Todai Robot Project

Can a machine solve university entrance exam problems automatically?

Noriko H. Arai

National Institute of Informatics

Todai Robot Project

Pursue a real breakthrough by challenging **a real intellectual task** through the reunion of the AI achievements in the past 30 years

Milestones

2016 – Mark a high score in the National Center Test

– "Comprehension & Thinking"

- Computer algebra (Quantifier elimination of RCF problems)
- Factoid
- Textual entailment recognition, …

2021 – Pass the entrance exam of the University of Tokyo

– "Comprehension, Thinking & Answer generation"

- Document summarization,
- Deep and precise language processing,
- Machine translation,
- Software component integration framework, …

University entrance exams in Japan

National Center Test (multiple choice) 7 subjects

- Mathematics (Introductory, Advanced)
- Natural Science (Physics, Chemistry, Biology, Earth Science)
- Social Studies (World History, Japanese History, Economics & Politics, Ethics, Geography)
- Japanese (Contemporary Japanese & Japanese&Chinese Classics)
- English

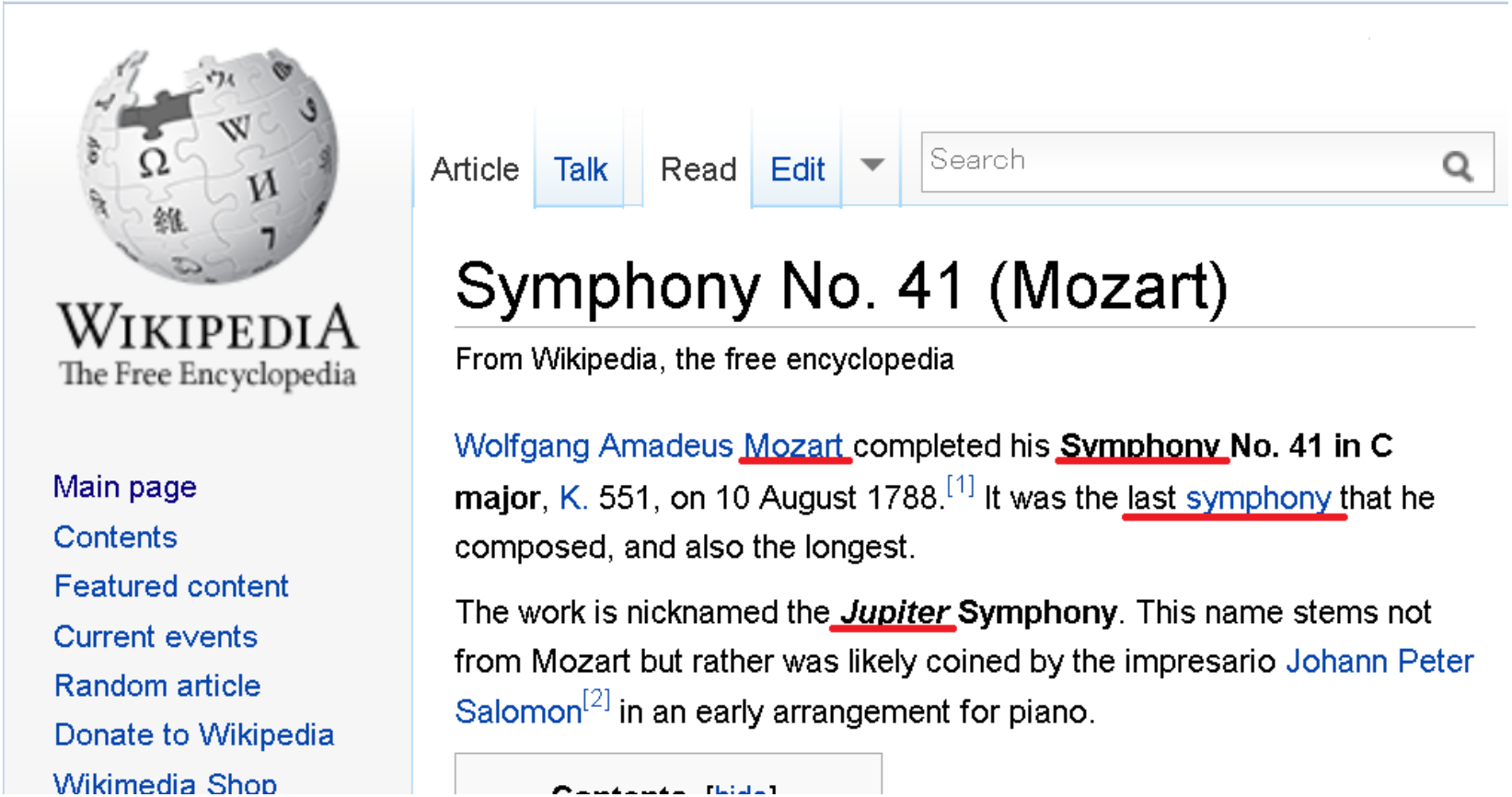
Tokyo University
Second Stage Exam (written test)

- Mathematics
- 2 × Natural Science or 2 × Social Science
- Japanese
- English

2011

MOZART'S LAST & PERHAPS MOST POWERFUL SYMPHONY SHARES ITS NAME WITH THIS PLANET

MOZART'S LAST SYMPHONY



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Symphony No. 41 (Mozart)

From Wikipedia, the free encyclopedia

Wolfgang Amadeus Mozart completed his **Symphony No. 41 in C major**, K. 551, on 10 August 1788.[1] It was the last symphony that he composed, and also the longest.

The work is nicknamed the ***Jupiter*** **Symphony**. This name stems not from Mozart but rather was likely coined by the impresario Johann Peter Salomon[2] in an early arrangement for piano.

