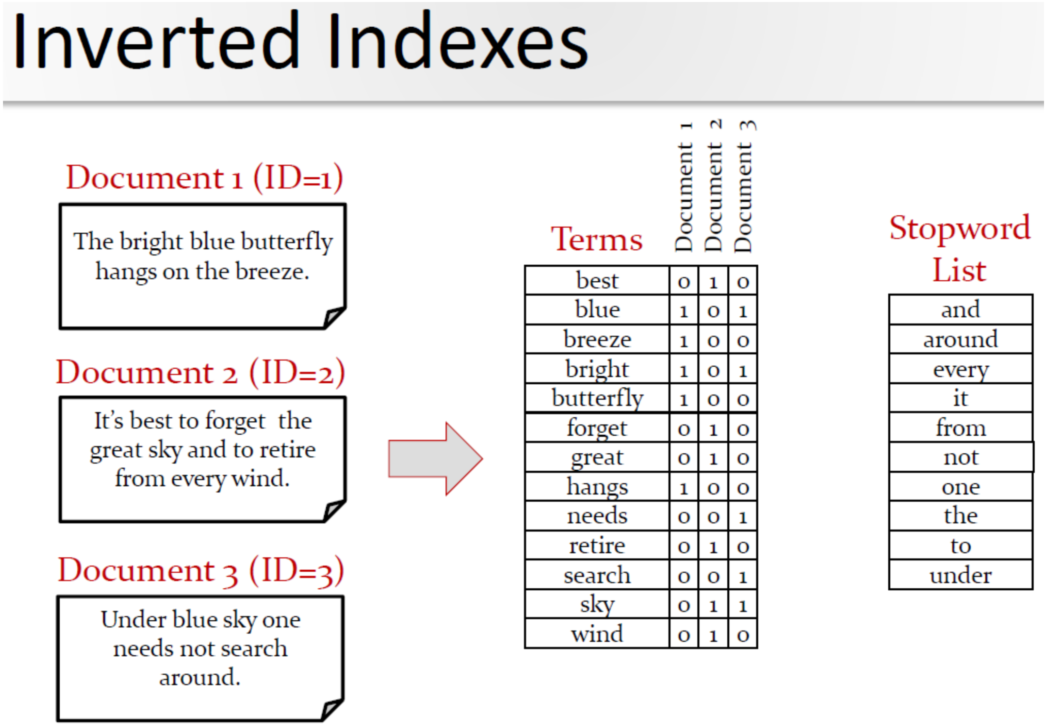
Information Retrieval

Buzzword Bingo

- Information Retrieval (IR)
  - finding material (usually documents) of an unstructured nature (usually text) that satisfies an information need of users from within large collections of documents (usually stored on computers).
- IR Process
  - Data -> Create Document Representation -> Index Docs -> Ready
    - Done beforehand
  - User query -> create query representation -> Search Indexed Docs -> Order
- Retrieval Model
  - Quality of a retrieval model depends on how well it matches user needs !
  - Determines
    - the structure of the document representation
    - the structure of the query representation
    - the similarity matching function
- Query
  - what users look for
  - list of words or phrases
- Document
  - Data
  - Bag of words
- Corpus/Collection
  - Set of documents
- Index
  - representation of information to make querying easier
  - Manual Indexing
    - Pro: Human indexers can establish relationships and concepts between seemingly different topics that can be very useful to future readers
    - Con: Slow and expensive
  - Automatic Indexing
    - Inverted Index
      - map terms to docs
      - finds docs matching query



    - Indexing with Controlled Vocabulary
        - Find synonyms
        - describe concepts with lists of terms
        - e.g. Vehicle, Car, Mercedes, Taxi all describe the same concept
        - can increase performance
    - Vector Space Models
        - map docs to terms
        - find docs matching query
        - ranks docs for best match
- Controlled Vocabulary
    - relationship between terms
    - find synonyms
    - List
        - e.g. alphabetical list
    - Ring
        - set of X terms
        - used in search engines
    - Taxonomy
        - hiarchical classification system
        - each term has one or more broader terms except the top term
        - each term has one or more narrower terms except the bottom terms
    - Thesaurus
        - taxonomy + additional relationships
- Boolean Queries
    - OR
    - AND
    - BUT
    - Ranking hard => yes, no answer
    - Relevance feedback hard => no ranking

  - all matched docs are returned
  - complex requests hard to write
- Union
  - everything in A + everything in B = OR
- Intersection
  - What's in both = AND
  - performance -> start with smallest set then keep ANDing
- Difference
  - (A OR B) - (A AND B) = BUT
- Term
  - word/concept in document or query
  - weighting
    - too frequent
    - significant
    - too rare
    - document with 10 occurences of a term is more important than a document with 1 occurance BUT not 10 times as important => weighting becasue relevance doesn't increase proportionally
- Dictionary
  - sorted list of terms used by the index
- Document Processing Pipeline / Normalization
  - Text
  - remove properties and formatting
  - parse
  - remove stopwords
  - stemming or lemmatization
  - synonym matching
  - indexing
- Token
  - small unit of meaningful text
- Tokenization
  - break into tokens on whitespaces
- Tokenization Problems
  - Specific domains like biomedical texts have lots of unusual symbols/special terms that should be interpreted correctly
  - Semantic meaning could be lost
- Lemmatization/Stemming
  - Stem = cut off
    - walk, walked, walking => walk => walk(ed | ing)
  - Lemmatizaton = get words like in dictionary through morphological analysis
- Morphology
  - knowledge how words are morphed => write, wrote, written = write
- Stop Word removal
  - Stop Word
    - small/no semantic content
    - the, a, an, is

