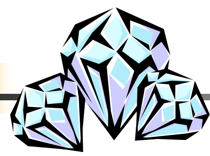
Data Mining and
Medical Informatics



Credit: R. E. Abdel-Aal

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  Definition, Functions, Scope, and Techniques
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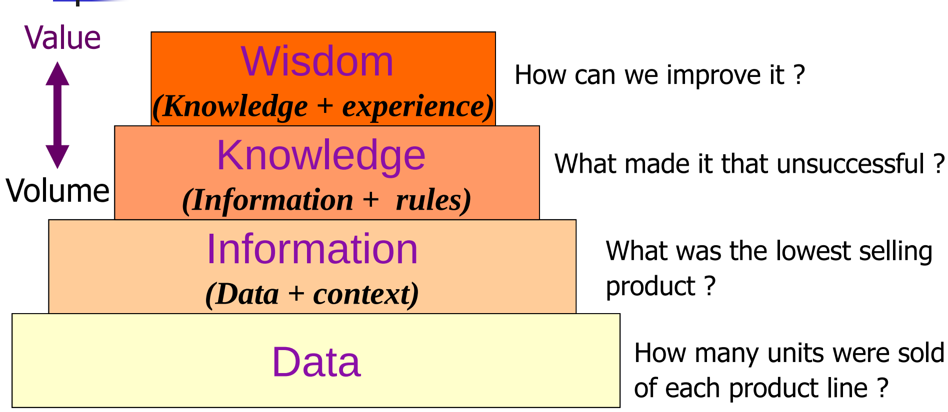
The Data Overload Problem

- Amount of data doubles every ~~18~~ 9 months !:
  - NASA's Earth Orbiting System sends 4,000,000,000,000 bytes a day
  - One fingerprint image library contains 200,000,000,000,000 bytes
- Data warehouses, data marts, … of historical data
- The hidden information and knowledge in these mountains of data are really the most useful
- "Drowning in data but starving for knowledge" ?
- "Siftware"

The Data Pyramid



What is wrong with conventional statistical methods ?

- Manual hypothesis testing:
  - Not practical with large numbers of variables
- User-driven… User specifies variables, functional form and type of interaction:
  - User intervention may influence resulting models
- Assumptions on linearity, probability distribution, etc.
  - May not be valid
- Datasets collected with statistical analysis in mind
  - Not always the case in practice

Recent advances in computers made data mining practical

- Cheaper, larger, and faster disk storage:
  - You can now put *all* your large database on disk
- Cheaper, larger, and faster memory:
  - You may even be able to accommodate it all in memory
- Cheaper, more capable, and faster processors:
- Parallel computing architectures:
  - Operate on large datasets in reasonable time
  - Try exhaustive searches and brute force solutions

Data Mining: Some Definitions

• Knowledge Discovery in Databases (KDD)

• The use of tools to extract 'nuggets' of useful information & patterns in bodies of data for use in decision support and estimation

• The automated extraction of hidden predictive information from (large) databases

Data Mining Functions

- Clustering into 'natural' groups (unsupervised)
- Classification into known classes; e.g. diagnosis (supervised)
- Detection of associations; e.g. in basket analysis:
  "70% of customers buying bread also buy milk"
- Detection of sequential temporal patterns; e.g. disease development
- Prediction or estimation of an outcome
- Time series forecasting

Data Mining Scope

- **Finance and business:**
  - Loan assessment, Fraud detection, Market forecasting
  - Basket analysis, Product targeting, Efficient mailing
- **Engineering:**
  - Process modeling and optimization
  - Machine diagnostics, Predictive maintenance
- **Internet:**
  - Text mining, Intelligent query answering
  - Web access analysis, Site personalization
- **Medical Informatics**

Data Mining Techniques (box of tricks)

