



# DATA ANALYTICS

## Unit 1:Data Reduction

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**Data reduction:** Obtain a reduced representation of the data set that is much smaller in volume but yet produces the same (or almost the same) analytical results

Why data reduction? — A database/data warehouse may store terabytes of data. Complex data analysis may take a very long time to run on the complete data set.

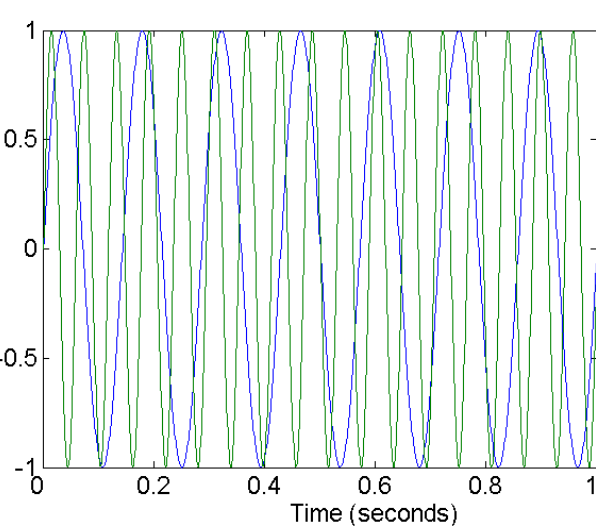
### Data reduction strategies

- Dimensionality reduction, e.g., remove unimportant attributes
  - Wavelet transforms
  - Principal Components Analysis (PCA)
  - Feature subset selection, feature creation
- Numerosity reduction (some simply call it: Data Reduction)
  - Regression and Log-Linear Models
  - Histograms, clustering, sampling
  - Data cube aggregation
- Data compression

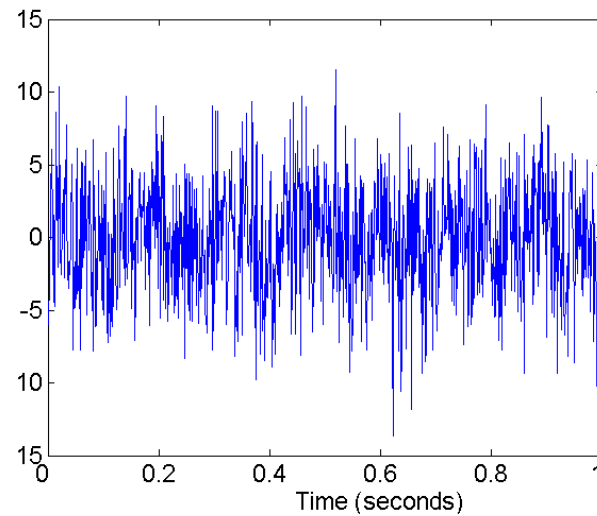
- **Curse of dimensionality**
  - When dimensionality increases, data becomes increasingly sparse
  - Density and distance between points, which is critical to clustering, outlier analysis, becomes less meaningful
  - The possible combinations of subspaces will grow exponentially

- **Dimensionality reduction**
  - Avoid the curse of dimensionality
  - Help eliminate irrelevant features and reduce noise
  - Reduce time and space required in data mining
  - Allow easier visualization
- **Dimensionality reduction techniques**
  - Wavelet transforms
  - Principal Component Analysis
  - Supervised and nonlinear techniques (e.g., feature selection)

