UMBC

DATA 601

Modeling in Data Science

Data Science Life Cycle

What is Modeling? Depends on Context...

- A mathematical model is a description of a system using mathematical concepts and language.
- A statistical model is a mathematical model that embodies a set of statistical assumptions concerning the generation of sample data (and similar data from a larger population). A statistical model represents, often in considerably idealized form, the data-generating process.
- A machine learning model is a file that has been trained to recognize certain types of patterns.

Machine Learning Modeling

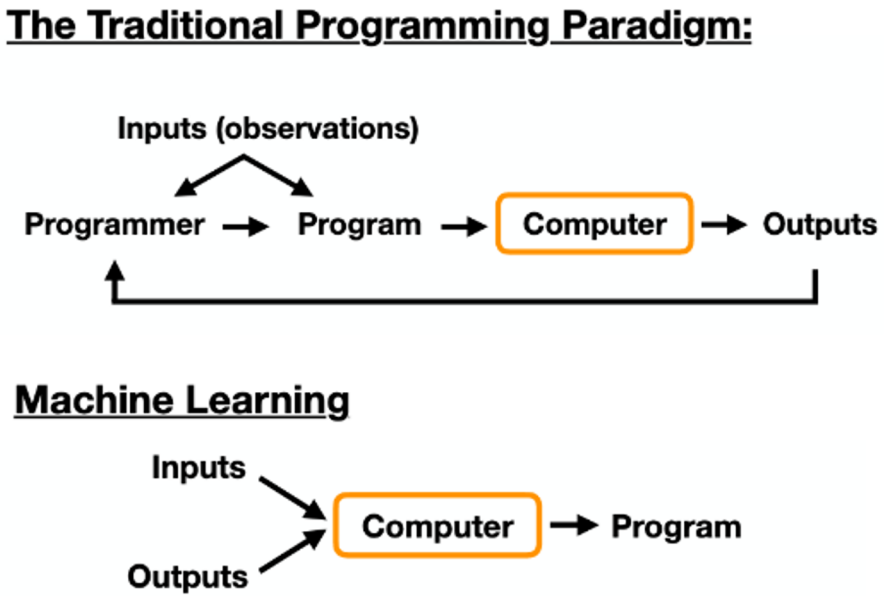
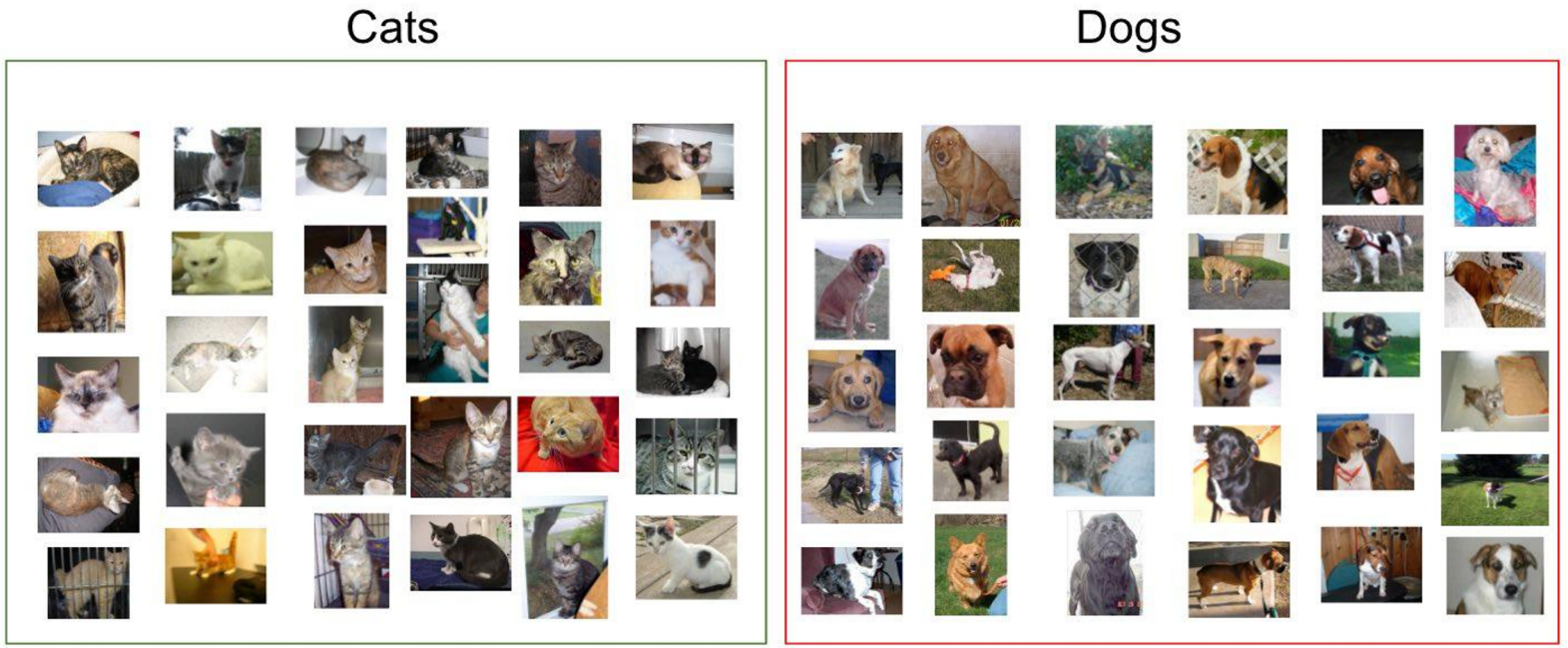


Figure 1: Machine learning vs. "classic" programming.

Formal Definition of learning in ML:

- A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E. (Tom Mitchell)

Cats vs Dogs?



Sample of cats & dogs images from Kaggle Dataset

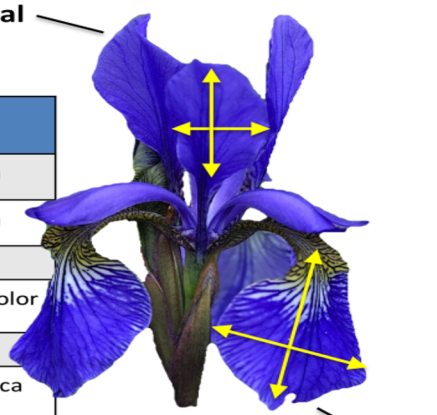
Types of Problems in ML

Supervised Learning	• Data is labeled • Goal: Predict (Values, classes, labels, etc.) for unseen cases.
Unsupervised Learning	• Data is unlabeled. • There is no ground truth. • Goal: Detect hidden/previously unknown structure in data.
Reinforcement Learning	• Data collected by an agent during the learning procedure. • Learning happens with reward/punishments. • Goal: Find actions that maximizes total reward.

