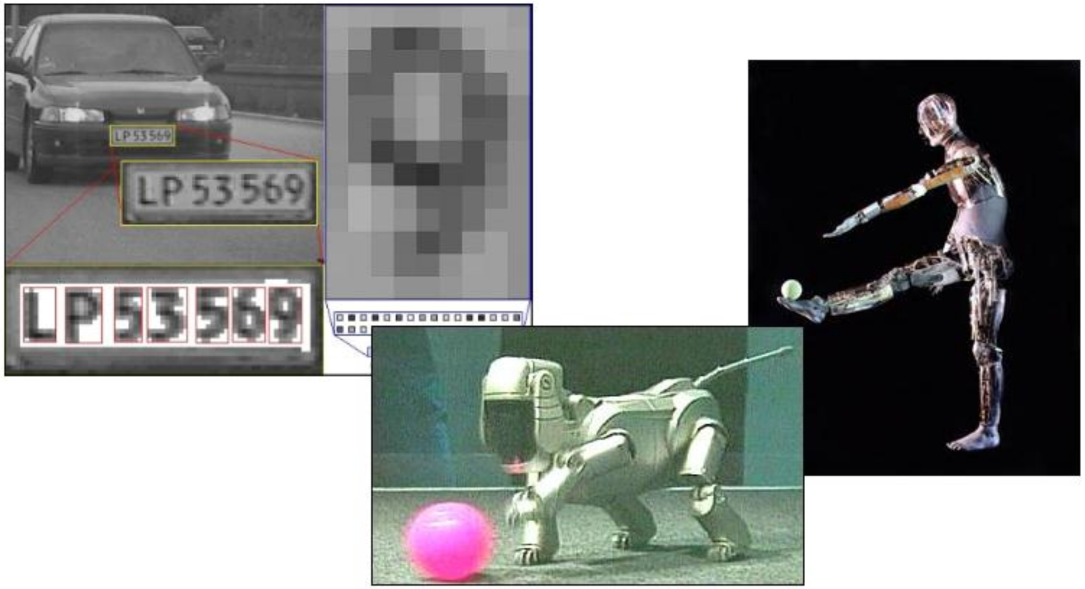


Welcome to Machine Learning

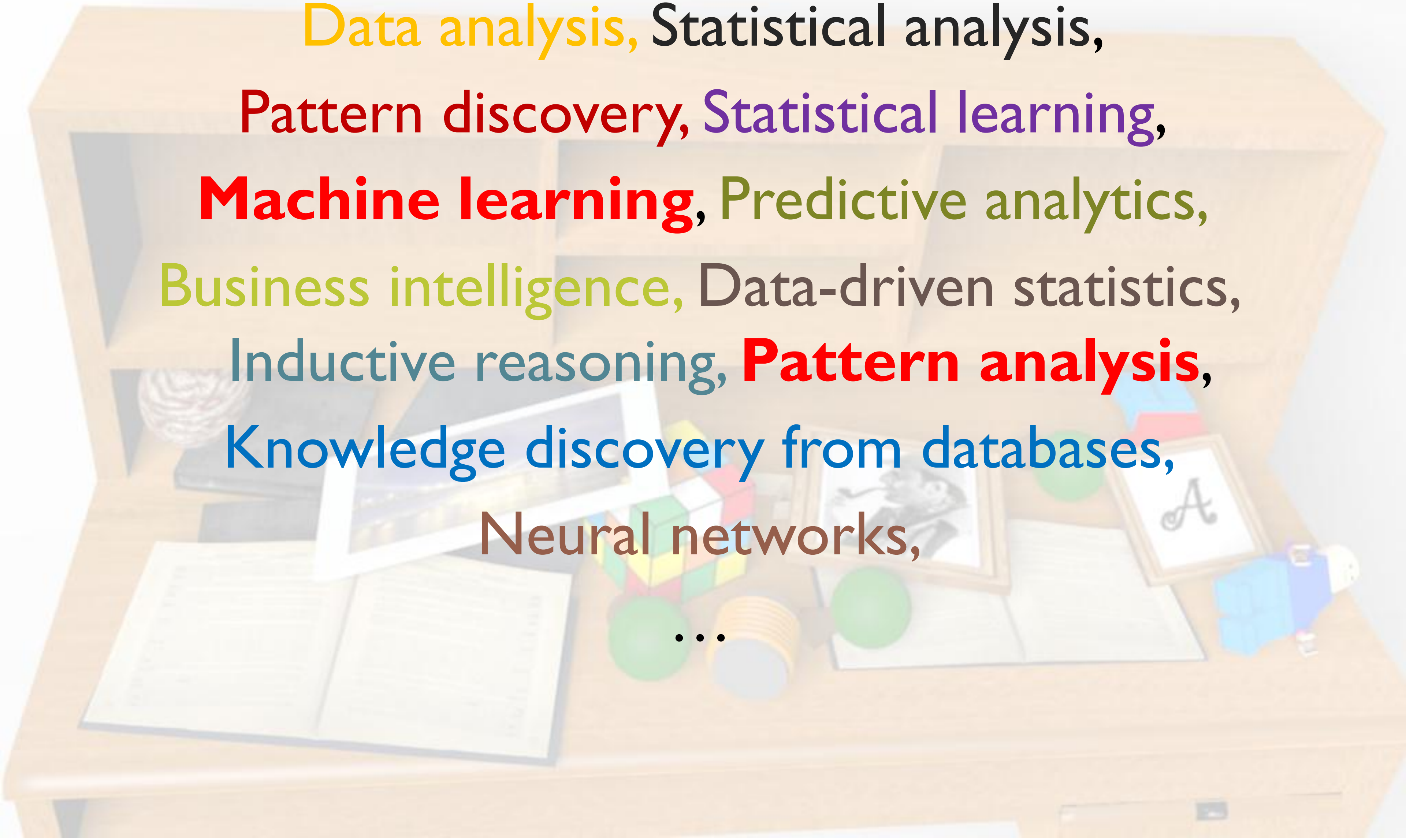
Konstantin Tretyakov
http://kt.era.ee

AACIMP 2012
August 2012

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,

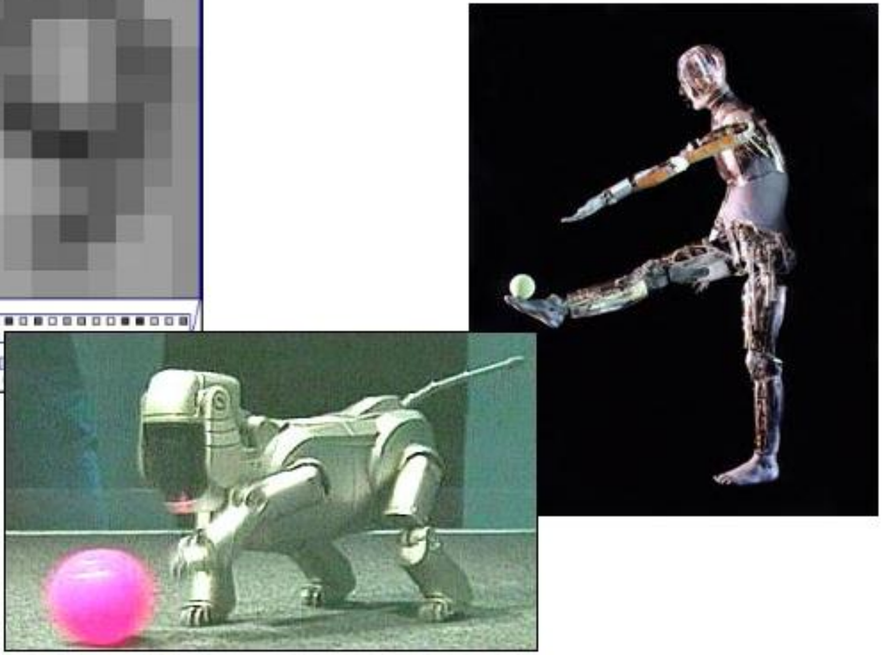
Business intelligence, Data-driven statistics,

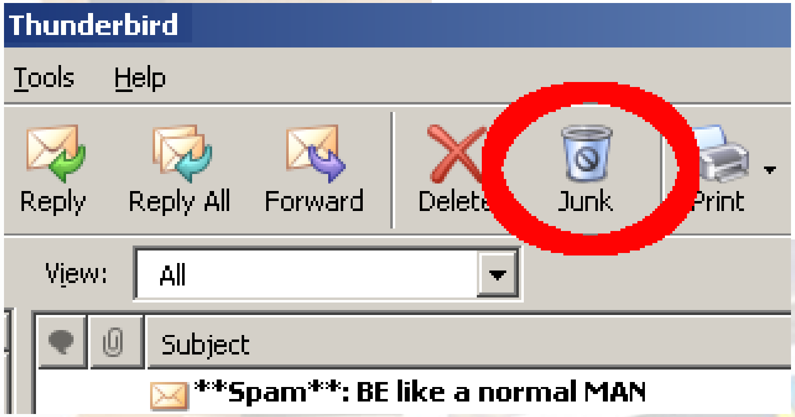
Inductive reasoning, **Pattern analysis**,

Knowledge discovery from databases,

Neural networks,

…





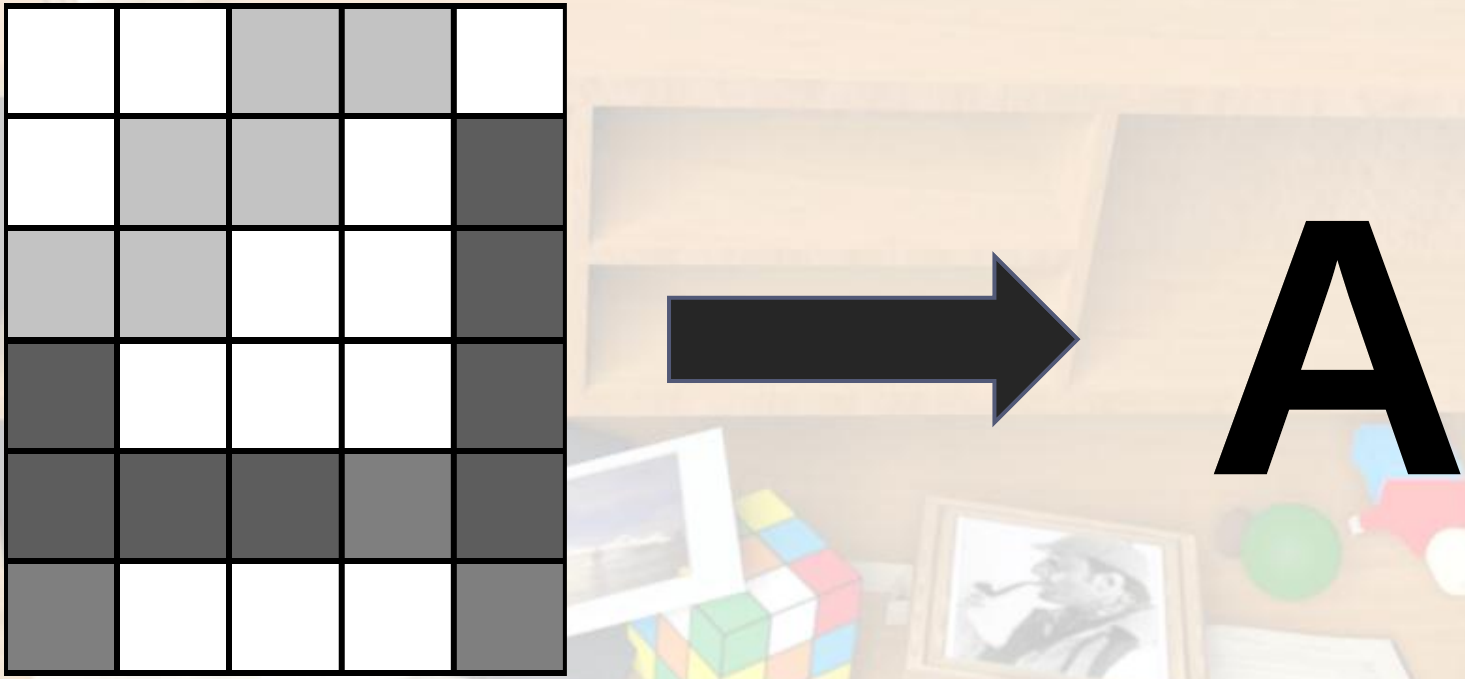
Spam: BE like a normal MAN

Google translate

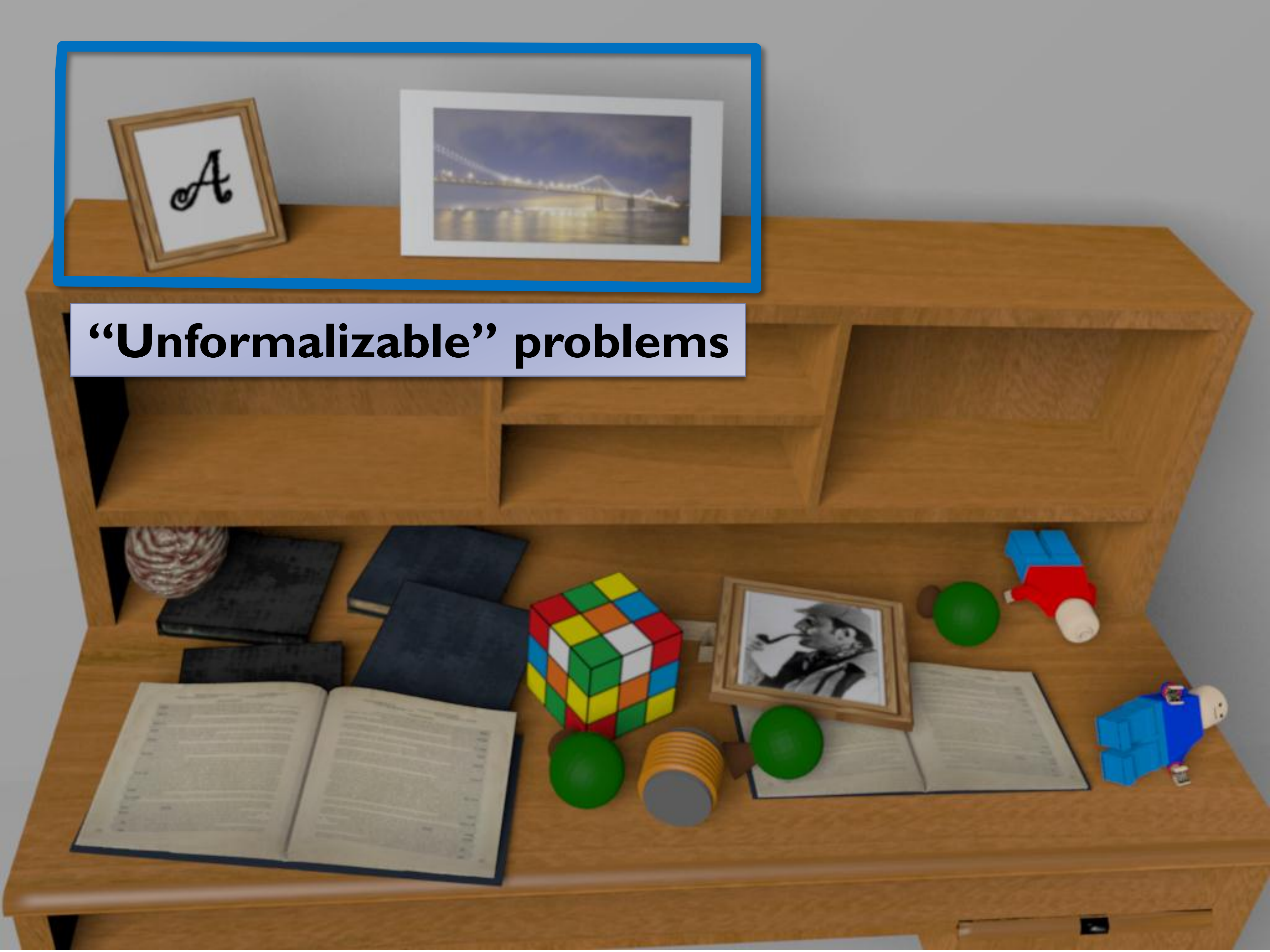
NETFLIX

A

A


A

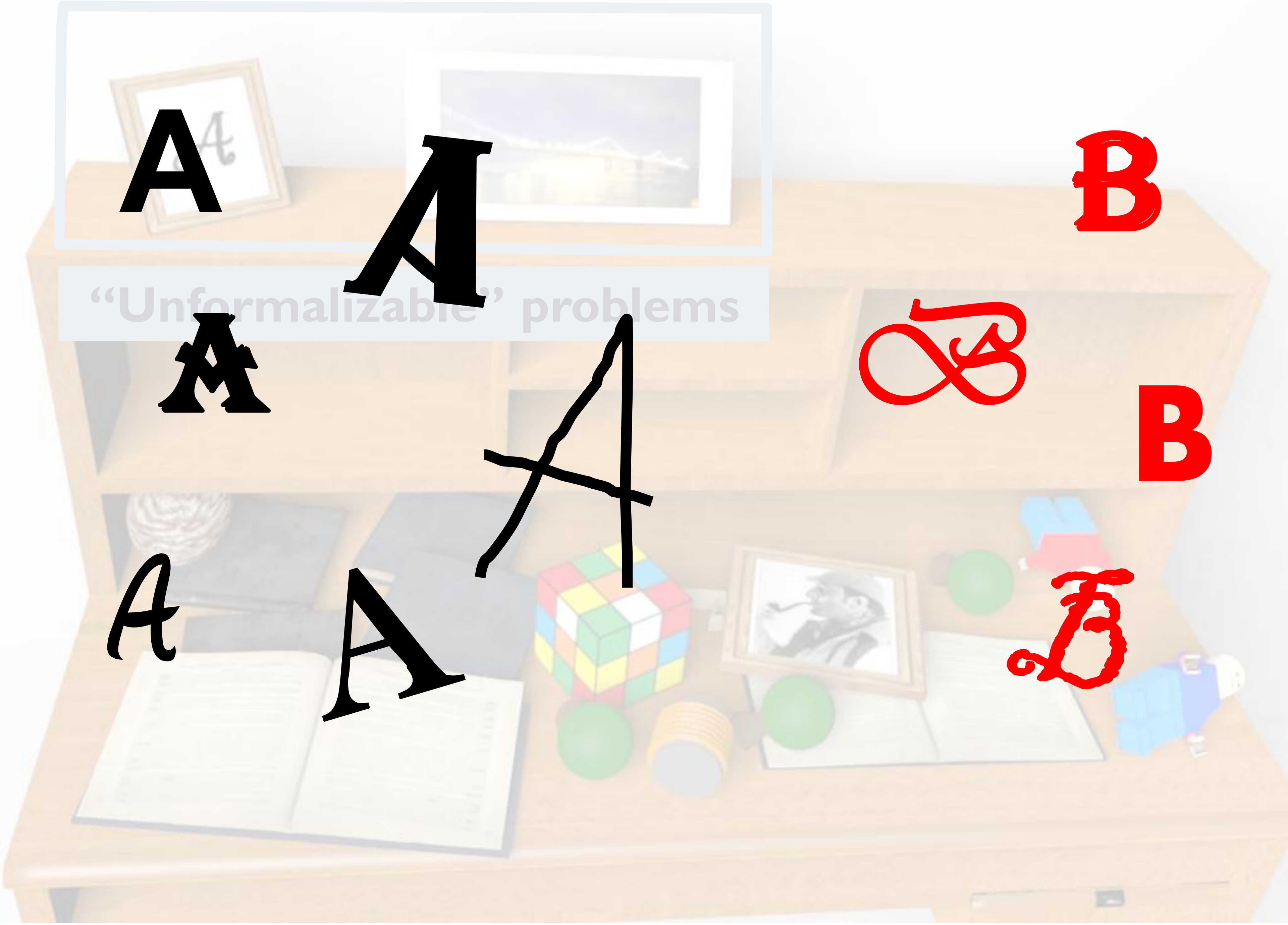
A



“Unformalizable” problems

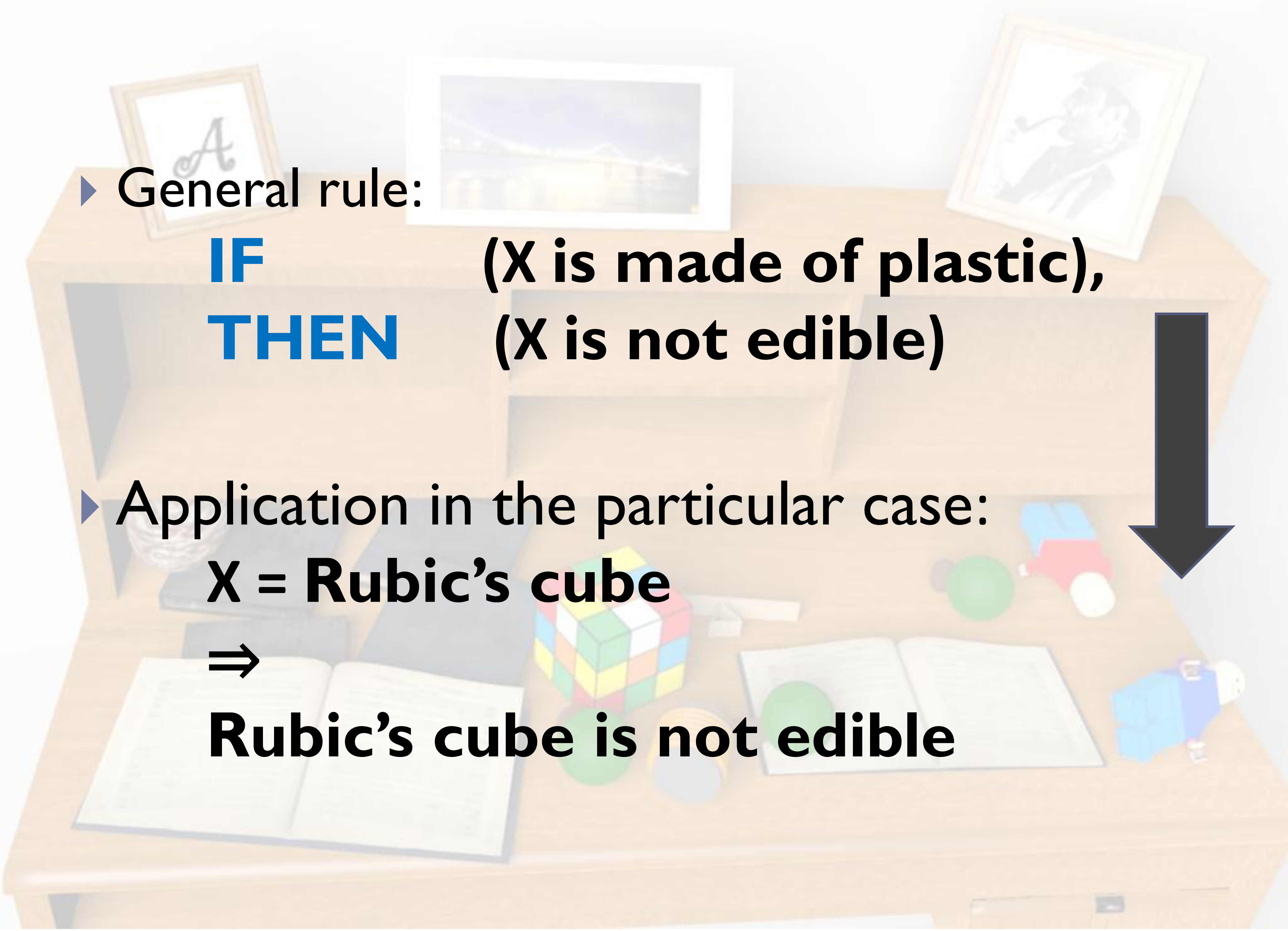
“Unformalizable” problems

“Unformalizable” problems



A

A



- General rule:

