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Toward Building A Natural Language Dialogue System Using Big Data and Deep Learning

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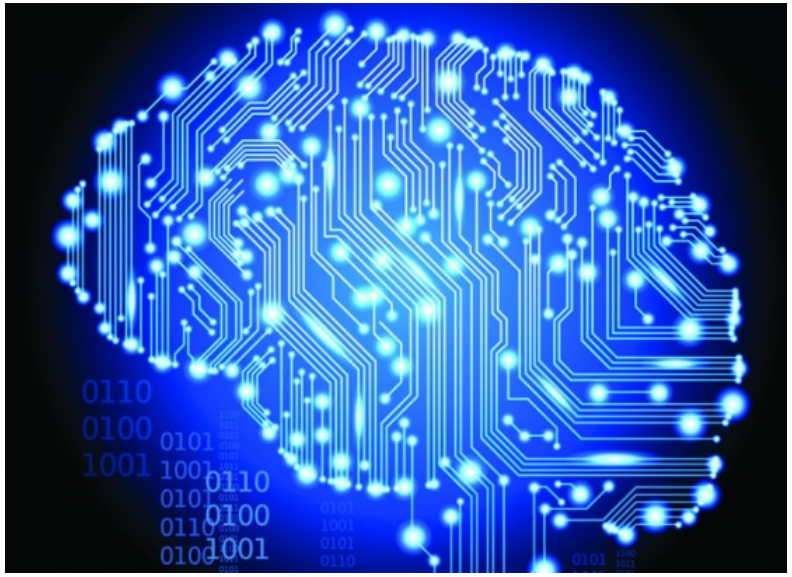
Demo: Neural Responding Machine

Outline

- Why Is AI So Hot?
- Why Is AI Challenging?
- Our Strategies in AI Research
- Our Effort toward Building Natural Language Dialogue System

AI is so hot, because it poses a big philosophical problem



A Philosophical Problem about AI

Can we completely build our own intelligence on computer?

Immanuel Kant

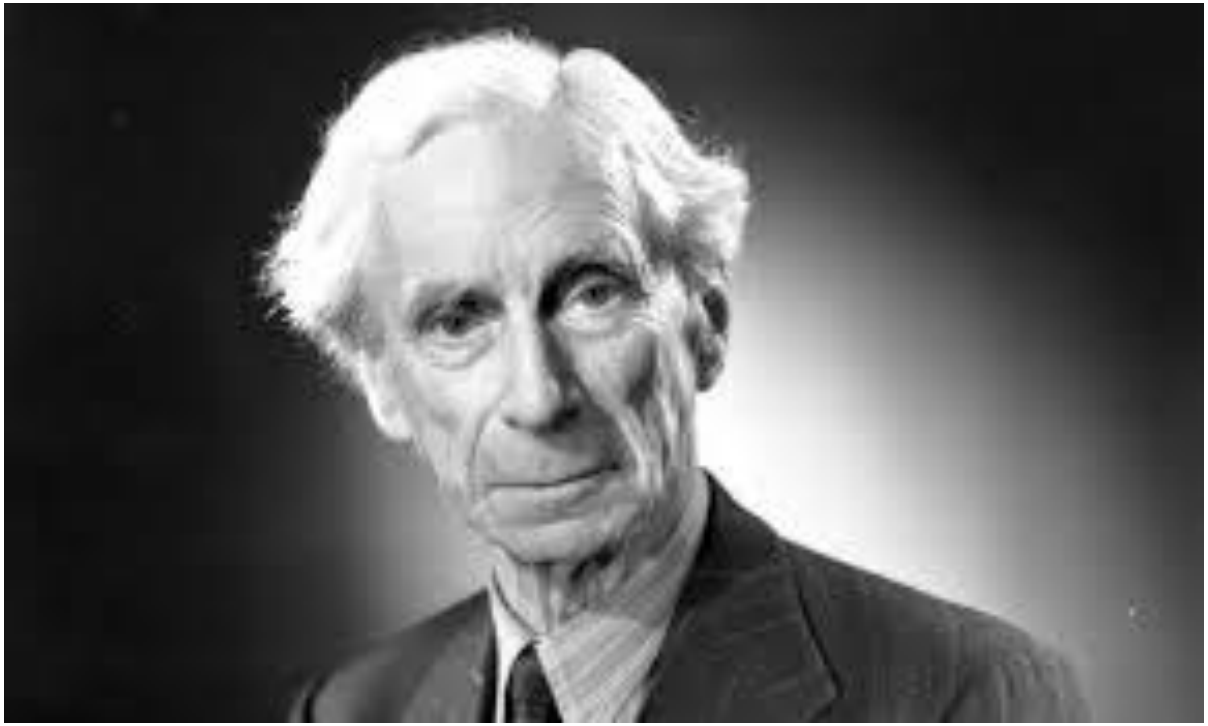
Three important philosophical problems:

What can I know? (epistemology)
What ought I to do? (morality and ethics)
What may I hope? (religion and belief)

The Philosophical Problem about AI

- Equally meaningful and important as Kant's three philosophical problems

- However, there are differences
- It might be difficult, even impossible, to falsify the proposition
- (It will only be verified when AI is realized)
- It will not be answered through speculation by philosophers, but through enormous research efforts by AI researchers



Bertrand Russell

Science is what you know, philosophy is what you don't know.

The AI Proposition

- No rigorous definition on “intelligence” and “completeness”
- There are, for example, several types of intelligence: common intelligence, expert intelligence, collective intelligence
- Many arguments about AI tend to be not-scientific (not refutable)

Our Attitude: Be Analytical and Practical

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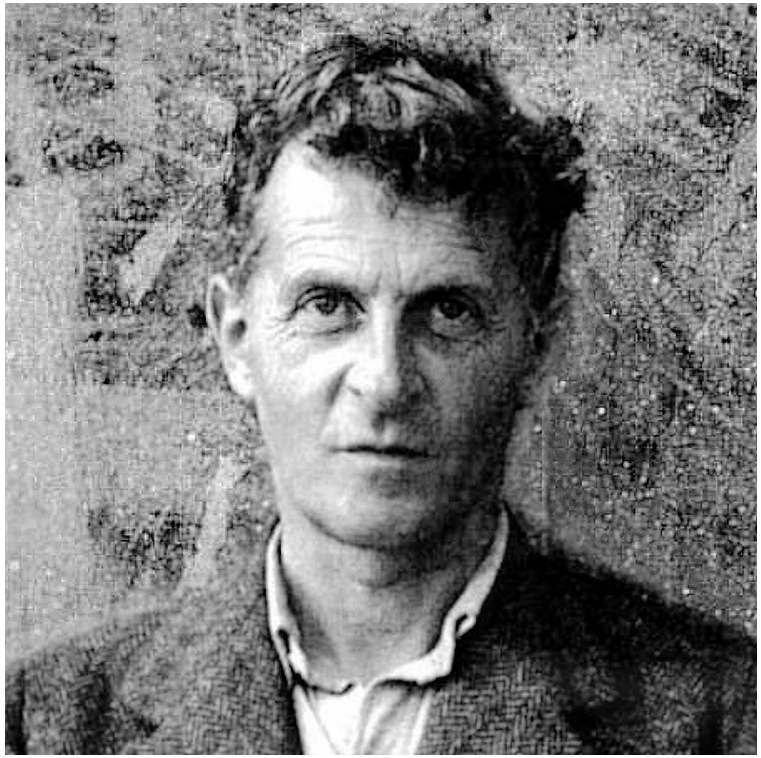
Our Answer to AI Challenge Question
- As Corollary of Wittgenstein's Philosophy

