Big Data Analytics and Healthcare

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Road Map

- ***Introduction***
- Data Sources
  - – Structured EHR data
  - – Unstructured EHR data
- Data Analytics Approaches
  - Processing of Structured data
  - Processing of Unstructured data
- Example Applications
- Conclusions

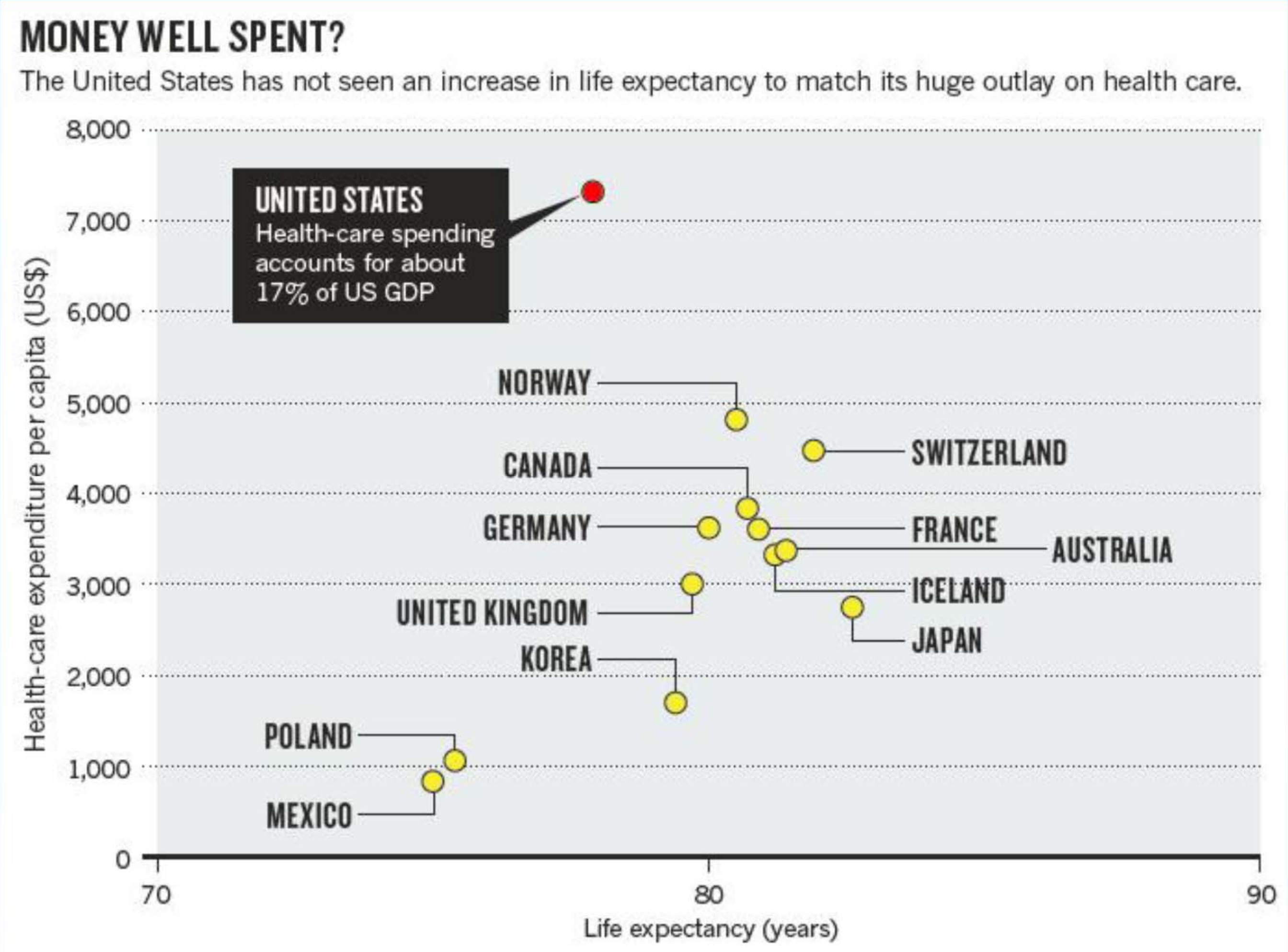
Big Data Applications

- Advertising and marketing
  - Customer shopping patterns
  - Response to promotional campaign
- Manufacturing
  - Maintenance of machine health
- Social Media
  - Browsing and sentiment analysis
  - Impact on buying patterns
- Email
  - Communication and interaction patterns
  - Influencing the product perception
- Government data
  - Efficient process management

Big Data Applications (cont’d)

- Stock Market
  - Stock performance prediction
- **Healthcare Management**
  - **Patient health monitoring**
  - **Impact of preventive care**
- Financial Institutions
  - Fraud detection and mitigation
- Weather
  - Prediction
  - Impact analysis and better disaster management

Healthcare Expenses



Hersh, W., Jacko, J. A., Greenes, R., Tan, J., Janies, D., Embi, P. J., & Payne, P. R. (2011). Health-care hit or miss? *Nature*, *470*(7334), 327.

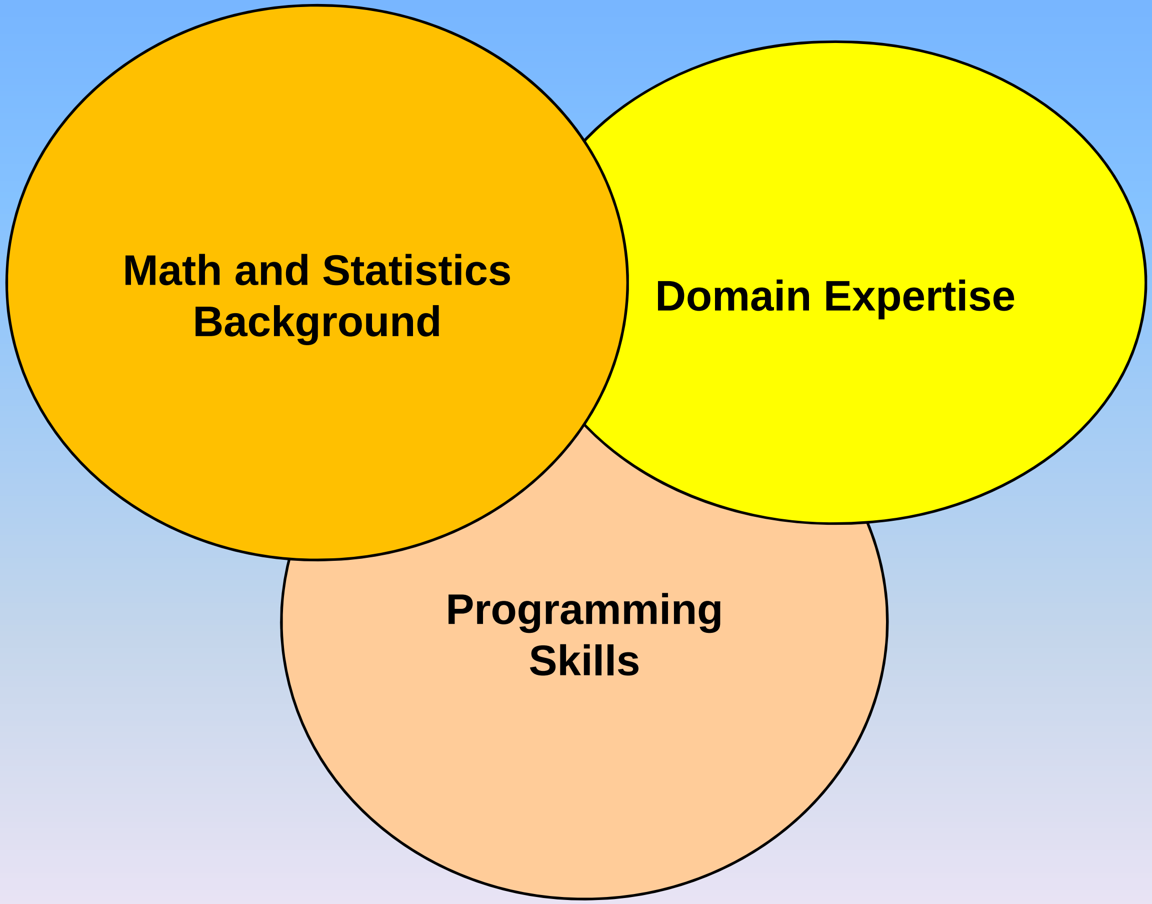
Why Big Data Analytics Now?

