Cognitive Computing

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What is Cognitive Computing?

- Cognitive computing is an emerging field of computer science
- Synergistic confluence of mathematics, neuroscience, computer science, statistics, machine learning, and psychology
- Create computer systems that behave, think and interact the way humans do
- Cognitive computing systems strive to emulate human senses – see, hear, taste, smell and touch
- They learn, reason, and understand natural language
- They experience their environment, act, learn, and improve it

Cognitive Computing Sample Topics

- Text Analytics and Insight Generation
- Analytical Platforms to Study the Brain-Computer Interface
- Cognitive computing to manage renewable energy, the environment, and other scarce resources
- Machine learning models and algorithms with Intra- and Inter-cognitive computing for big data classification
- Cognitive Biometrics
- Kernel Based Models for Transductive Learning and Cognitive Computing
- Deep Neural Network Architectures for Learning Semantic Associations Between Textual Narrative, Image and Video

Science and Technology Enablers

- Cognitive and computational neuroscience
- High performance computing
- Cloud services
- Big Data

Top 200 Terms in Cognitive Neuroscience Literature

https://neuroconscience.com/tag/neurosynth/

Cognitive Computing/Computer Science

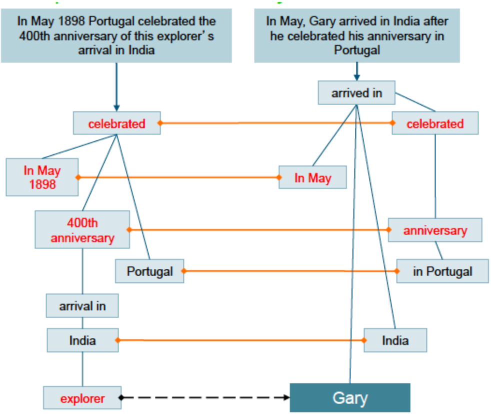
- Machine learning
- Information extraction and retrieval
- Natural language processing
- Digital image processing and computer vision
- Cognitive systems use multiple algorithms to gather evidence with greater certainty – temporal reasoning, geospatial reasoning, statistical paraphrase generation and several other NLP tasks

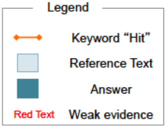
IBM Watson - The Beginning of a New Beginning

Jeopardy Question and a Plausible Answer

- In May 1898 Portugal celebrated the 400th anniversary of this explorer's arrival in India
- In May, Gary arrived in India after he celebrated his anniversary in Portugal

Need More Than Keyword Based Evidence





This evidence suggests "Gary" is the answer BUT the system must learn that keyword matching may be weak relative to other types of evidence

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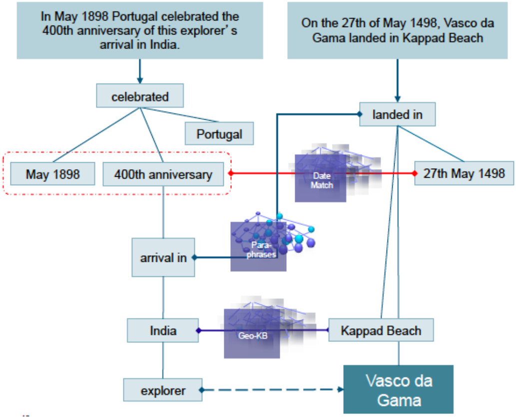
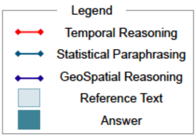
Multiple Algorithms to Gather Deeper Evidence





Stronger evidence can be much harder to find and score ...