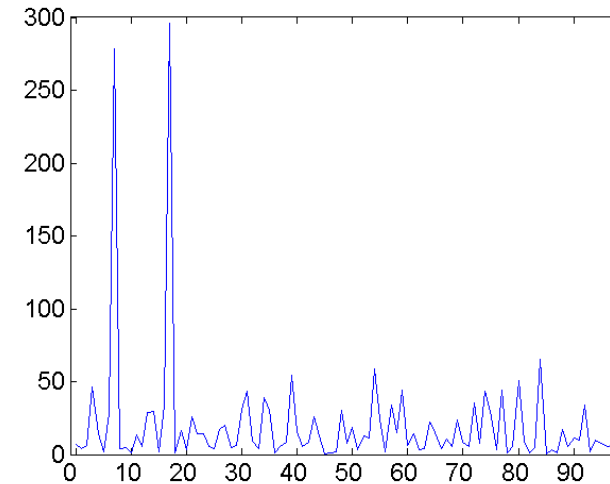
- Fourier transform
- Wavelet transform



**Two Sine Waves**



**Two Sine Waves + Noise**

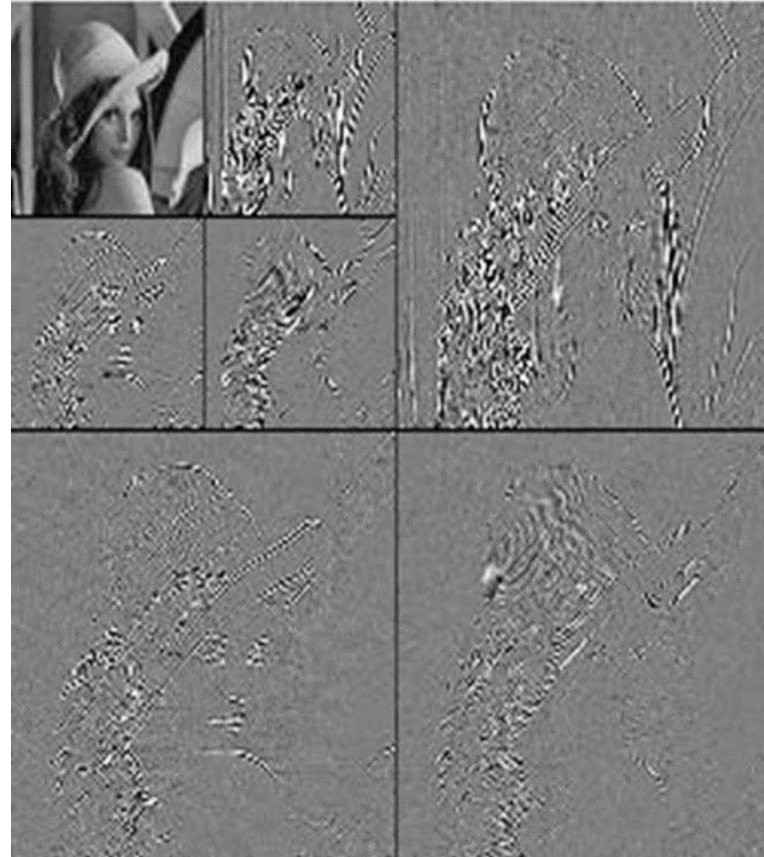


**Frequency**

# DATA ANALYTICS

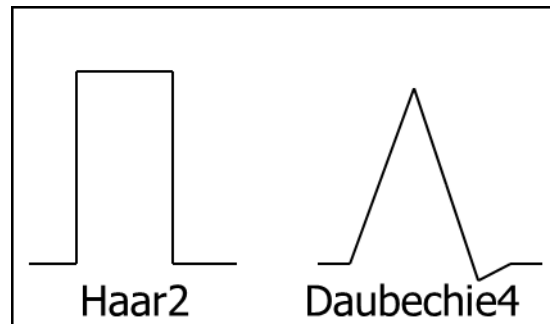
## What Is Wavelet Transform?

- Decomposes a signal into different frequency subbands
  - Applicable to n-dimensional signals
- Data are transformed to preserve relative distance between objects at different levels of resolution
- Allow natural clusters to become more distinguishable
- Used for image compression





- Discrete wavelet transform (DWT) for linear signal processing, multi-resolution analysis
- Compressed approximation: store only a small fraction of the strongest of the wavelet coefficients
- Similar to discrete Fourier transform (DFT), but better lossy compression, localized in space

