

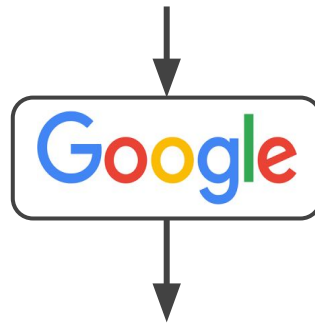
# Learning to Google

Rodrigo Nogueira and Kyunghyun Cho  
New York University



# Motivation

Query: "deepmind go paper"



**[PDF] Mastering the game of Go with deep neural networks ... - Go Game G...**  
<https://gogameguru.com/i/2016/03/deepmind-mastering-go.pdf> ▼  
by D Silver - Cited by 756 - Related articles  
networks play Go at the level of state-of-the-art Monte-Carlo tree search ..... Ostrovski for reviewing the paper; and the rest of the DeepMind team for their support ...  
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## Publications | DeepMind

<https://deepmind.com/publications.html> ▼

Nature 2016. Hybrid computing using a neural network with dynamic external memory. Authors: A Graves, G Wayne, M Reynolds, T Harley, I Danihelka, ...

## AlphaGo | DeepMind

<https://deepmind.com/research/alphago/> ▼

Jan 28, 2016 - Featuring expert analysis by Gu Li 9p and Zhou Ruiyang 9p, these games will prove an enlightening read for Go players of all levels.

## Mastering the game of Go with deep neural networks and tree search ...

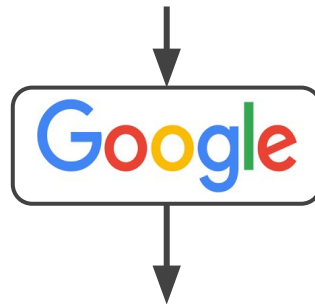
[www.nature.com/nature/journal/v529/n7587/full/nature16961.html](http://www.nature.com/nature/journal/v529/n7587/full/nature16961.html)

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Jan 28, 2016 - The game of Go has long been viewed as the most challenging of classic games for artificial intelligence owing to its enormous search space ...

# Motivation

Query: "google artificial intelligence paper asian board game"



Master of Go Board Game Is Walloped by Google Computer Program ...

<https://www.nytimes.com/2016/03/10/world/asia/google-alphago-lee-se-dol.html>

Mar 9, 2016 - Lee Se-dol, the world's top player of the boardgame Go, lost the first of five matches to a computer ... Kim Sung-ryong, a South Korean Go master who provided commentary during ... wondered Rodney Brooks, a pioneering artificial intelligence researcher. ... Order Reprints| Today's Paper|Subscribe.

Google AI beats legendary player in Chinese board game - The Hindu

[www.thehindu.com](http://www.thehindu.com) › Sci-Tech › Science ▼

Mar 9, 2016 - South Korea's professional Go player Lee Sedol, right, playing the game with against Google's artificial intelligence program, AlphaGo. ... In a new feat, Google-run artificial intelligence (AI) programme "AlphaGo" has defeated legendary player Lee Se-dol in Go — a complex ...



Google AI algorithm masters ancient game of Go : Nature News ...

[www.nature.com/news/google-ai-algorithm-masters-ancient-game-of-go-1.19234](http://www.nature.com/news/google-ai-algorithm-masters-ancient-game-of-go-1.19234) ▼

Jan 27, 2016 - Google AI algorithm masters ancient game of Go ... A computer has beaten a human professional for the first time at Go — an ancient board game that ... in Asia, has frustrated the efforts of artificial-intelligence researchers for ...

Game over? Computer beats human champ in ancient Chinese game

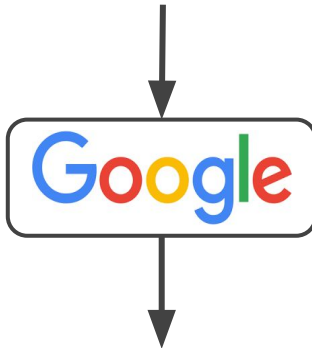
<https://phys.org> › Technology › Computer Sciences ▼

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## The Vocabulary Mismatch Problem

