



## Lesson 11: Real-World ML Examples (Dimensionality Reduction, Unsupervised and Reinforced Learning)

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SPRING 2022



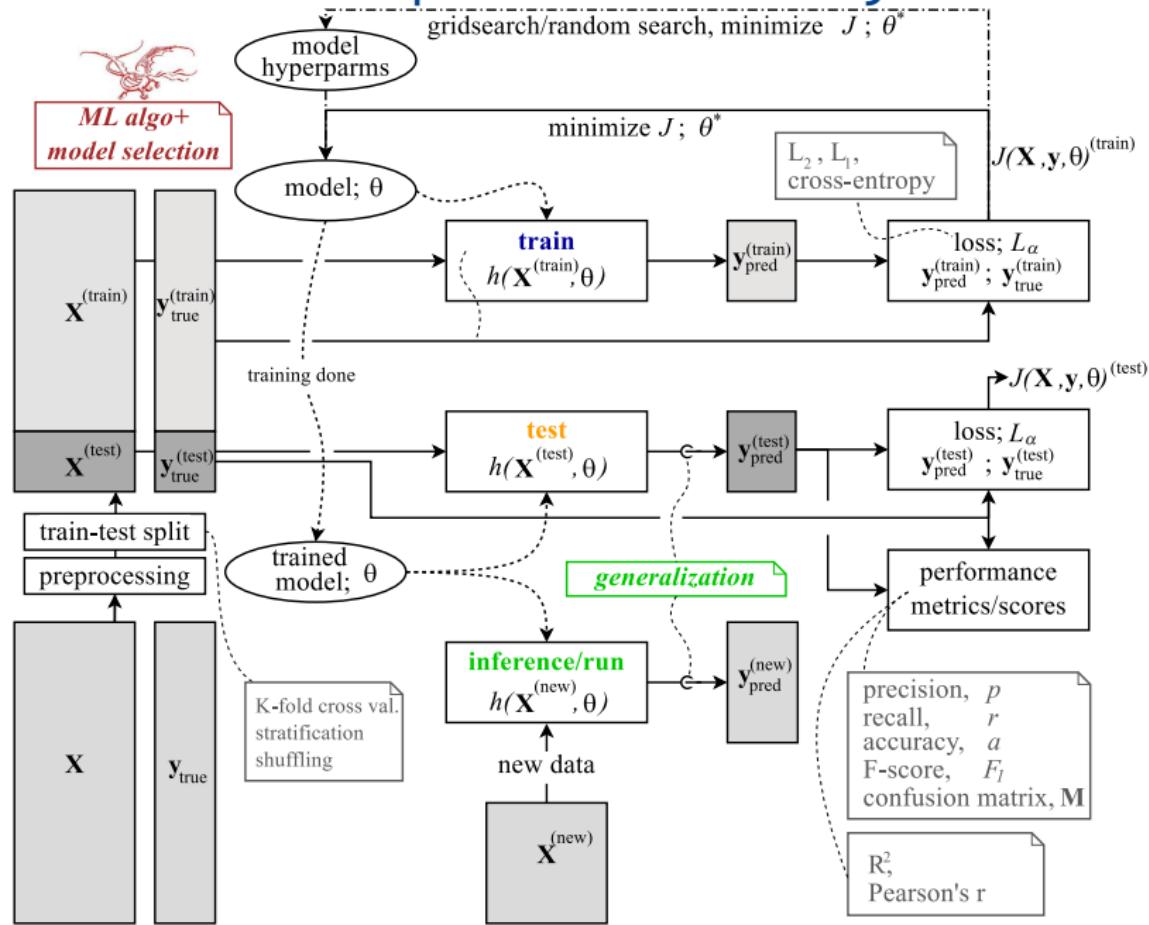
# Agenda

- ▶ Presentation by Enversion,
- ▶ RESUMÉ: The Map,
  - ▶ MNIST Search Quest II Hi-Score Cake.
- ▶ Real-world Examples,
- ▶ (Dimensionality Reduction,)
- ▶ (Unsupervised Learning,)
- ▶ (Reinforced Learning.)

# RESUMÉ: THE MAP

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# RESUMÉ: The Map (ML block diagram)

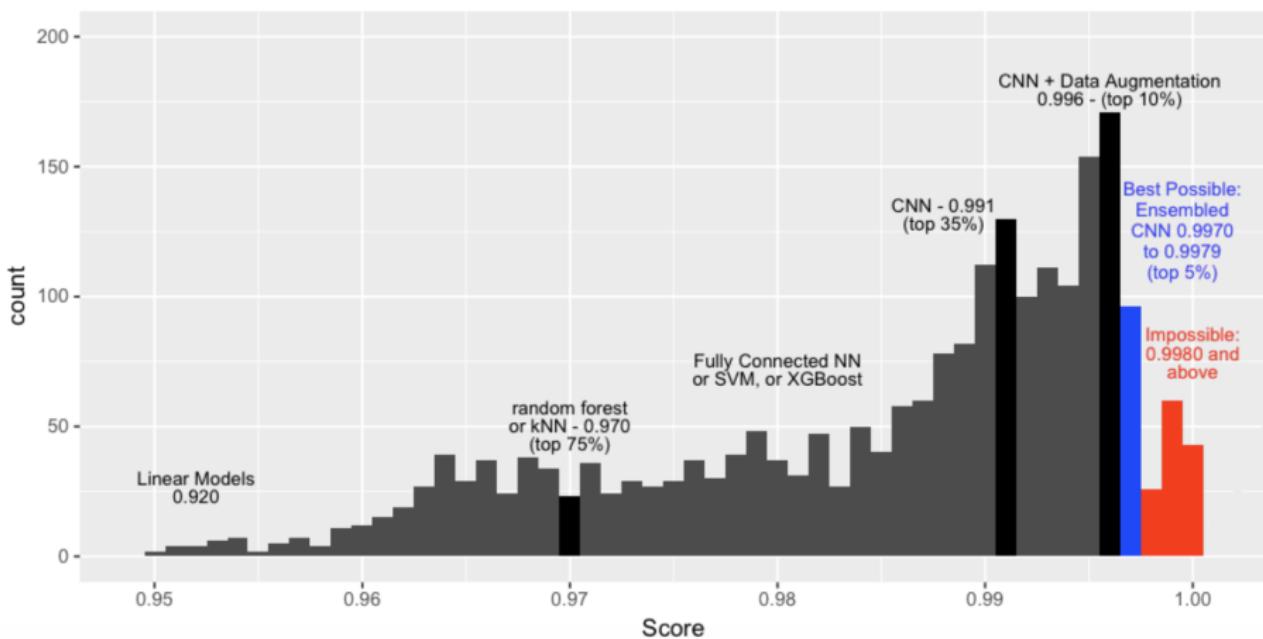


# Qd MNIST Search Quest II

## The LeNET-5 Architecture on MNIST

## Histogram of Kaggle MNIST

public leaderboard scores, July 15 2018



# Qd MNIST Search Quest II

ITMAL Search Quest

Send message...

E21: Grp28, score=0.973, KNN

F21: Grp20, score=0.979, SVC

???: Grp??, score=1.000, NN

Training time?

Dette semester:

Grp05: best: dat=mnist, score=0.99048,

CTOR for best model: SGDClassifier(alpha=0.001, eta0=0.01, penalty='l1',  
learning\_rate='invscaling', loss='perceptron',  
max\_iter=100000, penalty='l1')

Grp29: best: dat=iris\_, score=0.99048, model=SGDClassifier ??