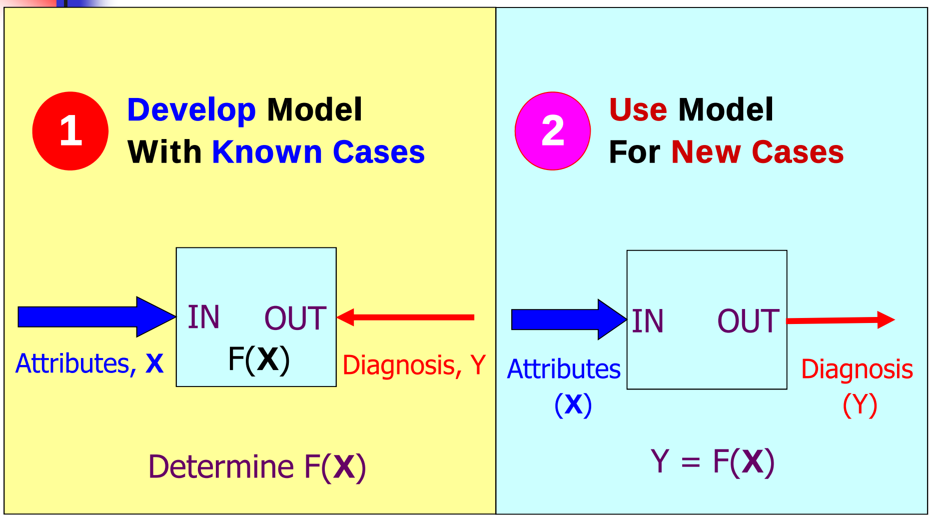
- Statistics
- Linear Regression
- Visualization
- Cluster analysis

Older,
Data preparation,
Exploratory

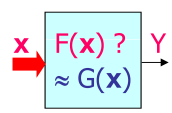
- Decision trees
- Rule induction
- Neural networks
- Abductive networks

Newer, Modeling,
Knowledge Representation

Data-based Predictive Modeling



Modeling by Supervised Learning



- Y=F(**x**): true function (usually not known) for population P
- 1. Collect Data: "labeled" training sample drawn from P

57,M,195,0,125,95,39,25,0,1,0,0,0,1,0,0,0,0,0,0,1,1,0,0,0,0,0,0,0,0 0
78,M,160,1,130,100,37,40,1,0,0,0,1,0,1,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0 1
69,F,180,0,115,85,40,22,0,0,0,0,0,1,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0 0
18,M,165,0,110,80,41,30,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0 1

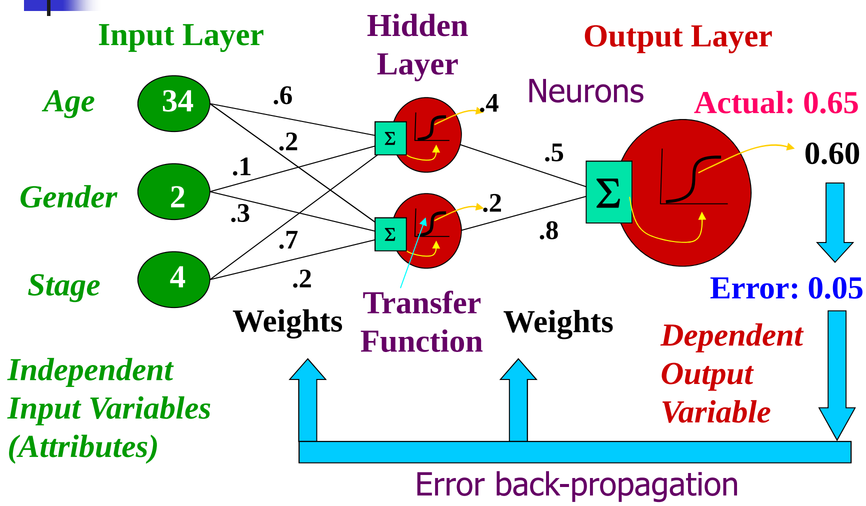
- 2. Training: Get G(**x**); model learned from training sample,
  Goal: $E<(F(\mathbf{x})-G(\mathbf{x}))^2> \approx 0$ for future samples drawn from P
  – Not just data fitting!
- 3. Test/Use:

71,M,160,1,130,105,38,20,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0 ?