- Human intelligence, for example, human language ability, still cannot be precisely depicted by *mathematical models*
- All computer systems must be built based on *mathematical models* (Turing machine)



Ludwig Wittgenstein

Early Philosophy: “Tractatus Logico-Philosophicus”
Later Philosophy: “Philosophical Investigations”

Tractatus Logico-Philosophicus
(Ludwig Wittgenstein, 1921)

- Facts in the world → represented as propositions → thought (also language) consists of propositions
- Meaningful thoughts (thoughts with sense) include
  - Logic
  - Facts
  - Their combinations
- "Whereof one cannot speak, thereof one must be silent"

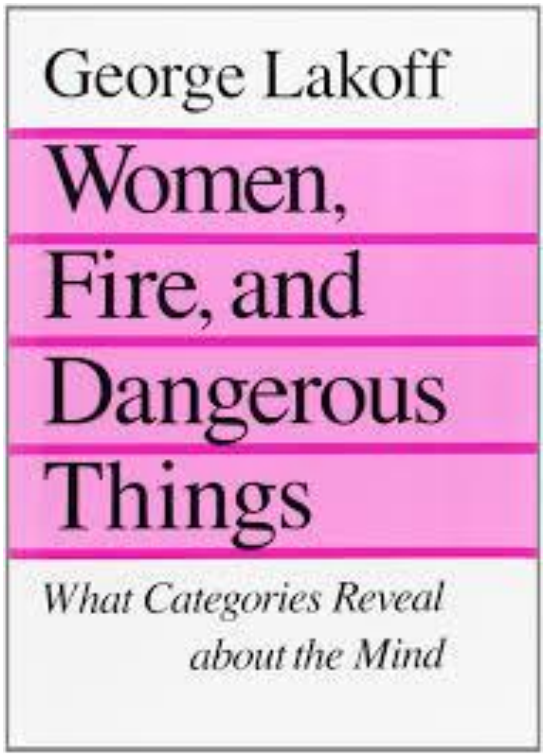
Philosophical Investigations
(Ludwig Wittgenstein, 1953)

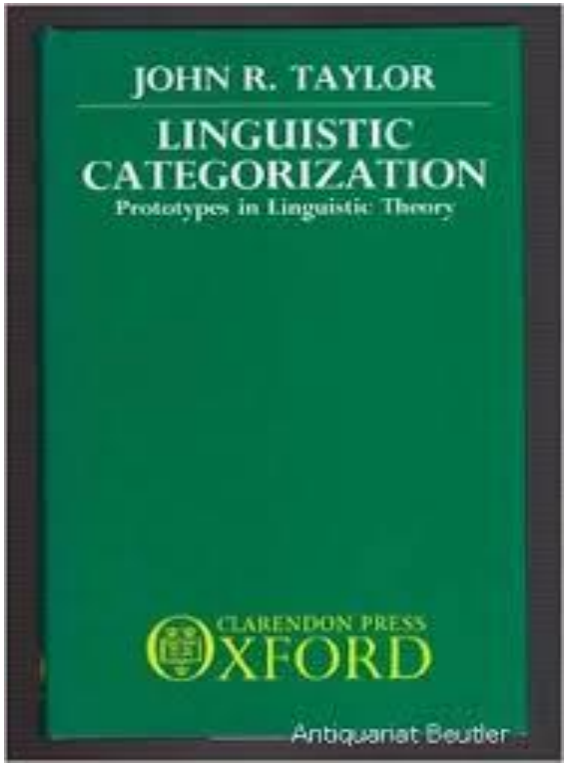
- "The meaning of a word is its use in the language"
- Language game: speaking of language is part of an activity, or a form of life, which gives language its meaning
- Family resemblance: e.g., the notion of "game"
- To understand the meaning of word, we should travel with the word's uses through "a complicated network of similarities overlapping and criss-crossing"
- Paradox: no course of action could be determined by a rule

Two Different Types of Intelligence

- Logic and math
- Cognition and language

Cognitive Linguistics
- Inspired by Wittgenstein's Later Philosophy





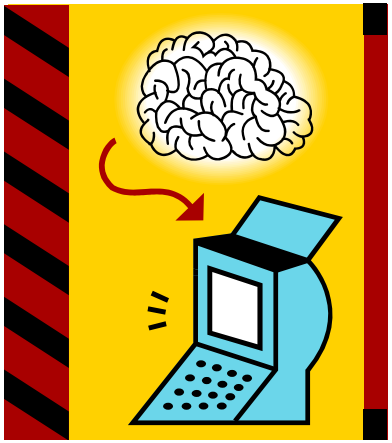
Two nice books on cognitive linguistics

Cognitive Linguistic View on Language

- Language is cognitive activities
- Language concept is based on *prototype*
- Language is metaphoric and metonymic
  - Metaphor： e.g., “you are the sun in the morning”
  - Metonymy： e.g., “relation between Beijing and Washington”
- Language is conventional

Language Processing by Computer

- A computer system must be constructed based on math
- Open question: whether it is possible to process natural language *as humans*, using math models
- Natural language processing is believed to be AI complete



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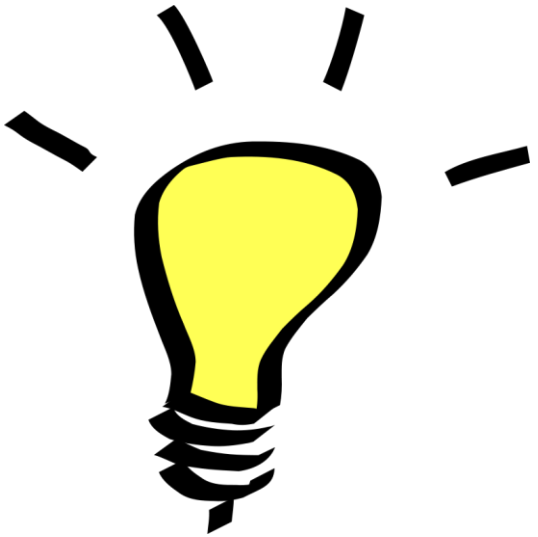
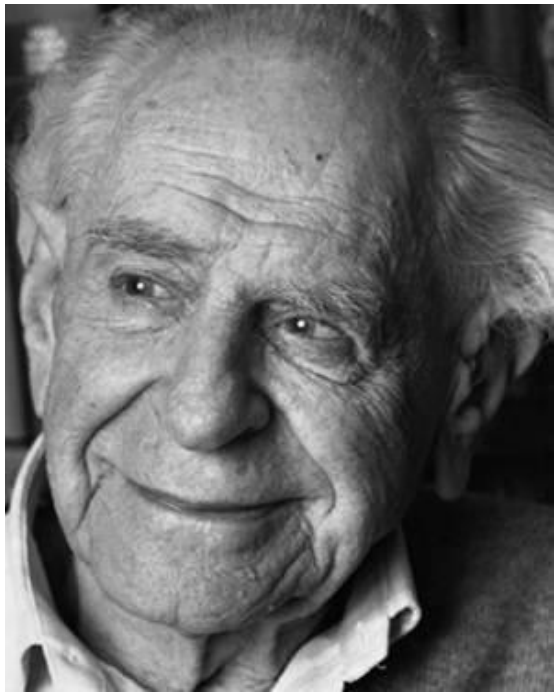
Our Strategies

- Strategy One: Task-driven
- Strategy Two: Hybrid
  - machine learning based
  - human-knowledge incorporated
  - human brain inspired

One Conclusion from Cognitive Linguistics

- “Meaning of natural language” can be better modeled when there is a clear need and interest
- “A specific task” makes everything clearer and easier to handle



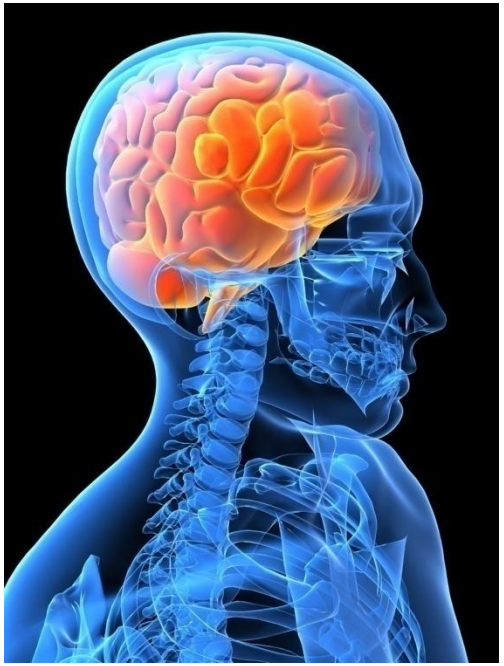


Karl Popper

We may add that objects can be classified, and can become similar or dissimilar, only in this way--by being related to needs and interests.