Grp01: best: dat=mnist, score=0.98057, model=RandomForestClassifier

Grp32: best: dat=mnist, score=0.97071, model=RandomForestClassifier

Grp04: best: dat=mnist, score=0.96890, model=RandomForestClassifier

Grp15: best: dat=mnist, score=0.96845, model=RandomForestClassifier

Grp19: best: dat=mnist, score=0.96738, model=RandomForestClassifier

Grp28: best: dat=mnist, score=0.96659, model=RandomForestClassifier

Grp02: best: dat=mnist, score=0.96622, model=RandomForestClassifier

Grp14: best: dat=mnist, score=0.96339, model=RandomForestClassifier

Grp23: best: dat=mnist, score=0.91690, model=SGDClassifier

Grp12: best: dat=iris\_, score=0.91534, model=SGDClassifier

Grp08: best: dat=mnist, score=0.91057, model=SGDClassifier

Grp16: best: dat=mnist, score=0.90390, model=SGDClassifier

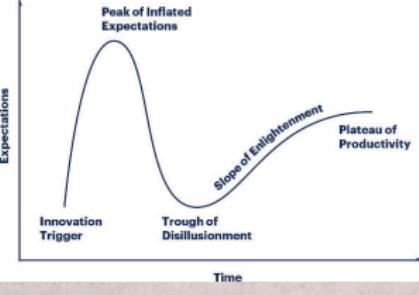
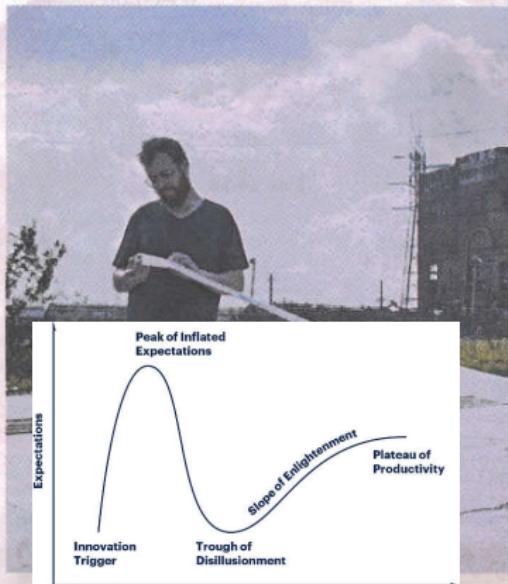
```
24/03 14:53> "Grp20: best: dat=mnist, score=0.90357,  
model=SGDClassifier(alpha=0.1,eta0=0.001,1_l_ratio=0.001,learning_rate='adaptive',loss='log',max_iter=10,penalty='l1')"  
22/03 17:16> "Grp18: best: dat=mnist, score=0.89893, model=SGDClassifier"  
22/03 16:39> "Grp10: best: dat=mnist, score=0.89514,  
model=SGDClassifier(alpha=0.001,eta0=0.0001,1_l_ratio=1,loss='log',max_iter=5,penalty='l1')"  
22/03 12:58> "Grp1: best: dat=mnist, score=0.89255, model=SGDClassifier(eta0=0.005,  
learning_rate='adaptive', tol=0.001)"  
22/03 12:58> "Grp 12: best: data=mnist, score=0.909, model=SGDclassifier(alpha = 10,  
eta0=0.01)"  
22/03 12:58> "Grp12: best: dat=mnist, score=0.90872,  
model=SGDClassifier(alpha=0.001,eta0=0.01,penalty='l1')"  
22/03 11:42> "Grp 12: best: dat=iris, score=0.91534,  
model=SGDClassifier(alpha=0.001,eta0=0.001,penalty='l1')"  
22/03 11:42> "Grp 11: best: data=mnist, score=0.89594, model=SGDclassifier"  
21/03 19:51> "Grp17: best: data=mnist, score=0.89702, model=SGDclassifier"  
20/03 14:23> "Grp29: best: dat=mnist, score=0.89176,  
model=SGDClassifier(alpha=0.001,eta0=0.01,penalty='l1')"  
19/03 17:55> "Høvse, 19/03 kl. 17.51 er ikke grp 9, men grp 29 :> Grp. 29: best: dat=iris  
score=0.99048, model=SGDclassifier(alpha=0.1,eta0=0.001,penalty='l1')"  
19/03 17:54> "Grp22: This cake is a lie (e.g. it crashed my computer)"  
19/03 17:51> "Grp. 9: best: dat=iris, score=0.99048,  
model=SGDClassifier(alpha=0.01,eta0=0.001,penalty='l1')"  
19/03 17:20> "Grp19: best: data=mnist, score=0.96738,  
model=RandomForestClassifier(criterion='gini',n_estimators=200)"
```

# REAL-WORLD EXAMPLES

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# På roadtrip med en insekthjerne

BY MARCEL BORIO

2016 slog computeren AlphaGo den 18-dobbelte verdensmester i brætspillet Go, Lee Sedol. Go er et kompliceret og abstrakt spil, som kræver intuition og kreativitet, men den kunstige intelligens vandt med en række innovative træk overlegen.

Underveis i spiller troede kommentatorerne

Inden karsturen havde han brugt måneder

Inden kæreturen havde han brugt måneder på at træne maskinen. Han satte den til at læse et stort korpus af moderne litteratur fra hele verden, så den kunne lære at skrive af de store forfattere.

»Det fungerer ligesom autokorrekturen på din telefon, bare klogere og trænet på en mere litterær kilde. Den skriver bogstav for bogstav, så den har lært sig selv at forudsige det næste.

„Har du dekonstrueret dem. Efter at have læst den i ét stræk og fået turen lidt på afstand har romanen fået en universalitet, så jeg kan projicere mine egne oplevelser ind i teksten,“ uddyber Goodwin.

— Du har beskrevet projektet som at lære en insekthjerne at skrive. Hvad betyder det?

»Jeg forsøgte at pointere, at maskinen ikke er på niveau med den menneskelige hjerne. Et artificielt neuralt net er en algoritme, der er lavet som vi tror, hjernen fungerer. Jeg synes



“Det er et forsøg på at skabe en ny brugerflade for at skrive. På en måde har jeg jo skrevet en roman med en bille,” fortæller Ross Goodwin om sin AI-forfattede bog *1 the road*.



# Hvad siger pressen?

Dato: 26 november 2021..

## Sidste dag med selvkørende busser i Aalborg

LÆS OP

ORDBOG

TEKST

AF

Jesper Knox Sørensen

Efter næsten to års drift er et forsøg med selvkørende busser i Aalborg Øst slut, og der er ingen planer om at genoptage det.

Det til trods for, at beboerne i området har været glade for busserne.

- Det er selvfølgelig ærgerligt for beboerne, for det er dem, vi har sat projektet i søen for at hjælpe, siger projektleder Maria Vestergaard fra Aalborg Kommune.

Hun forventer dog, at vi vil se selvkørende busser igen i fremtiden.

Men det nuværende projekt bliver altså ikke forlænget.

- Vores tilladelse udløber. Og de nuværende køretøjer er efterhånden forældet teknologi.

De selvkørende busser rullede ud på Astrupstien i Aalborg Øst i marts 2020, lige inden den første corona-nedlukning.

om migrantkrise i L

54 MIN. SIDEN

Sidste dag med selvkørende busser i Aalborg

I DAG KL. 09:04

To ministre udsprængt af minkommisionen

I DAG KL. 09:03

Aarhusiansk borgmester formand for KL: Rasmus Venstre

I DAG KL. 08:57

EU-formand efterlyser: Alle fly fra den østeuropæiske lande bør standses

I DAG KL. 08:40

Udvalg drøfter muligheden for at gendanne sms'er

I DAG KL. 08:30

Sydafrika kalder ind

# BREAKING

NYHEDER SPORT UNDERHOLDNING

# LIGE NU:

ALLE AI OVERSKRIFTER  
HAVDE MODALVERBER  
I NUTID (*skal give*)

MEN SÅ KOM  
DENNE.....

# BREAKING NEWS

Første ML artikel i datid: “Sådan gav ML resultater..”

# ING/VERSION2

NYHEDER BLOGS DEBAT JOB SEKTIONER ▾ MERE ▾ IT-TALENT INFOS

Sådan skal AI give resultater i det danske sundhedsvæsen



Masser af signaturprojekter skal anvende kunstig intelligens på sundhedsområdet. AI-forbedret diagnostik dominerer blandt de 25 projekter.



