INTRODUCTION

Simon Ellis
IBM Watson

Who is Stoker?
($1,000)

Who is Bram Stoker?
($17,973)

Who is Bram Stoker?
($5,600)
Watson is...

- ... a piece of software that will run on your laptop
  - Though very slowly
  - Specialised hardware and control platform

- ... an implementation of the DeepQA concept

- ... the first iteration of the ‘cognitive computing’ platform

- ... a very clever artificial intelligence
  - A very clever application of human intelligence
Background

- IBM agrees to give RPI a version of Watson
- Watson team is set up to undertake summer research on the Watson system
- Watson hardware/software configuration not ready at beginning of summer session
- So what do we do with:
  10 weeks, 5 undergraduates and 1 graduate…
Challenge accepted!

- Build a new version of Watson
  - Based on research published in *IBM J Res & Dev*
  - With support and input from IBM Research

- Use open source libraries wherever possible
  - Faster development
  - No IP issues

- Turns out to be a very useful project
  - Trains team in the details of the operation of Watson system
  - Can be used in education, training, testing, evaluation
Sample output

- Demo run of RPI version of Watson
- Shows output representing most of the “pipeline”
Inside Watson

Watson pipeline as published by IBM; see *IBM J Res & Dev* 56 (3/4), May/July 2012, p. 15:2
QUESTION ANALYSIS

Nicole Negedly
Question Analysis

Question analysis → Primary search CM → Primary search → Search result CM → Search result processing and candidate answer generation

Candidate answer CM

Context-independent answer scoring → Soft filtering → Supporting Evidence Retrieval

Supporting evidence CM

Search result processing and context-dependent answer scoring → Final merging and ranking → Answer
Question analysis

- What is the question asking for?
- Which terms in the question refer to the answer?
- Given any natural language question, how can Watson accurately discover this information?

Focus Terms: “Who”, “president of Rensselaer Polytechnic Institute”

Answer Types: Person, President
What information about a previously unseen piece of English text can Watson determine?

How is this information useful?

<table>
<thead>
<tr>
<th>Natural Language Parsing</th>
<th>Semantic Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>- <em>grammatical</em> structure</td>
<td>- <em>meanings</em> of words, phrases, etc.</td>
</tr>
<tr>
<td>- parts of speech</td>
<td>- synonyms, entailment</td>
</tr>
<tr>
<td>- relationships between words</td>
<td>- hypernyms, hyponyms</td>
</tr>
<tr>
<td>- <em>...etc.</em></td>
<td>- <em>...etc.</em></td>
</tr>
</tbody>
</table>
Stanford’s NLP toolset is used
Semantic relations in WordNet

- Princeton University’s WordNet

- Words are grouped into groups of synonyms called synsets

- Relationships exist between noun synsets
  - hypernym/hyponym: type-of relation
    - e.g. Canine is a hypernym of dog
  - holonym/meronym: part-of relation
    - e.g. Building is a holonym of window
How is this useful?

- This information can be used to “understand” a question

- Current Question Analysis work with RPI’s version of Watson

- Creating and training machine learning classifiers
Question analysis pipeline

- Unstructured Question Text
  - Parsing & Semantic Analysis
  - Machine Learning Classifiers
  - Structured Annotations of Question: Focus, answer types, Useful search queries
CANDIDATE GENERATION

Kate McGuire
Search Result Processing and Candidate Generation

Question analysis → Primary search CM → Primary search → Search result CM → Search result processing and candidate answer generation → Candidate answer CM

Context-independent answer scoring → Soft filtering → Supporting Evidence Retrieval → Search result processing and context-dependent answer scoring

Supporting evidence CM → Final merging and ranking → Answer
Primary Search

- **Primary Search** is used to generate our corpus of information from which to take candidate answers, passages, supporting evidence, and essentially all textual input to the system.

- It formulates queries based on the results of Question Analysis.

- These queries are passed into a search engine which returns a set number of highly relevant documents and their ranks.
Search Result Processing restructures the information in the document so it is useful.

- HTML tags are cleaned from the document
- Passage Retrieval/Chunking
  - Breaks the document down into smaller pieces
  - Adds information, such as the html text, length, place in the document, etc.
- Passage Parsing
  - Parse trees are formed for each passage
Candidate Generation generates a wide net of possible answers for the question from each document.