Three Possible Approaches to AI

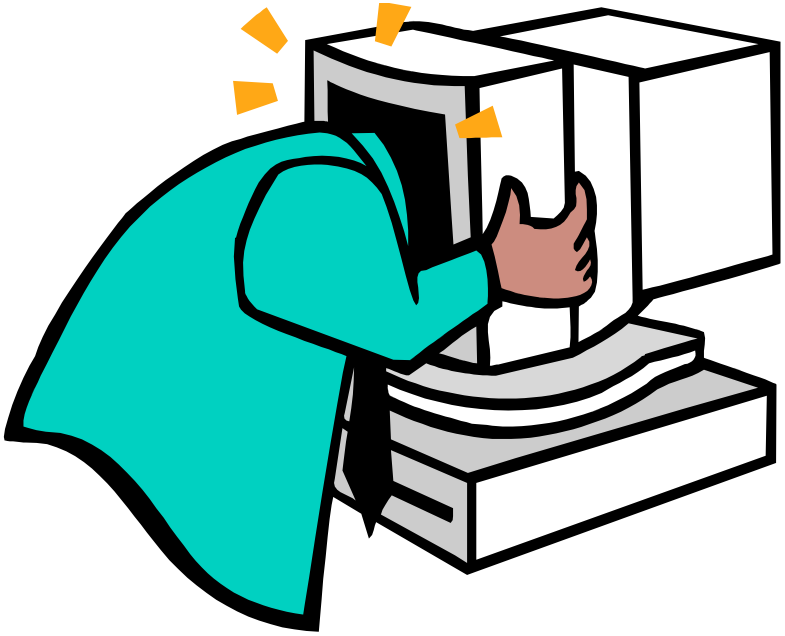
- Extrospection
- Introspection
- Simulation



Extrospection Approach

- Understand the mechanism of human brain and build AI system based upon it
- Computational neuroscience can be a tool

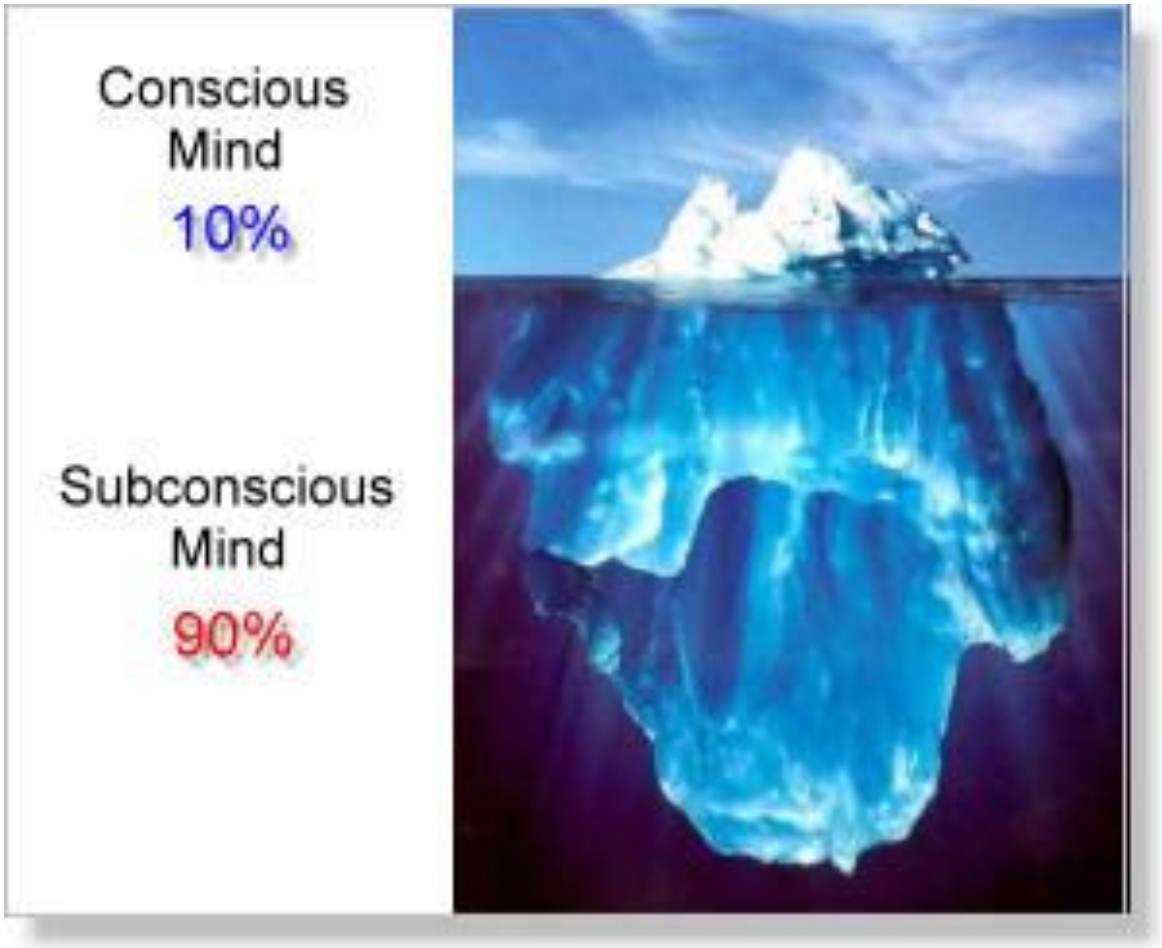
Difficult to Understand Whole Picture

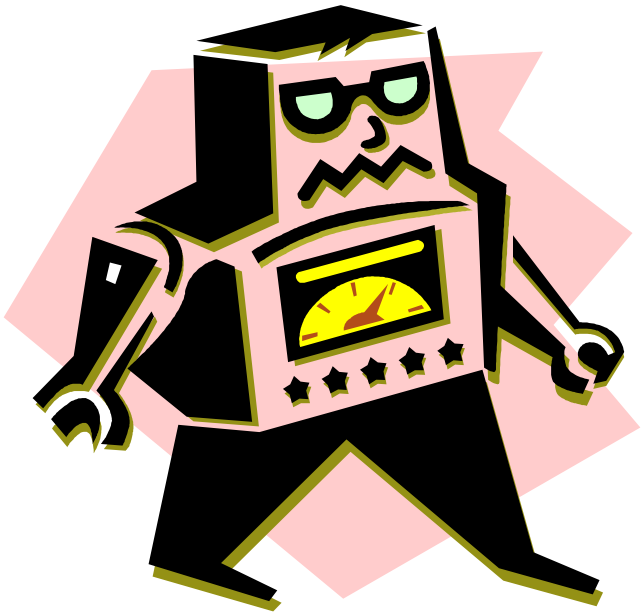


Introspection Approach

- Examine one's conscience thought and build AI system based upon it
- Expert system is an example