Supervised Learning Problem

Samples
(instances, observations)

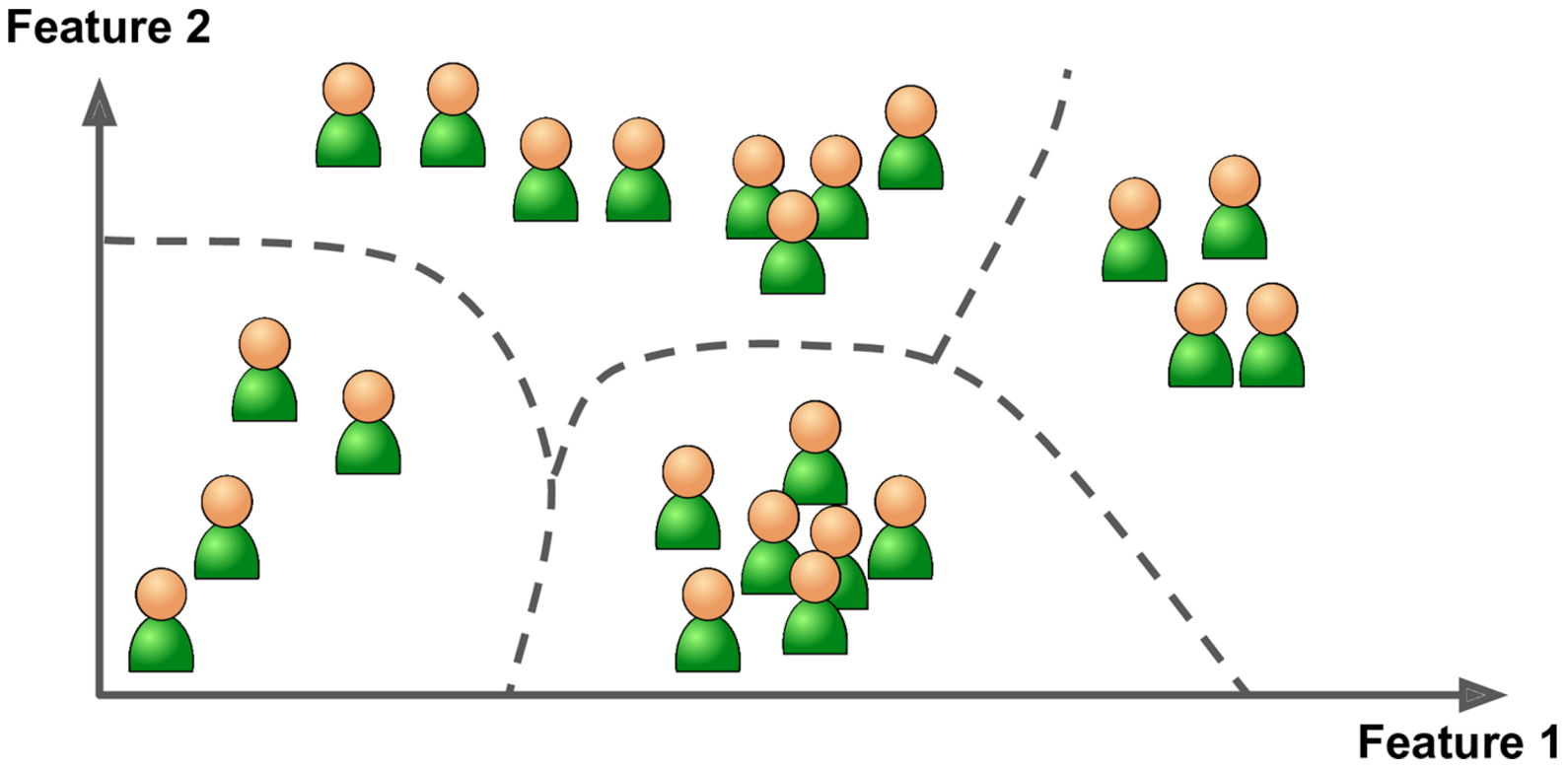
	Sepal length	Sepal width	Petal length	Petal width	Class label
1	5.1	3.5	1.4	0.2	Setosa
2	4.9	3.0	1.4	0.2	Setosa
			...		
50	6.4	3.5	4.5	1.2	Versicolor
			...		
150	5.9	3.0	5.0	1.8	Virginica



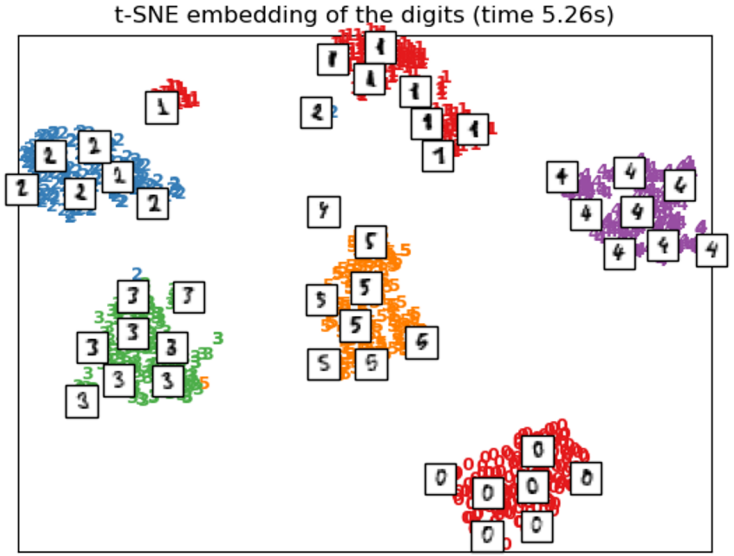
Class labels
(targets)

