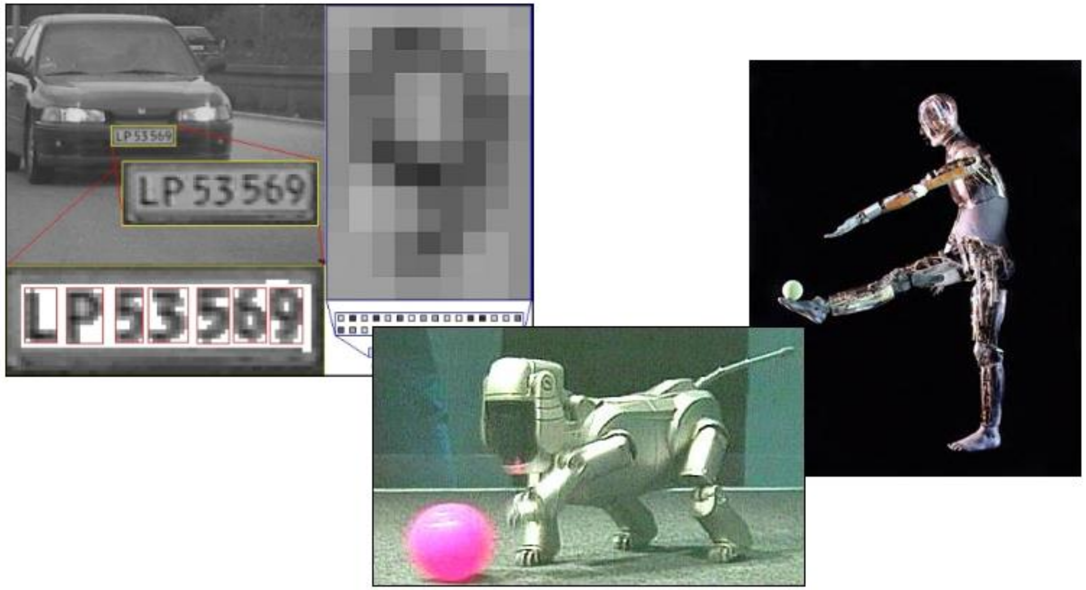


Welcome to Machine Learning

Konstantin Tretyakov
http://kt.era.ee

IFI Summer School 2014

STACC Software Technology and Applications Competence Center

BIIT

TARTU ÜLIKOOL · UNIVERSITAS TARTUENSIS · 1632

Data mining,

Data analysis, Statistical analysis,

Pattern discovery, Statistical learning,

Machine learning, Predictive analytics,

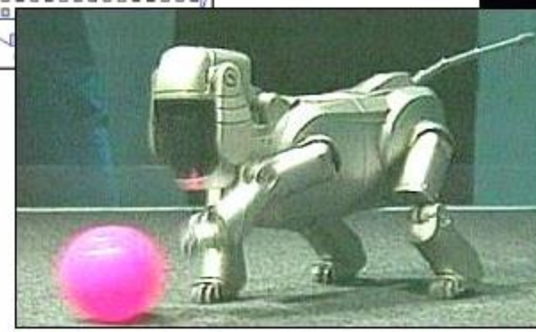
Business intelligence, Data-driven statistics,

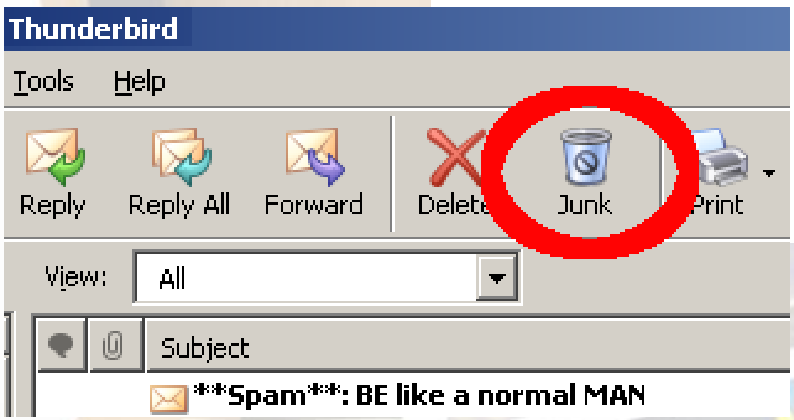
Inductive reasoning, **Pattern analysis**,

Knowledge discovery from databases,

Neural networks,

…



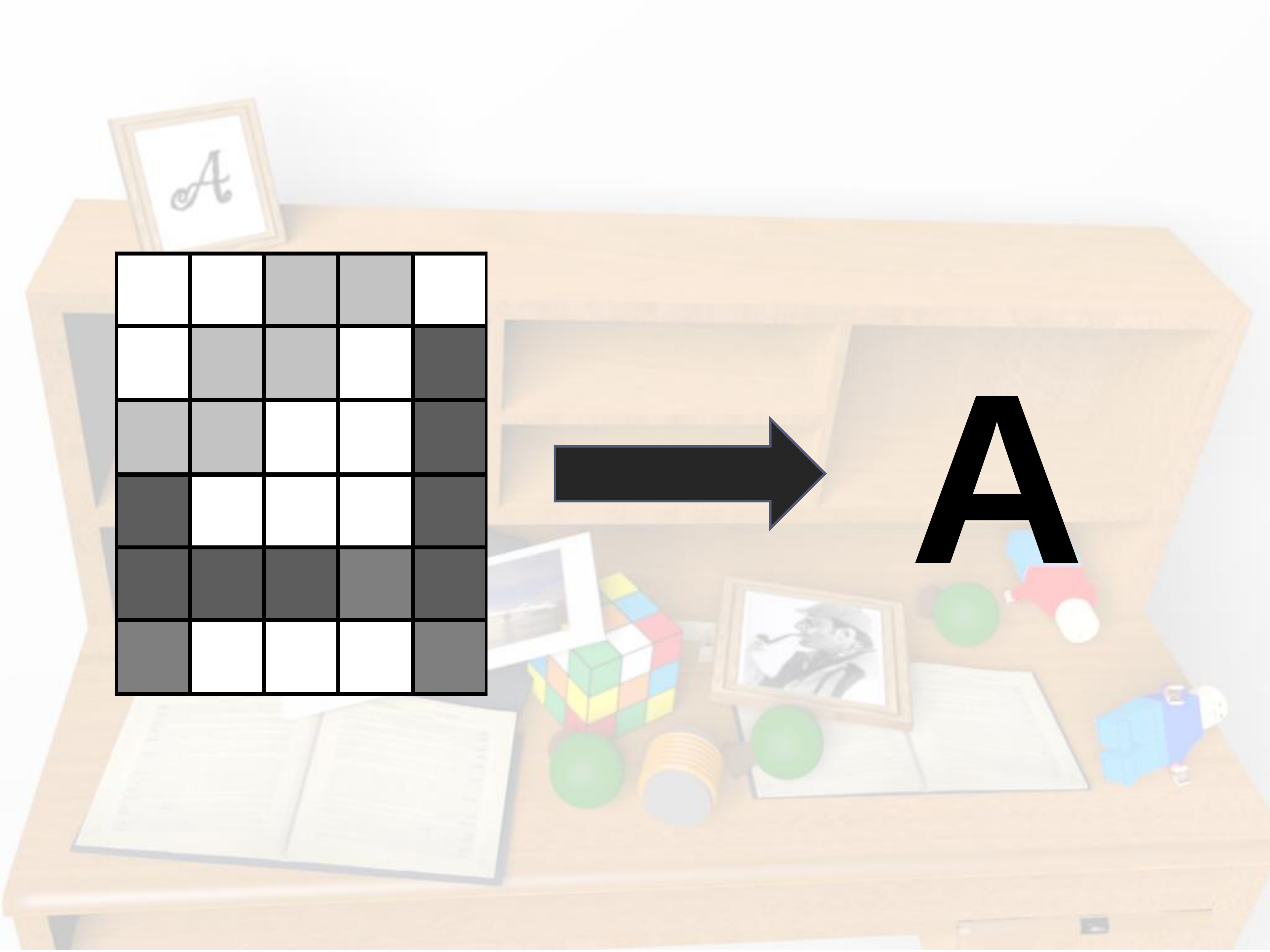


Google translate

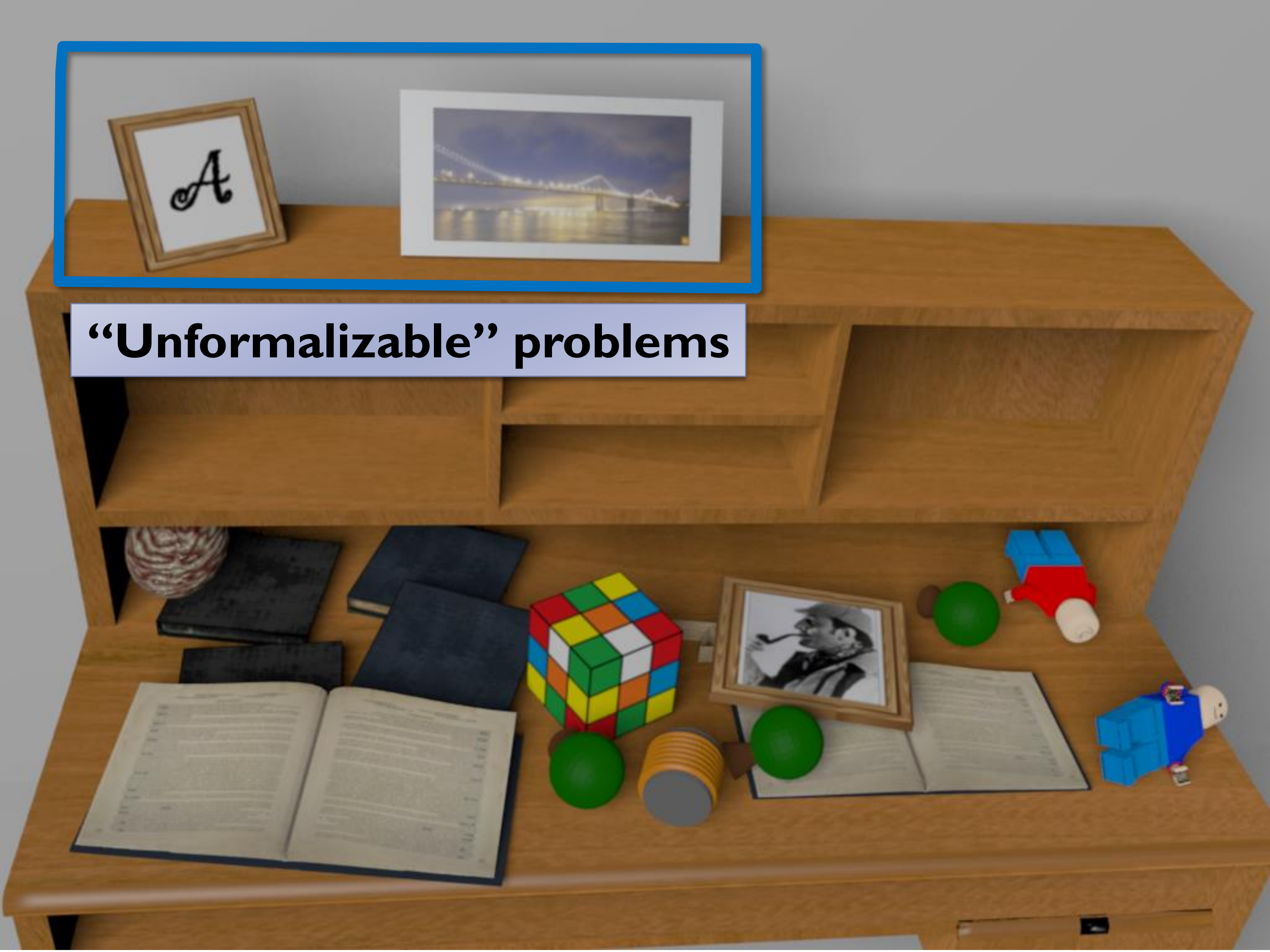
NETFLIX


A


A

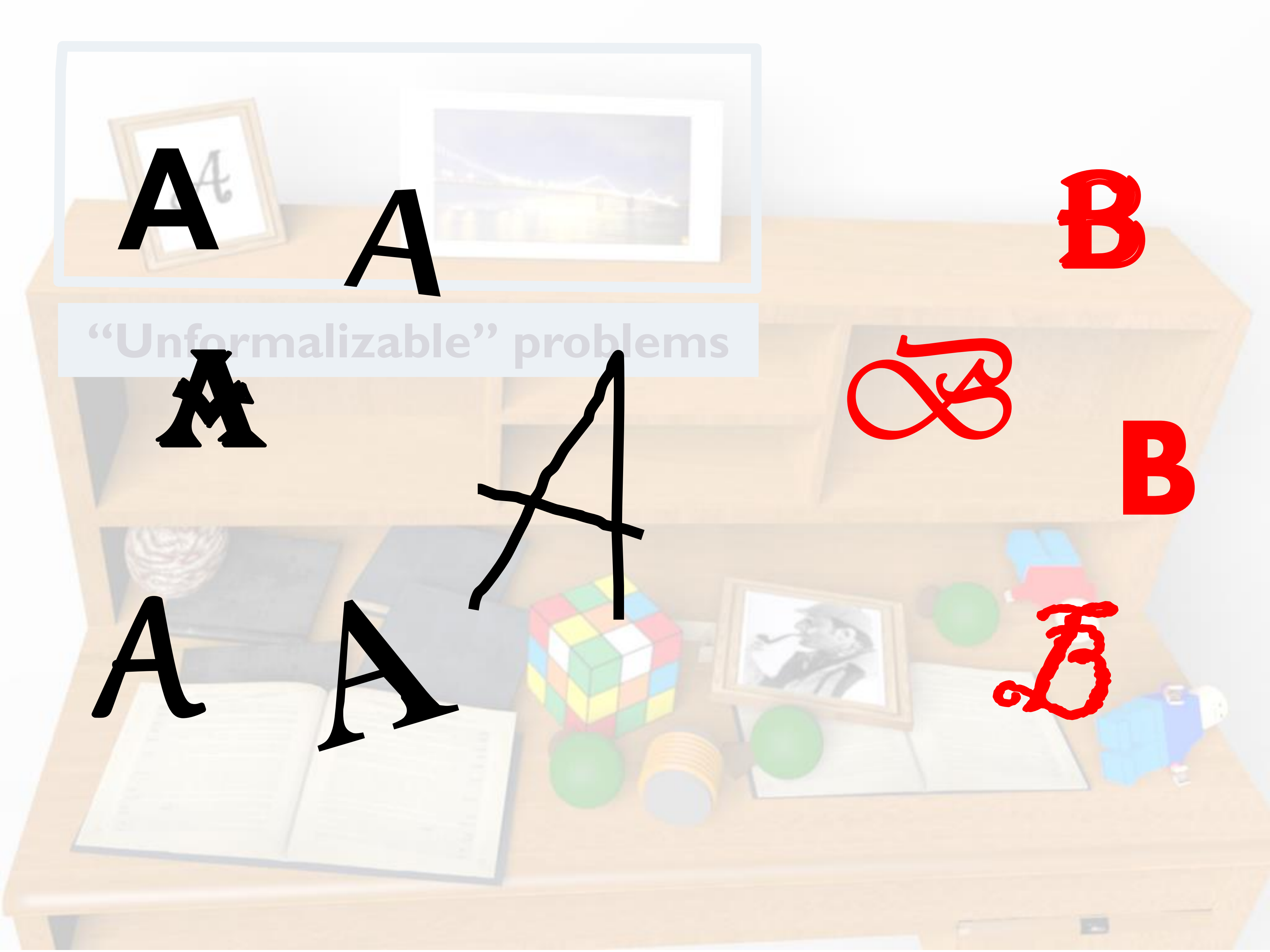

A


A


"Unformalizable" problems
A

“Unformalizable” problems

“Unformalizable” problems




A


A

- General rule:

  IF **(X is made of plastic),**

  THEN **(X is not edible)**

- Application in the particular case:

  X = Rubic's cube

  ⇒

  Rubic's cube is not edible

- General rule:

  add(x, y) = function { … }

- Application in the particular case:

  add(2,4)