20 years exam data
Dictionaries
Wikipedia JA…

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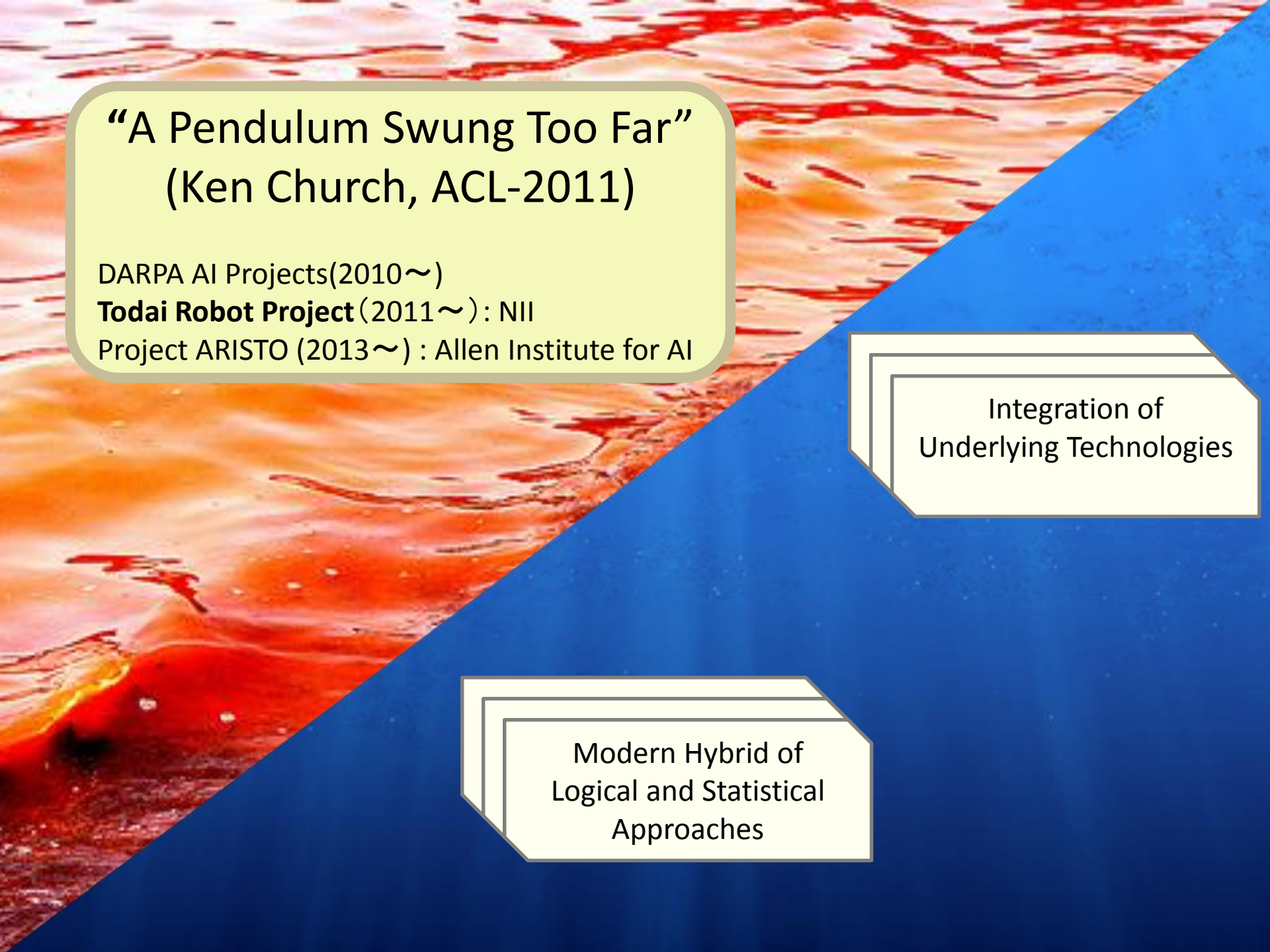

“A Pendulum Swung Too Far”
(Ken Church, ACL-2011)
DARPA AI Projects(2010～)
Todai Robot Project（2011～）: NII
Project ARISTO (2013～) : Allen Institute for AI
Integration of
Underlying Technologies
Modern Hybrid of
Logical and Statistical
Approaches

Development

Evaluation

Technology integration & Improvement

- Integration of elemental technologies
- Language understanding boosted by domain knowledge and inference
- co-reference & zero anaphora resolution

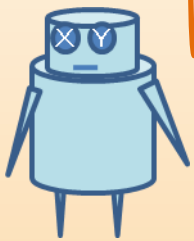
Technologies for secondary exams

- Text summarization
- Meta-knowledge structure recognition
- Undecidable math problems
- Image and NLP
- Qualitative reasoning

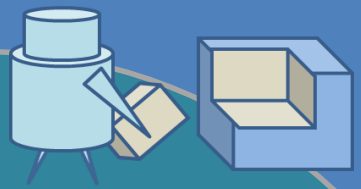
.....

Basic technologies for Center Tests

- Syntactic parsing
- Textual entailment recognition
- Physical simulation platform
- Semantic language design
- Semantic analysis



- Development of end-to-end systems with new technologies
- Performance analysis and improvement



Mathematica, Watson, Tsubaki, SyNRAC...

- Data building
- Problem analysis

- Baseline systems based on existing technologies
- Accuracy analysis

Start 2011

Development of a UIMA platform

Management of international evaluation tasks

2013

2016

Textual Entailment Recognition

2009 Center Test World History B

Choose the correct statement about military systems.

1. The Janissaries were standing troops in the Ottoman Empire.
2. The Frankish Kingdom established the thema system.

standing troops in the Ottoman Empire
← Ottoman sultan's household troops

X ← ... units that formed *X*

Janissary

... The Janissaries were infantry Musketeer units that formed the Ottoman sultan's household troops and bodyguards. The force was created by the Sultan Murad I from Christian boys ...

Theme (Byzantine district)

... The themes or themata were the main administrative divisions of the middle Byzantine Empire. ...