Difficult to Understand Whole Picture





Simulation Approach

- Make observations on human behaviors and build AI system based upon it
- Machine learning is example

Machine Learning

input

output

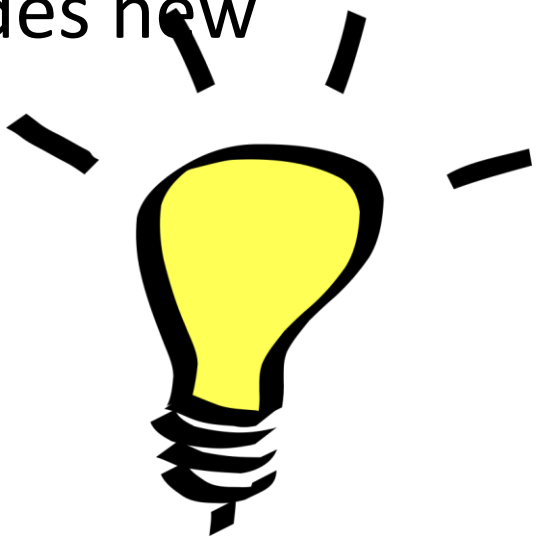
input

output

Heavily Relying on Observations

One Conclusion from Past Research

- Hybrid is most realistic and effective for natural language processing, and AI
  - machine learning based
  - human-knowledge incorporated
  - human brain inspired
- Big data and deep learning provides new opportunity



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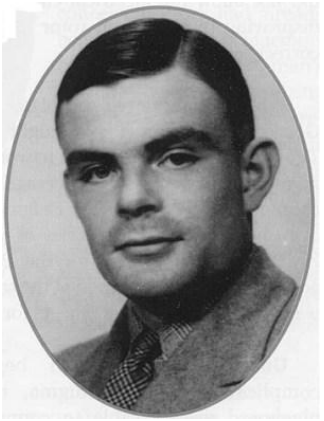
Natural Language Dialogue

- Vast amount of conversation data is available
- Powerful technologies like deep learning developed
- Single turn vs multi-turn dialogue
- Two approaches
  - Retrieval based
  - Generation based

Benchmark of AI



Alan Turing

Call for Participation

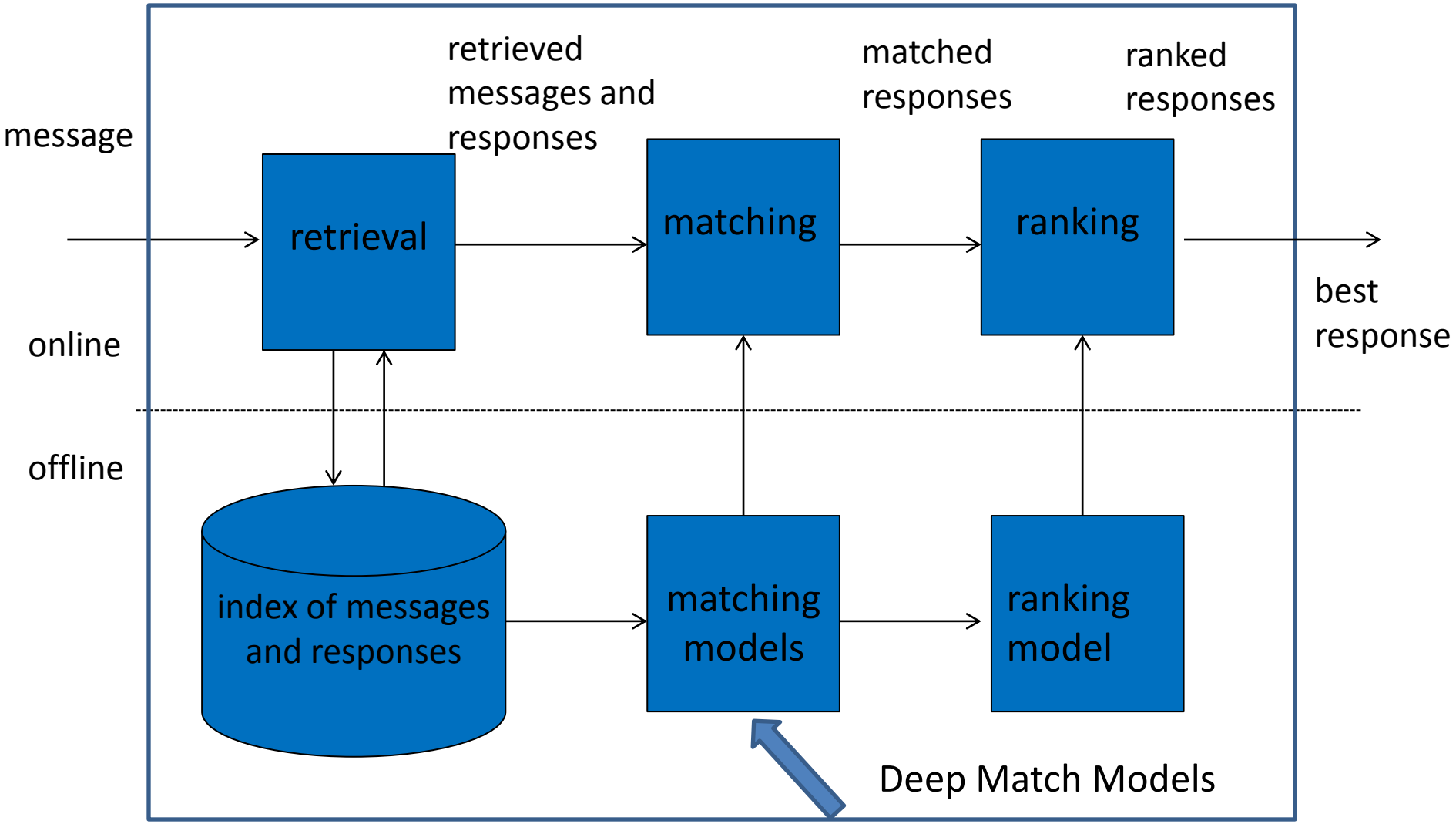
Short Text Conversation is a Pilot Task at NTCIR-12
http://ntcir12.noahlab.com.hk/stc.htm

- Retrieval-based approach to single turn dialogue
- 5 million Chinese Weibo data, 1 million Japanese Twitter data
- Registration deadline: Oct 31, 2015