Using each document, and the passages created by Search Result Processing, we generate candidates using three techniques:

- **Title of Document (T.O.D.)**: Adds the title of the document as a candidate.
- **Wikipedia Title Candidate Generation**: Adds any noun phrases within the document’s passage texts that are also the titles of Wikipedia articles.
- **Anchor Text Candidate Generation**: Adds candidates based on the hyperlinks and metadata within the document.
Future work

- Primary Search and Search Result Processing
  - Integrating the use of both online and offline sources
    - Indri Search Engine
  - More effective passage retrieval and ranking

- Candidate Generation
  - Improving speed and quality
  - Implementing Candidate Generation from Structured Sources
  - Better Information Extraction
Search Result Processing and Candidate Generation

PrimarySearchResult CAS containing Document HTML Text → Title of Document Candidate Generation → Search Result Processing (Passage Retrieval and Parsing) → Anchor Text Candidate Generation → Wikipedia Title Candidate Generation → PrimarySearchResult CAS containing Candidate Annotations → Candidate Generation Aggregate AE
SCORING & RANKING

Matt Klawonn
Scoring & Ranking

1. Question analysis
2. Primary search
3. Search result processing and candidate answer generation
4. Candidate answer CM
5. Search result CM
6. Context-independent answer scoring
7. Soft filtering
8. Supporting Evidence Retrieval
9. Search result processing and context-dependent answer scoring
10. Supporting evidence CM
11. Final merging and ranking
12. Answer
Scoring

- Analyzes how well a candidate answer relates to the question

- Two basic types of scoring algorithm
  - Context-independent scoring
  - Context-dependent scoring
Types of scorers

- Context-independent
  - Question Analysis
  - Ontologies (DBpedia, YAGO, etc)
  - Reasoning

- Context-dependent
  - Analyzes natural language that candidates appear in
  - Relies on “passages” found during search
Scorers

- Examples of scorers include
  - Passage Term Match
  - Textual Alignment
  - Skip-Bigram

- Each of these scores supportive evidence

- Scores are then merged to produce a single candidate score
Future work

- Develop more scorers
- Implement some machine learning
SYSTEM DEVELOPMENT

Avi Weinstock
For the MiniDeepQA project, most of my work has been in 5 major areas:

- Pipeline development
- Data caching
- Graphical and command line interfaces
- Parsing
- Scoring
Pipeline

- The pipeline is the framework in which the individual software modules fit.

- The pipeline is implemented as a set of UIMA modules in the shape of the DeepQA architecture.

- It controls when to run parsing, searching, candidate generation, scoring, and ranking, and transports data between them.
Data caching

- Some operations (particularly parsing and network I/O) are slow. It is a waste of time to run the same operations on the same data repeatedly.

- Some data are cached internally after processing so that subsequent runs of questions (and questions that share candidate answers) are faster.

- This enables easier testing of algorithms that operate later in the pipeline.
There are two main categories of parsers: phrase structure parsers and dependency parsers.

- Phrase structure parsers produce trees showing sentence structure.
- Dependency parsers produce relations between words.

I wrote some wrappers for the Stanford and Berkeley parsers that allow obtaining parse trees and dependency graphs from natural language strings with a simple function call, thus allowing easy experimentation with different parsers.
Scoring

- One of DeepQA’s main strengths is aggregating a number of different scoring algorithms capable of running in parallel.

- Type information (e.g. that the current answer being considered is a person) is a rather powerful piece of information for scoring.
  - DBpedia (a database compiled semi-automatically from Wikipedia) is the data source for a scorer I developed.
  - Although rather primitive, it help significantly with determining the accuracy of answers to some questions.
Overview

- Cognitive computing
  - What is ‘cognitive computing’?
  - What is cognition?
  - Is Watson ‘cognitive’?

- Artificial intelligence
  - What is intelligence?
  - Watson and the Chinese Room
  - Watson and the Turing Test

- Conclusion
“A **cognitive computer** is a proposed computational device with a non-von Neumann architecture that implements Hebbian learning. Instead of being programmable in a traditional sense within machine language or a higher level programming language such a device learns by inputting instances through an input device that are aggregated within a computational convolution or neural network architecture consisting of weights within a parallel memory system.” (Wikipedia)
Cognitive computing

“Computational cognition is the study of the computational basis of learning and inference by mathematical modeling, computer simulation, and behavioral experiments, seeking to learn the basis behind the processing of information.” (Wikipedia)
Do either of these definitions explain the manner of functioning of Watson?

Not really.

“[Cognitive computing systems are] a category of technologies that uses natural language processing and machine learning to enable people and machines to interact more naturally to extend and magnify human expertise and cognition.” (IBM)

Is there a better definition?
What is cognition?

- “Cognition is a faculty for the processing of information, applying knowledge, and changing preferences. Cognition, or cognitive processes, can be natural or artificial, conscious or unconscious. Within psychology or philosophy, the concept of cognition is closely related to abstract concepts such as mind, intelligence. It encompasses the mental functions, mental processes (thoughts), and states of intelligent entities (humans, collaborative groups, human organizations, highly autonomous machines, and artificial intelligences).” (Wikipedia)
“The computer’s techniques for unraveling Jeopardy! clues sounded just like mine. That machine zeroes in on key words in a clue, then combs its memory (in Watson’s case, a 15-terabyte data bank of human knowledge) for clusters of associations with those words. It rigorously checks the top hits against all the contextual information it can muster: the category name; the kind of answer being sought; the time, place, and gender hinted at in the clue; and so on. And when it feels ‘sure’ enough, it decides to buzz. This is all an instant, intuitive process for a human Jeopardy! player, but I felt convinced that under the hood my brain was doing more or less the same thing.”