Wikipedia

World History Problems via Textural Entailment Recognition

Multiple choice problems as textual entailment recognition

⇒ **judges truth/falsehood of a text *t2* under the premise *t1***

***t1*: Wikipedia & Textbooks**

***t2*: Choices in Social Studies Questions**

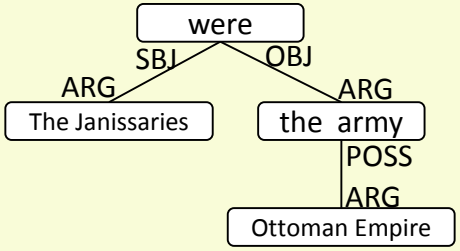
Q. Select a correct statement from 1)-3):
1) The Eight Banners was an army founded by the Shunzhi Emperor.
2) The Janissaries were the standing army of the Ottoman Empire.
3) In Francia, a system of farmer-soldiers was established under the theme system (system of military districts).

Accurate entailment recognition by logic/statistics hybrid system

ACL 2014

"Logical inference on dependency-based compositional semantics"

- Expressive & efficient meaning representation by algebraic forms with set operators
- Inference by logical operation and machine learning

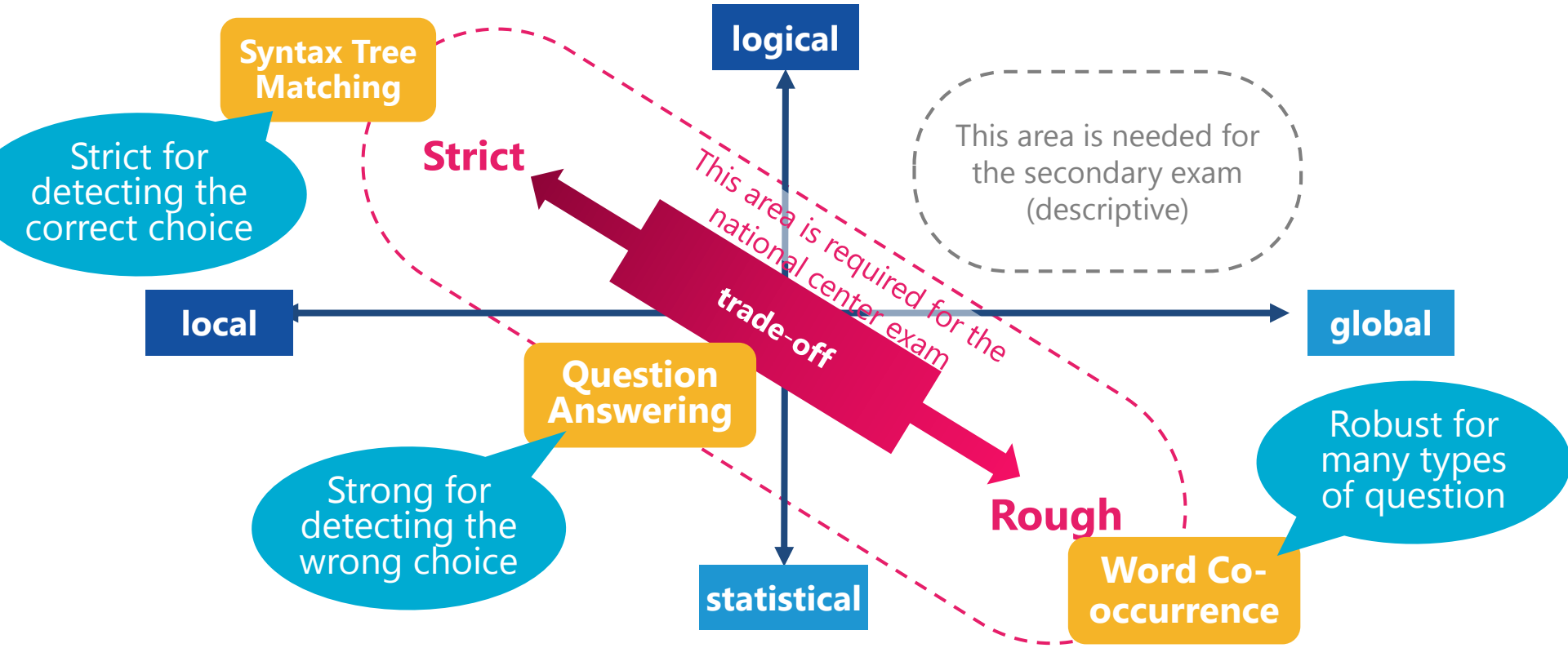


Evaluation tasks in NTCIR-11

System	Points (/100)
Shizuoka U.	57
CMU1	55
CMU2	52
CMU3	48
YNU	46
CMU4	45
CMU5	43
Fujitsu Lab	41
Fujitsu R&D	37
Fujitsu Lab2	34
Hokkkaido U.	31
Fujitsu Lab3	23
Baseline	20

Three Strategies for World History B

- By combining the three strategies, it became possible to solve the various questions



Example）Using Question Answering

- Converting the choice to the factoid question
  - "Charlemagne defeats the Magyar at the 8th century." (false choice)
  - → "Charlemagne defeats (PersonType) at the 8th century." →？

Search Results in textbooks and Wikipedia

Actually, "Avars" is correct

… At the end of the 8th century, the **Avars** that had dominated this land was subsumption to the Frank kingdom under attack of **Charlemagne**. …(Wikipedia)