- Volume
  - Data generated by 2020 will be in Zettabytes (10^{21})
  - Soon after that the measure will be Yottabyte (10^{24}) and Brontabyte (10^{27})
- Variety
  - Structured (transactional data)
  - Unstructured (image, video and text data)
- Velocity
  - Rate of data generation
  - Increase in the ability to process data
- Variability/Veracity
  - Trustworthiness of data
  - Quality of data

Big Data Analytics: Benefits

- Getting to know your patient better
  - Targeted medicine
  - Accurate diagnosis
  - Predicting disease onset
- Saving money
  - Fraud detection in medical industry
  - Risk Management
  - Lower cost and better outcomes
- Real-time decision making
  - Sensor data analysis
  - Influence of social sentiment on patient health

Data Scientist: A Challenging Combination of Backgrounds



Big Data Analytics

- Big Data Analytics = Big Data + Advanced Analytics
- Advanced Analytics includes:
  - Association Rules
  - Classification and decision trees
  - Text analytics
  - Clustering
  - Regression
  - Machine learning
  - Etc….
- Deployments of Analytics
  - MapReduced / Hadoop Based Deployment
  - In-Database Deployment
- Data Analytics is applicable to any size of data

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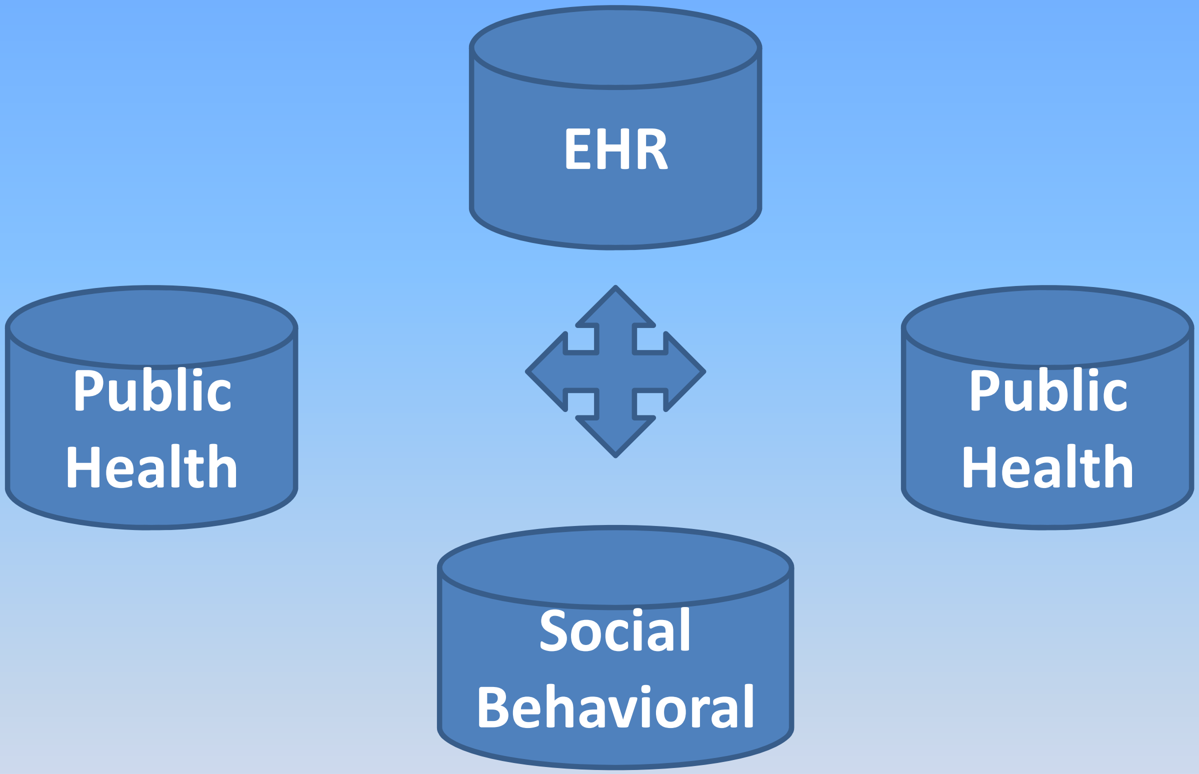
Healthcare Data Types