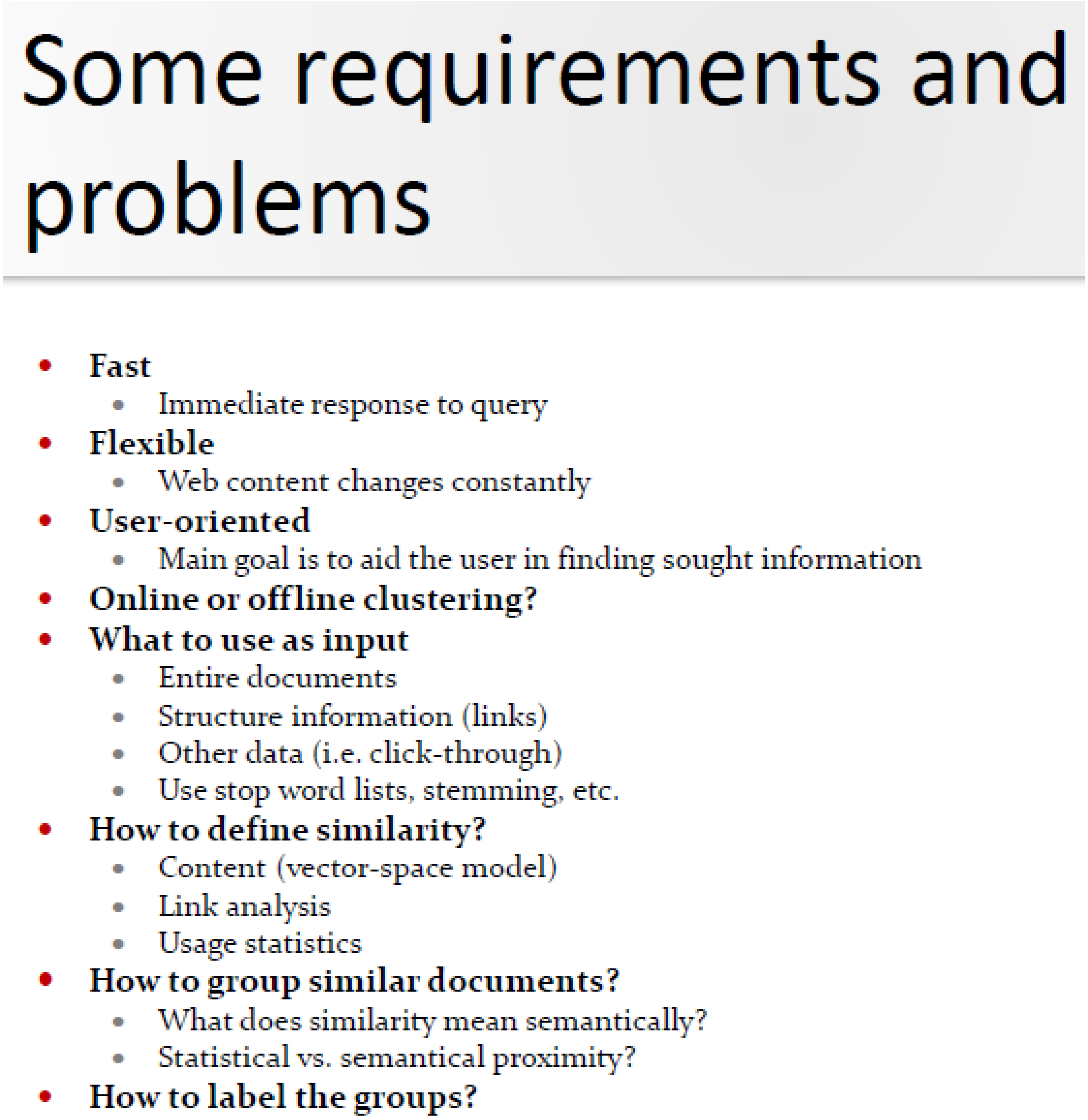
- Ranked Retrieval
  - more relevant = higher up
  - Jaccard Coefficinet
    - CONS:
      - term frequency doesn't matter
      - but rare terms are more informative than frequent ones
  - Statistical Models
    - vector space model
    - statistical info used for ranking => term frequency
    - Ranked based on similarity to query
    - similarity based on frequency of keywords
- Vector Space Model
  - Docs and queries are represente as N-dimensional vectors
  - Terms get a weight
  - Terms = Axes of the Vector Space
  - Documents are points or vectors in the vector space
  - Document collection can be represented as term-document matrix
    - Entry = Weight of term in a document
    - Term Frequnecy = frequenzy / most commont term
  - Document frequency
    - number of documents containing the term
  - Inverse Document Frequency
    - Terms that appear in many different documents are less
  - CONS
    - missing semantic info
    - missing syntactic info
    - assumption of term independenc (ignores synonyms)
    - Lacks the control of a Boolean model (e.g., indicative of overall topic
  - Term Frequency + Inverse Document Frequency:
    - TF-IDF Weighting
    - most common term weighting approach (vector-space model)
    - A term occurring frequently in the document but rarely in the rest of the collection is given high weight
- Similarity
  - Euclidean distance
  - Vector Product
  - Cosine similarity