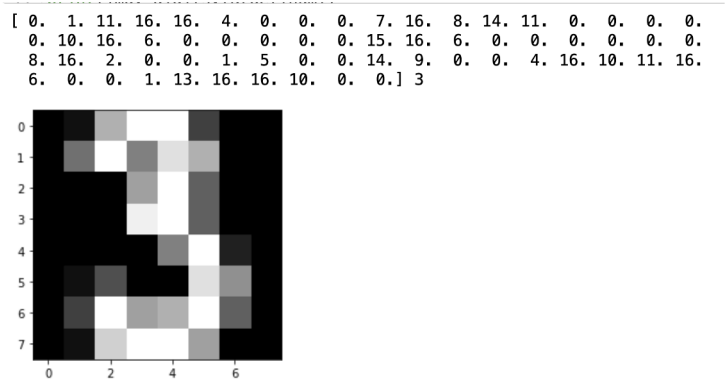
Features
(attributes, measurements, dimensions)

Unsupervised Learning Problem: Clustering

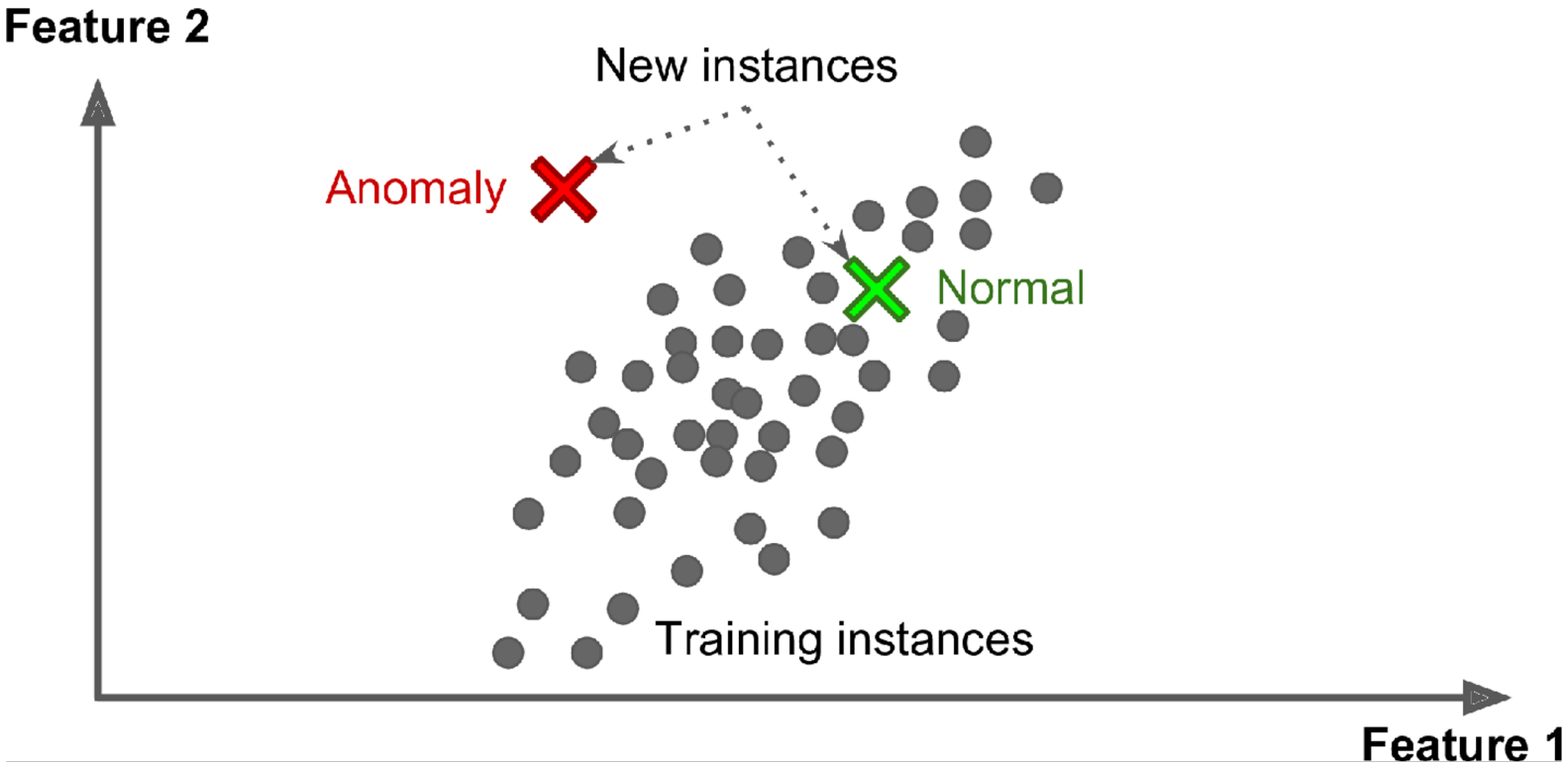


Unsupervised Learning: Dimension Reduction

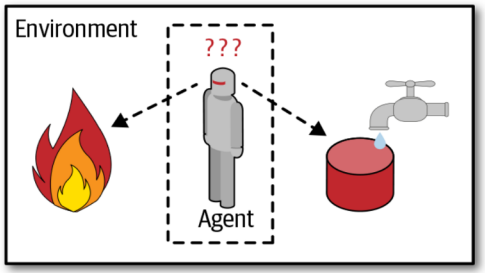




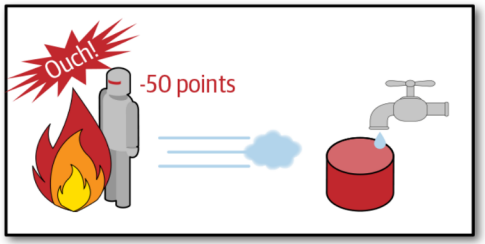
Unsupervised Learning: Anomaly Detection