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

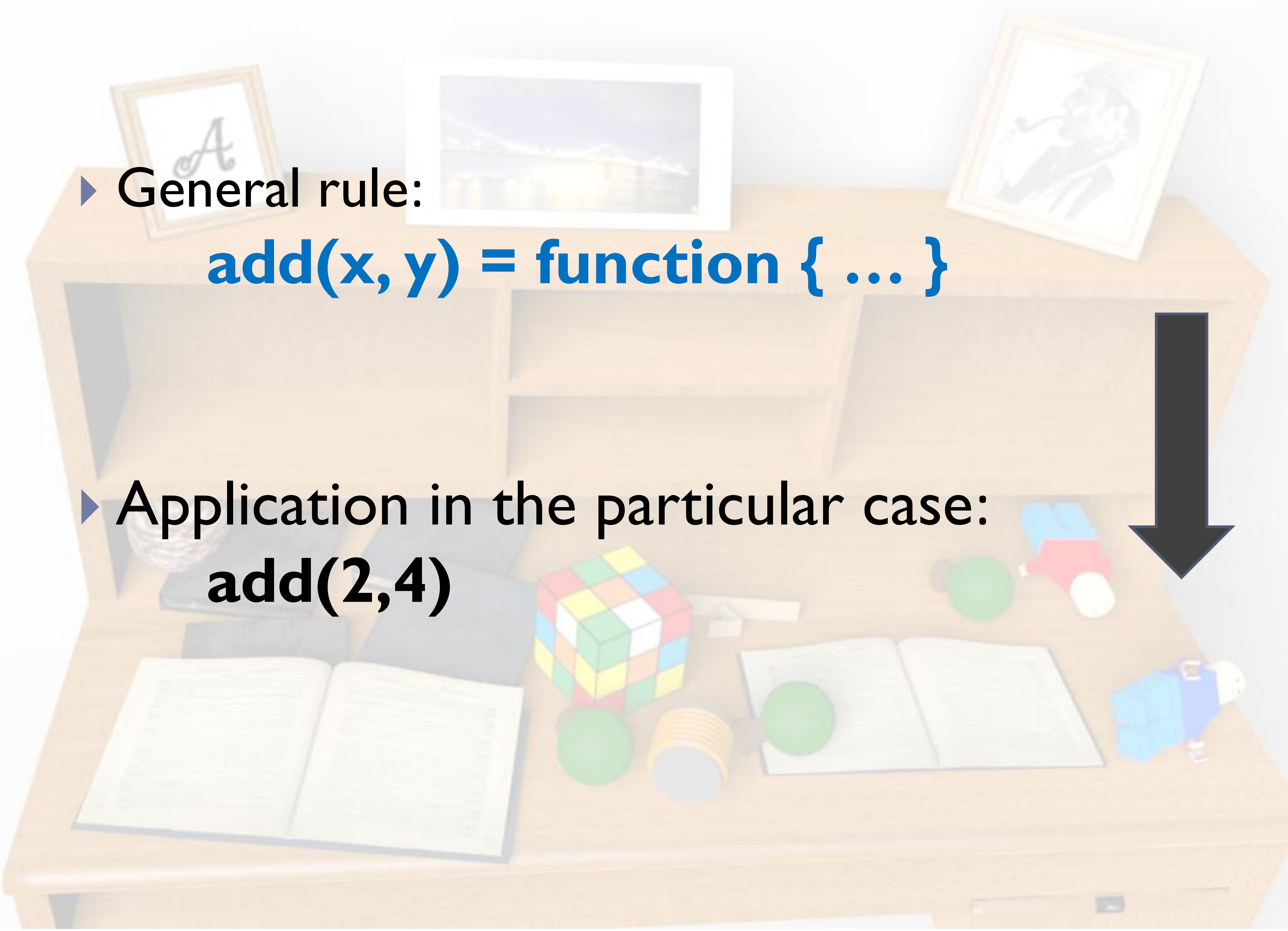
  THEN **(X is not edible)**

- 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 {
      ???
}
```

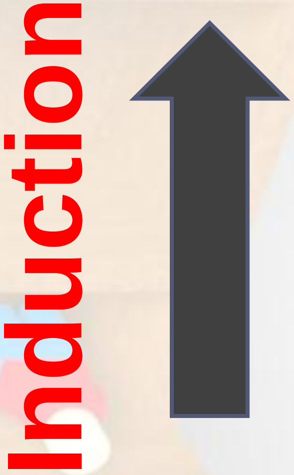
- Particular cases:

add(2,4) = 6

add(5,3) = 8

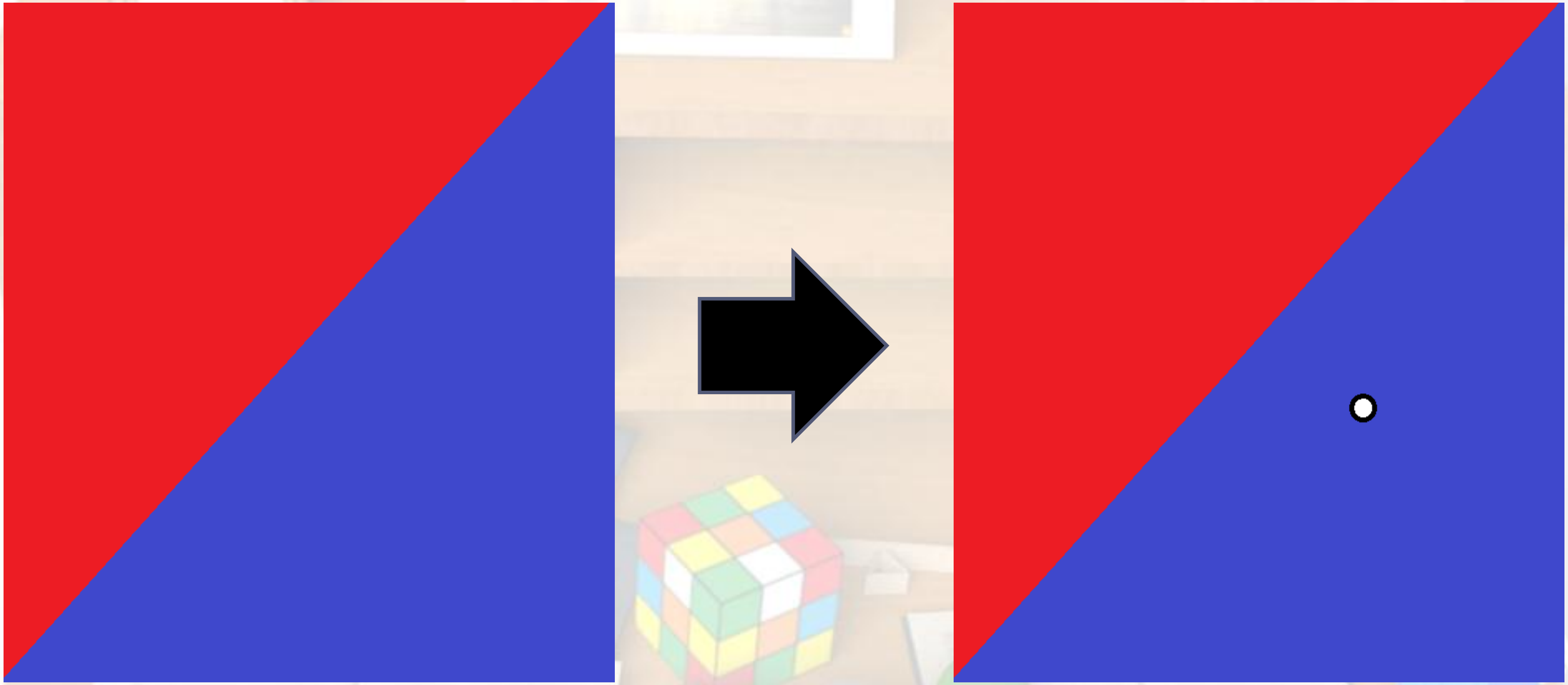
add(1,2) = 3

…



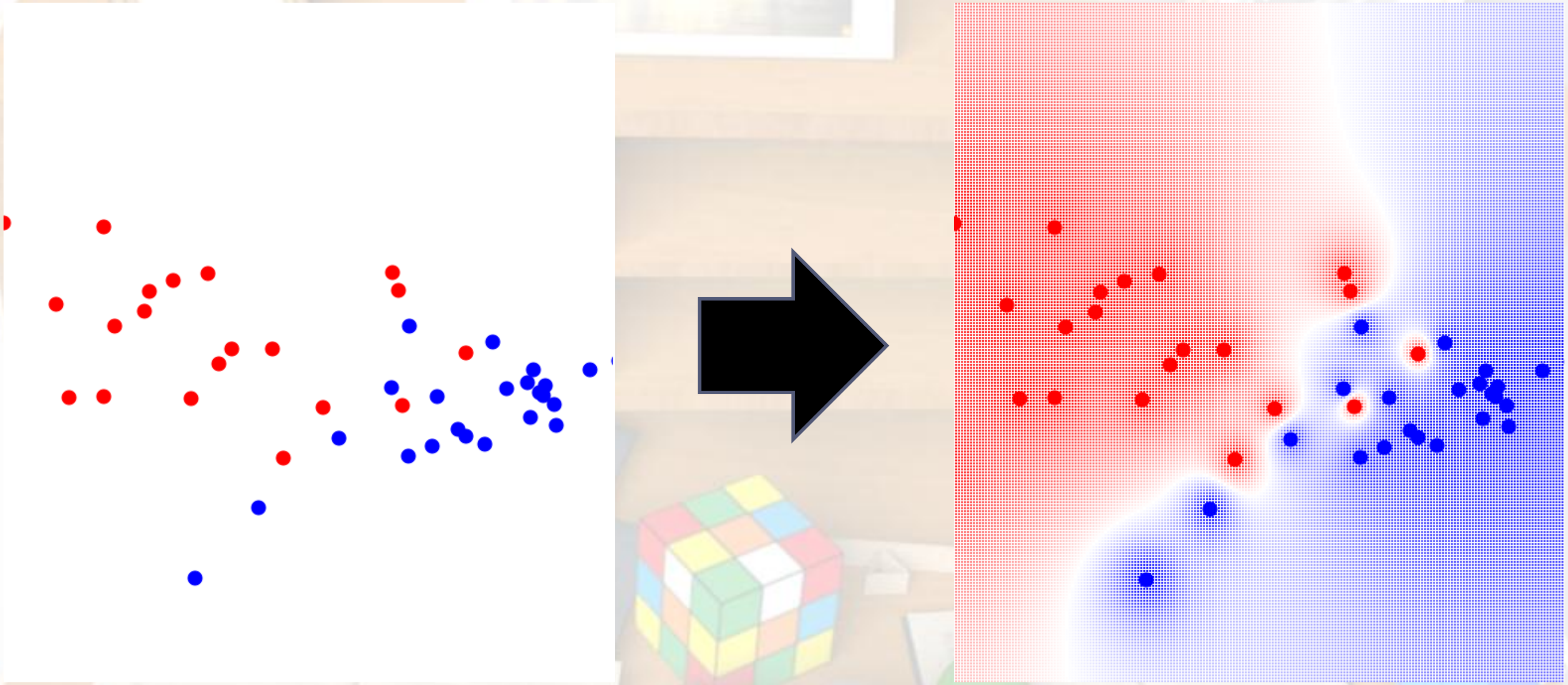
Induction

Deduction



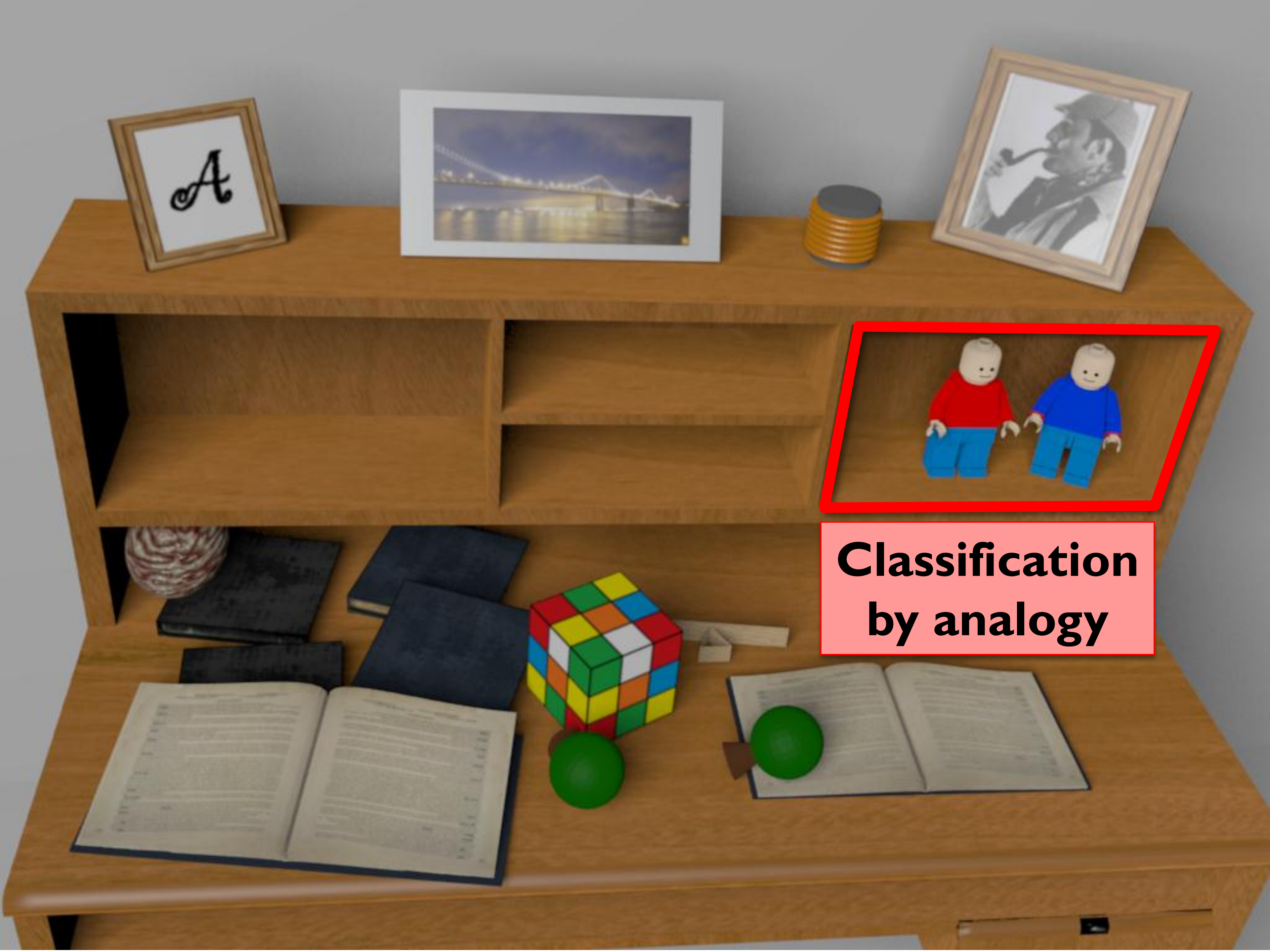
Given a general rule, make a decision in a particular case

Induction



Given particular cases, find a general rule

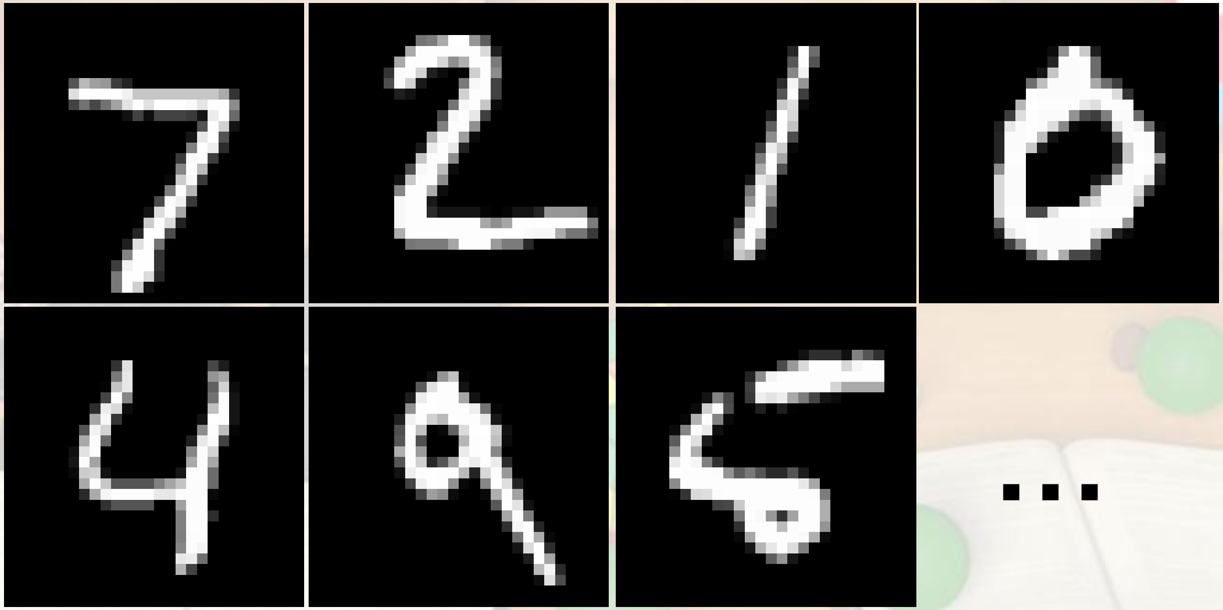
Deduction and Induction



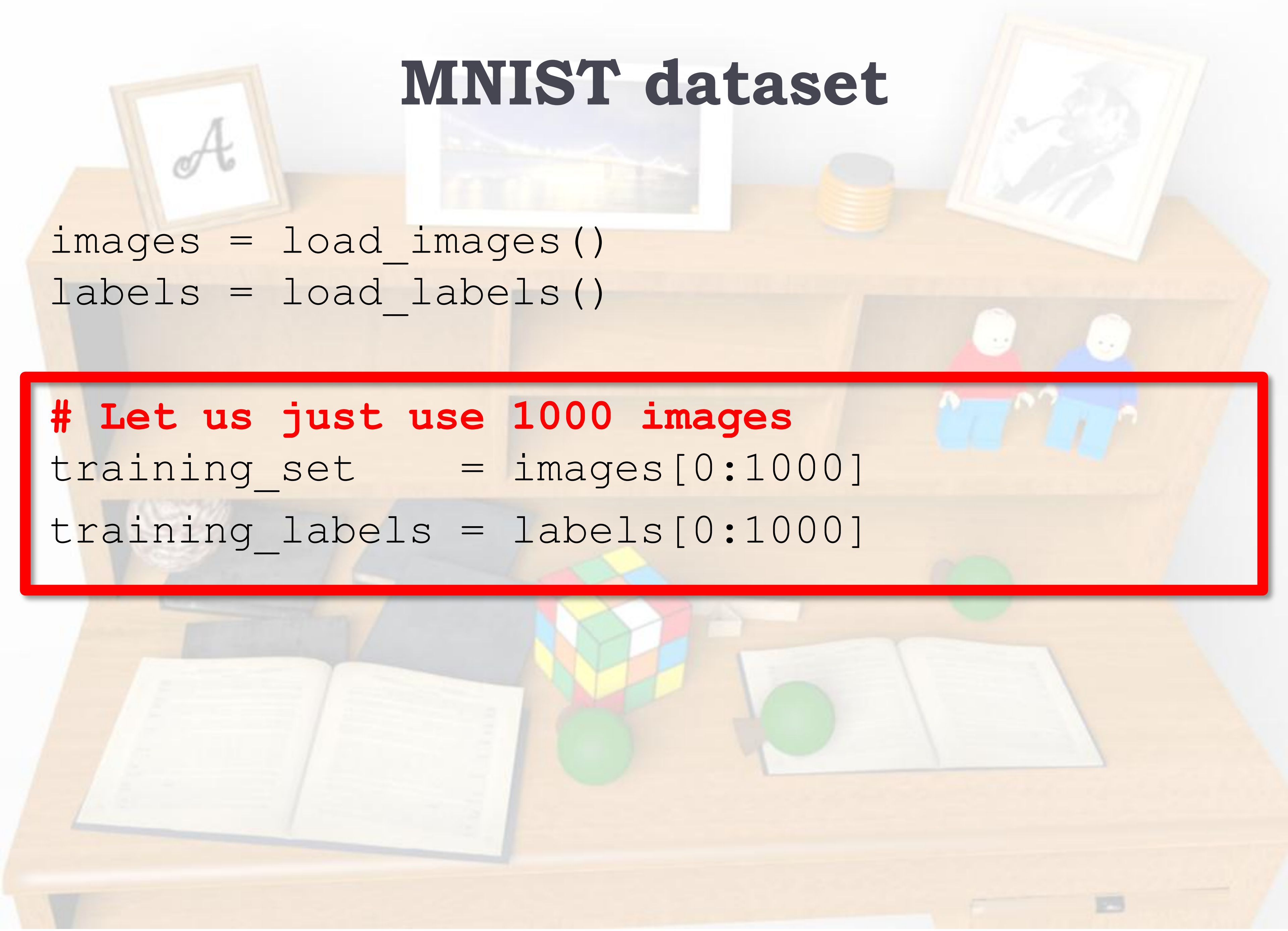
Classification by analogy

MNIST dataset

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



...

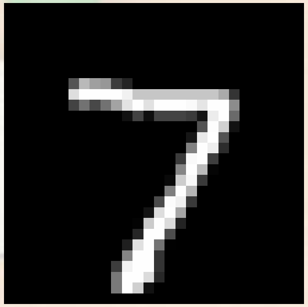


MNIST dataset

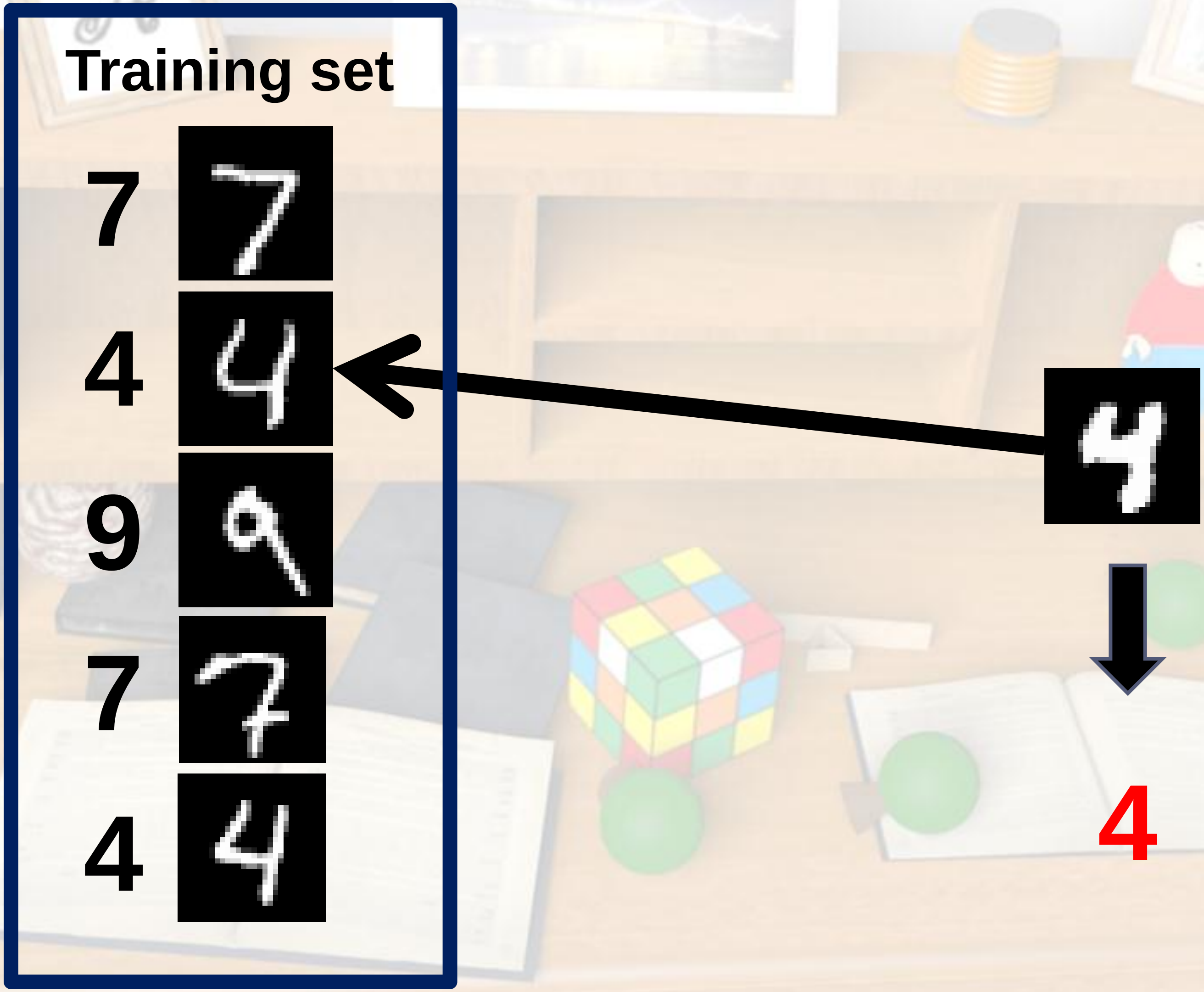
```
images = load_images()
labels = load_labels()

# 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

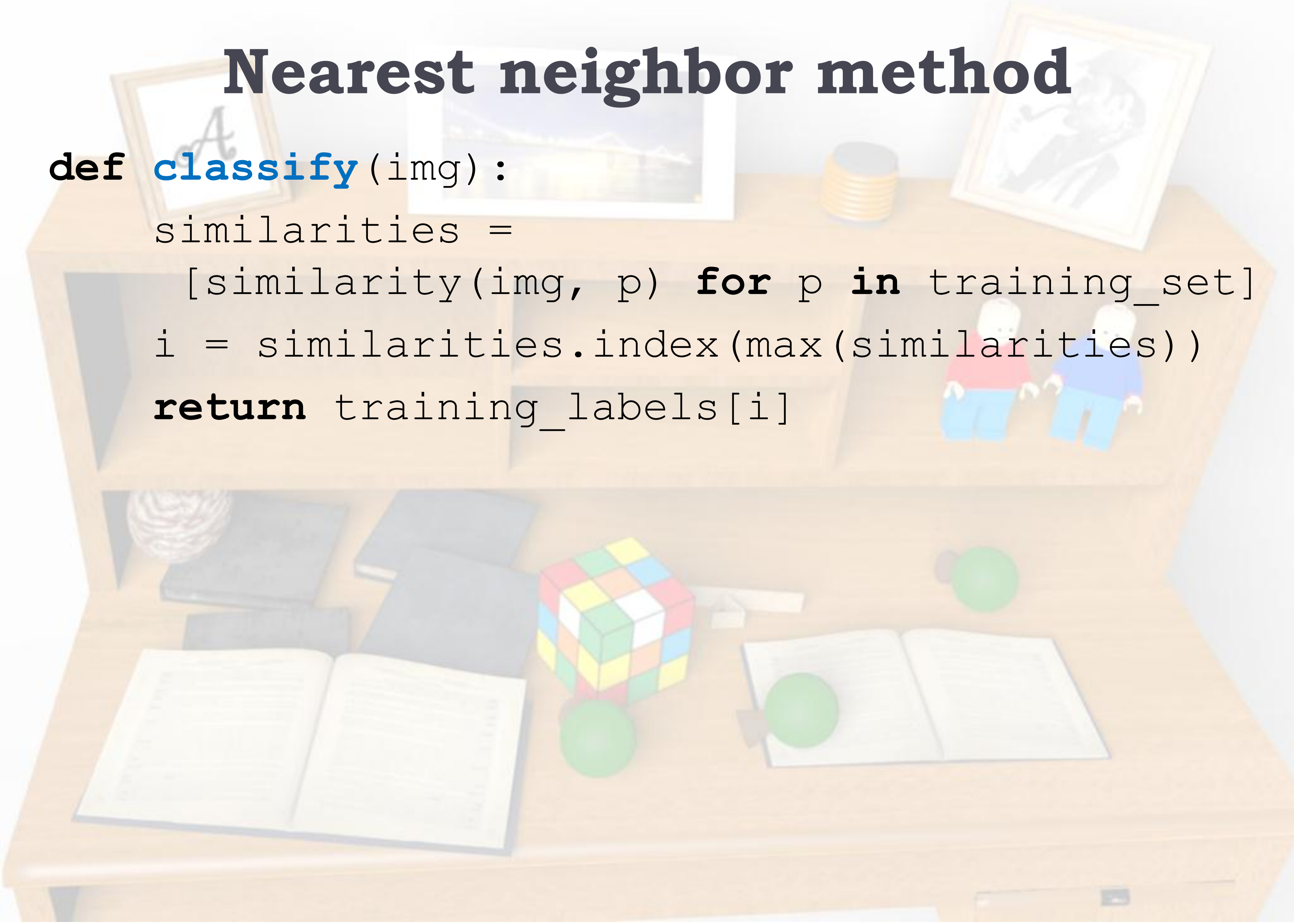
7

4

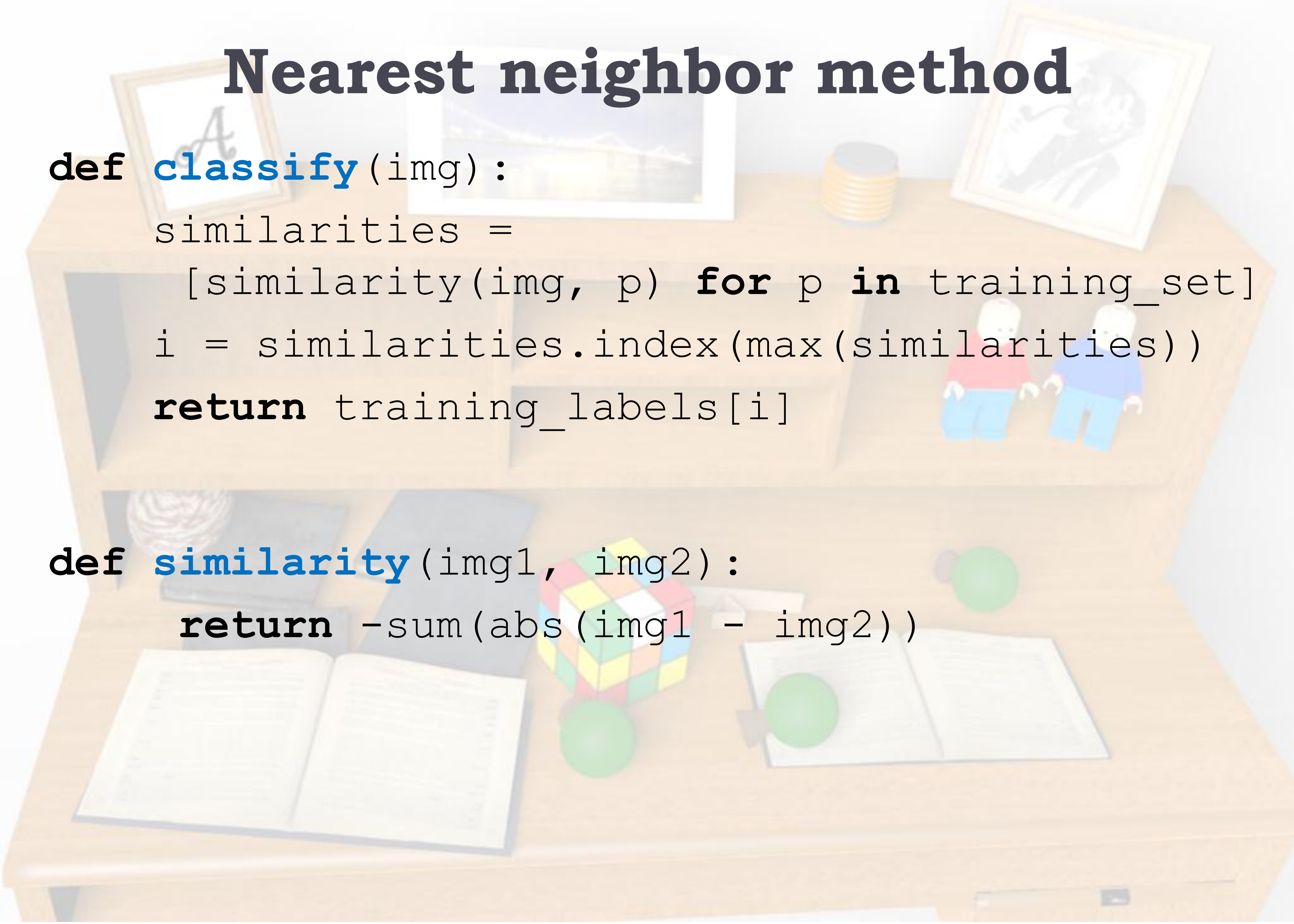
4

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



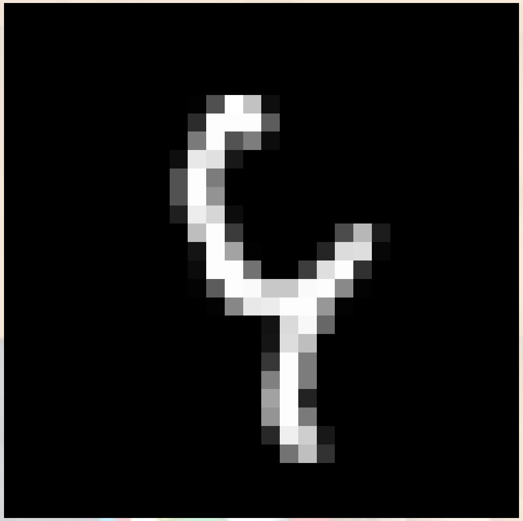
```
def classify(img):
    similarities =
     [similarity(img, p) for p in training_set]
    i = similarities.index(max(similarities))
    return training_labels[i]


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

Testing the algorithm

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


predicted_class = map(classify, test_set)


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

=> 843/1000

9 or 4?

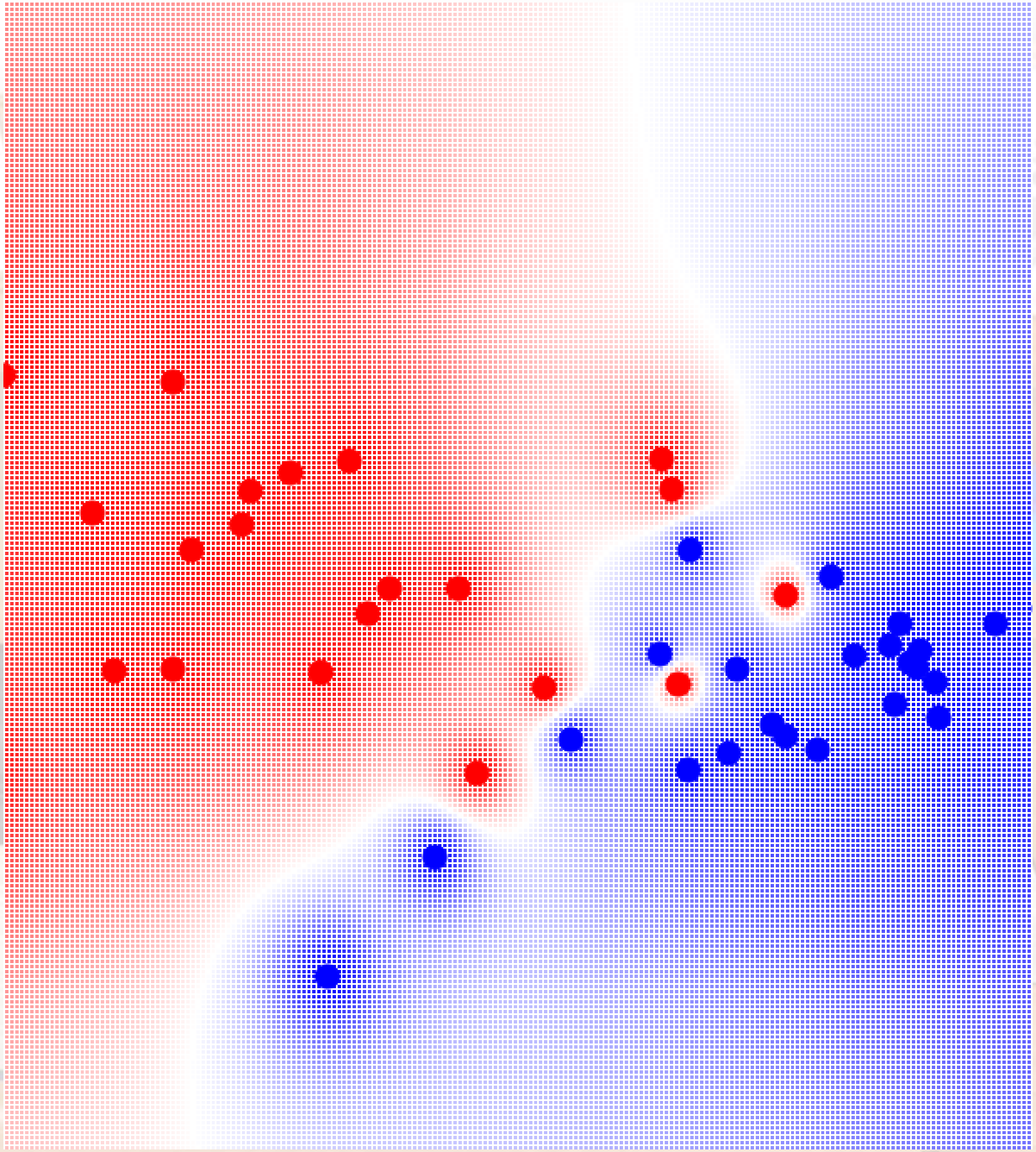


Scikit-learn

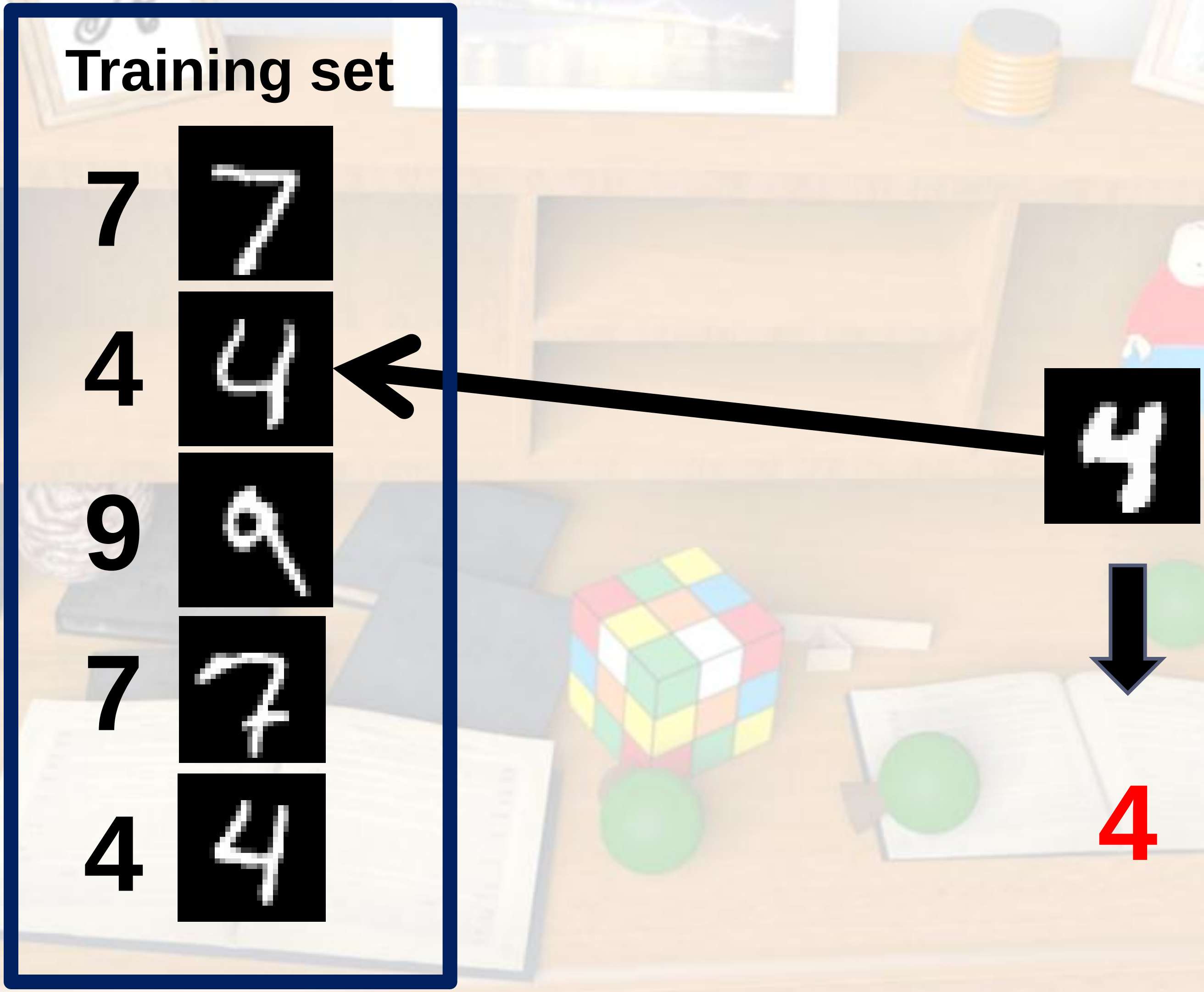
http://scikit-learn.org/