Rank	Word	Score
1	**Avars**	3.2
2	Mongolian	…
…	…	…
5	**Magyar**	1.1

Distance = 14 words
Convert the distance to the score

Calculate the difference from the first place as the cost

Cost of "Magyar" is 3.2 − 1.1=**2.1**

The score in 2015: 76

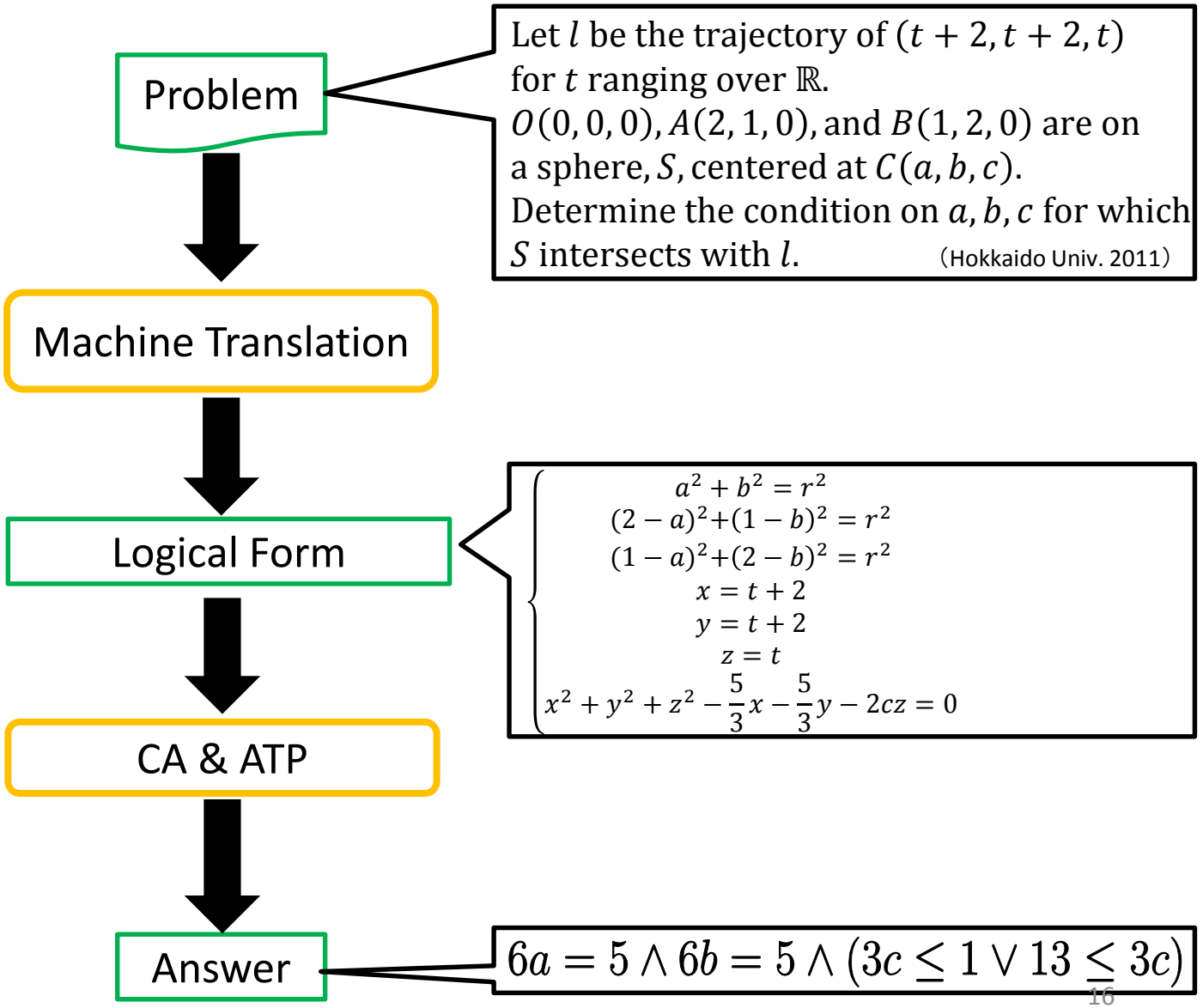
How about mathematics?

Let l be the trajectory of $(t+2, t+2, t)$ for t ranging over $\mathbb{R}$.
$O(0,0,0)$, $A(2,1,0)$, and $B(1,2,0)$ are on a sphere, S, centered at $C(a,b,c)$.

Determine the condition on a, b, c for which S intersects with l.

（Hokkaido Univ. 2011)

An Image of Automatic Math Problem Solving



Math - Jointing NLP and CA&ATP through Logic

- Syntactic Parsing
- Discourse analysis

Math Knowledge-base

- RCF-QE
- Gröbner basis

etc.

FUJITSU

Joint Research with Fujitsu Lab.

Problem

Language Understanding

Logical Form in ZF

Formula Rewriting

Logical Form in RCF

Computer Algebra

Answer

Let l be the trajectory of $(t+2, t+2, t)$ for t ranging over $\mathbb{R}$.
$O(0,0,0)$, $A(2,1,0)$, and $B(1,2,0)$ are on a sphere, S, centered at $C(a,b,c)$.
Determine the condition on a, b, c for which S intersects with l. (Hokkaido Univ. 2011)

$$\exists l \exists u \exists v \exists S \exists R(\\ l = \mathrm{line}(u,v) \ \wedge \ \forall p(p \in l \leftrightarrow \\ \exists t(p = (t+2, t+2, t))) \wedge \\ S = \mathrm{sphere}((a,b,c), R) \wedge (0,0,0) \in S \wedge \\ (2,1,0) \in S \wedge (1,2,0) \in S \wedge \\ \exists q(\mathrm{intersect}(S, l, q)))$$

$$\exists u_x \exists u_y \exists u_z (((\neg(u_x = 0)) \vee (\neg(u_y = 0)) \vee (\neg(u_z = 0))) \wedge (\exists v_x \exists v_y \exists \\ (tu_y + v_y - b)^2 + (tu_z + v_z - c)^2 = R^2)) \wedge (0 < R) \wedge (a^2 + b^2 + c^2 \\ \wedge((2-a)^2 + (1-b)^2 + c^2 = R^2))) \wedge (\exists v_{lx} \exists v_{ly} ((\exists v_{lz} ((0 = u_y(v_z - \\ \wedge(0 = u_z(v_x - v_{lx}) - u_x(v_z - v_{lz})))) \wedge (0 = u_x(v_y - v_{ly}) - u_y(v_x - \\ (((p_x = p_z + 2) \wedge (p_y = p_z + 2)) \vee (\forall t_2((\neg(p_x = t_2 u_x + v_x)) \vee (\neg(p_ \\ \vee(\neg(p_z = t_2 u_z + v_z)))))) \wedge (\forall p_t (\exists t_3((p_t = t_3 u_z + v_z) \wedge (p_t + 2 = t_3 \\ )) \wedge (\exists u_{lx} \exists u_{ly} ((\exists u_{lz} (((\neg(u_{lx} = 0)) \vee (\neg(u_{ly} = 0)) \vee (\neg(u_{lz} = 0))) \\ \wedge(0 = u_y u_{lz} - u_z u_{ly}) \wedge (0 = u_z u_{lx} - u_x u_{lz}))) \wedge (0 = u_x u_{ly} - u_y u_{lx})$$

$$6a = 5 \wedge 6b = 5 \wedge (3c \leq 1 \vee 13 \leq 3c)$$

Is it possible to determine the local theory just from wordings?