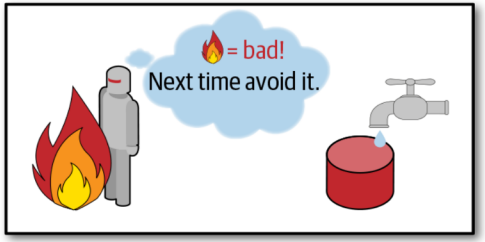
Reinforcement Learning



1. Observe
2. Select action using policy

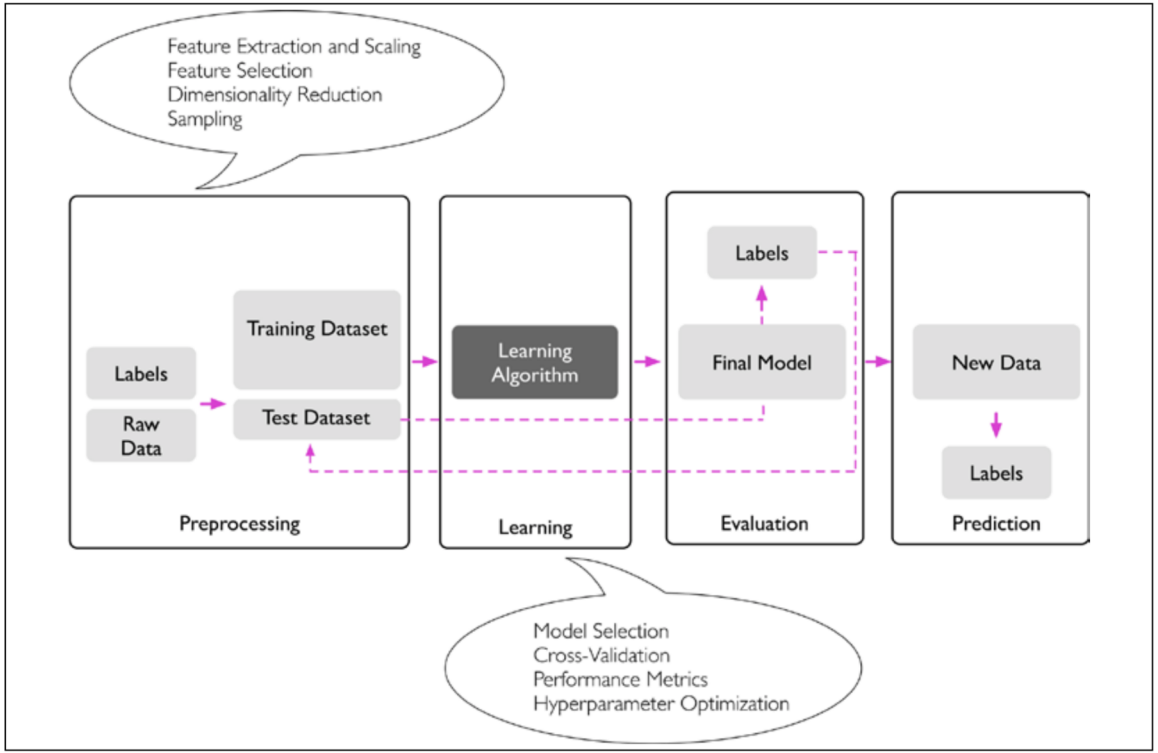


3. Action!
4. Get reward or penalty



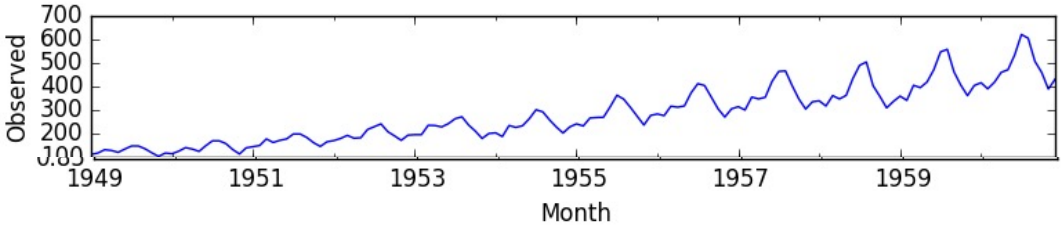
5. Update policy (learning step)
6. Iterate until an optimal policy is found

Procedures to Create ML Models



Time Series Continued

Temporal data has multiple factors present

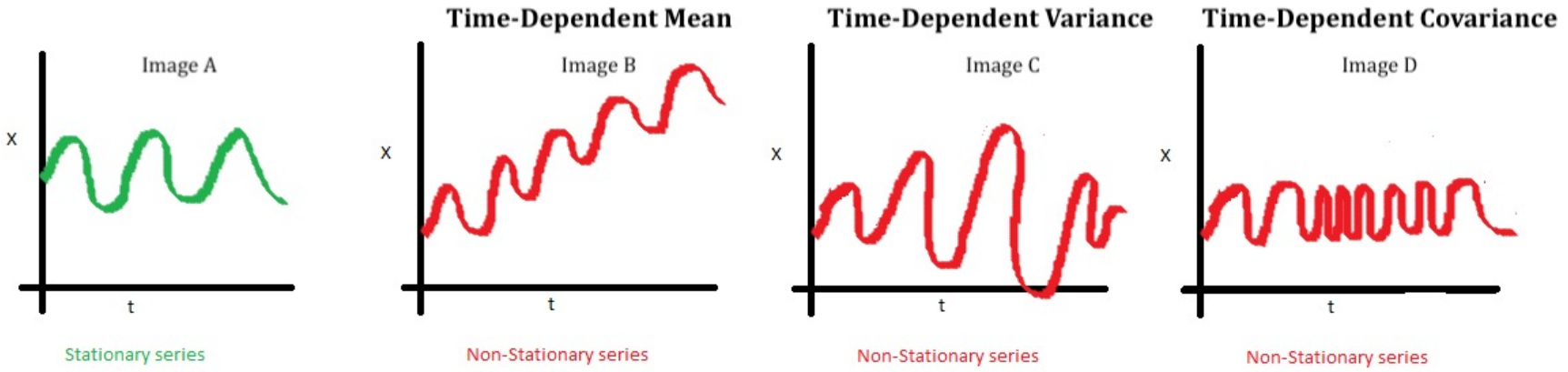


source

"The Airline Passengers dataset describes the total number of airline passengers over a period of time.

The units are a count of the number of airline passengers in thousands. There are 144 monthly observations from 1949 to 1960."