```
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



Training set

7

4

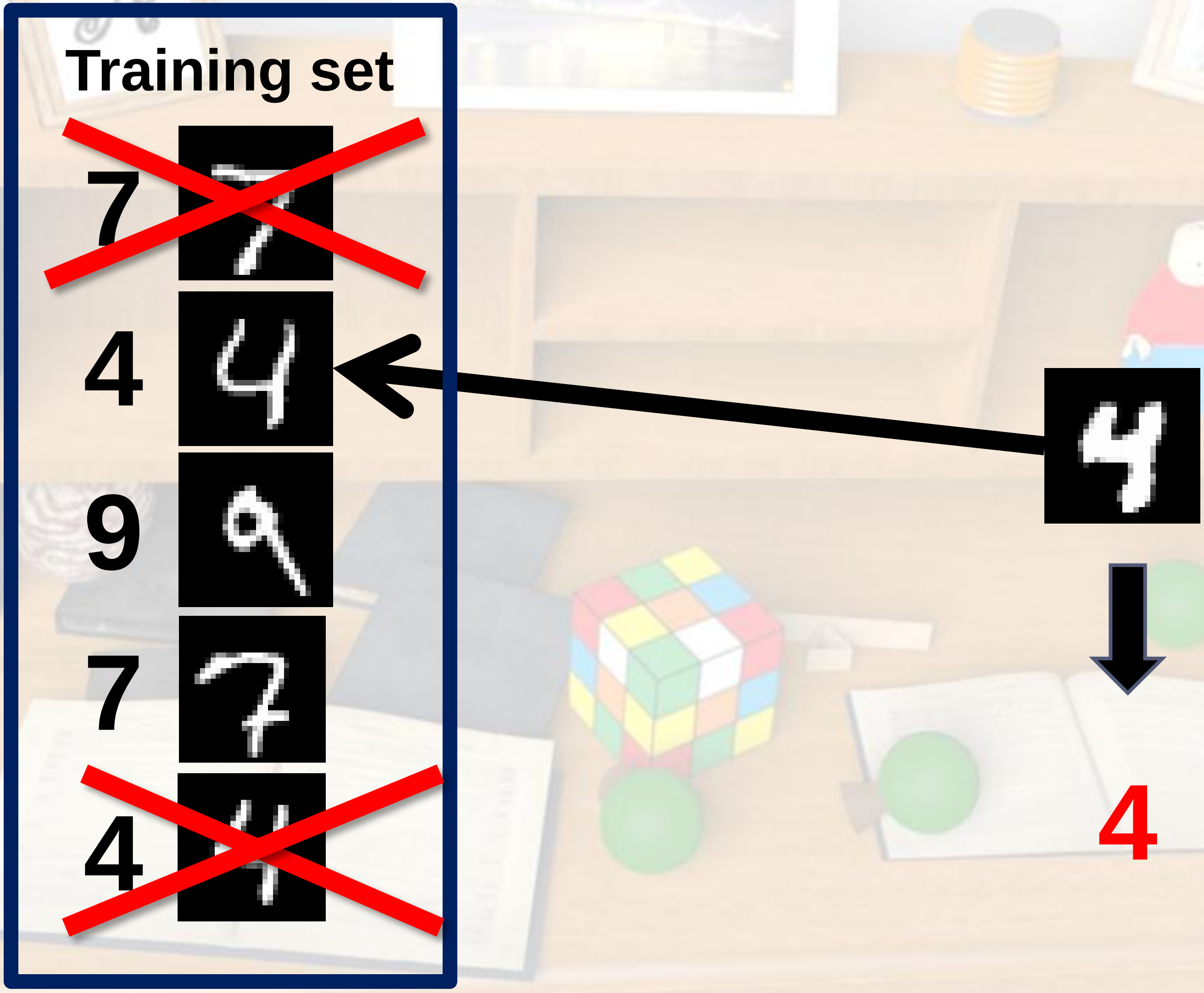
9

7

4

4

Some samples may be thrown away



Training set

7

4

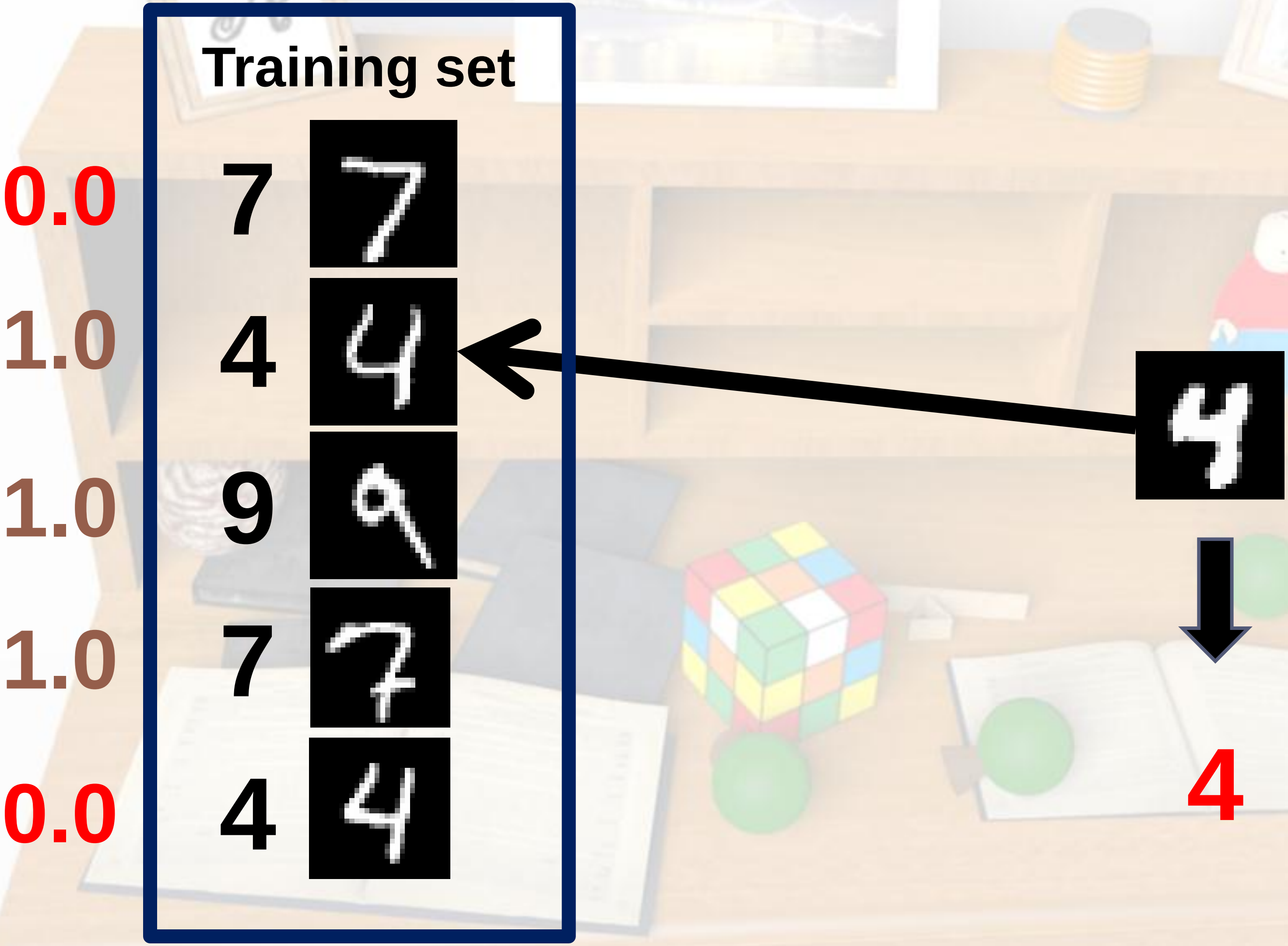
9

7

4

4

…or we can add "weights"

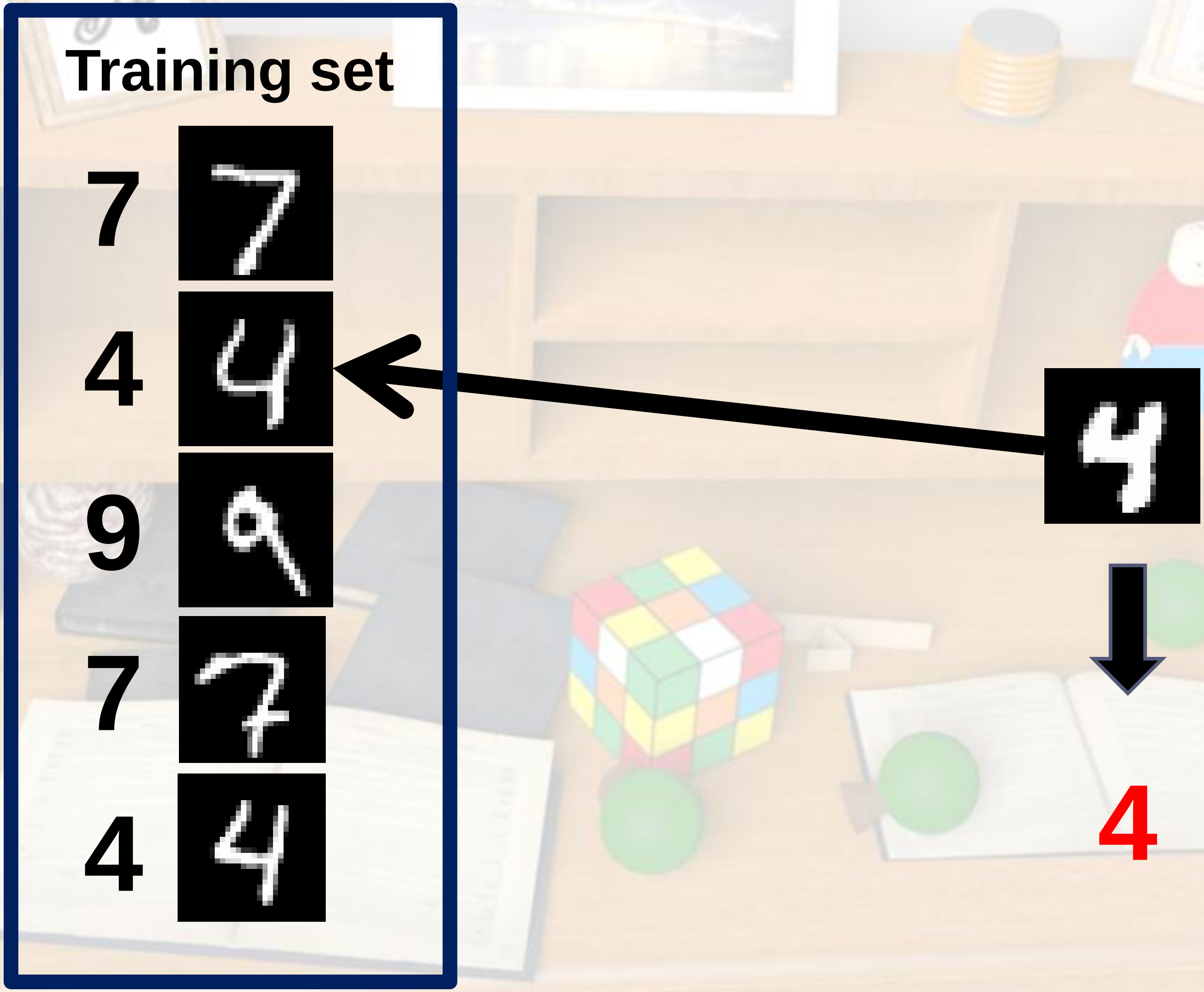


Training set

0.0	7
1.0	4
1.0	9
1.0	7
0.0	4

4

…or we can add "weights"

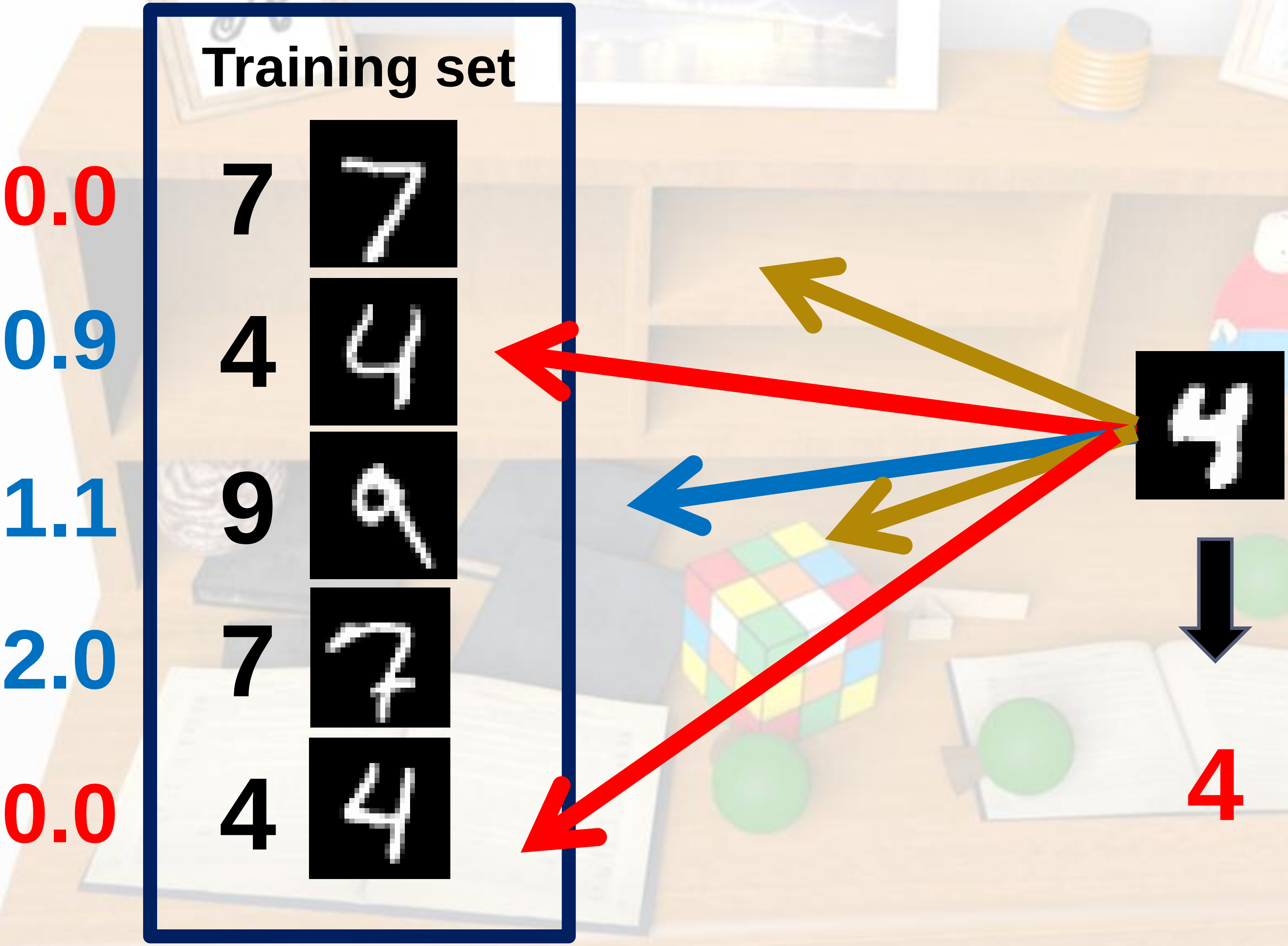


Training set

0.0	7
0.9	4
1.1	9
2.0	7
0.0	4

4

.. or we can SUM instead of MAX



Training set

0.0 7

0.9 4

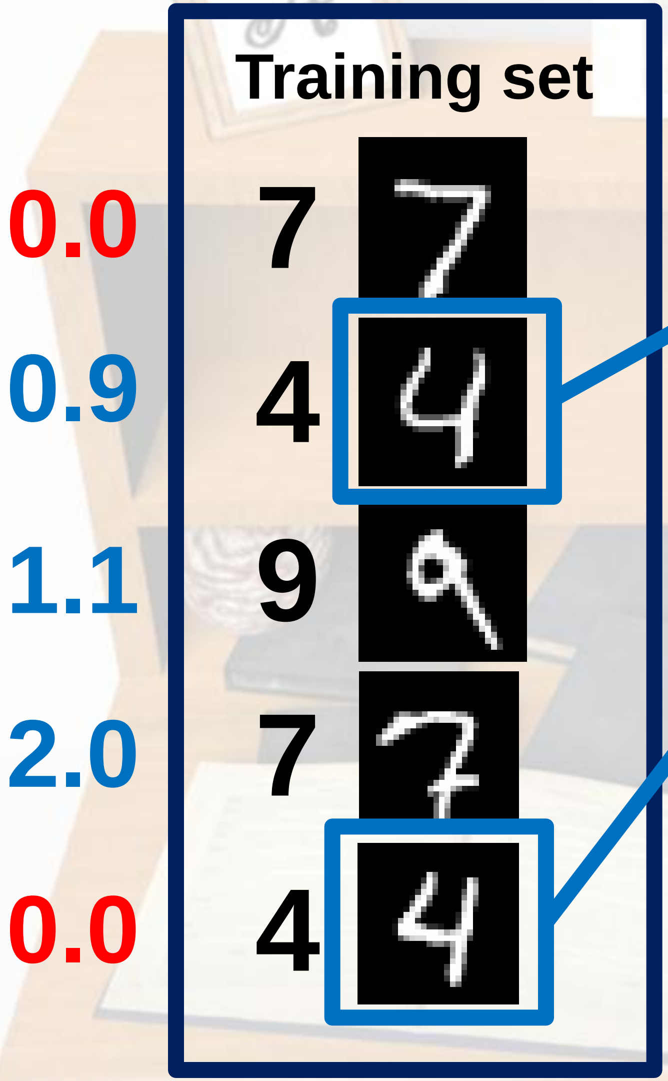
1.1 9

2.0 7

0.0 4

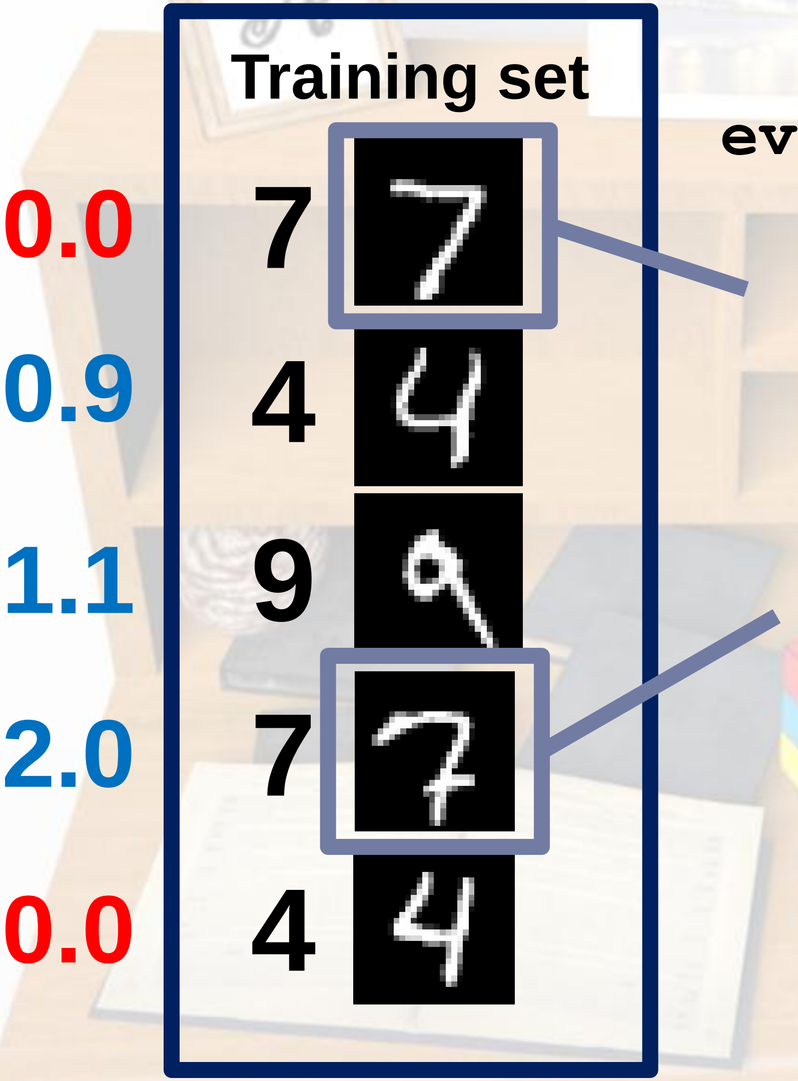
4

.. or we can SUM instead of MAX



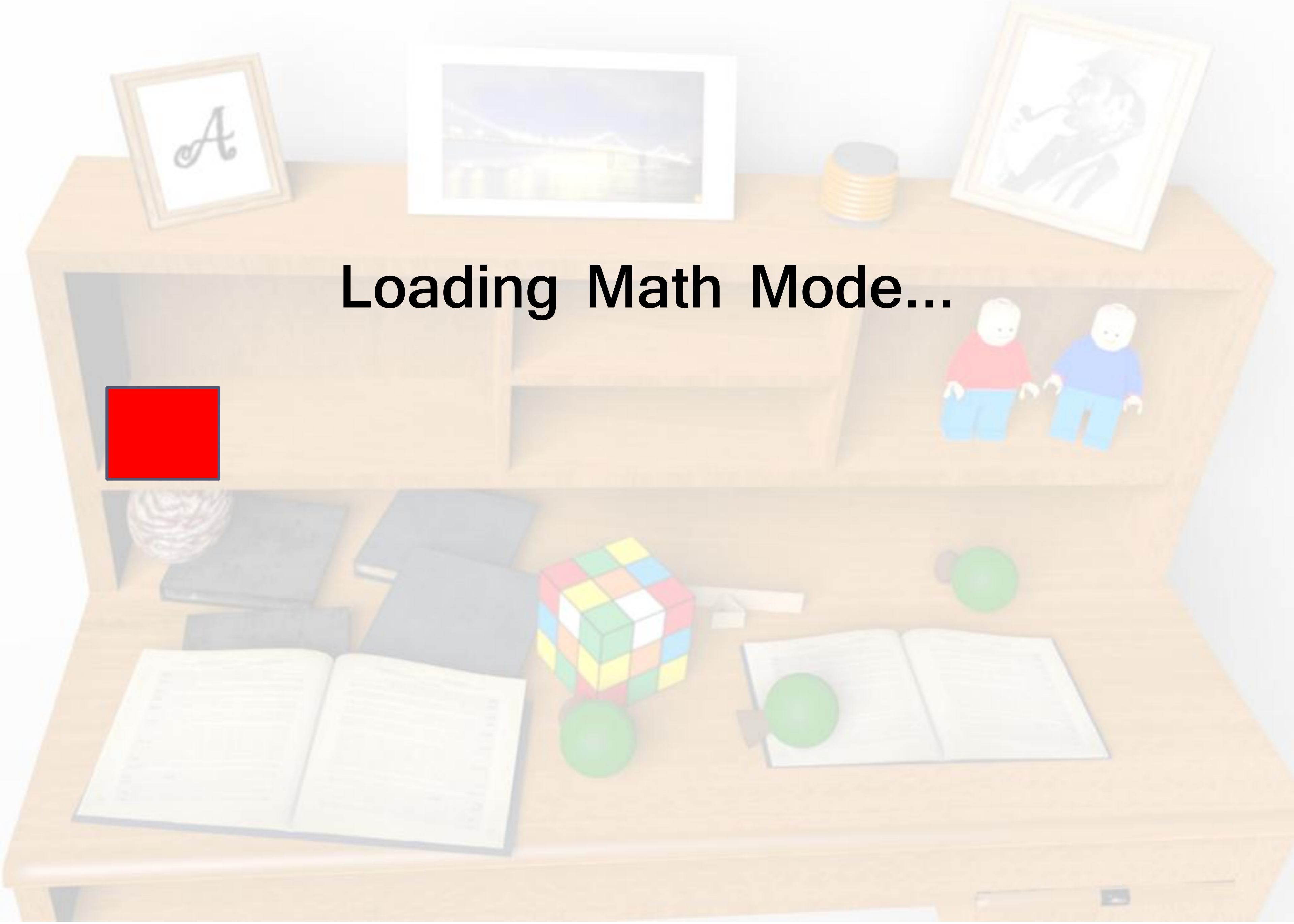
```
evidence(img, 4) =

  0.9 * similarity(img, tr[1])

  +

  0.0 * similarity(img, tr[4])

  = 34.0
```

.. or we can SUM instead of MAX

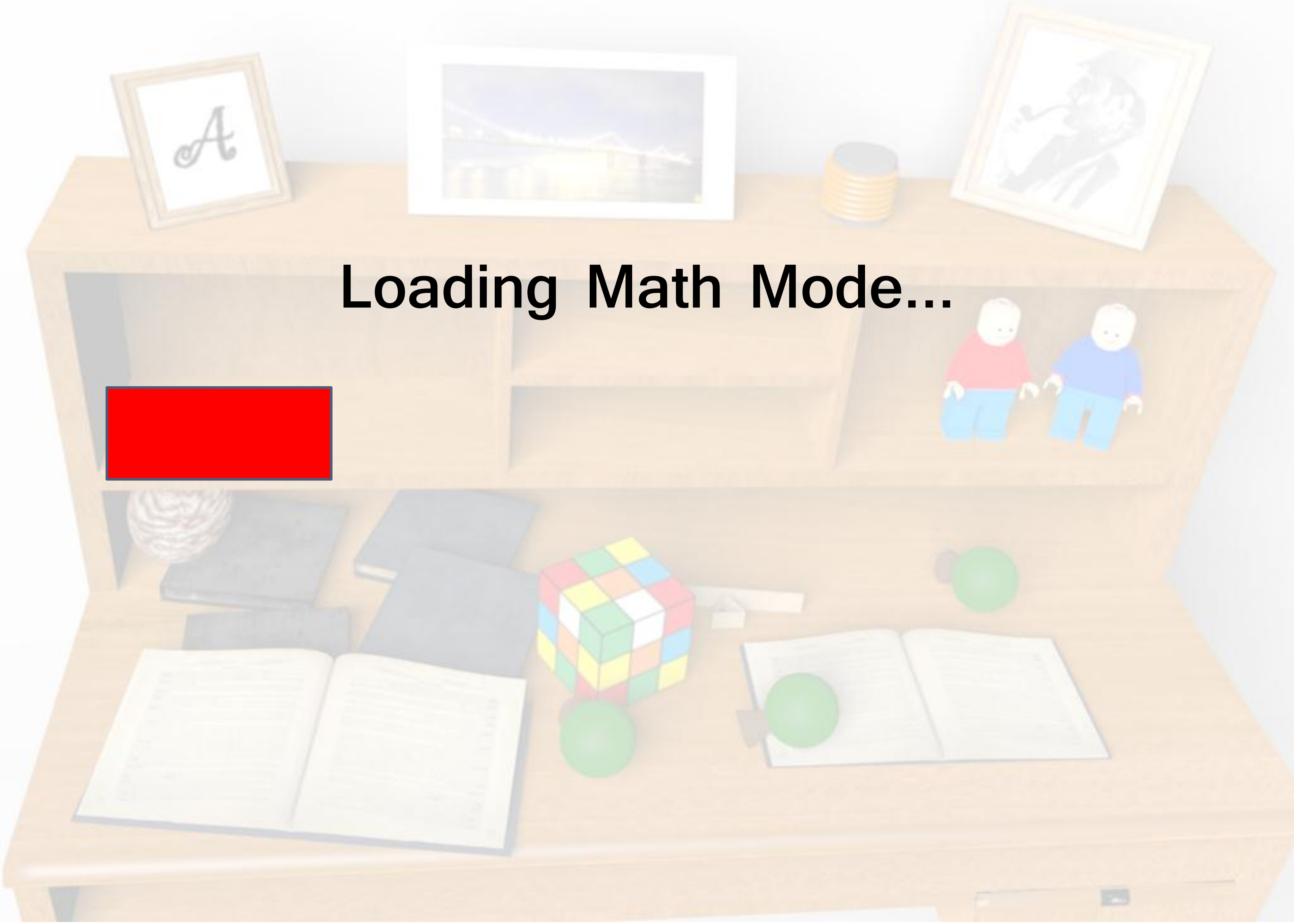


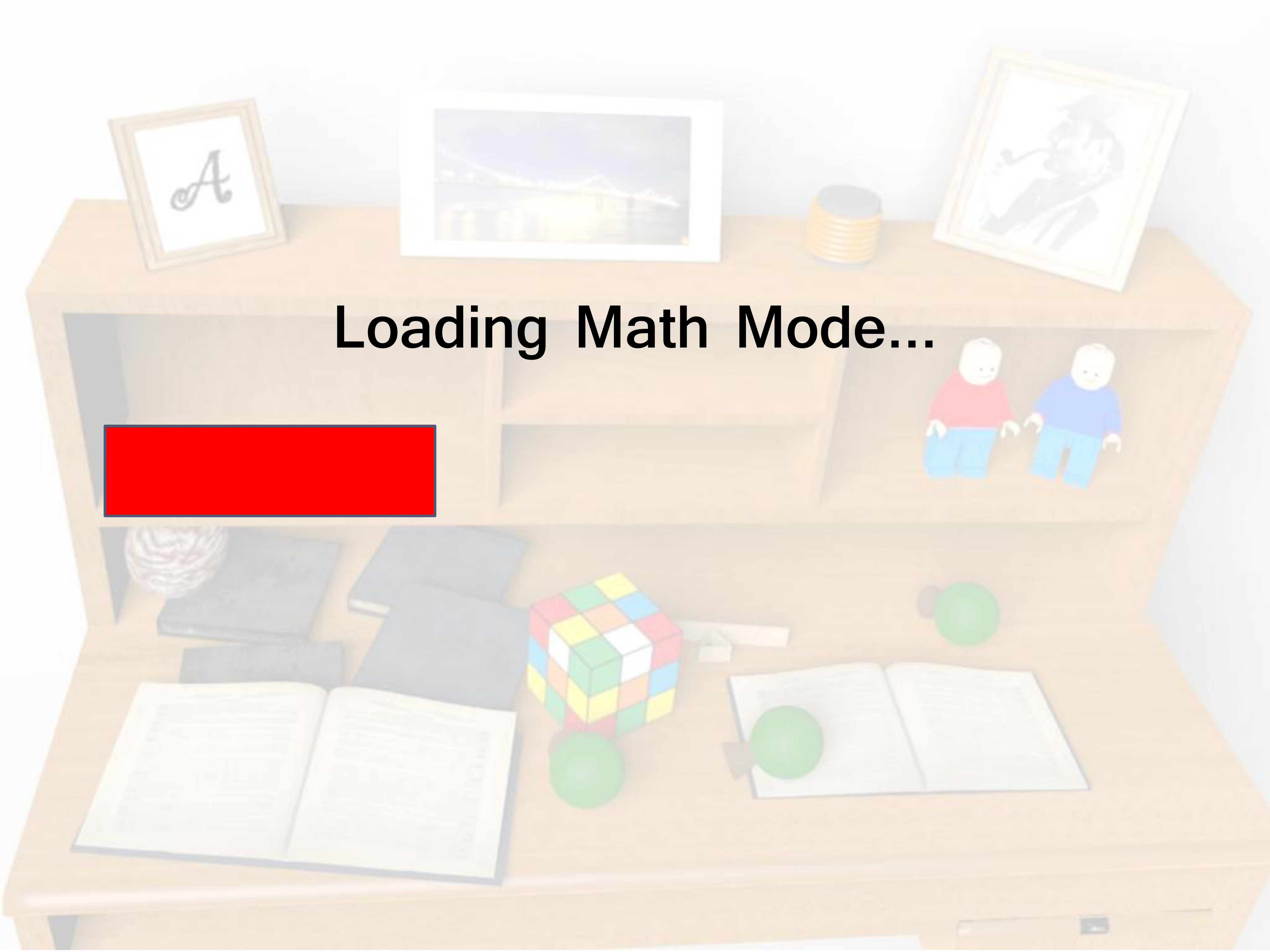
```
evidence(img, 7) =

  0.0 * similarity(img, tr[0])

  +

  2.0 * similarity(img, tr[3])

  = 20.0
```

Loading Math Mode...