# A computer vision system to monitor the infestation level of Varroa destructor in a honeybee colony

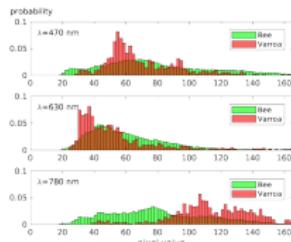


Figure 5: Histograms of bee and varroa pixel intensity values, for the spectral wavelengths 470 nm, 630 nm, and 780 nm respectively, recorded with the JAI camera. The image path is via the mirror-window-mirror, i.e., data were sampled with the setup given in figure 6. The image data for the histogram is the single bee with mite seen in figure 6.



Figure 6: The actual unprocessed camera view of the bees

spectively. The CM analysis was able to rank all wavelengths combinations, using one, two, three or four distinct wavelengths to give a ranking list of ‘best’ combination also taking the JAI camera spectrum into account.

The CM value of the actual choose wavelengths combination (470-630-780 nm) gave a rank just below the CM average score. This CM analysis was conducted after picking the actual used wavelengths, so later versions of the VMU might want to investigate a CM combination with a higher rank.

A specially designed diffuser and a number of narrow spectral LI were mounted in the camera focal diffuse illuminant fixtures.

Figure 6 disp along the passa era, with the gre with the NIR in

### 2.3.3. Real-time processing

A color and motion of 1296×96 from the camera over two separate sustained by ing frames real-

These data will post-process first matching rally coalescing producing a 24 the later image

Lossless real-time can be applied bandwidth that

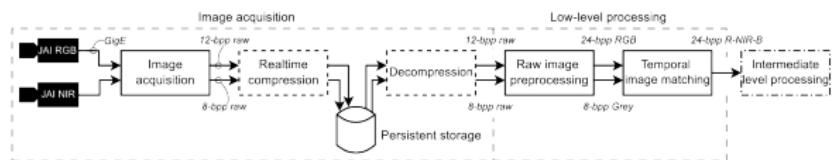


Figure 7: The low-level image processing pipeline. Raw camera images are stored on disk for later retrieval and post-processing. 12- and 8-bits per-pixel are used as the raw JAI/Bayer packed pixel format for the RGB and IR images respectively. Lossless, real-time compression can be introduced if persistent storage bandwidth is less than the raw-stream image rate of 93 MB/sec. The 12- and 8-bpp raw images from the network arrives out-of-order with respect to each other, hence the need for the temporal image matching.

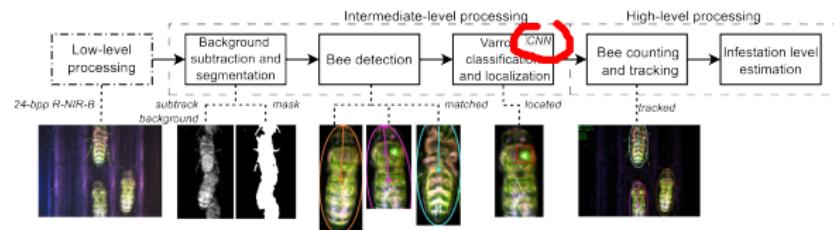
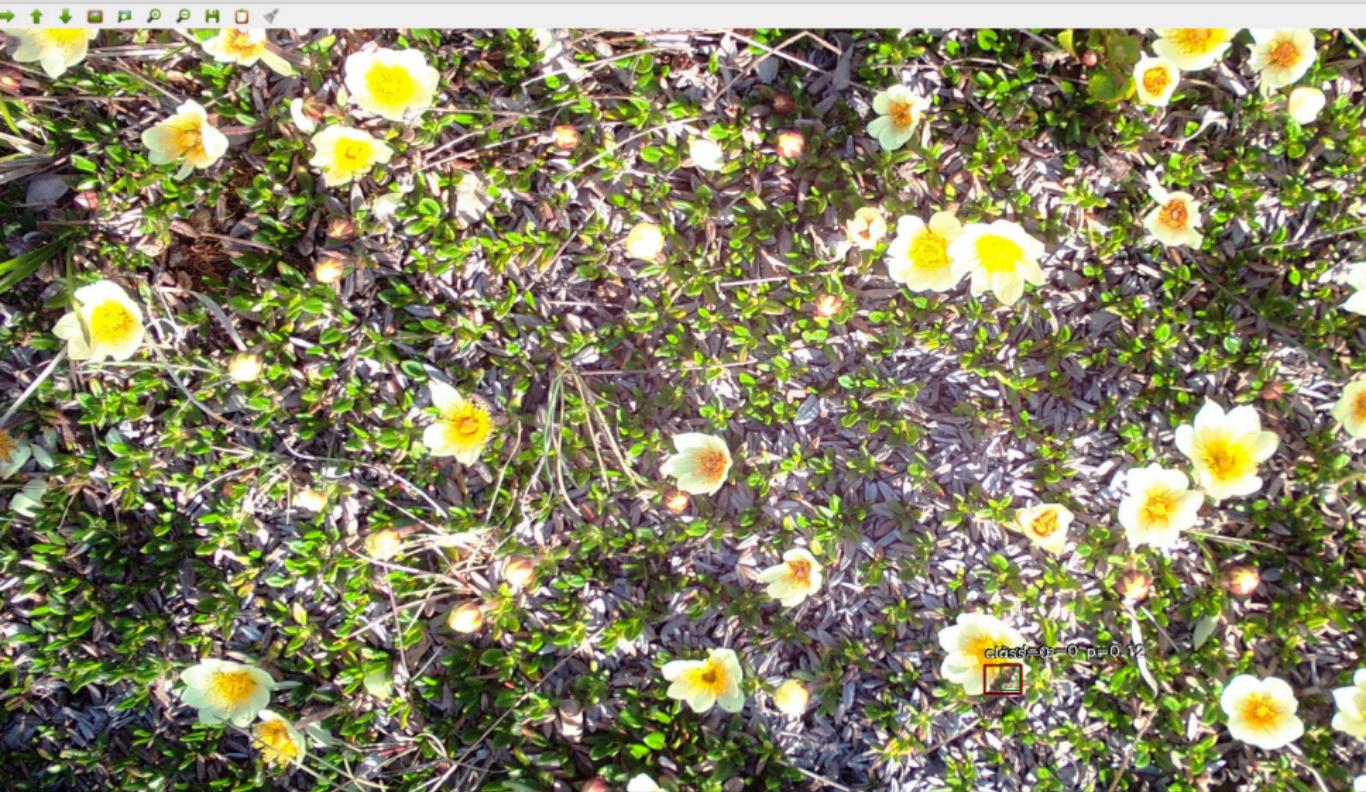
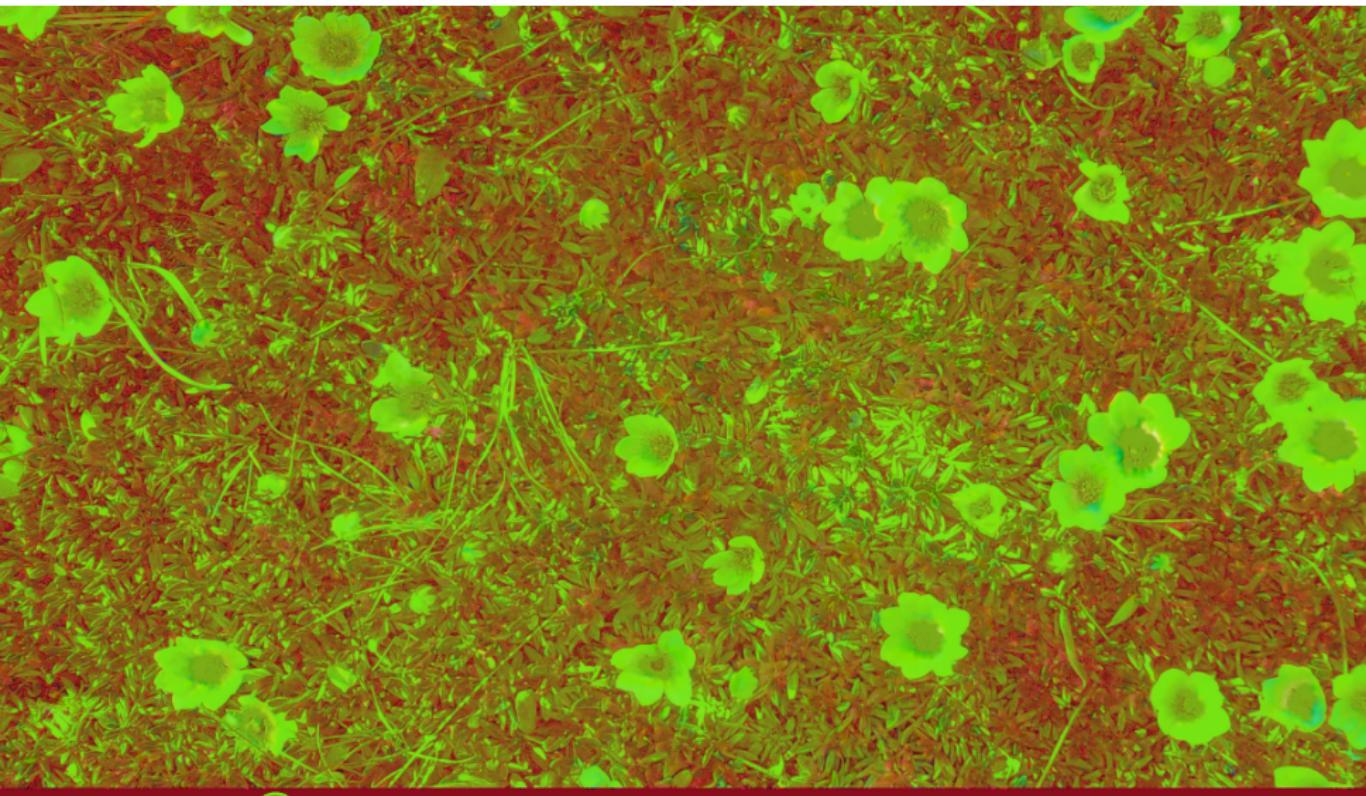


