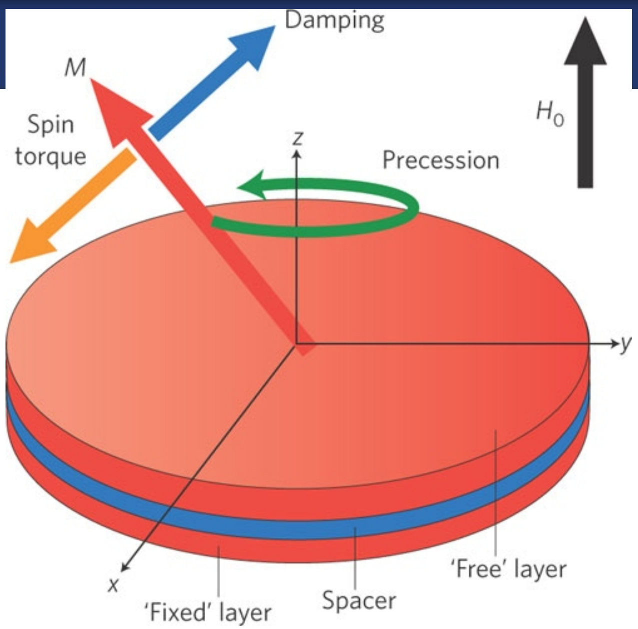
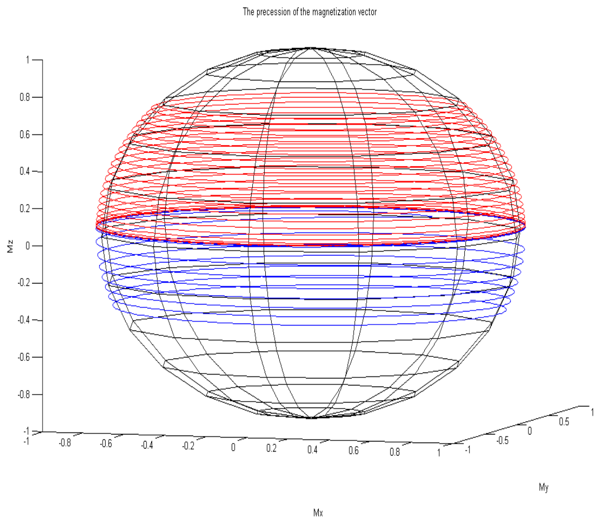
Object detection by oscillatory networks

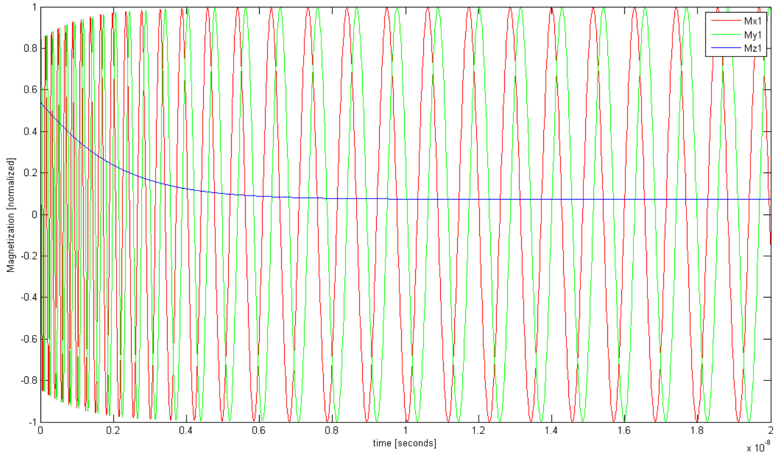
Improving machine learning method

Spin torque oscillators

- **„Let the physics do the computation”**
- Nano-scale
- Low power consumption
- Fast
- Needs extra effort to write and read