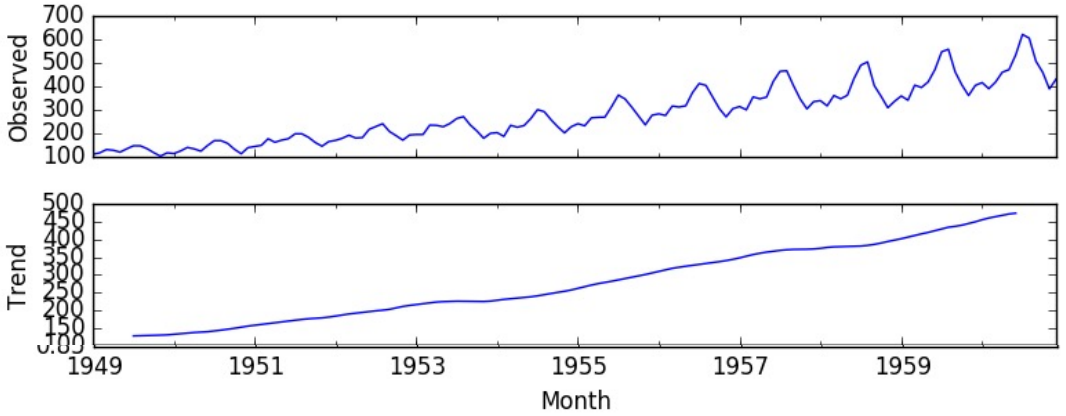
Stationary = **mean, variance, covariance, do not vary with time**



An illustration of the principles of stationarity, Source: BeingDatum

Motivation: decomposing temporal data

Step 1: separate the trend



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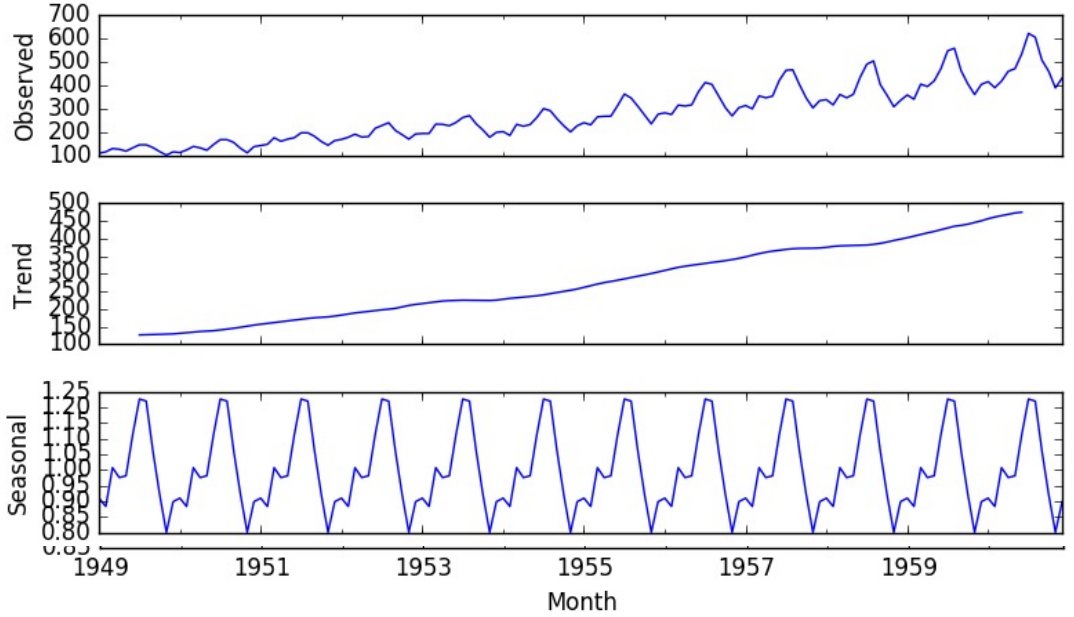
Motivation: decomposing temporal data

Step 2: separate seasonality



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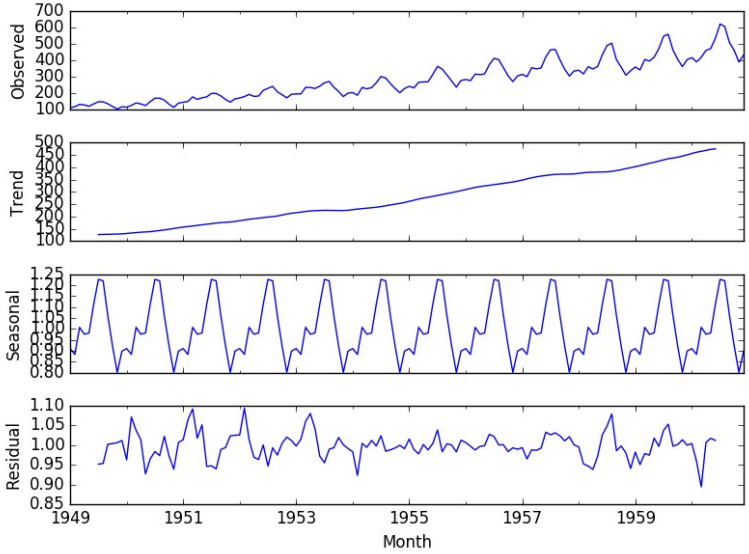
Motivation: decomposing temporal data



