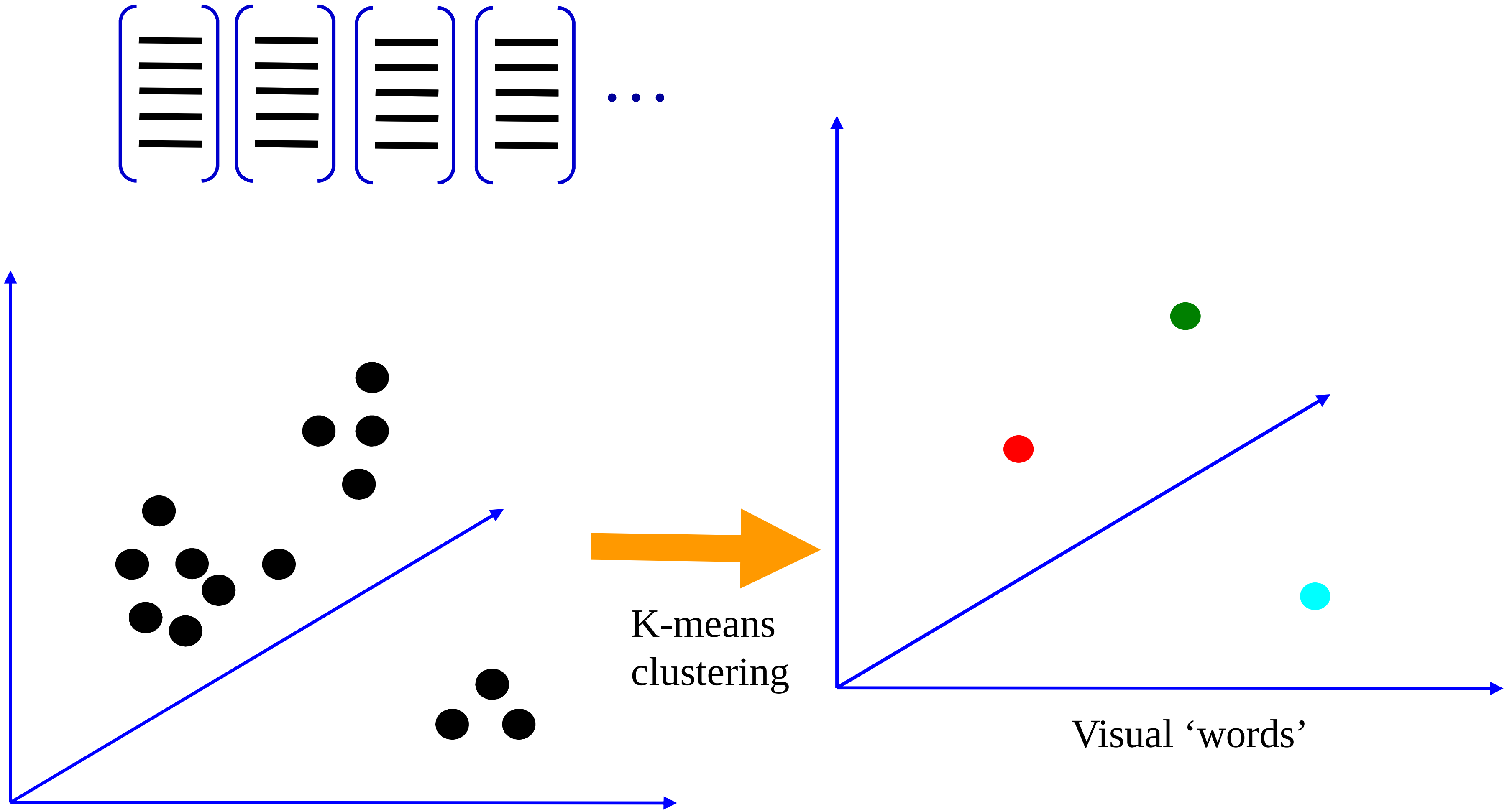


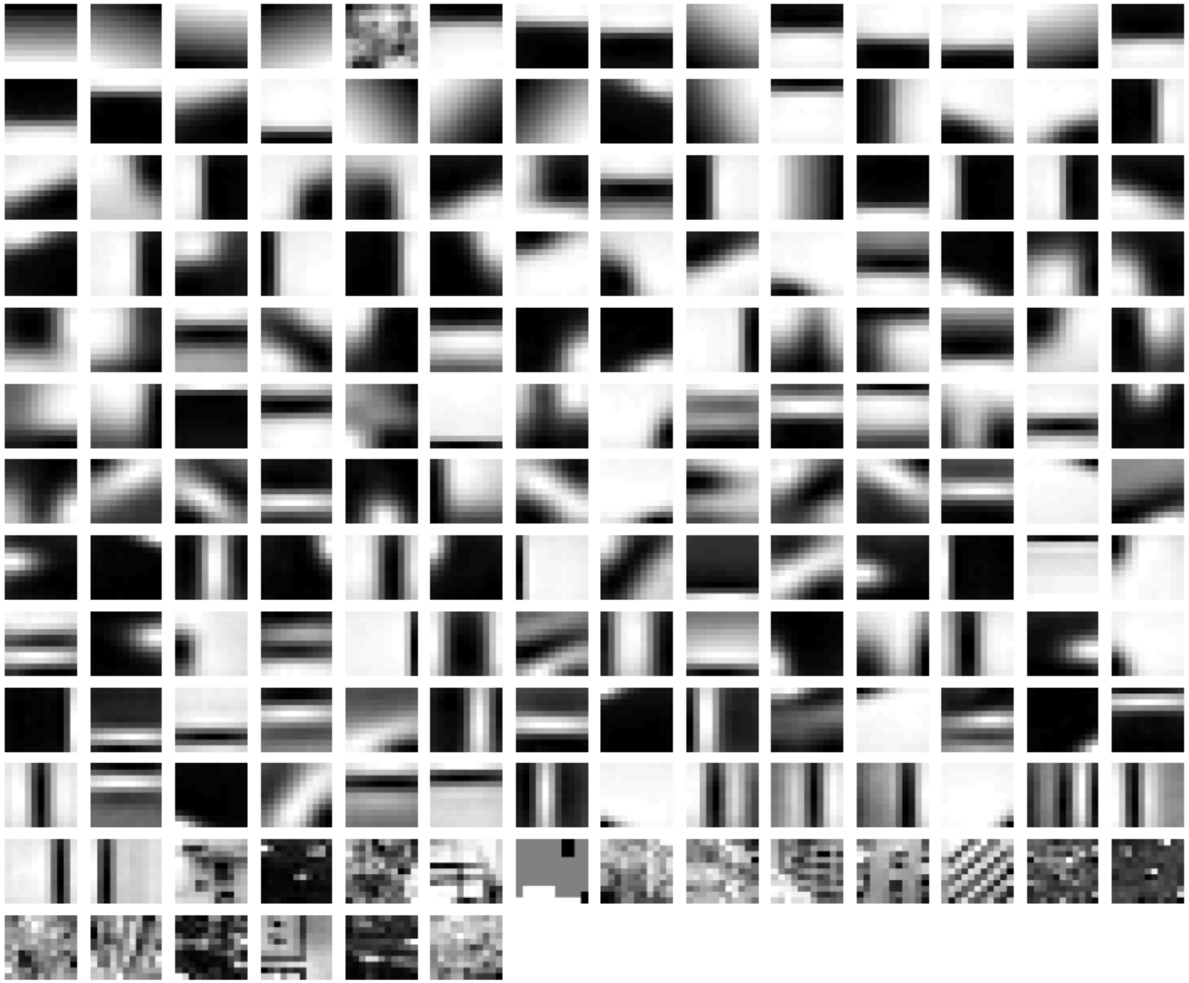
Based on slide by Josef Sivic

2. Learning the visual vocabulary



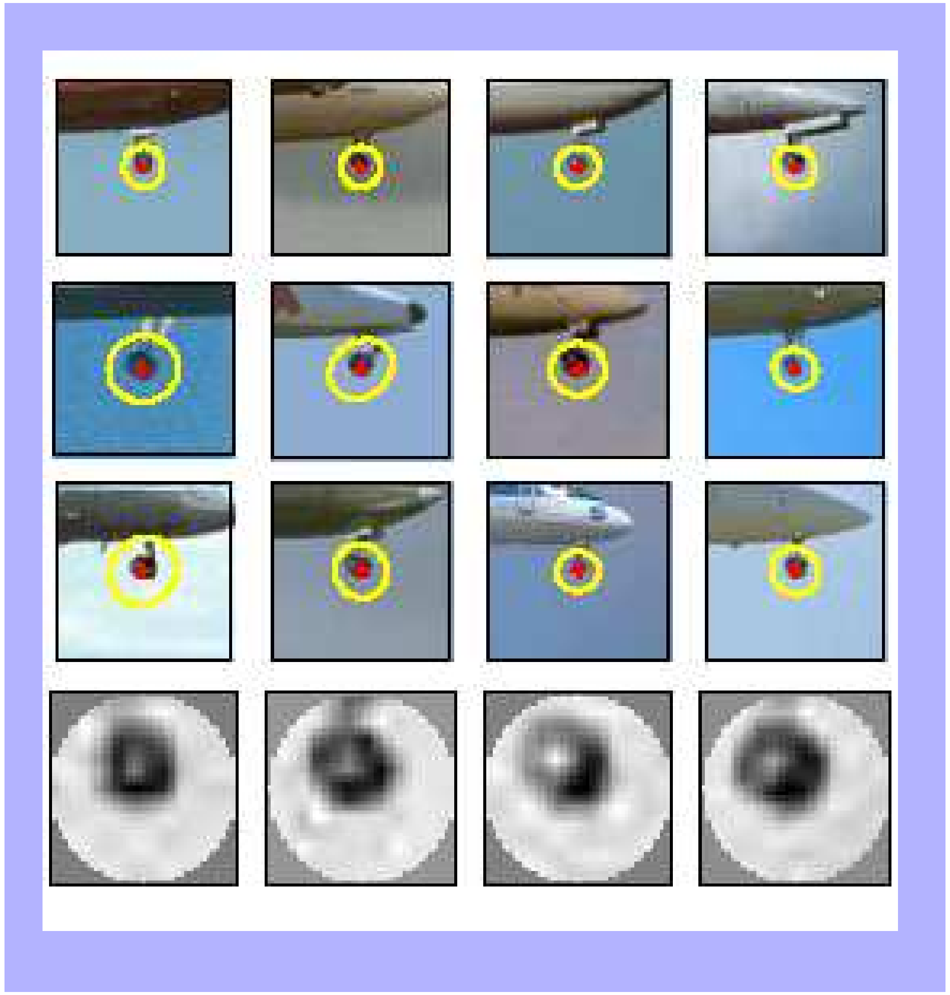
Based on slide by Josef Sivic