# The Idea

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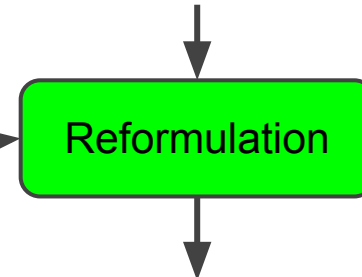
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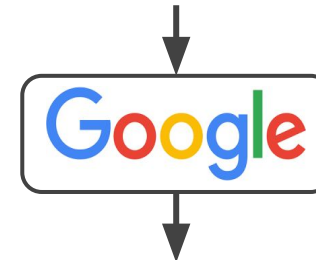
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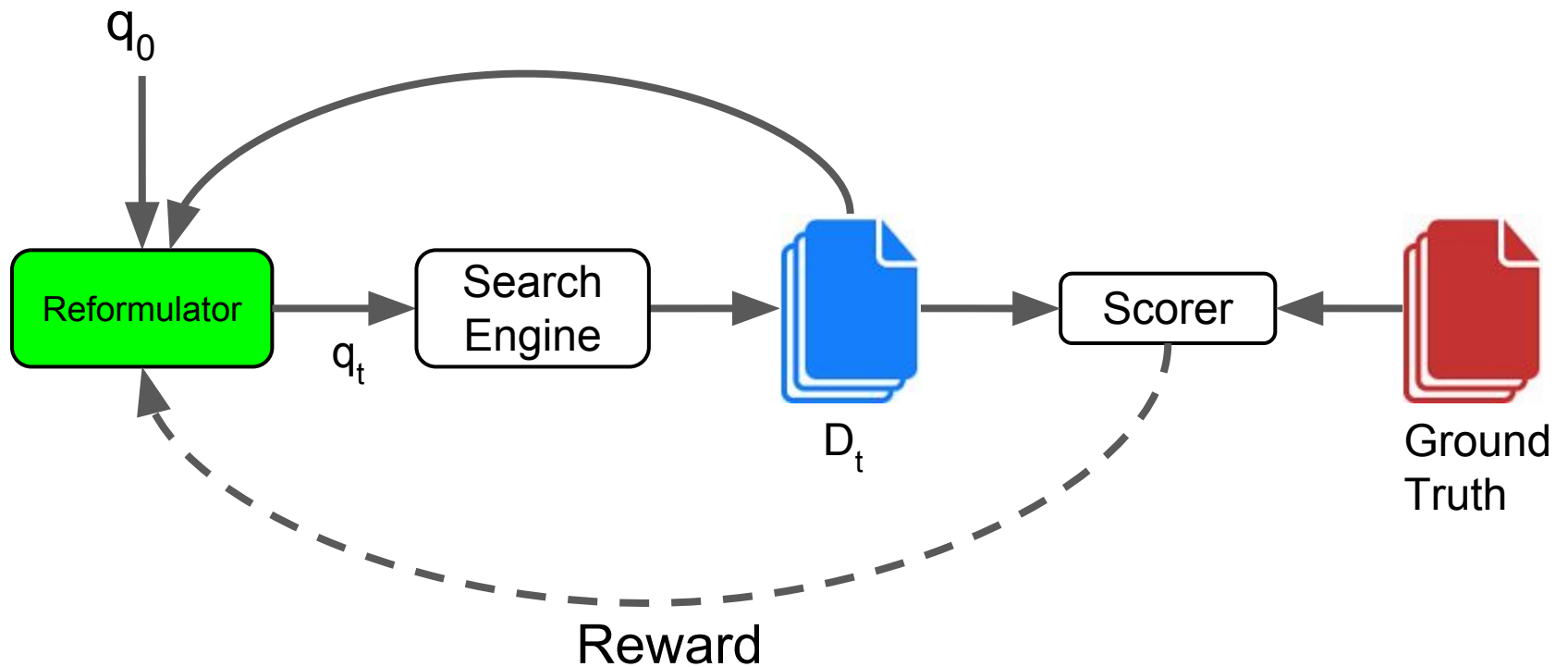
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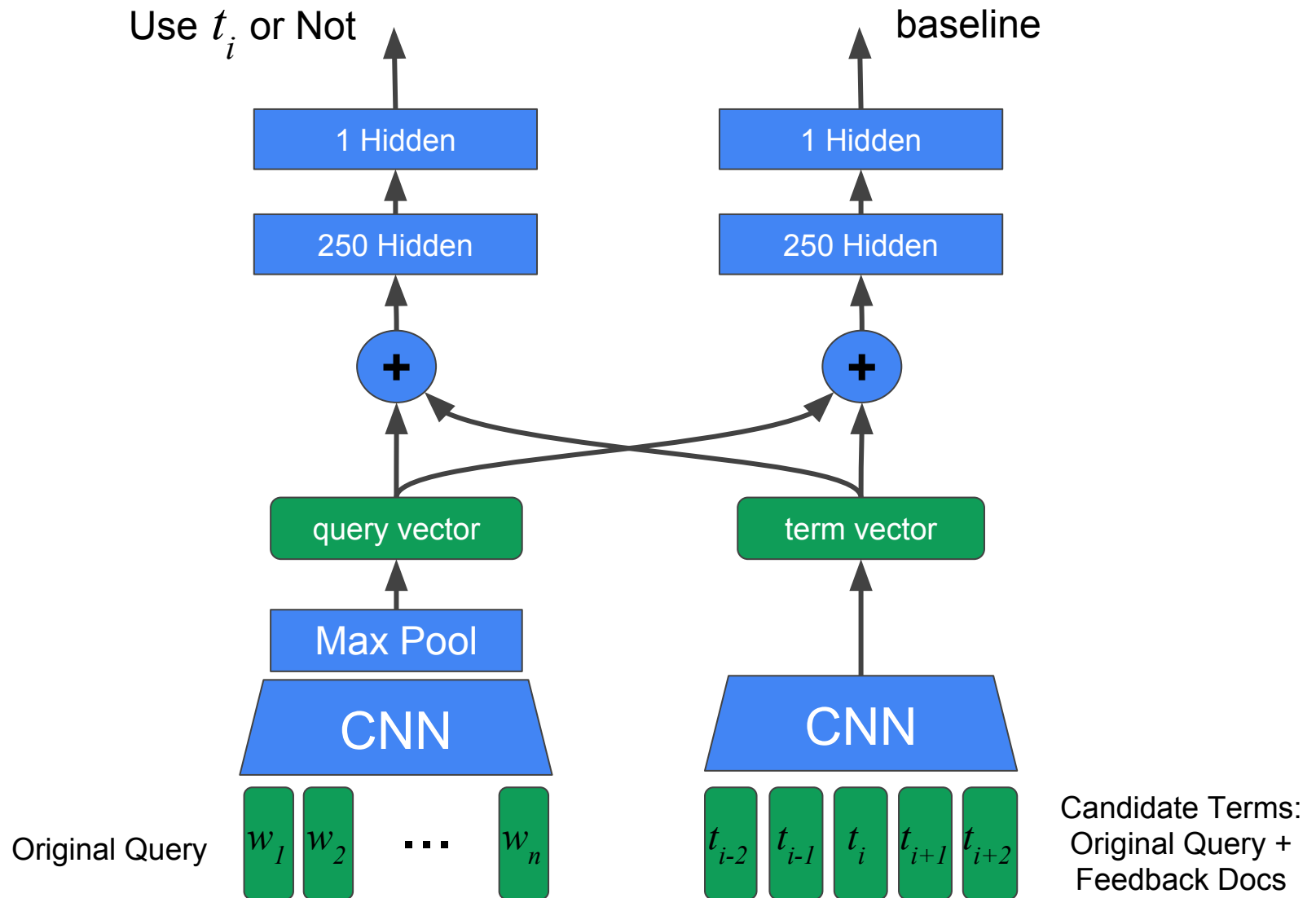
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# The Idea