Loading Math Mode...





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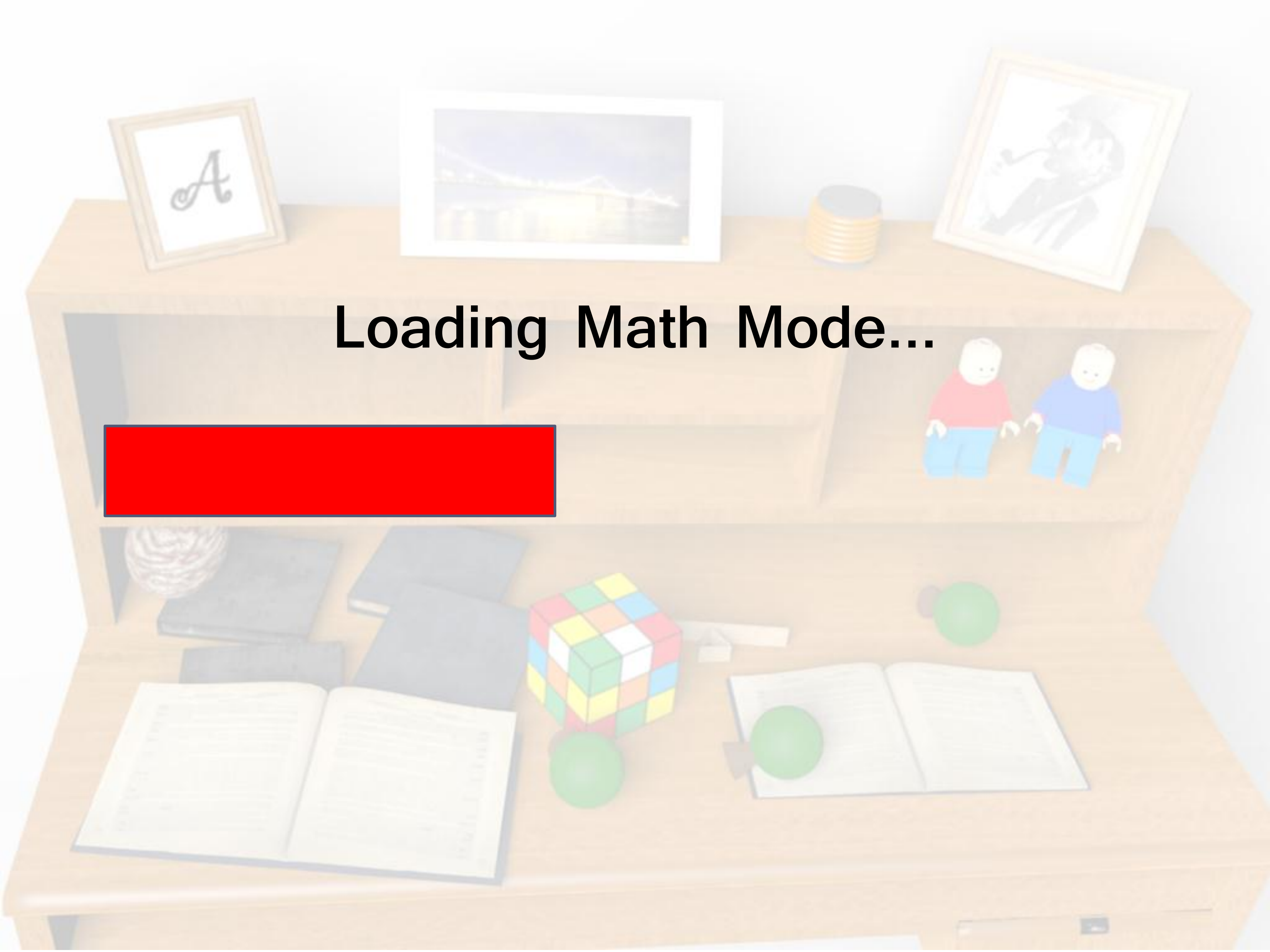
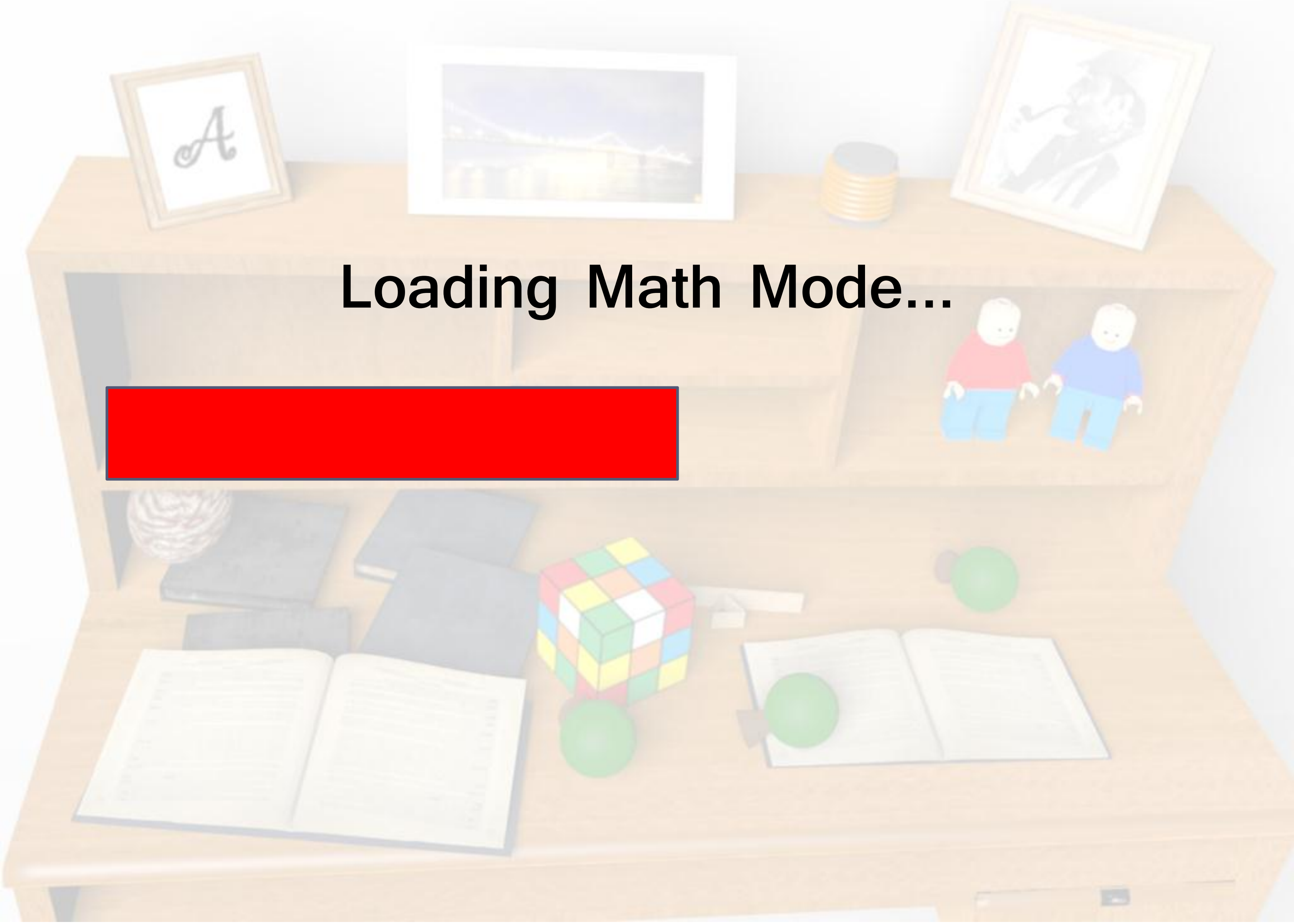
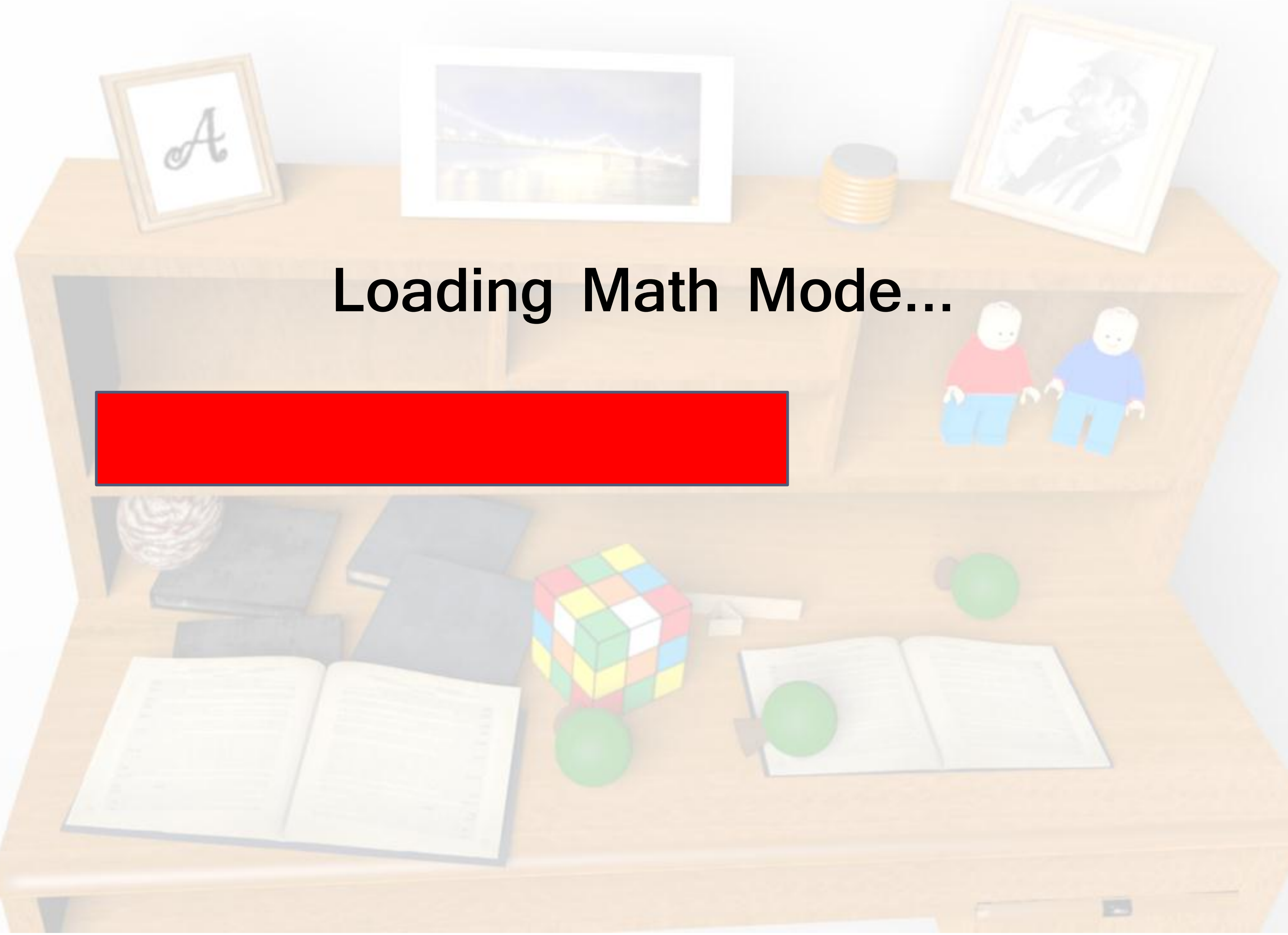


Loading Math Mode...



Loading Math Mode...



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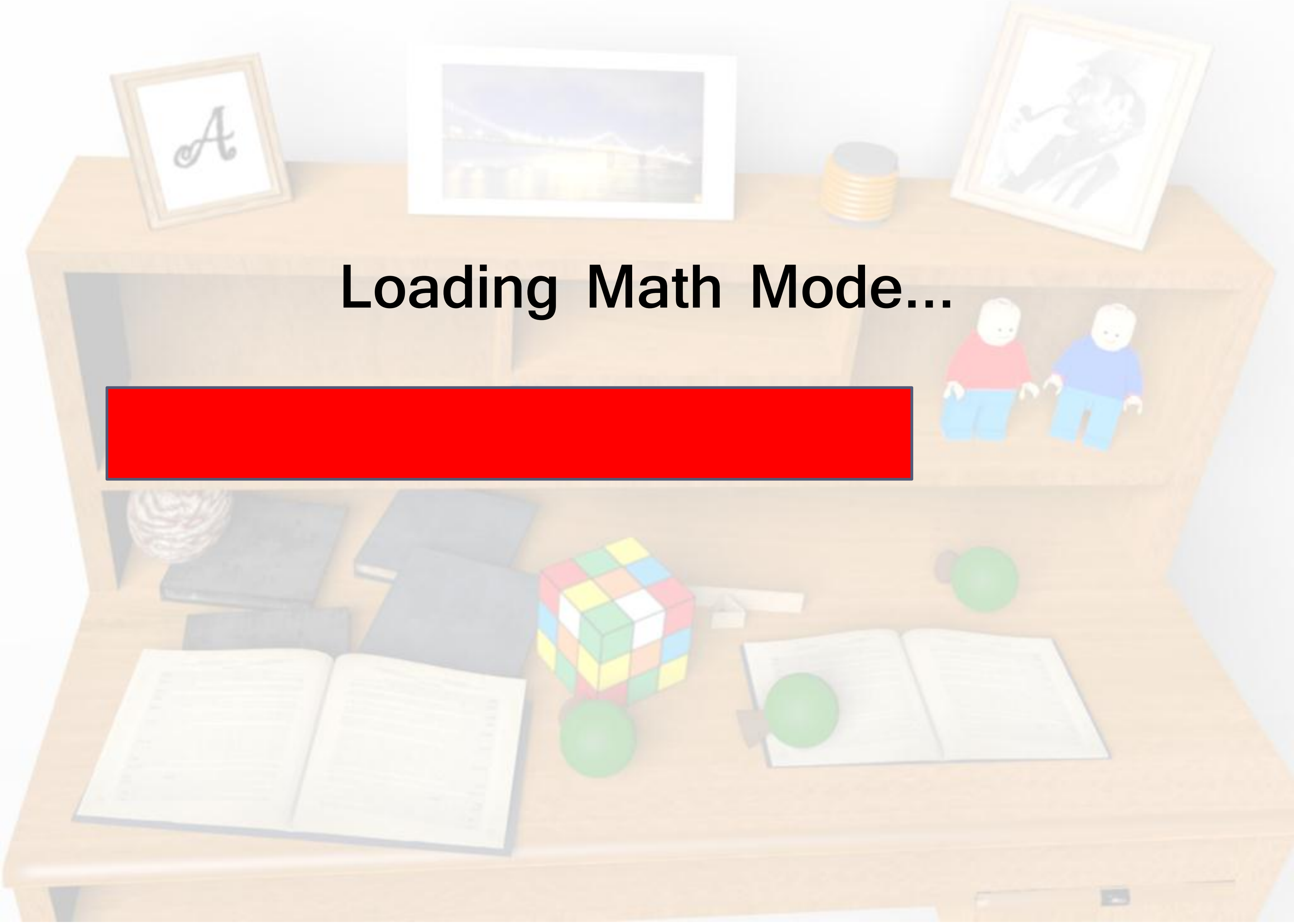

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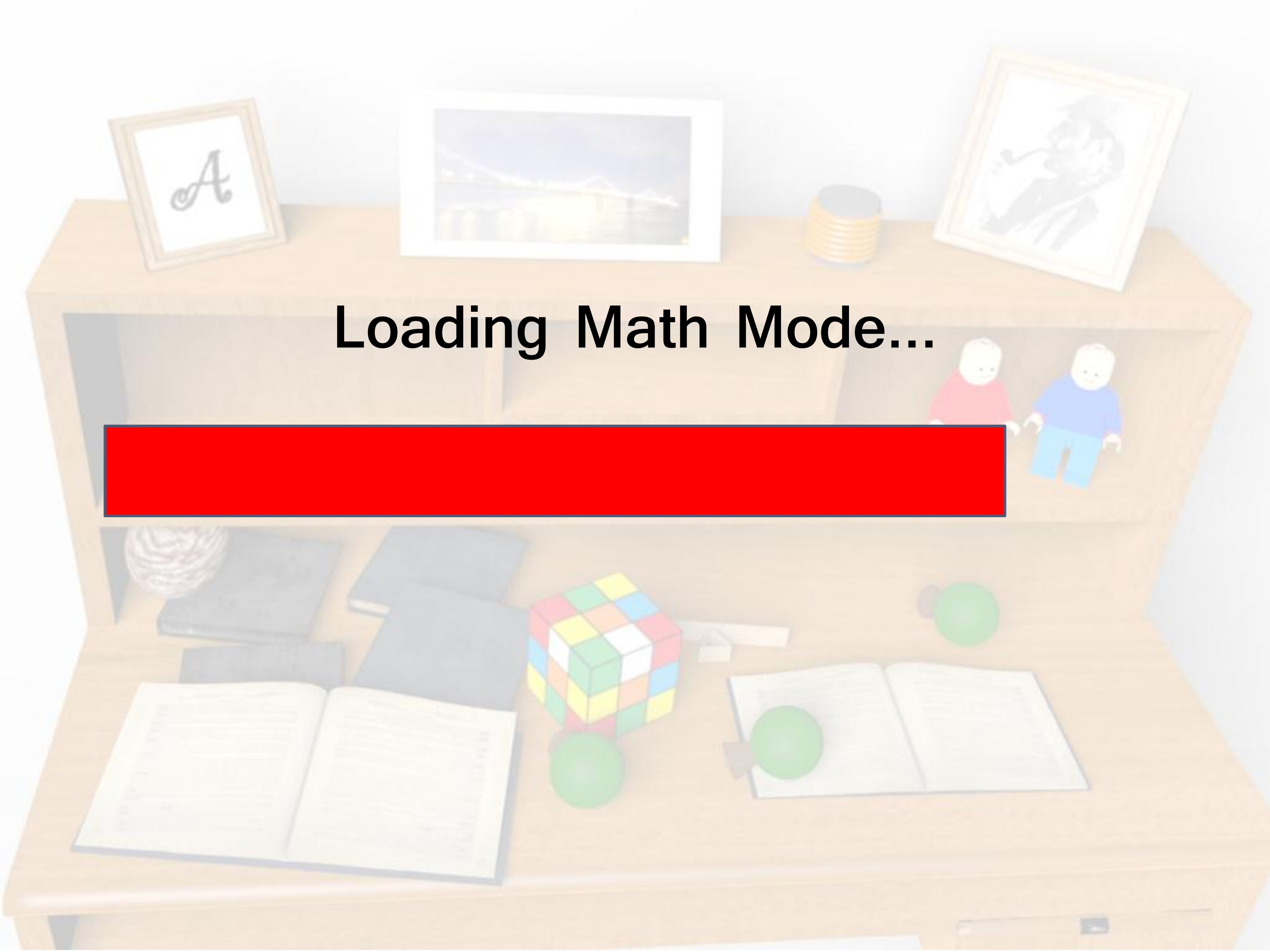

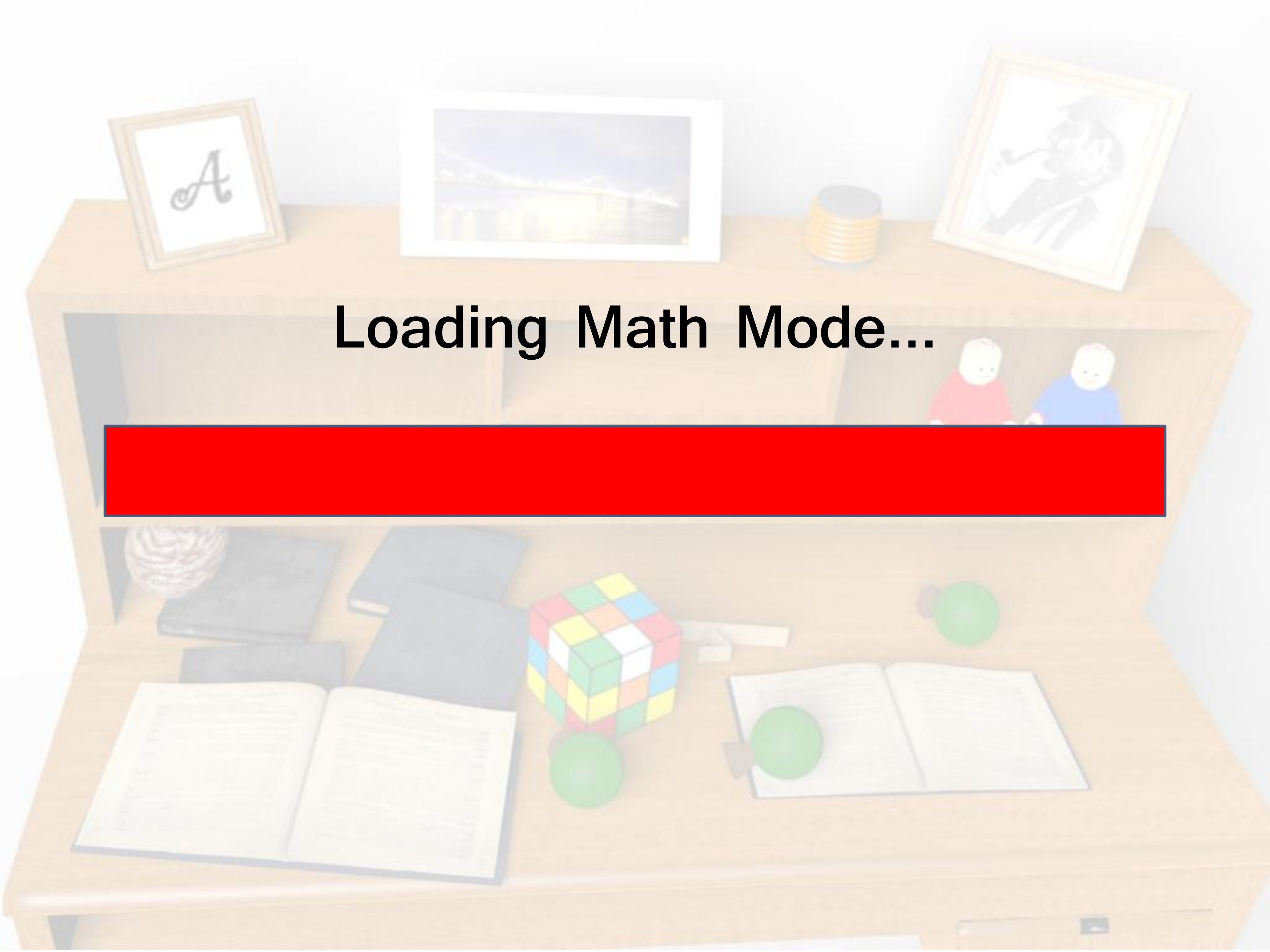

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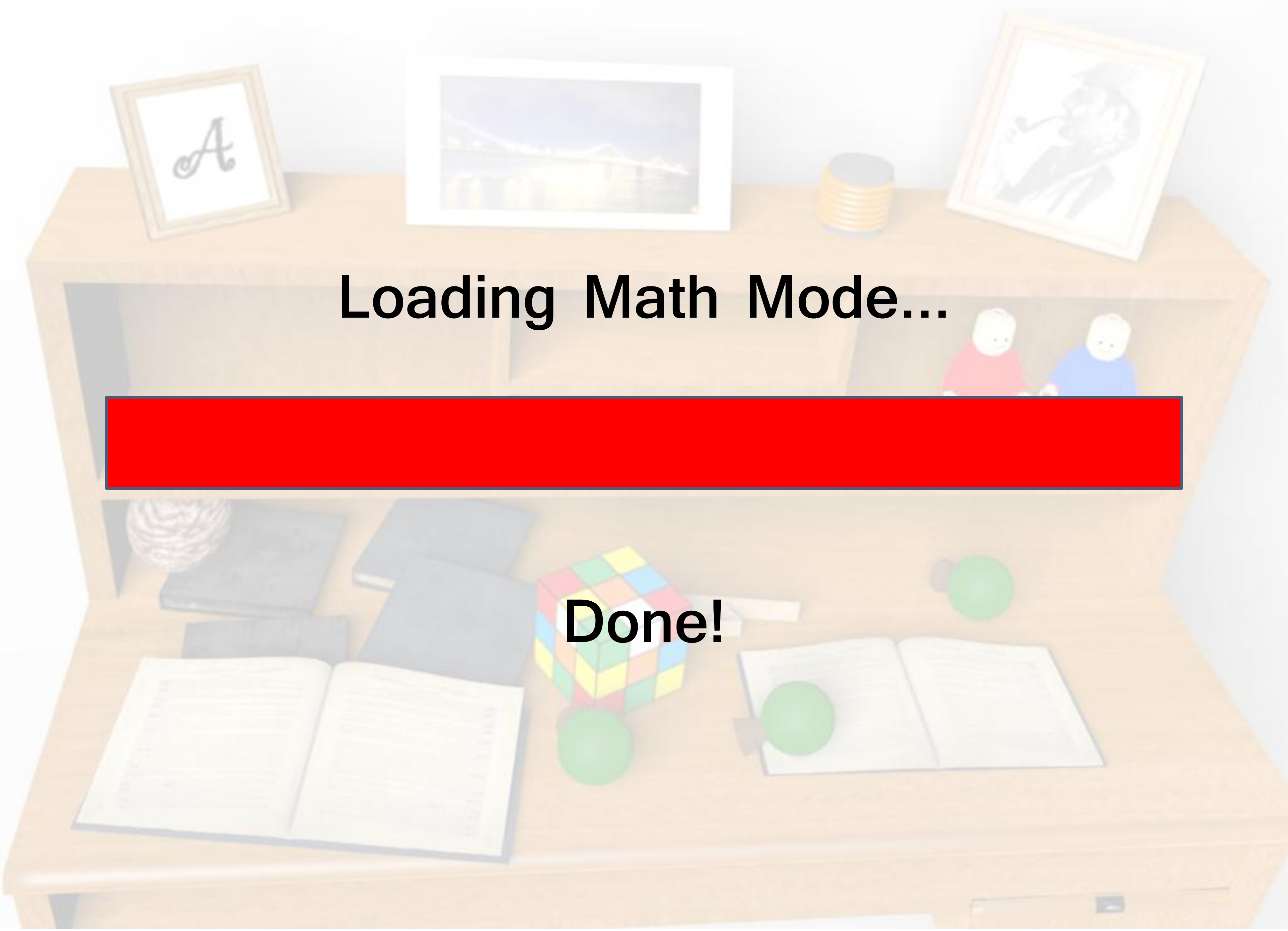
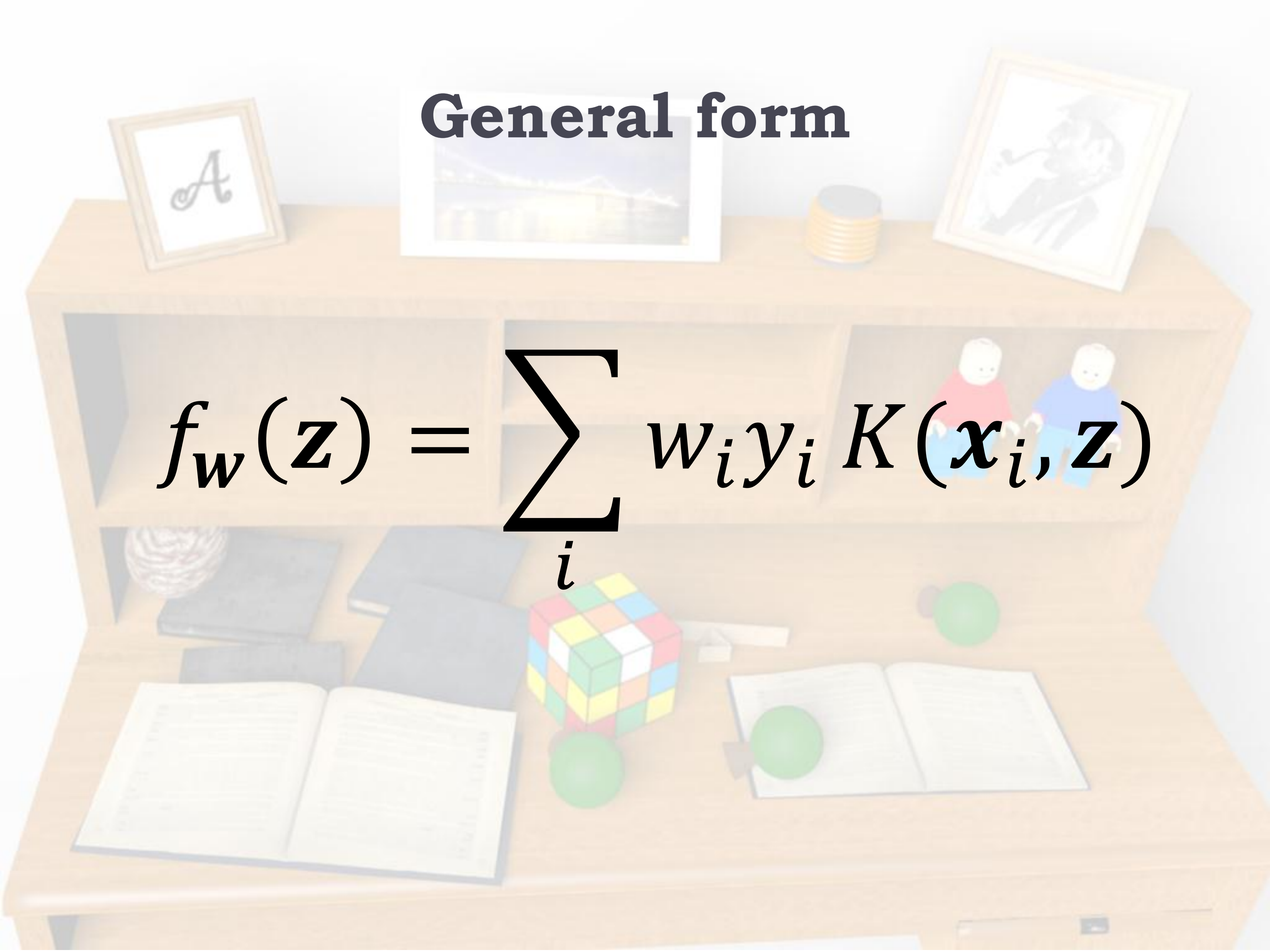


Loading Math Mode...

Done!