Example visual vocabulary



Fei-Fei et al. 2005

Image patch examples of visual words



Sivic et al. 2005

3. Image representation

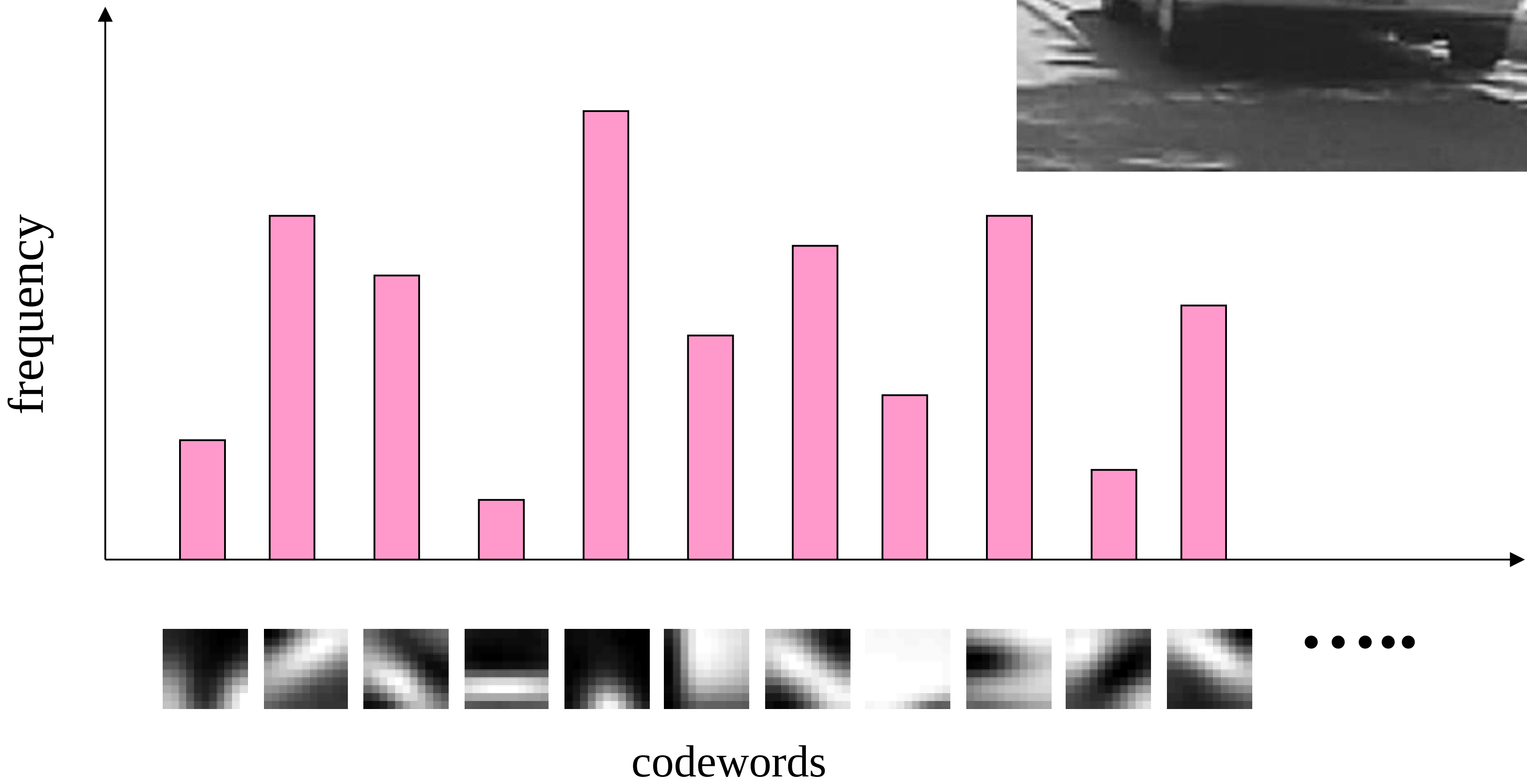
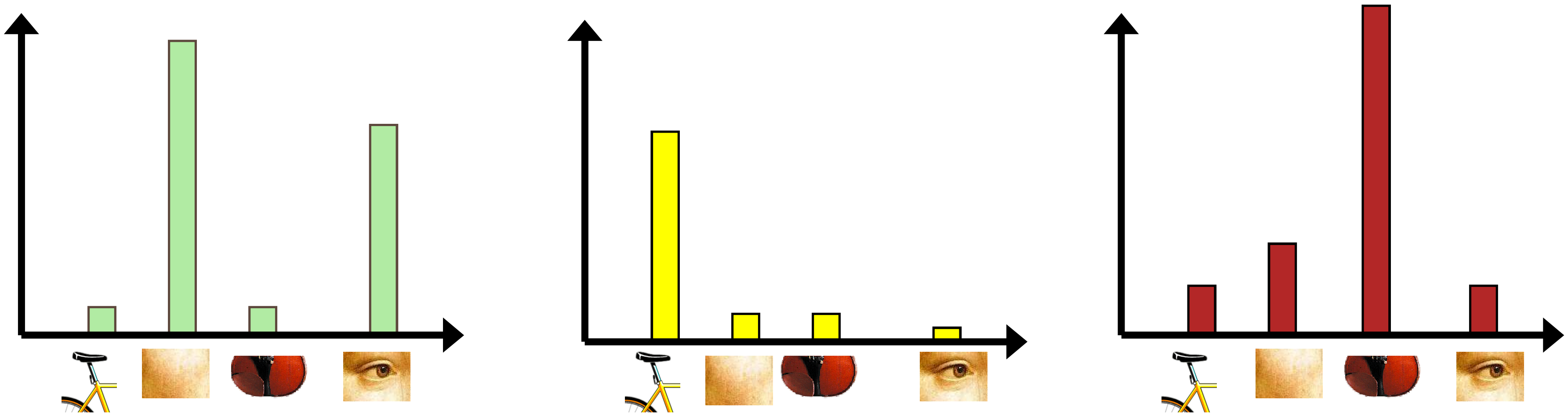