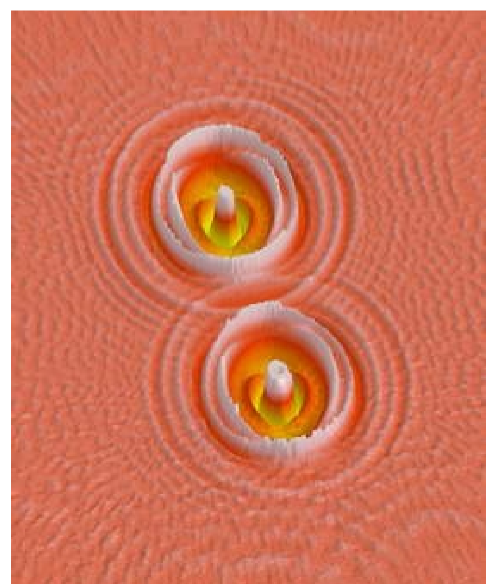




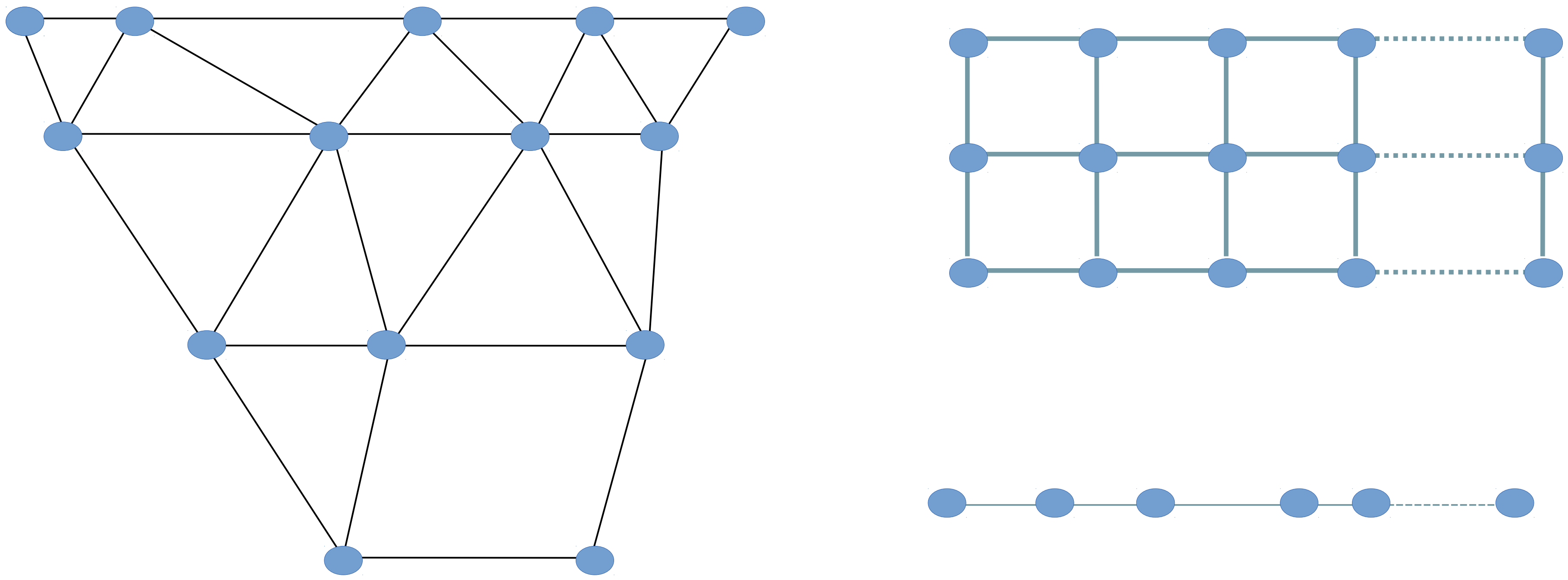


Synchronization in oscillations

- Important in many fields
- Encapsulates information
- Phase difference stores extra information