- Let *O* be a circle of radius 1 centered on the origin. Given points *A* and *B* on the circumference of *O*, find the point on the x-axis equidistant from A and B.
  - $\in$ RCF

- Let *O* be a circle of radius 1 centered on the origin. Find a point *A* on the x-axis such that the distance from point *A* to the origin is equal to the length of the circumference of *O*.
  - $\notin$ RCF

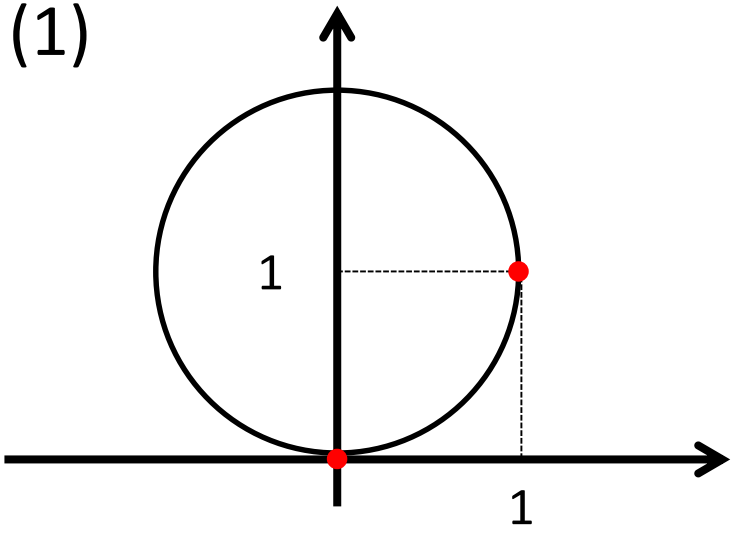
Demo

Cは原点と(1,1)を通る円である。
C is a circle that passes through the origin and (1, 1).

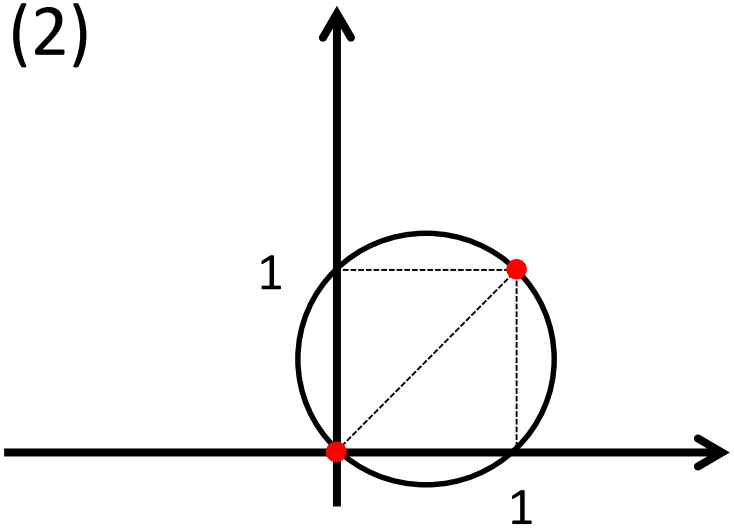
(1) Cがx軸と接するとき、Cの半径を求めよ。
Find the radius of C when C is tangent to the x-axis.

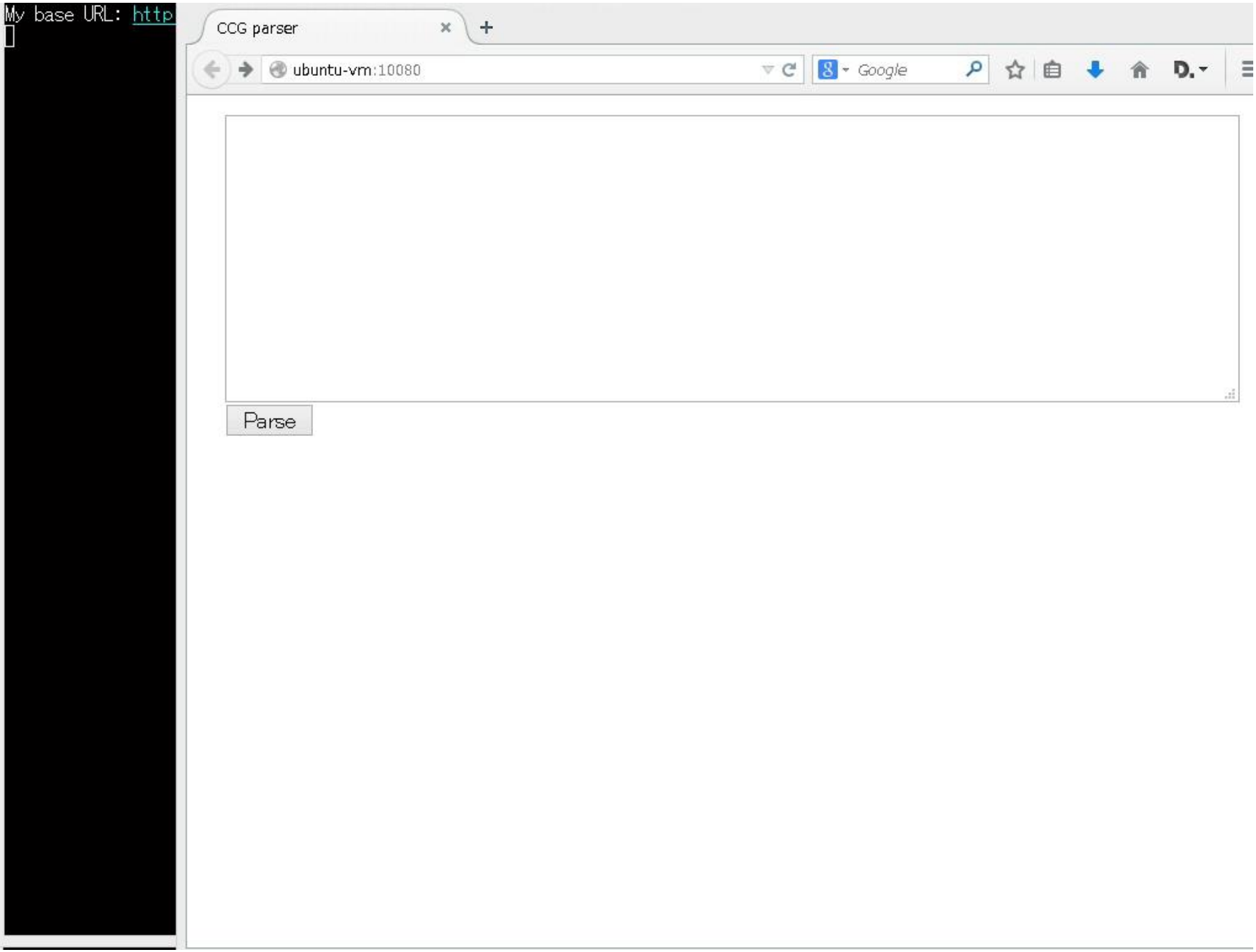
(2) Cの直径の最小値を求めよ。
Find the minimum diameter of C.