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Example

- `historical power df_analysis.ipynb`

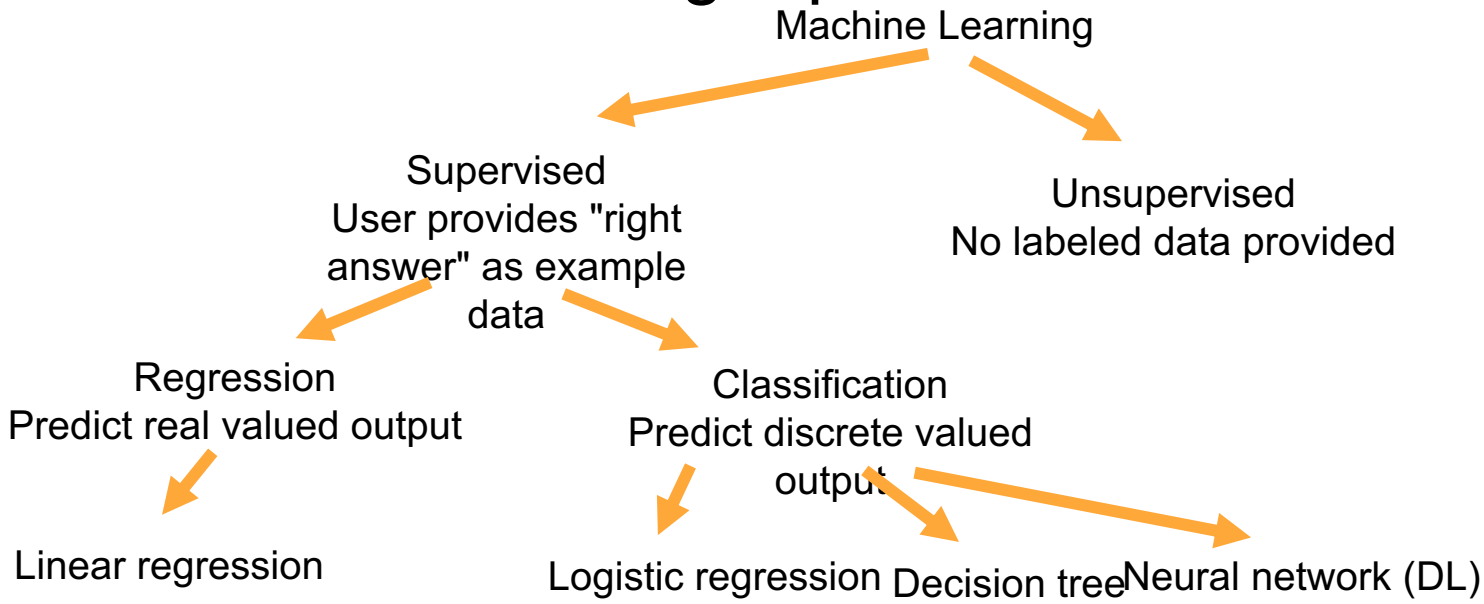
Methods to decompose temporal data

Trend removal

- Differencing
- Rolling average
- Linear regression

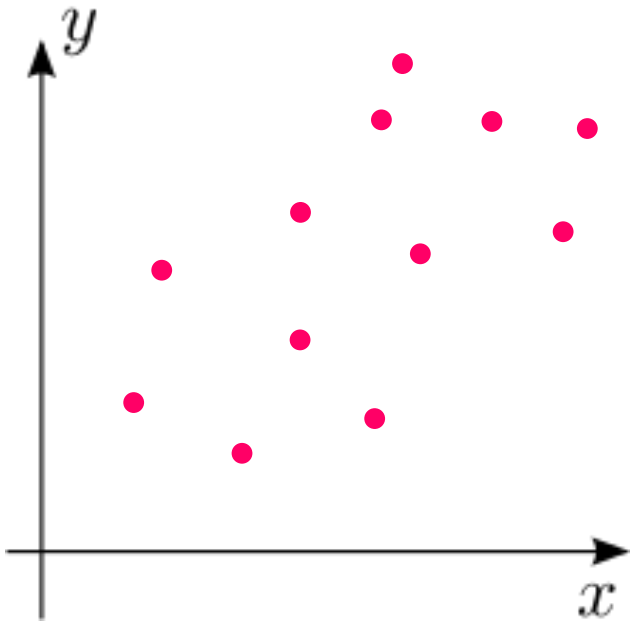
- ~~Decomposing time series~~
- Linear regression for trend analysis
- Fourier transform
- Homework

Map of Machine Learning topics



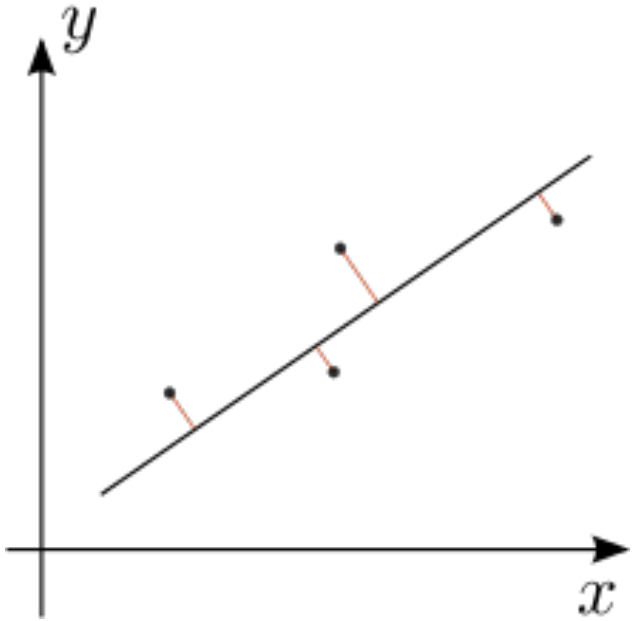
Activity: Draw best fit straight line on plot

Need a volunteer who is not in Data 602



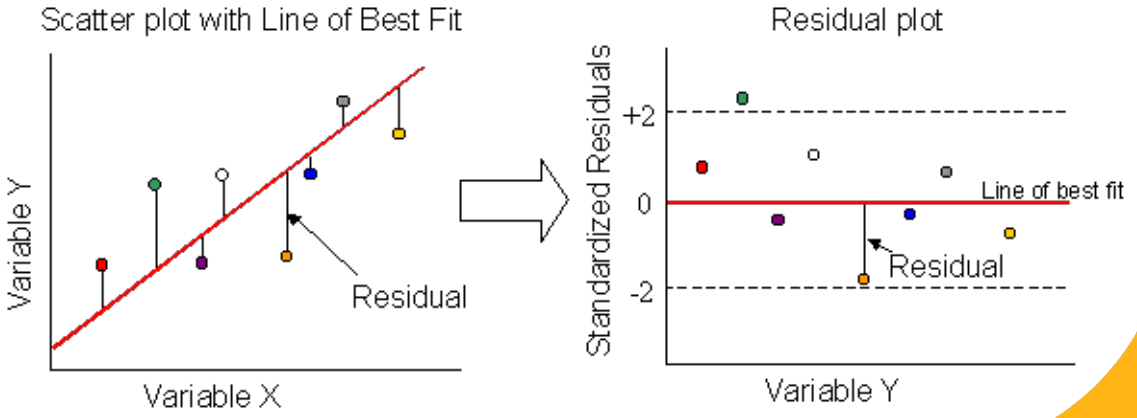
What you (probably) did

If there is uncertainty in both the x and y coordinates, then use an approach which admits variation in both
https://en.wikipedia.org/wiki/Deming_regression



Linear Regression concepts

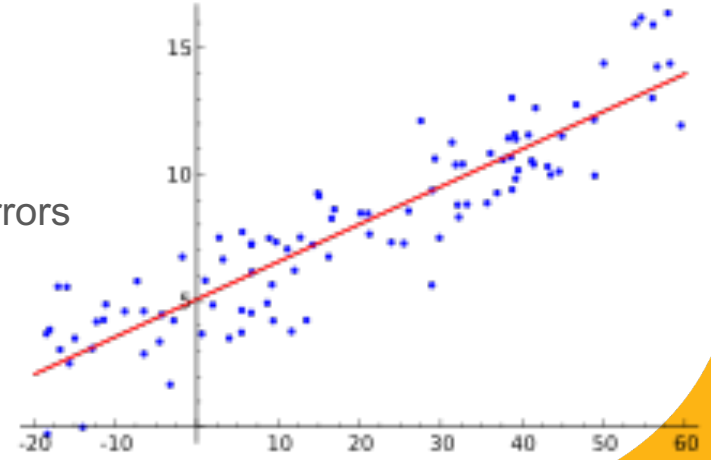
- Predict a target variable by fitting the *best linear relationship* between the dependent (Y) and independent (X) variable.
- The *best fit* is done by making sure that the sum of all the distances between the shape and the actual observations at each point is as small as possible.