Our Approach to Single-Turn Dialogue Using Deep Learning

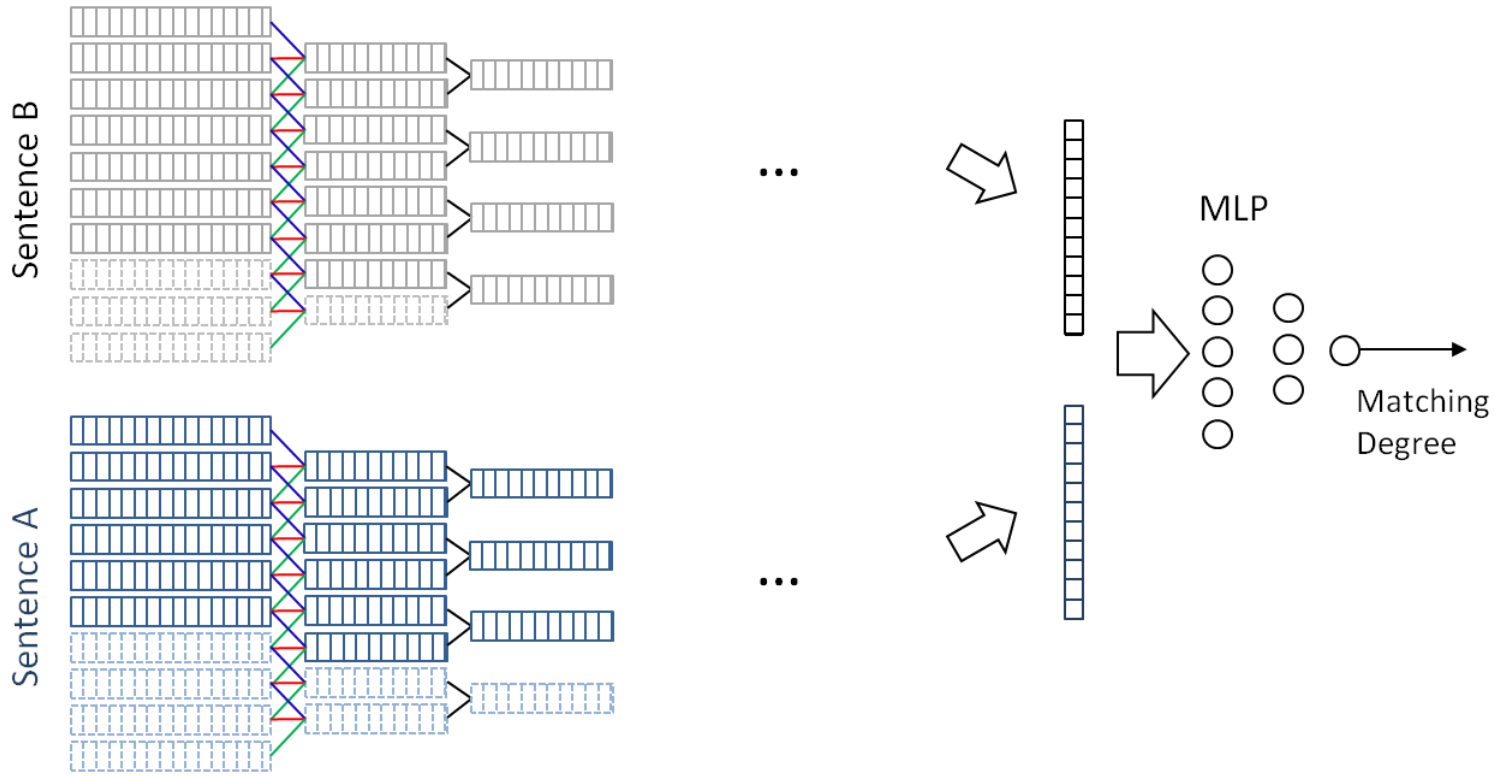
- Retrieval-based
  - Deep Match CNN (Hu et al., NIPS 2015)
  - Deep Match Tree (Wang et al., IJCAI 2015)
- Generation-based
  - Neural Responding Machine (Shang et al., ACL-IJCNLP 2015)