EHR

Public Health

Public Health

Social Behavioral

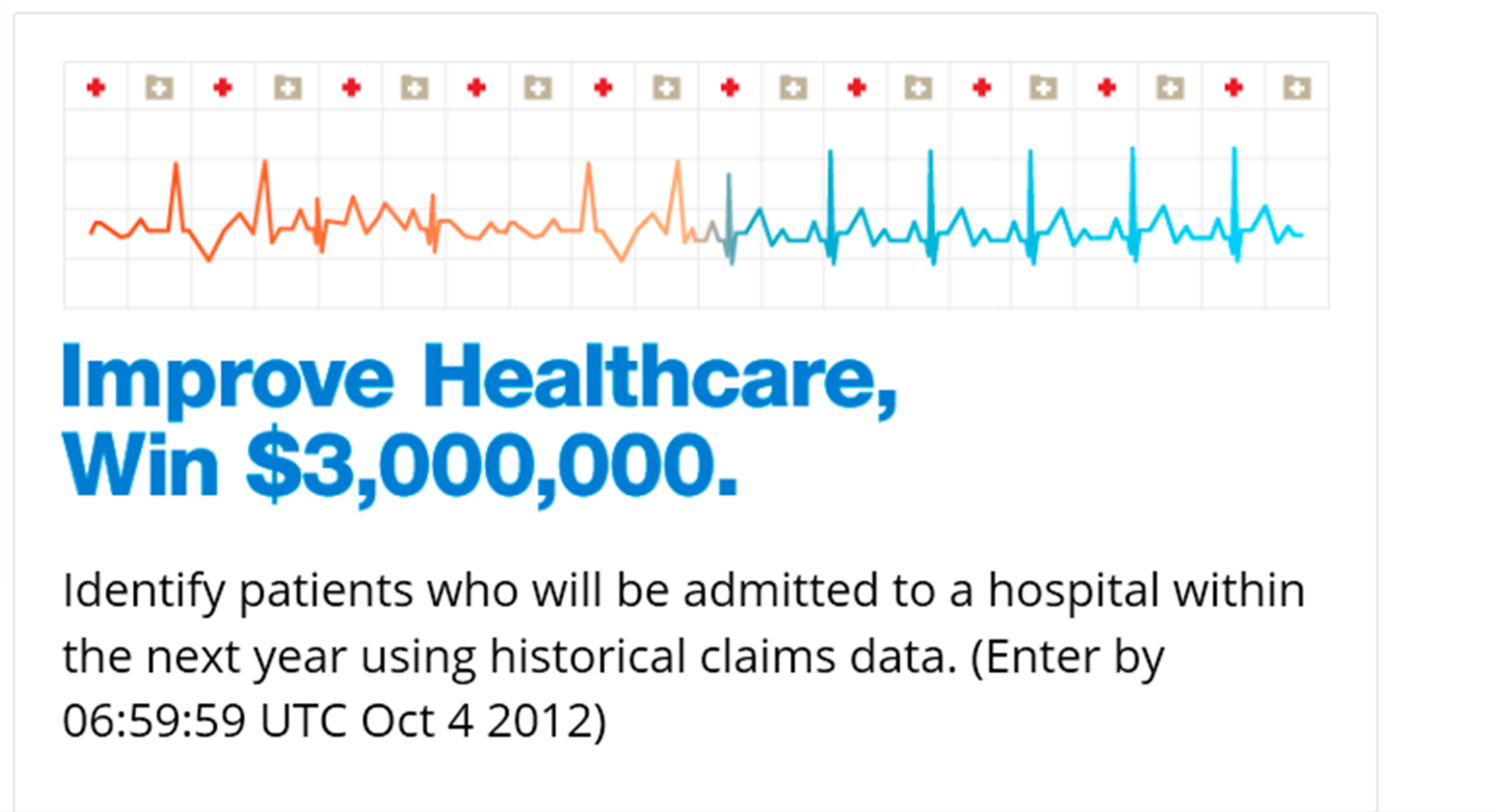
Healthcare Data

- Billing Data
  - International Classification of Diseases (ICD)
  - Current Procedural Terminology (CPT)
- Lab results
  - Logical Observation Identifiers Names and Codes (LOINC)
- Medication
  - National Drug Code (NDC) by Food and Drug Administration (FDA)

Healthcare Data (Cont’d)

- Clinical notes
  - Unstructured text data
- Image Data
  - Unstructured data
- Social Interaction data
  - Unstructured data