# Reformulator

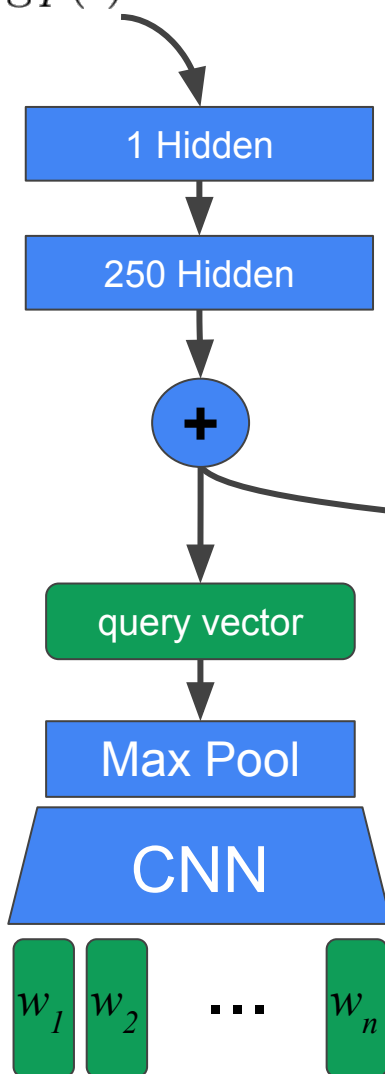


# Vanilla REINFORCE

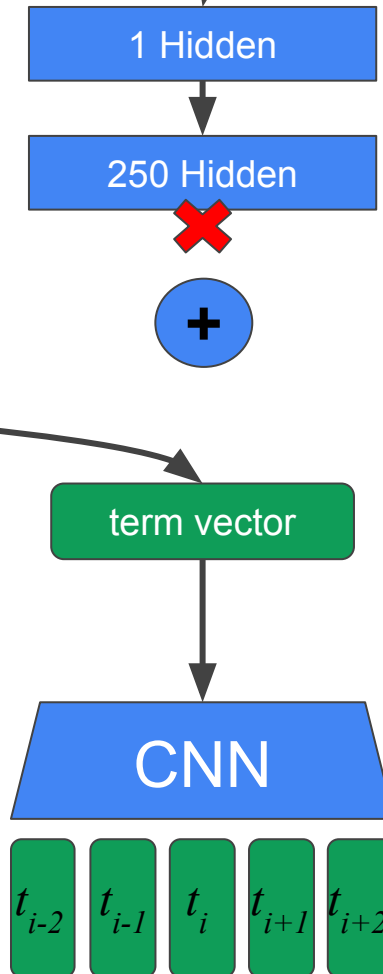
$$C_a = (R - b) \sum_{t \in T} -\log p(t)$$

Reward: **Recall**

Selected Terms



$$C_b = ||R - \bar{R}||^2$$





# Supervised Method

Step 1: Label each term as positive or negative based on its incremental reward.

Ex:

Query	Recall	Diff	Label
Google asian board game paper	0.40	-	-
Google asian board game paper <b>Deepmind</b>	0.45	0.05	<b>Pos</b>
Google asian board game paper <b>go</b>	0.43	0.03	<b>Pos</b>
Google asian board game paper <b>beats</b>	0.32	-0.08	<b>Neg</b>
Google asian board game paper <b>legendary</b>	0.35	-0.05	<b>Neg</b>

Step 2: Train a supervised classifier to predict if a term is positive or not.

Oracle: A classifier that perfectly selects relevant terms.

(Cao et al. 2008)

# Oracle - RL

A conservative upper-bound performance of a RL model in a particular environment:

- 1- Split the **validation or test** data into smaller subsets (~2000 samples)
- 2- Overfit the RL model on each subset
- 3- Oracle performance = Average reward over all subsets

# Datasets

- TREC-Complex Answer Retrieval
- Jeopardy
- Microsoft Academic

# TREC-Complex Answer Retrieval Dataset

**Input:** Wikipedia Title + Section

*"Sea Turtle Diet"*

**Output:** Wikipedia Paragraphs under the Section

## Sea turtle

---

### Diet [\[ edit \]](#)

The loggerhead, Kemp's ridley, olive ridley, hawksbill, flatback, and leatherback sea turtles are omnivorous for their entire life. Omnivorous turtles may eat a wide variety of plant and animal life including, [decapods](#), seagrasses, [seaweed](#), [sponges](#), [mollusks](#), [cnidarians](#), [echinoderms](#), worms and fish.<sup>[36][37][38][39]</sup> However some species specialize on certain prey.

The diet of green turtles changes with age.<sup>[40]</sup> Juveniles are omnivorous, but as they mature they become exclusively herbivorous.<sup>[37][40]</sup> This diet shift has an effect on the green turtle's morphology.<sup>[41][42]</sup> Green sea turtles have a serrated jaw that is used to eat sea grass and algae.<sup>[43]</sup>

Leatherback turtles feed almost exclusively on jellyfish and help control jellyfish populations.<sup>[44][45]</sup>

Hawksbills principally eat sponges, which constitute 70–95% of their diets in the Caribbean.<sup>[46]</sup>

**Corpus:** Paragraphs of all Wikipedia Articles

<http://trec-car.cs.unh.edu/>

# Jeopardy Dataset

**Input:** Jeopardy question

*"For the last 8 years of his life, Galileo was under house arrest for espousing this man's theory."*

**Output:** Wikipedia article whose title is the Answer.

## Nicolaus Copernicus

From Wikipedia, the free encyclopedia

*"Copernicus" redirects here. For other uses, see [Copernicus \(disambiguation\)](#).*