- Search far and wide
- Explore many hypotheses
- Find judge evidence
- Many inference algorithms

... and the evidence is still not 100% certain

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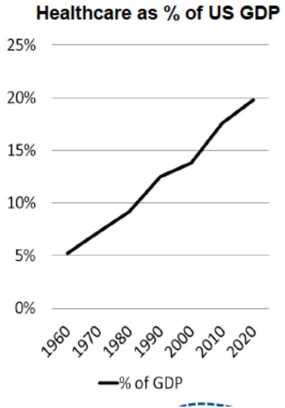

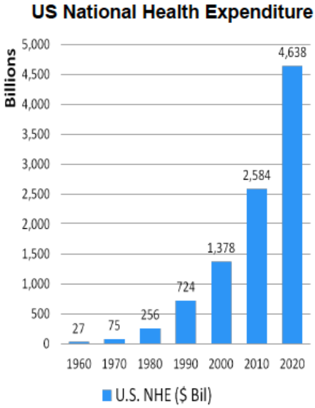

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IBM Watson Health

- PubMed is a free search engine for querying primarily the MEDLINE database of references and abstracts on life sciences and biomedical topics
- It stores over 24 million citations for biomedical literature from MEDLINE, life science journals, and online books
- New computational tools are needed to help organize, search, visualize, and understand these unstructured document repositories – topic modeling
- Explorys – largest healthcare databases derived from several financial, operational, and medical record source systems
- Phytel – interfaces with electronic medical record technologies to reduce patient hospital readmissions and improve patient outreach and engagement

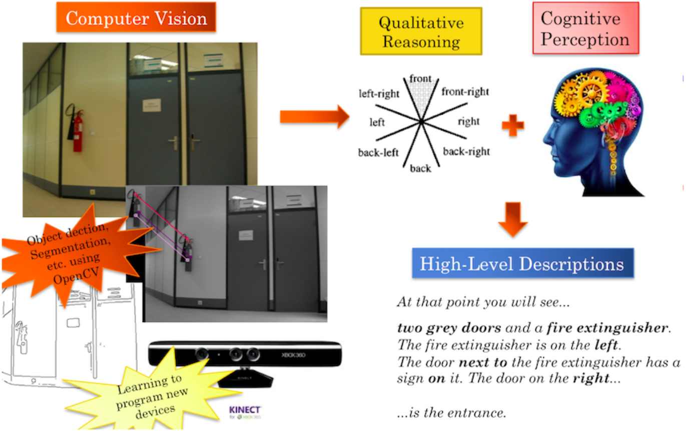
IBM Watson Developer Cloud

- 5,000 partners, developers, data hobbyists, entrepreneurs, students
- Over 6,000 applications built using Watson's cognitive computing capabilities
- Services:
    - Speech to Text
    - Text to Speech
    - Visual Recognition
    - Concept Insights
    - Trade-off Analysis

Brain-Computer Interface

- New analytic platforms for studying brain-computer interface (BCI)
- Use electroencephalogram (EEG), magnetoencephalography (MEG), and functional near-infrared spectroscopy (fNIRS) to record brain signals
- Signals are used to estimate a person's cognitive state, response, or intent for various purposes
- Estimates are used to help a severely disabled person, for example, control external devices such as a car

Cognitive Computing – Vision



http://cosy.informatik.uni-bremen.de/content/teaching/

cognitive-analysis-scenes-computer-vision-high-level-descriptions-reasoning-and

Cognitive Computing and NLP

- Physicist Eugene Wigner's 1960 essay, The Unreasonable Effectiveness of Mathematics in the Natural Sciences
- Provides compelling examples to demonstrate the extent to which abstract mathematical concepts hold validity far beyond the contexts in which they were developed
- Halevy, A., Norvig, P., Pereira, F., 2009: The Unreasonable Effectiveness of Data
- Accurate selection of a mathematical model ceases its importance when compensated by big enough data
- V. Gudivada, Dhana Rao, and V. Raghavan. Big Data Driven Natural Language Processing Research and Applications. http://www.academia.edu/14460000/Big_Data_Driven_Natural_Language_Processing_Research_and_Applications

Big Data and NLP

- Current NLP research is typically data driven and Big Data is transforming the way current NLP research is conducted
- About 16 years of video is uploaded daily to YouTube
- Searching for a given speaker in YouTube videos is a difficult task
- Localization of YouTube in 61 countries and across scores of languages