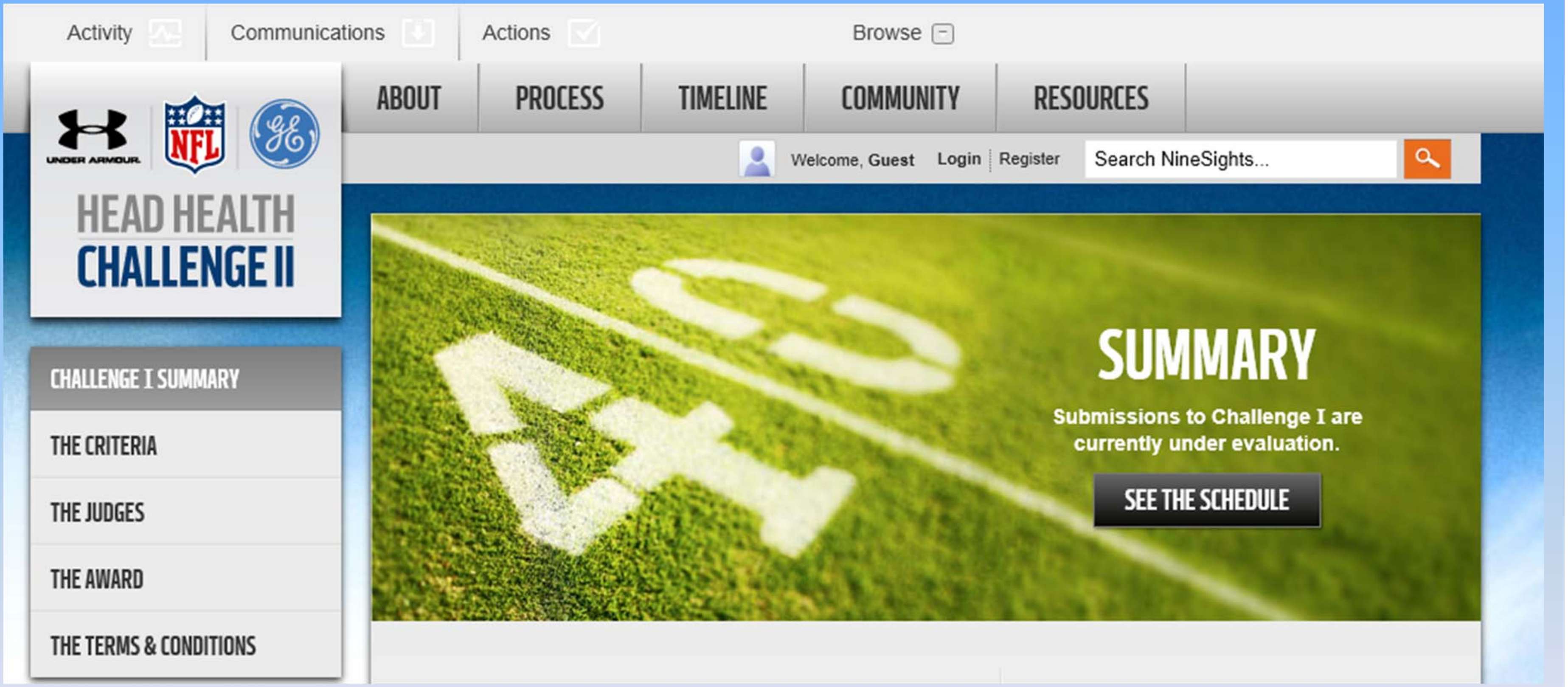
Heritage Health Prize



**Improve Healthcare,
Win $3,000,000.**

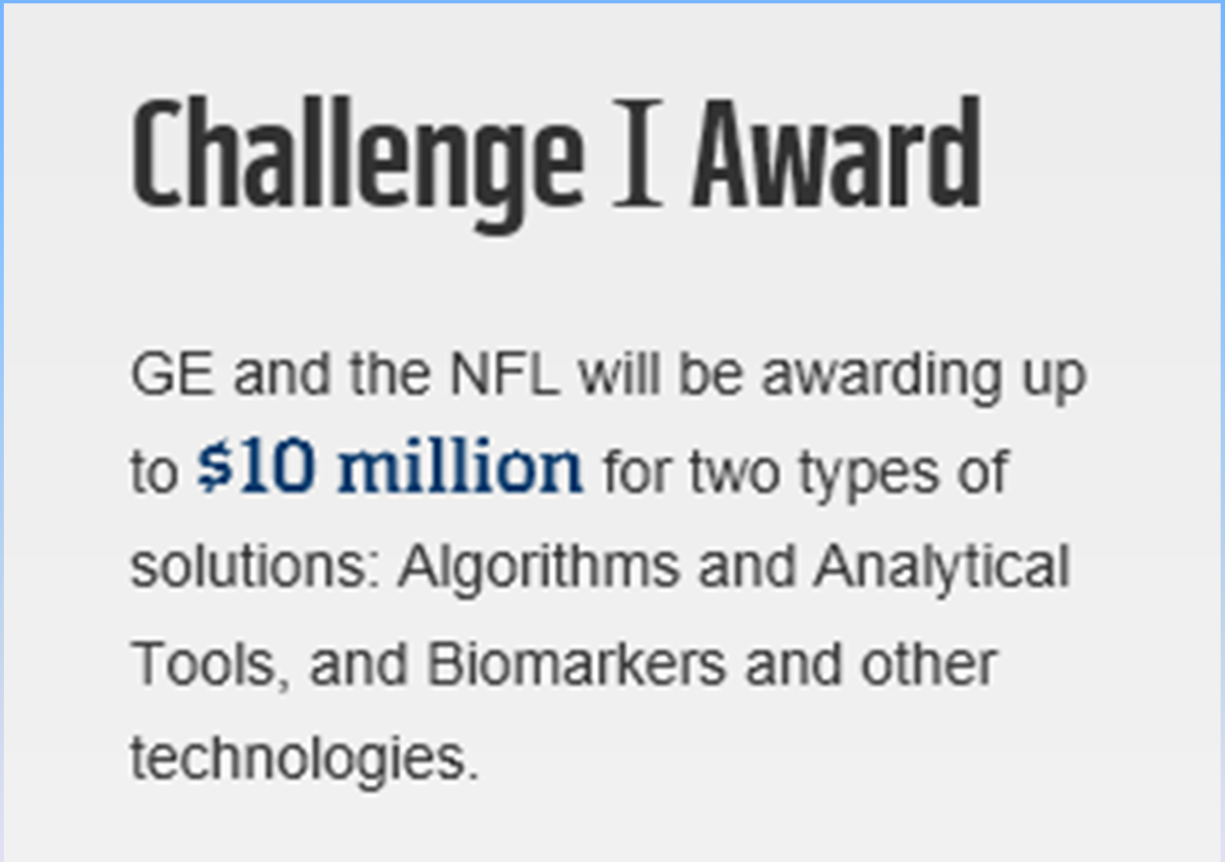
Identify patients who will be admitted to a hospital within the next year using historical claims data. (Enter by 06:59:59 UTC Oct 4 2012)

GE Head Health Challenge



Submissions to Challenge I are currently under evaluation.

GE Challenge I



Challenge I Award

GE and the NFL will be awarding up to **$10 million** for two types of solutions: Algorithms and Analytical Tools, and Biomarkers and other technologies.

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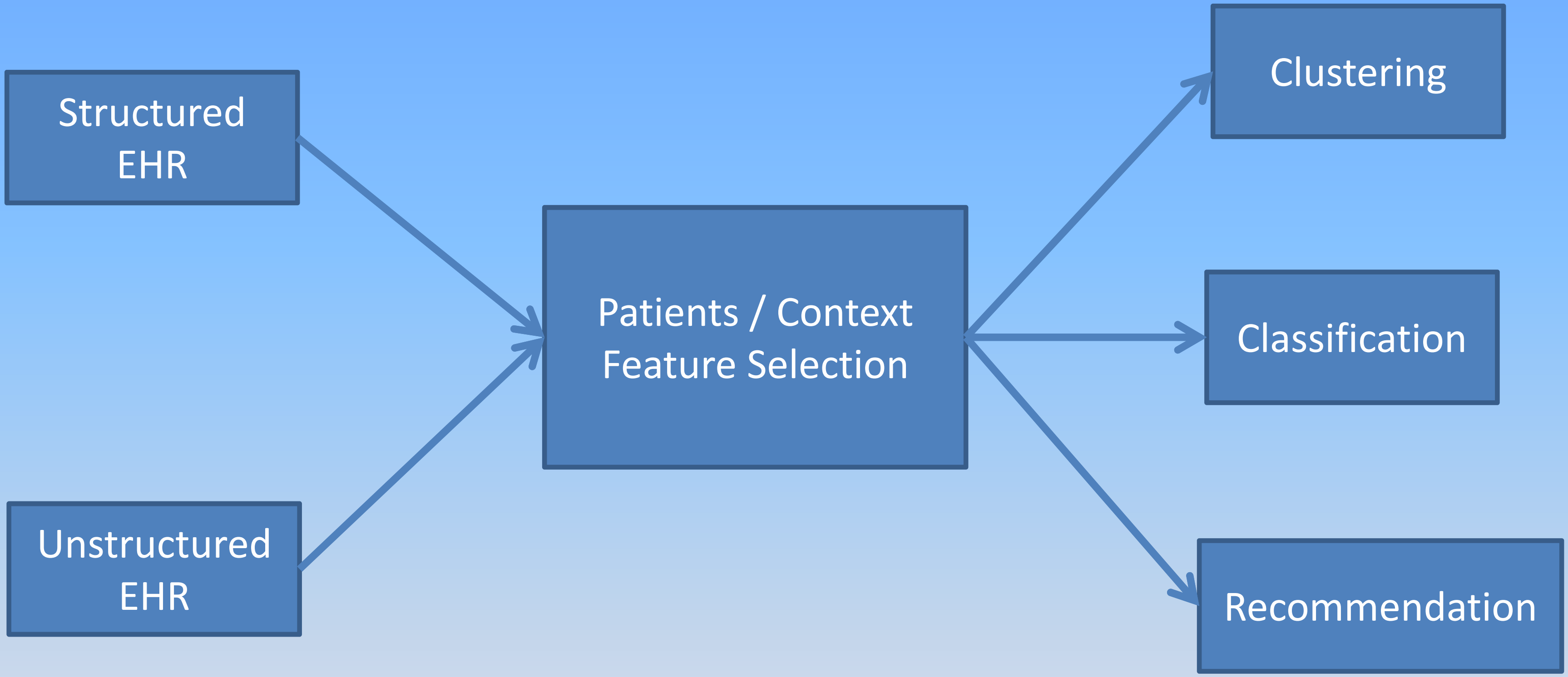
Analytic Platform



Structured EHR

Unstructured EHR

Patients / Context Feature Selection

Clustering

Classification

Recommendation

Types of Data Analysis

- Descriptive Analytics (traditional Business Intelligence):
  - Specifies the data characteristics
  - Also known as unsupervised learning
    - How to describe the system?
    - What happened in the system and when?
    - What are the parameters in the systems?
    - What is the impact of a parameter on the system?
    - Is there any co-relation between the parameters?
- Predictive Analytics: Uses data mining and predictive modeling
  - Also know as supervised learning
    - What are the future trends?
    - What is the decision based on past history?
    - Perform what if analysis.