Data-based Predictive Modeling by supervised Machine learning

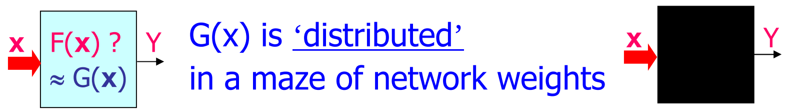
- Database of solved examples (input-output)
- Preparation: cleanup, transform, add new attributes...
- Split data into a training and a test set
- Training:
  Develop model on the training set
- Evaluation:
  See how the model fares on the test set
- Actual use:
  Use successful model on new input data to estimate unknown output

The Neural Network (NN) Approach



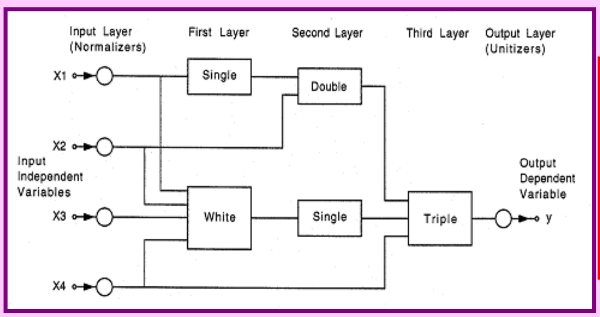
Limitations of Neural Networks

- Ad hoc approach for determining network structure and training parameters- Trial & Error ?
- Opacity or black-box nature gives poor explanation capabilities which are important in medicine



- Significant inputs are not immediately obvious
- When to stop training to avoid over-fitting ?
- Local Minima may hinder optimum solution

Self-Organizing Abductive (Polynomial) Networks



"Double" Element:

$$y = w0 + w1\ x1 + w2\ x2 \\ + w3\ x1^2 + w4\ x2^2 \\ + w5\ x1\ x2 \\ + w6\ x1^3 + w7\ x2^3$$

- Network of polynomial functional elements- not simple neurons
- No fixed *a priori* model structure. Model evolves with training
- Automatic selection of: Significant inputs, Network size, Element types, Connectivity, and Coefficients
- Automatic stopping criteria, with simple control on complexity
- Analytical input-output relationships

Data Mining in Medicine

Medicine revolves on Pattern Recognition, Classification, and Prediction

Diagnosis:
- Recognize and classify patterns in multivariate patient attributes

Therapy:
- Select from available treatment methods; based on effectiveness, suitability to patient, etc.

Prognosis:
- Predict future outcomes based on previous experience and present conditions

Need for Data Mining in Medicine

- Nature of medical data: noisy, incomplete, uncertain, nonlinearities, fuzziness ⇒ Soft computing
- Too much data now collected due to computerization (text, graphs, images,…)
- Too many disease markers (attributes) now available for decision making
- Increased demand for health services: (Greater awareness, increased life expectancy, …)
  - Overworked physicians and facilities
- Stressful work conditions in ICUs, etc.

Medical Applications

- Screening
- Diagnosis
- Therapy
- Prognosis
- Monitoring
- Biomedical/Biological Analysis
- Epidemiological Studies
- Hospital Management
- Medical Instruction and Training

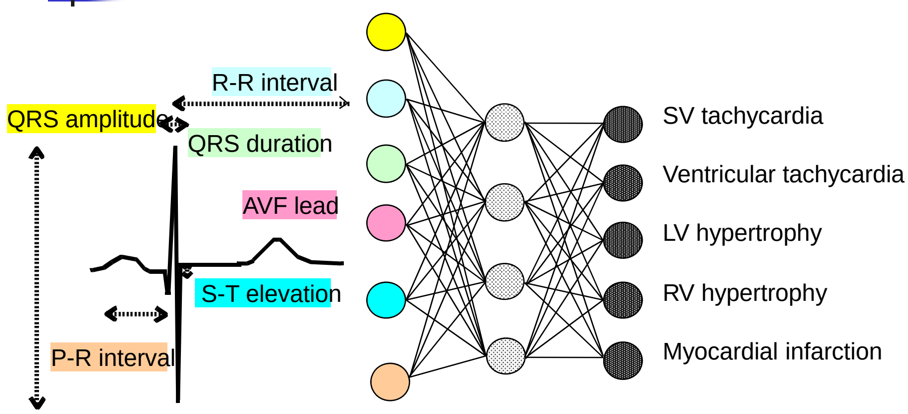
Medical Screening

- Effective low-cost screening using disease models that require easily-obtained attributes:
  (historical, questionnaires, simple measurements)
- Reduces demand for costly specialized tests (Good for patients, medical staff, facilities, …)
- Examples:
  - Prostate cancer using blood tests
  - Hepatitis, Diabetes, Sleep apnea, etc.