Oscillatory network structures



Improving machine learning

The „traditional” classification method

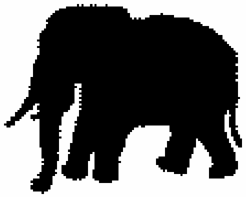


Image →

Feature extraction
Extraction of low dimensional, meaningful information

→ Feature vector →

Classification
Comparing the feature vector with stored labeled feature vectors

→ Class

The proposed classification method

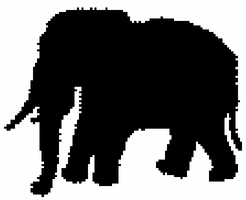


Image →

Feature extraction
Extraction of low dimensional, meaningful information

↓ Feature vector

OCNN array(s)

↑ Signature(s)

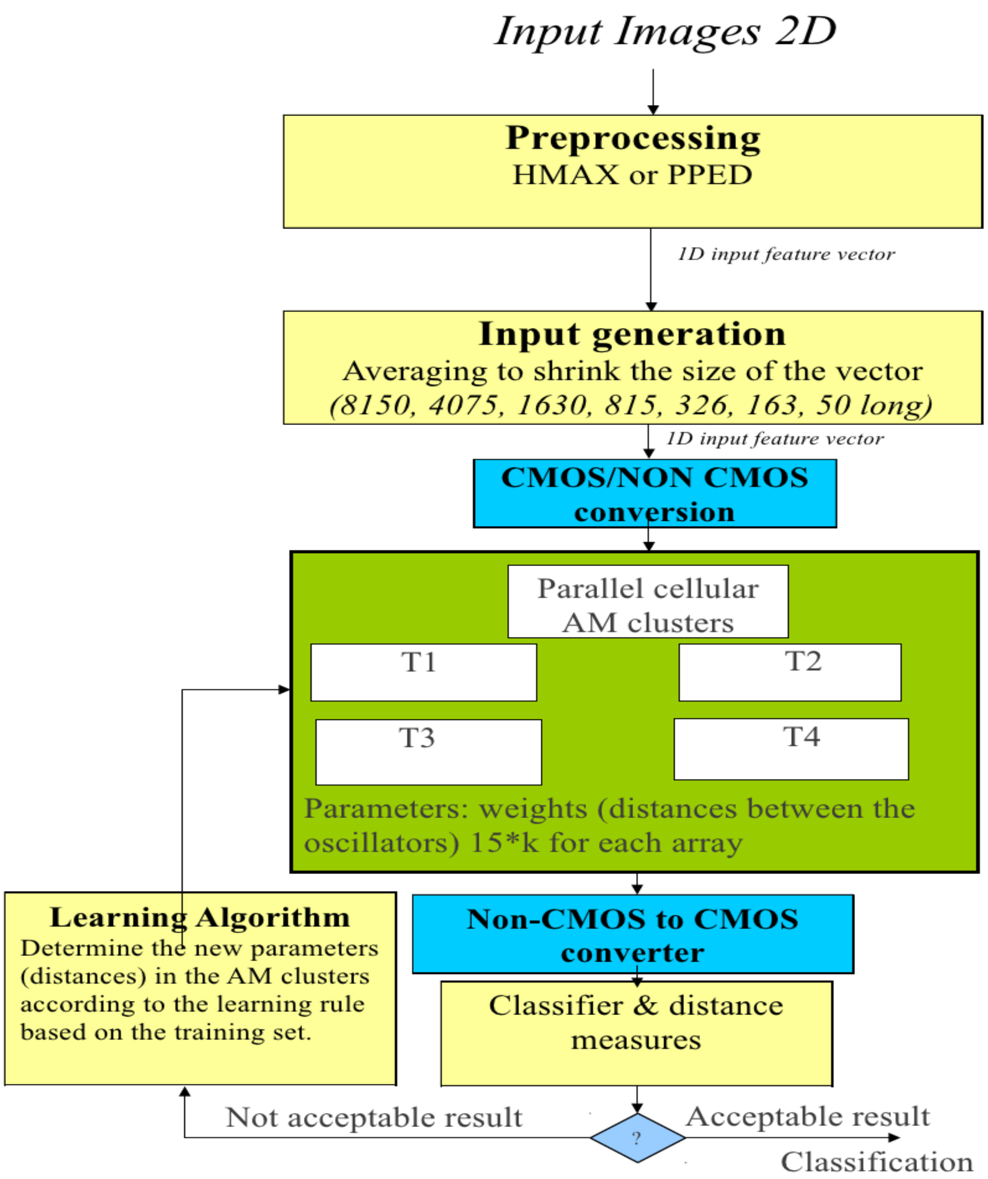
Classification
Comparing the signature with stored labeled signatures