Clustering Classification

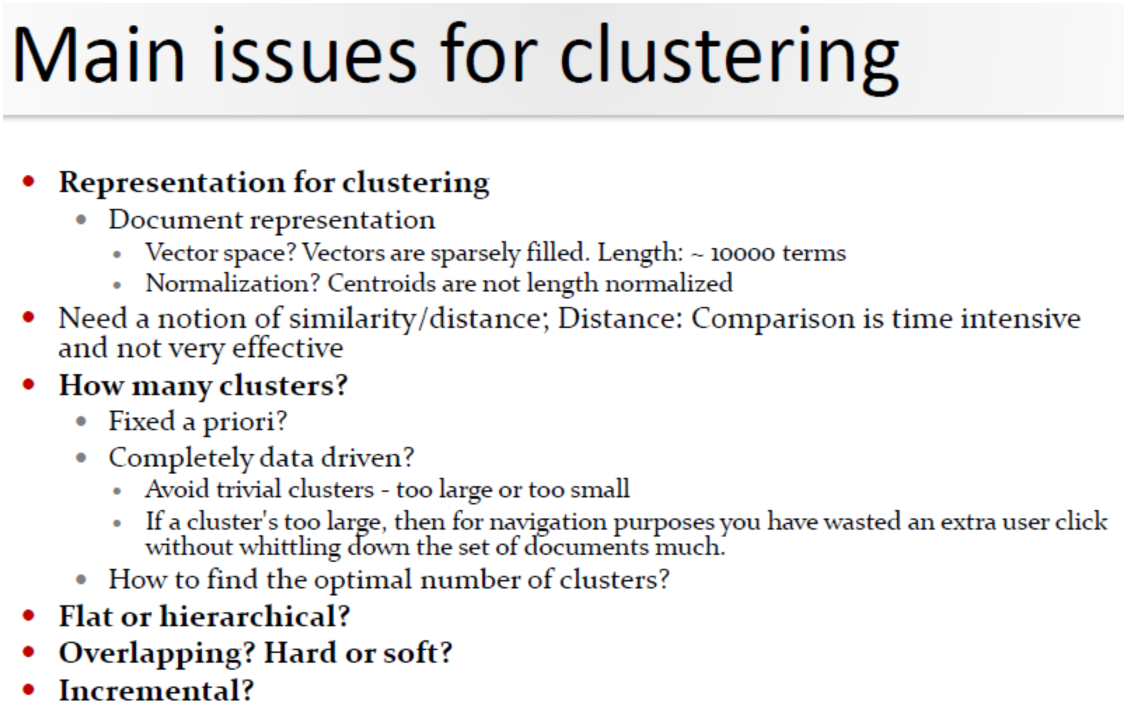
Buzzword Bingo

- Clustering

  - infers groups based on clustered objects
  - the process of grouping a set of objects (documents) into classes of similar objects (documents)

- most common form of unsupervised learning
- Docs in same cluster behave similar with respect to relevance to information needs
- Applications
  - Speed up vector space retrieval
  - imporved recall => better search results
- Requirements
  - 

- Problems

- 

  - Documents within a cluster should be similar
  - Documents from different clusters should be dissimilar
  - Algos
    - Distance Based
      - K Means
      - single-pass
    - Hirarchical
      - Bottom Up
      - Top Down
    - Other
      - Suffix Tree Clustering

- Pipeline
  - Partitioning Algo
    - create k clusters

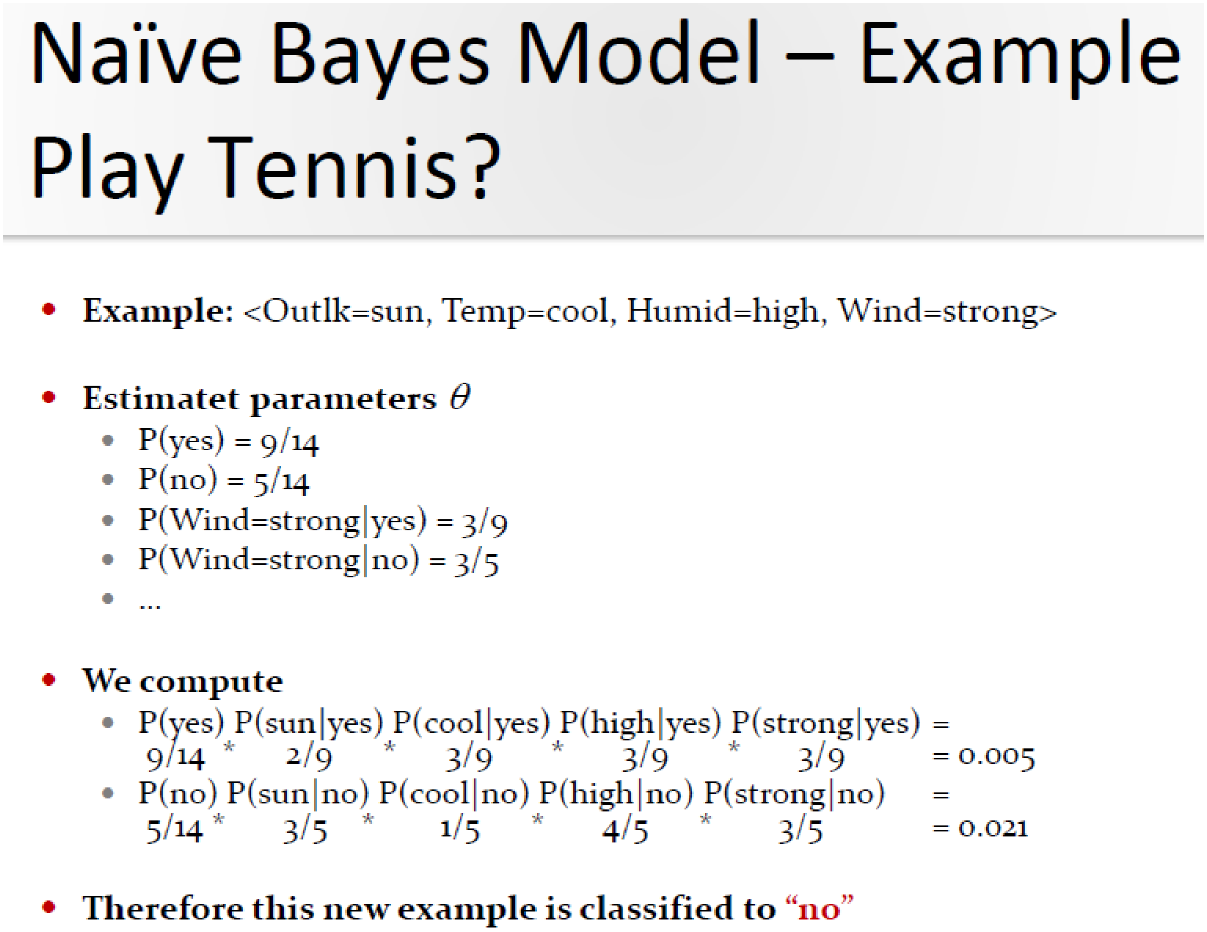
- K-Means
  - clusters based on centroids
  - Reassignment of instances to clusters is based on distance to the current cluster centroids