Implementation Options

- In-Database Analytics
- Distributed Analytics
  - Cluster and cloud computing based
  - Hadoop / MapReduce based

In-Database Analytics

- Allows analytic computation to be carried out in the database
  - Uses SQL and
  - SQL extensions
- Advantages
  - Computation is close to data and does not require data movement
  - Analytic centralization may allow easy security, data and version management
  - Client access to in-database analytics is easy
  - Higher analytics efficiency, easy usability, better database manageability
- Disadvantages
  - Vendor dependent
  - Limited data type support in databases
    - Cannot run location dependent analytics or Text analytics
  - Cost of analytics

Distributed Analytics

- Motivation
  - Large data size
  - Complex computation logic
  - Real time processing requirement
  - Cheaper hardware
  - Larger and faster storage space
- Challenges
  - How to divide and distribute data?
  - How to divide the algorithm?
  - How to manage distributed resources?
- Limitations
  - Many problems are not suitable for distributed computing
    - Sequential algorithms
    - For example, computing Fibonacci sequence

Cluster and Cloud Computing

Benefits

- Availability of large computing resource
- Huge storage space availability
- Easy distribution of data and computation logic
- Availability of more flexible distributed programming paradigm
  - MapReduce
- Effective implementation of MapReduce
  - Hadoop
  - R-Hadoop

Hadoop Based Analytics

- Allows analytics to be carried out on any type of data store
- Provides standard framework for computation
  - On cloud environment
  - On in-premises network
- Advantages
  - Vendor independent
  - Allows any type of analytics to be carried out
  - Provides flexible and adaptable architecture for implementation
- Disadvantages
  - Complex implementation

MapReduce

- Allows use of large computational resources
  - Inter cluster communication is managed by MapReduce
- MapReduce architecture supports
  - Data and task distribution
  - Fault monitoring
  - Task and data replication
  - Simple programming model
- Limitations of MapReduce
  - Cannot solve all the problems

MapReduce: A Pragmatic Approach

- It can solve many Big Data problems
  - Data filtering
  - Statistics and aggregation
  - Graph analytics
  - Decision Tree and classification
  - Clustering and recommendations
- Practical Distributed API
  - Easier to understand and use
- Higher level APIs exist
  - To reduce the complexity of programming
  - Ability to schedule multi-stage jobs

Phases in Hadoop Processing

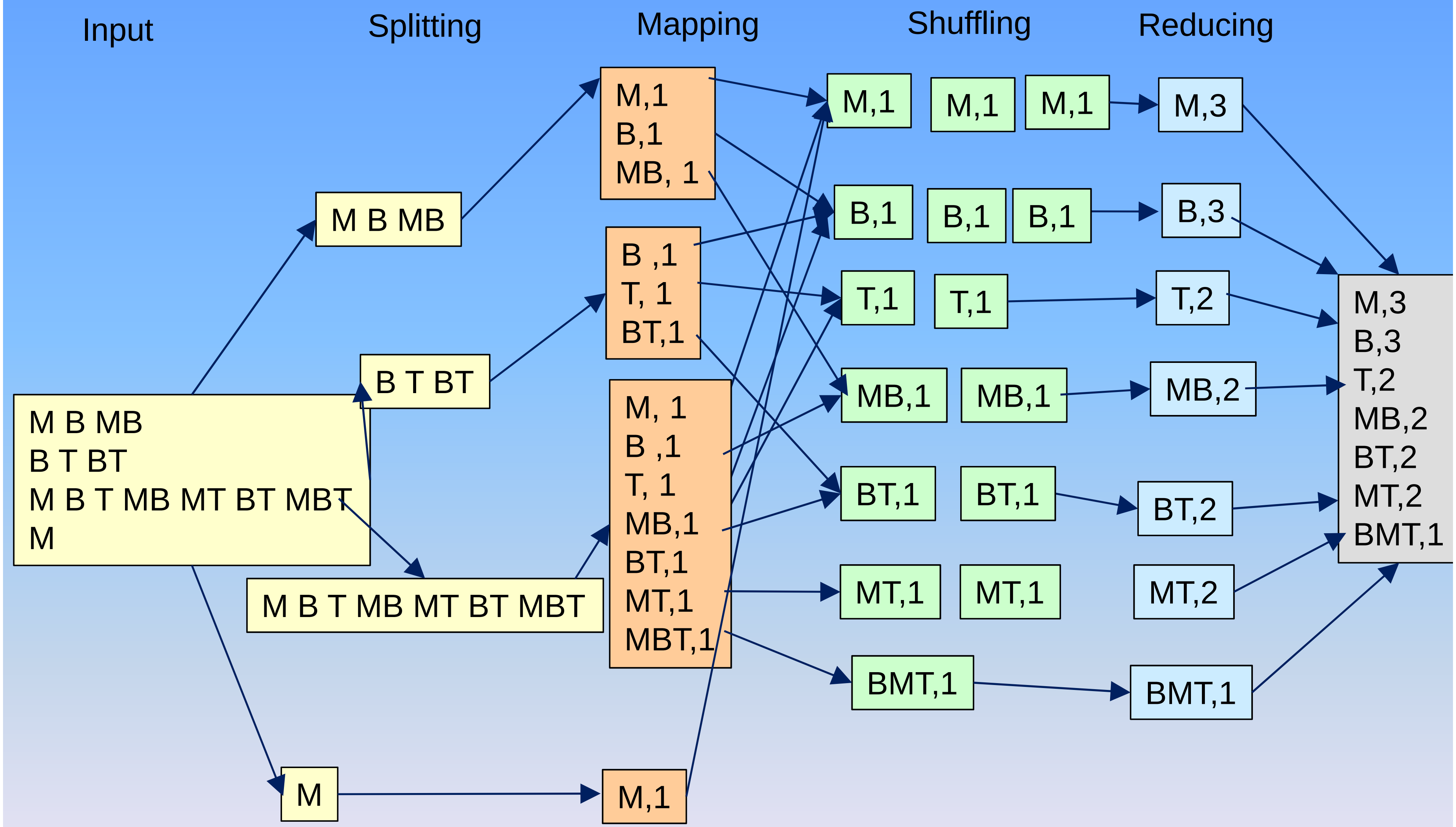
- Data Processing with Hadoop goes through three phases
  - Map Phase
    - Processes the data and generate <key, Value> pairs
  - Shuffle Phase
    - Moves the data <key, value> pairs to appropriate processing node for reduction
  - Reduce Phase
    - Processes the data <key, value> pairs to generate final output
- Hadoop can use multiple machines for each phase

Association Rule Example

- In order to compute support
  - The number of times each product and its combinations occur in the data has to be calculated
- The original transaction file format
  - 1, milk, bread
  - 2, bread, butter
  - 3, milk, bread, butter
  - 4, milk