- General rule:

```
add(x, y) = function {
    ???
}
```

- Particular cases:

add(2,4) = 6

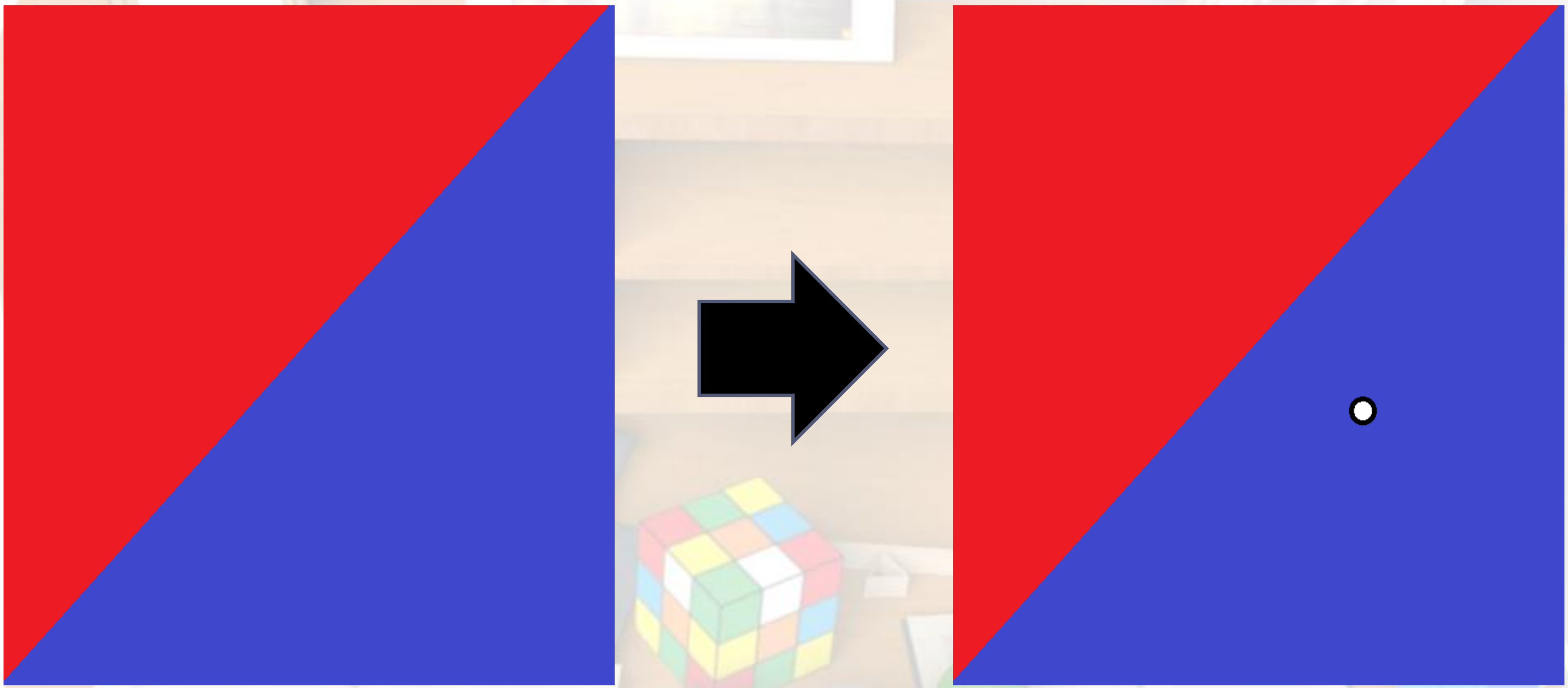
add(5,3) = 8

add(1,2) = 3

…

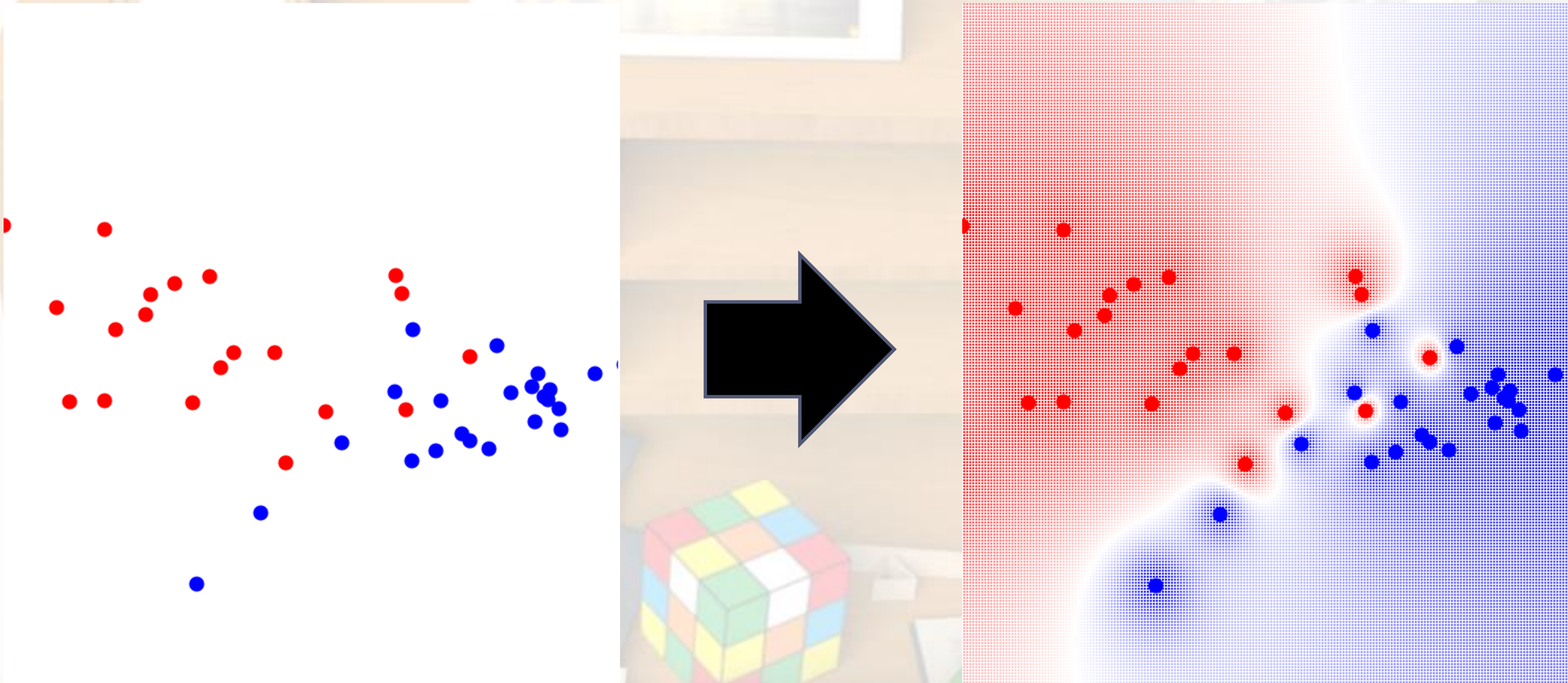
Induction

Deduction



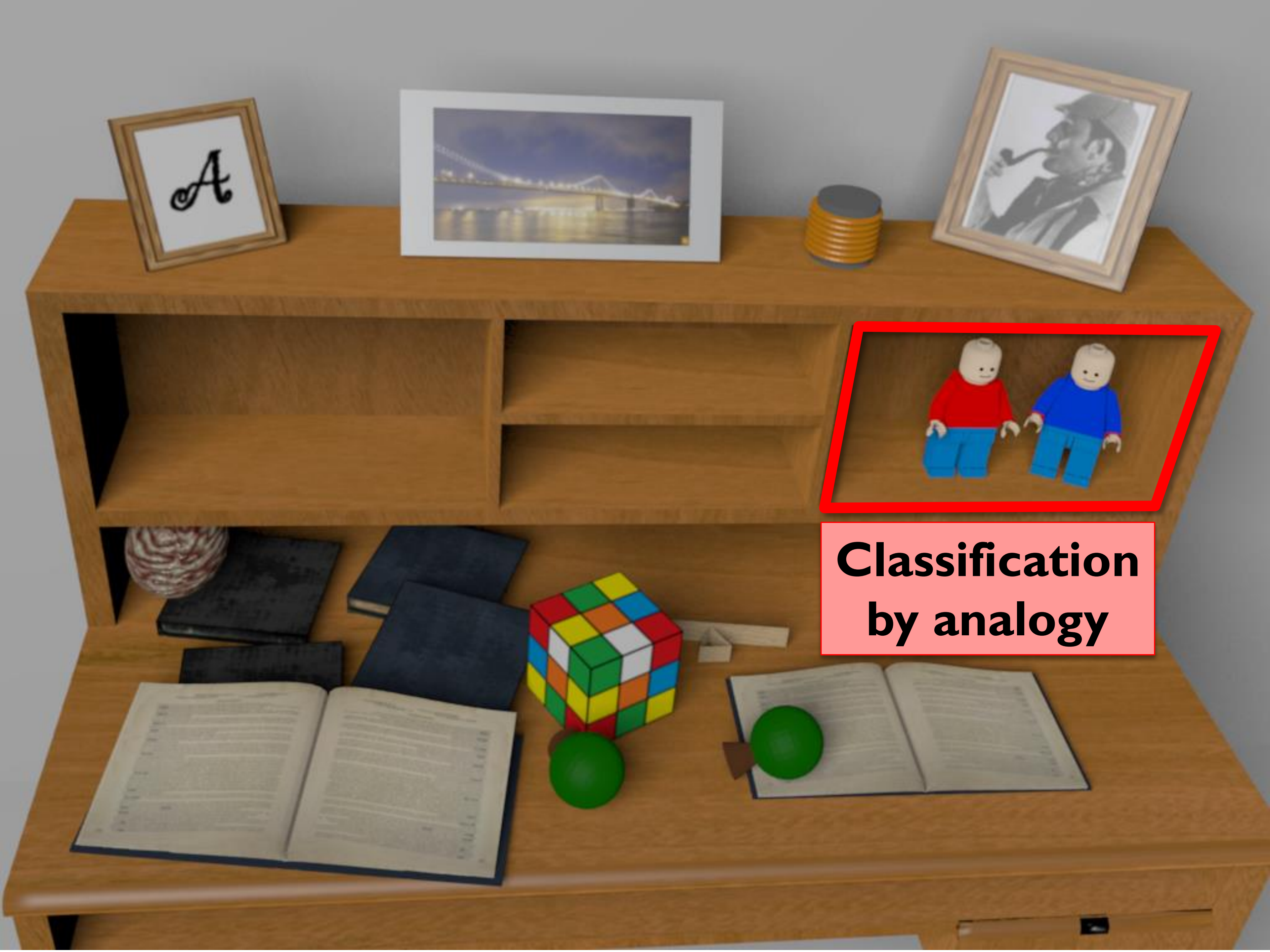
Given a general rule, make a decision in a particular case

Induction



Given particular cases, find a general rule

Deduction and Induction


A
Classification
by analogy

MNIST dataset

- http://yann.lecun.com/exdb/mnist/
- Handwritten digits, 28 x 28

...

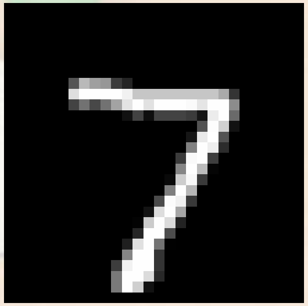
MNIST dataset

```
images = load_images()
labels = load_labels()
```

```
# Let us just use 1000 images
training_set    = images[0:1000]
training_labels = labels[0:1000]
```

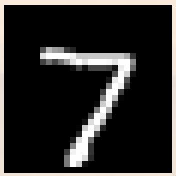
MNIST dataset

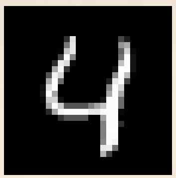
```
> training_set[0]

    array([ 0, 0, 0, ...,
            254, 241, 198, ...])

> training_labels[0]

    '7'
```

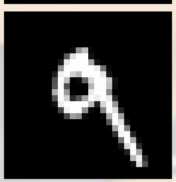


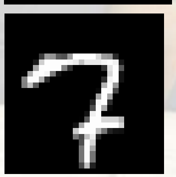
Nearest neighbor method

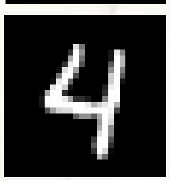
Training set

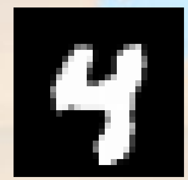
7 

4 

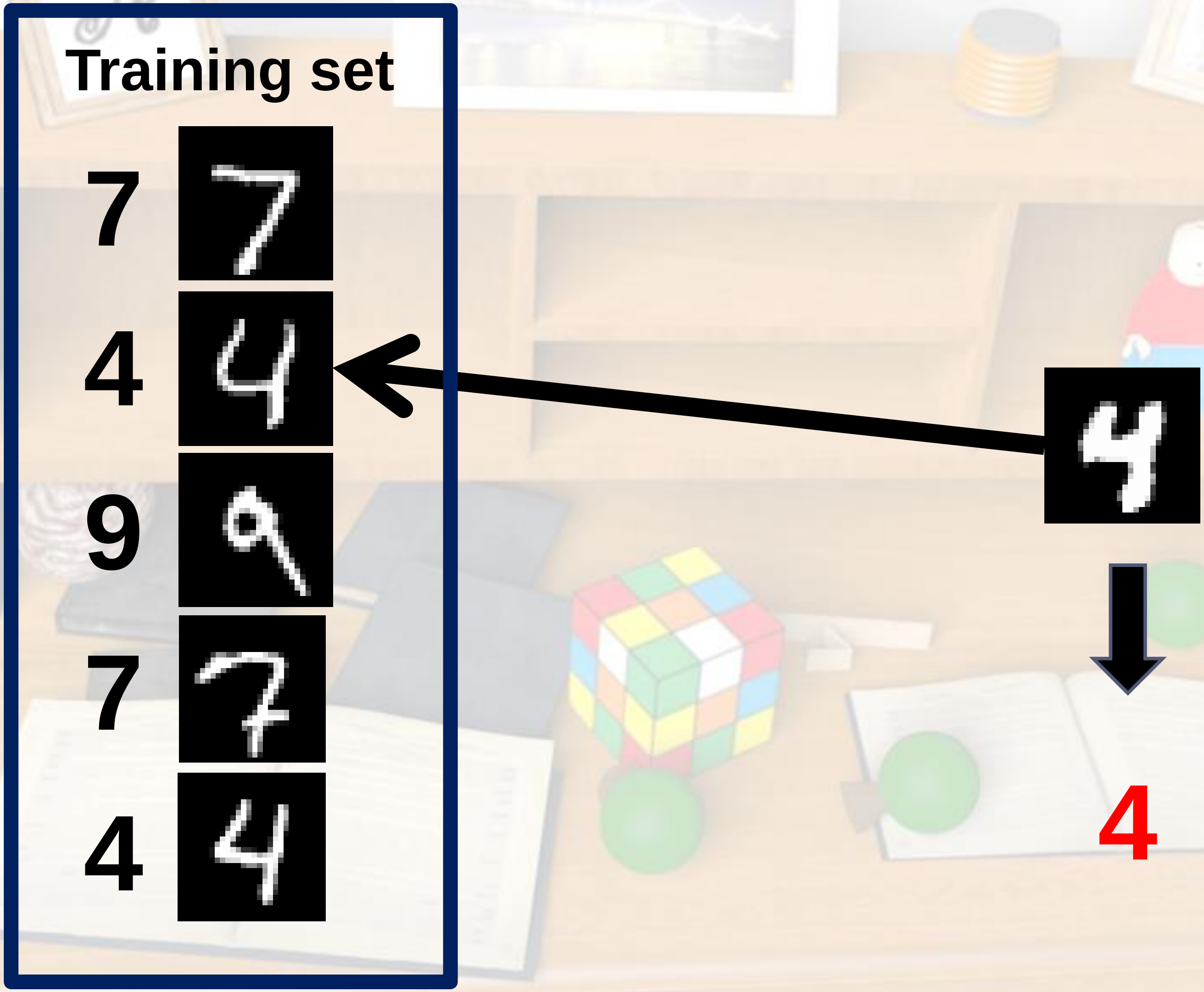
9 

7 

4 

 ?

Nearest neighbor method



Nearest neighbor method

```
def classify(img):
    similarities =
      [similarity(img, p) for p in training_set]
    i = similarities.index(max(similarities))
    return training_labels[i]
```

Nearest neighbor method

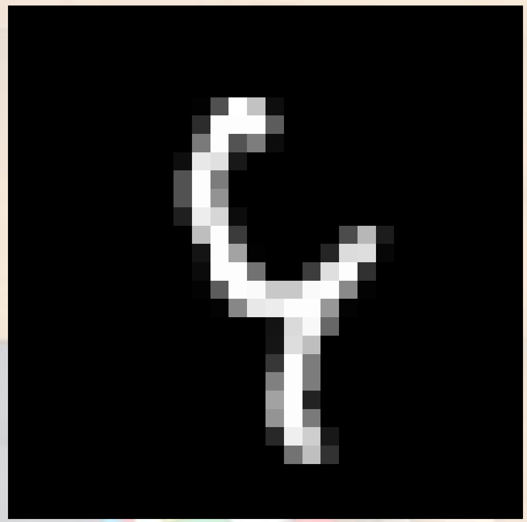
```
def classify(img):
    similarities =
     [similarity(img, p) for p in training_set]
    i = similarities.index(max(similarities))
    return training_labels[i]


def similarity(img1, img2):
     return -sum(abs(img1 - img2))
```

Testing the algorithm

```
test_set    = images[1000:2000]
test_labels = labels[1000:2000]


predicted_class = [classify(p) for p in test_set]


n_successes =
    sum(array(predicted_class) ==
                            array(test_labels))
```

=>   843/1000

9 or 4?