- Hard Clustering
  - one doc => one cluster
  - K-means

- Soft Clustering
  - one doc => set of clusters
  - gives a probability that a doc belongs to a specific cluster
  - Sum of possibilties = 1
  - Types

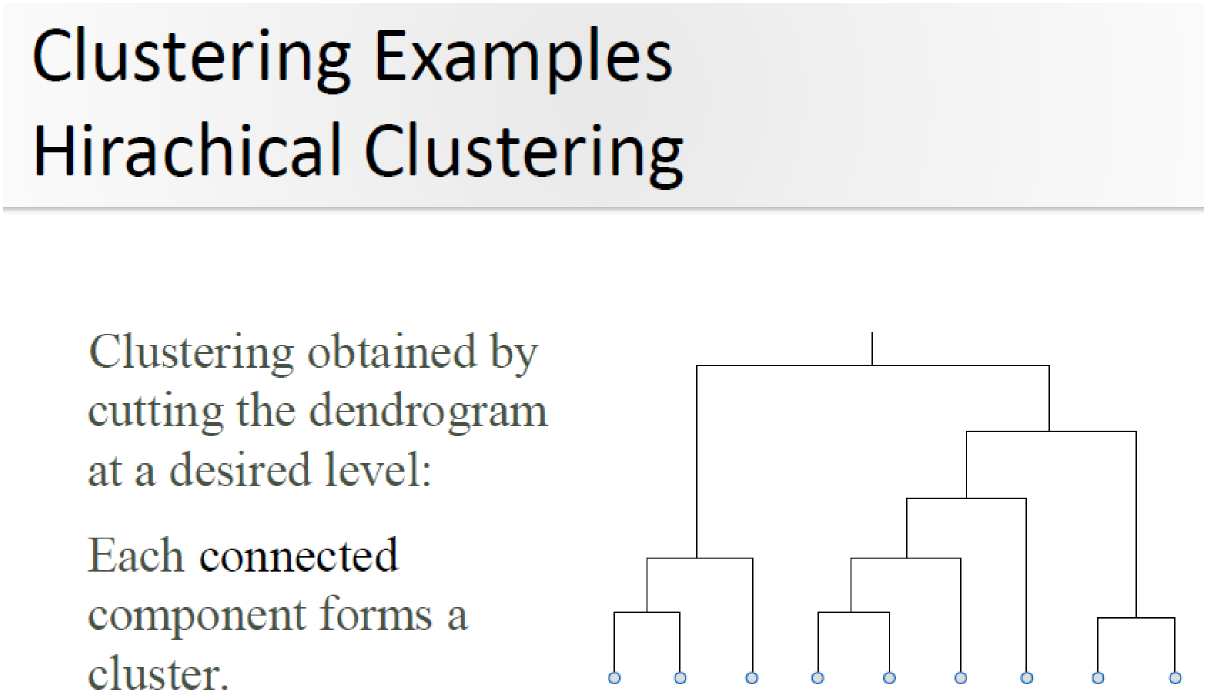
- Fuzzy Clustering (pattern recognition)
- soft K-means

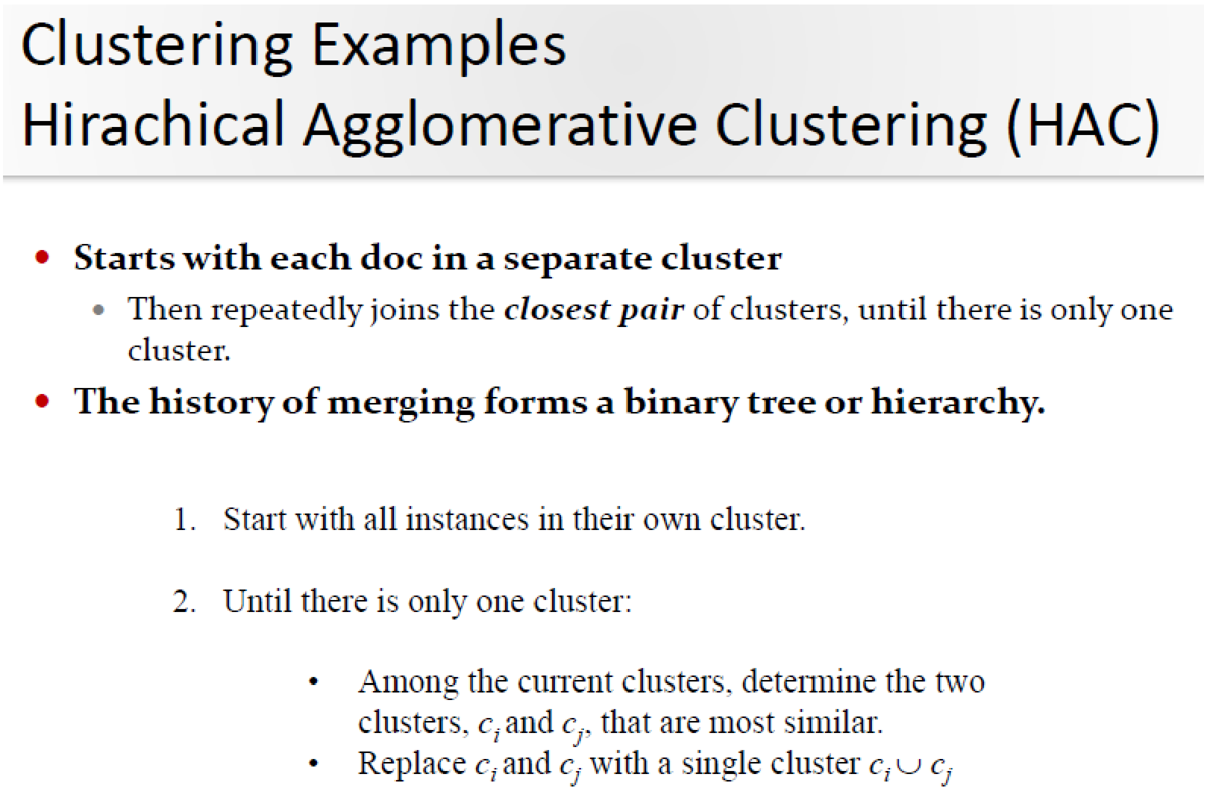
- Naive Bayes Model



- Expectation Maximization Algo
  - uses bayes model
  - Expectation
    - Use naive bayes to compute probability => soft label
  - Maximization
    - use standard naives bayes training to learn to re-estimate params