Figure 8: The processing pipeline of the intermediate- to high-level image processing algorithms to analyze and count the number of bees with *Varroa destructor*. A trained convolutional neural network (CNN) was used for the Varroa classification and localization stage.

# BA Project: generic annotation tool



# Insects...where?



WINGSCAPES



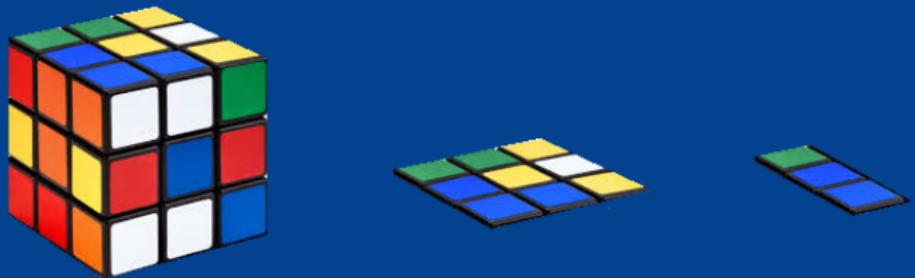
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07 JUN 2017 06:07 p

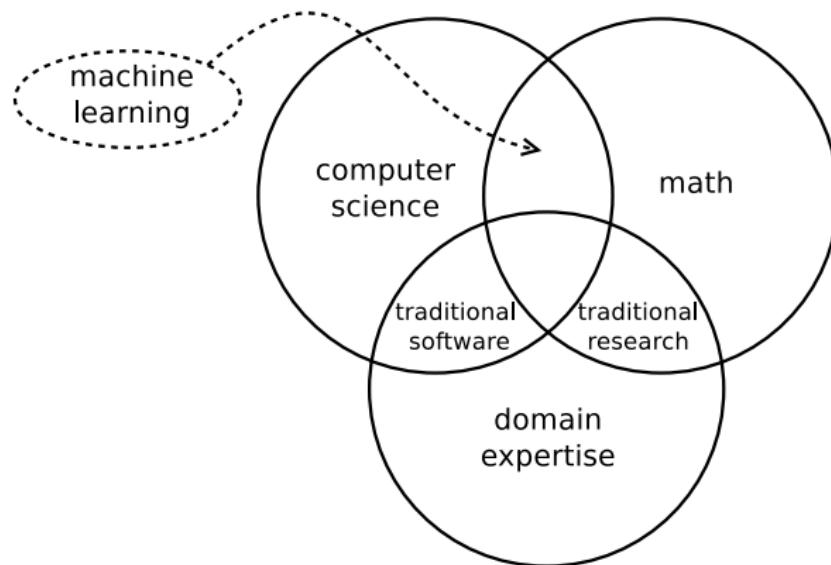
# DIMENSIONALITY REDUCTION

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# Machine learning baggrund

## Machine learning: ekspertise



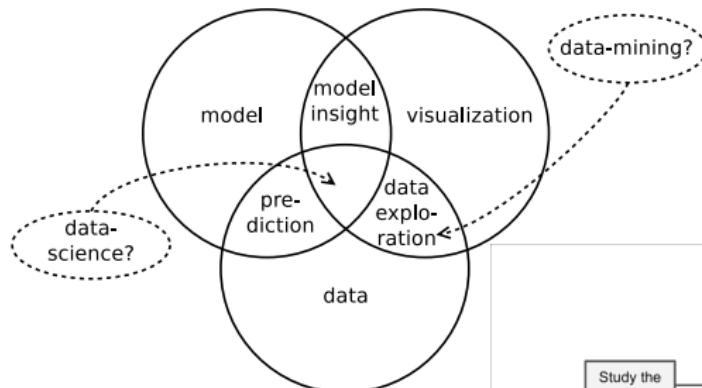
- ▶ ML ekspert er computer science og matematik ekspert.
- ▶ ML ekspert er IKKE (nødvendigvis) domæne ekspert!

### NOTE:

[<https://imarticus.org/what-are-the-skills-you-need-to-become-a-machine-learning-engineer/>]

# Machine learning baggrund

Machine learning: data science ekspert



- ▶ fra white-box domæne ekspert til black-box ML data scientist,
- ▶ stadig polytekniker:
  - ▶ math- og computer science,
  - ▶ pattern-recognition,
  - ▶ neurocomputation,
  - ▶ datamining,
  - ▶ visualization,
  - ▶ etc..