Image classification

Given a *bag-of-features* representation of each image:

- Train a classifier using the histograms as feature vectors
- Could involve defining a measure of histogram similarity



Tracking

- Following objects or features through an image sequence
- Estimating location (and orientation) in each frame
- Physical Constraints:
  - Inertia: motion cannot change abruptly

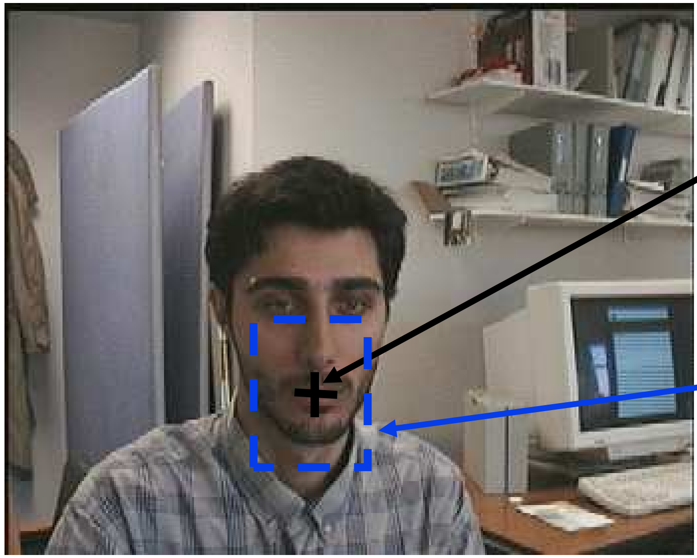
    ⇨No abrupt motion changes are observed *provided that* the frame rate is fast enough
  - If a 3D trajectory is smooth then its 2D projection is also smooth
- Useful Assumptions:
  - Location, speed and direction of motion do not change much between frames
  - Image motion is smooth

Targets to Track

- Local features (e.g. interest points, small objects)
- Contour fragments (e.g. partial object boundaries)
- Objects (possibly multiple parts, possibly deformable)

Tracking example

- Search in a local window
- Window position depends on previous estimate
- Extent of window depends on expected maximum speed of image motion

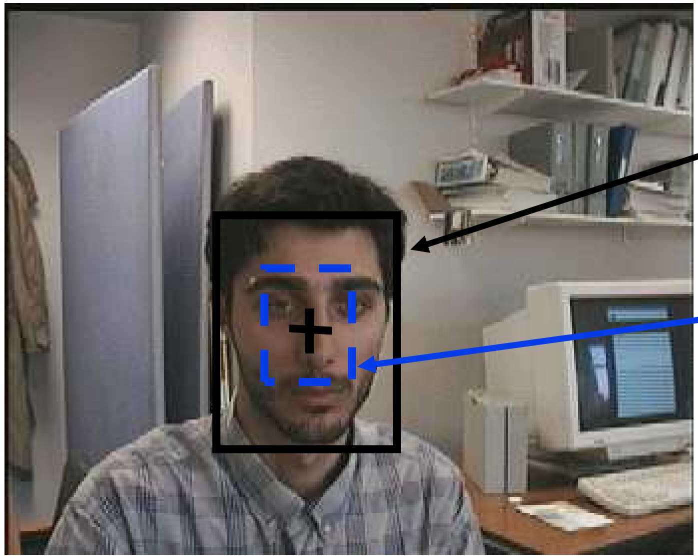


Estimate at frame t

Search window for frame t+1

Face tracking example

- Want to estimate location and scale (fixed aspect ratio)
- Search ranges depend on previous estimates