→ Class

Improving machine learning

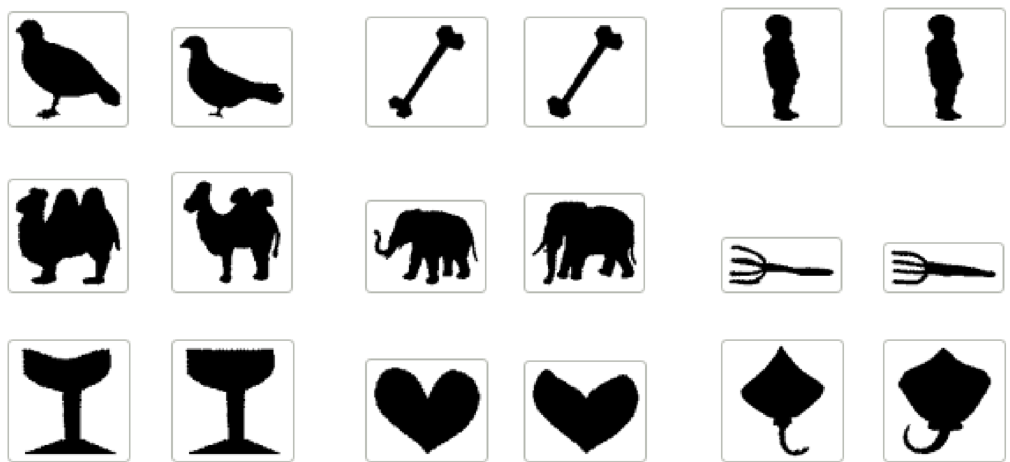
- 2D input flow
- 1D vector feature
- 1D signature
- Class

- Classification
  - Compare to signature prototypes (templates)

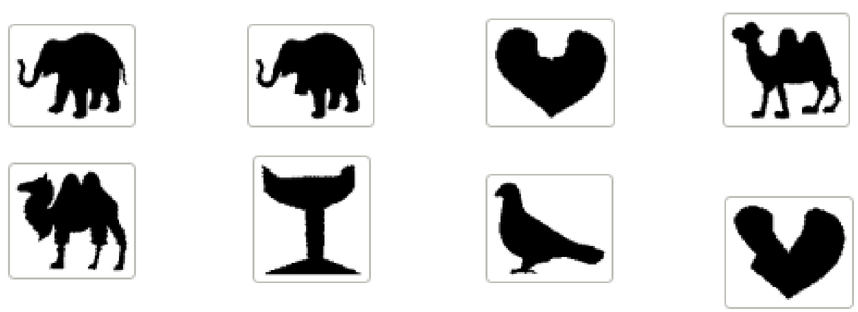


Example

- 64 shape images from the Shape Database of The Vision Group at LEMS, Brown University
- Train set
  9 classes