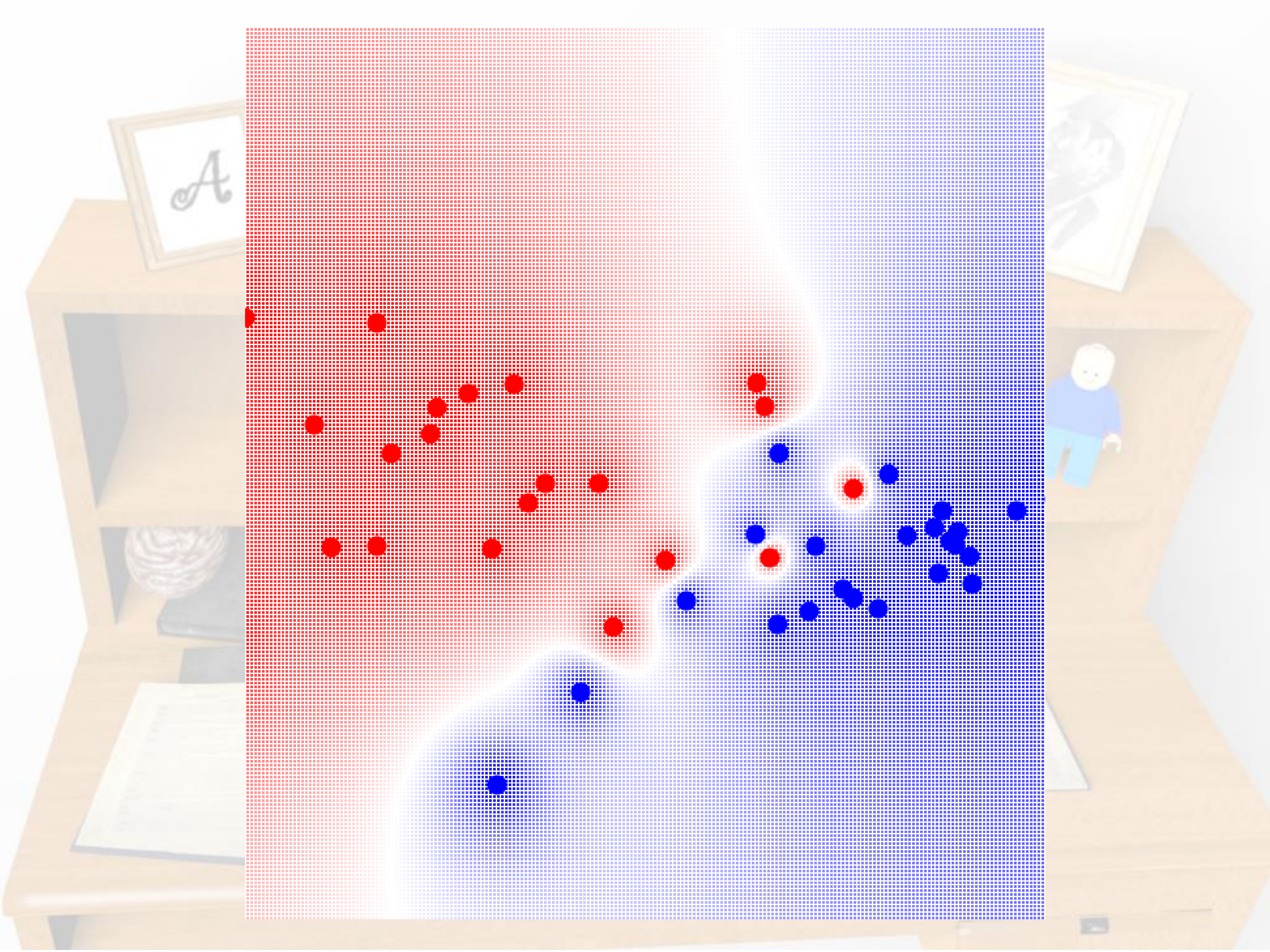


Scikit-learn

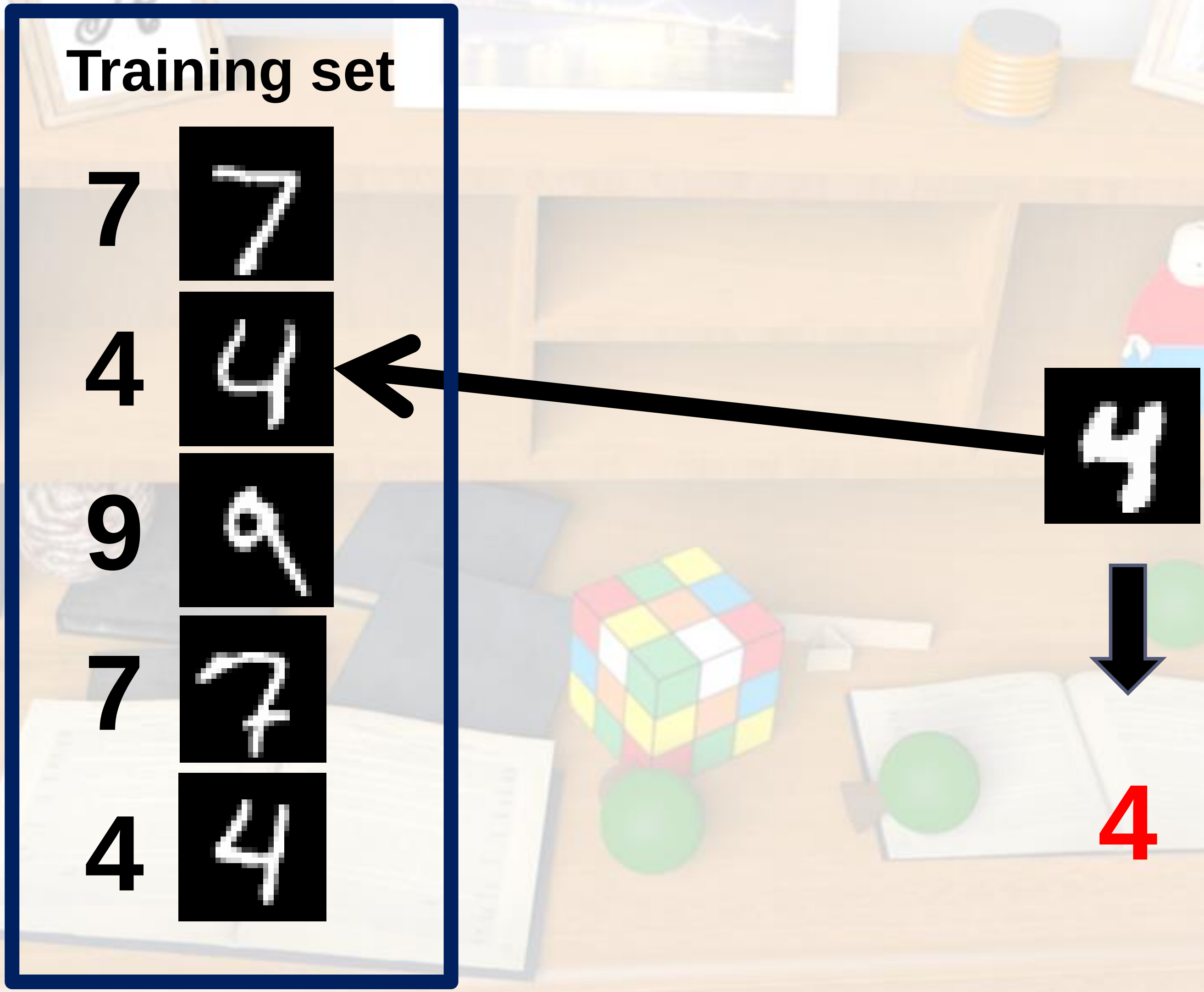
http://scikit-learn.org/

```
from sklearn.neighbors import
                                    KNeighborsClassifier

clf = KNeighborsClassifier(n_neighbors=1)
clf.fit(training_set, training_labels)

predicted_class = clf.predict(test_set)
```