— Ken Jennings
Artificial intelligence

- What is artificial intelligence?
  - “The study and design of intelligent agents.” (Poole, Mackworth & Goebel, 1998)
    - “An intelligent agent is a system that perceives its environment and takes actions that maximize its chances of success.” (Wikipedia)
  - “The science and engineering of making intelligent machines.” (John McCarthy, 1955)
  - “Intelligence through artifice.”
    - Artifice: “Technical skill; artistry, ingenuity. Skill in devising and using expedients; artfulness, cunning, trickery.” (OED)
- So what is intelligence?
What is intelligence?

- Not well defined
  - “I’ll know it when I see it.”
  - “… [the] ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought. … Concepts of ‘intelligence’ are attempts to clarify and organize this complex set of phenomena. Although considerable clarity has been achieved in some areas, no such conceptualization has yet answered all the important questions, and none commands universal assent. Indeed, when two dozen prominent theorists were recently asked to define intelligence, they gave two dozen, somewhat different, definitions.” (Intelligence: Knowns and Unknowns; APA, 1995)
What is intelligence?

- The Oxford English Dictionary
  - “The faculty of understanding; intellect. Also as a count noun: a mental manifestation of this faculty, a capacity to understand.”
  - “The action or fact of mentally apprehending something; understanding, knowledge, comprehension (of something). Also (now rare): an act of mental comprehension.”
  - “Understanding as a quality admitting of degree; spec. quickness or superiority of understanding, sagacity.”

... is this helpful?
What is intelligence?

- A more useful definition
  - “A very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings — ‘catching on,’ ‘making sense’ of things, or ‘figuring out’ what to do.” (‘Mainstream Science on Intelligence’; *WSJ*, 13th December, 1994)

- So can a computer be intelligent?
Is Watson intelligent?

- Are humans intelligent?
  - Humans do very dumb things sometimes, after all.

- Can non-humans be intelligent?
  - What counts as “being intelligent”?
    - Dogs fetching sticks?
    - Parrots talking?
    - Computers winning Jeopardy!?
  - Beware ascribing intelligence indiscriminately
    - Intelligence vs stimulus response-mediated behaviour
      - Tumbleweed plant ‘moving’ from a dry area.
      - Clownfish changing gender in response to population pressure.
A thought experiment

- Artificial intelligence research has succeeded in constructing a computer that behaves as if it understands Chinese.
- It takes Chinese characters as input and, by following the instructions of a computer program, produces other Chinese characters, which it presents as output.
- Suppose that this computer performs its task so convincingly that it convinces a human Chinese speaker that the program is itself a live Chinese speaker.

Does the computer understand Chinese?
Two possible definitions of understanding

1. “A process related to a physical or abstract object whereby one is able to think about it and use concepts to deal adequately with that object. It is a relation between the knower and the object of understanding. It implies abilities and dispositions with respect to an object of knowledge sufficient to support intelligent behaviour.” (Wikipedia)

2. The ability to manipulate predetermined sets of symbols in a manner that appears intelligent to an external agent possessed of intelligence.
“‘When in disgrace with fortune and men’s eyes / I all alone beweep my outcast state.’ Tell me: are these just words to you? Or do you fathom the meaning?”

— Cmdr Bruce Maddox, ST:TNG, The Measure of a Man
“Can machines think?”
- How do we define ‘machine’ and ‘think’?
- Solution: redefine the problem.

‘The Imitation Game’
- Correct name for “the Turing Test”.
- Entities A and B, interrogator C.
- C poses questions to A and B in turn via a console or printer.
- C must decide if A and B are human or computer.
Watson and the Turing Test

- Does Watson pass the “Turing Test”?
  - It understands questions in English.
  - It presented all its answers in English.
  - It played *Jeopardy!* and won — resoundingly.

- No, it doesn’t...
  - ... but it comes tantalisingly close.
    - Watson does not use articles of speech – ‘a’ and ‘the’ – in its answers.
    - Most people would use them automatically.
    - To be fair, this is a very hard problem to solve.
Conclusion

- Is Watson cognitive?
  - Arguably, yes: it simulates cognitive processes using digital analogues of human cognition.

- Is Watson intelligent?
  - No: it merely *appears* intelligent through careful application of human intelligence.

- *Watson appears* more intelligent than any other computer system yet designed.

- Watson is only a first step: there are many more yet to come.