- Test set
  46 images



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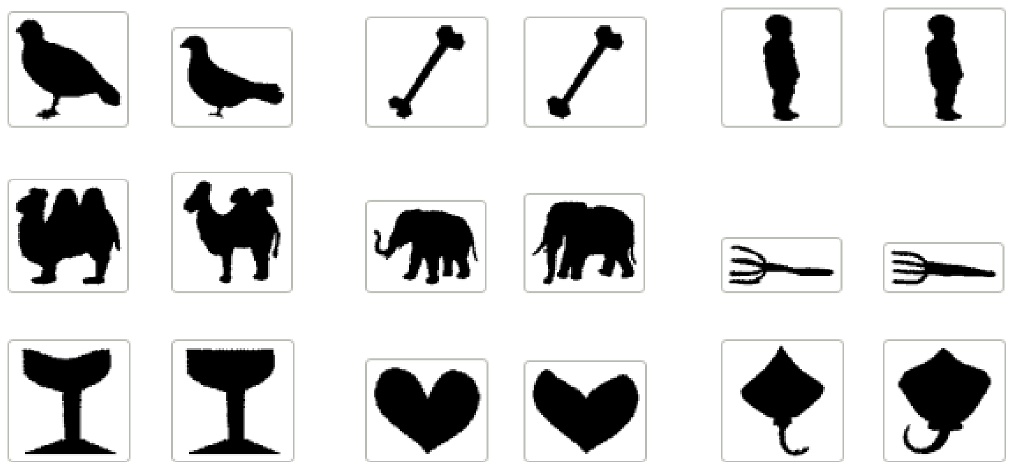

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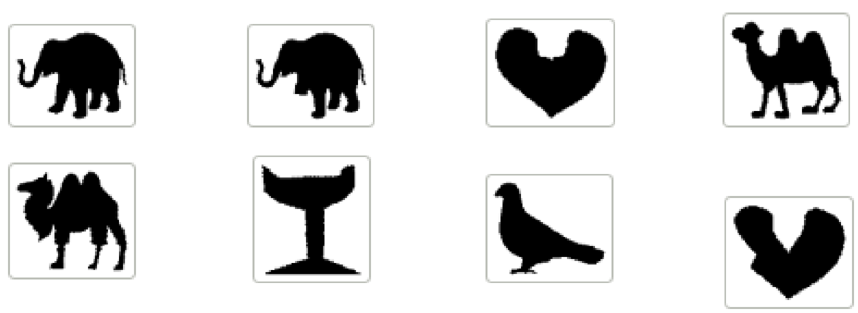
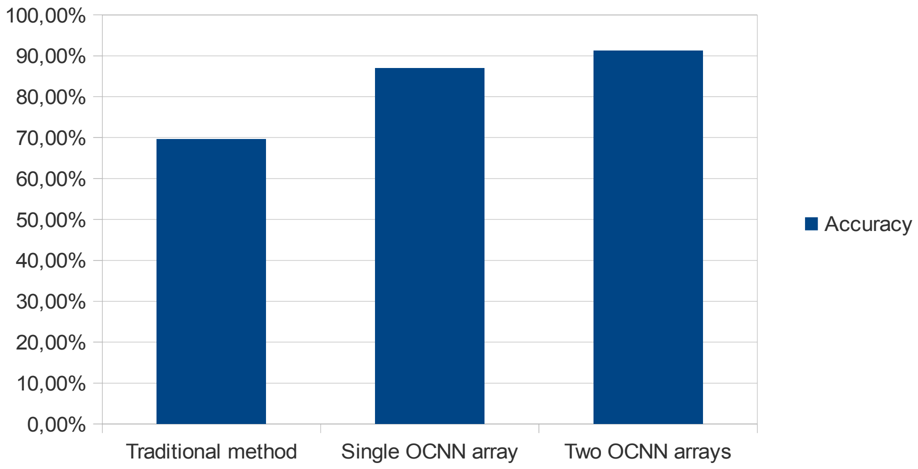


Tuning the weights

- Genetic computation
  1. Generate 100-1000 random weight vectors (depending on the input dimension)
  2. Try the vectors resulting accuracy values as fittness functions
  3. Keep the best 50-100 vectors
  4. Generate 50-100 mutated vectors
     - Change every value with the probability p=0.15-0.2
  5. Generate 50-10 crossover vectors
     - Randomly select two vectors and assemble a new vector from their elements
  6. Repeat steps 2-5.