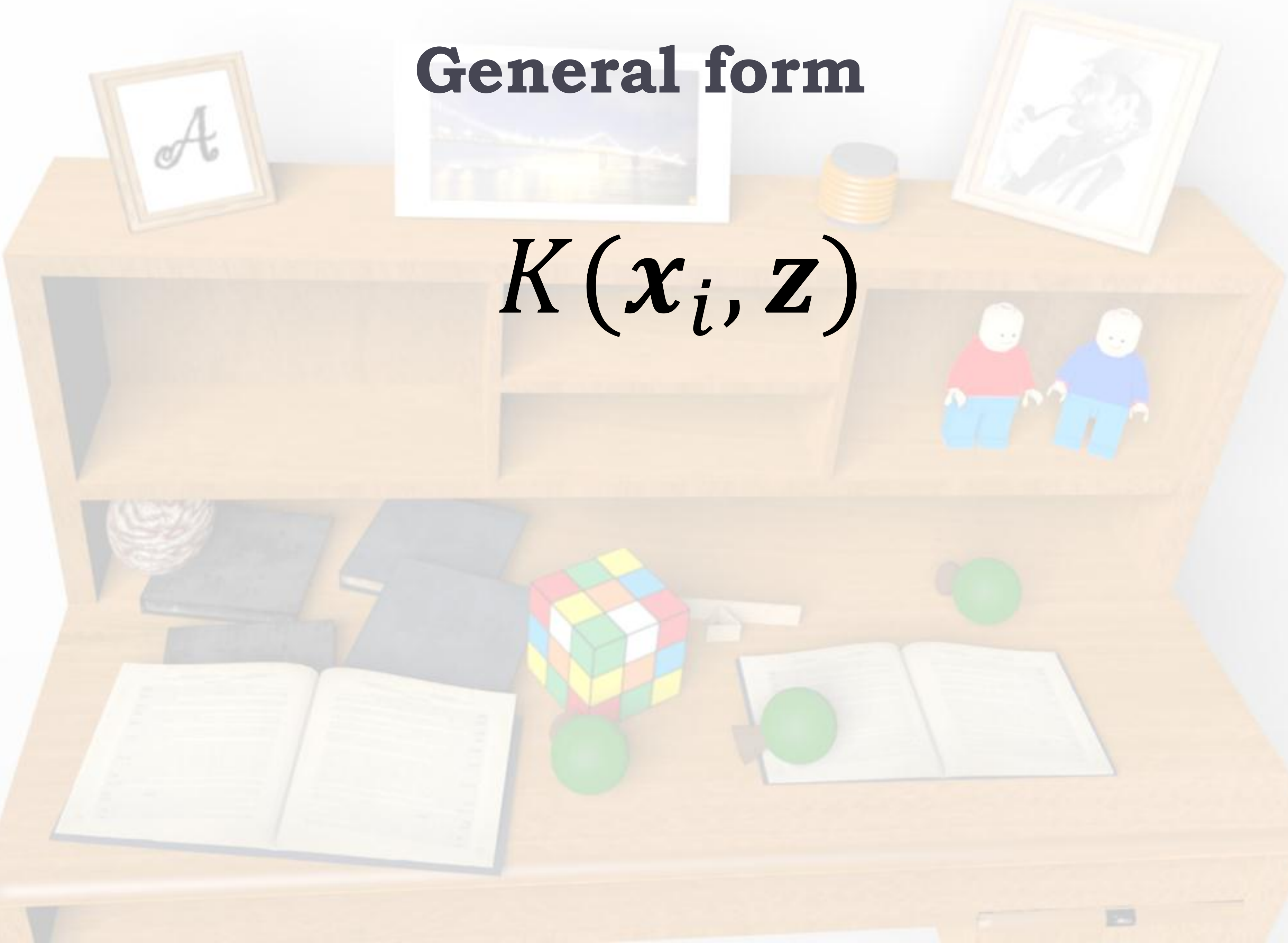
General form



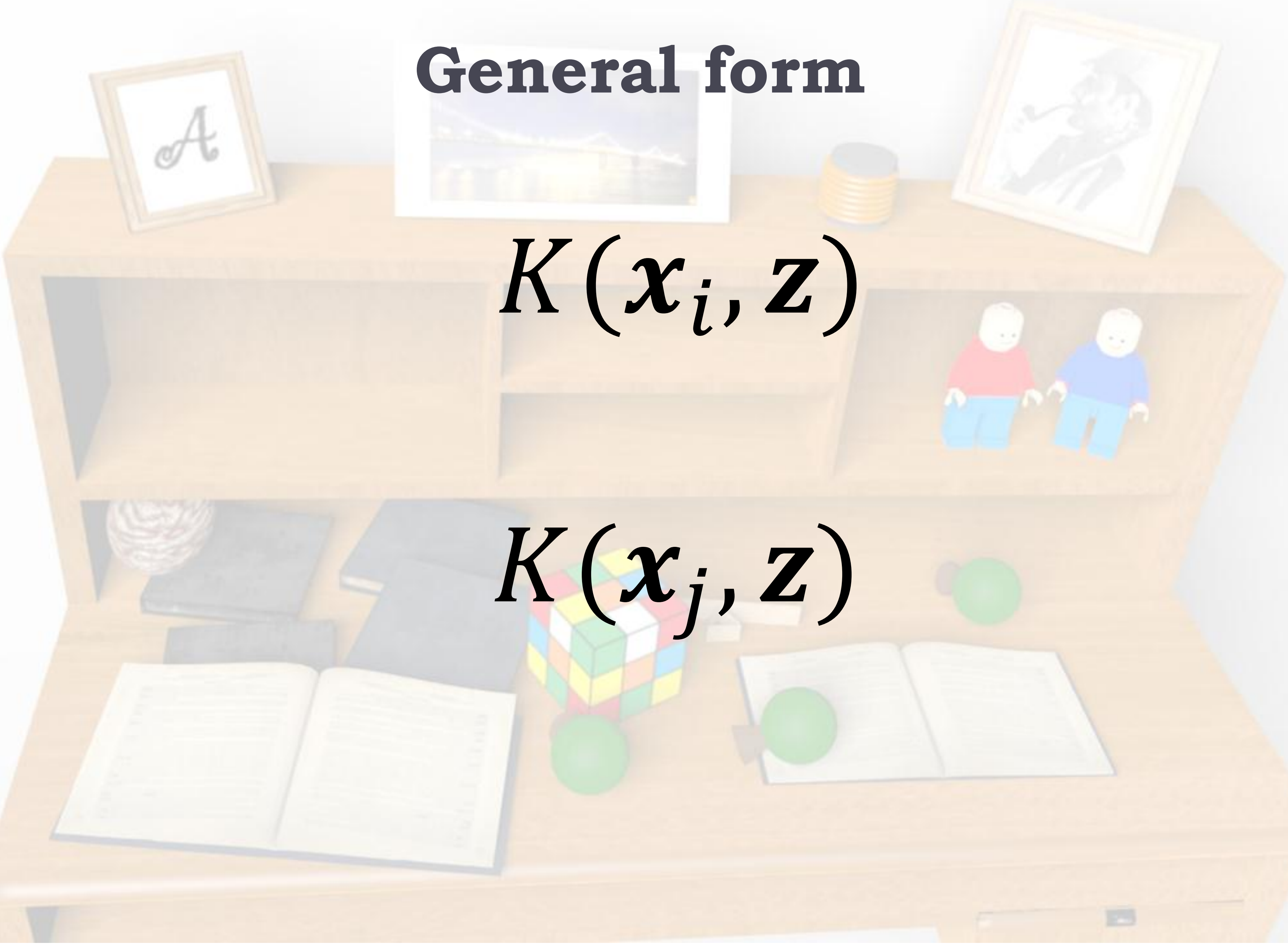
$$f_{\boldsymbol{w}}(\boldsymbol{z}) = \sum_{i} w_i y_i K(\boldsymbol{x}_i, \boldsymbol{z})$$

General form

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

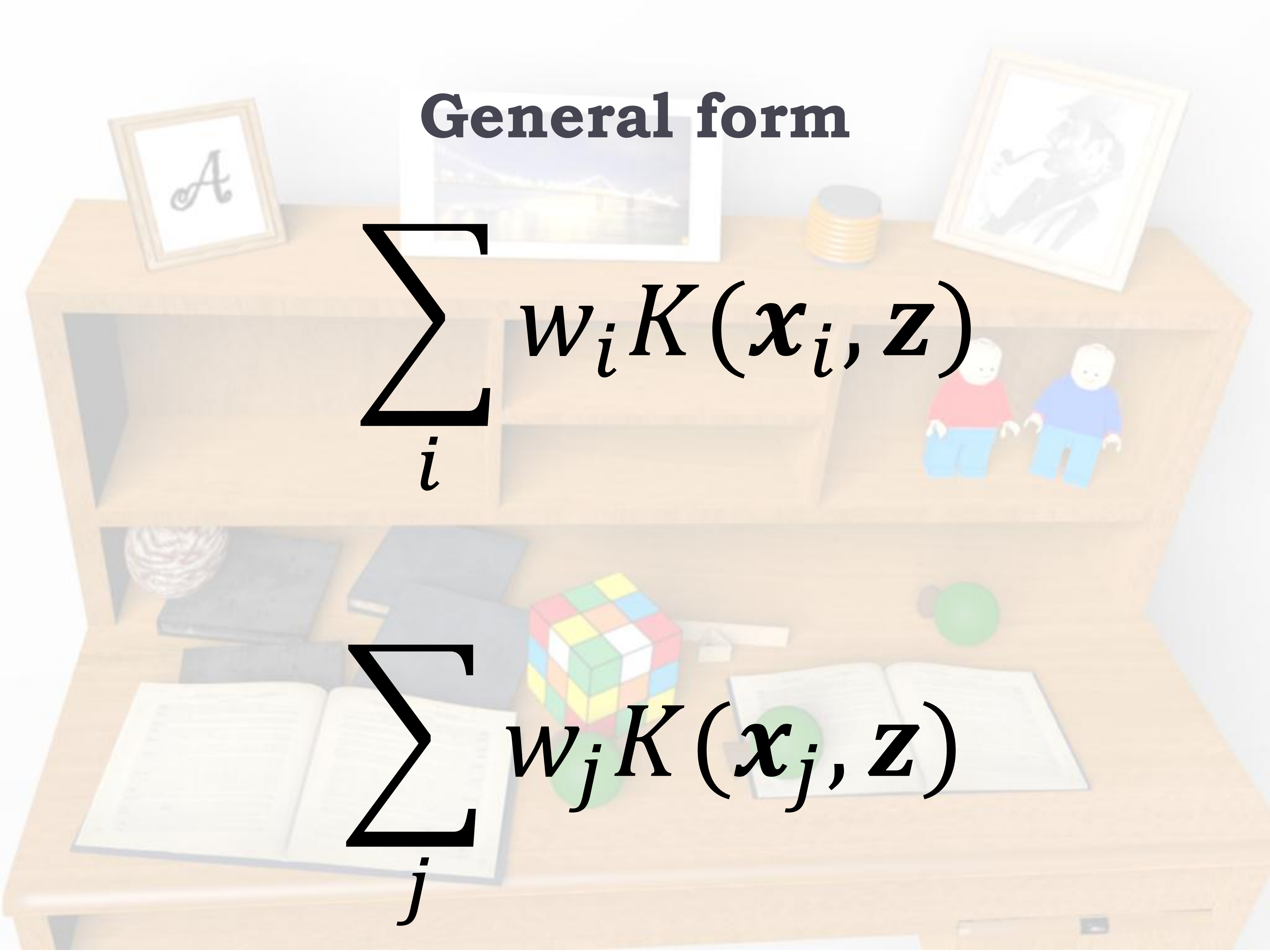


General form



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

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



General form

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

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

General form

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

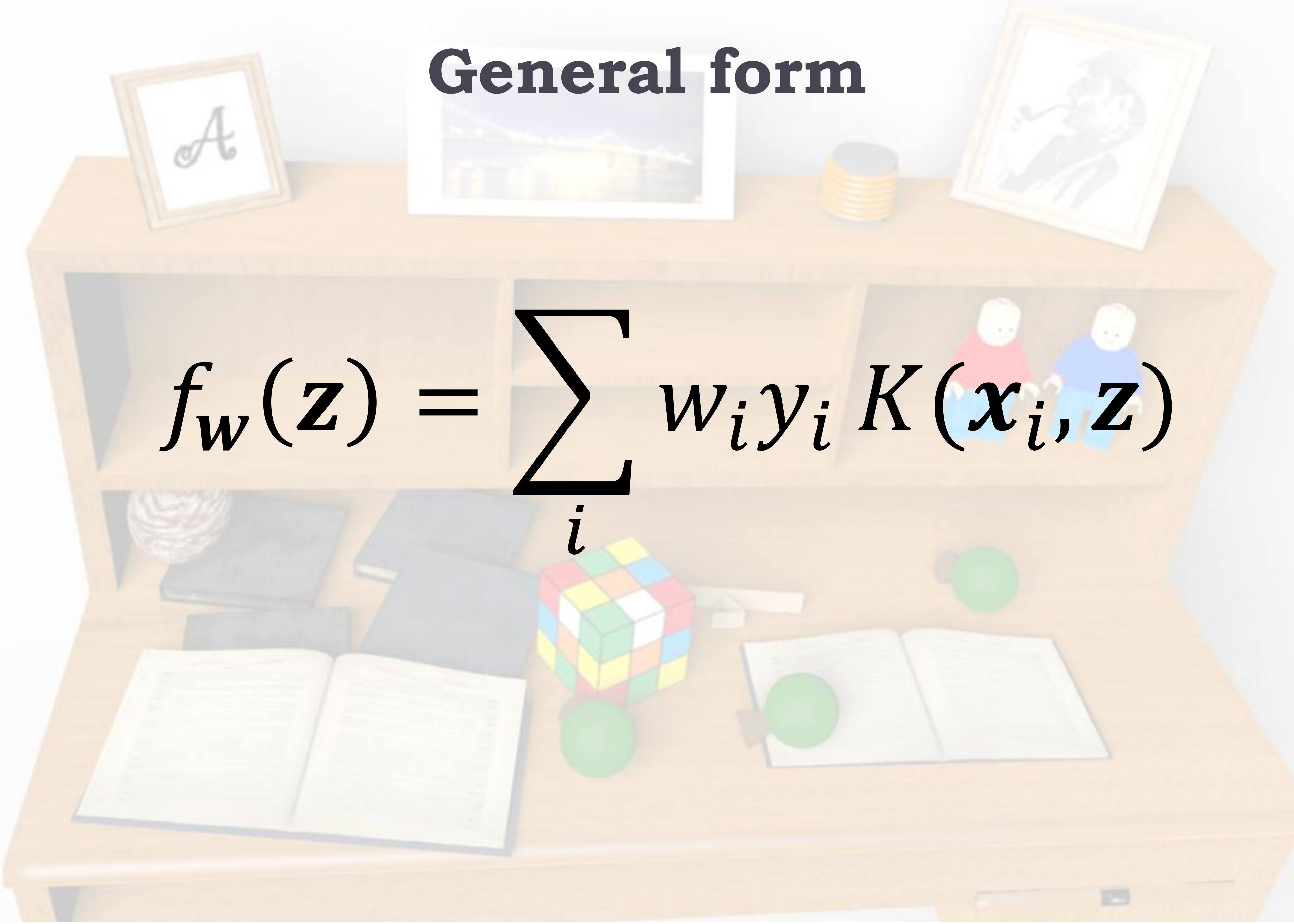
$$-\sum_j w_j K(\boldsymbol{x}_j, \boldsymbol{z})$$

General form

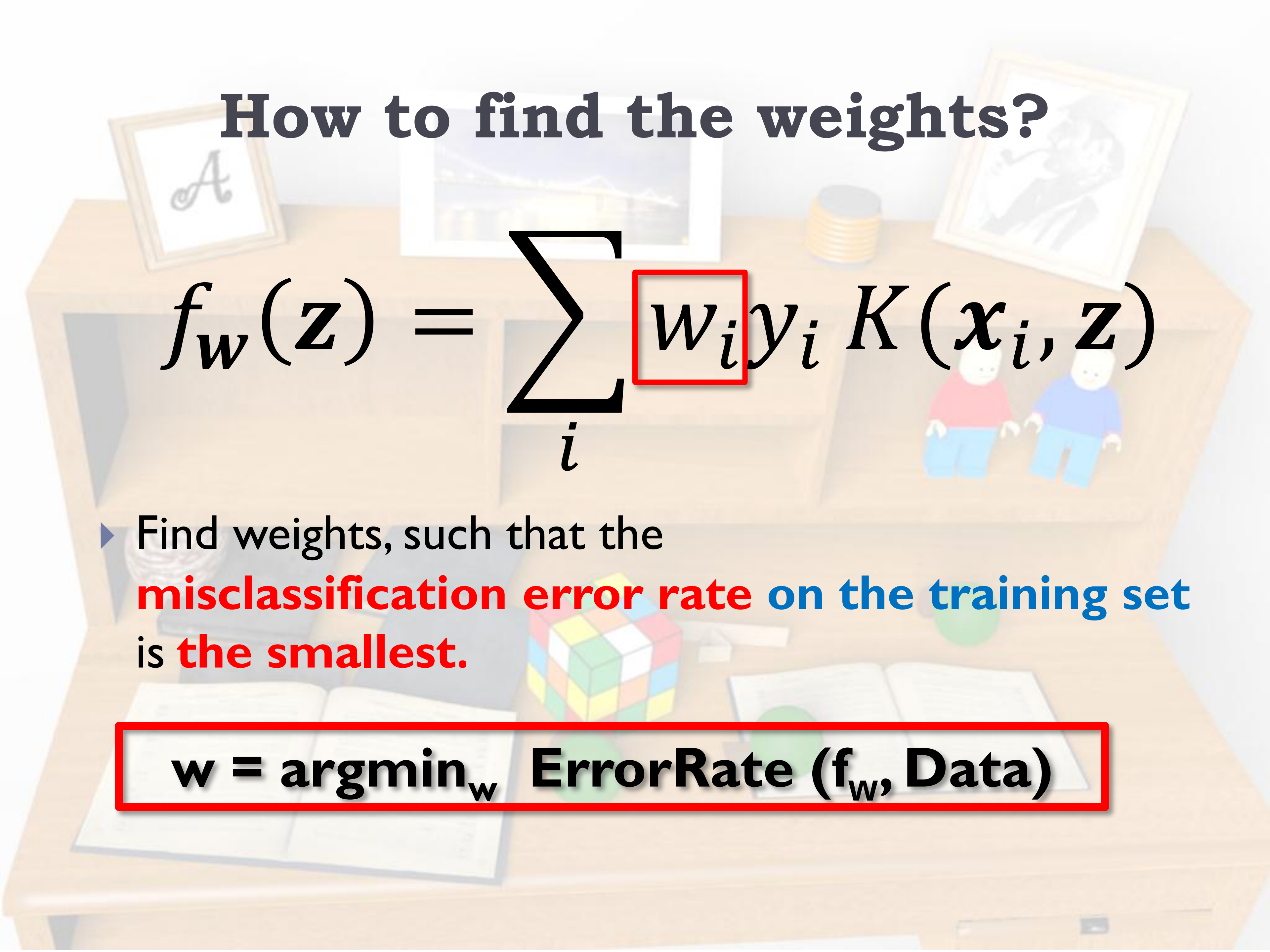
$$\sum_i w_i y_i K(\boldsymbol{x}_i, \boldsymbol{z})$$

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

General form



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



How to find the weights?

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

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

w = argmin$_{w}$ ErrorRate (f$_{w}$, Data)

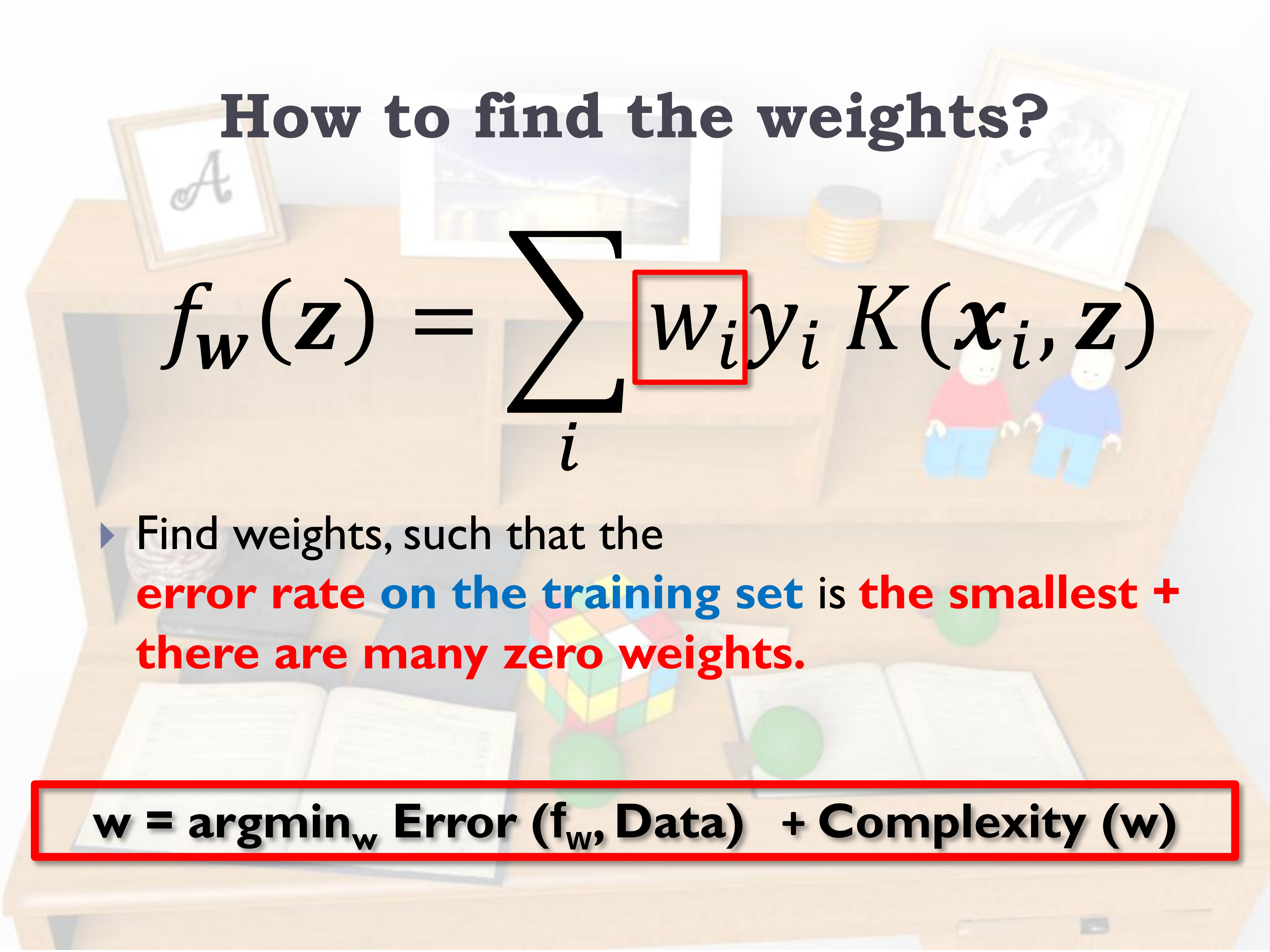
How to find the weights?

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

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

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

How to find the weights?

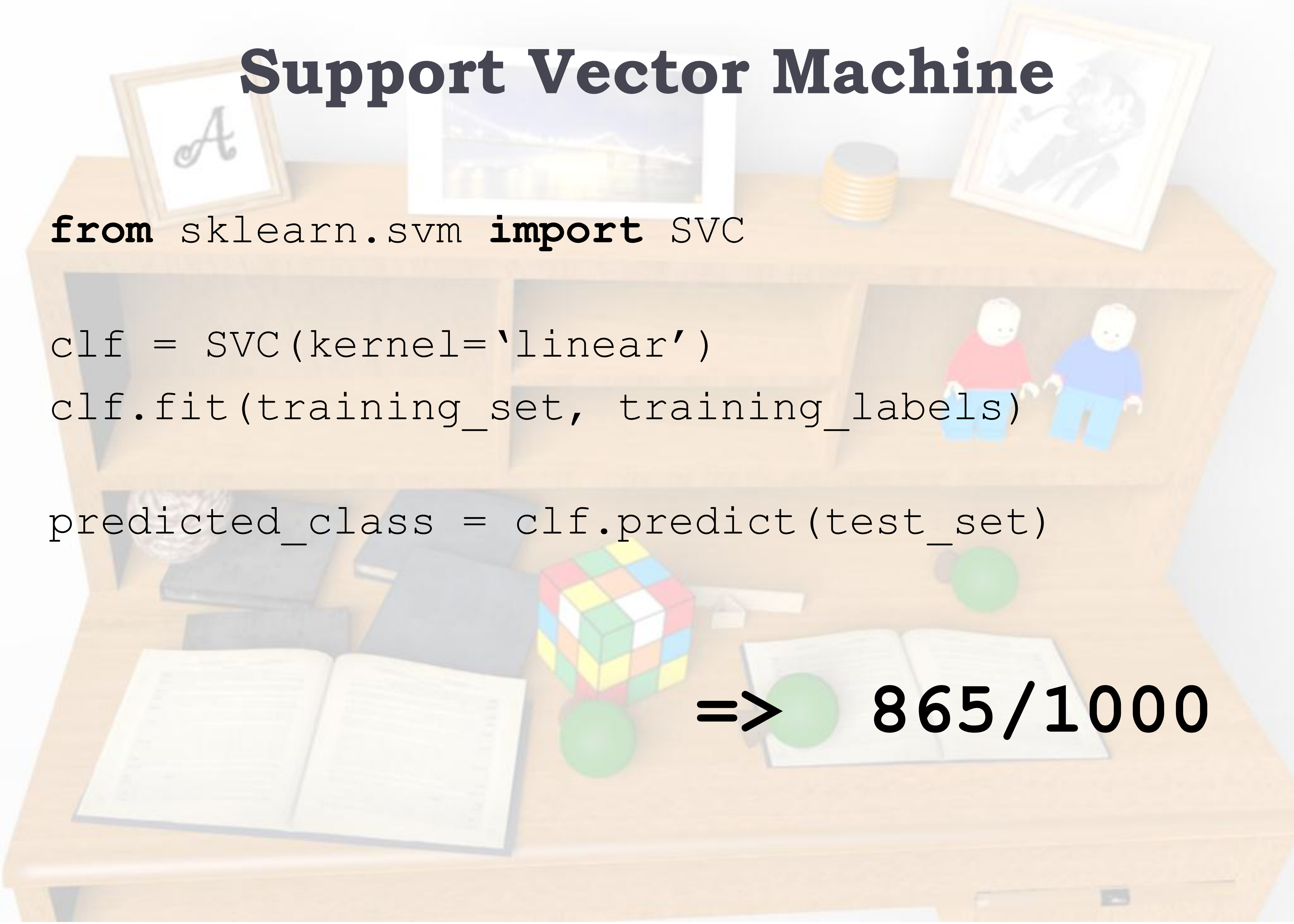


$$f_{\mathbf{w}}(\mathbf{z}) = \sum_i \boxed{w_i} y_i\, K(\mathbf{x}_i, \mathbf{z})$$

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

$$\boxed{\mathbf{w = argmin_w\ Error\ (f_w, Data)\ \ + Complexity\ (w)}}$$

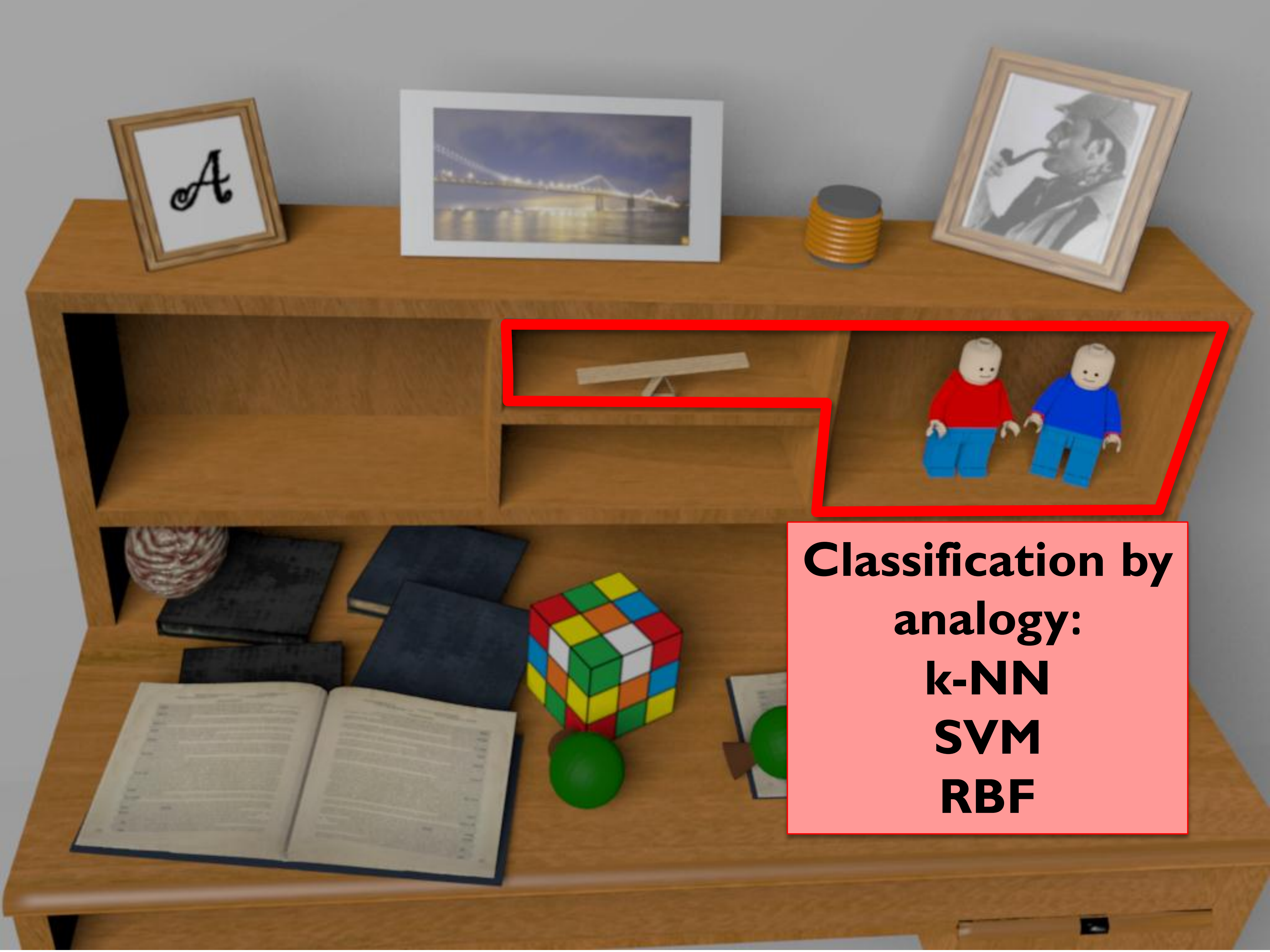
Support Vector Machine



```
from sklearn.svm import SVC

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

predicted_class = clf.predict(test_set)
```