Diagnosis and Classification

- Assist in decision making with a large number of inputs and in stressful situations
- Can perform automated analysis of:
  - Pathological signals (ECG, EEG, EMG)
  - Medical images (mammograms, ultrasound, X-ray, CT, and MRI)
- Examples:
  - Heart attacks, Chest pains, Rheumatic disorders
  - Myocardial ischemia using the ST-T ECG complex
  - Coronary artery disease using SPECT images

Diagnosis and Classification
ECG Interpretation



Therapy

- Based on modeled historical performance, select best intervention course: e.g. best treatment plans in radiotherapy
- Using patient model, predict optimum medication dosage: e.g. for diabetics
- Data fusion from various sensing modalities in ICUs to assist overburdened medical staff

Prognosis

- Accurate prognosis and risk assessment are essential for improved disease management and outcome

  Examples:

  - Survival analysis for AIDS patients
  - Predict pre-term birth risk
  - Determine cardiac surgical risk
  - Predict ambulation following spinal cord injury
  - Breast cancer prognosis

Biochemical/Biological Analysis

- Automate analytical tasks for:

  - Analyzing blood and urine
  - Tracking glucose levels
  - Determining ion levels in body fluids
  - Detecting pathological conditions

Epidemiological Studies

Study of health, disease, morbidity, injuries and mortality in human communities

- Discover patterns relating outcomes to exposures
- Study independence or correlation between diseases
- Analyze public health survey data
- Example Applications:
  - Assess asthma strategies in inner-city children
  - Predict outbreaks in simulated populations

Hospital Management

- Optimize allocation of resources and assist in future planning for improved services

  Examples:
  - Forecasting patient volume, ambulance run volume, etc.
  - Predicting length-of-stay for incoming patients

Medical Instruction and Training

- Disease models for the instruction and assessment of undergraduate medical and nursing students
- Intelligent tutoring systems for assisting in teaching the decision making process

Benefits:

- Efficient screening tools reduce demand on costly health care resources
- Data fusion from multiple sensors
- Help physicians cope with the information overload
- Optimize allocation of hospital resources
- Better insight into medical survey data
- Computer-based training and evaluation

The KFUPM Experience

Medical Informatics Applications

- Modeling obesity (KFU)
- Modeling the educational score in school health surveys (KFU)
- Classifying urinary stones by Cluster Analysis of ionic composition data (KSU)
- Forecasting patient volume using Univariate Time-Series Analysis (KFU)
- Improving classification of multiple dermatology disorders by Problem Decomposition (Cairo University)

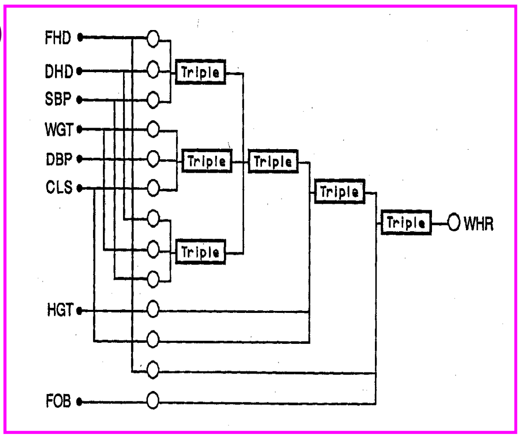
Modeling Obesity Using Abductive Networks

- Waist-to-Hip Ratio (WHR) obesity risk factor modeled in terms of 13 health parameters
- 1100 cases (800 for training, 300 for evaluation)
- Patients attending 9 primary health care clinics in 1995 in Al-Khobar
- Modeled WHR as a categorical variable and as a continuous variable
- Analytical relationships derived from the continuous model adequately 'explain' the survey data

Modeling Obesity: Categorical WHR Model

- WHR > 0.84: Abnormal (1)
- Automatically selects most relevant 8 inputs

		Predicted	
		1 (250)	0 (50)
True	1 (249)	248	1
	0 (51)	2	49

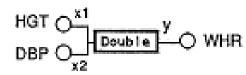


Classification Accuracy: 99%

Modeling Obesity:

Continuous WHR - Simplified Model

- Uses only 2 variables: Height and Diastolic Blood Pressure
- Still reasonably accurate:
  - 88% of cases had error within ± 10%
- Simple analytical input-output relationship
- Adequately explains the survey data