(1)

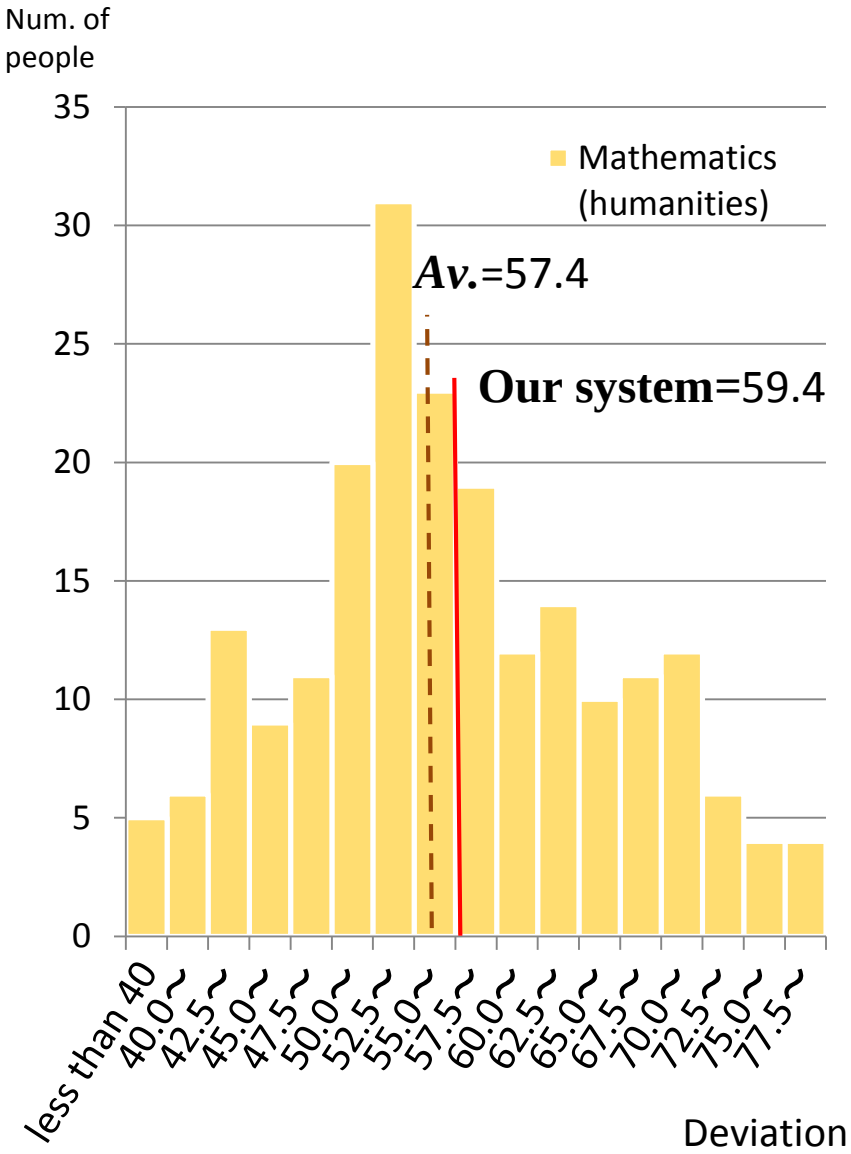


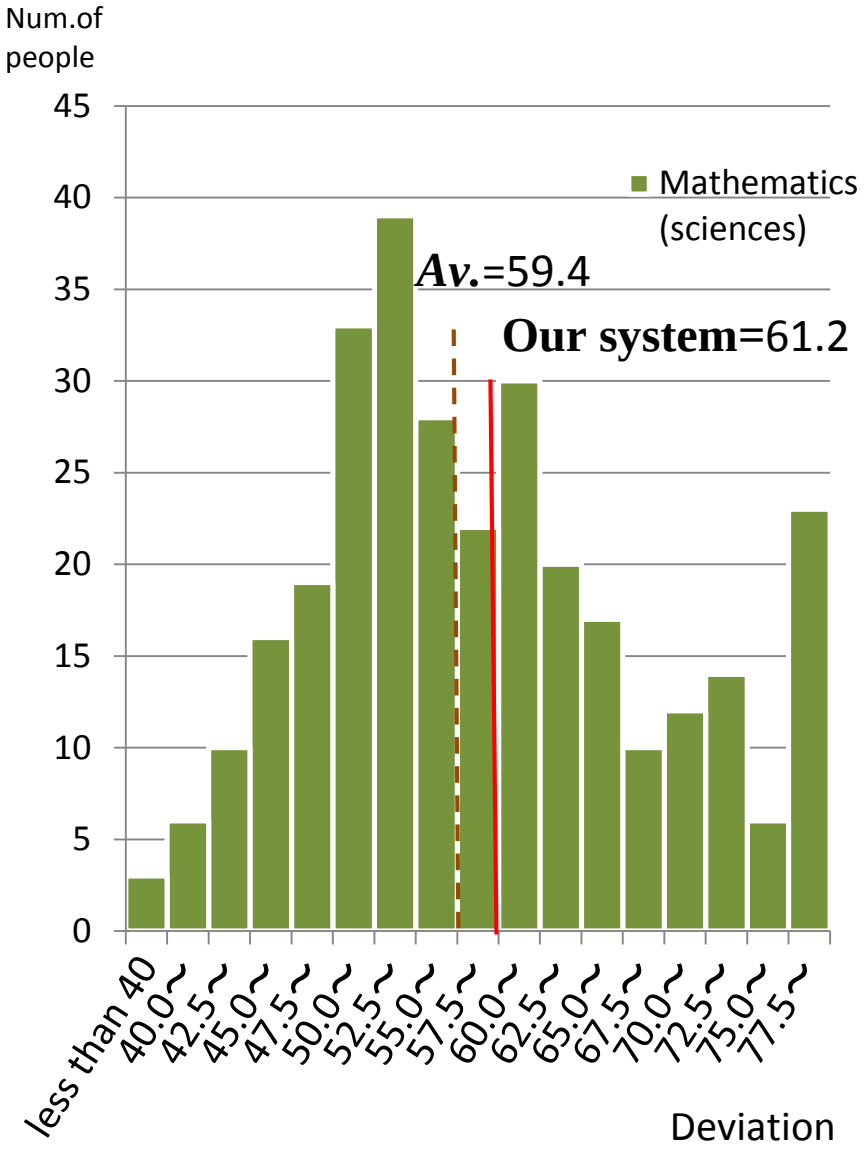
(2)




My base URL: http