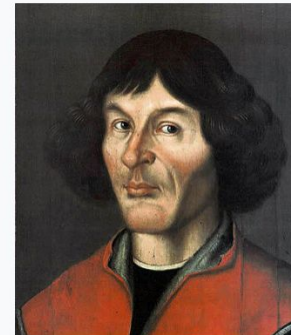
**Nicolaus Copernicus** (/koʊˈpɜːrnɪkəs, kəˈ<sup>[</sup>1<sup>]</sup>[2<sup>]</sup>[3] Polish: *Mikołaj Kopernik* [miˈkɔwaj kɔˈpɛrɲik] ( listen); German: *Nikolaus Kopernikus*; 19 February 1473 – 24 May 1543) was a [Renaissance](#) mathematician and astronomer who formulated a [model](#) of [the universe](#) that placed [the Sun](#) rather than the Earth at the center of the universe, likely independently of [Aristarchus of Samos](#), who had formulated such a model some eighteen centuries earlier.<sup>[a]</sup>

The publication of Copernicus' model in his book *De revolutionibus orbium coelestium* (*On the Revolutions of the Celestial Spheres*), just before his death in 1543, was a major event in the [history of science](#), triggering the [Copernican Revolution](#) and making an important contribution to the [Scientific Revolution](#).<sup>[7]</sup>

Copernicus was born and died in [Royal Prussia](#), a region that had been part of the [Kingdom of Poland](#) since 1466. A [polyglot](#) and [polymath](#), he obtained a doctorate in [canon law](#) and was also a [mathematician](#), [astronomer](#), [physician](#), [classics scholar](#), [translator](#), [governor](#), [diplomat](#), and [economist](#). In 1517 he derived a [quantity theory of money](#) – a key concept in economics – and in 1519 he formulated an economics principle that later came to be called [Gresham's law](#).<sup>[8]</sup>

**Contents** [hide]

Nicolaus Copernicus



1580 portrait (artist unknown) in the Old Town City Hall, Toruń

(Nogueira and Cho, NIPS 2016)

# Microsoft Academic Dataset

**Input:** Title/Abstract of a Paper

**Output:** References in that paper

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## ImageNet Classification with Deep Convolutional Neural Networks

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Alex Krizhevsky      Ilya Sutskever      Geoffrey E. Hinton  
University of Toronto      University of Toronto      University of Toronto  
kriz@cs.utoronto.ca      ilya@cs.utoronto.ca      hinton@cs.utoronto.ca

### Abstract

We trained a large, deep convolutional neural network to classify the 1.2 million high-resolution images in the ImageNet LSVRC-2010 contest into the 1000 different classes. On the test data, we achieved top-1 and top-5 error rates of 37.5% and 17.0% which is considerably better than the previous state-of-the-art. The neural network, which has 60 million parameters and 650,000 neurons, consists of five convolutional layers, some of which are followed by max-pooling layers, and three fully-connected layers with a final 1000-way softmax. To make training faster, we used non-saturating neurons and a very efficient GPU implementation of the convolution operation. To reduce overfitting in the fully-connected layers we employed a recently-developed regularization method called “dropout” that proved to be very effective. We also entered a variant of this model in the ILSVRC-2012 competition and achieved a winning top-5 test error rate of 15.3%, compared to 26.2% achieved by the second-best entry.

### References

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- [4] D. Cireřan, U. Meier, and J. Schmidhuber. Multi-column deep neural networks for image classification. *Arxiv preprint arXiv:1202.2745*, 2012.
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- [9] G. Griffin, A. Holub, and P. Perona. Caltech-256 object category dataset. Technical Report 7694, California Institute of Technology, 2007. URL <http://authors.library.caltech.edu/7694>.
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(An in-house crawl of 500k papers)

# Datasets - Summary

	<b>TREC-CAR</b>	<b>Jeopardy</b>	<b>MS Academic</b>
Corpus	Wikipedia Paragraphs	Wikipedia Articles	Academic Papers
Corpus Size	5.9M	3.5M	500k
Train / Valid / Test	580k / 195k / 195k	120k / 10k / 10k	270k / 20k / 20k