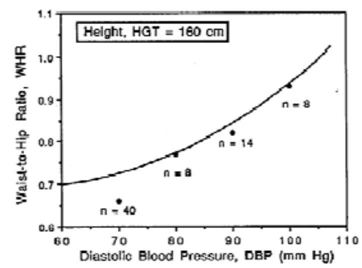


$x1 = -16.7 + 0.1\ HGT$
$x2 = -7.49 + 0.092\ DBP$

$WHR = 0.791 + 0.128\ y$

$y = 0.356\ x2 - 0.18\ x1^2 + 0.104\ x2^2 - 0.244\ x1\ x2$

$$WHR_{con} = 0.033868\ DBP + 1.1292 \times 10^{-4}\ DBP^2 + 0.10035\ HGT - 2.304 \times 10^{-4}\ HGT^2 - 2.8765 \times 10^{-4}\ HGT\ DBP - 9.1357,$$



Modeling the Educational Score in School Health Surveys

- 2720 Albanian primary school children
- Educational score modeled as an ordinal categorical variable (1-5) in terms of 8 attributes:

  region, age, gender, vision acuity, nourishment level, parasite test, family size, parents education
- Model built using only 100 cases predicts output for remaining 2620 cases with 100% accuracy
- A simplified model selects 3 inputs only:

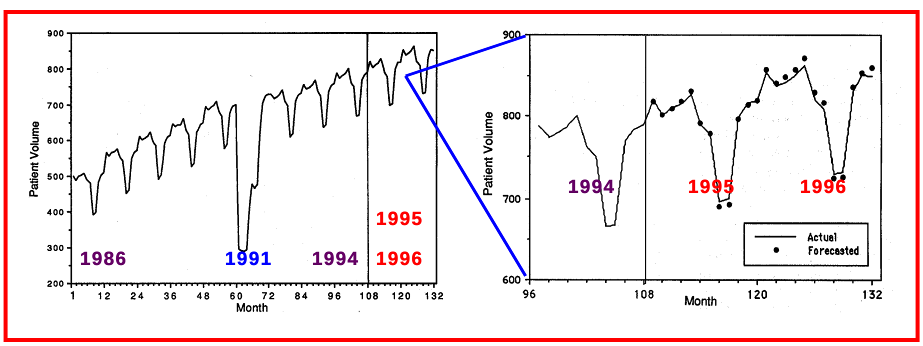
  - Vision acuity
  - Number of children in family
  - Father's education

Classifying Urinary Stones by Cluster Analysis of Ionic Composition Data

- Classified 214 non-infection kidney stones into 3 groups
- 9 chemical analysis variables: Concentrations of ions: CA, C, N, H, MG, and radicals: Urate, Oxalate, and Phosphate
- Clustering with only the 3 radicals had 94% agreement with an empirical classification scheme developed previously at KSU, with the same 3 variables

Forecasting Monthly Patient Volume at a Primary Health Care Clinic, Al-Khobar Using Univariate Time-Series Analysis

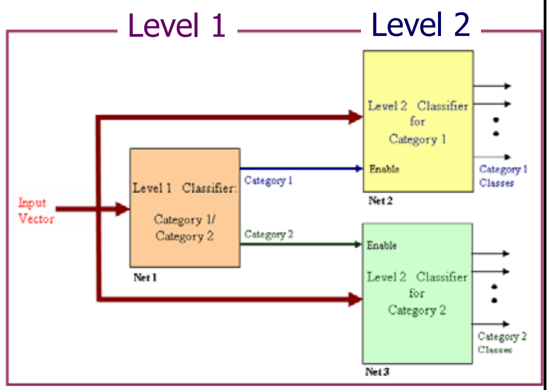
- Used data for 9 years to forecast volume for two years ahead



Error over forecasted 2 years: Mean = 0.55%, Max = 1.17%

Improving classification of multiple dermatology disorders by Problem Decomposition (Cairo University)

- Standard UCI Dataset
- 6 classes of dermatology disorders
- 34 input features
- Classes split into two categories
- Classification done sequentially at two levels



- Improved classification accuracy from 91% to 99%
- About 50% reduction in the number of required input features

Summary

- Data mining is set to play an important role in tackling the data overload in medical informatics
- Benefits include improved health care quality, reduced operating costs, and better insight into medical data
- Abductive networks offer advantages over neural networks, including faster model development and better explanation capabilities