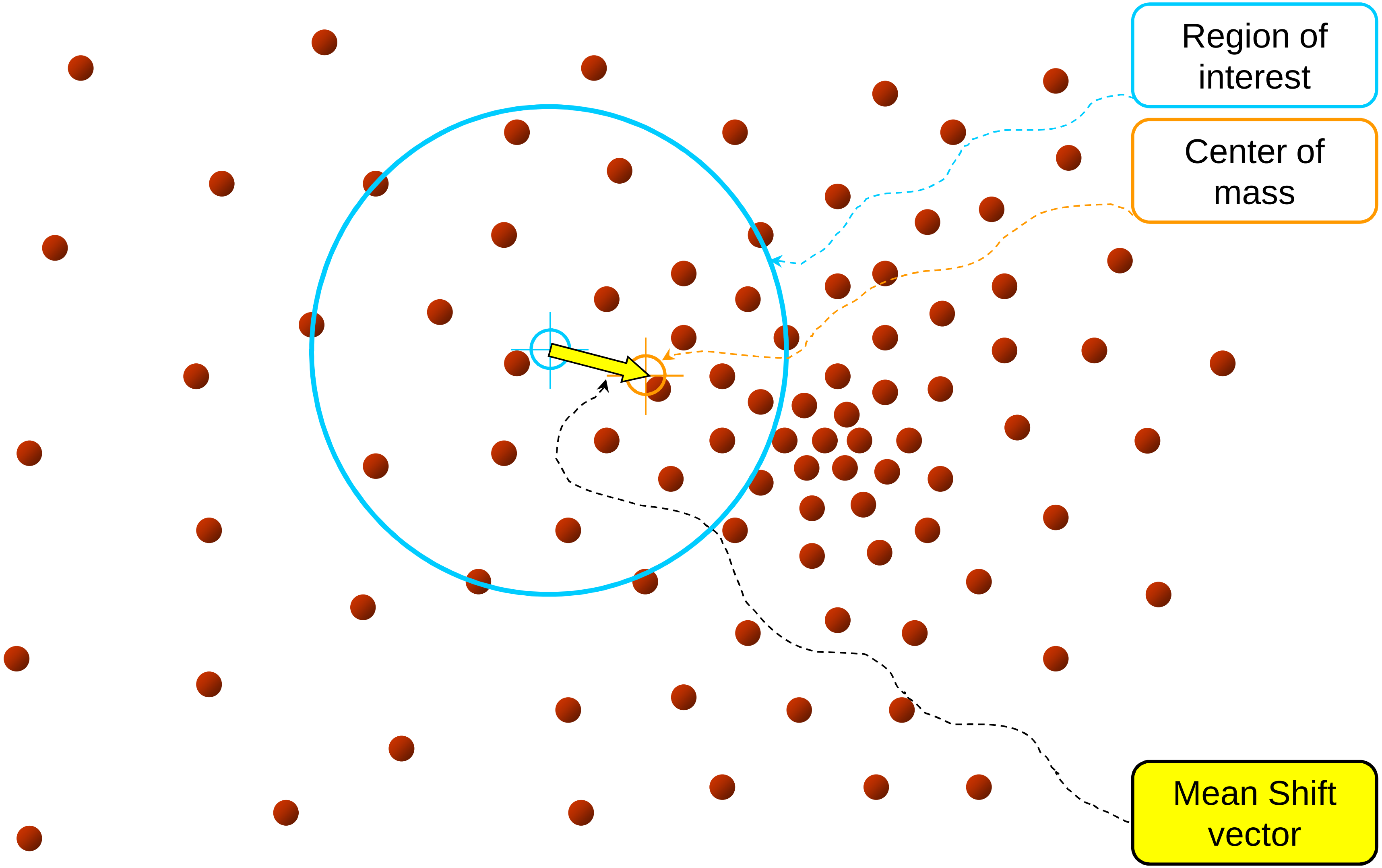


Box indicates estimated location and scale at time t

At t+1, search for object centred within this window and at a range of scales

Example: Head Tracking

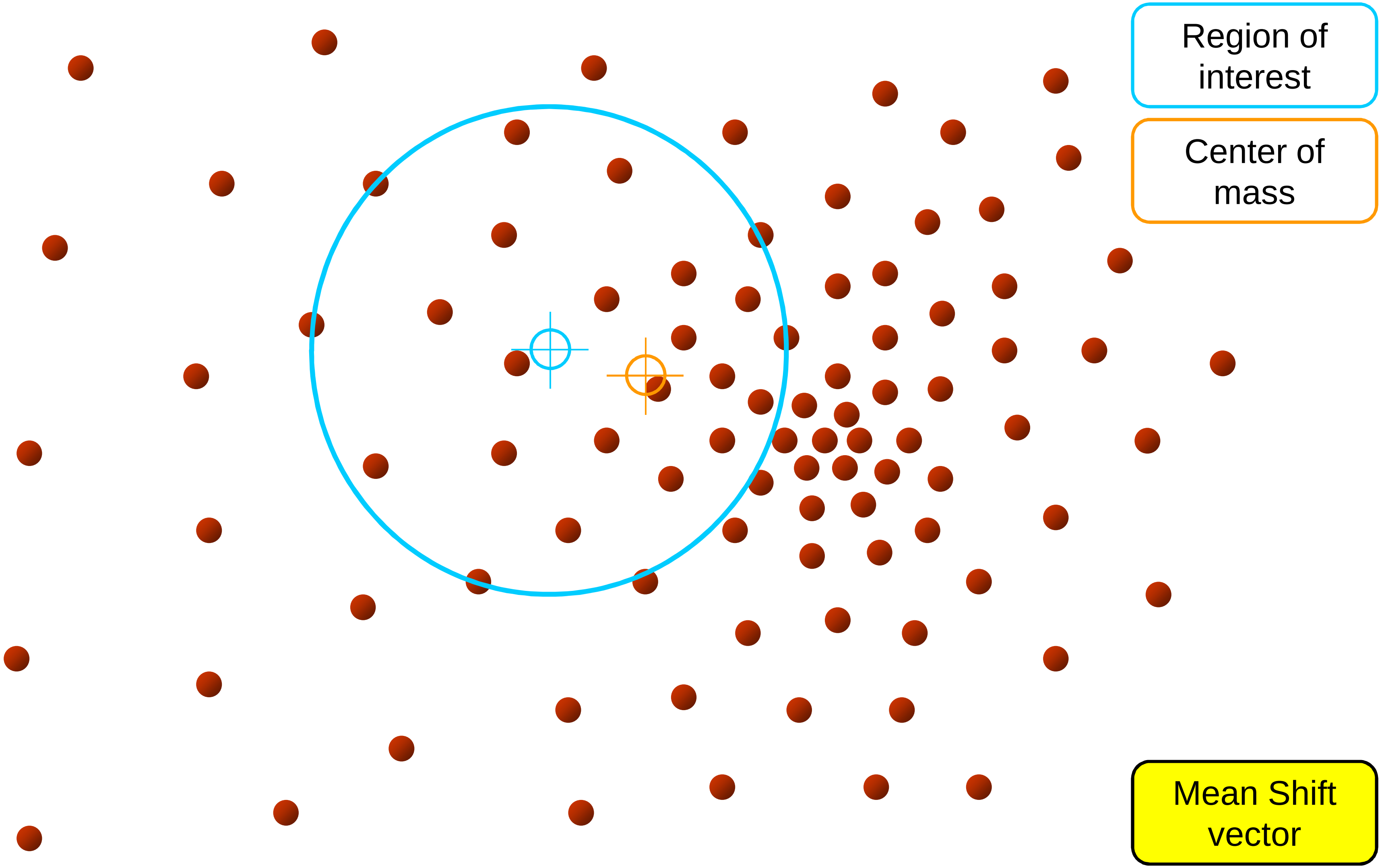
Mean Shift: Intuitive Description



Objective : Find the densest region

Distribution of identical billiard balls

(Slide credit: Yaron Ukrainitz & Bernard Sarel)