CCG parser
ubuntu-vm:10080
Google
Parse

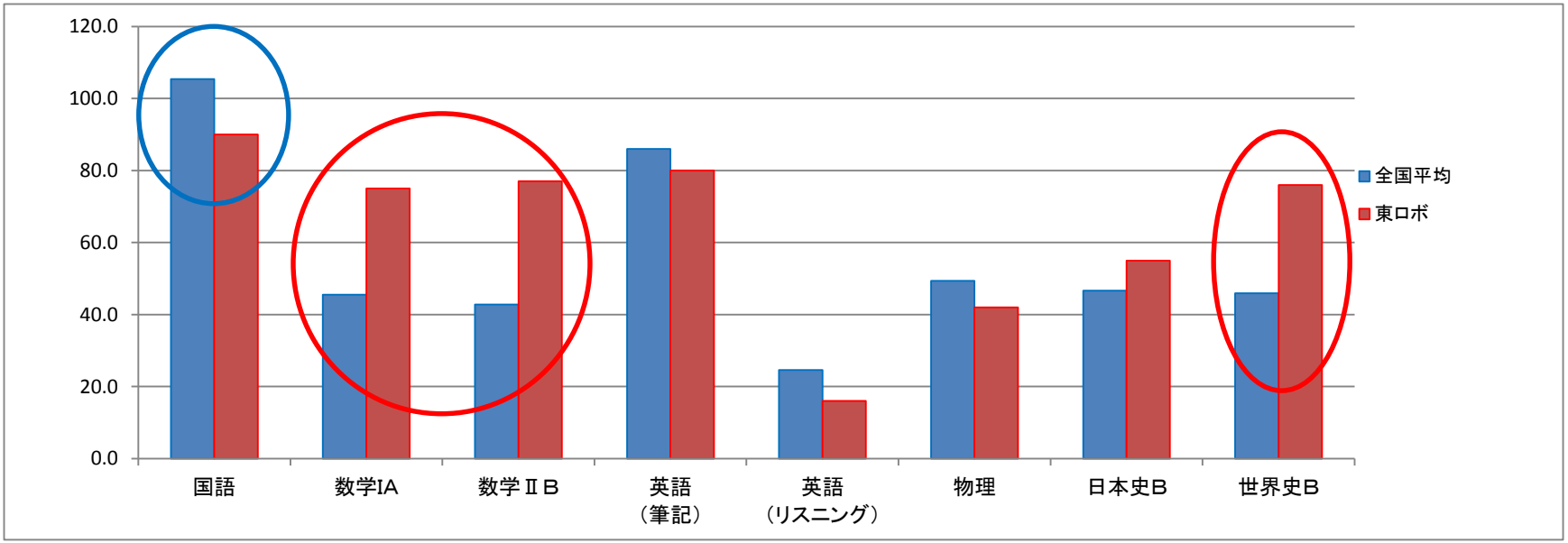
Tokyo Univ. prep test (Math, 2013)