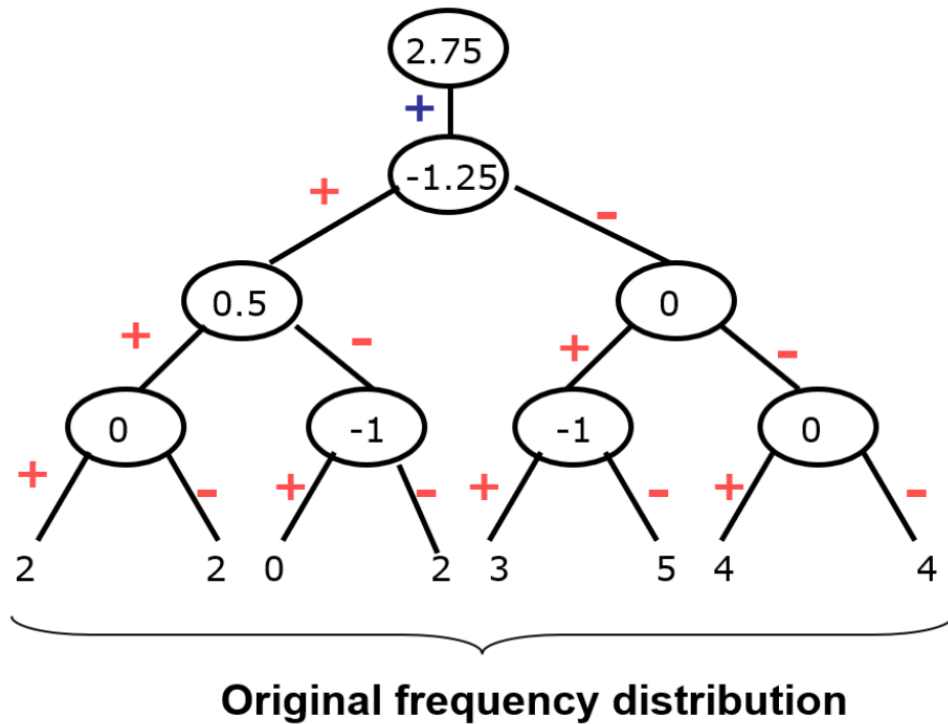


- Method:
  - Length,  $L$ , must be an integer power of 2 (padding with 0's, when necessary)
  - Each transform has 2 functions: smoothing, difference
  - Applies to pairs of data, resulting in two set of data of length  $L/2$
  - Applies two functions recursively, until reaches the desired length

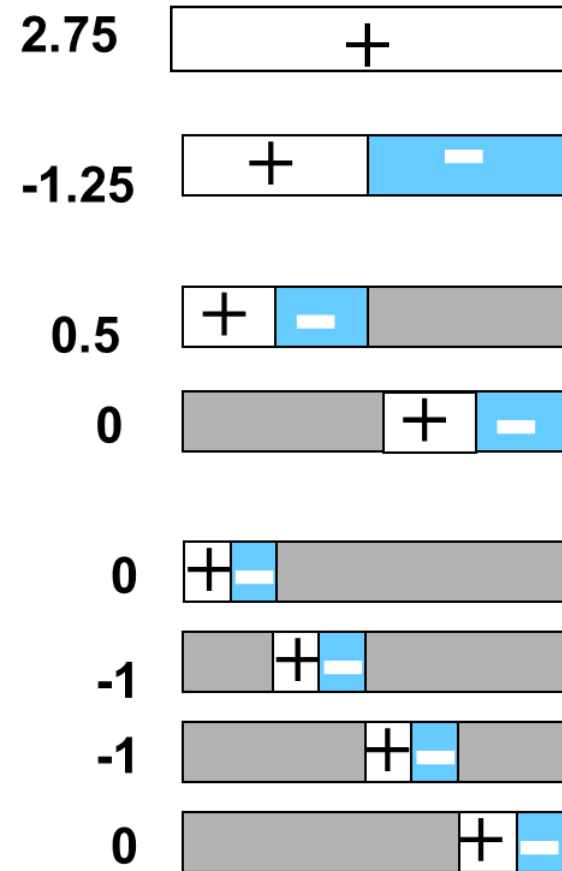
- Wavelets: A math tool for space-efficient hierarchical decomposition of functions
- $S = [2, 2, 0, 2, 3, 5, 4, 4]$  can be transformed to  $S_{\wedge} = [2^3/4, -1^1/4, 1/2, 0, 0, -1, -1, 0]$
- Compression: many small detail coefficients can be replaced by 0's, and only the significant coefficients are retained

Resolution	Averages	Detail Coefficients
8	$[2, 2, 0, 2, 3, 5, 4, 4]$	
4	$[2, 1, 4, 4]$	$[0, -1, -1, 0]$
2	$[1\frac{1}{2}, 4]$	$[\frac{1}{2}, 0]$
1	$[2\frac{3}{4}]$	$[-1\frac{1}{4}]$