- Hirarchical clustering - HAC

- 

- 

* Buckshot Algo
    - HAC + K-means
* When is clustering good?
    - nodes in a cluster similar (intra-calss similarity = high)
    - nodes in other clusters different (inter-class similarity = low)
* Cluster Quality Evaluation
    - purity

- ratio of dominant class and the size of the cluster
- entropy of classes
  - mutual information

- Silhouette Values

  - Good clusters have the property that cluster members are close to each other and far from members of other clusters

-

- Classification

  - assigns objects to predefined groups
  - Rocchio Method
    - tf-idf weights
    - assign to the closest centroid
  - k Nearest Neighbor kNN

Information Extraction

- Identify specific pieces of information (data) in a unstructured or semi structured textual document.

- Transform unstructured information of a corpus of documents or web pages into a structured database

- processing human language documents utilizing natural language processing (NLP)

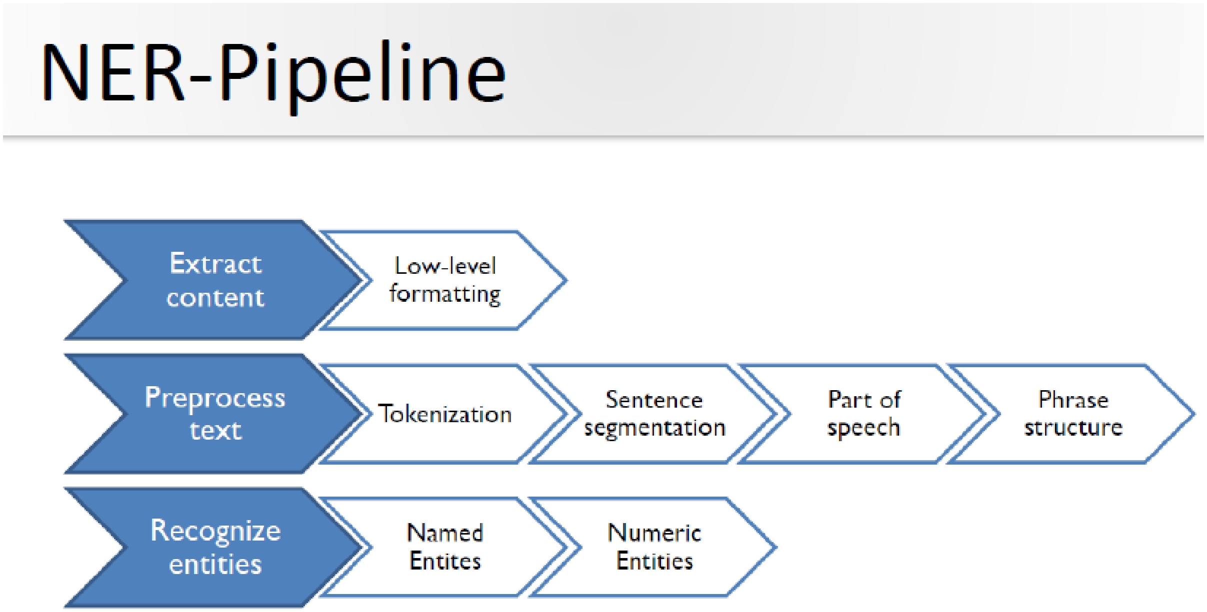
- current approaches to IE focus on narrowly restricted domains: sports, medicine, business

- Extraction of

  - Entities => e.g. Person => You
    - Generic => Person, Organization, ...
    - Custom => domain specific e.g. Drugs, Deseases
    - Numeric => Time, Date, Numbers
  - Attributes => e.g. Title of a Person => BSc
  - Facts => relations between entities => Suckerberg works at Facebook
  - Events => activity or occurance => NSA - terroristic acts, ABC merges with BBC etc.

- NER - Named Entity Recognition

  - mark each element which represents
    - person
    - company
    - country
    - ...
  - NER involves identification of proper names in texts, and classification into a set of predefined categories of interest

- 

- Extract Content
  - remove irrelevant content = junk
    - Pictures
    - Tables
    - Diagrams
    - Adds
- Tokenization
  - extract tokens
  - Problems
    - symbols like (. , : "" '' ...)
- Sentence Segmentation
  - Nomen est Omen
- POS Tagging
  - Assign types to words
    - Noun
    - Adjective
    - Verb
    - ...
  - Problem: ambiguity
  - Rule based approach
    - analyze word, word before, word after etc.
    - analyze surrounding context
  - Probabilistic Approach
    - How common is it that this type of word is after such a type of word
  - Unigram Tagger
    - assign most likely tag to token
  - Stochastic / N-gram / HMM
  - N-gram
    - generalization of unigram tagger
    - look at sequences of words and assign tags
    - consider all possible combination and take the most likely one
  - HMM-based tagging

            - (Informally) Markov models are the class of probabilistic models that assume we can predict the future without taking too much account of the past
        - Bigram Tagger
            - assign tags to groups of two words
        - Phrase Structure
            - identify syntactical froups within a sentence
                - Noun Phrase
                - Verb Phrase
            - Chunking (Partial Parsing)
                - divide sentence in prase chunks
        - Recognize Entities
            - find named entities
                1. Segmentation
                2. Classification
    - Morphology
        - get root form of a word

- Sequence Labeling

    - Local: the previous label
    - Global: lable by maximizing on the whole sentence

- TE - Tempalte Element Task

    - generic object with attributes
    - draws evidence from everywhere in the text

- TR - Tempalte Realtion

    - find the relationship
    - e.g. employee_of, product_of, location_of

- ST - Scenario Template Task

    - extract specific event information
    - relate info to organization/person/artifact

- CO - Coreference Task

    - ???