=> 865/1000

A



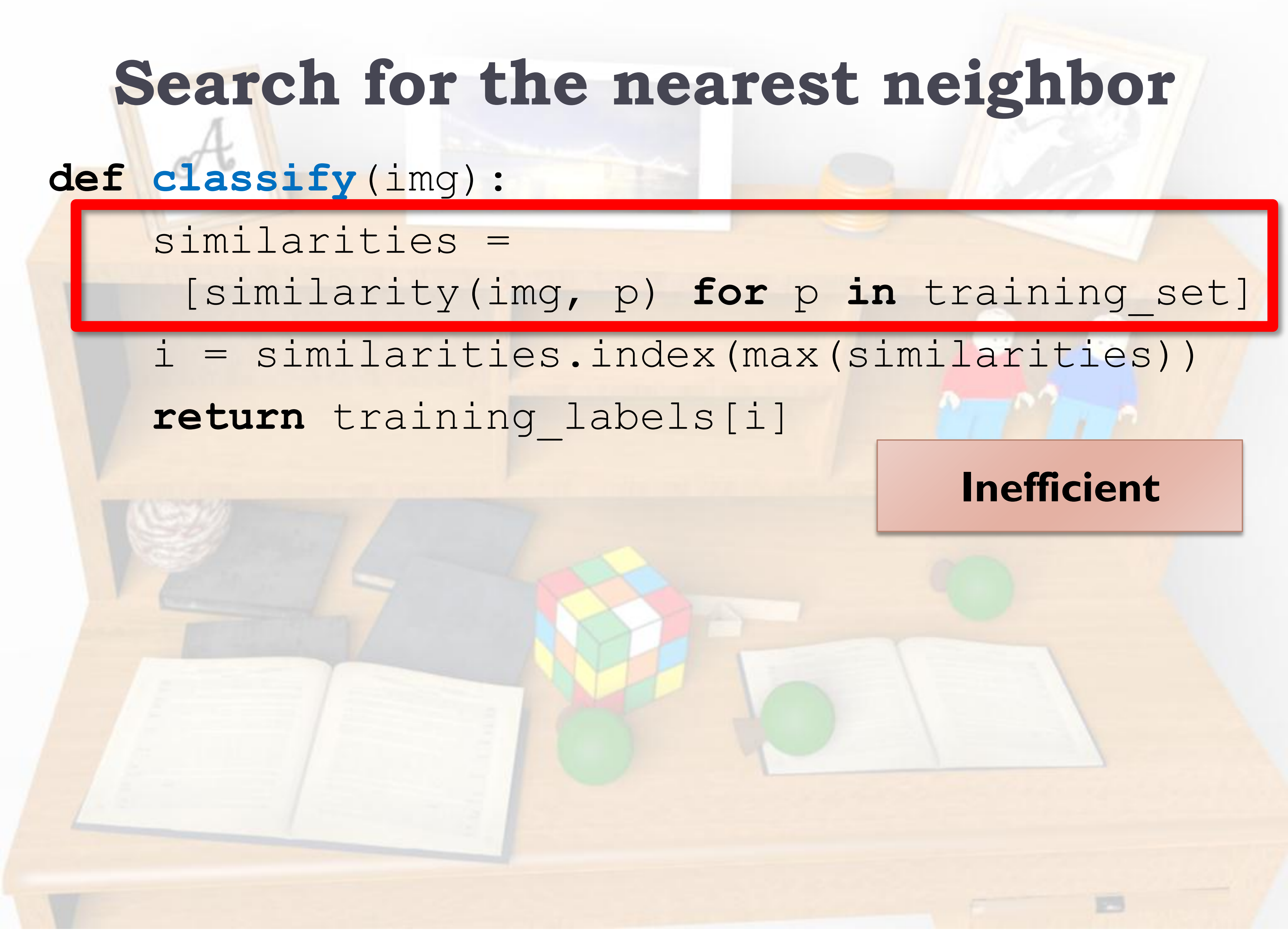
Classification by analogy:

k-NN

SVM

RBF

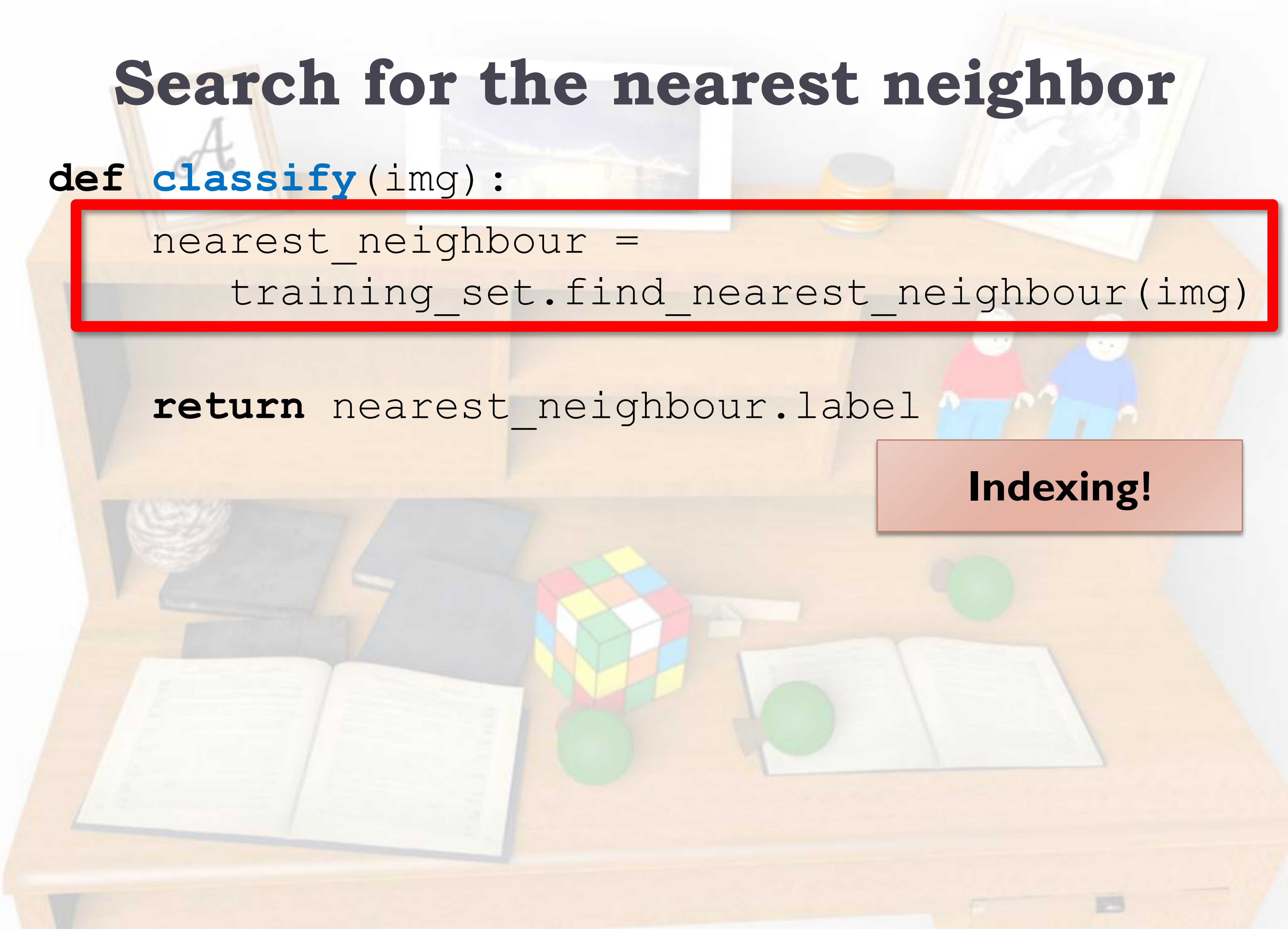
Search for the nearest neighbor



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

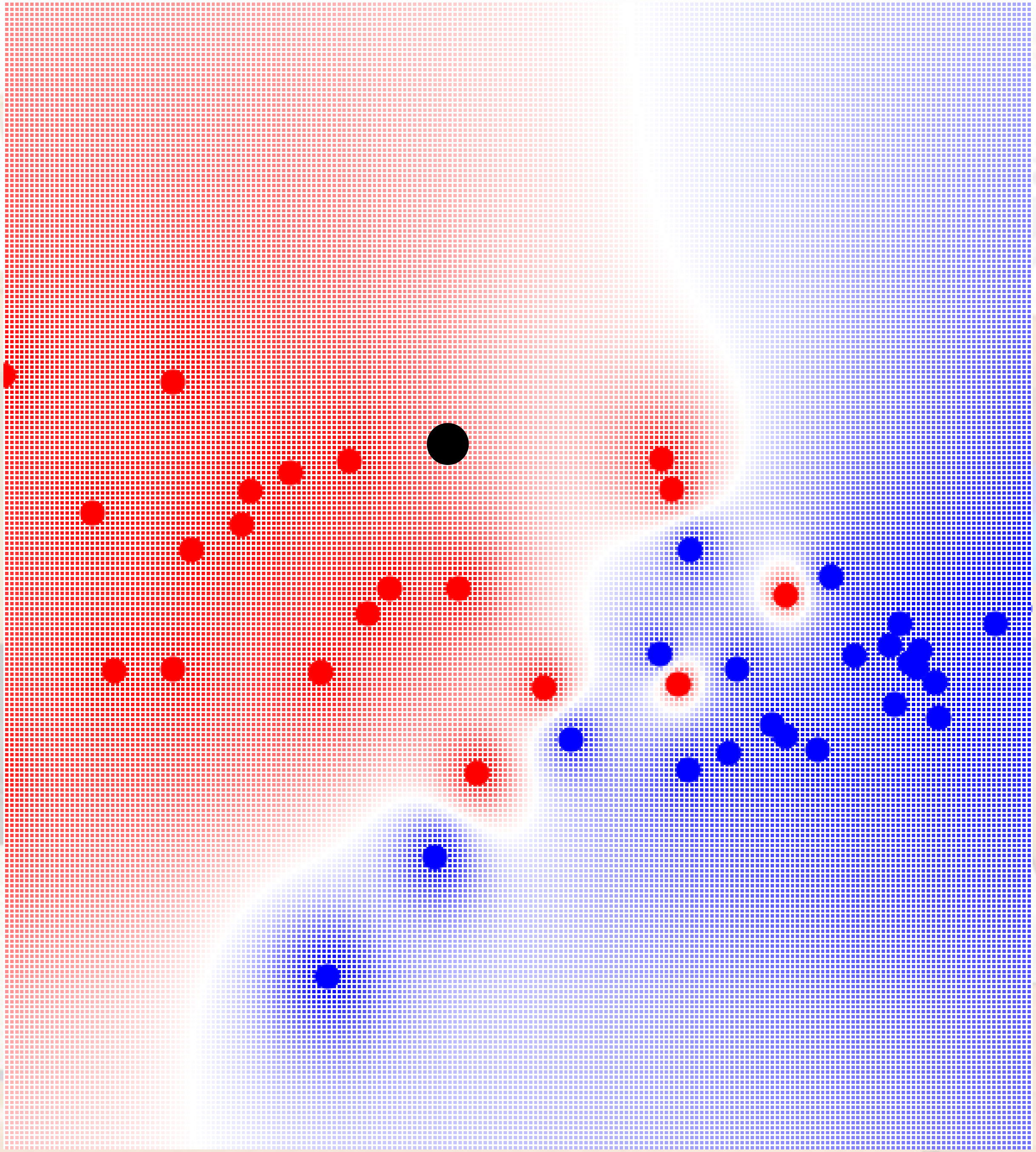
Inefficient

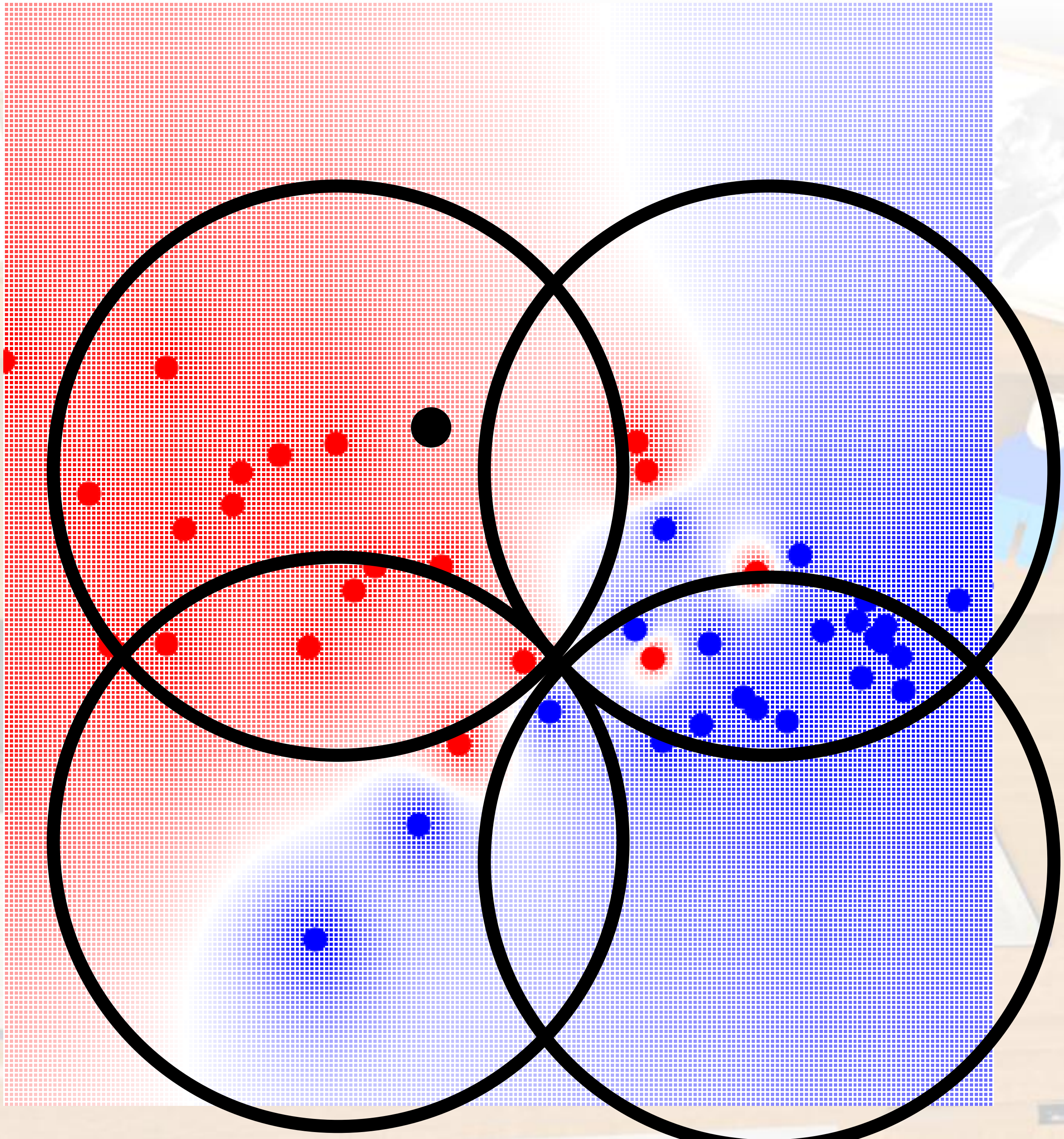
Search for the nearest neighbor

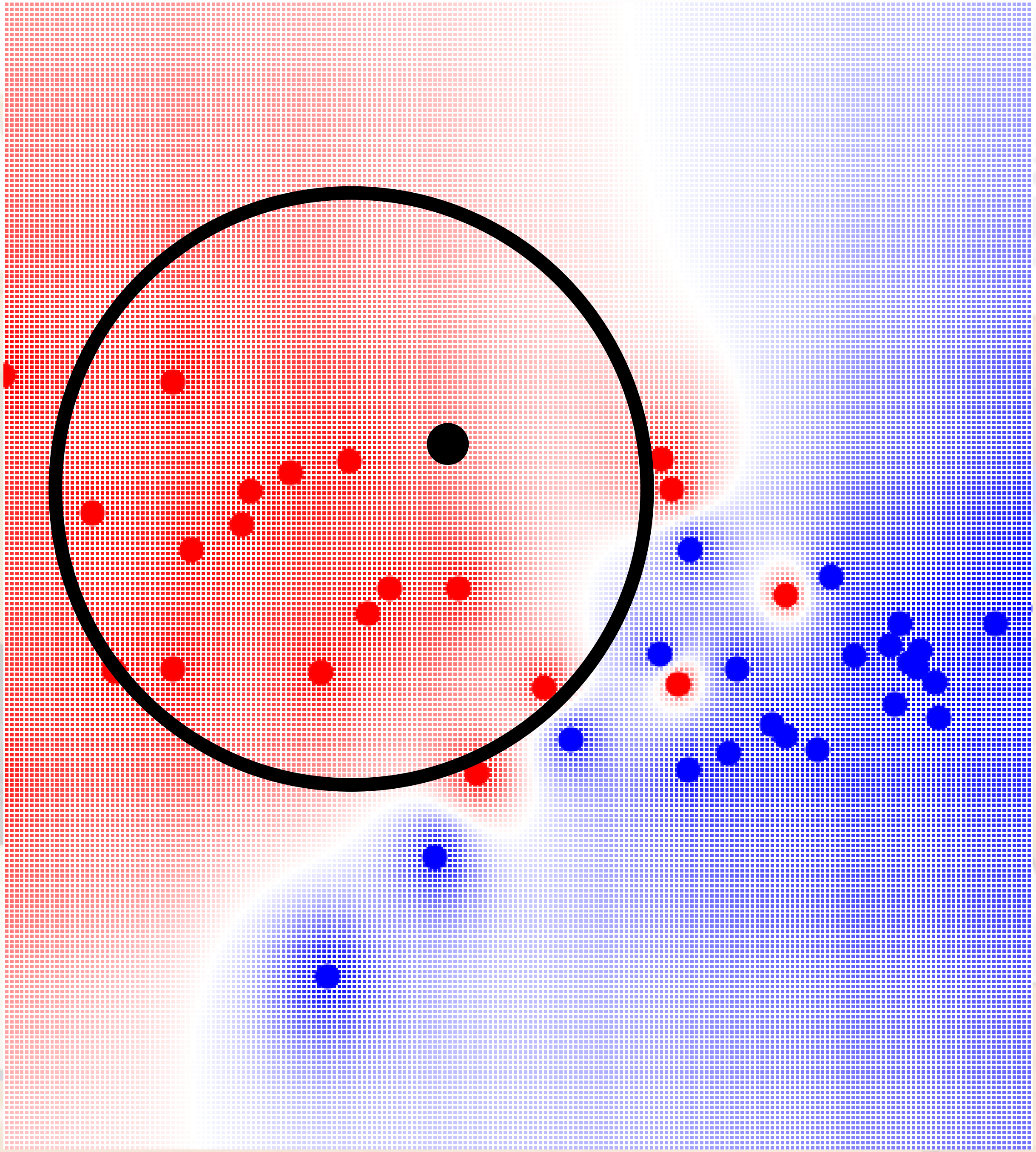


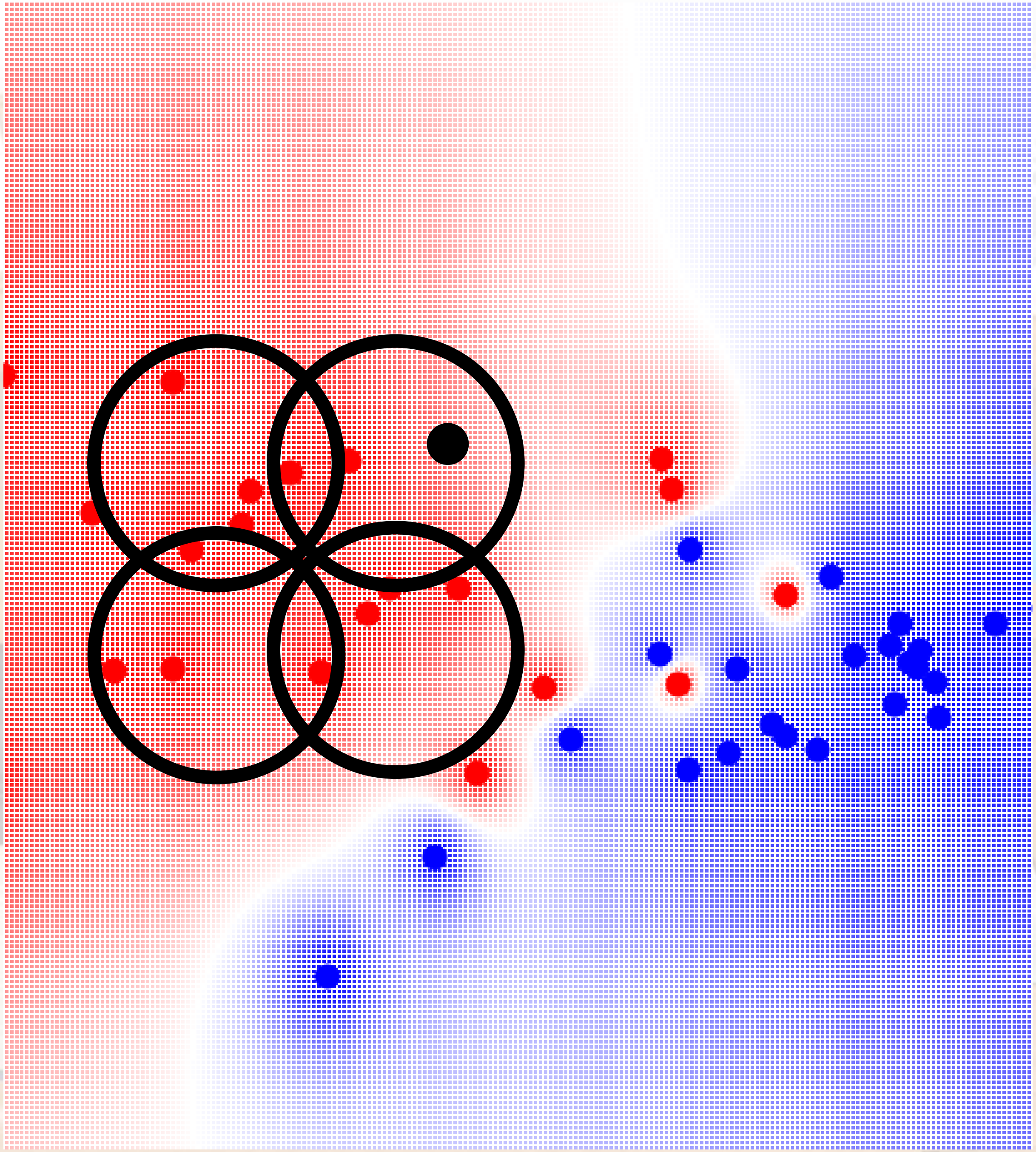
```
def classify(img):
    nearest_neighbour =
        training_set.find_nearest_neighbour(img)

    return nearest_neighbour.label
```

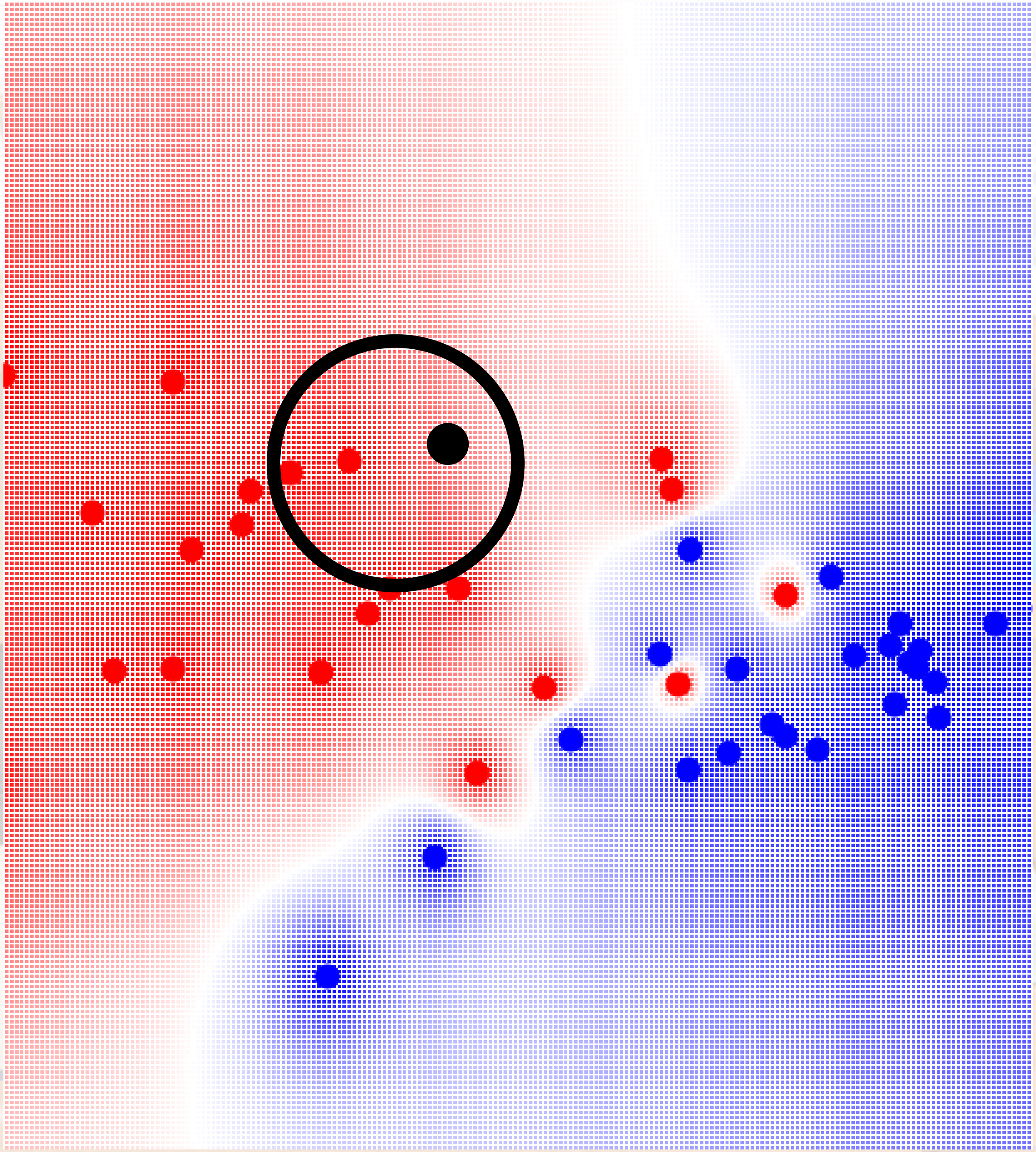
Indexing!







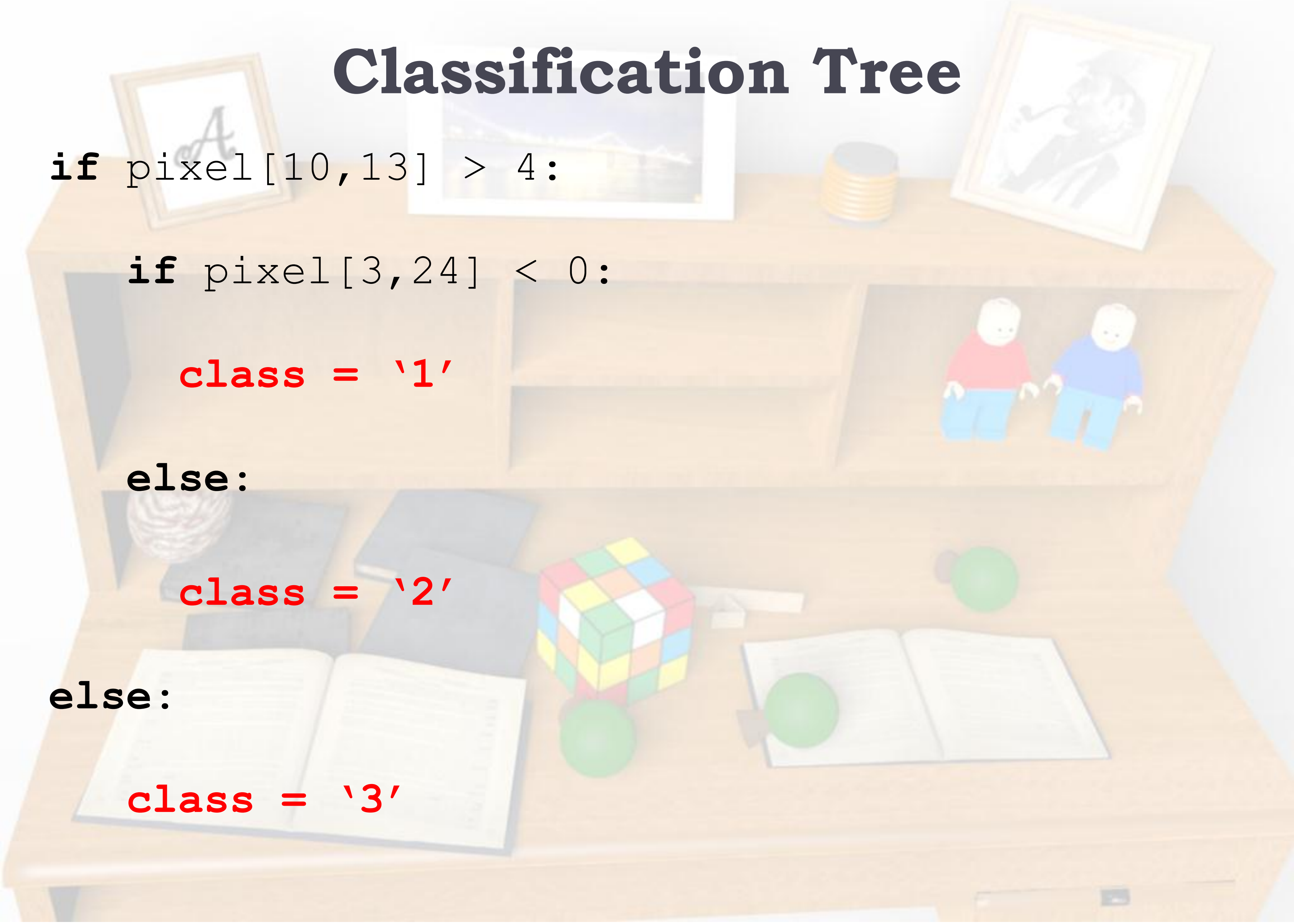




find_nearest_neighbour

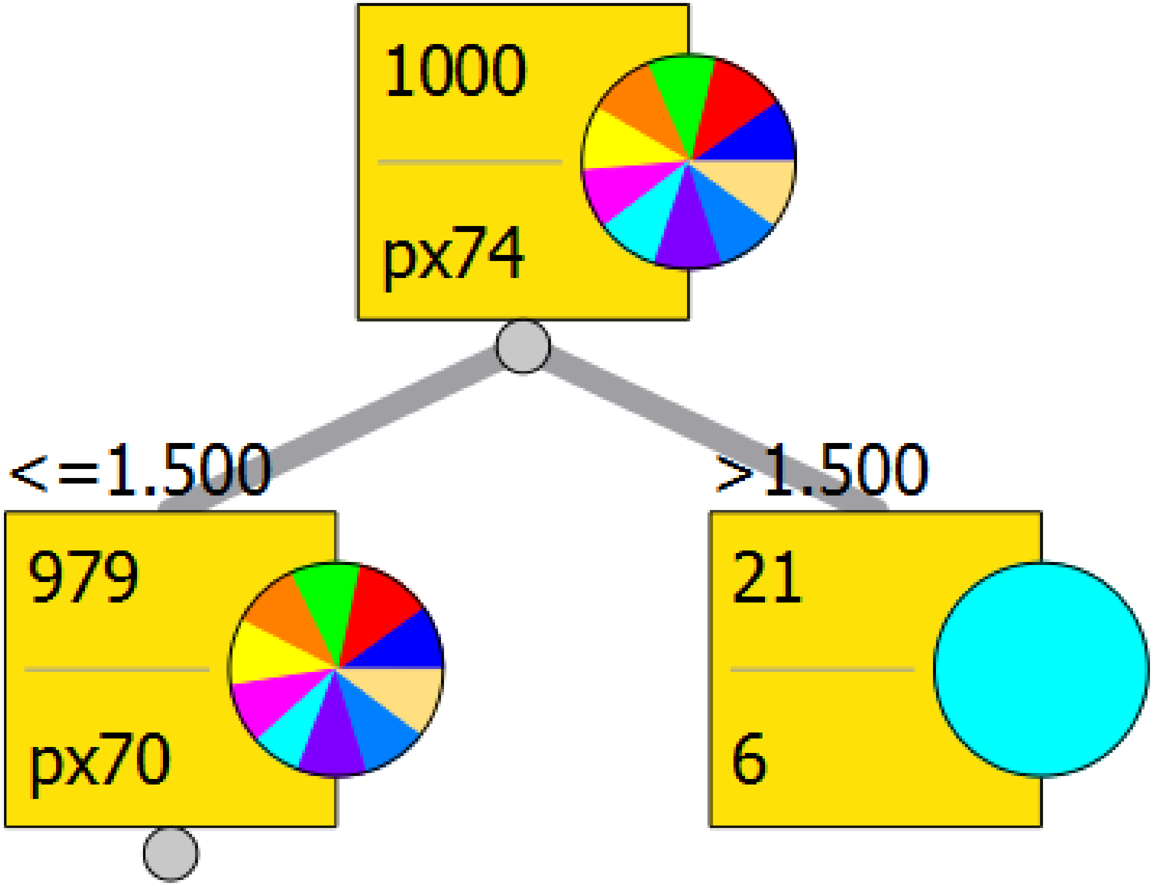
```
if pixel[10,13] > 4:
  if pixel[3,24] < 0:
    nearest_neighbour = A
  else:
    nearest_neighbour = B
else:
  nearest_neighbour = C
```