# Results

## Recall@40 on Test Set

	TREC-CAR	Jeopardy	MS Academic
Original Query	43.6	23.4	12.8
Pseudo Relevance Feedback - TFIDF	44.3	29.9	13.1
Pseudo Relevance Feedback - Word2Vec	44.5	27.5	11.9
Google	-	30.1	-
Supervised	44.1	31.1	14.0
REINFORCE	<b>47.3</b>	<b>33.4</b>	<b>14.9</b>
Oracle, Supervised	50.8	38.8	17.3
Oracle, RL	55.9	42.4	24.6



# Examples

**Original:** *It can be a herdsman's little house in the Swiss Alps, or a ski lodge built in that style*

**Reformulated:** *house Swiss Alps ski lodge that style castle board  
chalet*

**Original:** Homelessness in Canada, Public Policy

**Reformulated:** *homelessness in canada public policy human  
service programs social policy california treatment of the  
homeless numerous*

# Experiment Details

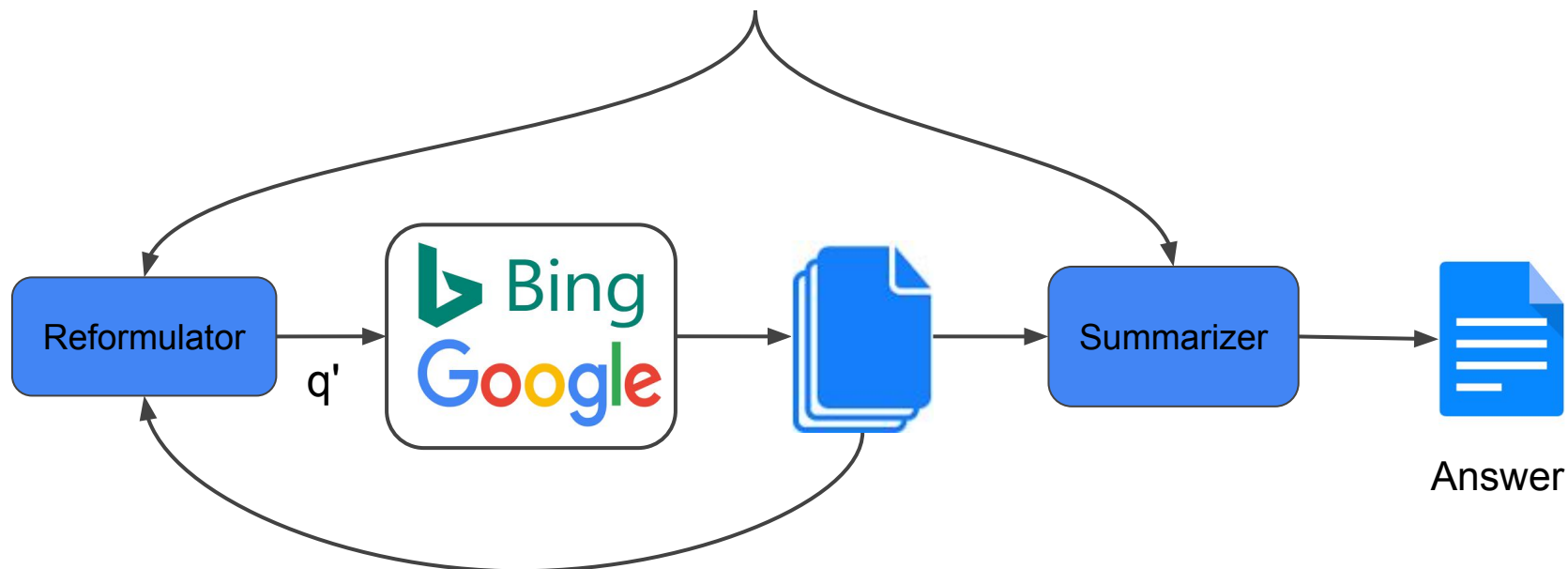
Choice	Why?
Search Engine: Lucene	Free and Fast!
Feedback docs: Top-5 Wikipedia Articles Feedback terms: 300 first words of a Wikipedia doc	Maximum fit on a GPU
CNN for Docs: 1st layer: 9-word window, 250 filters 2nd layer: 3-word window, 500 filters  CNN for Query: 2 layers, 3-word window, 250 filters	Painful Manual Trial-and-Error
Reward: Recall@40	Query Reformulation: Recall Ranking Functions: Precision

# Discussion

- Oracle shows lots of room for improvements.
- Applicability: Commercial search engines have click-through datasets.
- Querying the search engine is 90% of training time.

# Future Work: Automated Researcher

**Query:** *"What are the most promising directions to cure cancer and why?"*



Thank you!