- Examples of IE

    - Disaster Events

- Components of an IE system

    1. Tokenization
        - split input into parts = tokes
    2. Morphological and lexical analysis
        - Part of Speech - POS Tagging

            - assign type to word (verb, noun, adjective, ...)
        - disambiguating the sense of ambigous words
            - words that are written the same but have different meanings
            - flies => the flies sit on a pile of shit, or a bird flies
    3. Syntactic analysis
        - connection between parts of a sentence
    4. Domain analysis
        - combine all info from the steps before
        - describes relationship between entities
        - CO COreference Resolution - Anaphora Resolution
            - match indirect references
            - e.g. they in the next sentence refers to an entity from the privioud one
    5. Integration
        - Merge results with oter IE systems (Onthologies)

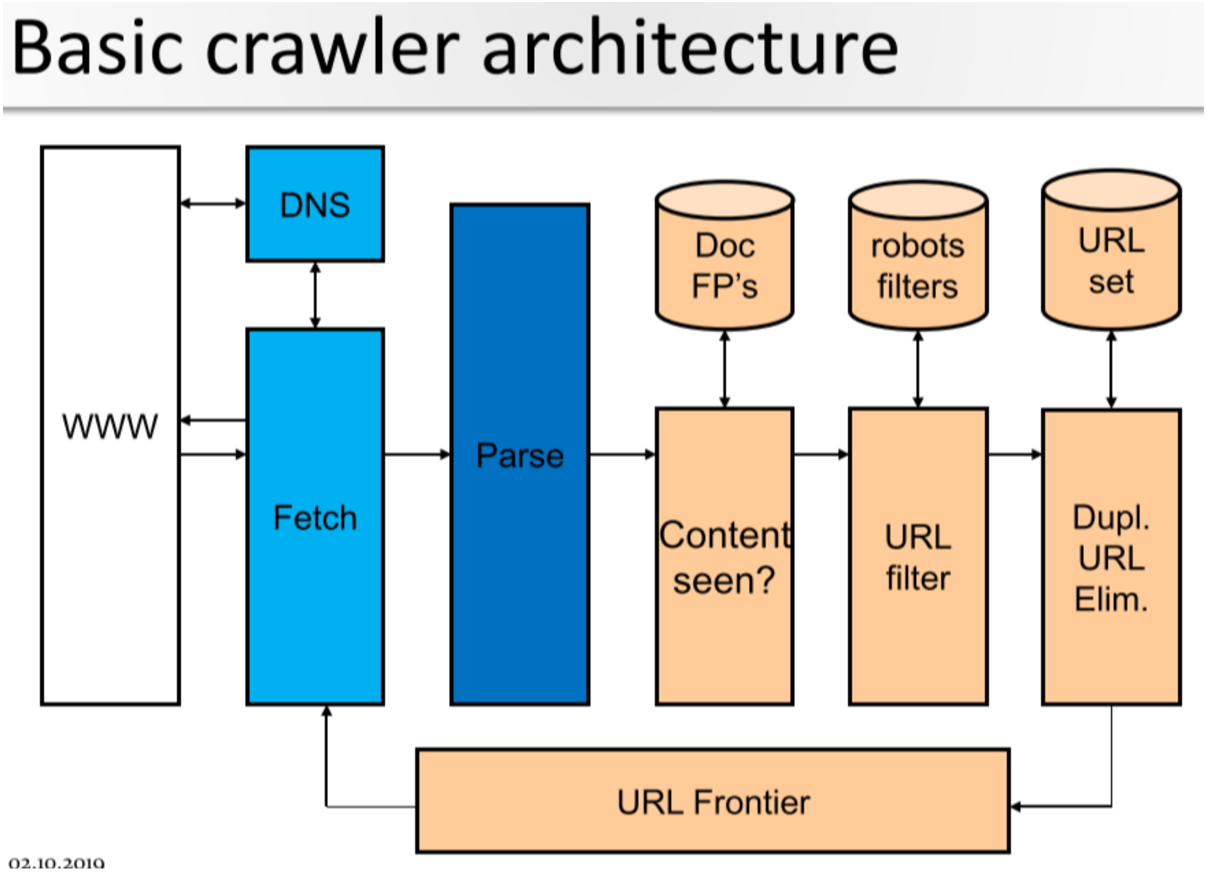
- Evaluation

    - Precision
        - probability that retrieved doc is relevant
    - Recall
        - probability that relevant doc is retreived in a search
    - F-measure
        - combines precision and recall

Web Search & Crawling

- User Needs
    - Informational
    - Navigational
    - Transactional
- Result Quality
    - Relevance not enough
    - Trustworthy?
- Precision vs Recall
    - Precision
    - Recall: not relevant in Web
- Crawler Operations
    - begin with known URLs
    - fetch and parse them
        - extract URLs
        - Place extracted URL on queue
    - Fetch each URL on the queue and repeat
- Crawler Props
    - DISTRIBUTED SYSTEM => one crawler not feasible
    - Malicious pages
        - SPAM

        - Spider Traps
    - Non Malicious
        - Latency can be an issue
        - How deep should you crawl a sites URL hierarchy?
        - Duplicate pages
- What Crawlers must do
    - be polite
        - only allowed pages
    - be robust
        - spider traps etc.
- What Crawlers should do
    - distribute operations
    - be scalable
    - perfomance
    - high quality pages first
    - continous operations
        - check sites in cycles
    - Extensible
        - new data formats
- Crawling steps
    - pick URL
    - fetch document at URL
    - parse URL
        - link extraction
    - Check if URL has content already seen
        - if not add indices
    - For each extracted URL
        - pass URL filter test
        - check if it is in frontier