Natural Language Dialogue System - Retrieval based Approach



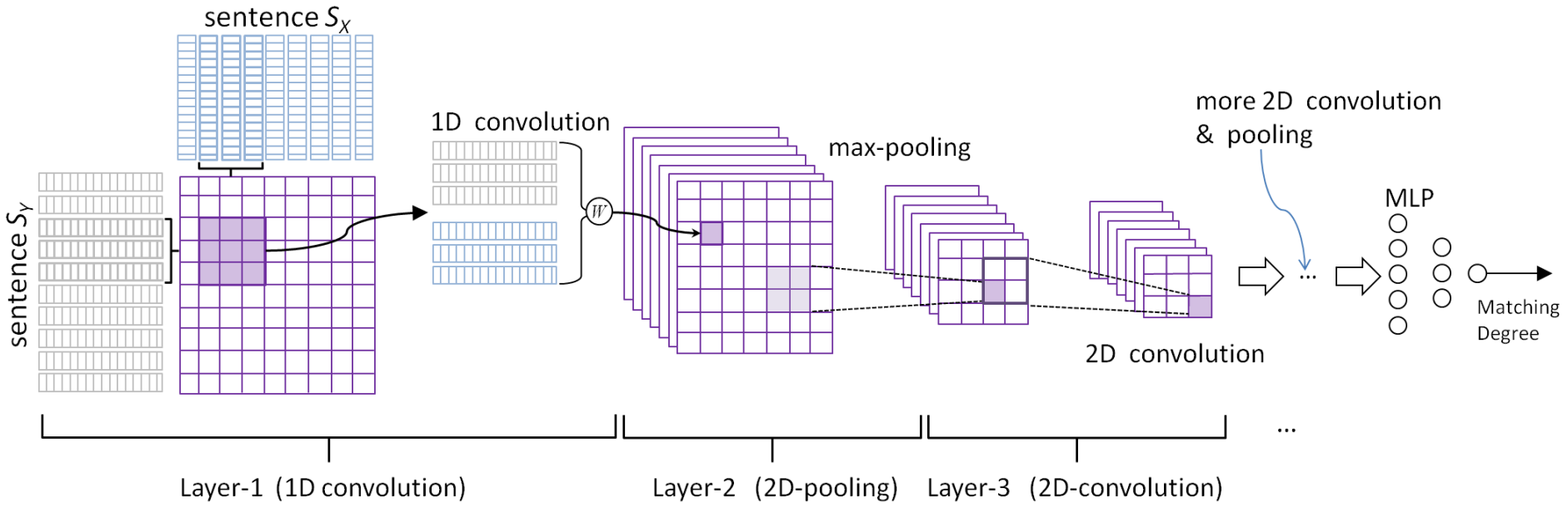
Deep Match CNN
- Archtecture I

- First represent two sentences, and then match



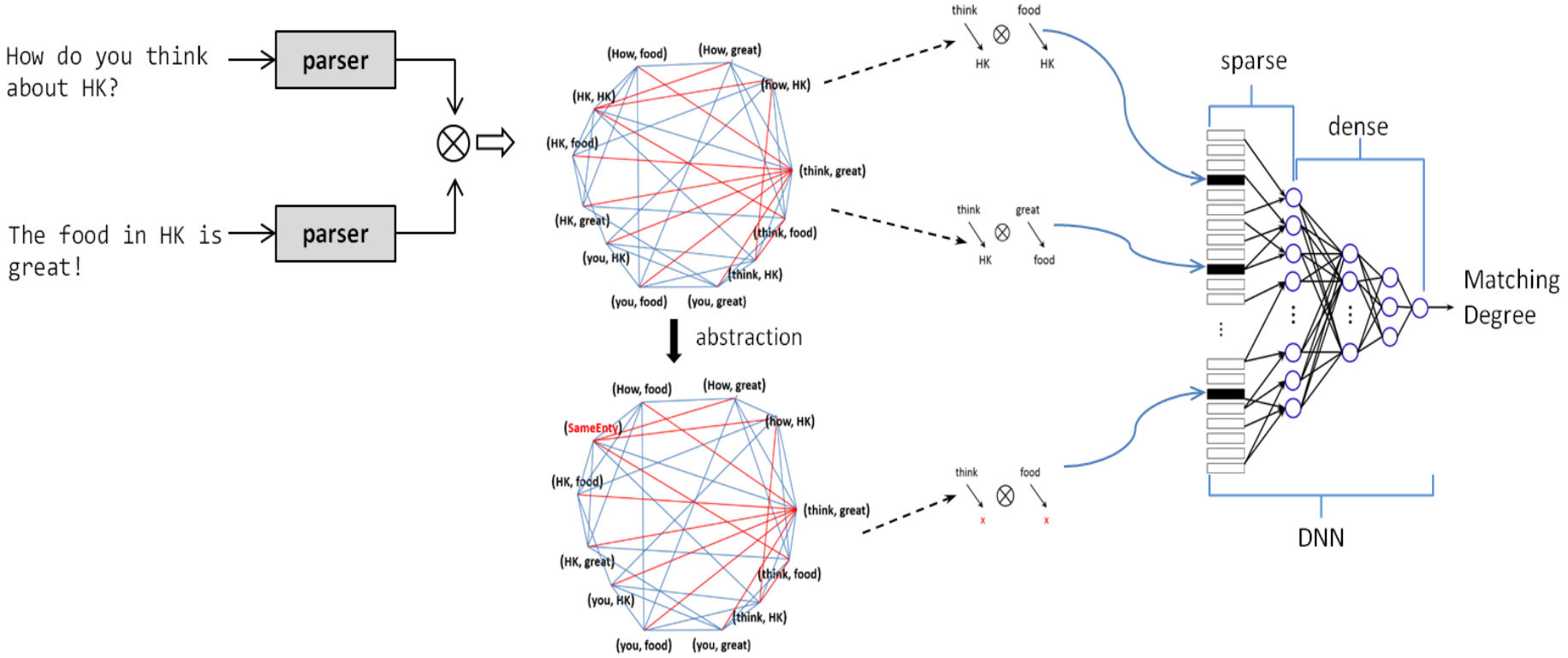
Deep Match CNN - Architecture II

- Represent and match two sentences simultaneously
- Two dimensional convolutional model



Deep Match Tree

- Deep neural network, with first layer corresponding mined matching patterns



Retrieval based Approach:

Accuracy = 70%+

上海今天好熱，堪比新加坡。

It is very hot in Shanghai today, just like Singapore . It is unusually hot.

上海今天热的不一般。

I want to go to Mountain

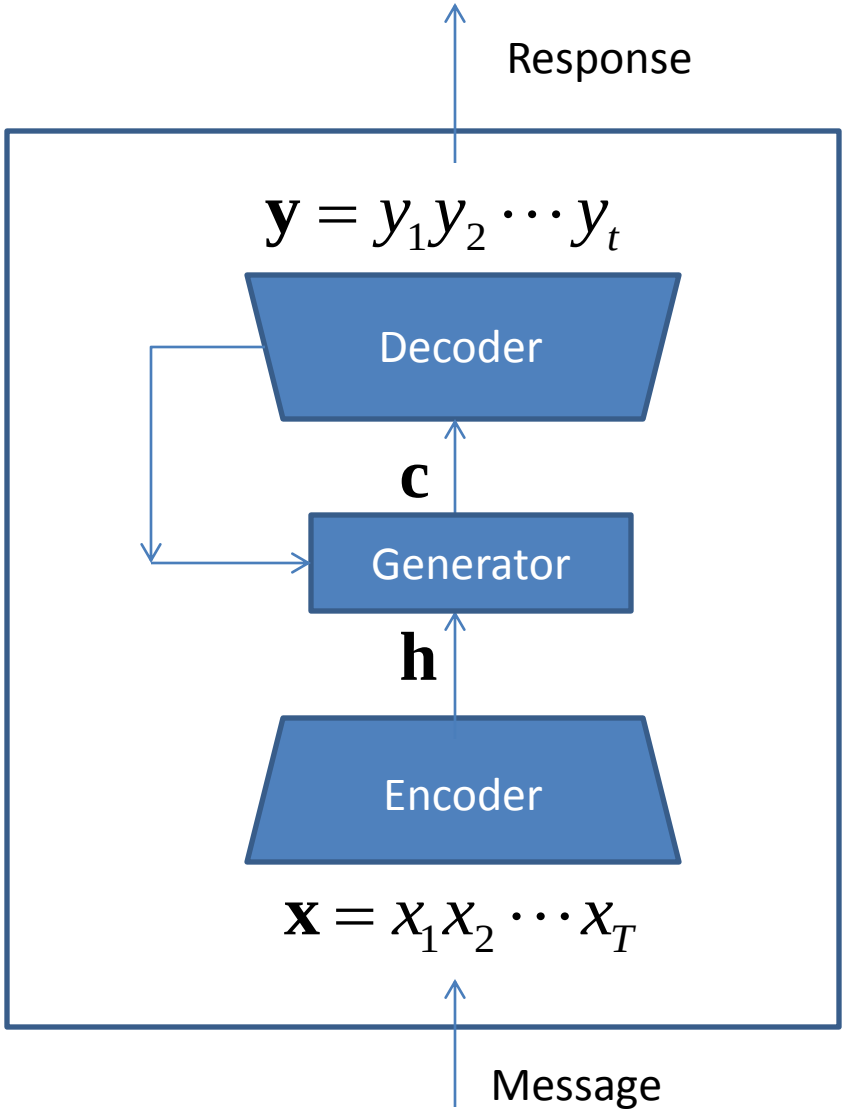
想去武当山 有想同游的么？

Wudang, it there anybody going together with me?

我想跟帅哥同游~哈哈

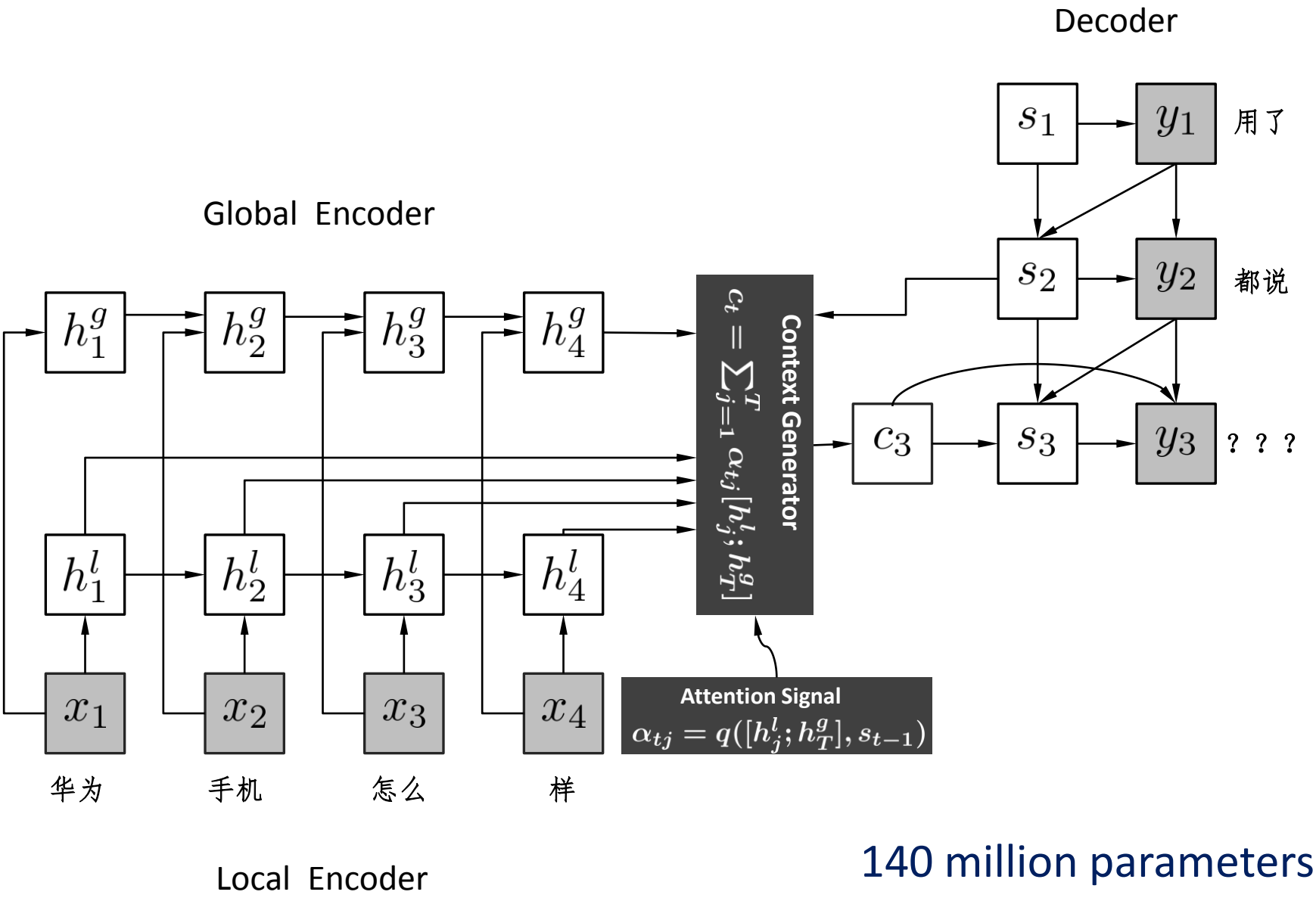
Haha, I want to go with you, handsome boy