Transaction ID	Milk (M)	Bread (B)	Butter (T)
1	1	1	0
2	0	1	1
3	1	1	1
4	1	0	0

Association Rule MapReduce



Input

M B MB
B T BT
M B T MB MT BT MBT
M

Splitting

M B MB

B T BT

M B T MB MT BT MBT

M

Mapping

M,1
B,1
MB, 1

B ,1
T, 1
BT,1

M, 1
B ,1
T, 1
MB,1
BT,1
MT,1
MBT,1

M,1

Shuffling

M,1 M,1 M,1

B,1 B,1 B,1

T,1 T,1

MB,1 MB,1

BT,1 BT,1

MT,1 MT,1

BMT,1

Reducing

M,3

B,3

T,2

MB,2

BT,2

MT,2

BMT,1

M,3
B,3
T,2
MB,2
BT,2
MT,2
BMT,1

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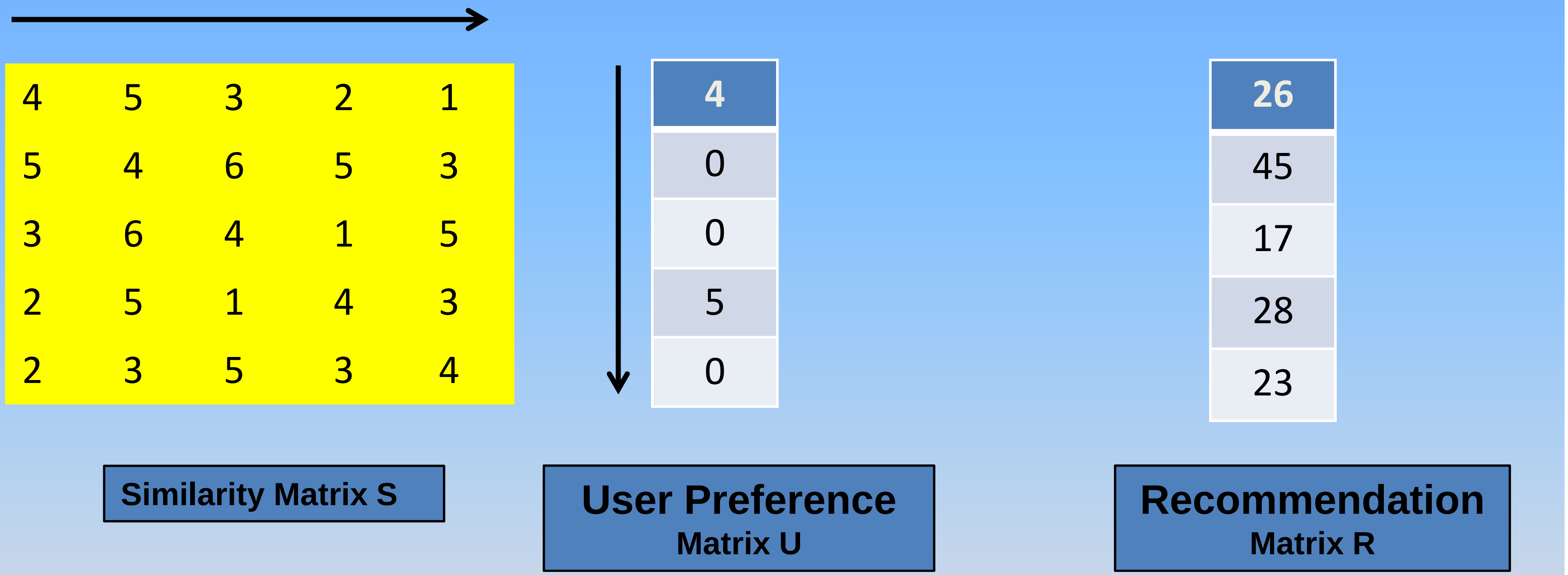
Steps in Structured Data Analytics

- Step 1: Business domain analysis
- Step 2: Data exploration and investigation
- Step 3: Data preparation and cleaning
- Step 4: Model design and development
- Step 5: Model verification and testing
- Step 6: Analyze the output

Application for Recommendation Framework

- Medicine
  - Disease recommendation
  - Drug recommendation
  - Case based search
- Marketing
  - Cell phone companies for identifying users that may switch
  - Recommending books at Amazon
  - Recommending products on the web sites
- Education
  - Universities guiding students what courses to take
  - Conference organizers assigning papers to reviewers

Similarity Concept Used in Recommendation Framework



$$\begin{bmatrix} 4 & 5 & 3 & 2 & 1 \\ 5 & 4 & 6 & 5 & 3 \\ 3 & 6 & 4 & 1 & 5 \\ 2 & 5 & 1 & 4 & 3 \\ 2 & 3 & 5 & 3 & 4 \end{bmatrix} \quad \begin{bmatrix} 4 \\ 0 \\ 0 \\ 5 \\ 0 \end{bmatrix} \quad \begin{bmatrix} 26 \\ 45 \\ 17 \\ 28 \\ 23 \end{bmatrix}$$

Similarity Matrix S

User Preference Matrix U

Recommendation Matrix R

- Recommender can use the following rule:
  - Matrix[S] x Matrix[U] = Matrix[R]

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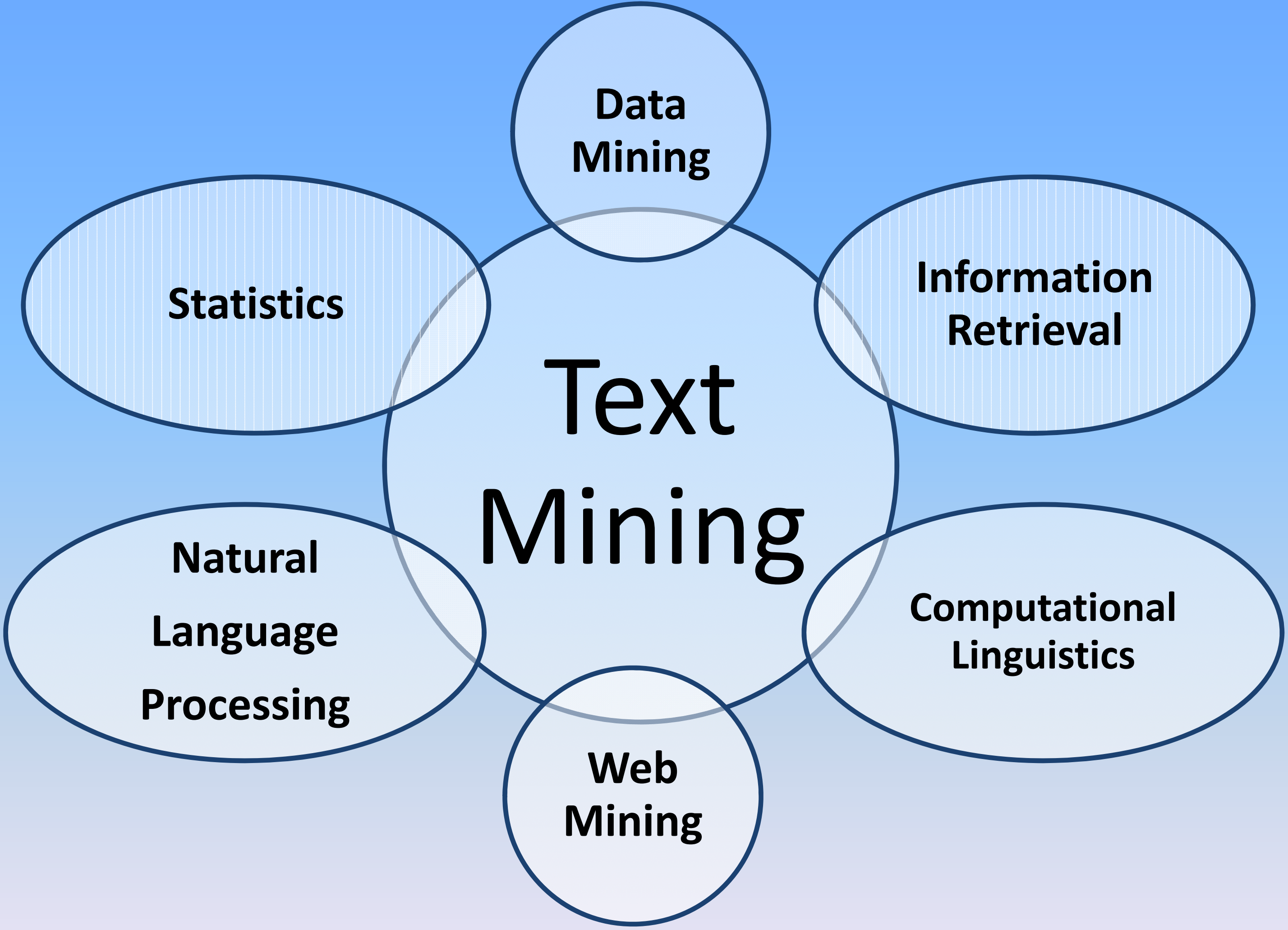
Scope of Text Mining