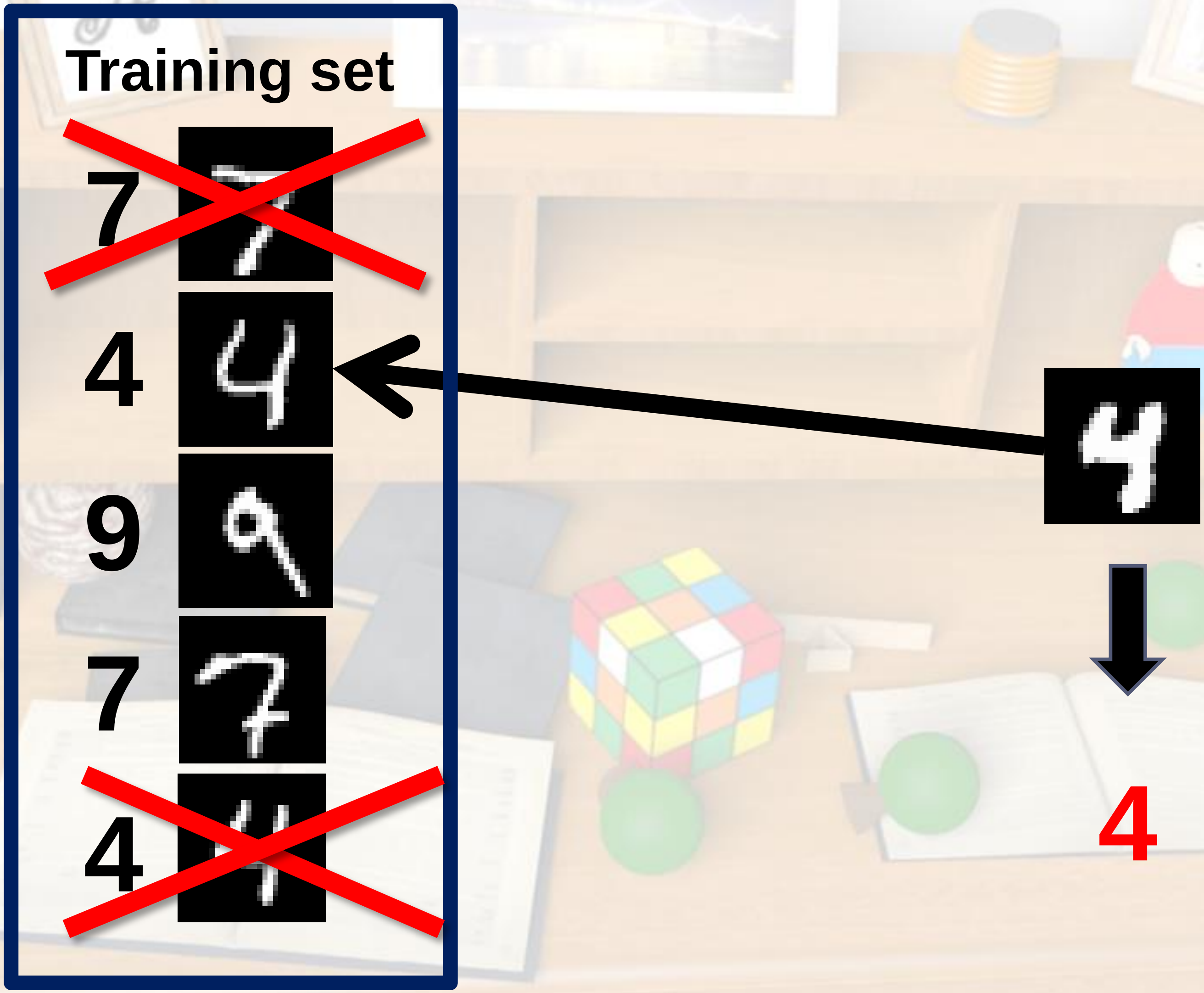
=> 855/1000



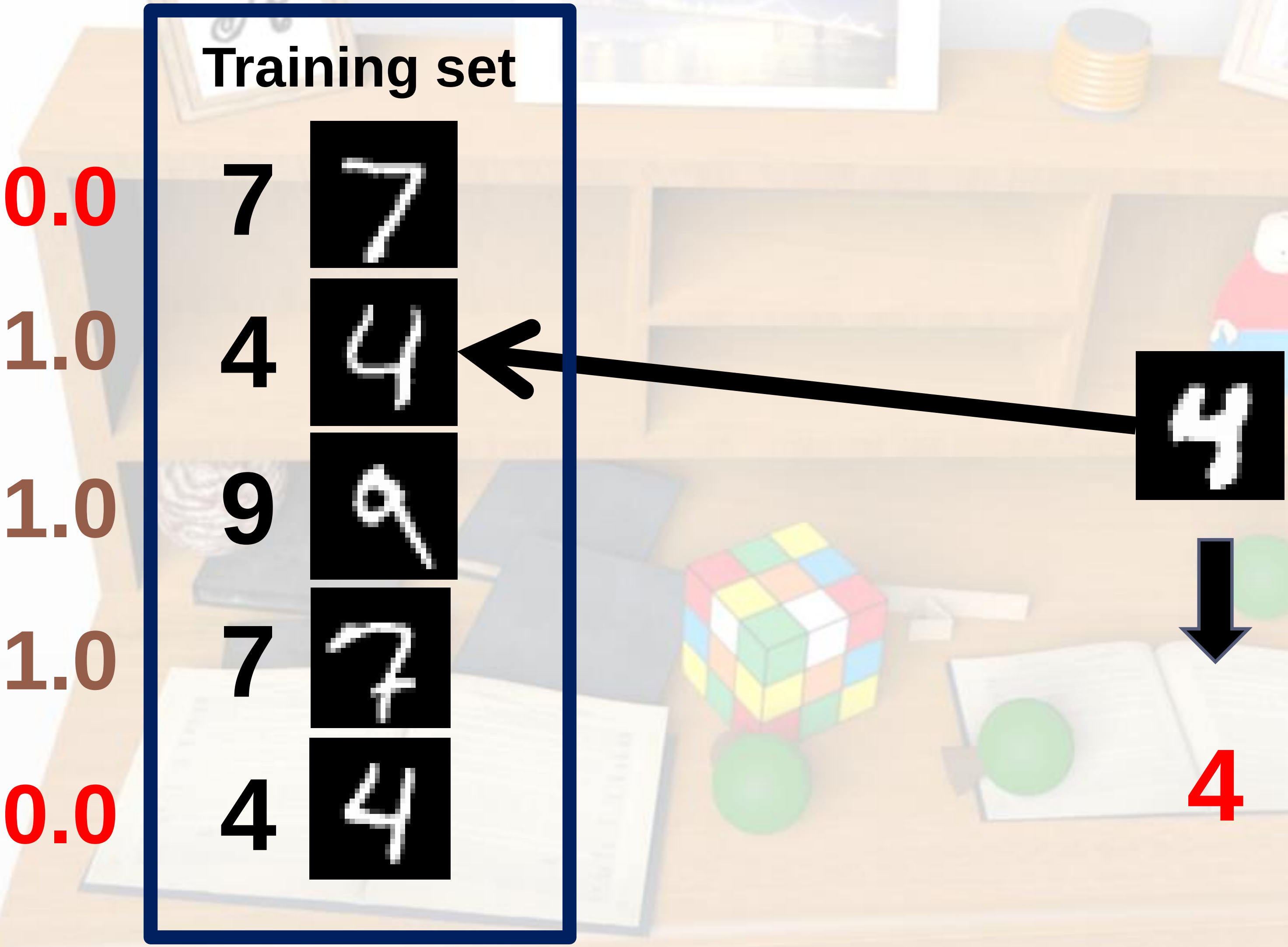
Nearest neighbor method



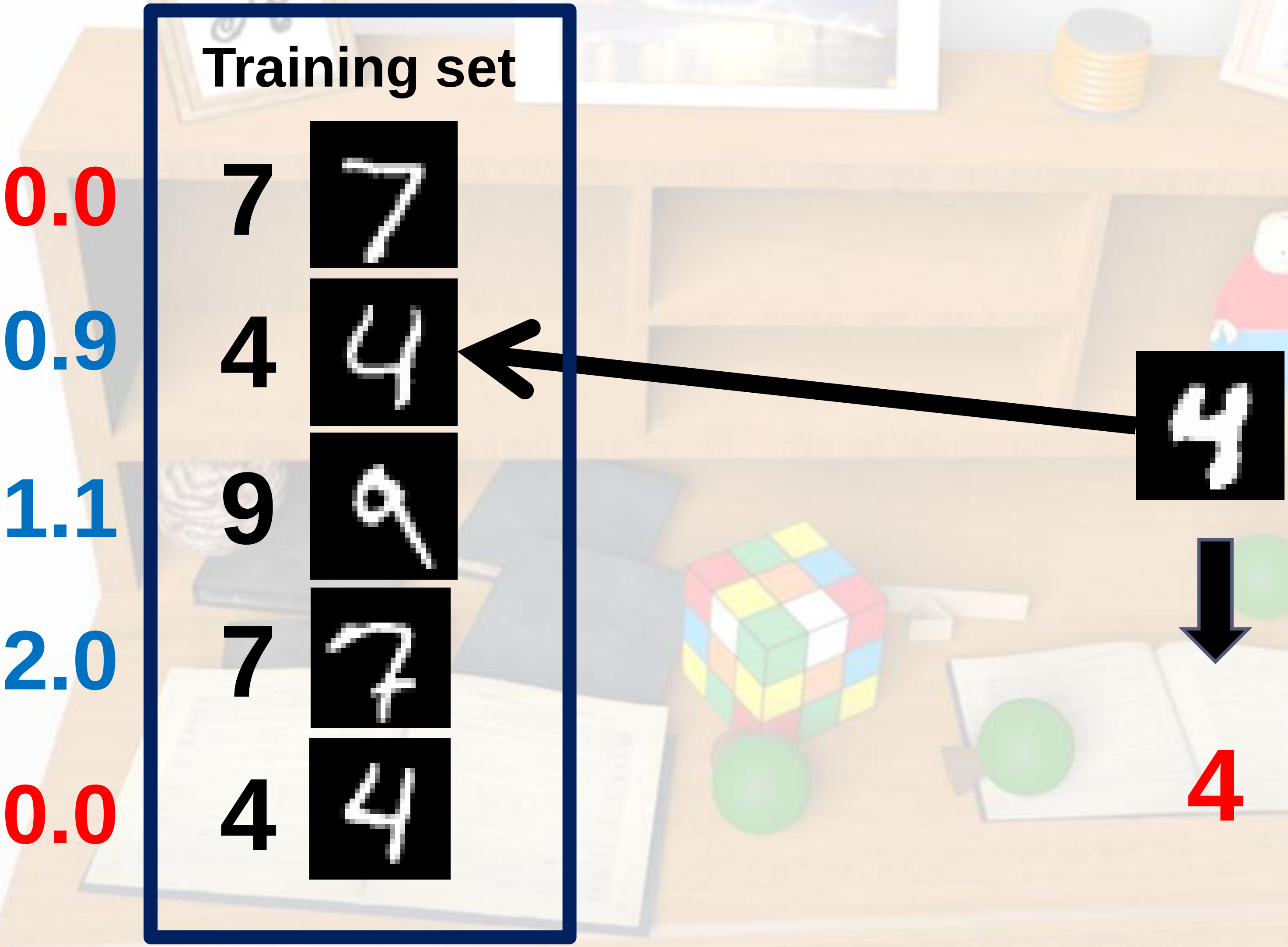
Some samples may be thrown away



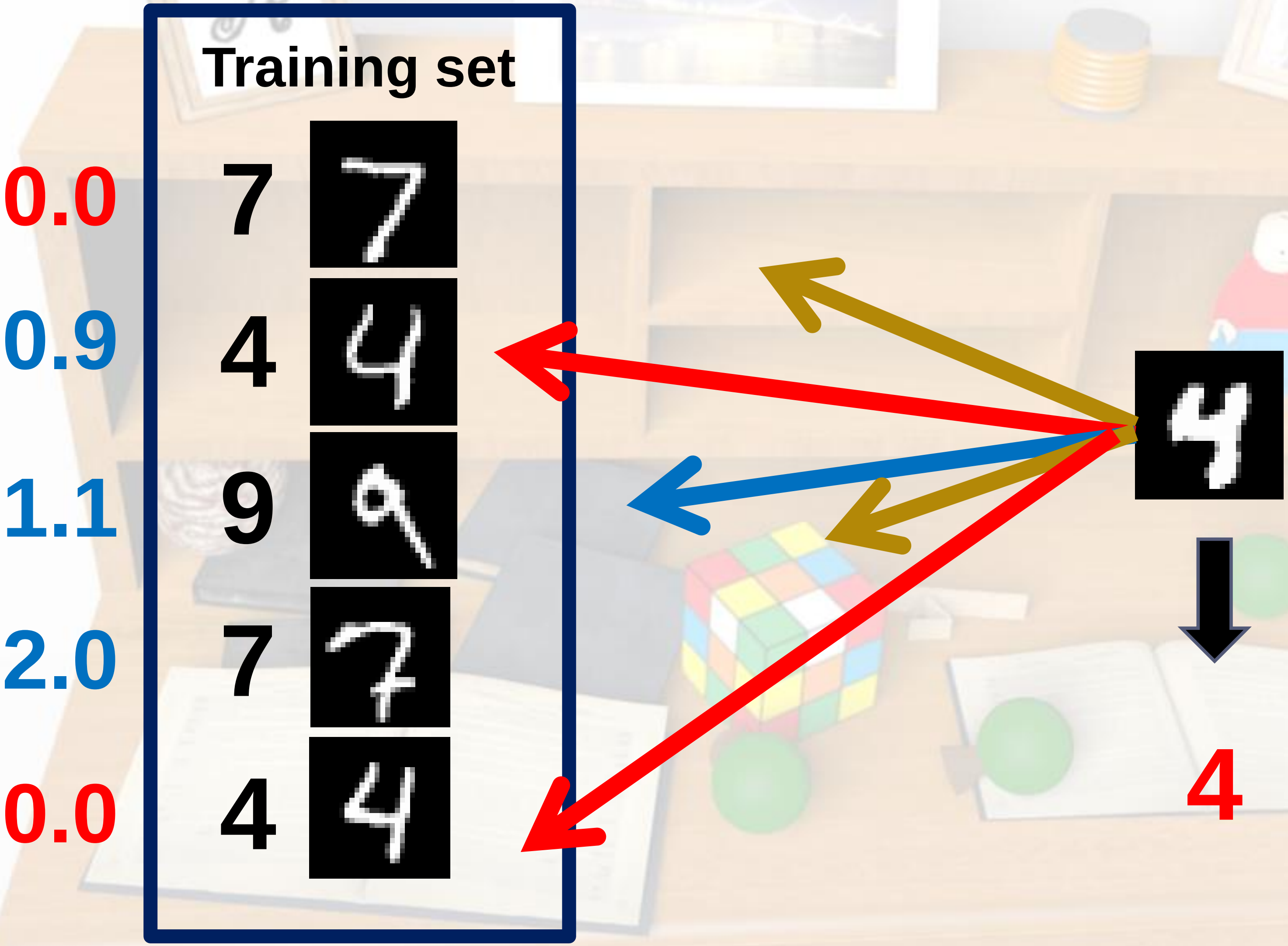
…or we can add “weights”



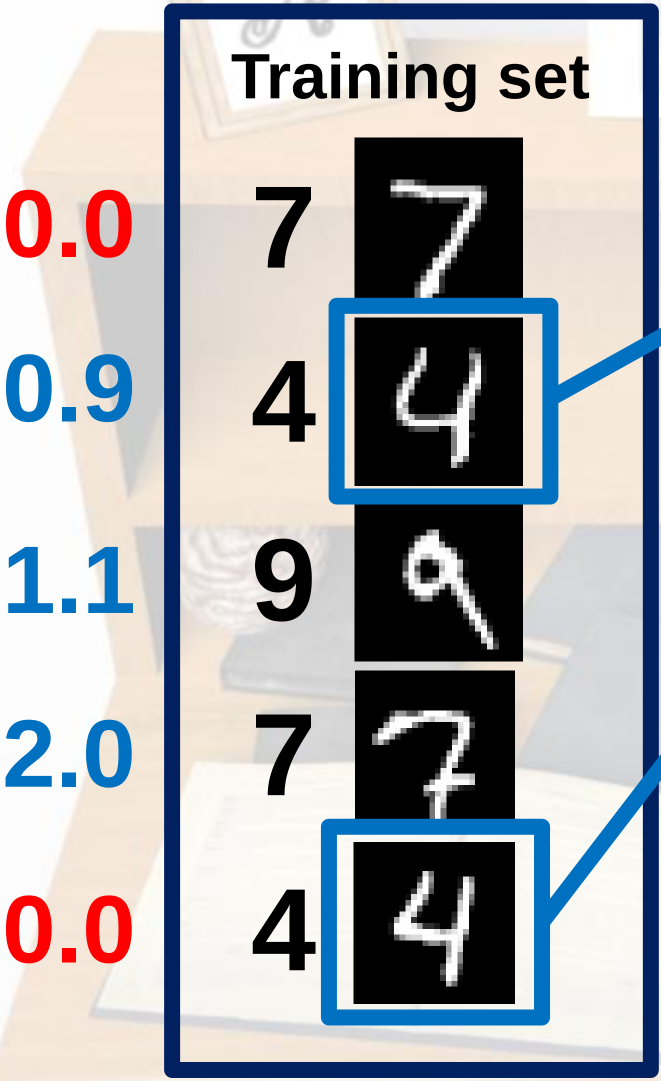
...or we can add "weights"



.. or we can SUM instead of MAX

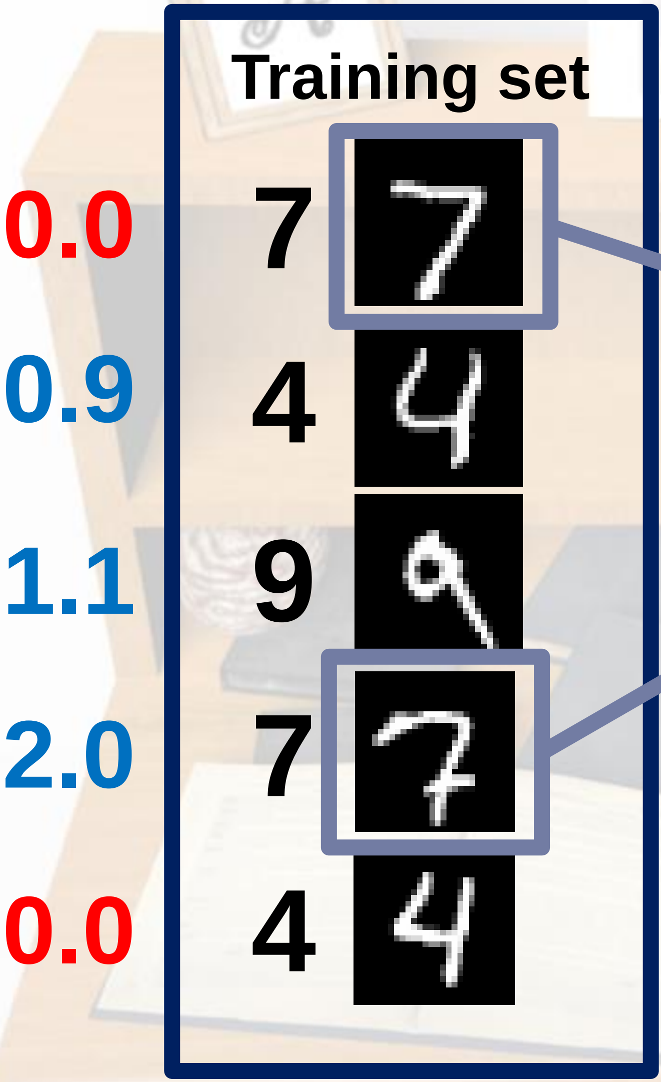


.. or we can SUM instead of MAX




```
evidence(img, 4) =

  0.9 * similarity(img, tr[1])

  +

  0.0 * similarity(img, tr[4])

  = 34.0
```

.. or we can SUM instead of MAX




```
evidence(img, 7) =

  0.0 * similarity(img, tr[0])

  +

  2.0 * similarity(img, tr[3])

  = 20.0
```

General form

$$K(\boldsymbol{x}_i, \boldsymbol{z})$$

General form

$$K(\boldsymbol{x}_i, \boldsymbol{z})$$

$$K(\boldsymbol{x}_j, \boldsymbol{z})$$

General form

$$\sum_i w_i K(\boldsymbol{x}_i, \boldsymbol{z})$$

$$\sum_j w_j K(\boldsymbol{x}_j, \boldsymbol{z})$$

General form

$$\sum_i w_i K(\boldsymbol{x}_i, \boldsymbol{z}) - \sum_j w_j K(\boldsymbol{x}_j, \boldsymbol{z})$$

General form

$$\sum_i w_i y_i K(\boldsymbol{x}_i, \boldsymbol{z})$$

$$+ \sum_j w_j y_j K(\boldsymbol{x}_j, \boldsymbol{z})$$

General form

$$f_{\boldsymbol{w}}(\boldsymbol{z}) = \sum_{i} w_i y_i K(\boldsymbol{x}_i, \boldsymbol{z})$$

How to find the weights?

$$f_{\boldsymbol{w}}(\boldsymbol{z}) = \sum_i \boxed{w_i} y_i K(\boldsymbol{x}_i, \boldsymbol{z})$$

How to find the weights?

$$f_{\boldsymbol{w}}(\boldsymbol{z}) = \sum_i \boxed{w_i} y_i \, K(\boldsymbol{x}_i, \boldsymbol{z})$$

- Find weights, such that the **misclassification error rate** **on the training set** is **the smallest.**

$$\boxed{\mathbf{w = argmin_w \;\; ErrorRate\ (f_w, Data)}}$$

How to find the weights?

$$f_{\boldsymbol{w}}(\boldsymbol{z}) = \sum_i \boxed{w_i} y_i K(\boldsymbol{x}_i, \boldsymbol{z})$$

- Find weights, such that the **approximation to misclassification error** **on the training set** is **the smallest.**

$$\boxed{\mathbf{w} = \mathrm{argmin}_{\mathbf{w}}\ \mathrm{Error}\,(f_{\mathbf{w}}, \mathrm{Data})}$$

How to find the weights?

$$f_{\mathbf{w}}(\mathbf{z}) = \sum_i \boxed{w_i}\, y_i\, K(\mathbf{x}_i, \mathbf{z})$$

- Find weights, such that the **error rate on the training set** is **the smallest + there are many zero weights.**

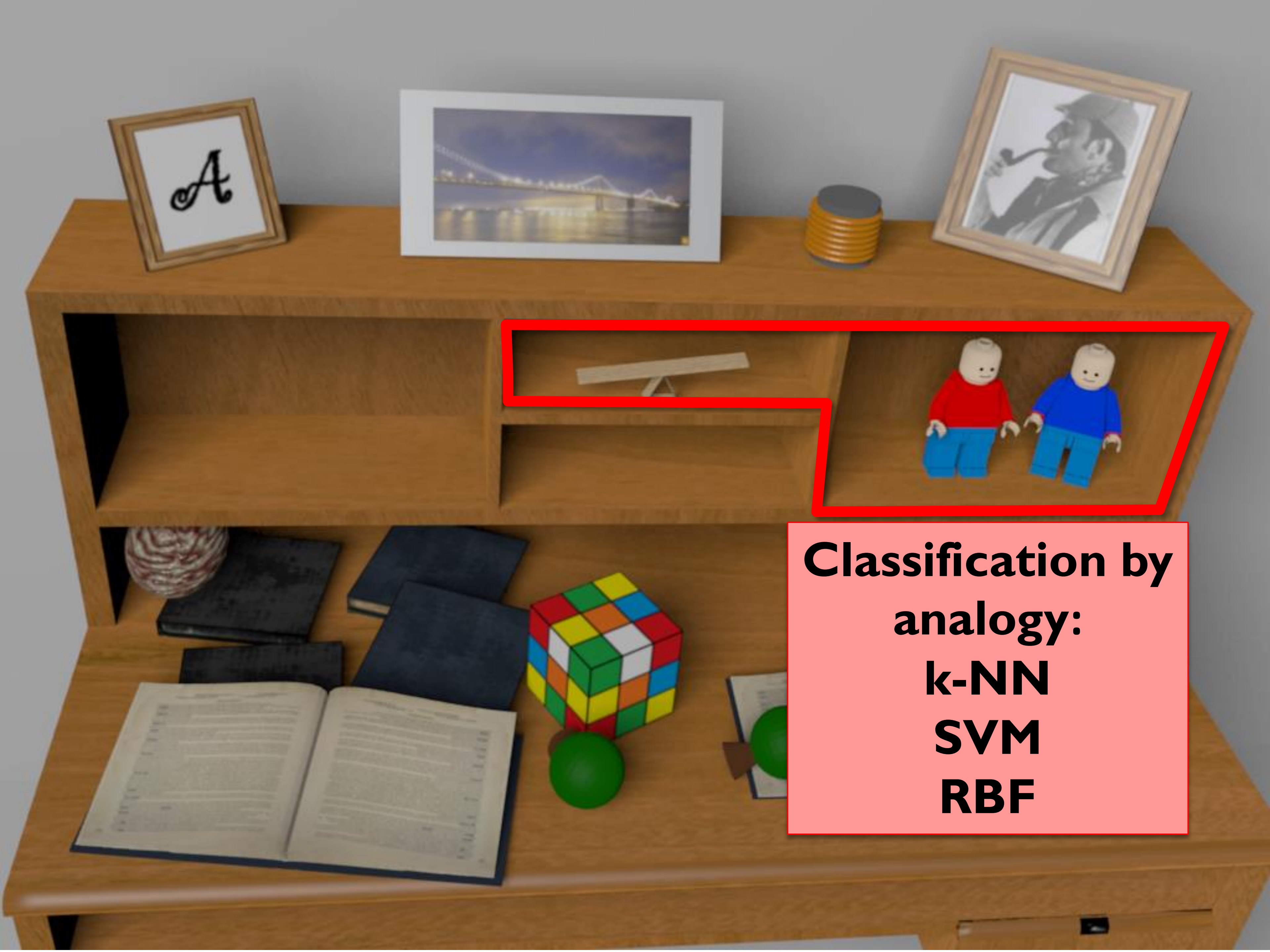
w = argmin$_w$ Error (f$_w$, Data) + Complexity (w)