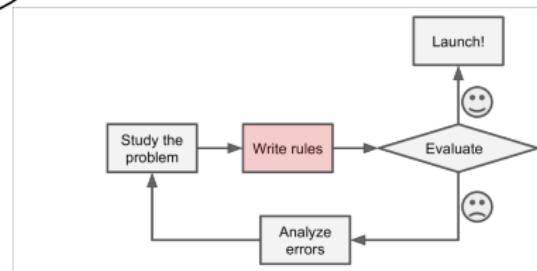


Figure 1-1. The traditional approach

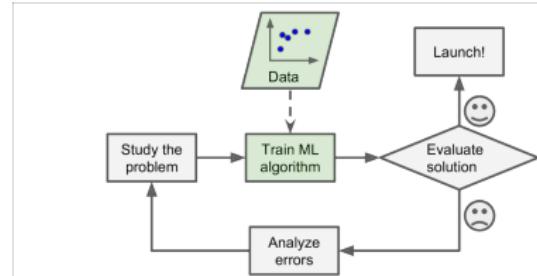
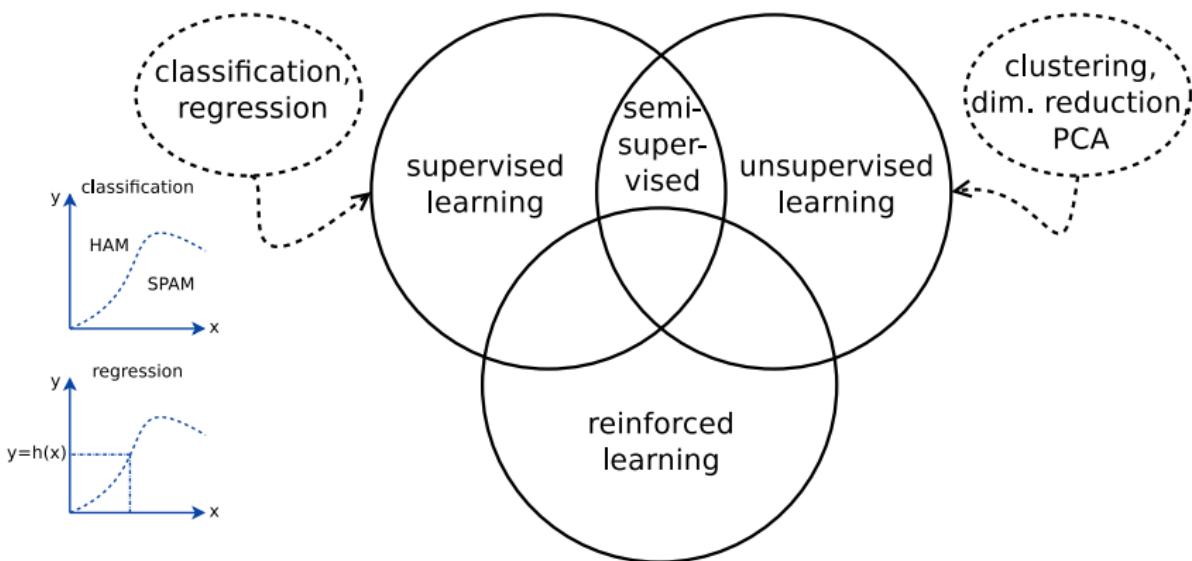


Figure 1-2. Machine Learning approach

# Machine learning taksonomi

## Machine learning læringstyper



# The Course of Dimensionality

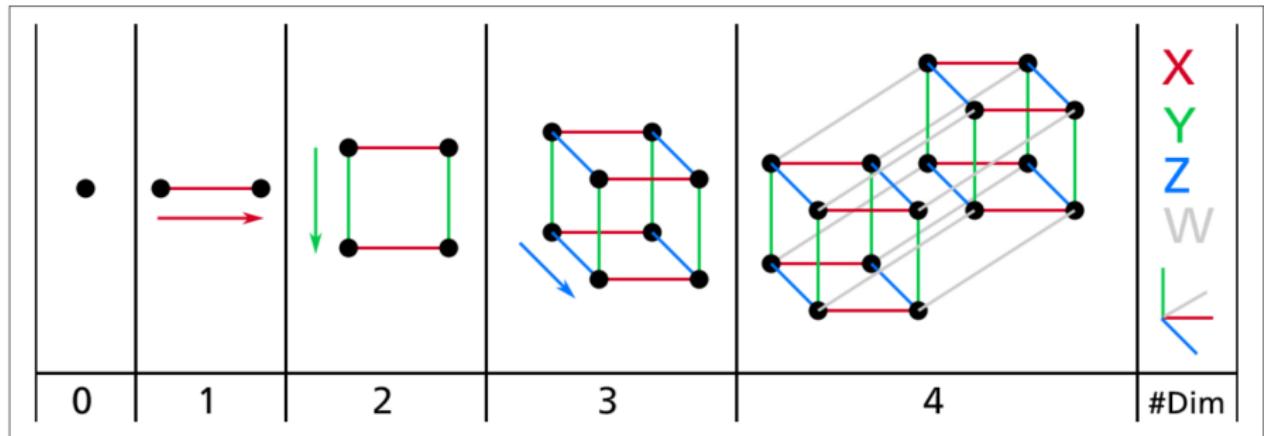


Figure 8-1. Point, segment, square, cube, and tesseract (0D to 4D hypercubes)<sup>2</sup>

# Manifold Learning

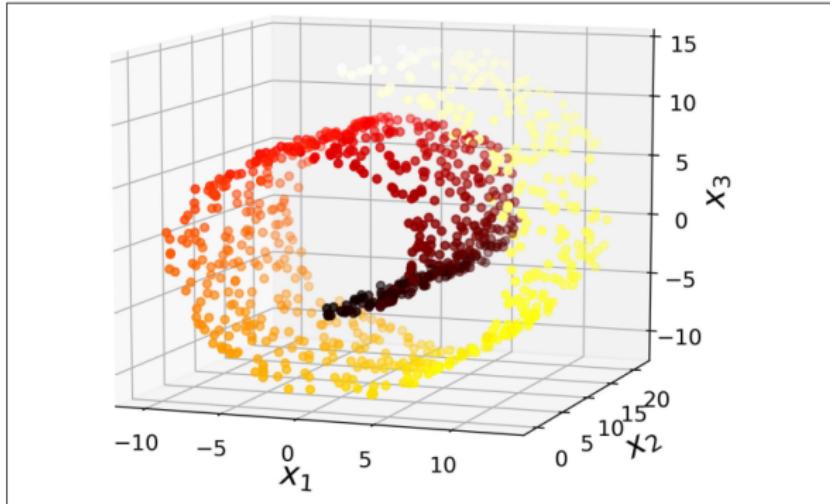


Figure 8-4. Swiss roll dataset

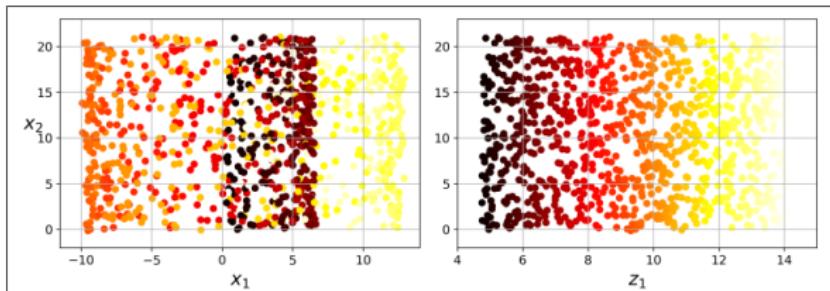


Figure 8-5. Squashing by projecting onto a plane (left) versus unrolling the Swiss roll (right)