Natural Language Dialogue System - Generation based Approach



- Encoding messages to intermediate representations
- Decoding intermediate representations to responses
- Recurrent Neural Network (RNN)

Neural Responding Machine



140 million parameters

Generation based Approach

Accuracy = 76%+

占中终于结束了。

Occupy Central is finally over.

下一个是陆家嘴吧？

Will Lujiazui (finance district in Shanghai) be the next?

我想买三星手机。

I want to buy a Samsung phone

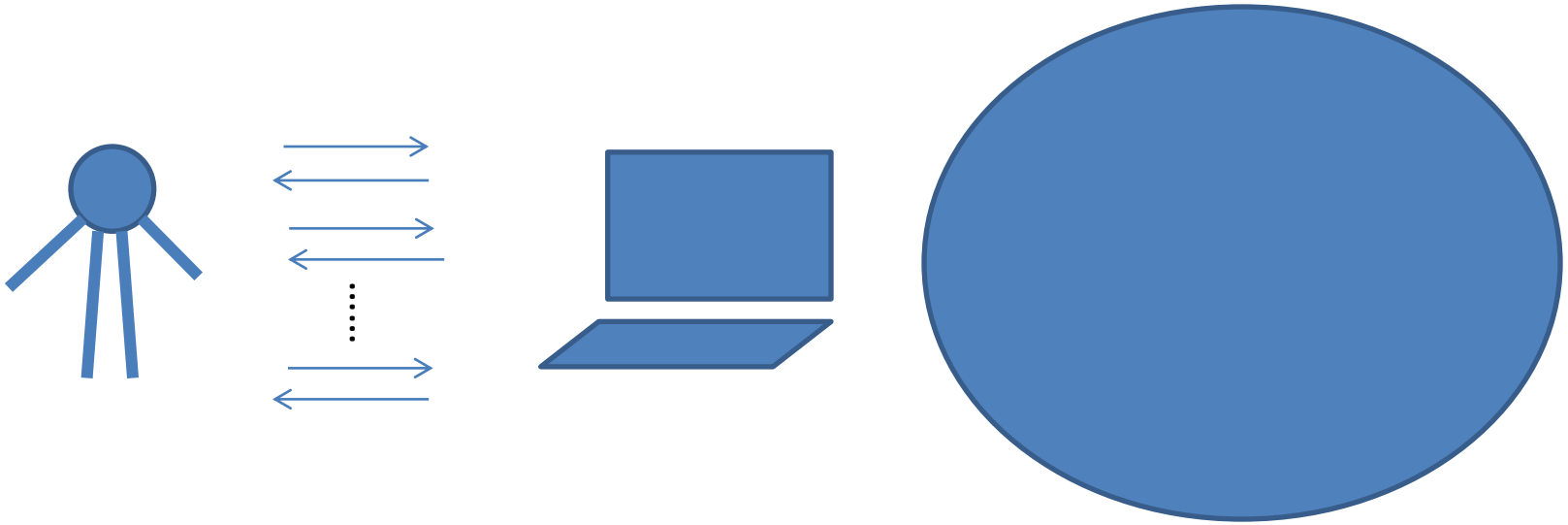
还是支持一下国产的吧。

Why not buy our national brands?

How are the two strategies being applied?

Strategy One: Task-Oriented

Natural Language Dialogue in Specific Tasks



- Multi-turn dialogue
- Goal: task completion, mostly information access
- Evaluation: completion rate / cost
- Including traditional search and question answering as special cases

Example One: Hotel Booking on Smartphone

P: How may I help you?
U: I'd like to book a hotel room for tomorrow.
P: For how many people?
U: Just me. What is the total cost?
P: That would be $120 per night.
U: No problem. Book the room for one night, please.

Example Two: Auto Call Center

- **U:** hello
- **H:** hello, how can I help you?
- **U:** can you tell me how to find ABC software?
- **H:** please go to this URL to download
- **U:** how to activate the software?
- **H:** please see this document

Objective Functions in Learning of Current Models

- Retrieval-based single-turn dialogue
  - Maximum precision at top 1 position

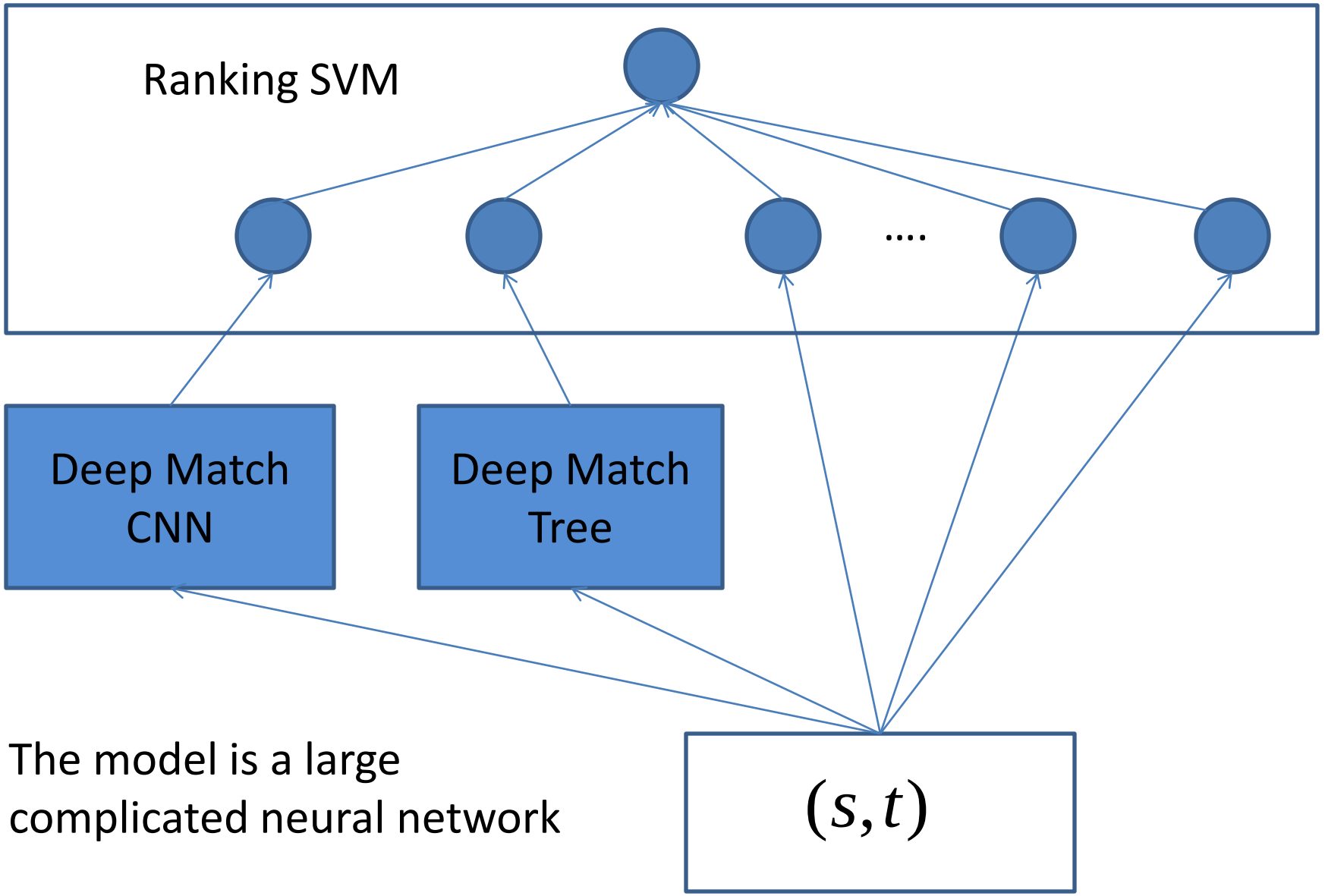
$$\sum_{i=1}^{m} \mathrm{Pre}(t_{i,1}, t_{i,2}, \cdots t_{i,n} \mid s_i)$$