Support Vector Machine

```
from sklearn.svm import SVC

clf = SVC(kernel='linear')
clf.fit(training_set, training_labels)

predicted_class = clf.predict(test_set)
```

=> 865/1000


A


Classification by analogy:
k-NN
SVM
RBF

Search for the nearest neighbor

```
def classify(img):
    similarities =
     [similarity(img, p) for p in training_set]
    i = similarities.index(max(similarities))
    return training_labels[i]
```

Search for the nearest neighbor

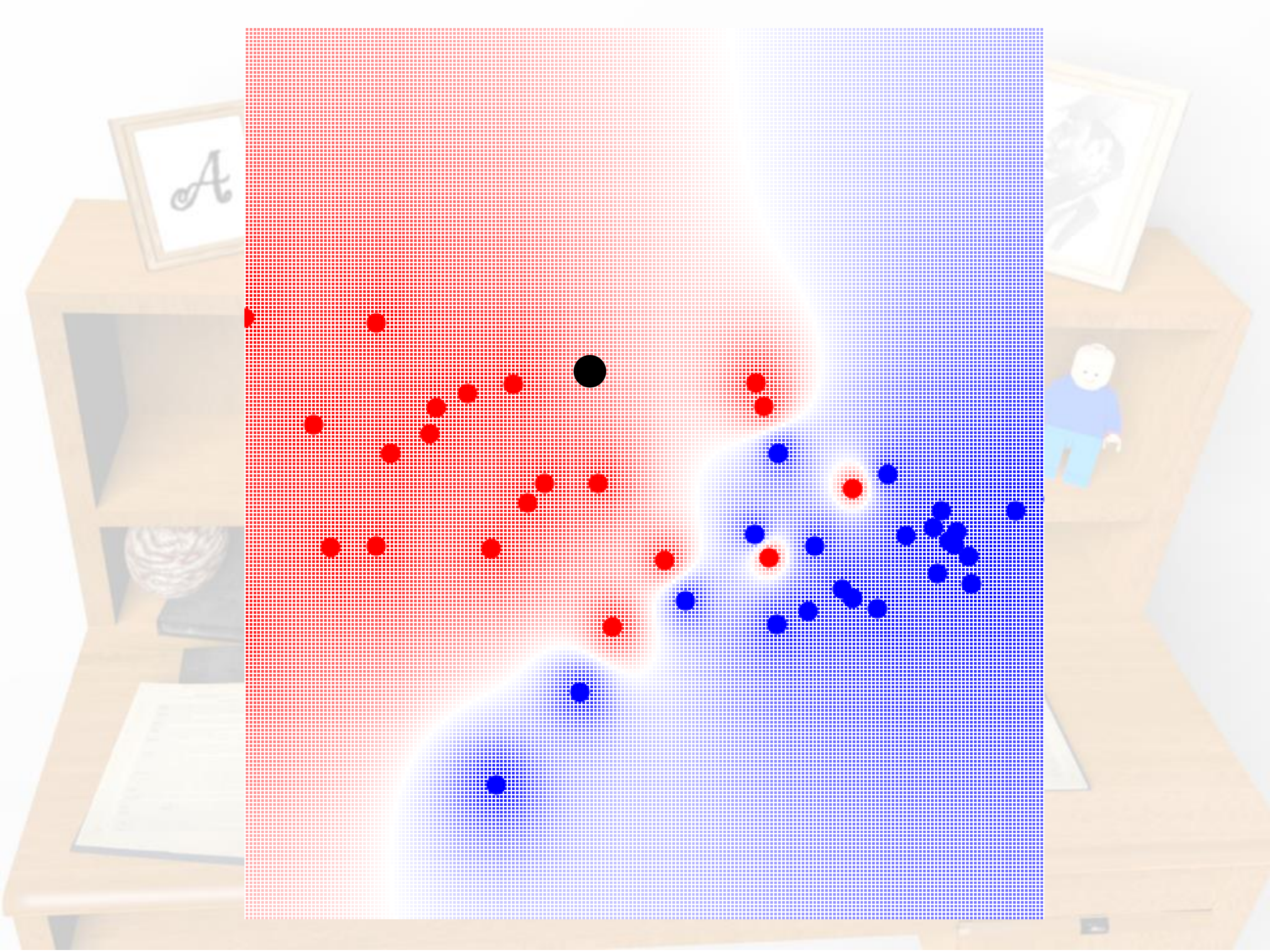
```
def classify(img):
    similarities =
      [similarity(img, p) for p in training_set]
    i = similarities.index(max(similarities))
    return training_labels[i]
```

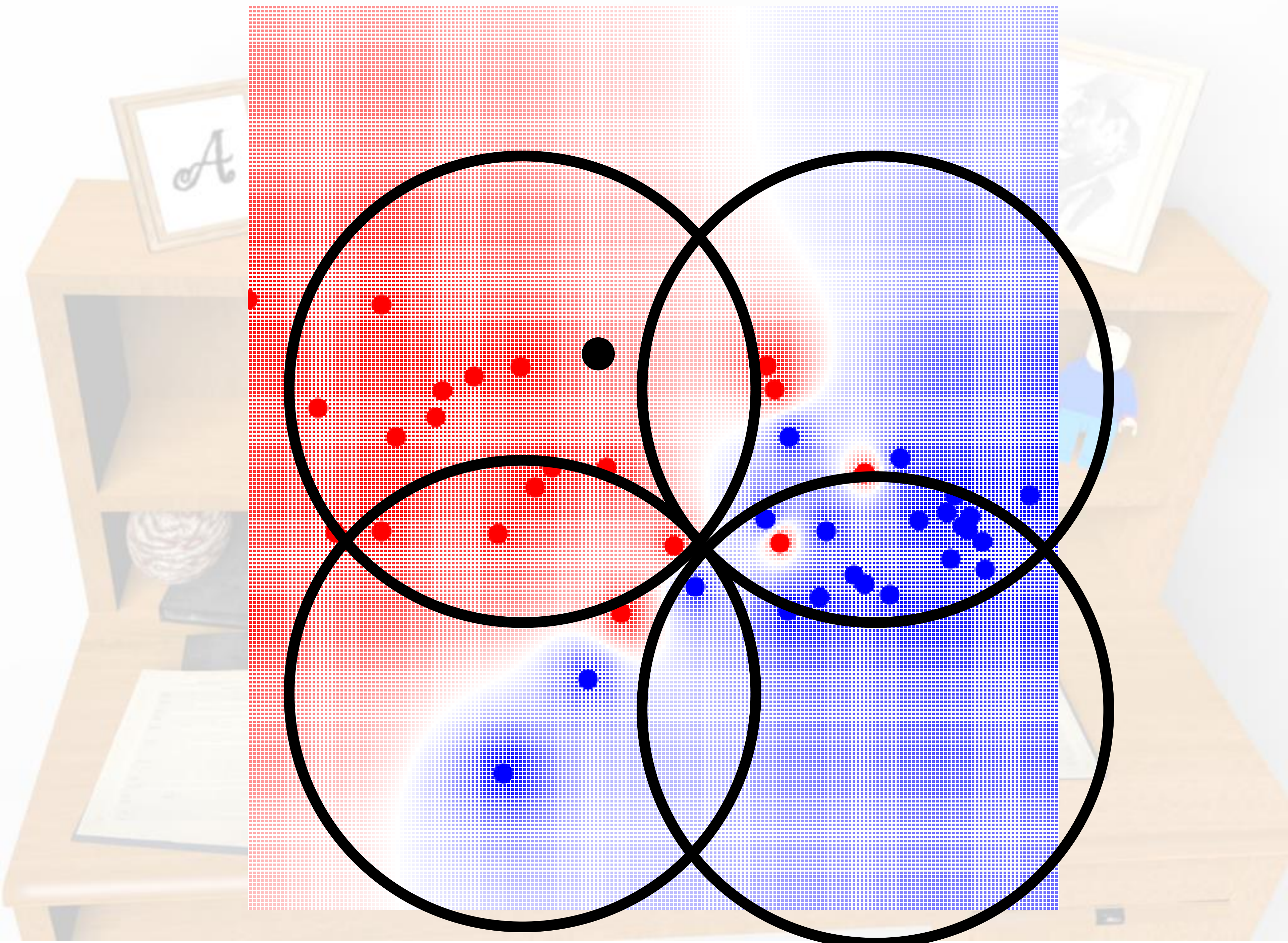
Inefficient

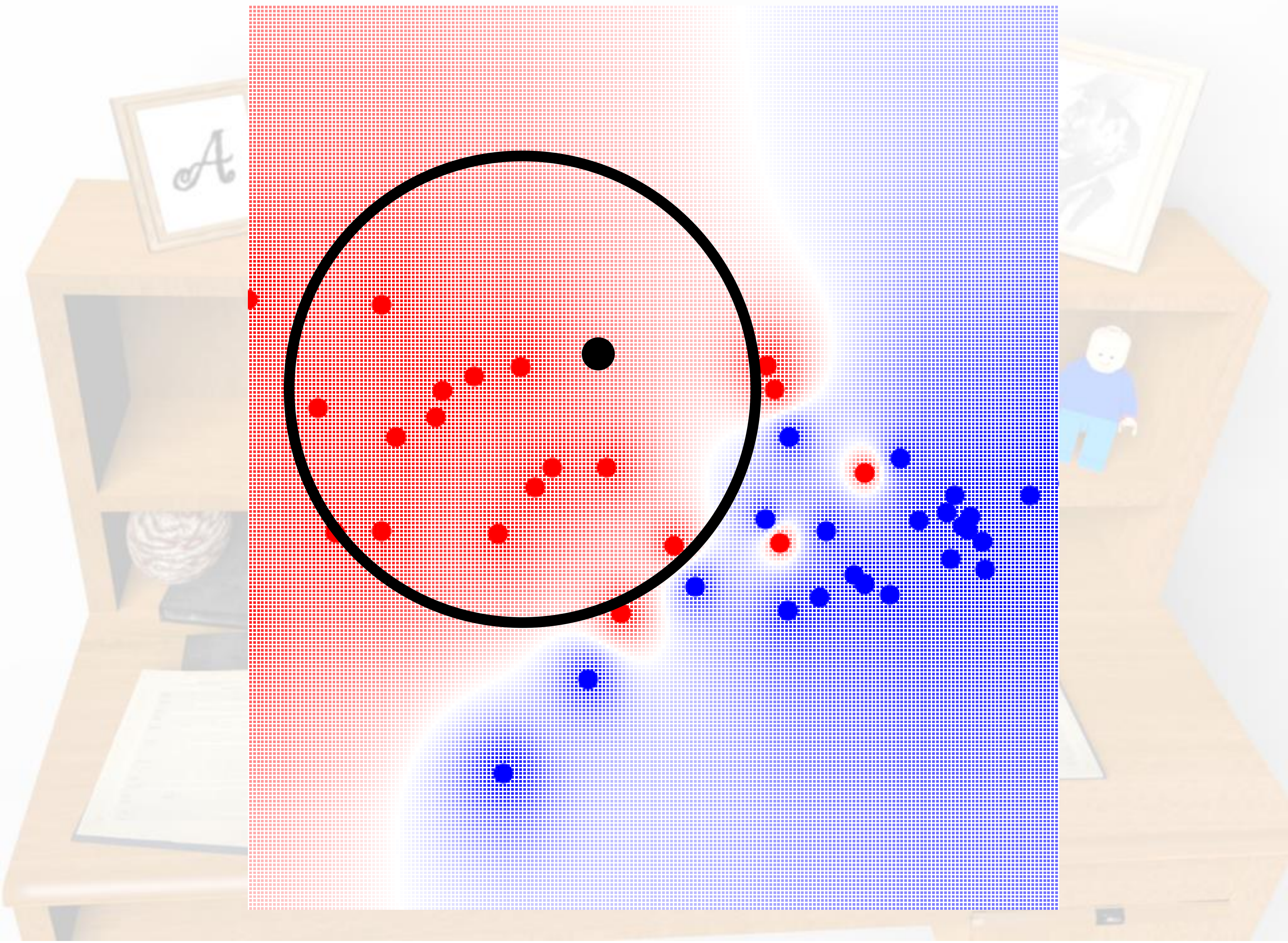
Search for the nearest neighbor

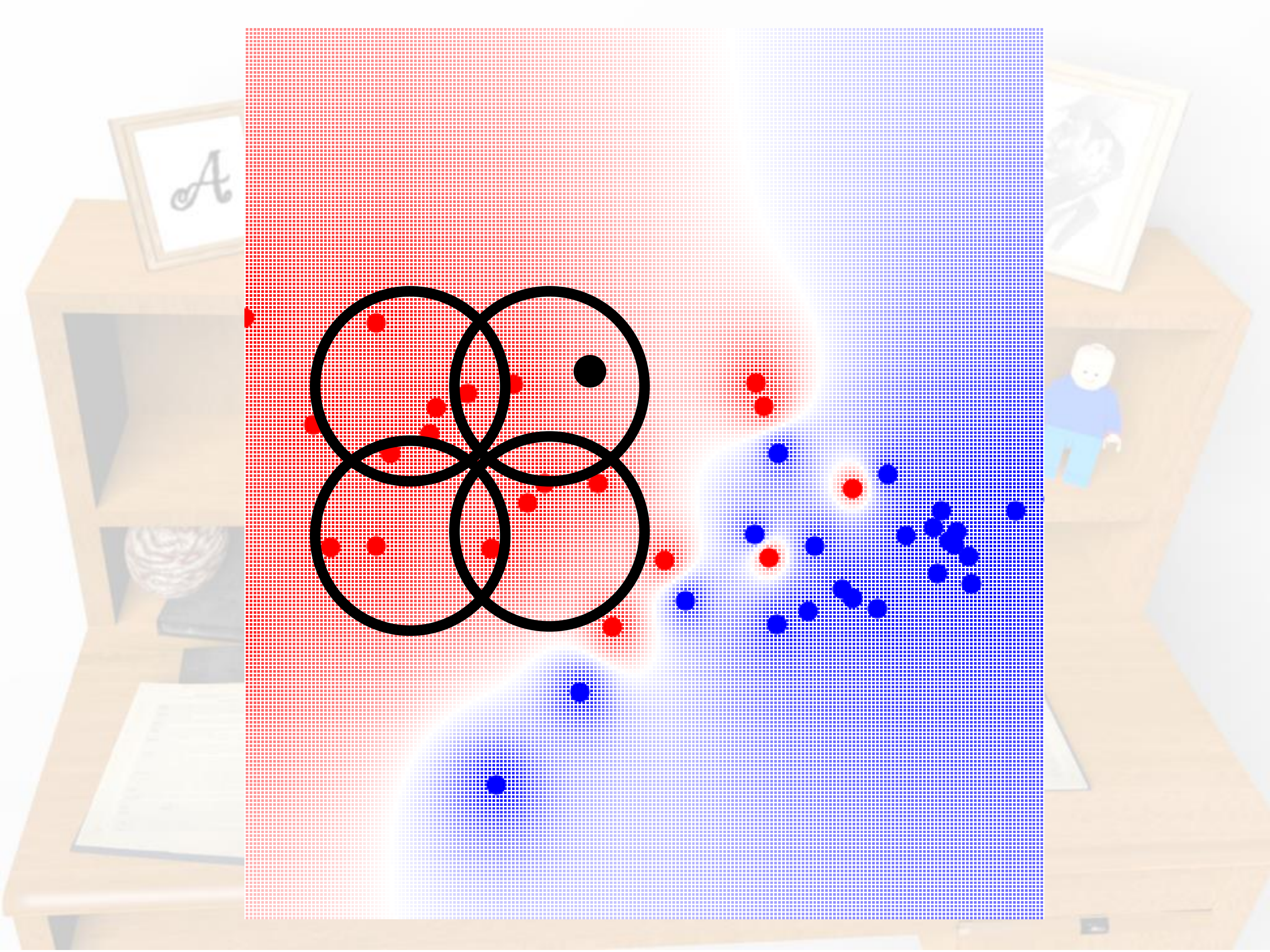
```
def classify(img):
    nearest_neighbour =
        training_set.find_nearest_neighbour(img)

    return nearest_neighbour.label
```