# Manifold Learning

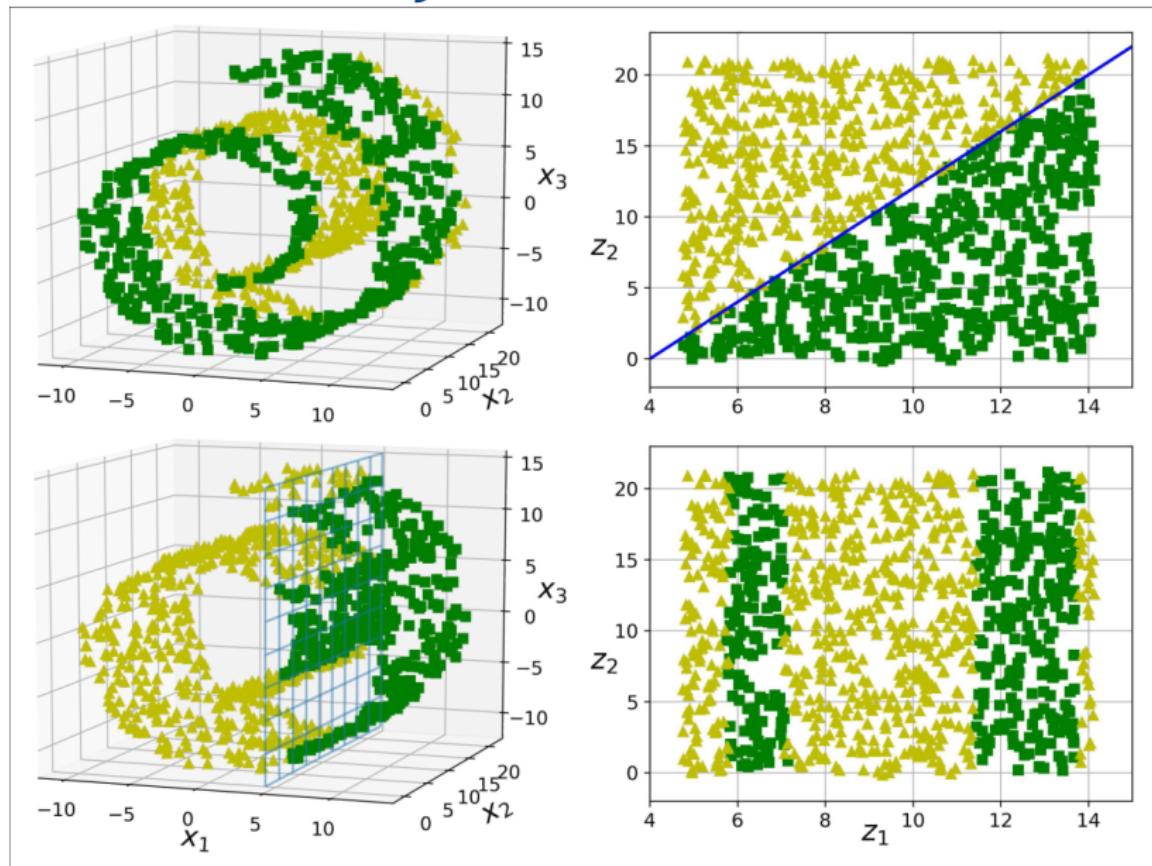
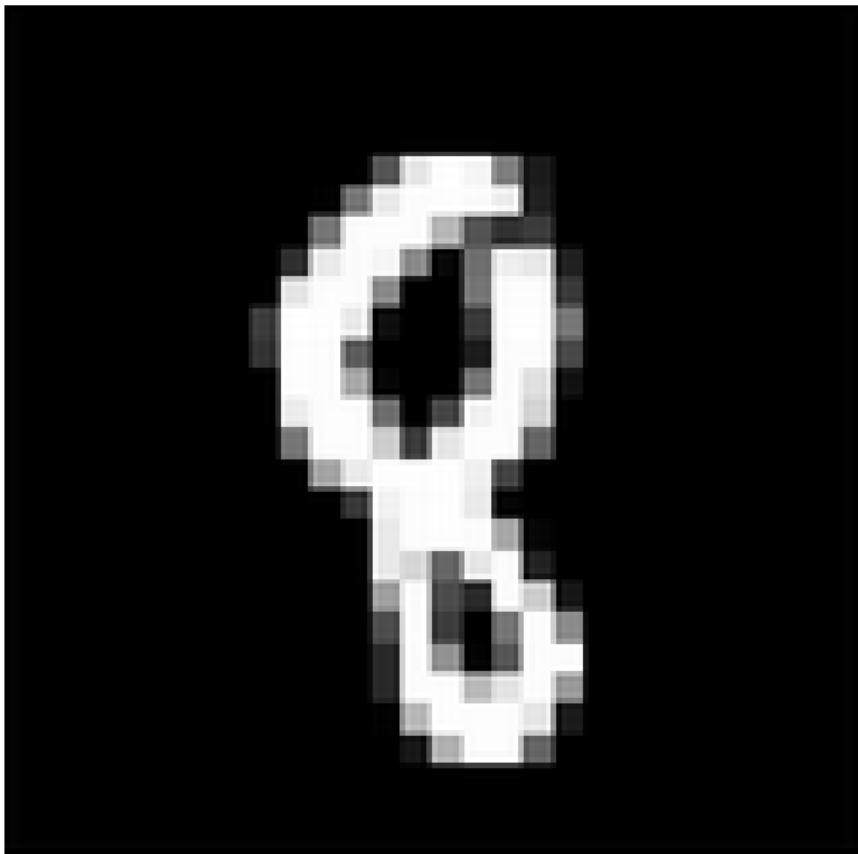


Figure 8-6. The decision boundary may not always be simpler with lower dimensions

# Manifold Learning

Random generated 28x28 image? MNIST is on a manifold..



# PCA

## Projecting Down to $d$ Dimensions

Once you have identified all the principal components, you can reduce the dimensionality of the dataset down to  $d$  dimensions by projecting it onto the hyperplane defined by the first  $d$  principal components. Selecting this hyperplane ensures that the projection will preserve as much variance as possible. For example, in [Figure 8-2](#) the 3D dataset is projected down to the 2D plane defined by the first two principal components, preserving a large part of the dataset's variance. As a result, the 2D projection looks very much like the original 3D dataset.

To project the training set onto the hyperplane, you can simply compute the matrix multiplication of the training set matrix  $\mathbf{X}$  by the matrix  $\mathbf{W}_d$ , defined as the matrix containing the first  $d$  principal components (i.e., the matrix composed of the first  $d$  columns of  $\mathbf{V}$ ), as shown in [Equation 8-2](#).

*Equation 8-2. Projecting the training set down to  $d$  dimensions*

$$\mathbf{X}_{d\text{-proj}} = \mathbf{X}\mathbf{W}_d$$

The following Python code projects the training set onto the plane defined by the first two principal components:

```
W2 = Vt.T[:, :2]
X2D = X_centered.dot(W2)
```

# PCA for Image Compression

```
pca = PCA(n_components = 154)  
X_reduced = pca.fit_transform(X_train)  
X_recovered = pca.inverse_transform(X_reduced)
```

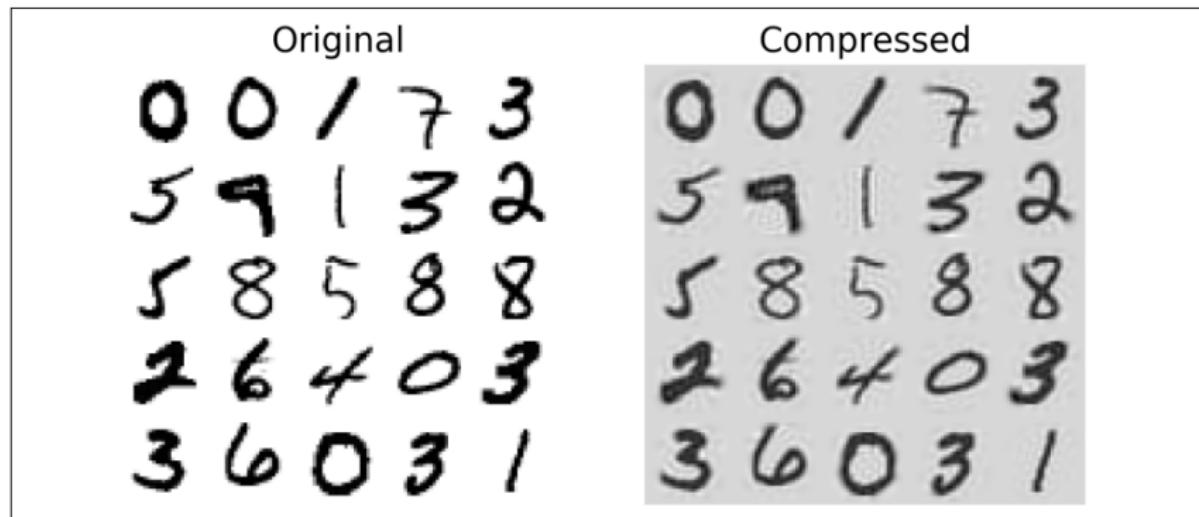
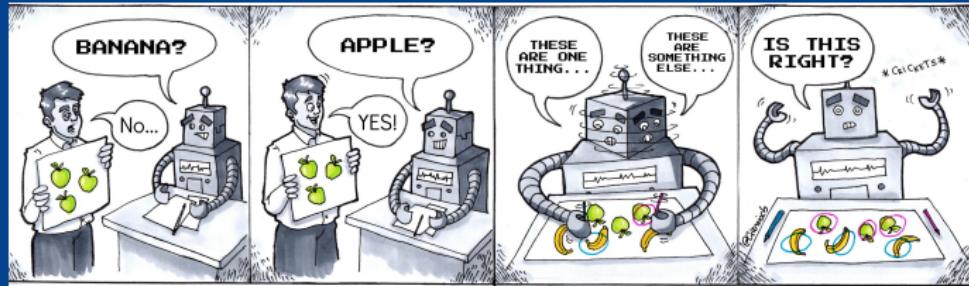