Results

- Without OCNN
  - Accuracy: 69,57%
- With OCNN, the simplest configuration
  - Accuracy: 86,95%
- With OCNN, two simple 1-D arrays
  - Accuracy: 91,3%



Results on H-MAX data

- Dimension reduction by averaging

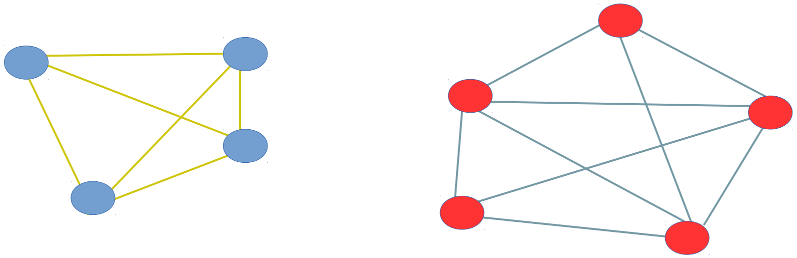
Vector length	accruacy
50:	85 %
163:	87.5%
326:	82.5%
815:	77.5%
1630:	77.5%
4075:	75%
8150:	75%

- Dimension reduction by vector quantization

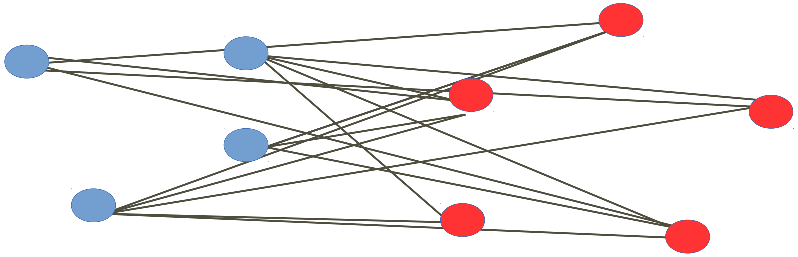
Vector length	accruacy
50:	100 %
163:	100%
326:	100%
815:	100%

Quantitative results

- Cross Group distances (CGD)
- In Group distances (IGD)
- To normalize, observe the rate
  AD = CGD/IGD



In-Class distance – Average of the distances of elements in one class



Cross-Class distance – Average of the distances of elements of other classes

Quantitative results

- Cross Group distances (CGD)
- In Group distances (IGD)
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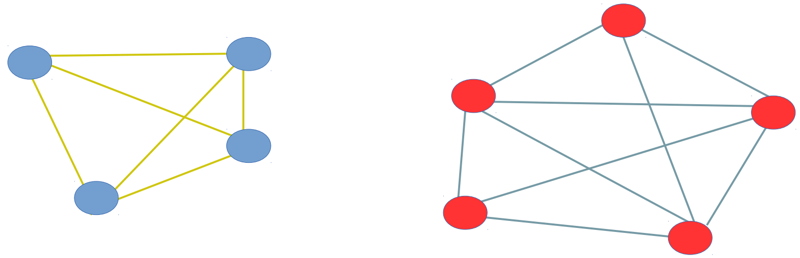