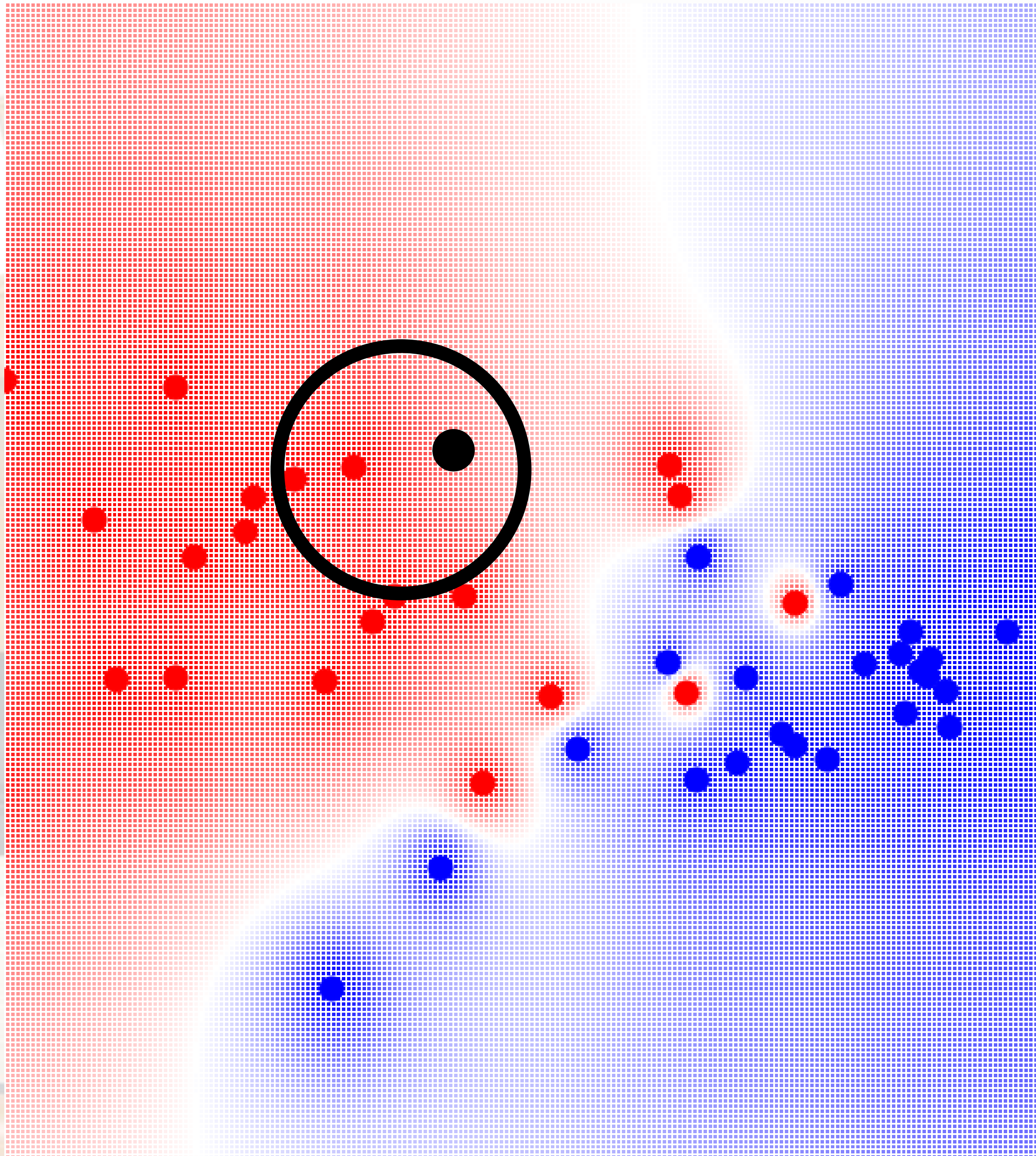
Indexing!








A



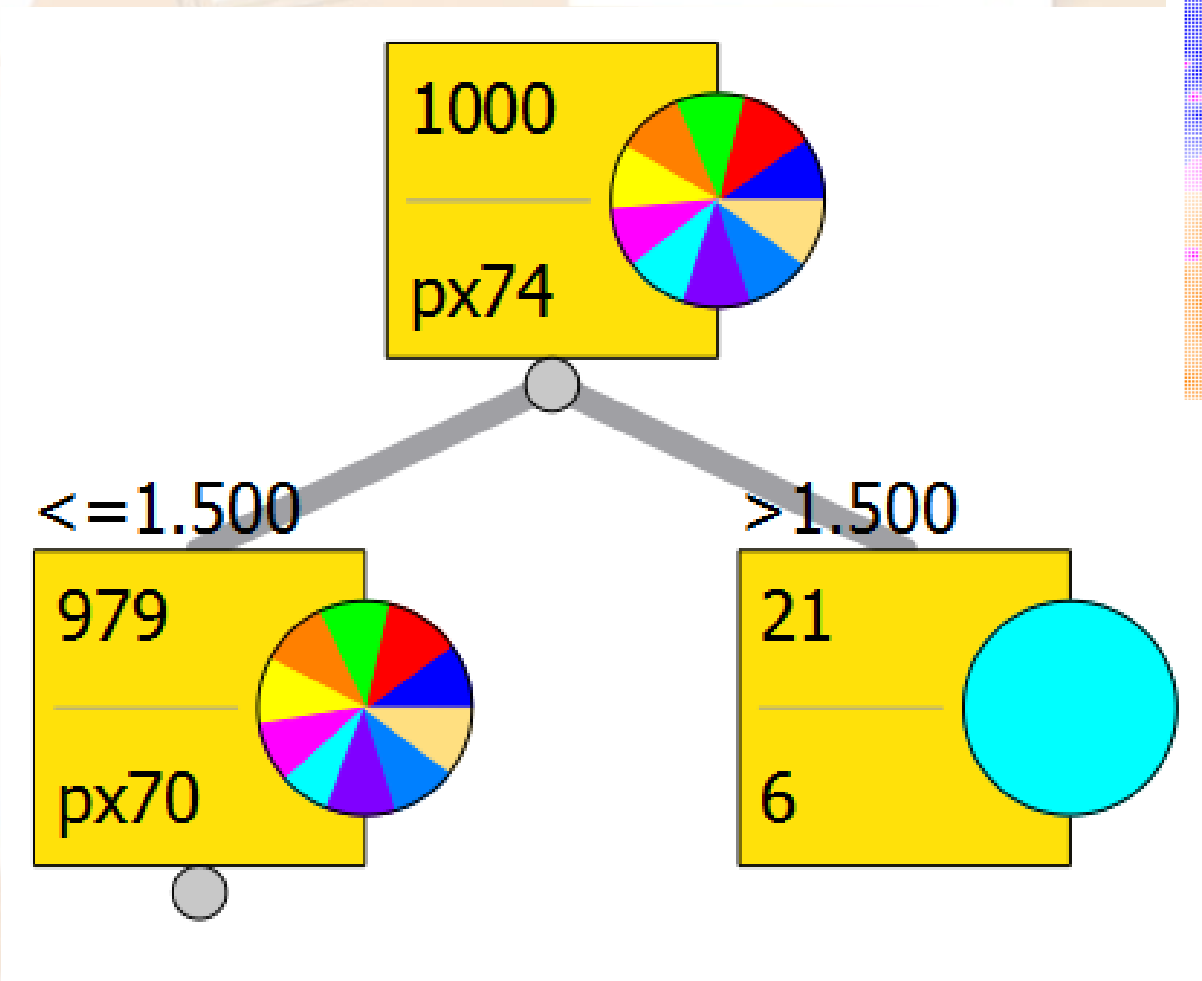
find_nearest_neighbour

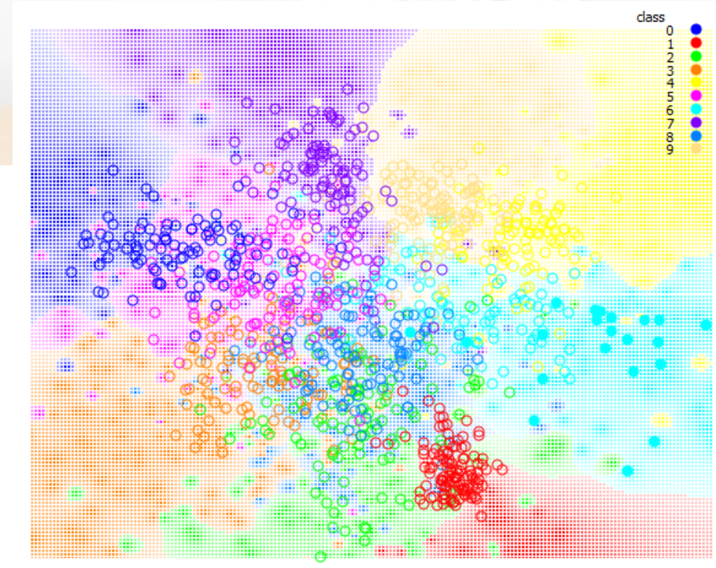
```
if pixel[10,13] > 4:

   if pixel[3,24] < 0:

      nearest_neighbour = A

   else:

      nearest_neighbour = B

else:

   nearest_neighbour = C
```

Classification Tree

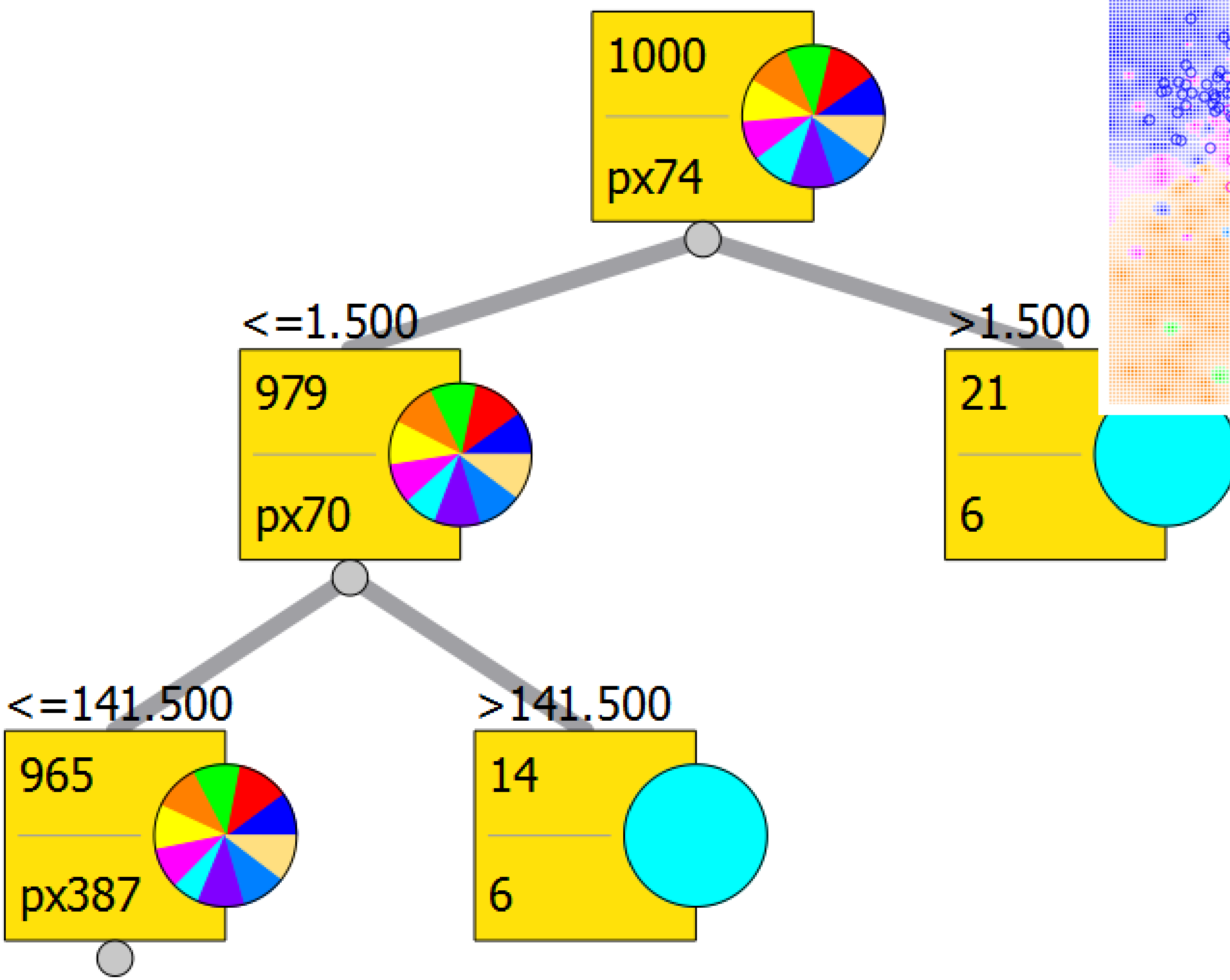
```
if pixel[10,13] > 4:
    if pixel[3,24] < 0:
        class = ‘1’
    else:
        class = ‘2’
else:
    class = ‘3’
```

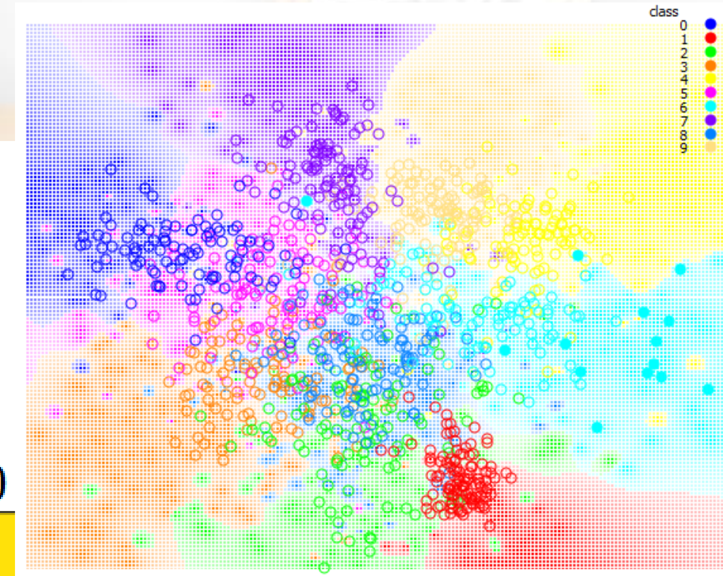
Classification Tree



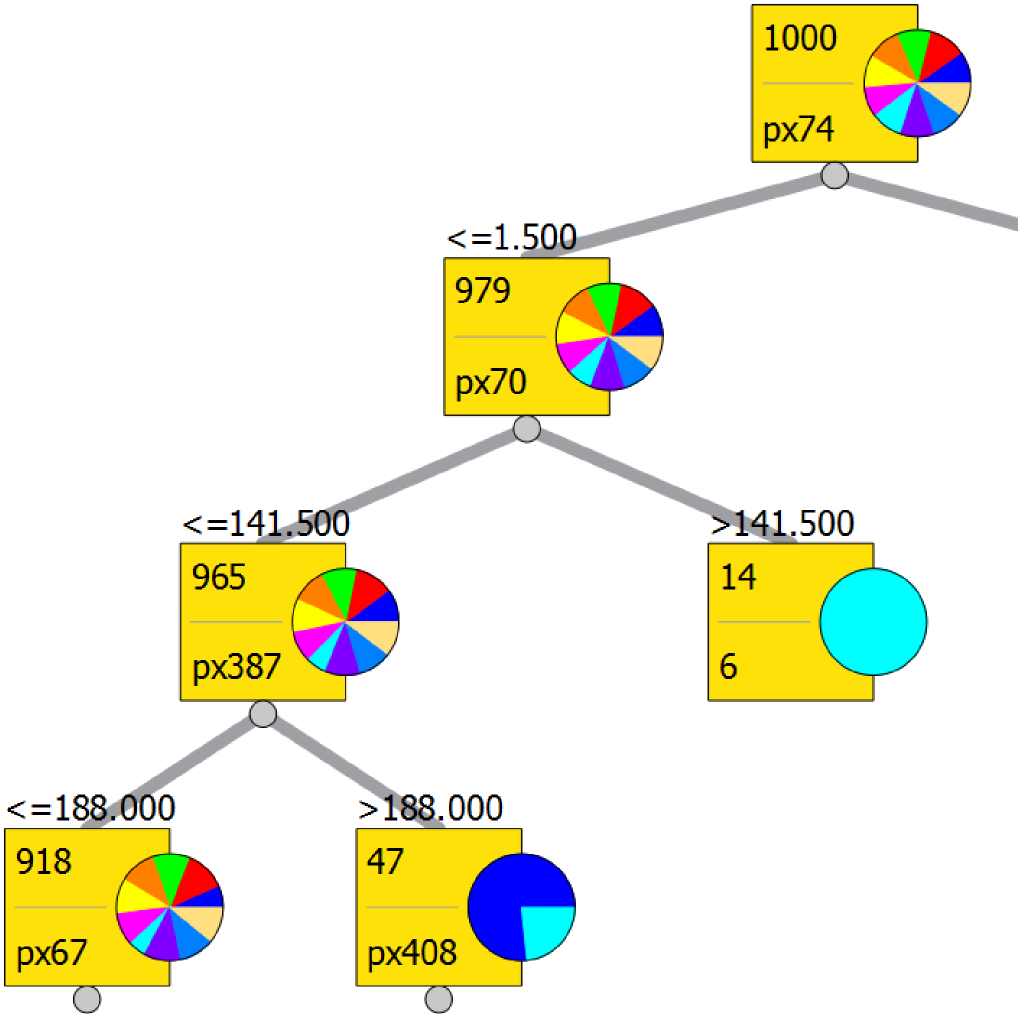


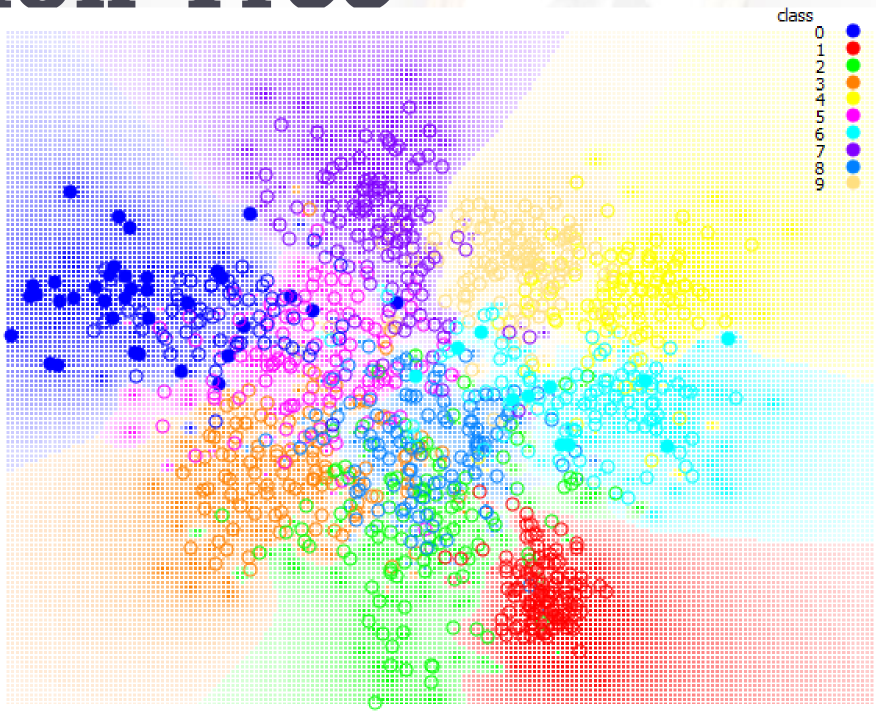
Classification Tree





Classification Tree





Orange

http://orange.biolab.si/

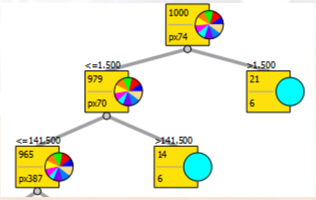

Trees
ID3
C4.5
RegTree

General form of a model

$$f_{\boldsymbol{w}}(\boldsymbol{z}) = \sum_i w_i y_i \, K(\boldsymbol{x}_i, \boldsymbol{z})$$