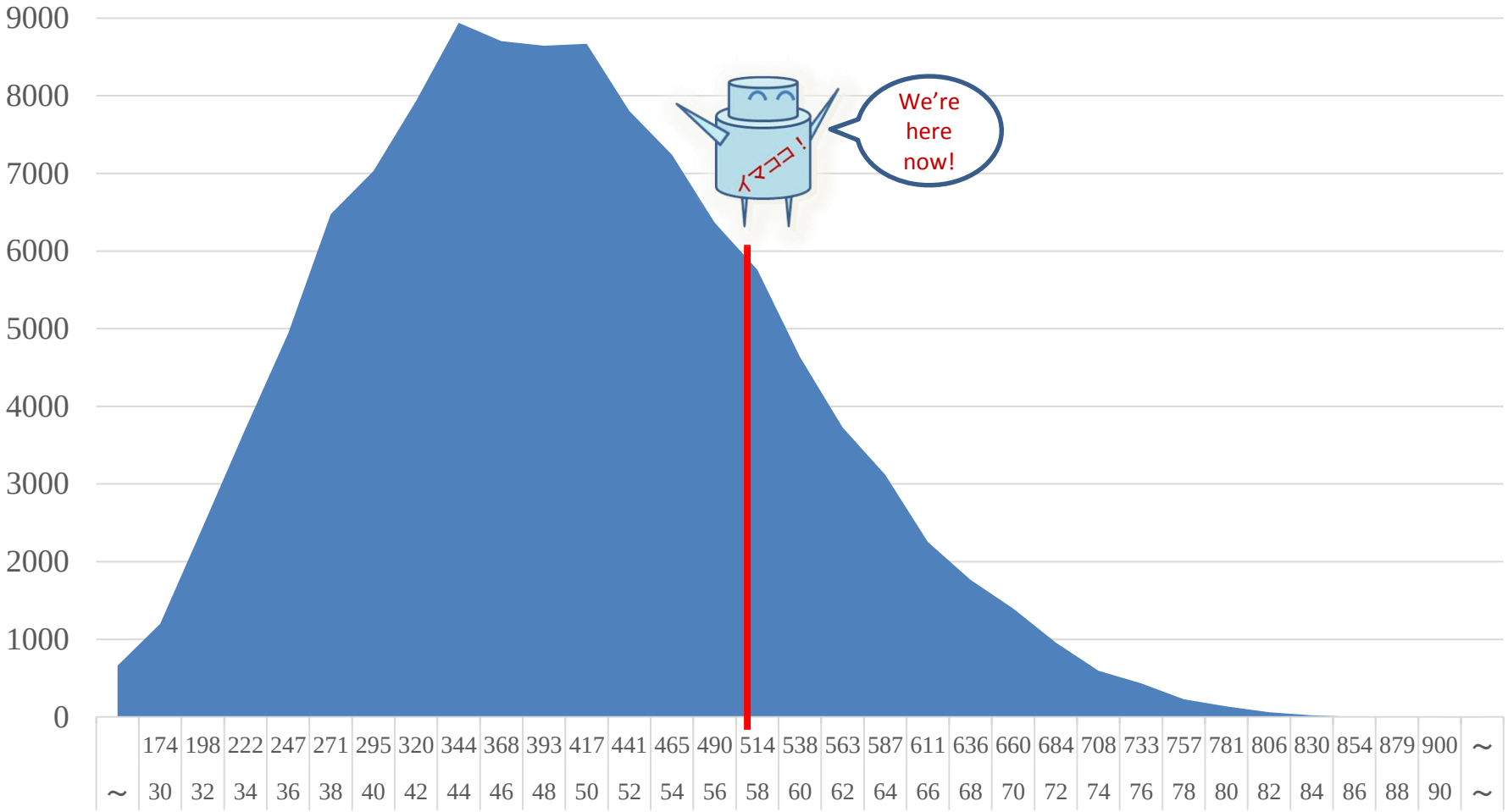
2016 Center Mock Test Result ①

	Japanese	Intro-Math	Adv-Math	English writing	English Listening	Physics	Japanese History	World History	5 subjects
Allot	200	100	100	200	50	100	100	100	950
Average	105.4	45.5	42.8	86.0	24.6	49.4	46.6	45.9	416.4
Todai Robot	90.0	75.0	77.0	80.0	16.0	42.0	55.0	76.0	511.0
T-Score	45.1	**64.0**	**65.8**	48.4	40.5	46.5	**54.8**	**66.5**	**57.8**



Todai Robot marked higher than human examinee in Mathematics (Introductory, Advanced), Japanese History and World History. Need more improvements in Physics, Japanese and English.

2016 Center Mock Test Result ②



How did it do on written test?

University of Tokyo : Mock Test Results on World History				
	I **600 words Essay** on "Changes of state systems of Western Europe and Asian countries from 16 to 18 centuries"	II Short essays (60-90 words)	III Factoid questions	Total
Average	4.3	6.5	6.4	17.2
Todai Robot	**9**	**0**	**5**	**21**
T-Score	**61.8**	**35.6**	**43.9**	**54.1**

Is there any university our system can enter?

Evaluation of our system in National Center prep test (2015)

	Number of Universities and Departments	Universities which our system can enter with a probability of more than 80%
National universities	170 universities, 570 departments	**33** university, 39 departments
Private universities	580 universities, 1723 departments	**441** universities, 1055 departments
Total	750 universities, 2293 departments	**474** universities, 1094 departments

Our system possibly enters
more than half universities
(moe than 3/4 private universities) in Japan!

Media Appearance

The New York Times, The Wall Street Journal, Fortune Magazine, IEEE Spectrum, Yomiuri Shimbun, Asahi Shimbun, Nihon Keizai Shimbun, Nikkei BP, The Economist, Nikkei Computer, …

September 12, 2012, 10:02 AM

Can a Robot Get Into Japan's Most Prestigious University?

Article | Comments

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By YOREE KOH CONNECT

Tokyo University's notoriously difficult entrance exam shatters the dreams of thousands of Japanese high school students each year. Can it also crush the hopes of Japan's best robot scientists?

National Institute of Informatics

The logo for the Todai Robot project spearheaded by the National Institute of Informatics.

The scientists won't be taking the test themselves. Instead, this being Japan, researchers have posed the question of whether a robot could pass the test to get into the country's most prestigious university.

Fujitsu Ltd. is betting artificial intelligence is smart enough to make the grade for Todai — as the university is also known. In response to the challenge "Can a Robot Pass the Todai Entrance Exam"?, the electronics company said Monday that its research subsidiary, Fujitsu Laboratories Ltd. will join forces with Japan's National Institute of Informatics,

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Can an AI Get Into the University of Tokyo?

The school's notorious entrance exam could be the perfect test for artificial intelligence

By Eliza Strickland
Posted 21 Aug 2013 | 15:37 GMT

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For the thousands of secondary school students who take Japan's university entrance exams each year, test days are long-dreaded nightmares of jitters and sweaty palms. But the newest test taker can be counted on to keep its cool: AIs don't sweat.

Photo: John S. Lander/LightRocket/Getty Images

Enter: Students, human and robotic, must pass an exam to get through the gates of

At Japan's National Institute of Informatics (NII), in Tokyo, a

NHK Special
"Computer Revolution: Emergence of the most powerful computers ever "
NHK News 7 (prime time news)
BS Nihon TV (40min news Show)

Thank you.