Hierarchical decomposition structure (a.k.a. “error tree”)



Coefficient “Supports”



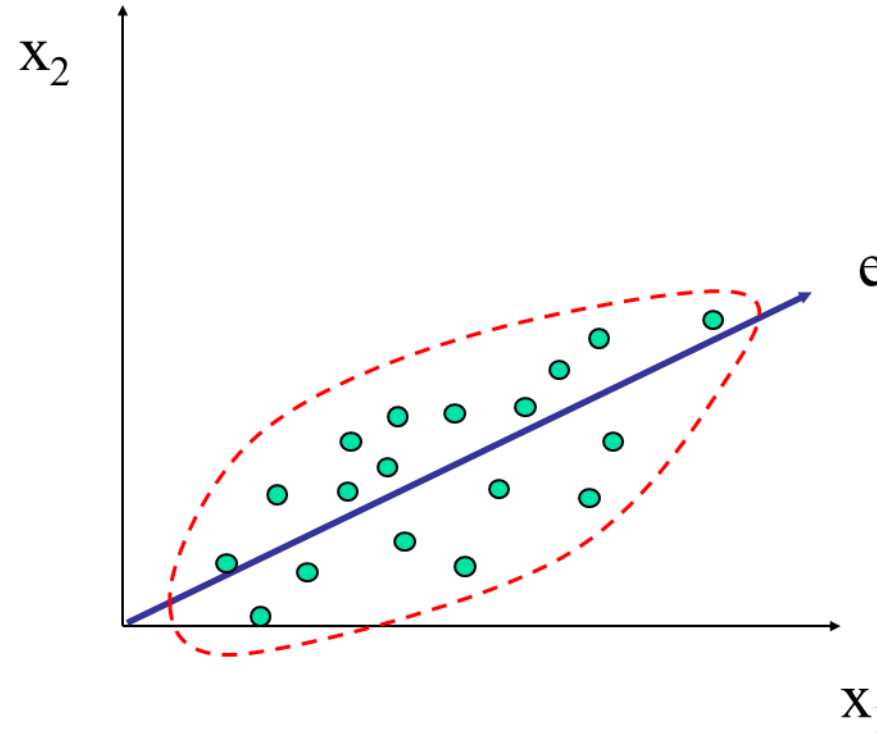
## Why Wavelet Transform?

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- Use hat-shape filters
  - Emphasize region where points cluster
  - Suppress weaker information in their boundaries
- Effective removal of outliers
  - Insensitive to noise, insensitive to input order
- Multi-resolution
  - Detect arbitrary shaped clusters at different scales
- Efficient
  - Complexity  $O(N)$
- Only applicable to low dimensional data

## Principal Component Analysis (PCA)

- Find a projection that captures the largest amount of variation in data
- The original data are projected onto a much smaller space, resulting in dimensionality reduction. We find the eigenvectors of the covariance matrix, and these eigenvectors define the new space



## Principal Component Analysis (Steps)

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- Given  $N$  data vectors from  $n$ -dimensions, find  $k \leq n$  orthogonal vectors (*principal components*) that can be best used to represent data
  - Normalize input data: Each attribute falls within the same range
  - Compute  $k$  orthonormal (unit) vectors, i.e., *principal components*
  - Each input data (vector) is a linear combination of the  $k$  principal component vectors
  - The principal components are sorted in order of decreasing “significance” or strength
  - Since the components are sorted, the size of the data can be reduced by eliminating the *weak components*, i.e., those with low variance (i.e., using the strongest principal components, it is possible to reconstruct a good approximation of the original data)
  - Works for numeric data only