  - 

- URL Frontier
  - multiple pages from the same host possible
  - avoid fetching them all at the same time
  - try to keep crawling threads busy
- DNS
  - get IP to URL
  - use DNS caching (lookups can take seconds)
  - Batch DNS requests
- Parsing - URL Normalization
  - some extracted links are relative URLs
  - solution
    - expand URLs => absolute path
- Content already seen?
  - duplication widespread
  - if a page is in the index do not process it
  - verify with
    - doc fingerprint e.g. Hash
    - shingles = compare text parts (Shingle)
- Duplicate URL Eliminator
  - one-shot crawl => just once not continuous

Link Analysis

- The Web is a directed graph
- Indexing anchor text
  - can score anchor text with a weight depending on the authority of the anchor page's website
- Citation Analysis

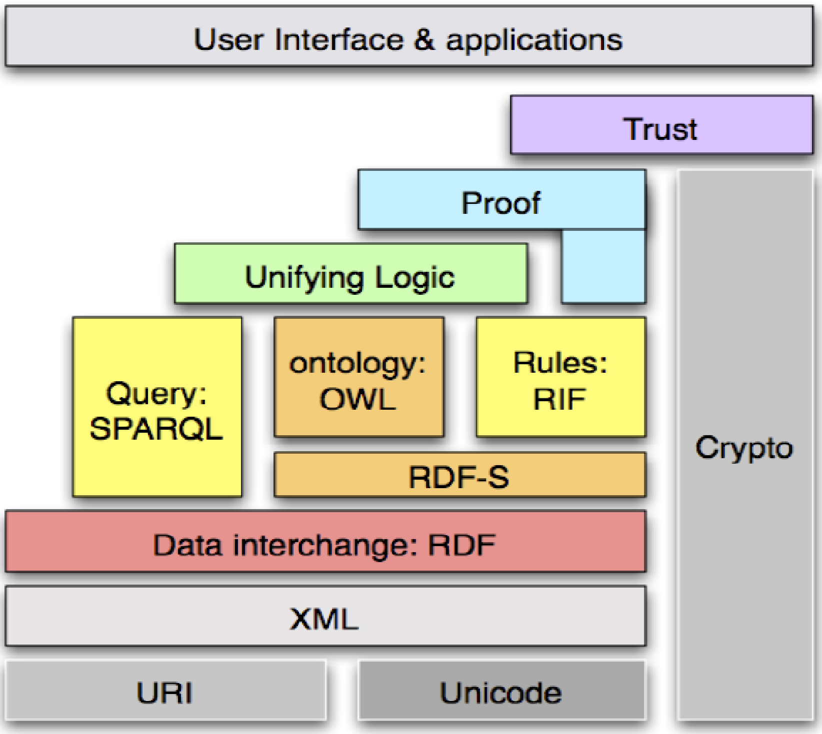
    - citation frequency
    - Co-citation coupling frequency
    - Citation Indexing
    - Pagerank preview
- Query independent ordering
    - count links
        - undirected = inlink + outlink
        - directed = inlink
- Page Rank
- Topic specific Page Rank
- HITS
    - hub page
    - authority page
- High-level scheme

Semantic Knowledge Models, Semantic Web Stack

- Semantics = study of meaning
- common languages
    - Index = common terms and symbols
    - Glossary = their meaning => vocabulary in a domain with definitions for terms
    - Taxonomy = classification of concepts
        - hierarchical classification
        - classes of objects and relations between them
        - NO description or definition of objects
    - Thesaurus = Associations between concepts
        - is unambigious - UNLIKE NATURAL LANGUAGE
        - It is a model that attempts to describe and represent a topic exactly
        - a systematically ordered collection of concepts
        - controlled vocabulary => (attribute, value, range)
        - manages synonyms, broader/narrower and related terms
    - Map
        - spatial visualization of the structure
            - representation) provides information on the semantic meaning of what is shown
            - content
            - ideas and knowledge
            - information and resources
    - Topic Map
        - is the collection of knowledge on subjects
        - TAO
            - Topic = concept => person
            - Association = realtionship between concepts e.g. mother
            - Occurence = representation of information resources on a specific topic
    - Onthology = Rules and knowledge about which crosslinks are permitted
        - explicit specification of a conceptualization
        - agreement among people with a common motive of sharing

            - defines a common vocabulary for info sharing in a domain
            - purpose
                - structuring
                - communication
                - interoperability
                - data exchange
                - systems engineering, reliability, reusability, ...
            - Components
                - concepts
                - types
                - individuals
                - properties
                - inheritance
                - axioms
                    - a truth that's not questioned anymore
                - desribes a segment of the world in a given domain
                - Things = concepts
                    - classes
                    - individuals
                - concepts have
                    - props
                        - follow restrictions
                    - relationships
                        - follow restrictions
                -
        - Folksonomy
            - Social network => social tagging in social software
            - generated by machines
            - no
                - hierarchy
                - quality control
                - sound theory
- Web 2.0
    - users are now prosumers (producer + consumer)
    - users create and edit content themselves
        - wikis, blog, sharing (youtube), social networks
- Web 3.0
    - extension of the current web
    - give content meaning and connect content
    - improves machine-human interaction
    - based on RDF
    - is a common framework for information sharing
    - W3C
    - Semantic Web Stack

Semantic Web Stack des W3C

- 

- Character Set
  - Unicode
    - basic coding standard
  - URI
    - Unambigous identification of resources
    - only ASCII chars
    - URIs are the standard for the identification of (online) resources
    - Resources are objects
  - IRI
    - uses UNICODE character set > ASCII
- XML
  - extended markup language
  - syntax basis
  - Namespaces
    - allows usage of the same tag in different contexts
- RDF
  - assigns specific URIs to its individual fields
  - RDF
    - provides assertion
    - is machine processable
    - is defined by a set of triplets
    - Resources are identified by URIs
    - Predicates are defined by the RDF vocab