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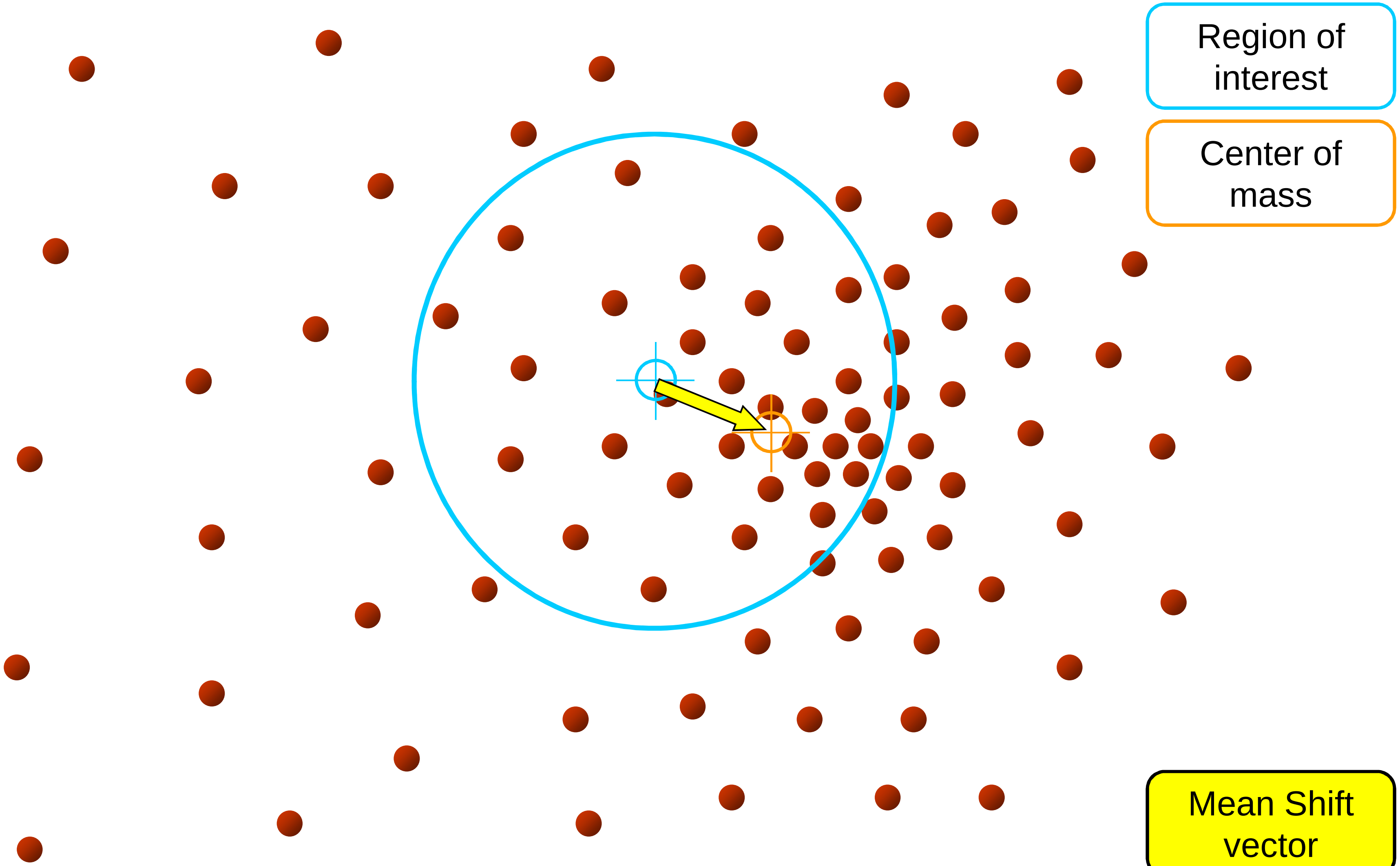

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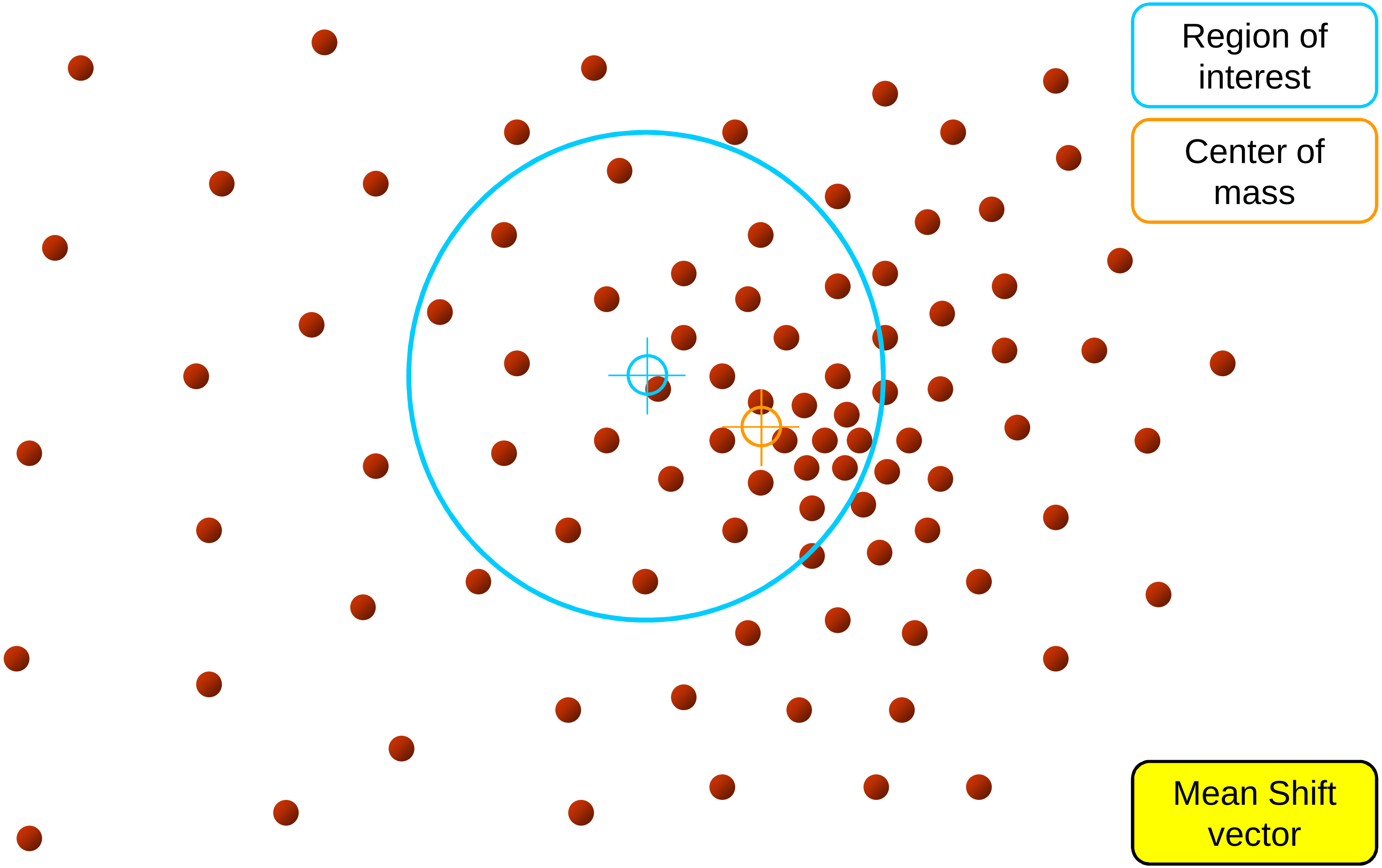