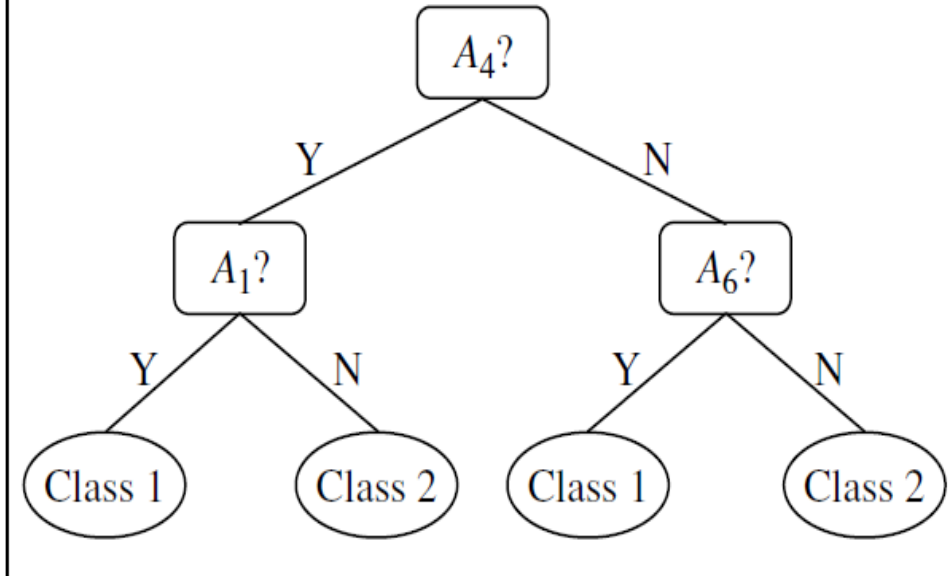
- Another way to reduce dimensionality of data
- Redundant attributes
  - Duplicate much or all of the information contained in one or more other attributes
  - E.g., purchase price of a product and the amount of sales tax paid
- Irrelevant attributes
  - Contain no information that is useful for the data analysis task at hand
  - E.g., students' ID is often irrelevant to the task of predicting students' GPA



## Heuristic Search in Attribute Selection

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- There are  $2^d$  possible attribute combinations of  $d$  attributes
- Typical heuristic attribute selection methods:
  - Best single attribute under the attribute independence assumption: choose by significance tests
  - Best step-wise feature selection:
    - The best single-attribute is picked first
    - Then next best attribute condition to the first, ...
  - Step-wise attribute elimination:
    - Repeatedly eliminate the worst attribute
  - Best combined attribute selection and elimination
  - Optimal branch and bound:
    - Use attribute elimination and backtracking

Forward selection	Backward elimination	Decision tree induction
<p>Initial attribute set:  <math>\{A_1, A_2, A_3, A_4, A_5, A_6\}</math></p> <p>Initial reduced set:  <math>\{\}</math>  <math>\Rightarrow \{A_1\}</math>  <math>\Rightarrow \{A_1, A_4\}</math>  <math>\Rightarrow</math> Reduced attribute set:  <math>\{A_1, A_4, A_6\}</math></p>	<p>Initial attribute set:  <math>\{A_1, A_2, A_3, A_4, A_5, A_6\}</math>  <math>\Rightarrow \{A_1, A_3, A_4, A_5, A_6\}</math>  <math>\Rightarrow \{A_1, A_4, A_5, A_6\}</math>  <math>\Rightarrow</math> Reduced attribute set:  <math>\{A_1, A_4, A_6\}</math></p>	<p>Initial attribute set:  <math>\{A_1, A_2, A_3, A_4, A_5, A_6\}</math></p>  <pre> graph TD     A4["A4?"] -- Y --&gt; A1["A1?"]     A4 -- N --&gt; A6["A6?"]     A1 -- Y --&gt; C1_1((Class 1))     A1 -- N --&gt; C2_1((Class 2))     A6 -- Y --&gt; C1_2((Class 1))     A6 -- N --&gt; C2_2((Class 2))         </pre> <p><math>\Rightarrow</math> Reduced attribute set:  <math>\{A_1, A_4, A_6\}</math></p>

## Attribute Creation (Feature Generation)

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- Create new attributes (features) that can capture the important information in a data set more effectively than the original ones
- Three general methodologies
  - Attribute extraction
    - Domain-specific
  - Mapping data to new space (see: data reduction)
    - E.g., Fourier transformation, wavelet transformation, manifold approaches
  - Attribute construction
    - Combining features
    - Data discretization

- ☐ Mention and explain the different data reduction strategies.
- ☐ Explain how Wavelet transform and Principal Component Analysis are used in the process of data reduction.

### Text Book:

- [Data Mining: Concepts and Techniques](#) by Jiawei Han, Micheline Kamber and Jian Pei, The Morgan Kaufmann Series in Data Management Systems, 3rd Edition.



## THANK YOU

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