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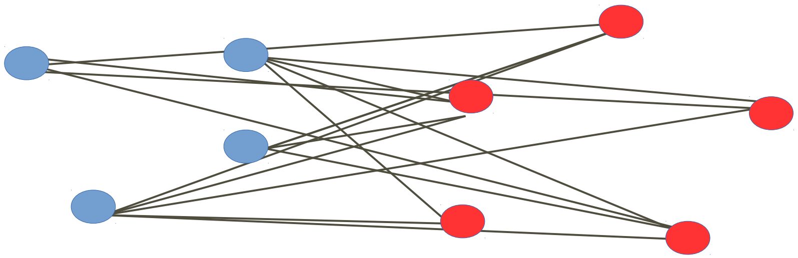
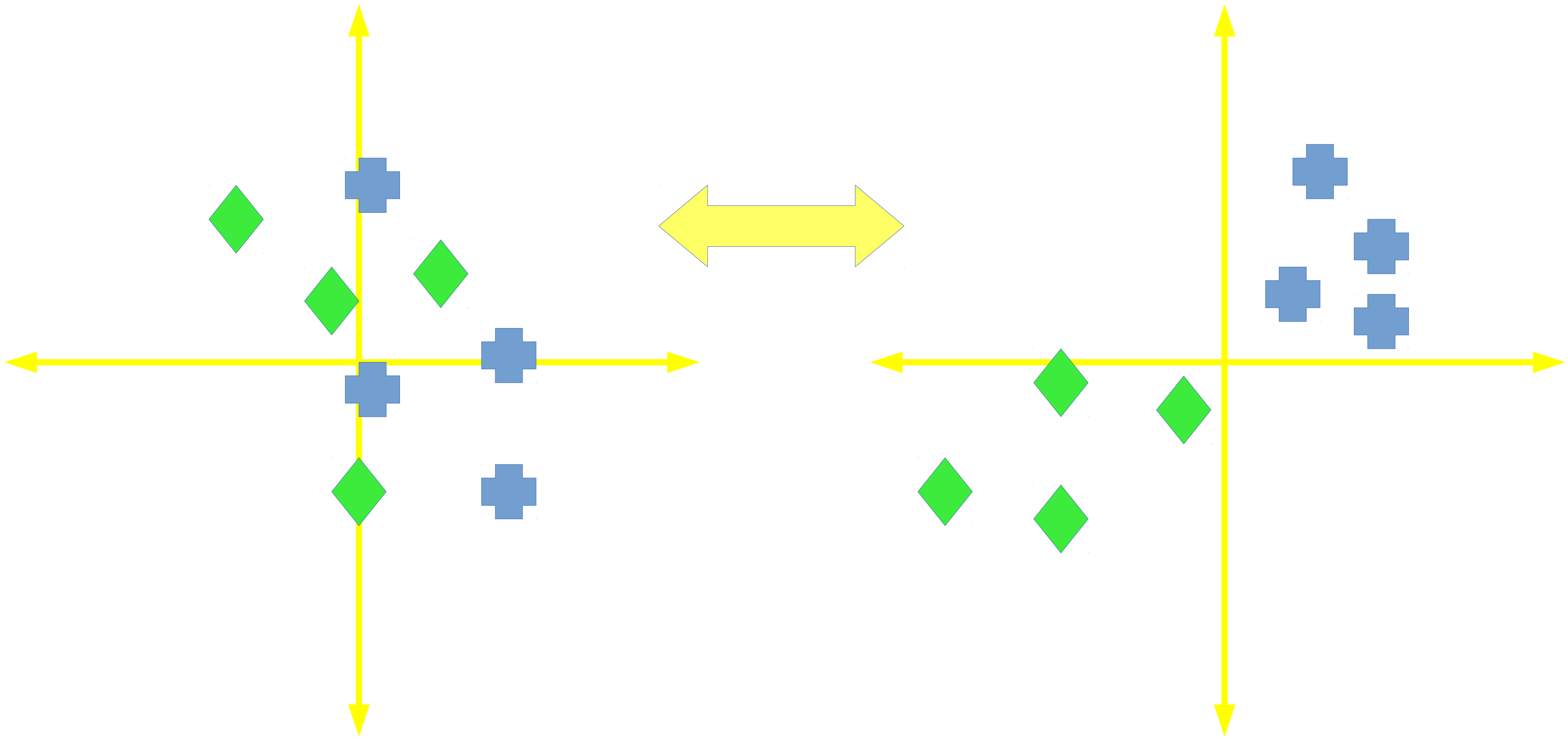


Cross-Class distance – Average of the distances of elements of other classes

Effect of a 1D oscillator chain



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Thank you for your attention