Big Data and NLP

- Enables overcoming problems associated with small data samples in several ways
- Relaxing the assumptions of theoretical models
- Avoiding overfitting of models to training data
- Dealing with noisy training data
- Providing ample test data to validate models

NLP Core Tasks

- Statistical Language Modeling

$$\sum_{x \in \mathcal{V}^*} p(x) = 1, \text{ and } p(x) \geq 0 \text{ for all } x \in \mathcal{V}^*$$

- Maximum likelihood estimates

$$q(\text{processing} \mid \text{natural language}) = \frac{count(\text{natural language processing})}{count(\text{natural language})}$$

- Unigram model:

$$p(x_1 x_2 \ldots x_n) \approx \prod_{i=1}^{n} q(x_i)$$

- Bigram model:

$$p(x_1 x_2 \ldots x_n) \approx \prod_{i=1}^{n} q(x_i \mid x_{i-1})$$

- Trigram model:

$$p(x_1 x_2 \ldots x_n) \approx \prod_{i=1}^{n} q(x_i \mid x_{i-2} x_{i-1})$$

Big Data for Building Language Models

- Trillion-word dataset summarizes theWeb pages content by counting the number of occurrences of each word, and two-, three-, four-, and five-word sequences
- Used for solving spelling correction, decoding secret codes, and word segmentation problems
- Spelling correction: for a given typed word w, determining what word c was most likely intended

$$\underset{c}{\operatorname{argmax}}\, p(c \mid w) = \underset{c}{\operatorname{argmax}}\, p(w \mid c) p(c)$$

- $p(c)$ is the language model and $p(w \mid c)$ is the probability that word w was typed when the intended word is c

Word Segmentation

- Word segmentation is a difficult problem in many of these languages as there is no explicit delimiter
- For segmenting phrases such as naturallanguageprocessing, a simple n-gram look up will suffice.
- For larger phrases, unigram-, bigram-, and trigram-based language models are used
- Consider every possible way to split the text into a first word followed by rest of the remaining text
- For each split, the best way to segment the remaining phrase is computed
- The split that corresponds to the highest p(first) p(remaining) is the best

POS Tagging

- A POS refers to a category of words which have similar grammatical properties
- Words that are assigned to the same POS category generally play similar roles within the grammatical structure of sentences
- Algorithms for POS tagging fall into two broad categories: rule based and stochastic
- Stochastic POS algorithms are based on supervised learning models such as HMM, log-linear model (aka Maximum Entropy Markov Model), and conditional random field (CRF)

Named Entity Recognition (NER)

- Identify names of people, locations, organizations, and other entities of interest in text documents
- NER is also used in other tasks and applications including co-reference resolution, word-sense disambiguation, semantic parsing, QA, dialog systems, textual entailment, information extraction, information retrieval, and text summarization
- NER used to enhance the POS tagging task and vice versa
- Named entities are often not simply singular words
- United States of America as an entity requires chunking multiple words as a text unit
- The three major approaches to NER are based on lexicon, rules, and machine learning

Other NLP Tasks

- Parsing – process of deriving a syntactic structure for a sequence of words in the language
- A parse tree is one such representation
- Current formalisms for syntactic structures include context-free grammars (CFG), categorical grammars, head-driven phrase structure grammars, lexical functional grammars, minimalist syntax, and tree adjoining grammars

NLP Applications

- Machine Translation
- Information Extraction
- Topic Modeling
- Text Summarization
- Document Clustering and Classification
- QA and Dialog Systems
- Natural Language User Interfaces

Conclusions

- Explosion of data, particularly unstructured and machine generated, which will be beyond human comprehension
- Synergistic confluence of Big Data, Analytics, and Cognitive Computing.
- Facts used for making a decision is expected to grow to 1000 from the current 100
- Brain mapping and nanobots will create several societal issues