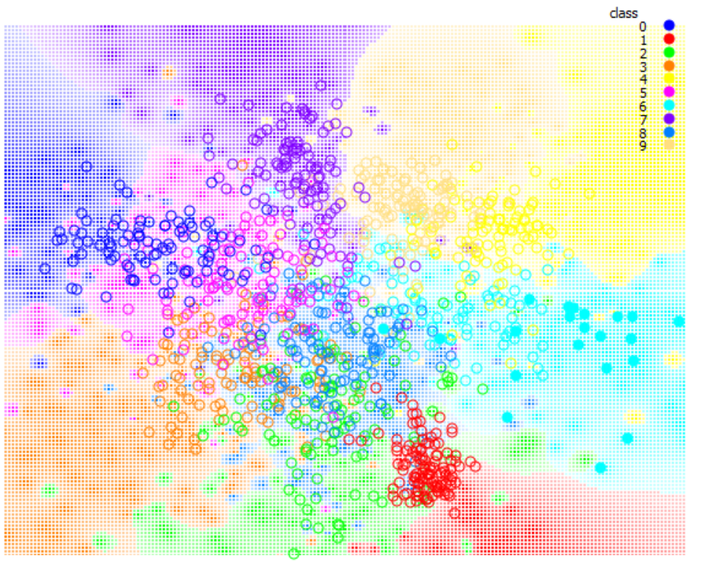
Classification Tree



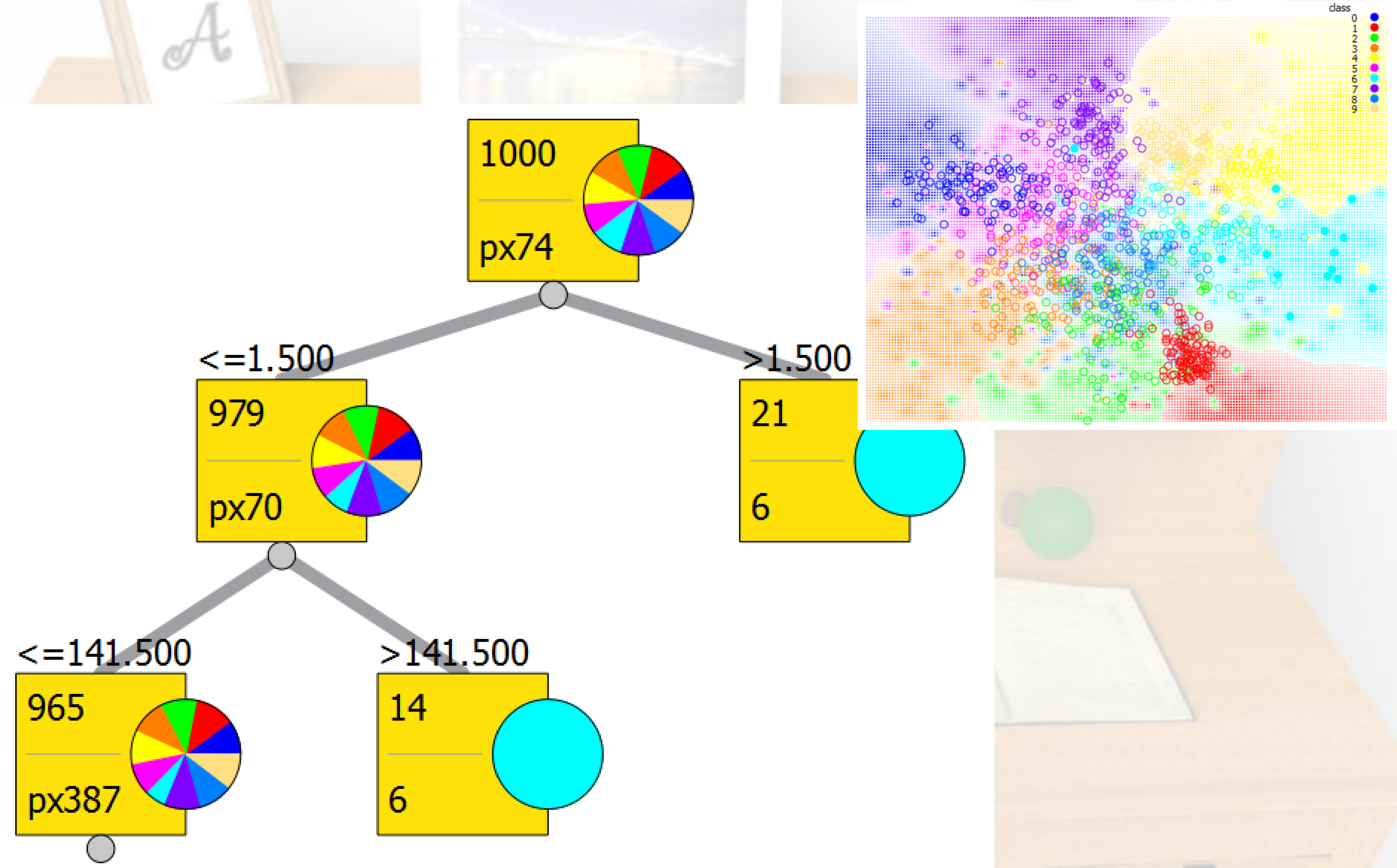
```
if pixel[10,13] > 4:
   if pixel[3,24] < 0:
      class = ‘1’
   else:
      class = ‘2’
else:
   class = ‘3’
```

Classification Tree

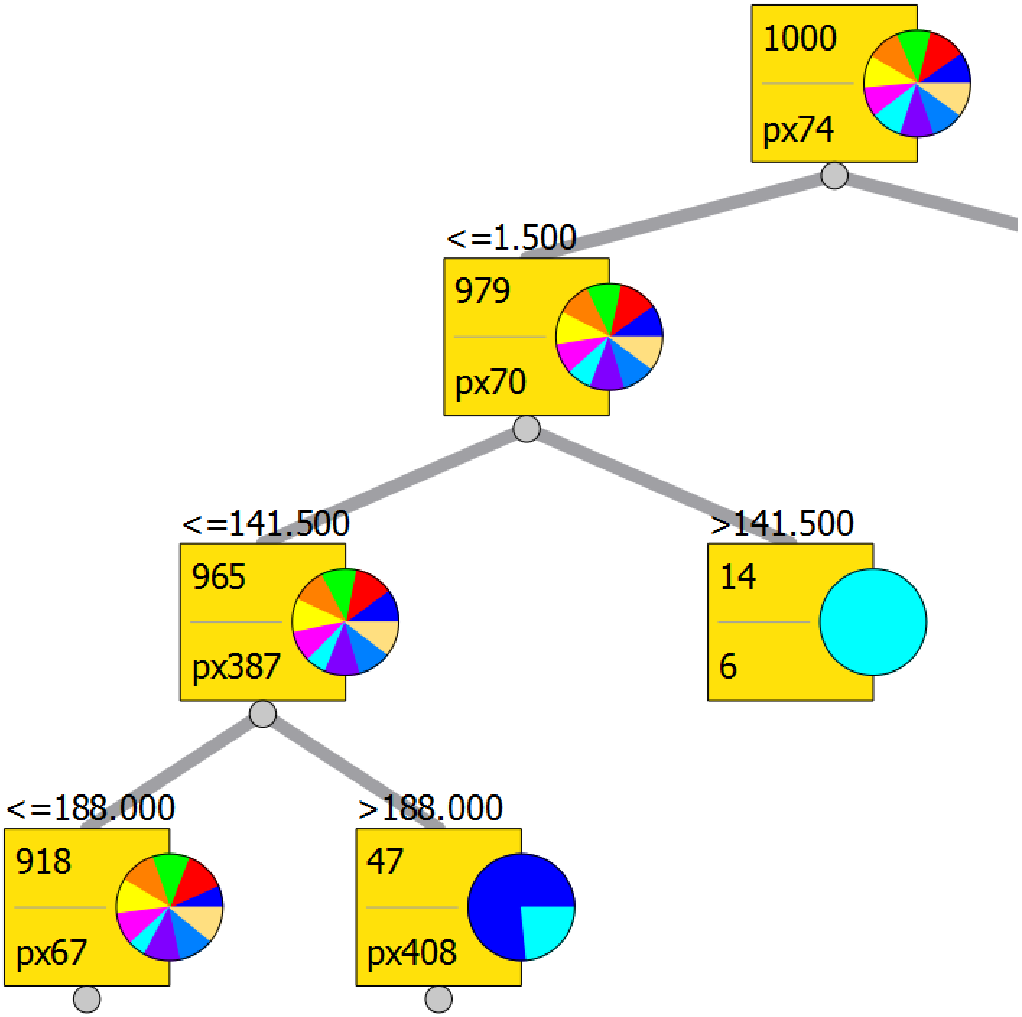


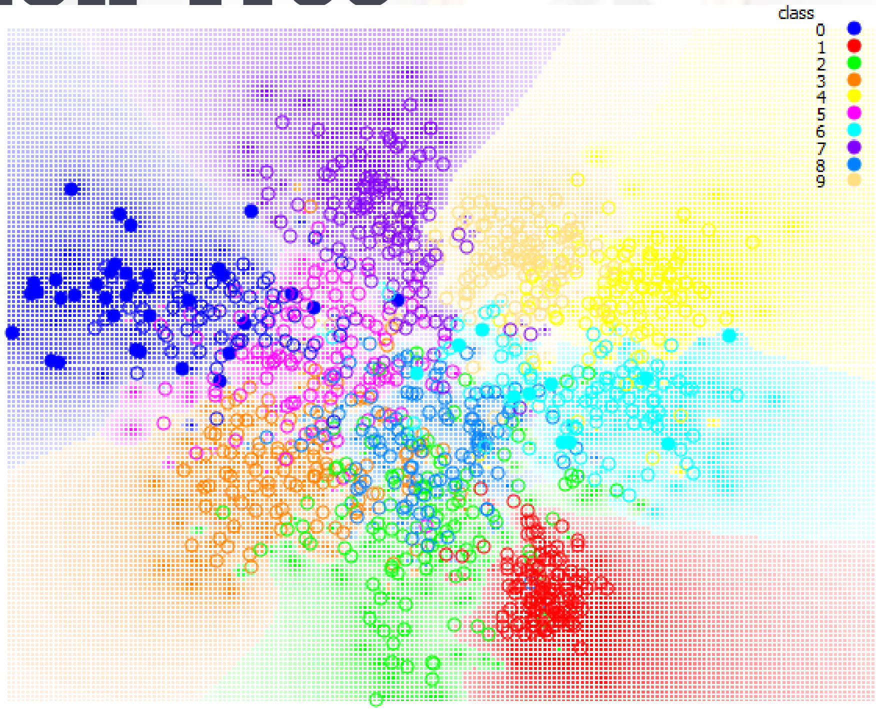


Classification Tree



Classification Tree



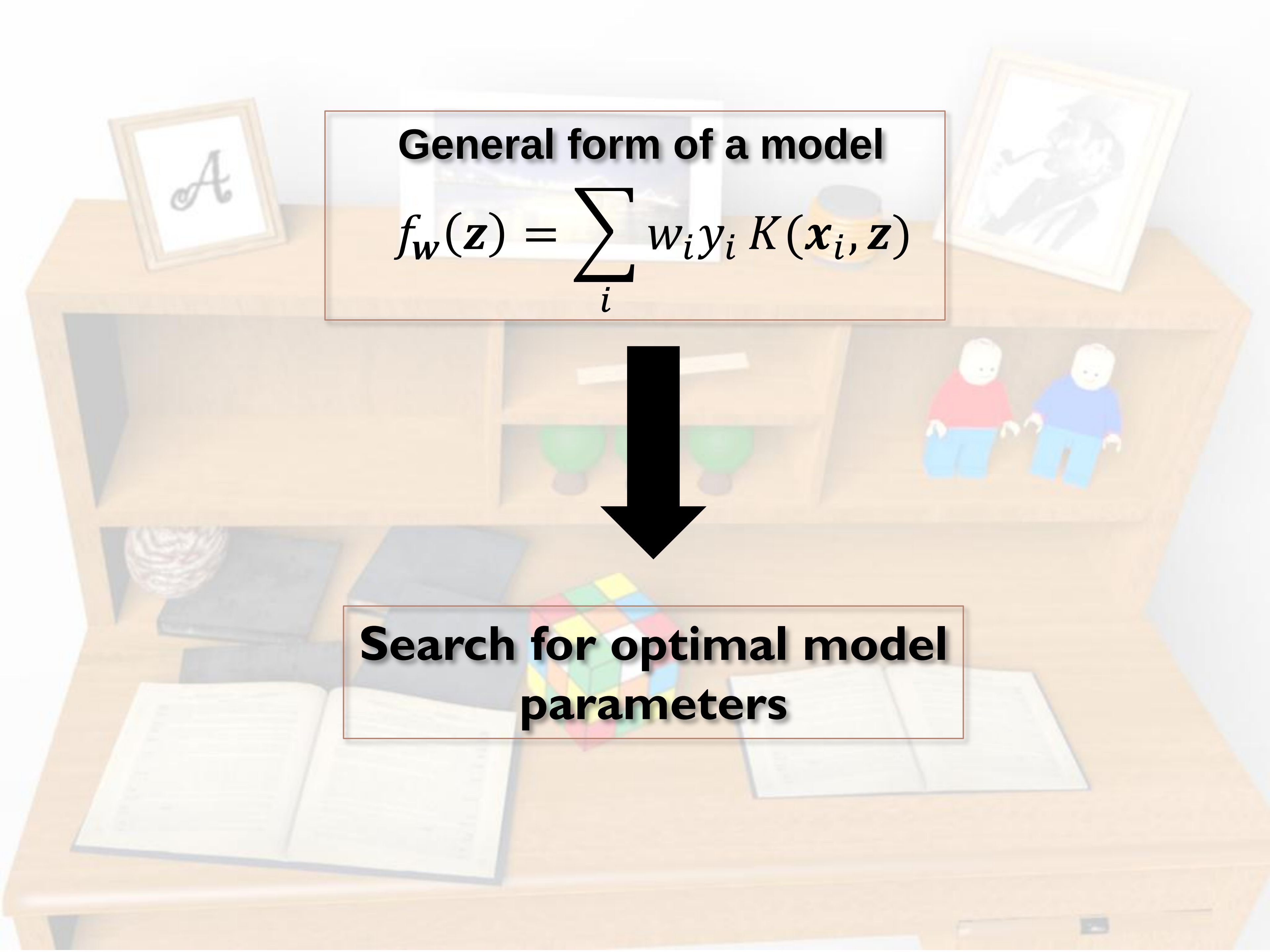


Orange

http://orange.biolab.si/

A

Trees
ID3
C4.5
RegTree



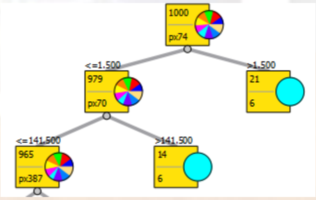
General form of a model

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

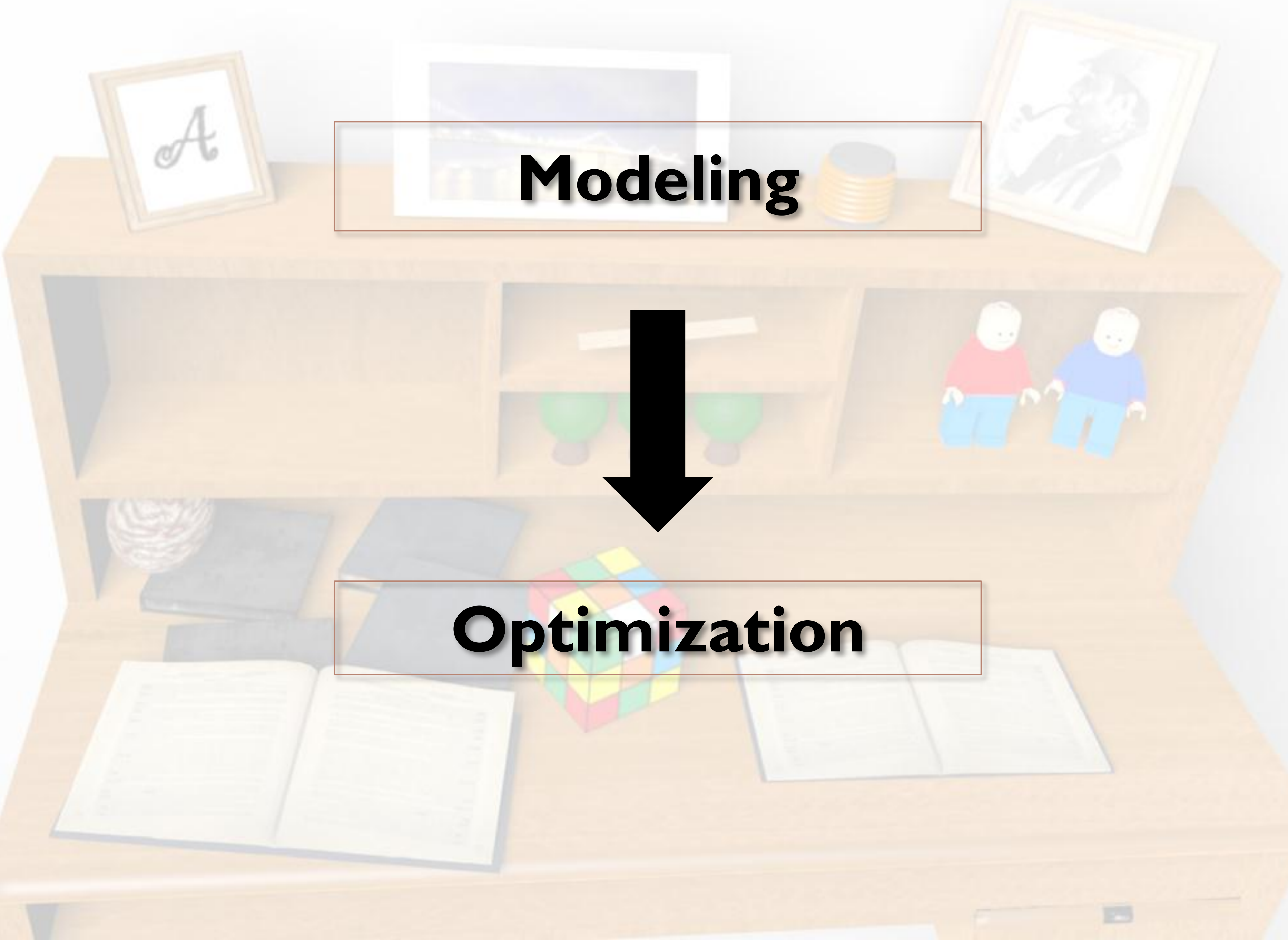
⬇

Search for optimal model parameters

General form of a model

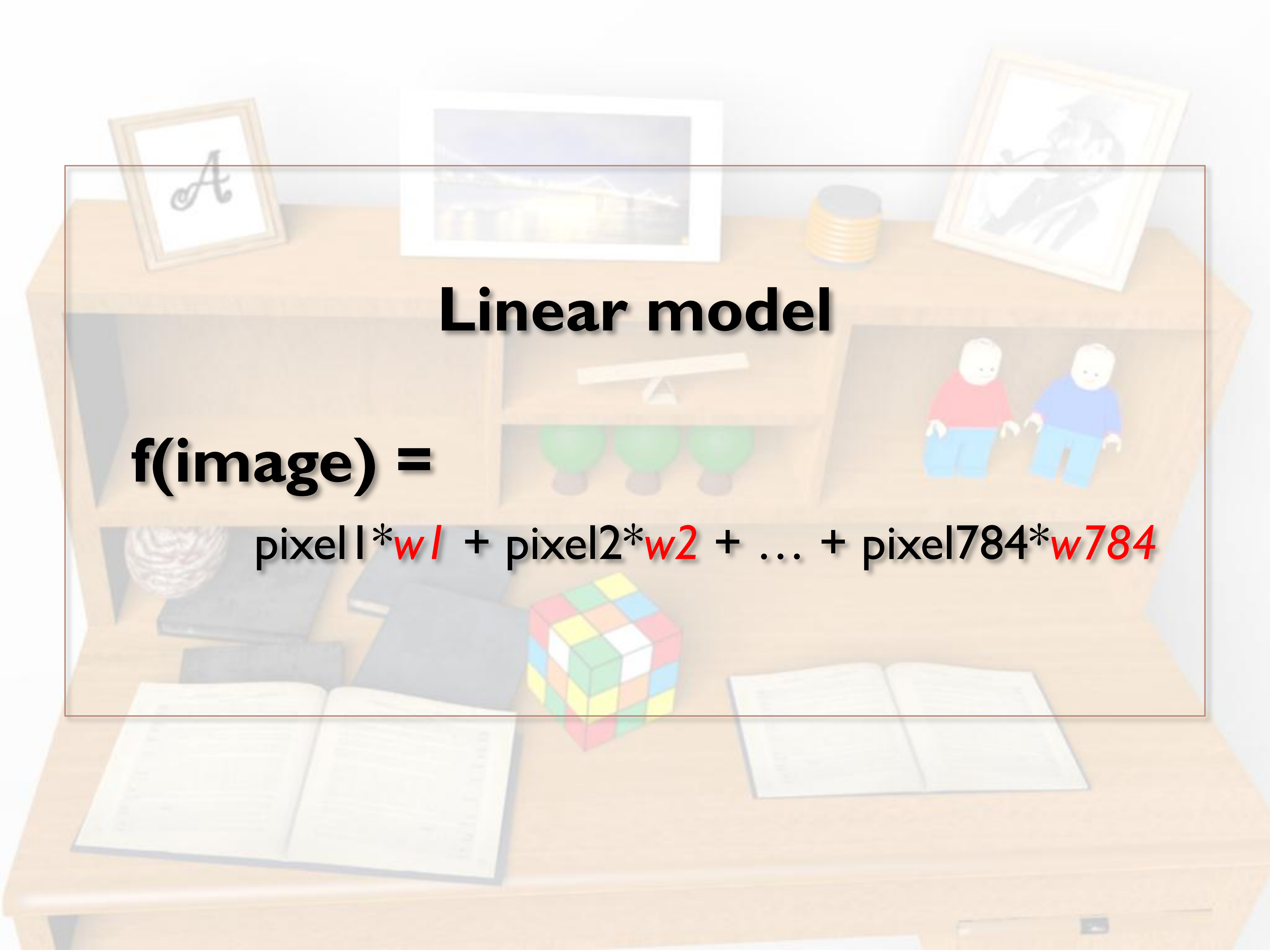


Search for the optimal tree



Modeling

Optimization

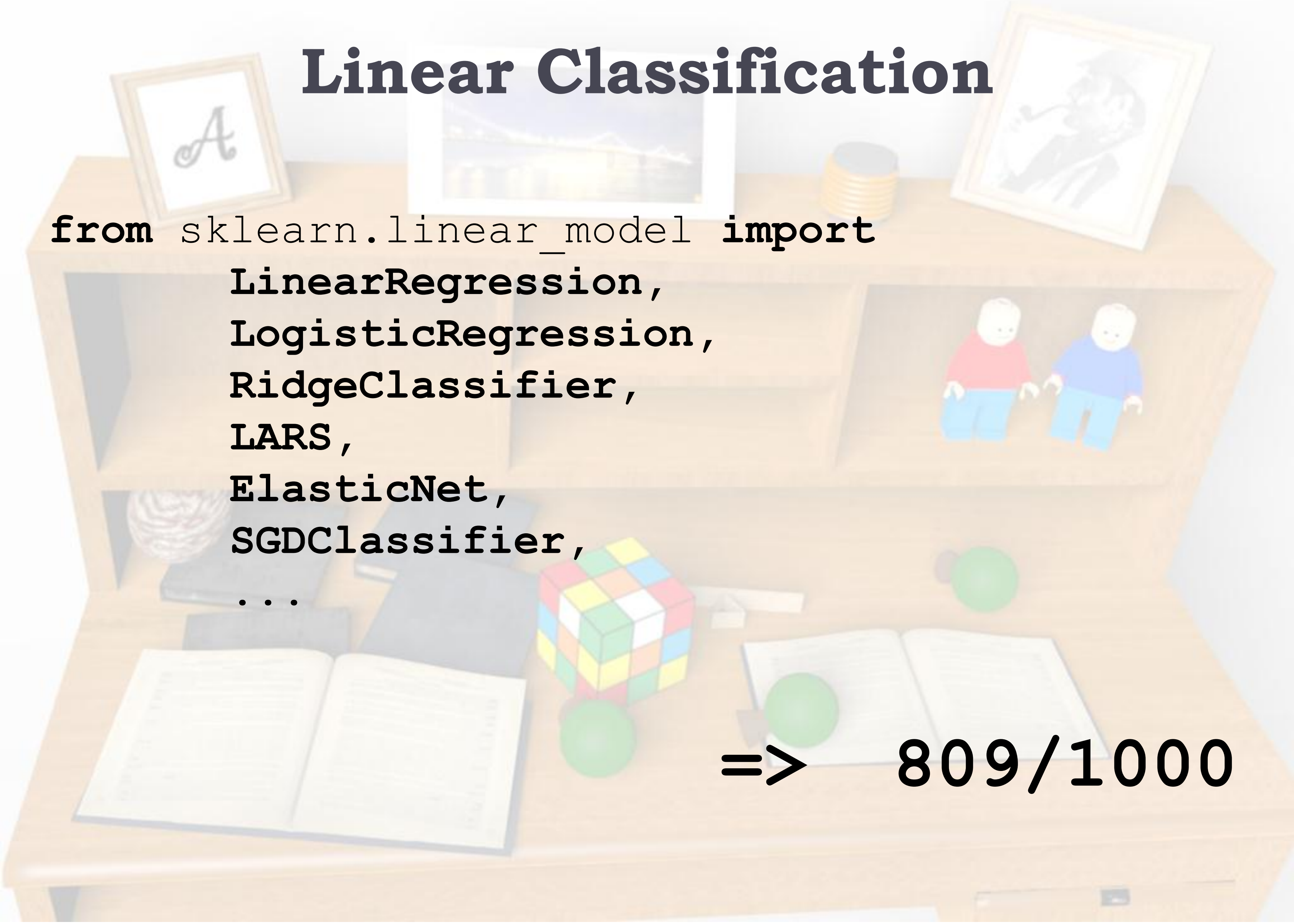


Linear model

f(image) =

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

Linear Classification



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

=> 809/1000

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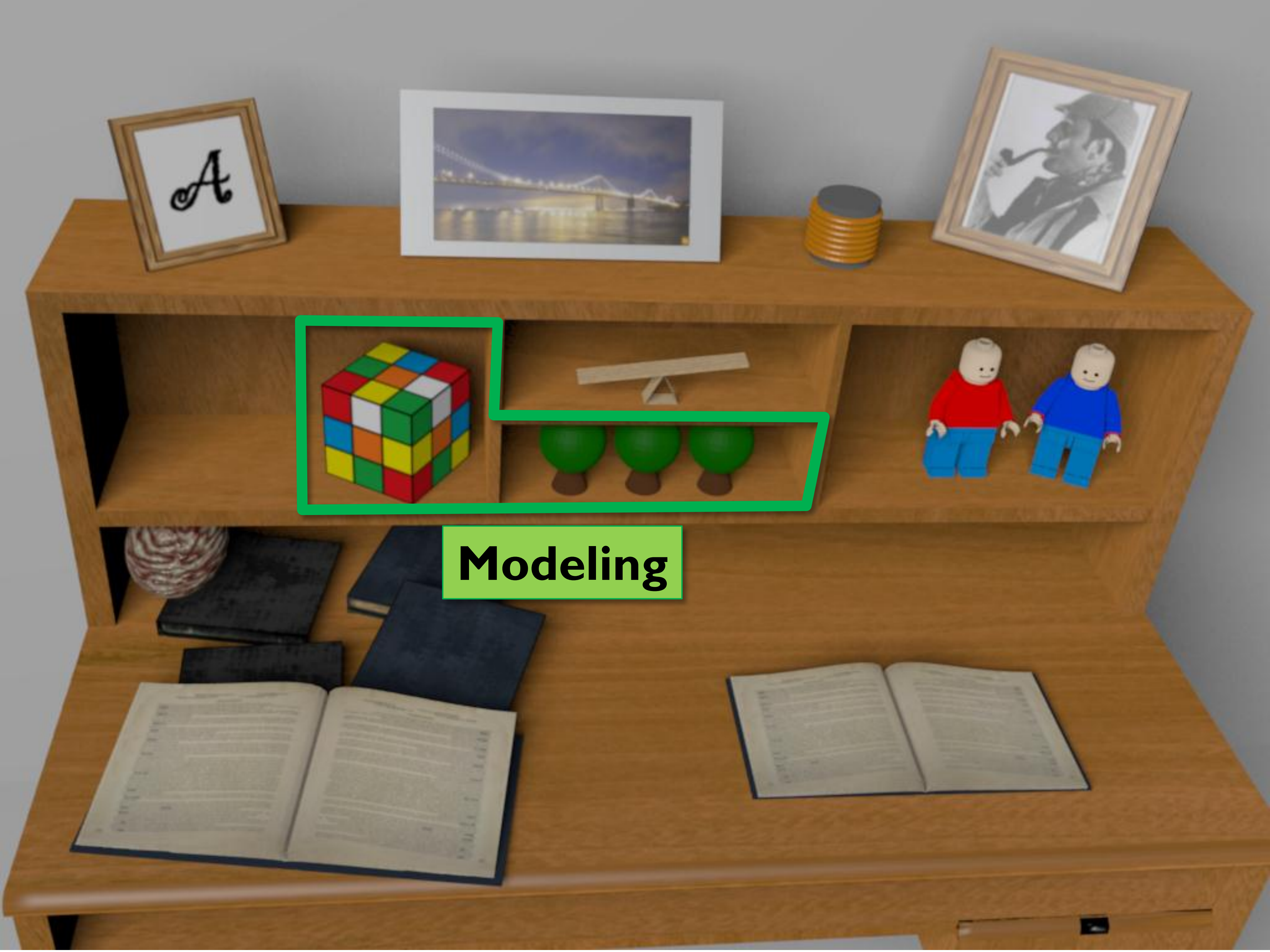
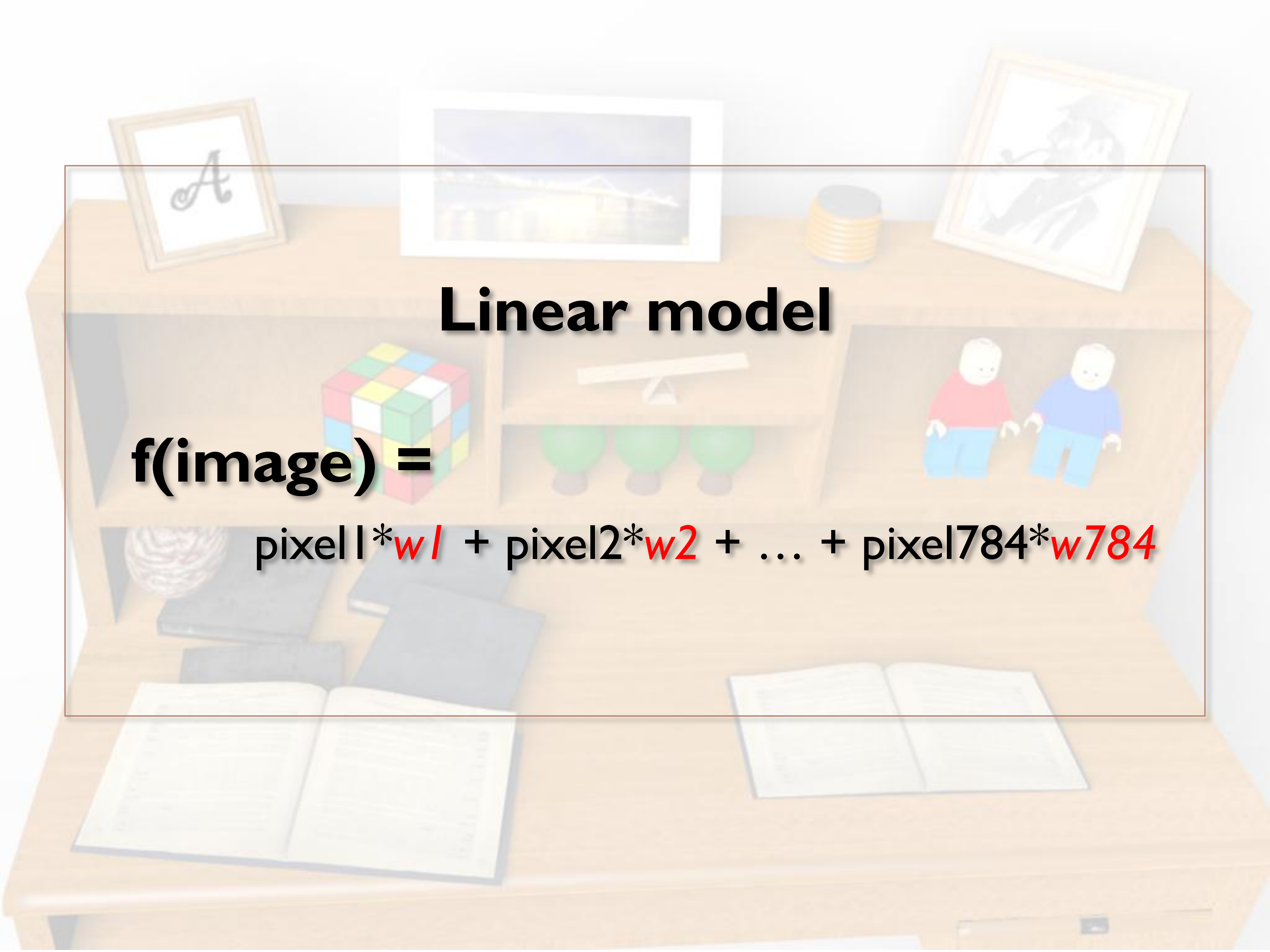