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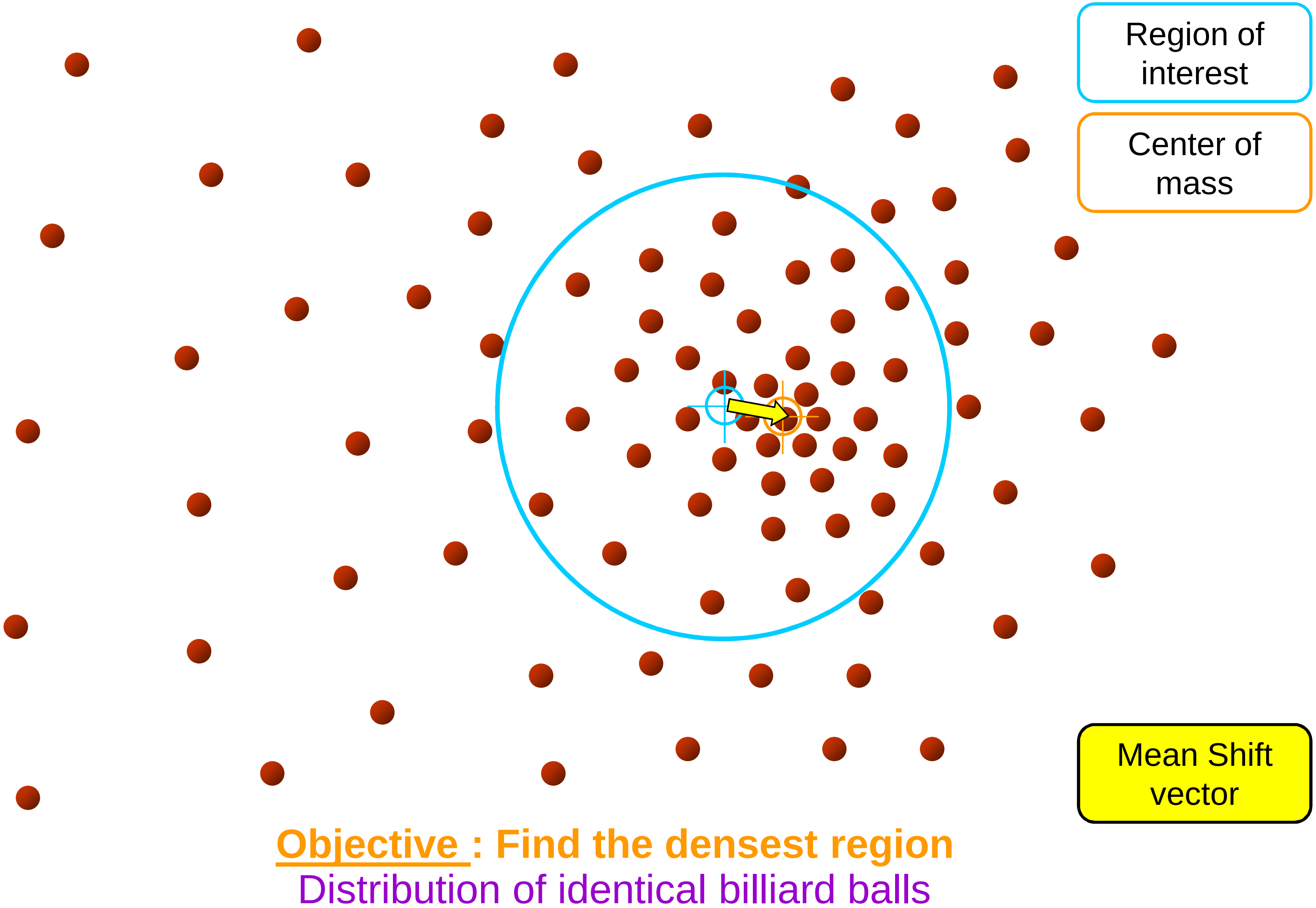

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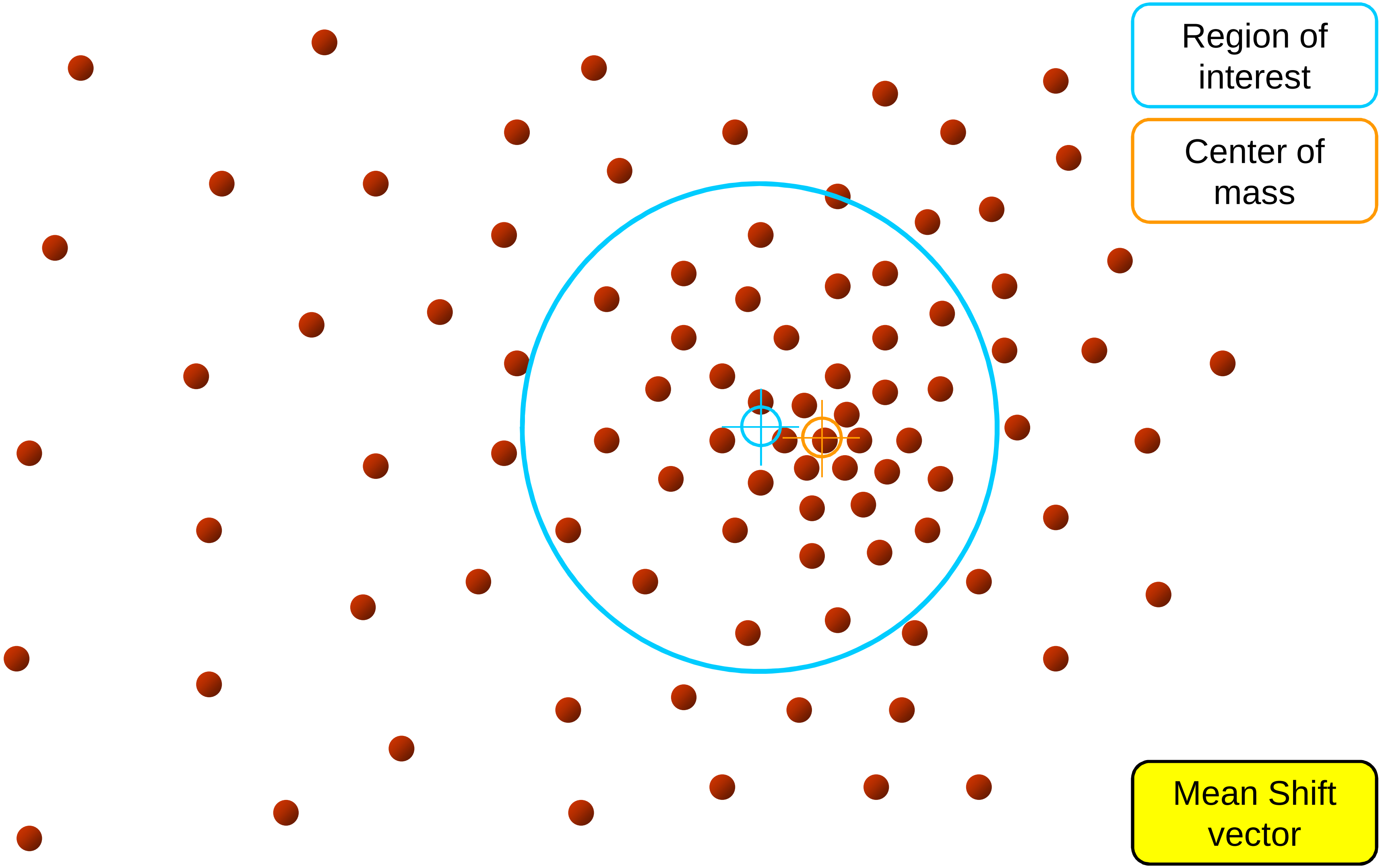