Figure 8-9. MNIST compression preserving 95% of the variance

# UNSUPERVISED LEARNING

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Supervised Learning

Unsupervised Learning

# K-Means

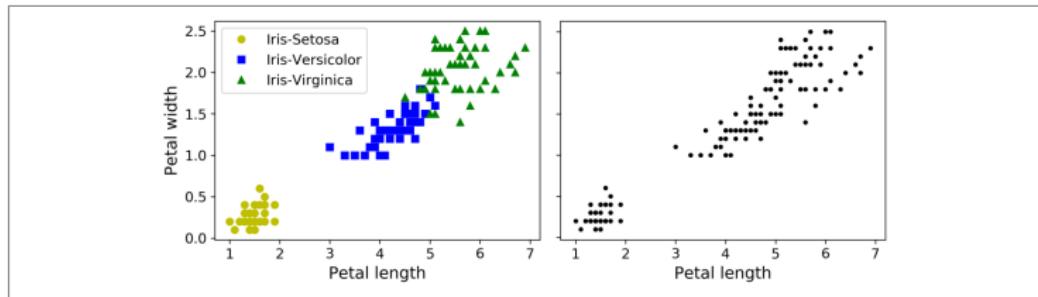


Figure 9-1. Classification (left) versus clustering (right)

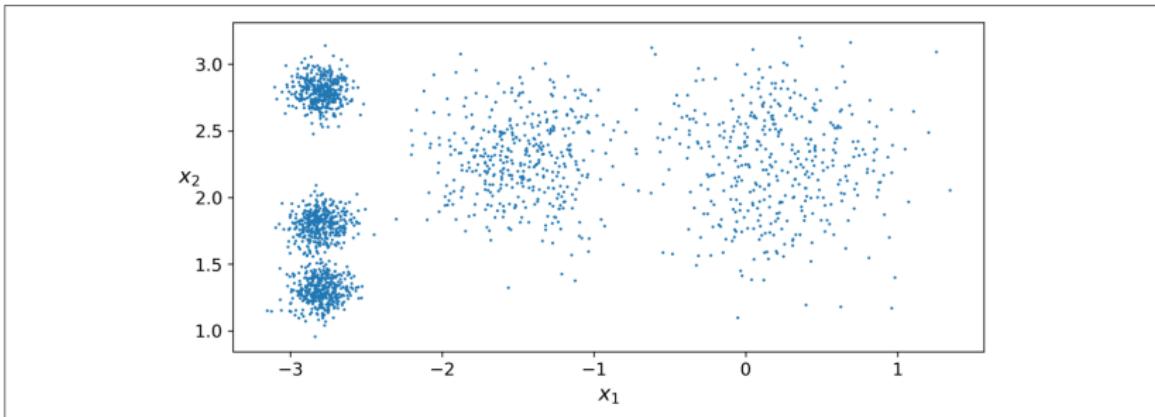
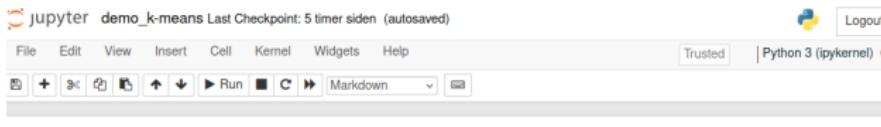


Figure 9-2. An unlabeled dataset composed of five blobs of instances

# K-Means

## Scikit-learn demo..

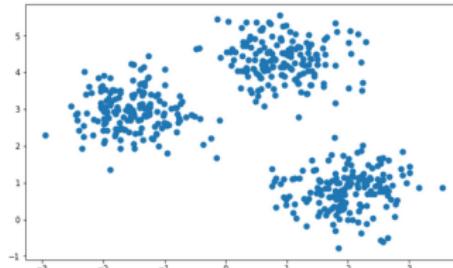


### K-Means Demo

Source: <http://deciphertoknow.com/mnist-k-means-clustering/>

```
In [7]: import matplotlib.pyplot as plt
from sklearn.datasets import make_blobs

features, label = make_blobs(n_samples=500, centers=3, cluster_std=0.55, random_state=0)
plt.figure(figsize=(10, 6))
plt.scatter(features[:, 0], features[:, 1], s=50);
```

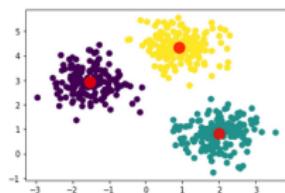


```
In [12]: from sklearn.cluster import KMeans
kmeans = KMeans(n_clusters=3)
kmeans.fit(features)
kmeansLabels = kmeans.predict(features)
plt.scatter(features[:, 0], features[:, 1], c=kmeansLabels, s=50, cmap='viridis')

clusterCenters = kmeans.cluster_centers_
plt.scatter(clusterCenters[:, 0], clusterCenters[:, 1], c='red', s=200, alpha=0.8)

print("OK")
```

OK



# K-Means

Algorithm..

- ▶ Choose K random points as cluster centers or cluster means.
- ▶ For all the N data points: Assign each data point  $\mathbf{x}_i$  to one of the K clusters—i.e that cluster whose center is closest to the data point
- ▶ For K clusters repeat

$$C(i) = \arg \min_{\mathbf{m}_k} \|\mathbf{x}_i - \mathbf{m}_k\|^2, \quad i = 1, \dots, N$$

- ▶ Update the cluster center by taking the average of points within cluster.
- ▶ Repeat above two steps until converge or clusters mean doesn't change.

# K-Means

```
from sklearn.cluster import KMeans
k = 5
kmeans = KMeans(n_clusters=k)
y_pred = kmeans.fit_predict(X)

>>> y_pred
array([4, 0, 1, ..., 2, 1, 0], dtype=int32)
>>> y_pred is kmeans.labels_
True
```

We can also take a look at the 5 centroids that the algorithm found:

```
>>> kmeans.cluster_centers_
array([[-2.80389616,  1.80117999],
       [ 0.20876306,  2.25551336],
       [-2.79290307,  2.79641063],
       [-1.46679593,  2.28585348],
       [-2.80037642,  1.30082566]])
```

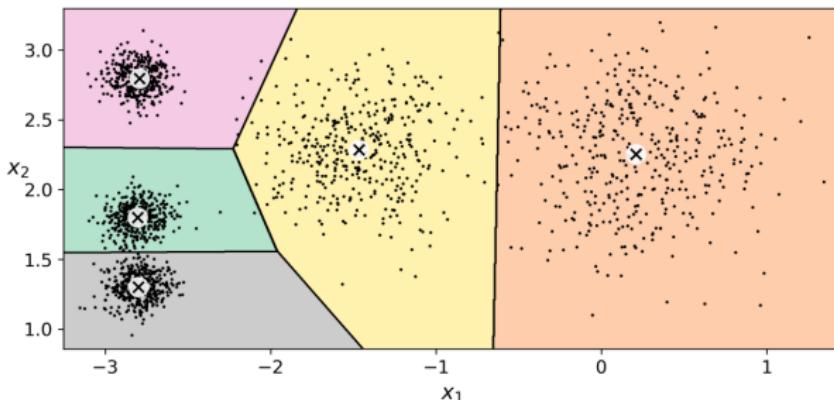


Figure 9-3. K-Means decision boundaries (Voronoi tessellation)