Modeling



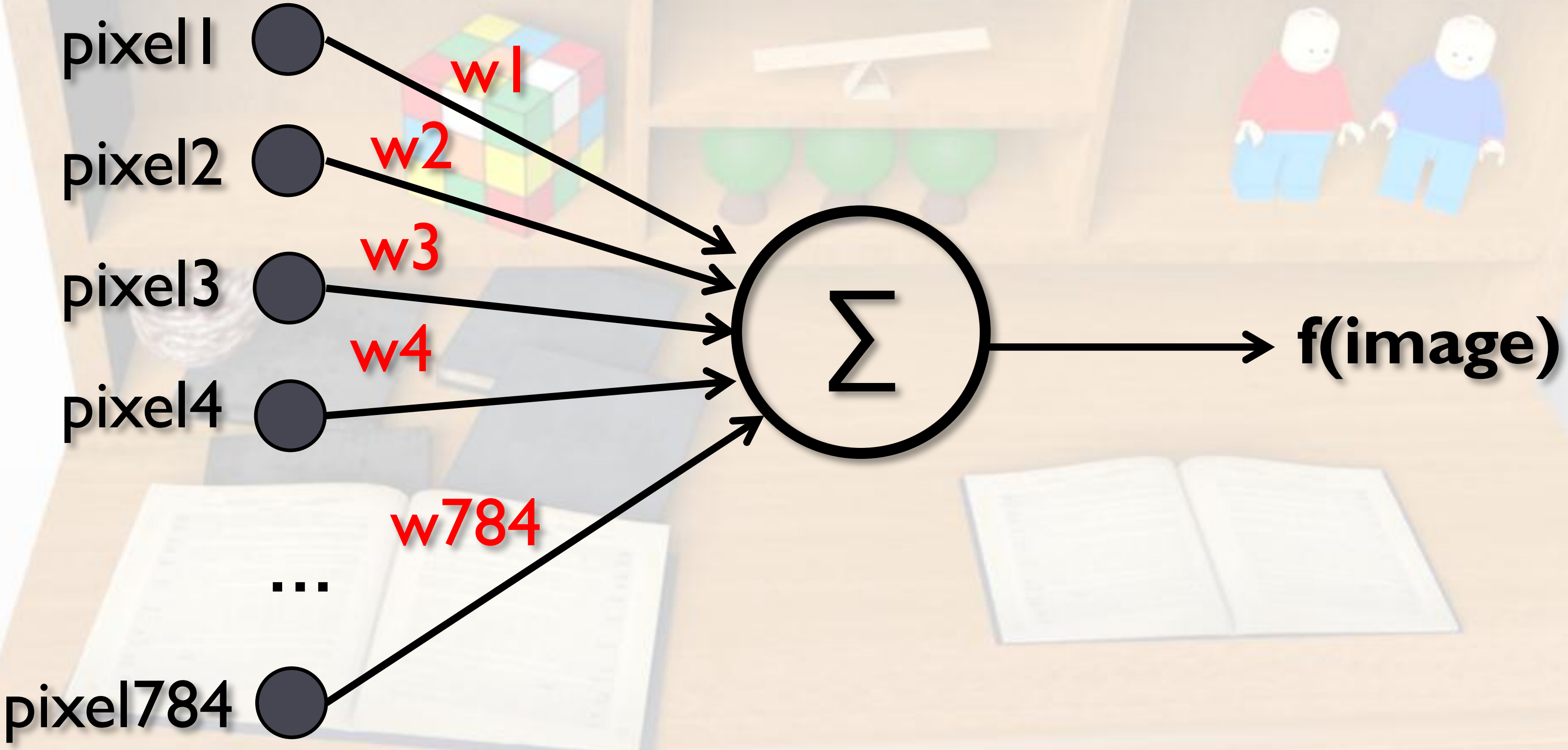
Linear model

f(image) =

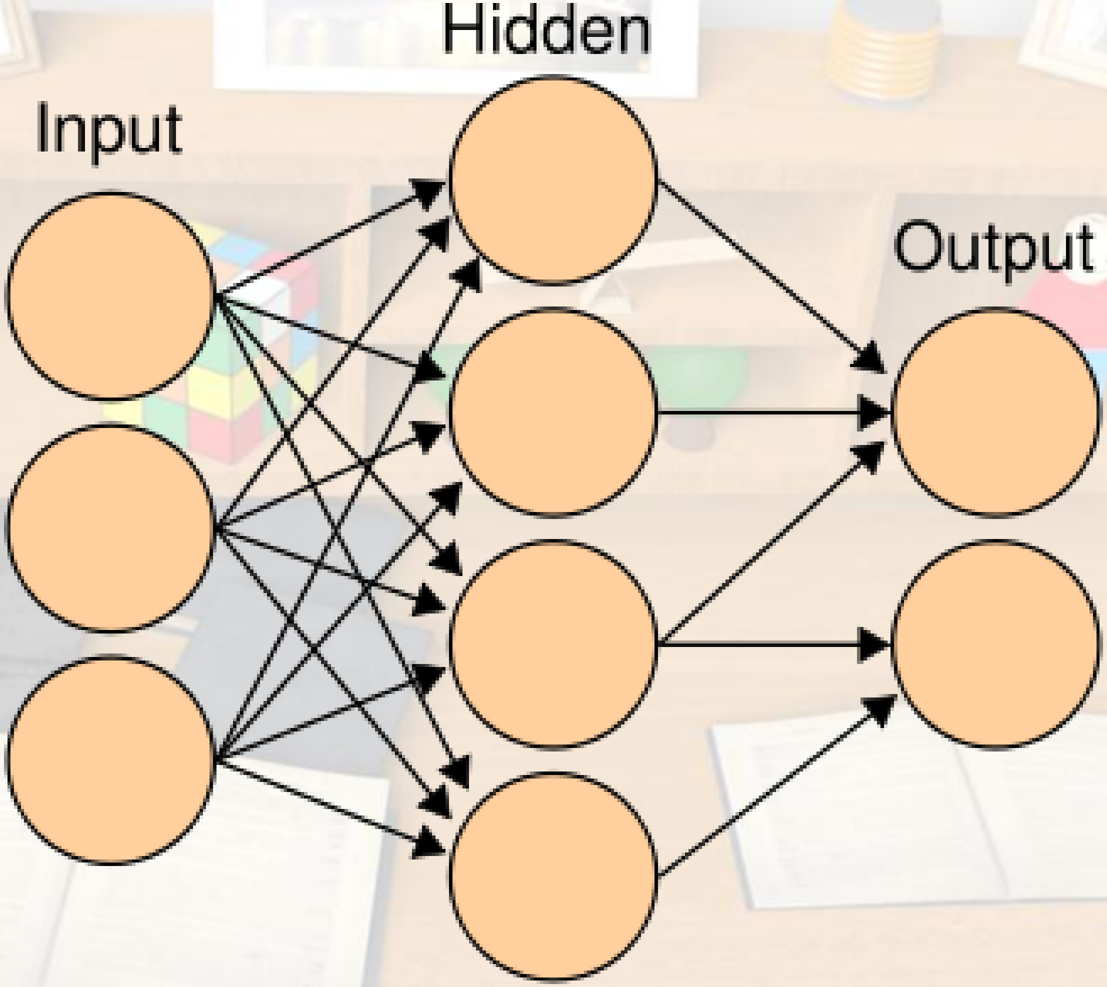
pixel1*w1 + pixel2*w2 + … + pixel784*w784

f(image) =

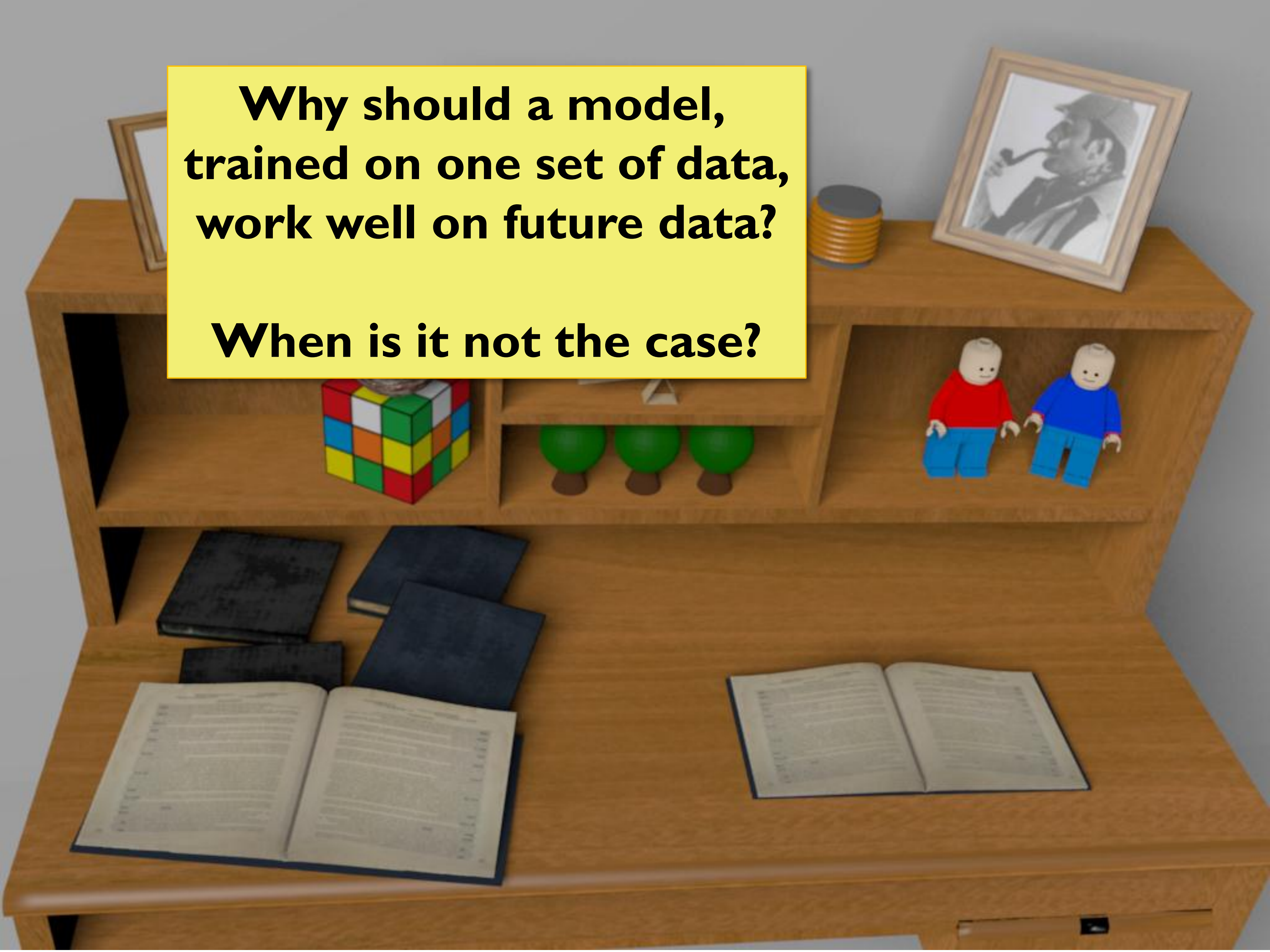
pixel1*w1 + pixel2*w2 + … + pixel784*w784



Neural network

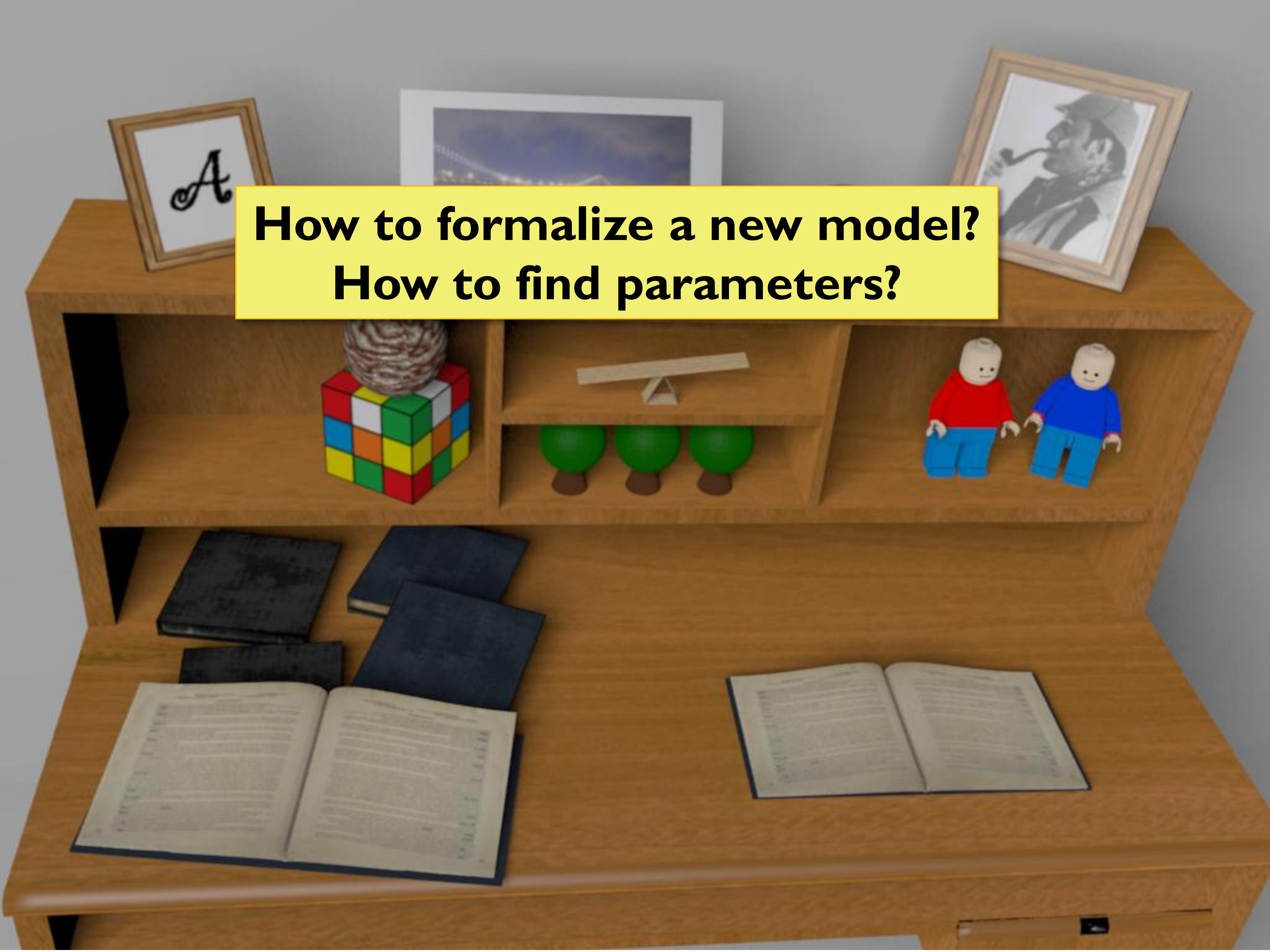


Modeling



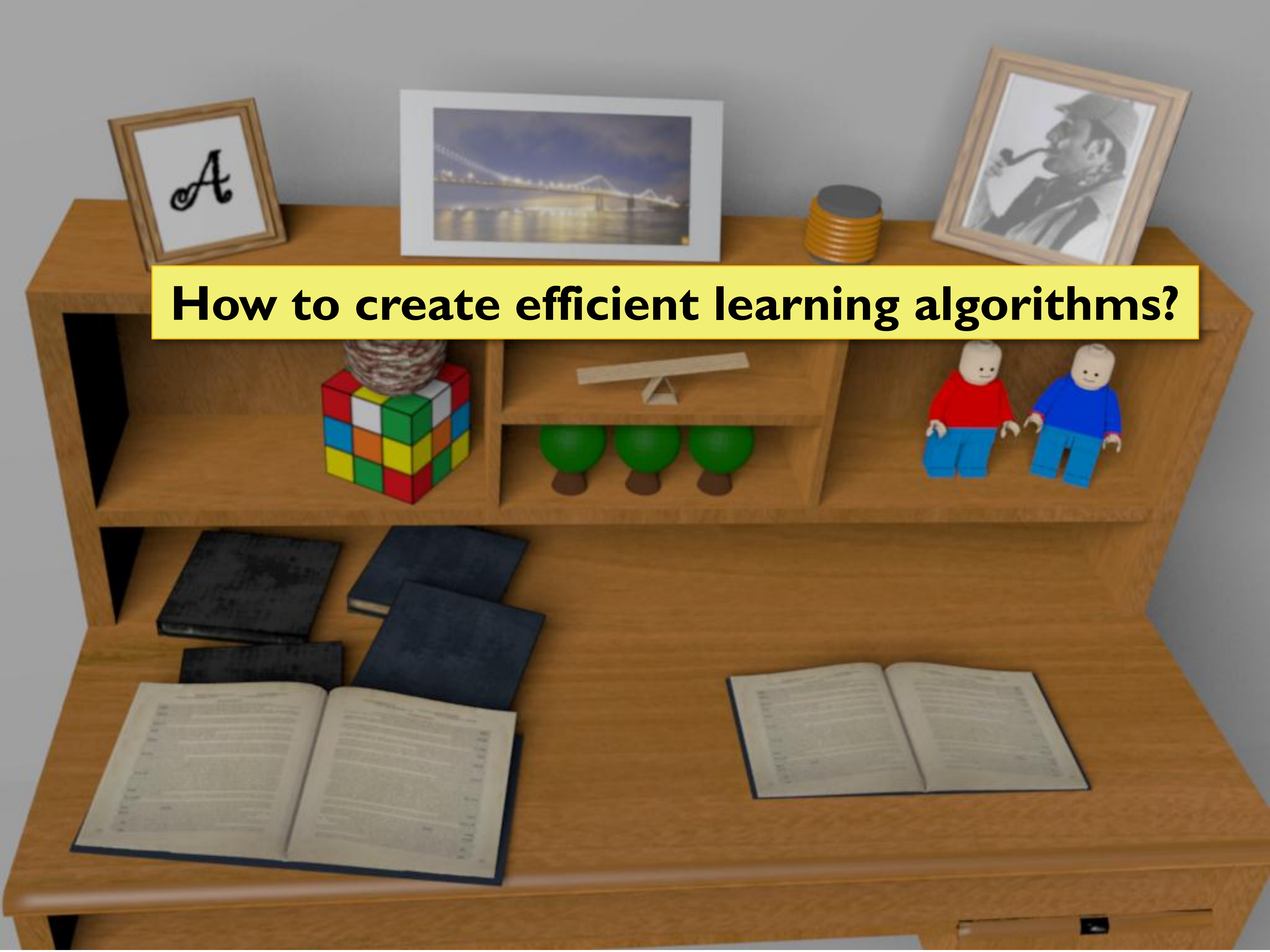
Why should a model, trained on one set of data, work well on future data?

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

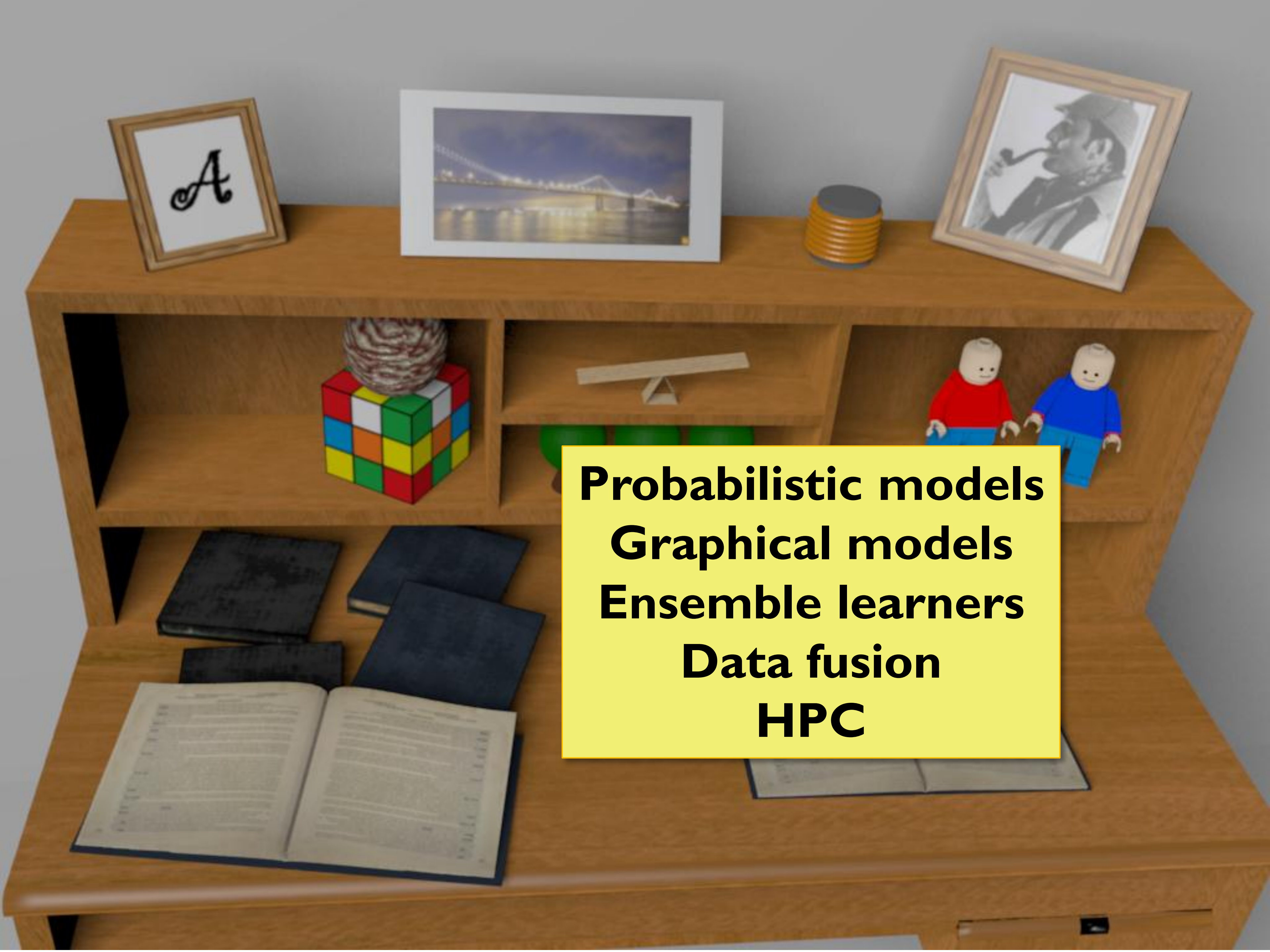
Semi-supervised learning

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, …

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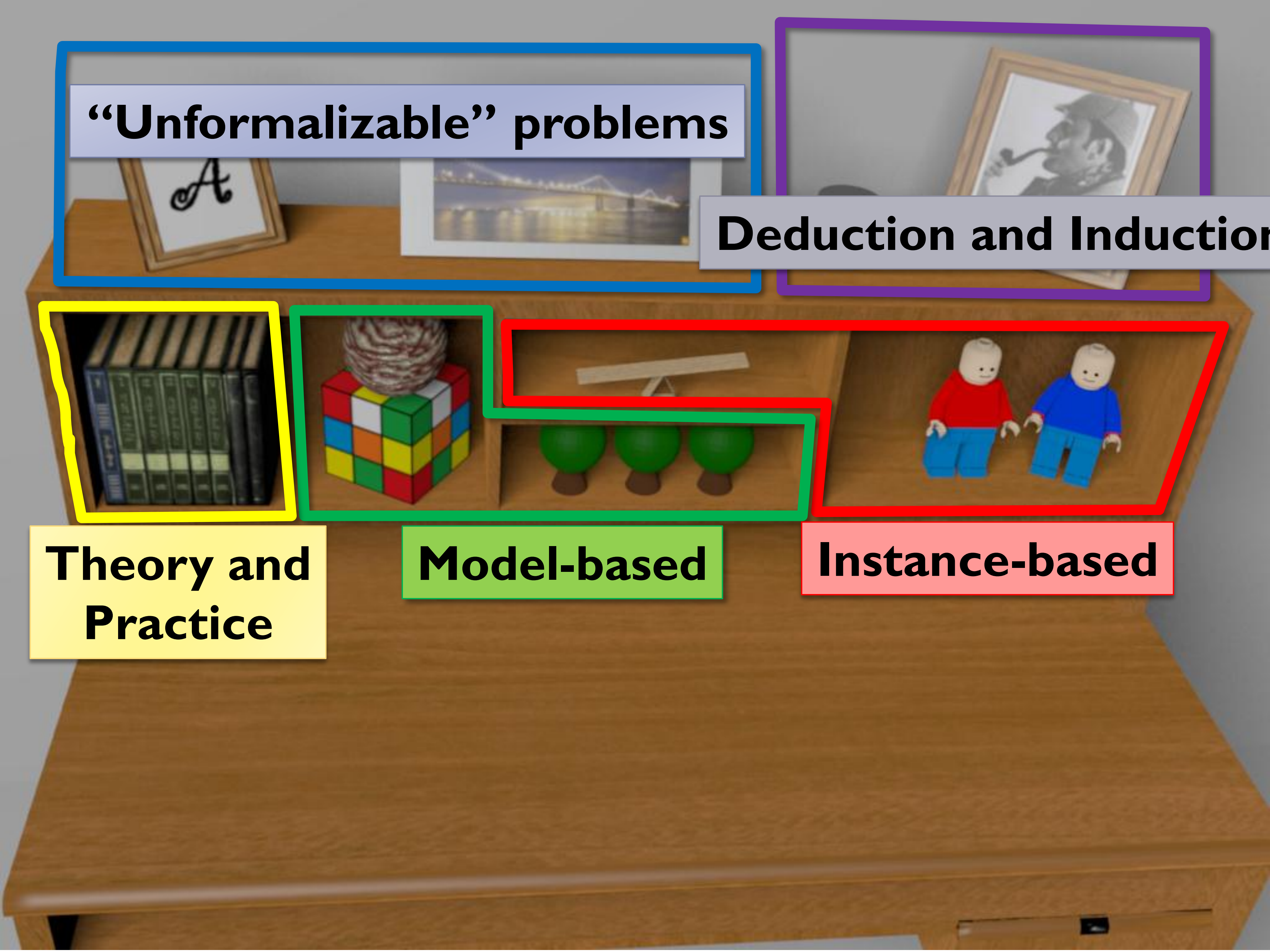


“Unformalizable” problems

Deduction and Induction

Theory and Practice

Model-based

Instance-based

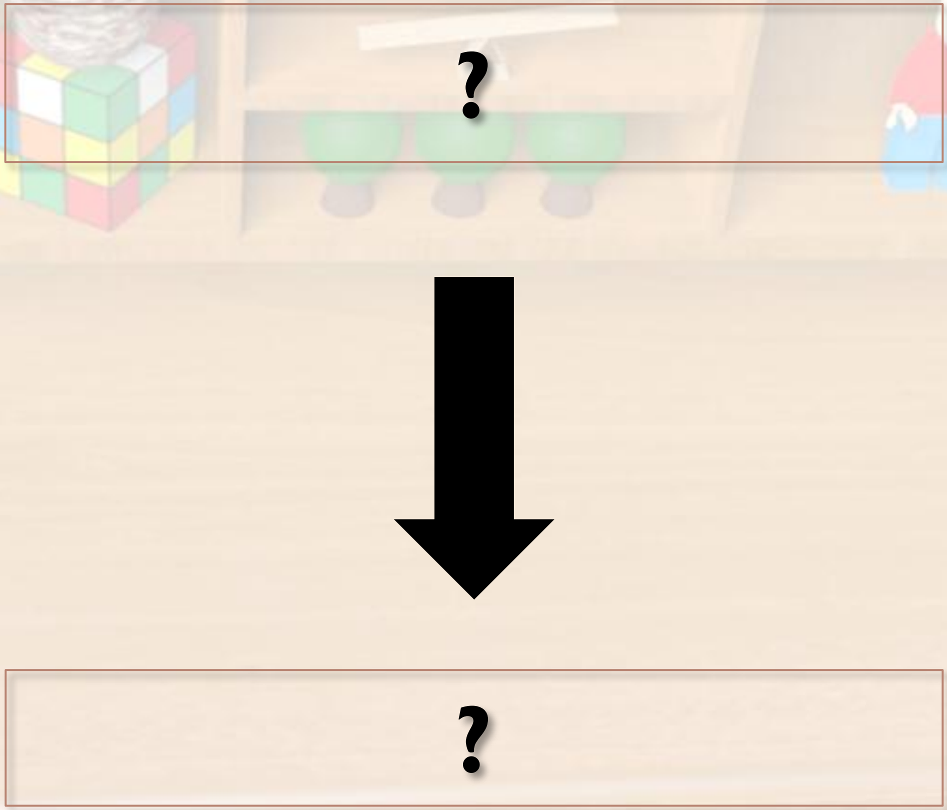
Quiz

- 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

$$\mathrm{argmin}_{\boldsymbol{w}} \;\_\_\_\_\_\_\_\_\_\_\_\_ + \lambda \;\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

Quiz

- Two important components of machine learning:



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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**

Questions?