Challenges in Text Mining

- Each document text may contain large amounts of text
  - High dimensionality
  - Difficult to identify which part is important to a pattern
- Ambiguity of content due to language features
- Sematic issues
  - Words and phrases may not be semantically independent
  - May have subtle and complex relations between concepts in text
- Complexity of natural language processing
- Processing large training set

General Steps in Text Mining

- Text Splitting
  - Split text into bag of words using text tokenization
  - Disadvantage: often loses semantic meaning
- Text Preprocessing
  - Removal of numbers
  - Removal of punctuation marks
  - Text case conversion as needed
- Feature selection
  - Determine nGrams necessary
  - Stop word removal (can use pre-specified list or generic list)
  - Stemming (identify word by its root)

General Steps in Text Mining (Cont'd)

- Determining the weighting of individual words
  - Term Frequency-Inverse Document Frequency (TF-IDF)
- Creating a Term Document Matrix
  - Terms and frequency of each word in a document
    - Simple TD
    - TF-IDF
    - Latent Semantic Indexing matrix

Stop Words

- Most common words in English that do not contribute to classification, clustering or association are:
  - Articles – a, an, the
  - Conjunctions – and, or…
  - Prepositions – as, by, of …
  - Pronouns – you, she, he, it …
- Text documents are high-dimension data
  - Removal of stop words acts as technique for dimensionality reduction
- Other non-context related words can also be removed

Stemming

- The process for reducing inflected (or sometimes derived) words to their stem, base or root form
  - Typically achieved by removing – ing, - s, -er -ed etc.
  - For example: “mining”, “miner”, “mines”, “ mined”
  - Stemmed word “mine”
- Common Algorithms are
  - Porter’s Algorithm
  - KSTEM Algorithm
  - Snowball Stemming

Steps in Association Mining

- Loading the data
- Text preprocessing (as needed)
  - Cleaning
  - Punctuation removal
  - Number removal
  - Stop word removal
  - Stemming
- Building term document matrix
- Finding frequent term association

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Impact of Data Driven Features

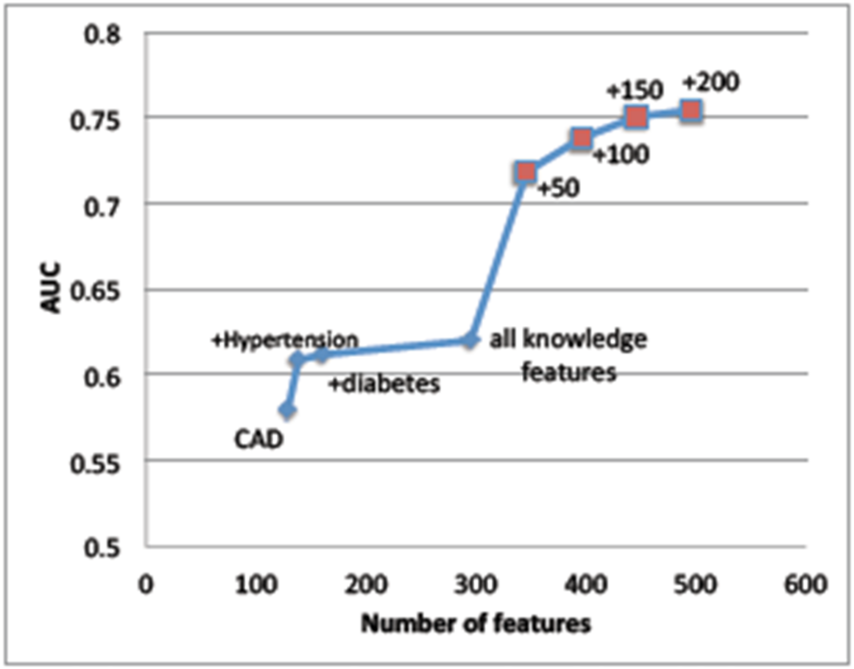


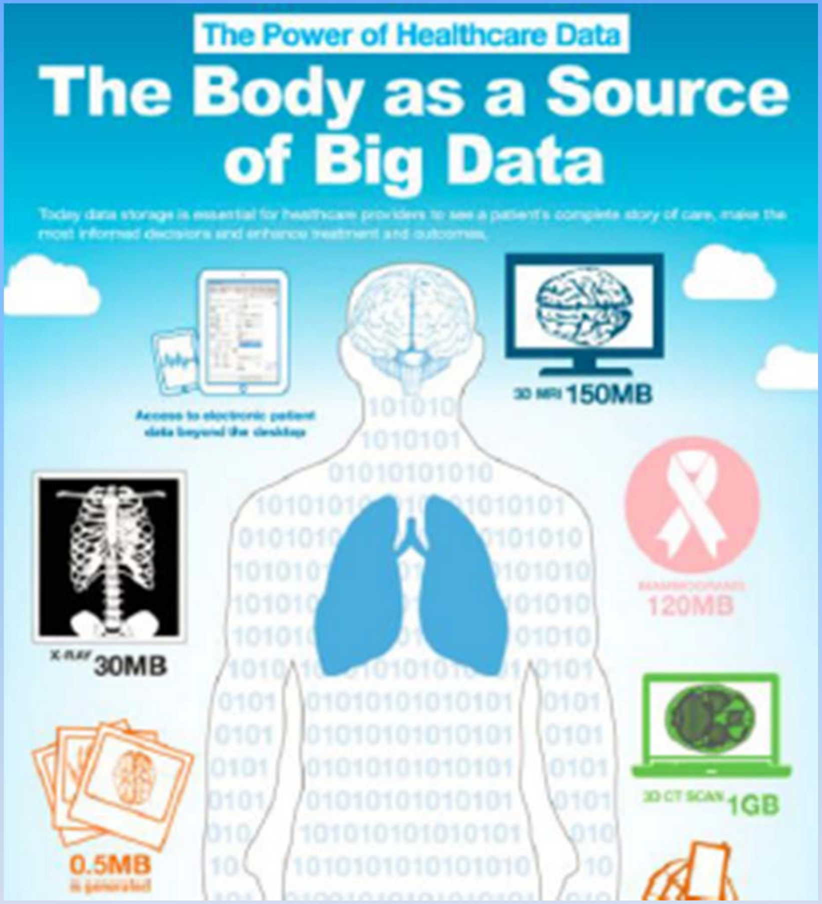
Figure 2: AUC significantly improves as complementary data driven risk factors are added into existing knowledge based risk factors. A significant AUC increase occurs when we add first 50 data driven features.