                - namespaces shorten URIs
                - RDFS
                    - RDF Schema
                    - onthology language
                    - allows the creation of vocabs
                    - classes, properties, domains, ranges, inheritance (class and property), containers
                    - meaningless statements can be prevented through the use of classes
                        - e.g. only authors can write books
                        - e.g. only books can be written
        - OWL - Web Onthology Language
            - based on RDF
            - higher expressiveness than RDF
            - allows complex relationships
        - Rule SWRL und RIF
            - SWRL
                - OWL + Rule markup language
            - RIF
                - Rule Interchange Format
                - translation between rule languages
        - SPARQL
            - RDF query language
        - Logic Framework
            - inference engine
            - draw conclusions
            - derive new knowledge
            - proof is hard
            - apply rules and draw conclusions
        - Trust
            - required to check the validity of information
            - trustworthiness of the source
            - authenticity of the source
            - digital signatures => to ensure
        - Cryptography
            - ensure data security
        - User Interface & Applications
            - use semantic web applications
            - Tools
            -

Knowledge Engineering & Onthology Description

- Kowledge Engineering
    - Knowledge Base
        - facts
        - rules

- Inference Engine
    - Brain
    - new knowledge generated by inference
- User Interface
    - Fill KB
    - Query
    - inference results
    - update knowledge
- Knowledge Aquisition
    - get expert knowledge
- Formalization
- Knowledge Processing
    - for problem solving
    - e.g. inference
- Knowledge Representation
    - UI
- Phases
    - indentify task
    - LOOP
        - Knowledge acquisition
        - ontohology => specify vocabulary
        - formalization => Axioms and instances
        - inference procedure => Evaluate + Test
        - implementation, maintenance
    - END LOOP
    - Phase 1 - Problem Description
        - identify task
        - specify domain
        - elect experts => Competence questions
    - Phase 2 - Knowledge Acquisition
        - gather knowledge
        - direct
            - expert does it
        - indirect
            - knowledge engineer uses KM methods with experts
        - autoamted
            - machine learning
        - model-based
            - KM models
        - list important concepts
            - wine
            - grape type
            - color
            - taste
            - ...
        - documentation

        - Phase 3 - Conceptualization
            - specify the vocabulary
                - onthology
            - cognitive to representation level
            - consisten representation of knowledge
            - define classes and the hierarchy
                - Taxonomy = Hierarchy:
                    - Wine
                        - Red
                            - Cabernet Franc
                            - Pinot Noir
                            - ...
                        - White
                            - ...
                        - Rose
                            - ...
        - Phase 4 - Formalization
            - Instances
            - Axioms
                - Inheritance
                - Disjunction
            - Constraints
                - cardinality
                - transitivity
                - symmetry
            - DEFINE
                - relationships
                - properties / slots
                - values / facts
        - Phase 5 - Evaluation
            - Inference
            - Validate acquired knowledge
                - completeness
                - reliability
            - Iterate if necessary => continue with Phase 2
        - Phase 6 - Implementation and Maintenance
            - Implementation
            - UI
                - query
                - explanation/visualizaton component
                - manipulation component

Onthology description language

- Why?
    - base for data and knowledge sharing
    - common vocab

- same understanding of terms
- Automation (Reasoning)
  - derive implicit knowledge
  - identify inconsistency
  - determine concept hierarchies
- Onthologies
  - set of concepts
  - and relationships between them
  - includes
    - description and definition of terms/concepts
    - properties
    - relationships
    - limitations
    - inference and integrity rules
    - individuals
- RDF
  - basic onthology language
  - SPO Triples
  - (subject, predicate, object)
  - (resource, property, property value)
  - (kasperl, hasFriend, Pezi)
  - resource = object
  - resource identified with URI
- RDFS
  - classes, properties and hierarchies
  - inheritance => subclassOf
- OWL
  - Domains and Ranges are AXIOMS not constraints
  - Object property = link to individual
    - inverse
      - hasPartent/isParent
    - functional
      - exactly one individual is in relation with this property
      - hasBirthmothe
    - inverse functional
      - the inverse property is functional
      - isBirthmotherOf
    - transitiv
      - has ancestor
    - symmetric
      - hasSibling
    - asymmetric
      - hasChild
    - reflexive
      - must relate to self
      - knows

        - irreflexive
            - relates a and b
            - a and b cannot be the same individual
            - isMotherOf
    - Datatype Property
        - functional = only one value allowed
        - else = multiple values allowed
    - Datatype property = link to XML schema/datatype value or rdf literal
    - Annotation properties
        - add info
    - Describe a detail of the world:
        - What things are there?
        - What is the relation of these things?
        - What characteristics do these things and the relationships with each other have?
    - Ontology description = Syntax
    - Ontology rules = Semantics
    - Types
        - Named class
        - disjoint
        - union
        - complementary
        - anonymous
        - enumeration
    - Anonymous class
        - pattern matching
        - classification
        - limited on properties
        - e.g. all elements which have a hasFriend relationship
- Primitive Classes
    - A member of a named class must satisfy the conditions
    - An individual which satisfies the conditions is not necessarily an element from the named class
- Defined Class
    - Elements of the defined class satisfy the conditions
    - if an element satisfies the conditions it is also the defined class
- Necessary vs . Necessary and Sufficient Conditions
- Partial vs . Complete Definitions
- Open World
    - All that's not explicitly marked as impossible can exist
    - OWL
- Closed World
    - All that's not explicitly allowed is impossible
    - Database
- Rules - SWRL
    - more powerful deductive reasoning
    - body -> head
    - body and head = conjunction of atoms

  - atom = (arg1, arg2, ..., argN)
  - Class Atom
    - Person(?p)
  - Individual Property Atoms
    - hasBrother(?x, ?y)
  - Data Valued Property Atoms
    - hasAge(?x, ?age)
  - Different and Same Individuals
    - differentFrom(?x, ?y)
  -

SPARQL

- Queries
  - SELECT
    - get
  - ASK
    - true/false
  - CONSTRUCT
    - get RDF Graph
  - DESCRIBE
    - get RDF graph describing resources
    - not important
- SQL like
- not XML like
-