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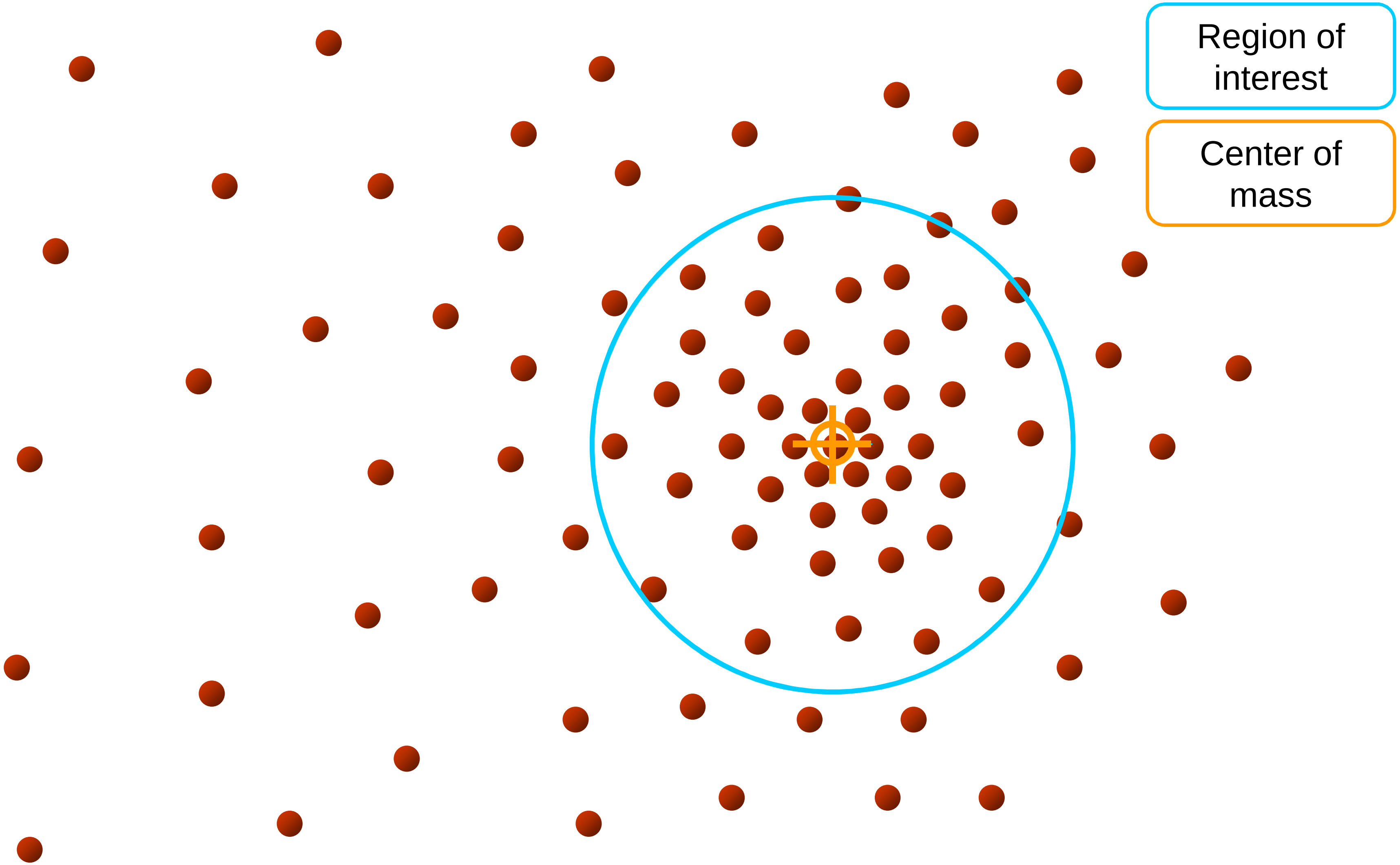

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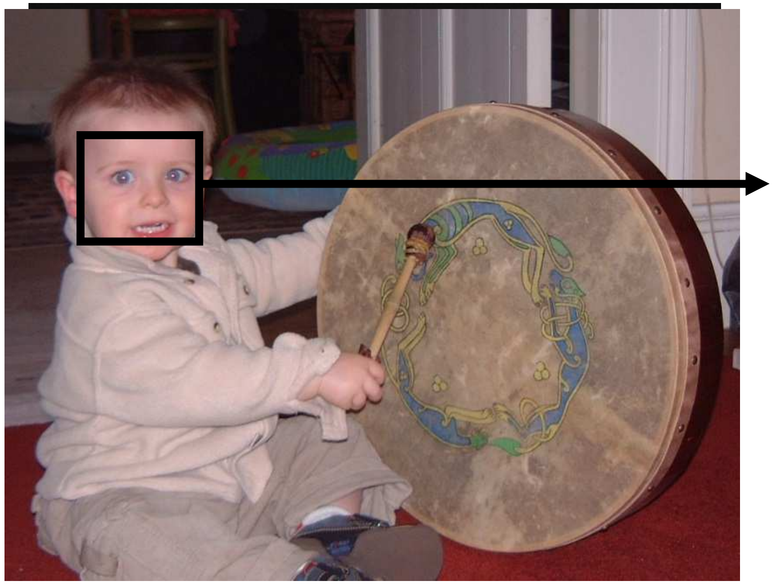
What is Mean Shift ?

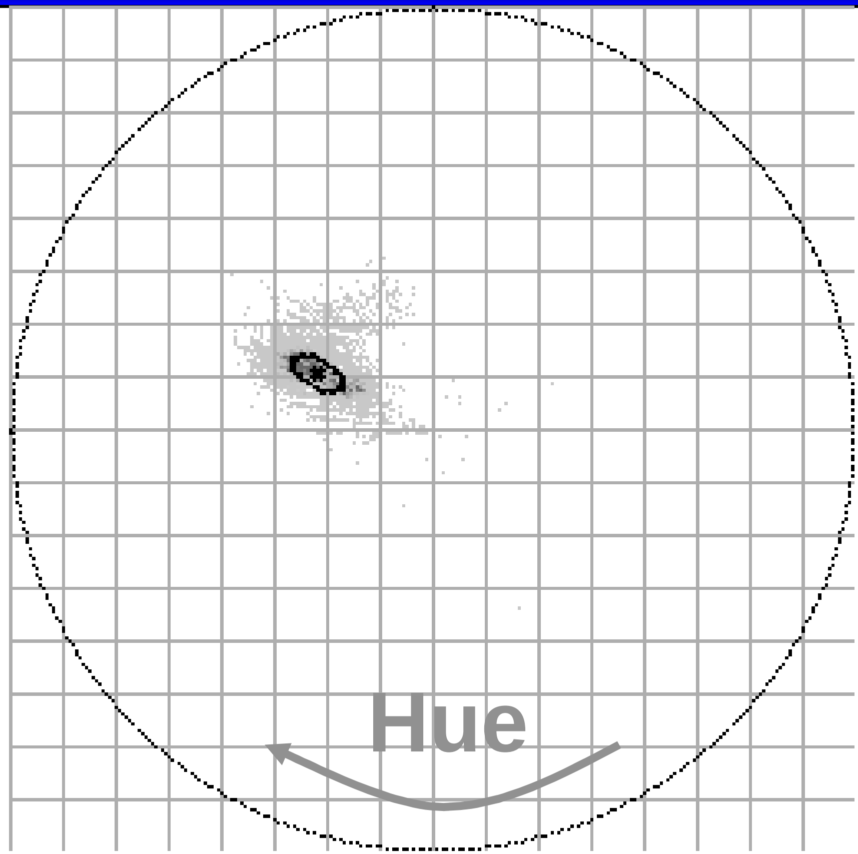
A tool for:
Finding modes in a set of data samples, manifesting an underlying probability distribution