- Generation-based single-turn dialogue
  - Maximum likelihood

$$\sum_{i=1}^{m} -\log P(t_i \mid s_i)$$

Strategy Two: Hybrid

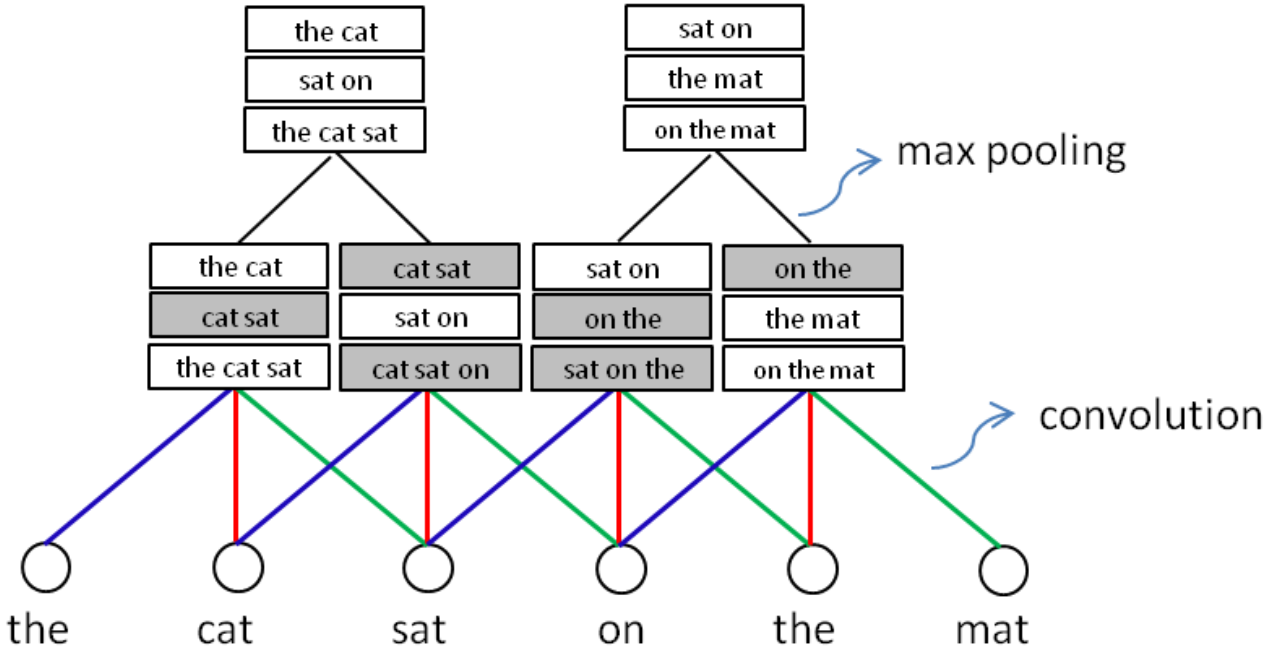
Architecture of Retrieval based Model



The model is a large complicated neural network

Convolutional Neural Network Is Inspired by Human Brain

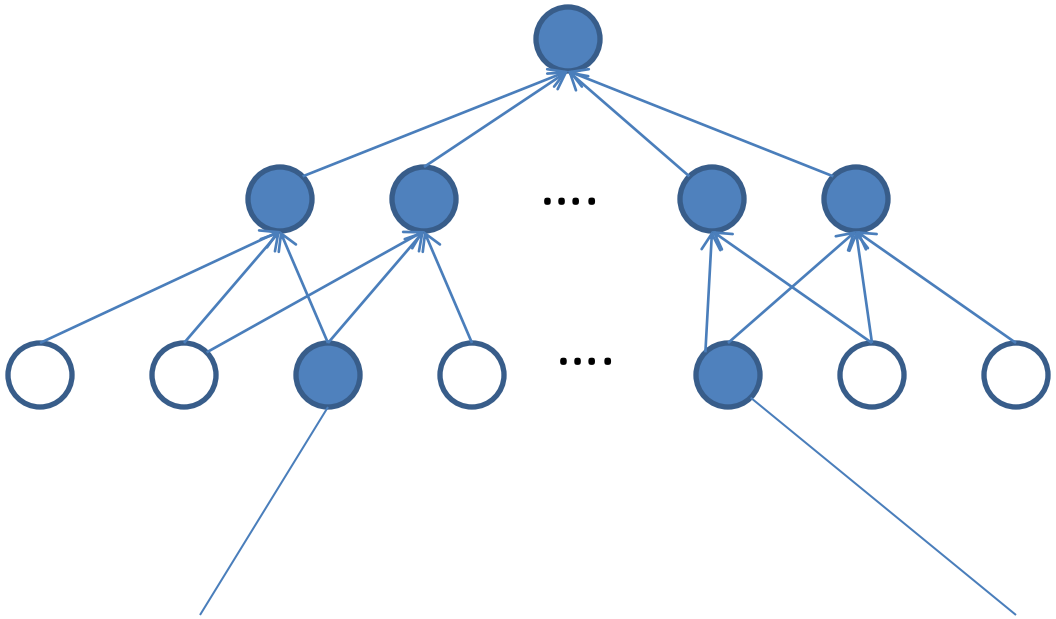
- Hubel & Wiesel's cat experiment, 1959
- Neocognitron, Fukushima, 1980
- Convolutional Neural Network, LeCunn et al. 1998
- *CNN is inspired by human brains*
- Local receptive field
- Cascaded structure



Deep Match CNN

Deep Match Tree Is Incorporated with Human Knowledge

- Parse two sentences first
- Find all match sub-trees between two sentences
- Feed match results into deep neural network
- *Parsing depends on human knowledge*



(How do you think about X? The food in X is great.) (think about, great)

How do you think about Nanchang? The food in Nanchang is great.

Take-away Messages

- AI is a philosophical problem
- AI is challenging, because intelligence is difficult to capture using math models
- Two strategies: task-driven and hybrid (learning based, knowledge incorporated and human brain inspired)
- Making progress in building natural language dialogue system by using big data and deep learning

Thank you!

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