Search for optimal model parameters

General form of a model



Search for the optimal tree

Modeling

↓

Optimization

Linear model

f(image) =

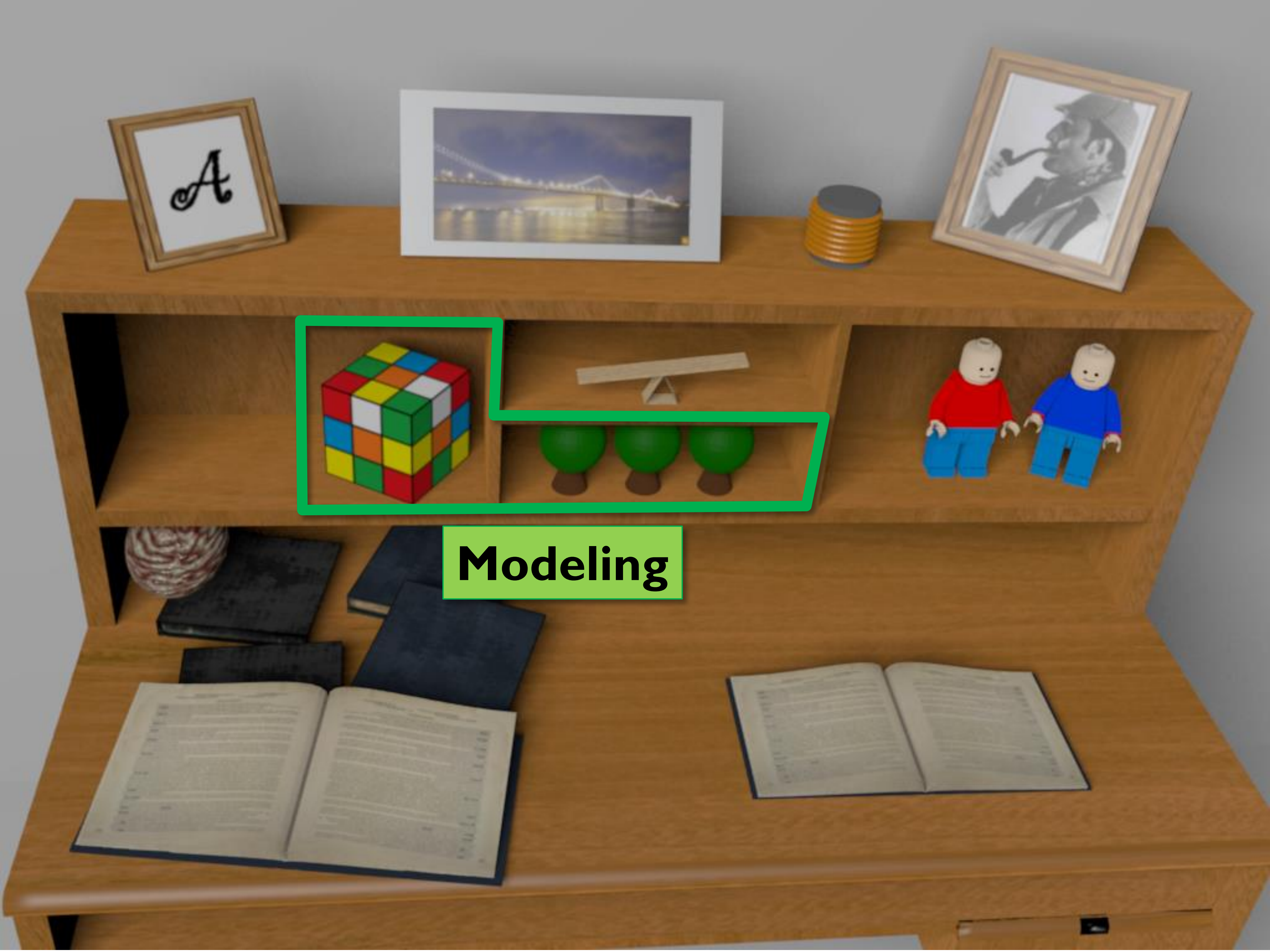
pixel1*_w1_ + pixel2*_w2_ + … + pixel784*_w784_

Linear Classification

```
from sklearn.linear_model import
        LinearRegression,
        LogisticRegression,
        RidgeClassifier,
        LARS,
        ElasticNet,
        SGDClassifier,
        ...
```

=> 809/1000


A


Modeling

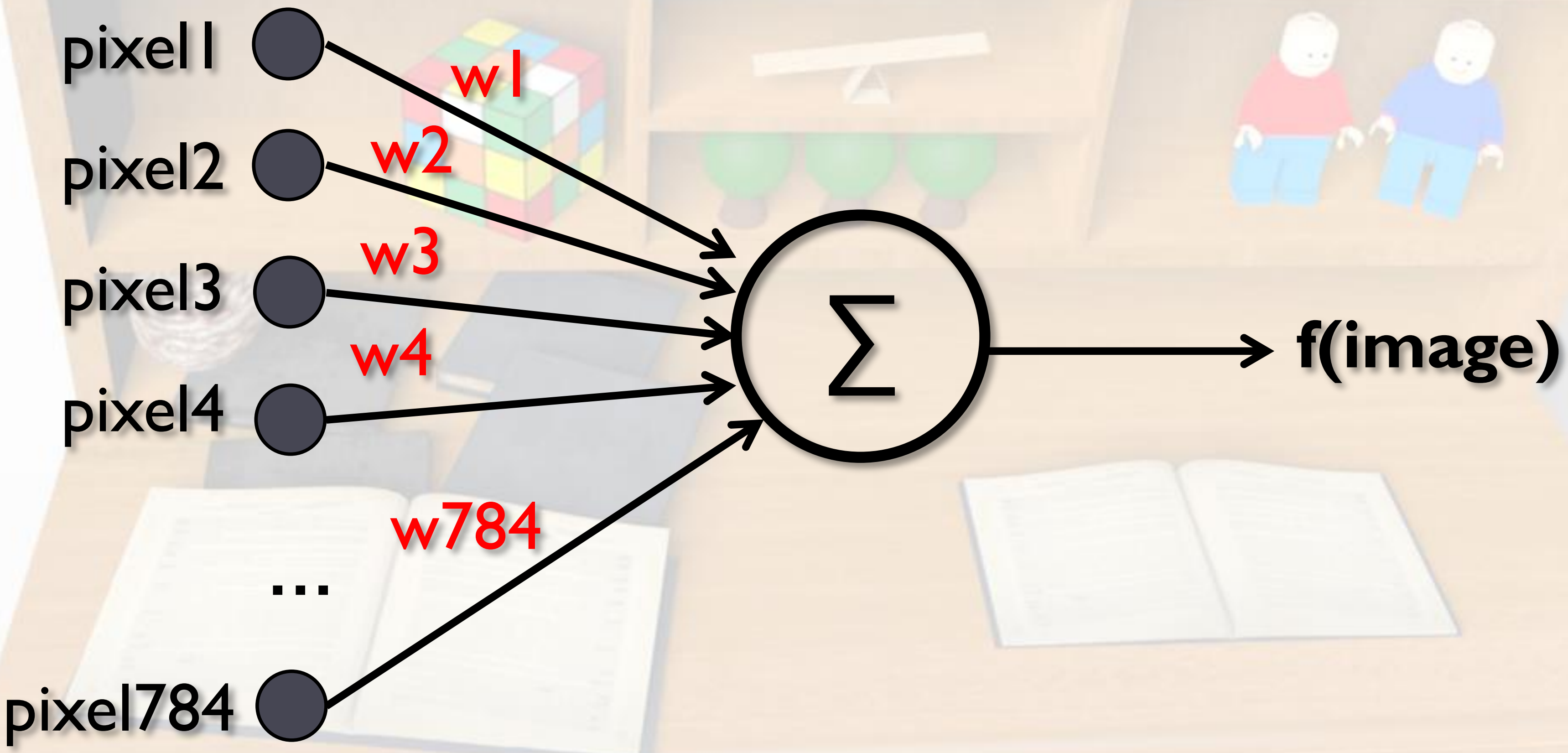
Linear model

f(image) =

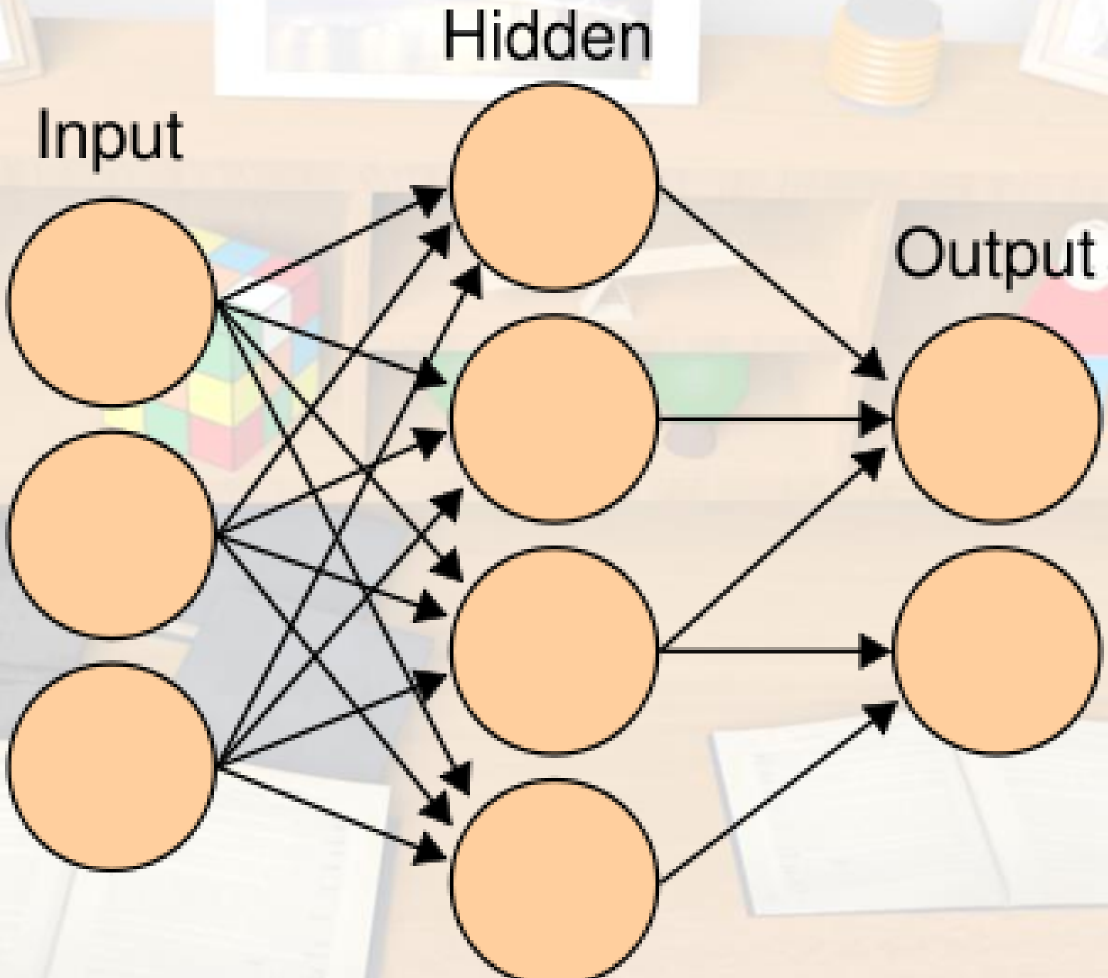
pixel1*$w1$ + pixel2*$w2$ + … + pixel784*$w784$