The distribution could be in:

- **Color space**
- **Image space**
- **Scale space**
- **Actually any feature space you can conceive**
- **…**

Estimate histogram (model)

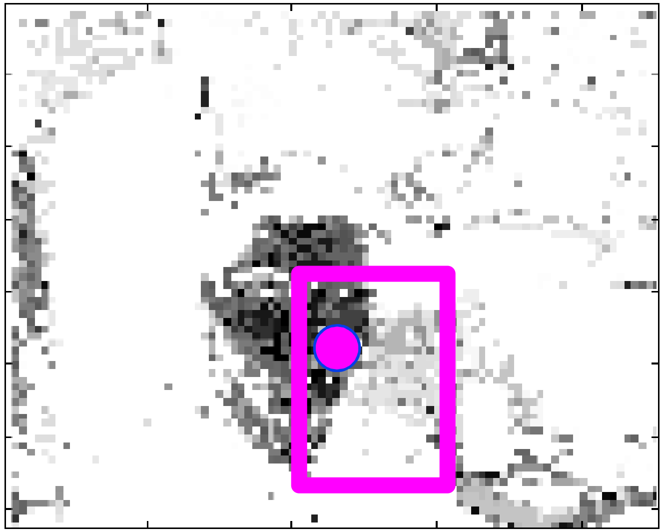




Mean-Shift Tracking using Colour

• Given each new video frame, compute a likelihood image from it by "looking up" each pixel in the histogram.
• Pixels form uniform grid of data points, each with a weight (pixel value) proportional to likelihood that the pixel is on the object we want to track.

• Perform mean-shift using this weighted set of points.



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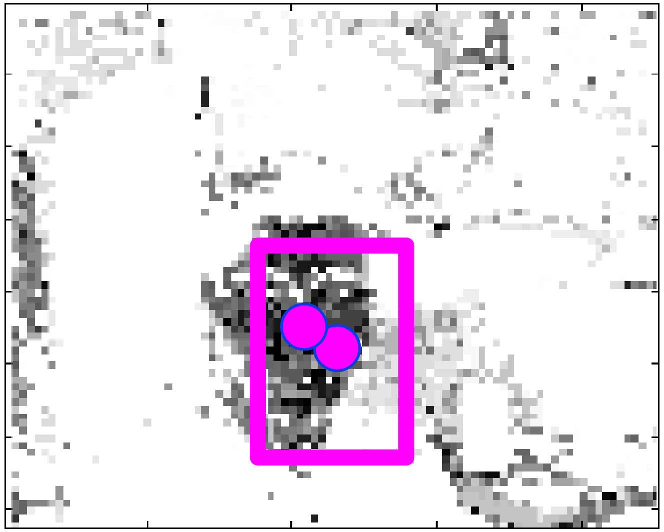

36

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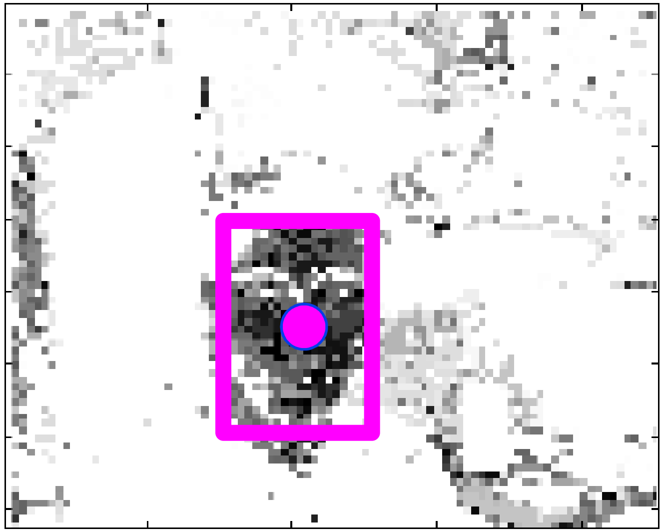


37

Mean-Shift Tracking using Colour

- This is fast and can work well when histogram is unimodal (i.e. object is “one” colour)
- Alternative is to build a histogram from search window, compute similarity function of image and model histograms, and perform mean-shift search to maximise this function.
- Can also adapt scale (by searching nearby scales).
- Can also use other features (e.g. texture)

Further reading:

Collins, R. “Mean-shift Blob Tracking through Scale Space”
IEEE Conference on Computer Vision and Pattern Recognition (CVPR), 2003

38

Tracking

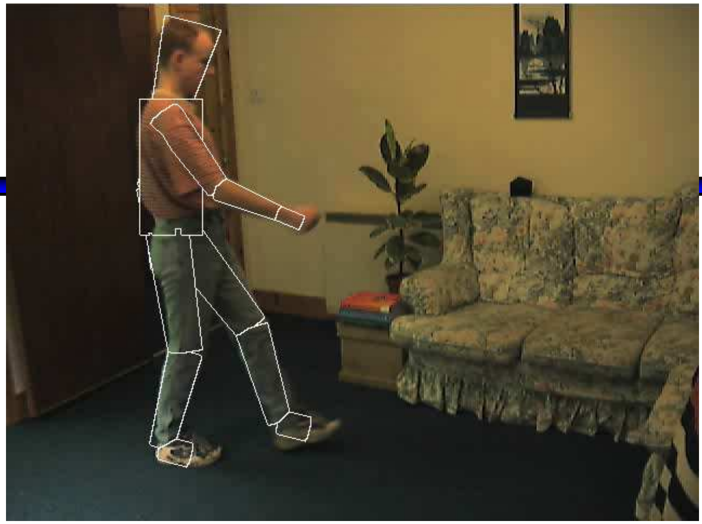
CAMShift in Matlab Computer Vision System Toolbox:

vision.HistogramBasedTracker System object

CAMShift uses a heuristic method to deal with scale.

G. Bradski, “Computer vision face tracking for use in a perceptual user interface” *Intel Technology Journal*, 2nd Quarter, 1998.

Further reading:
Y. Raja, S. J. McKenna, and S. Gong.
Tracking and segmenting people in varying lighting conditions using colour.
IEEE International Conference on Face & Gesture Recognition, 228-233, 1998.

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