Residual = difference between what the current model gives us and the "right" output

Best approach to minimize the residual depends on your data

- ordinary least squares for independent and identically distributed errors
- generalized least squares for arbitrary covariance
- weighted least squares for heteroskedastic errors (error in y varies with x)
- feasible generalized least squares with autocorrelated errors (function repeats)



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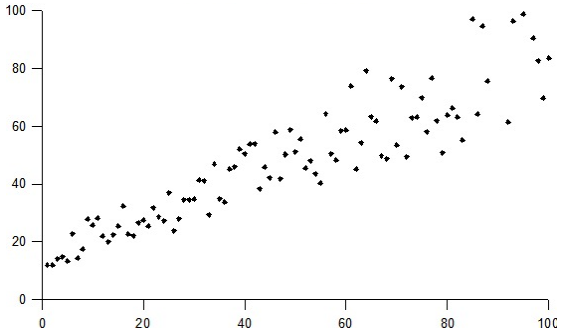
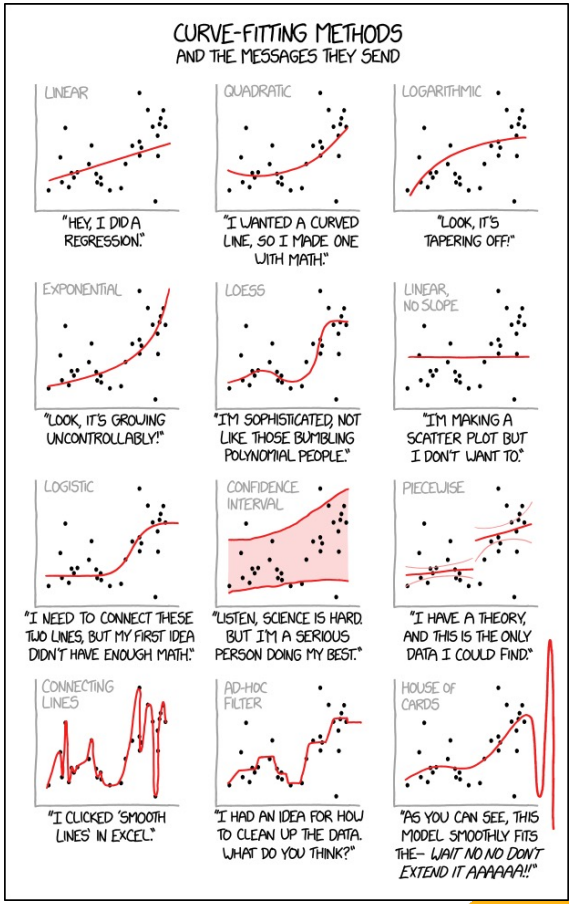
(function repeats)



Residual = difference between what the current model gives us and the "right" output

Best approach to minimize the residual depends on your data

- ordinary least squares for independent and identically distributed errors
- weighted least squares for heteroskedastic errors
  (error in y varies with x)
- generalized least squares for correlated residuals
- feasible generalized least squares with autocorrelated errors
  (function repeats)



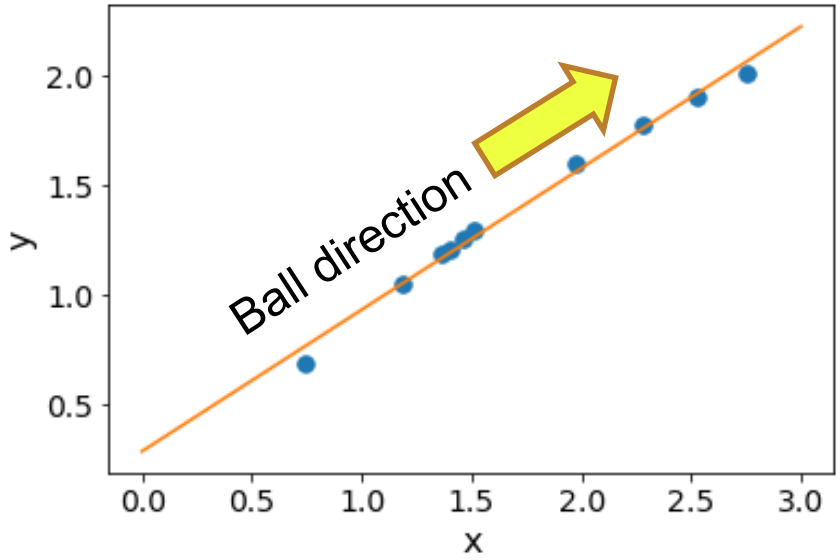
https://xkcd.com/2048

Linear regression = fit data, but for what?

- Prediction
  - Extrapolation = independent variable (x) being evaluated is outside the range of values you already have information on
  - Interpolation = value you are evaluating is within the range of values you already know
- Fitting Trends
- Measure Correlation of two variables