# K-Means Algorithm

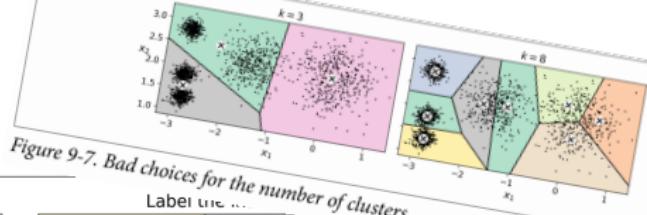
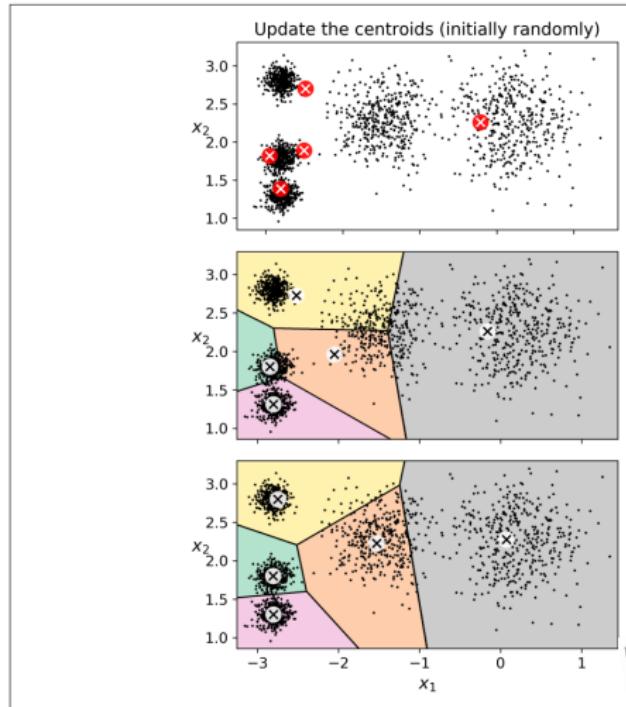
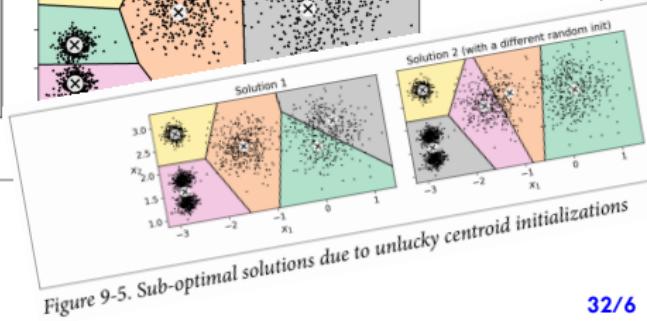


Figure 9-4. The K-Means algorithm



# K-Means on MNIST

## Using Clustering for Semi-Supervised Learning

```
k = 50
kmeans = KMeans(n_clusters=k)
X_digits_dist = kmeans.fit_transform(X_train)
representative_digit_idx = np.argmin(X_digits_dist, axis=0)
X_representative_digits = X_train[representative_digit_idx]
```

Figure 9-13 shows these 50 representative images:

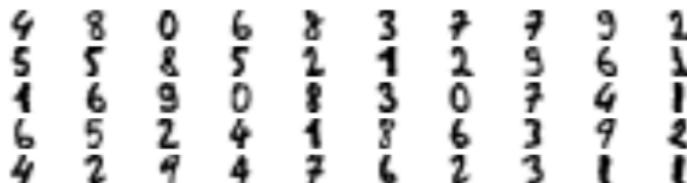


Figure 9-13. Fifty representative digit images (one per cluster)

Now let's look at each image and manually label it:

```
y_representative_digits = np.array([4, 8, 0, 6, 8, 3, ..., 7, 6, 2, 3, 1, 1])
```

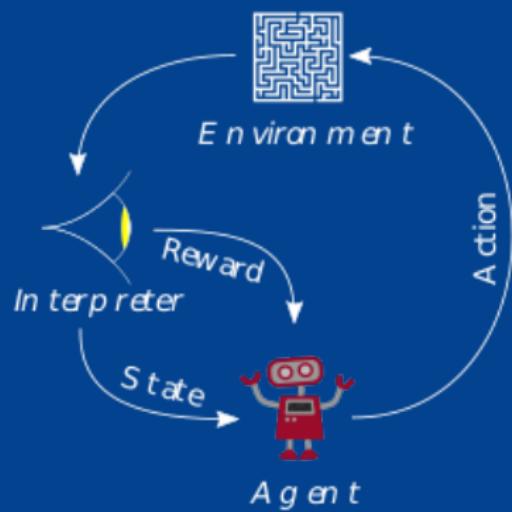
Now we have a dataset with just 50 labeled instances, but instead of being completely random instances, each of them is a representative image of its cluster. Let's see if the performance is any better:

```
>>> log_reg = LogisticRegression()
>>> log_reg.fit(X_representative_digits, y_representative_digits)
>>> log_reg.score(X_test, y_test)
0.9244444444444444
```

Wow! We jumped from 82.7% accuracy to 92.4%, although we are still only training

# REINFORCED LEARNING

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# Reinforced Learning

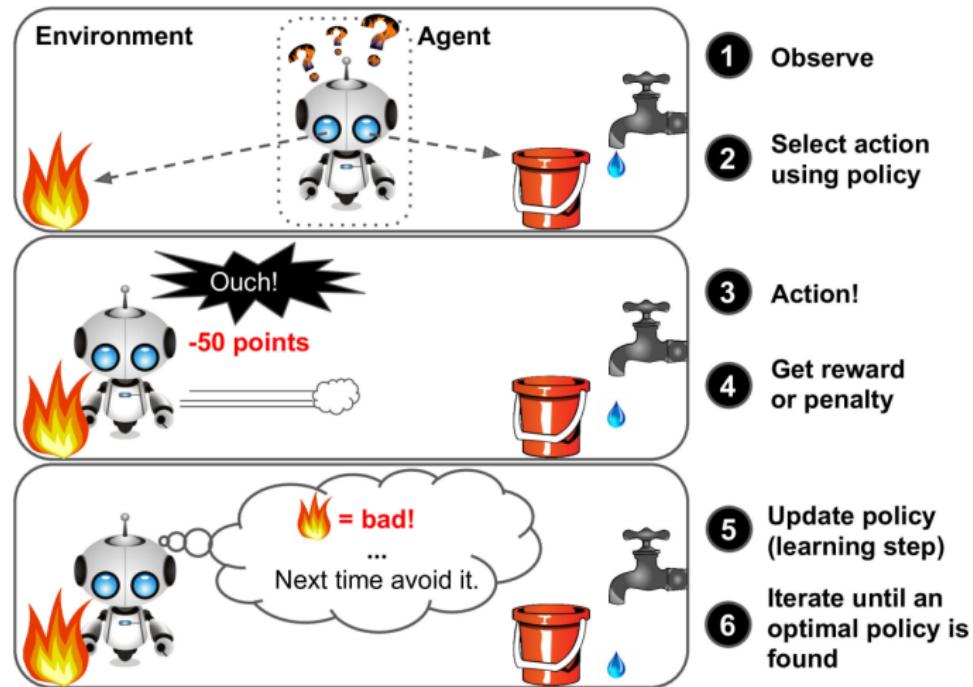


Figure 1-12. Reinforcement Learning

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