Jimeng Sun, Jianying Hu, Dijun Luo, Marianthi Markatou, Fei Wang, Shahram Ebadollahi, Steven E. Steinhubl, Zahra Daar, Walter F. Stewart. Combining Knowledge and Data Driven Insights for Identifying Risk Factors using Electronic Health Records. AMIA 2012.

Applications of Patient Similarity

- Heart Failure Prediction
- Likelihood of Diabetic onset
- Disease recommendation
- Medicine recommendation

Medical Imaging



The Power of Healthcare Data

The Body as a Source of Big Data

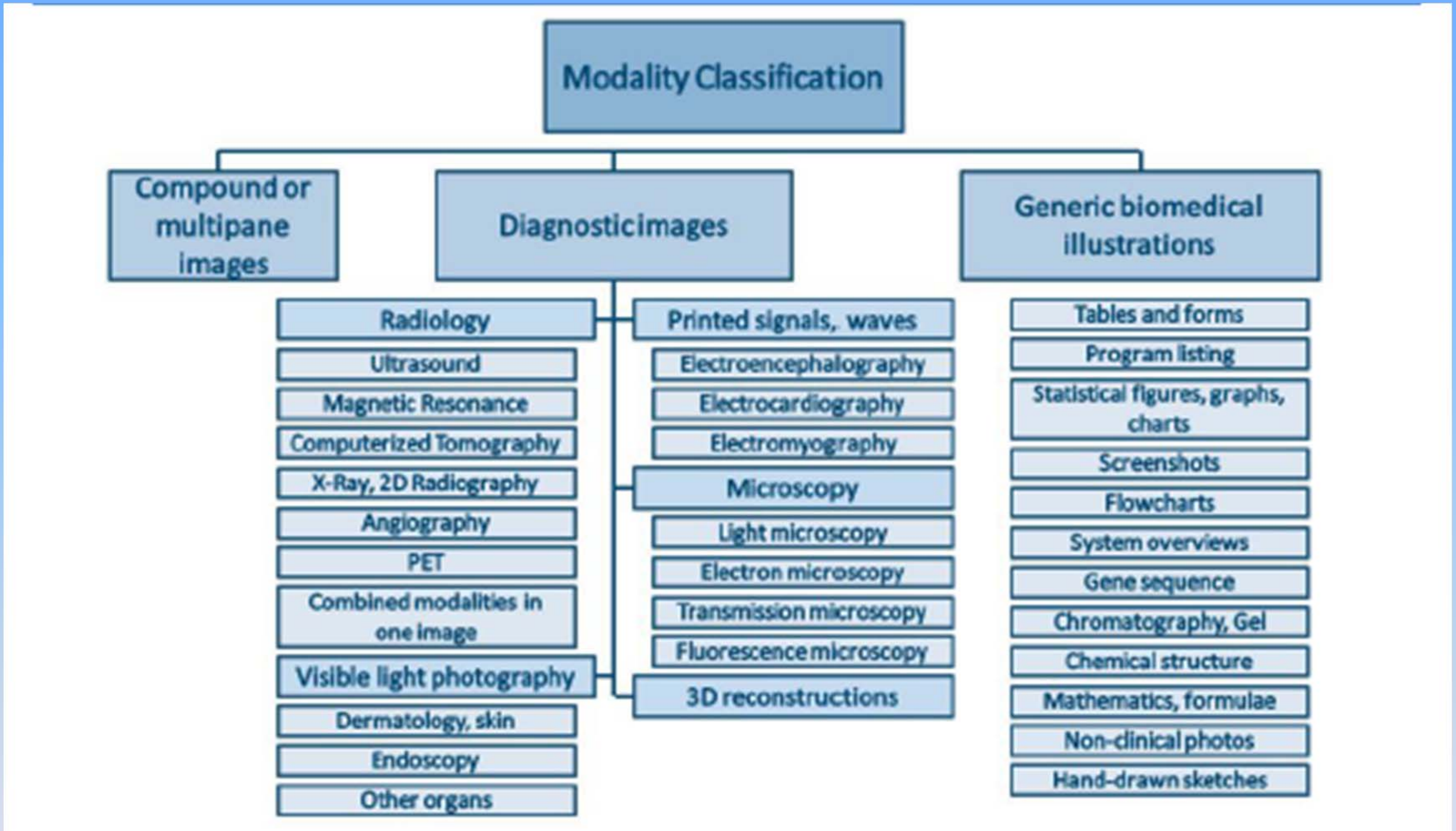
Today data storage is essential for healthcare providers to see a patient's complete story of care, make the most informed decisions and enhance treatment and outcomes.

Image Source: http://medcitynews.com/2013/03/the-body-in-bytes-medical-images-as-a-source-of-healthcare-big-data-infographic/

Analysis Outcomes

- Modality Classification
- Image-based Retrieval
- Case-based Retrieval

Modality Classification



- Modality Classification
  - Compound or multipane images
  - Diagnostic images
    - Radiology
      - Ultrasound
      - Magnetic Resonance
      - Computerized Tomography
      - X-Ray, 2D Radiography
      - Angiography
      - PET
      - Combined modalities in one image
    - Visible light photography
      - Dermatology, skin
      - Endoscopy
      - Other organs
    - Printed signals, waves
      - Electroencephalography
      - Electrocardiography
      - Electromyography
    - Microscopy
      - Light microscopy
      - Electron microscopy
      - Transmission microscopy
      - Fluorescence microscopy
    - 3D reconstructions
  - Generic biomedical illustrations
    - Tables and forms
    - Program listing
    - Statistical figures, graphs, charts
    - Screenshots
    - Flowcharts
    - System overviews
    - Gene sequence
    - Chromatography, Gel
    - Chemical structure
    - Mathematics, formulae
    - Non-clinical photos
    - Hand-drawn sketches

Image Query

- Image-based Retrieval
  - Given a query image and find the most similar images
- Case-based Retrieval
  - Given a case description, details of the symptoms, tests including images
  - Find similar cases including images with case descriptions

Genetic Data

- Human genome is composed of DNA with four building blocks
  - A, T, C, G
- Contains three billion pairs of bases of A, T, C, G
- Size of human genome is 3GB

Genome Wide Association Studies (GWAS)

- Identifying common genetic factors that influence health and diseases
- Compare DNA of patients with disease and similar people without disease
- Single nucleotide polymorphisms (SNPs) are DNA sequence variations that occurs when a single nucleotide in genome sequence differs between individuals

Epidemiology Data

- Source
  - Surveillance Epidemiology and End Results (SEER) Program at NIH
- Usage
  - Understanding the disparity in diseases related to race, age and gender
  - Information correlation with other data sources such as pollution, climate and socio economic
  - Can use predictive analysis for various disease trends

Social Networks for Patients

- PatientsLikeMe
  - Has more than 200,000 patients and is tracking more than 1600 diseases
  - www.patientslikeme.com

Big Data Analytics: Barriers

- Cost of analytics
- Lack of skilled talent
- Difficult to architect a Big Data Solutions
- Big data scalability issues
- Limited capability of existing database analytics
- Tangible business justification
- Lack of understanding of Big Data benefits

Concluding Remarks

- Better diagnosis
- Better health care delivery
- Better value for patient, provider and payer
- Better innovation
- Better living