Physics experiment: ski jump

Projectile motion after ball launches

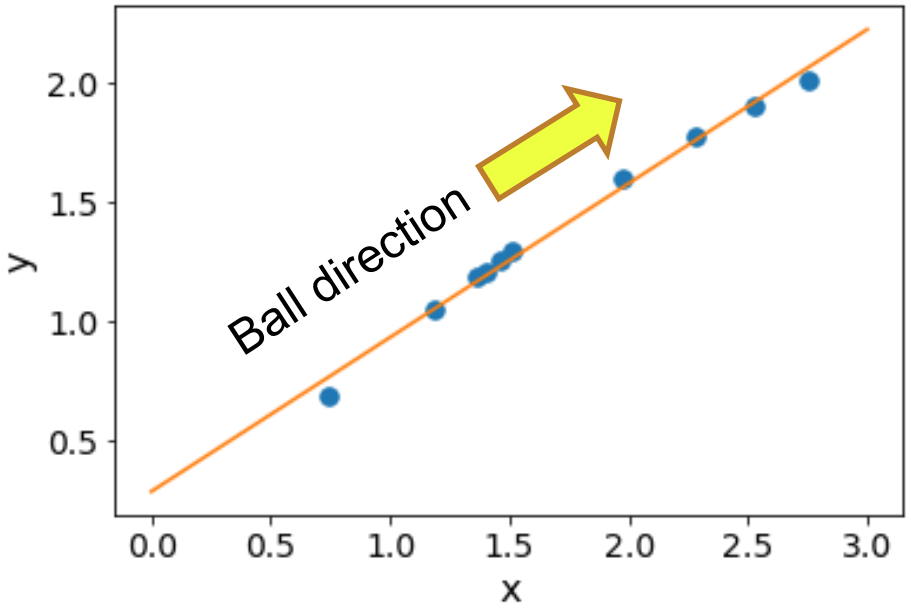


X and Y correlation = 0.996179

Y = 0.64672026*X + 0.28288071

Ramp ends here

Projectile motion *activity*: identify 2 problems



X and Y correlation = 0.996179

Y = 0.64672026*X + 0.28288071

Ramp ends here

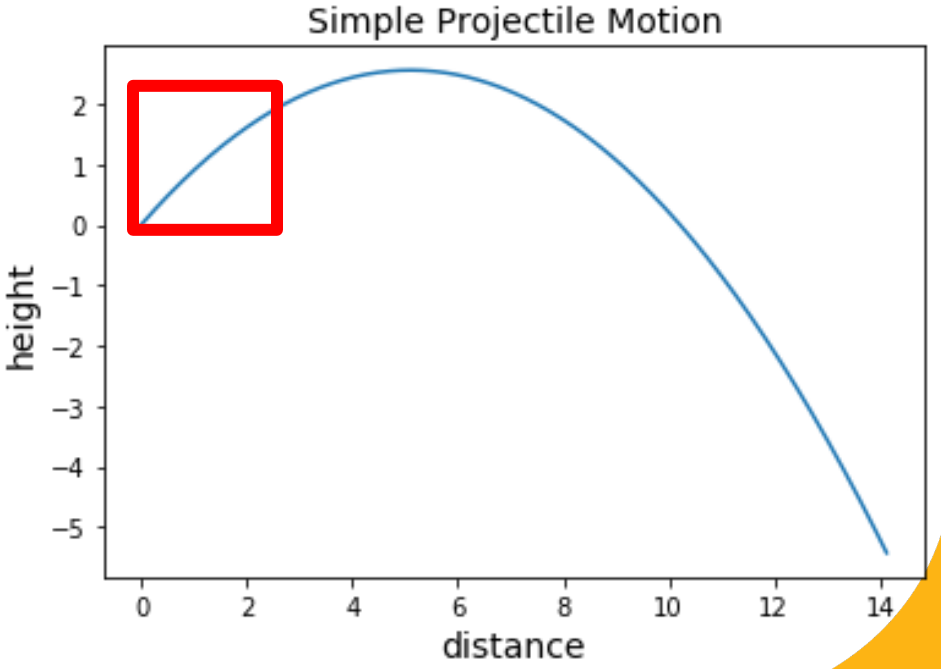
Raise your hand if you have an observation

Issues

- Insufficient sampling in relevant range

While points within the sampling window are correct, the range of interest is the full arc

- Fitting a line to the data appears adequate, but misses the underlying physics of projectile motion: a parabolic path is a second order polynomial



Lesson: Simply trusting data leads to invalid conclusion

- Consistently question your data and your own analysis
- Investigate how data was collected, by whom, for what purpose
- Additional data often helps. Can relevant data be gathered?

statistics emphasizes inference
machine learning emphasizes prediction

- Statistics: *infer the process by which data you have was generated.*
- Machine learning: *predict what future data will look like with respect to some variable.*

--> Knowing how the data was generated matters to the story you tell

When does linear regression apply?

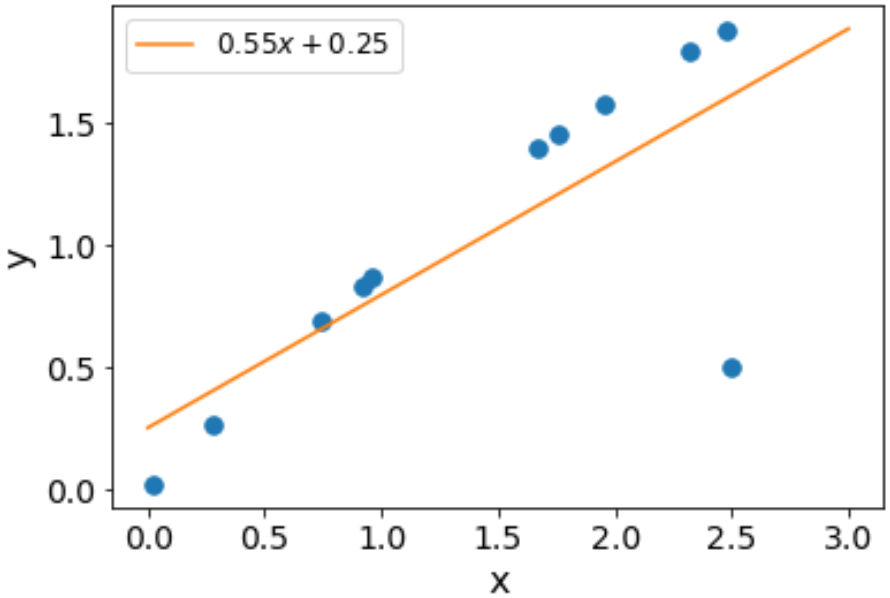
- Is the data numerical? (Necessary but not sufficient.)
- The stronger the correlation coefficient is,

the more of a linear relationship exists.

Recall from previous lecture

- **Variance** measures width of a distribution
- Covariance is the measure of variance for two random variables (joint variability)
- **Correlation** is the normalized covariance, from –1 to 1

Danger to blindly applying linear regression: Outliers



Correlation without outlier: 0.996
Correlation with outlier: 0.76

- ~~Linear regression for trend analysis~~
- Fourier Transform
- Homework

Fourier Transform:

- FFT only applies to data in which the timestamp is uniform

fourier_transform.ipynb