f(image) =

pixel1*w1 + pixel2*w2 + … + pixel784*w784



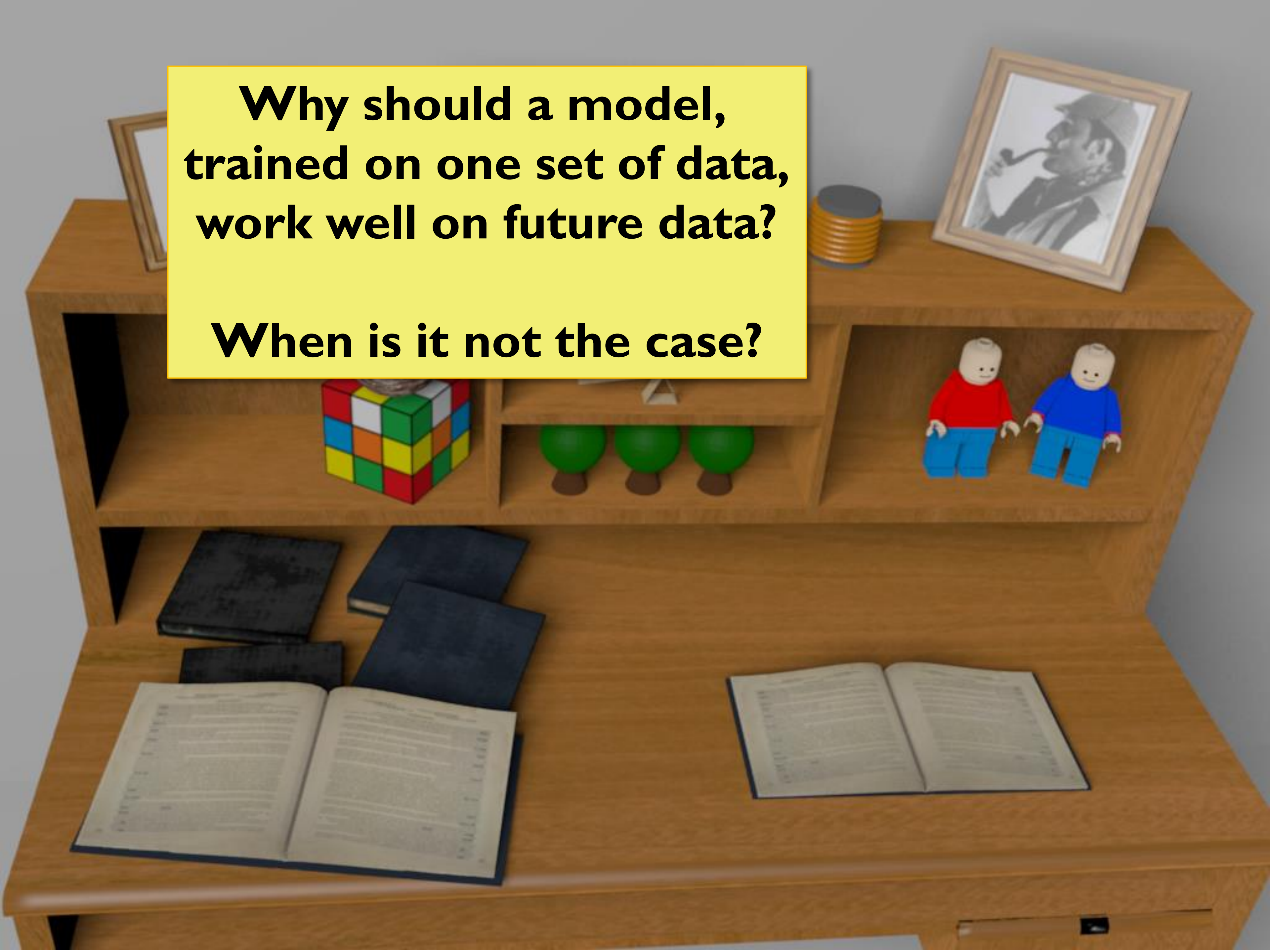
Neural network

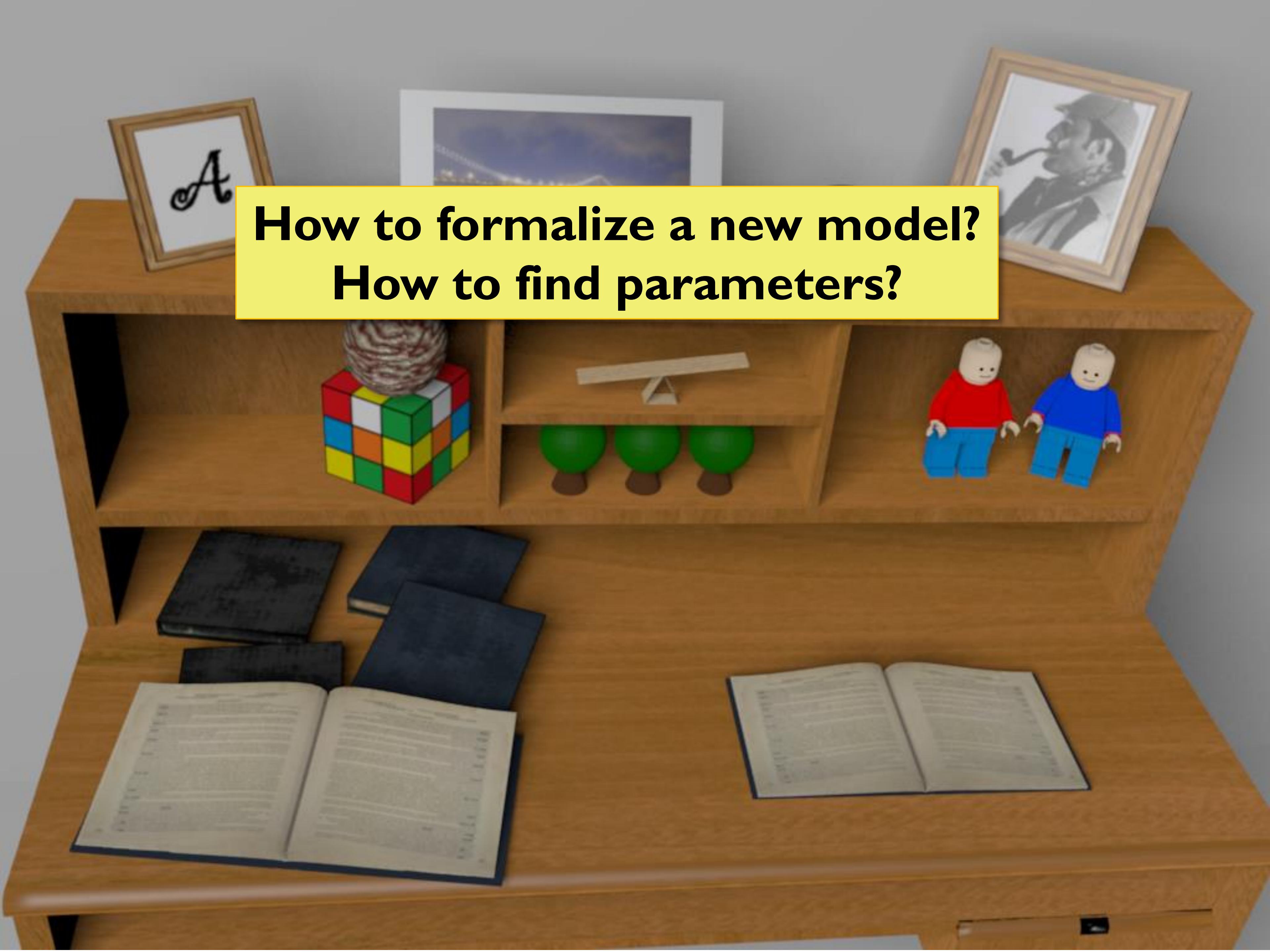


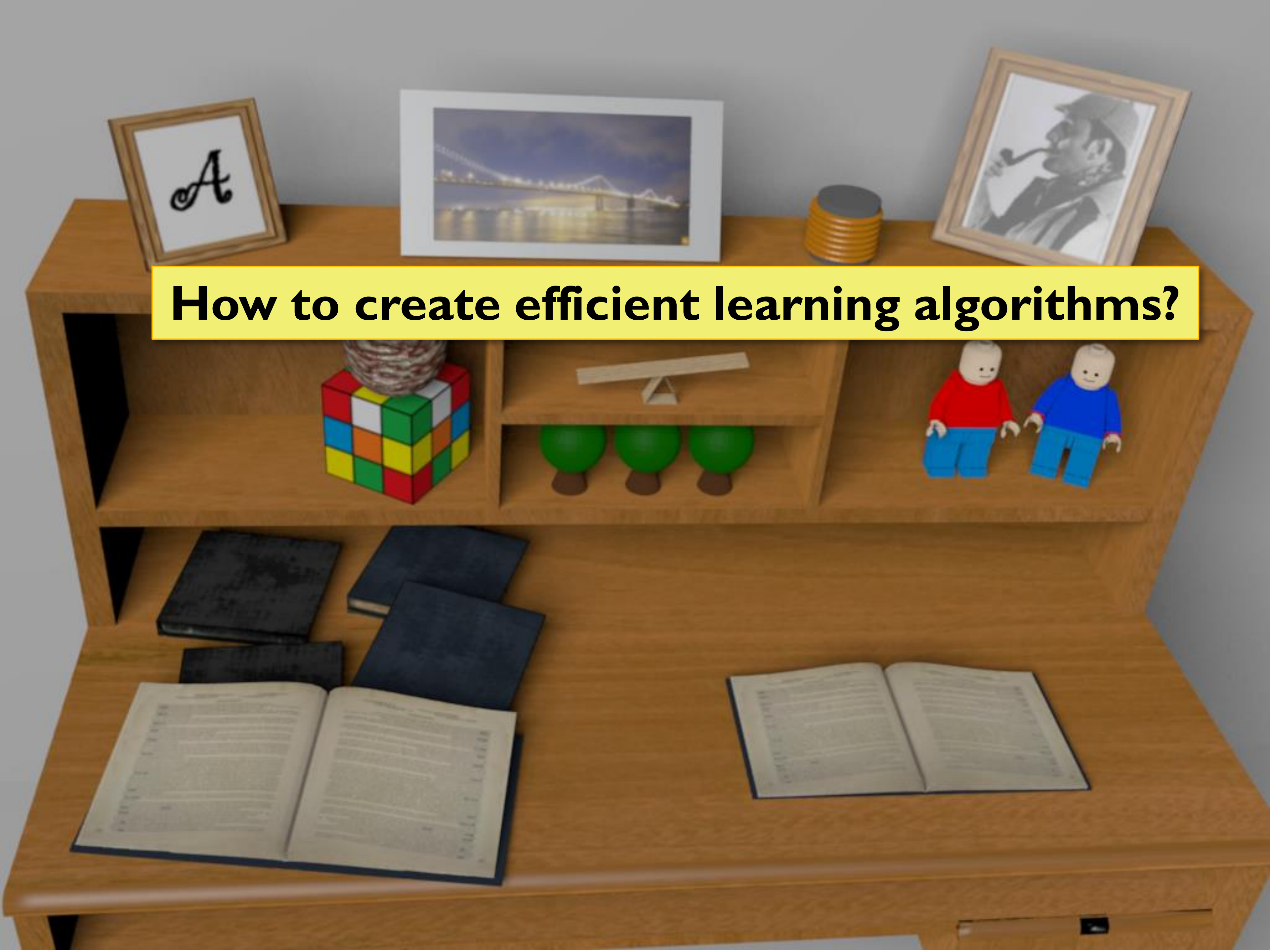
Modeling

Why should a model, trained on one set of data, work well on future data?

When is it not the case?

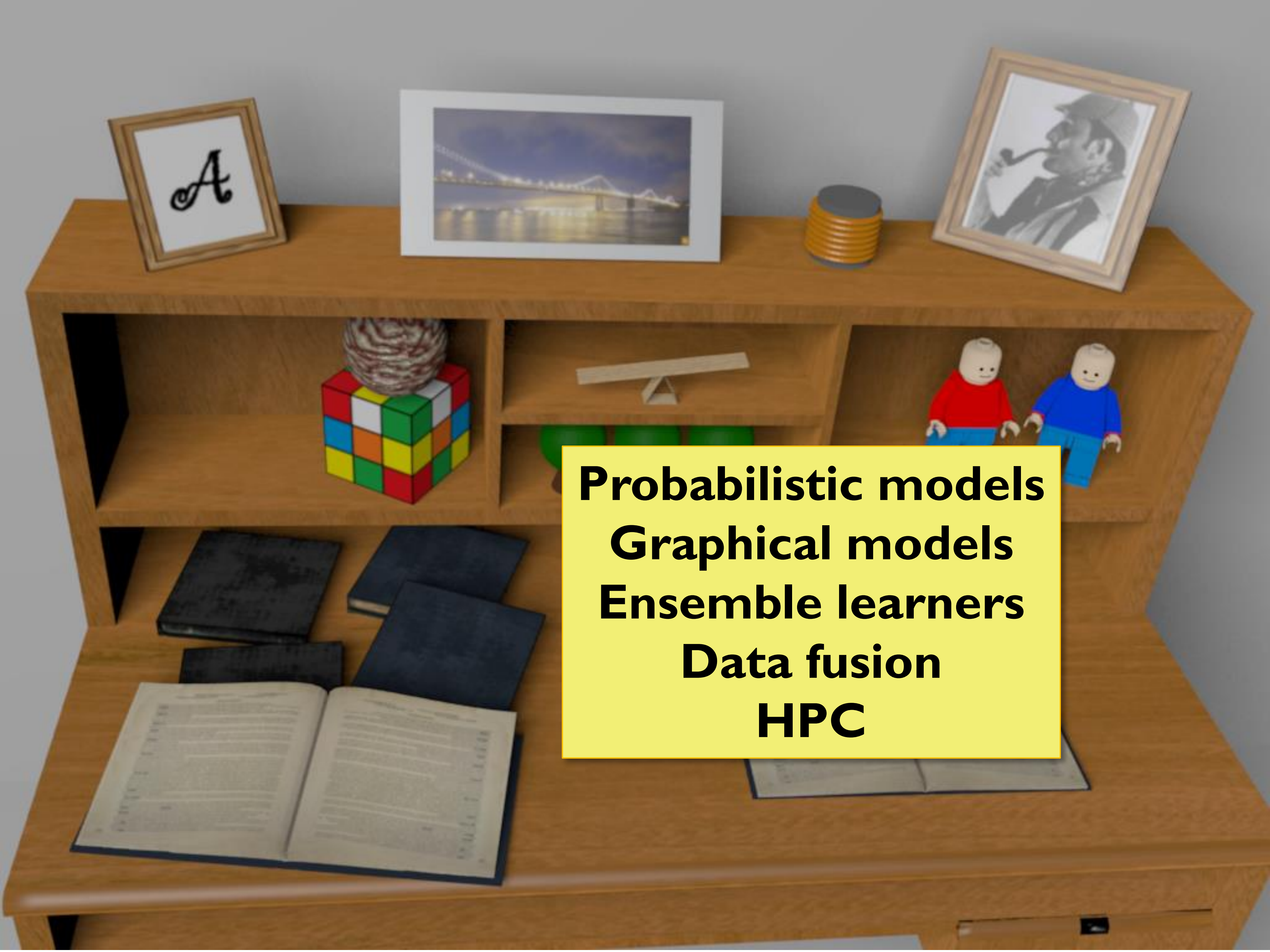



How to formalize a new model?
How to find parameters?


How to create efficient learning algorithms?

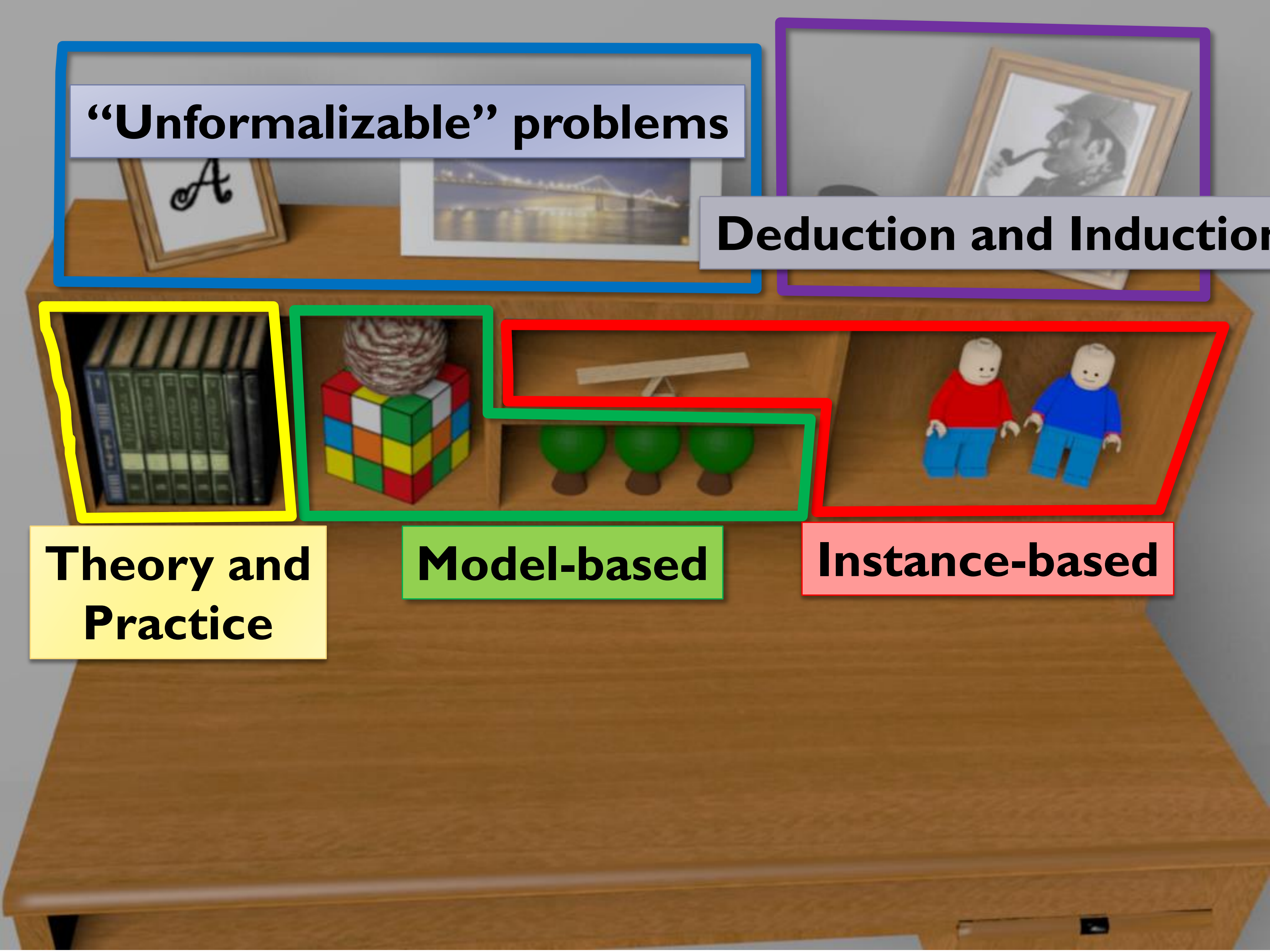

How to handle structured data?


Unsupervised learning
Semi-supervised learning
On-line learning
Active learning
Multi-instance learning
Reinforcement learning


Probabilistic models
Graphical models
Ensemble learners
Data fusion
HPC

Tools:
R, Weka, RapidMiner, Orange, scikits-learn, MLPy, MDP, PyBrain, …


A



“Unformalizable” problems
Deduction and Inductio
Theory and Practice
Model-based
Instance-based

Quiz

- The OCR problem is unusual in that it is ____.
- The two important perspectives on machine learning are _______-based and ______-based.
- The "soul" of machine learning is the minimization task

$$\operatorname{argmin}_{\boldsymbol{w}} \_\_\_\_\_\_\_\_\_\_\_\_ + \lambda \_\_\_\_\_\_\_\_\_\_\_\_\_$$

Quiz

- Two important components of machine learning:

?

↓

?

Quiz

- The machine learning algorithms mentioned in this lecture were:

Quiz

- The machine learning algorithms mentioned in this lecture were:
  - **K-nearest neighbor classifier**
  - **SVM**
  - **Classification trees**
  - **Linear models**
  - **Neural networks**


A
Questions?