

Grand Challenges of AI: The Unfinished Agenda

Raj Reddy
Carnegie Mellon University
Talk at the Heidelberg Laureate Forum
September 27, 2019

A Grand Challenge is a Difficult To Accomplish -
Goal-Directed Research Effort With Distinct Metrics

Why Grand Challenges?

- GCs Encourage Thinking Outside the Box
 - Unlike grants and contracts, which are awarded in the hope that the recipient will be successful, prizes allow establishment of ambitious goals and reward the winning entry
 - Allow multiple approaches without knowing which is most likely to succeed,
 - Make way for novel approaches that might otherwise seem too risky
- GCs Encourage Broad Participation
 - GCs attract a wide array of potential solvers to tackle a problem and not just the usual experts in a given field
 - Wright Brothers Vs
- GC Economics Are Great
 - Awards are given only if someone succeeds
 - In many cases, the amount of time and money invested by multiple teams exceeds the size of the prize purse itself.

Longitude Prize

- In 1714 the British government passed the [Longitude Act](#) which offered large financial rewards to the first person to demonstrate a practical method for determining the longitude of a ship at sea
- In 1773 John Harrison was awarded the prize for the invention of Chronometer
 - 10,000 pounds in 1773 (23,065 in total partial payments)
 - About 1.5 Million Pounds today (about 3.5 million today)

Ortieg Prize

- The Orteig Prize of \$25000 (about \$370K today) was a reward offered in 1919 to the first Allied aviator(s) to fly non-stop from New York City to Paris or vice versa
- American Charles Lindbergh won the prize in 1927
 - in his aircraft Spirit of St. Louis
- The Orteig Prize inspired the \$10 million Ansari X Prize
 - for repeated suborbital private spaceflights.
 - announced in 1996, some eight years before it was won in 2004

XPRIZES (Partial List)

- \$10 million Ansari XPRIZE : Announced 1996. Won 2004
 - Lower the risk and cost of going to space by incentivizing the creation of a reliable, reusable, privately financed, manned spaceship making private space travel commercially viable
 - Challenge: build private spaceships capable of carrying three people and fly two times within two weeks
 - Won By Mike Melville, Brian Binnie, Designed by Burt Rutan, and Funded by Paul Allen
- \$10 Million Automotive XPRIZE: Announced 2007. Won 2010
 - Design, build and race super-efficient vehicles that achieve 100 [MPGe](#) efficiency, produce less than 200 grams/mile well-to-wheel CO₂ equivalent [emissions](#), and could be manufactured for the mass market
 - Team Edison2 won the \$5 million Mainstream competition with its four-passenger [Very Light Car](#), obtaining 102.5 MPGe.
 - Team Li-Ion Motors won the \$2.5 million Alternative competition with aerodynamic Wave-II electric vehicle achieving 187 MPGe.
 - Team X-Tracer Switzerland won the \$2.5 million Alternative Tandem competition with their 205.3 MPGe faired electric motorcycle.
- \$15 Million Global Learning XPRIZE: Announced 2014. Won 2019
 - Develop scalable solutions that enable children to teach themselves basic reading, writing and arithmetic within 15 months
 - Won by **Kitkit School** from South Korea and the USA, and **Onebillion** from Kenya and UK

DARPA Grand Challenges (partial list)

- **Autonomous Robotic Ground Vehicles Challenge (2007):** Demonstrate that autonomous ground vehicles can travel long distances over difficult terrain at militarily relevant rates of speed
 - \$2M Prize won by Stanford Stanley (Sebastian Thrun et al)
- **Urban Challenge (2007):** build an autonomous vehicle capable of driving in traffic, performing complex maneuvers such as merging, passing, parking and negotiating intersections
 - \$2M Prize Won by CMU BOSS (Red Whittaker et al)
- **DARPA Network Challenge (2009):** Explore problem solving using social networking tools. Find and submit the locations of 10 moored, 8-foot, red, weather balloons at 10 fixed locations in the continental United States.
 - \$40K Prize Won by a Social Media Team headed by MIT by finding all 10 in under 7 hours
- **DARPA Chikungunya Challenge (2015):** Forecasting the Spread of Infectious Diseases by predicting the speed, severity and direction of Chikungunya outbreak.
 - 11 Awards from \$150K to \$10K

NAE, RAE and CAE: Engineering Grand Challenges

1. providing access to clean water;
2. preventing nuclear terror;
3. engineering better medicines;
4. advancing health informatics;
5. making solar energy economical;
6. developing carbon sequestration methods;
7. securing cyberspace;
8. reverse-engineering the brain;
9. managing the nitrogen cycle;
10. providing energy from fusion;
11. restoring and improving urban infrastructure;
12. engineering the tools of scientific discovery;
13. enhancing virtual reality; and
14. advancing personalized learning.

UN Sustainable Development Goals

The 17 sustainable development goals (SDGs) to transform our world

1. No Poverty
2. Zero Hunger
3. Good Health and Well-being
4. Quality Education
5. Gender Equality
6. Clean Water and Sanitation
7. Affordable and Clean Energy
8. Decent Work and Economic Growth
9. Industry, Innovation and Infrastructure
10. Reduced Inequality
11. Sustainable Cities and Communities
12. Responsible Consumption and Production
13. Climate Action
14. Life Below Water
15. Life on Land
16. Peace and Justice Strong Institutions
17. Partnerships to achieve the Goal

Recent Progress AI Grand Challenges

World Champion Chess Machine Challenge

- Defeat the Reigning World Champion in Chess
- The challenge was settled in 1996 when IBM Deep Blue (developed by Hsu, Anantharaman, Campbell, Hoane et al) defeated the reigning World Champion of Chess, Garry Kasparov ([https://en.wikipedia.org/wiki/Deep_Blue_\(chess_computer\)](https://en.wikipedia.org/wiki/Deep_Blue_(chess_computer))).
- History
 - Greenblatt, MIT, MacHack' 1968
 - Gillogly, CMU, Tech, 1970
 - Atkin and Slate, Northwestern, 1970-80, Rating 1950
 - Thompson and Condon, Bell Labs, 1972-80, Masters level, 2250
 - Berliner, CMU, HiTech, International Master
 - Hsu, Anantharaman, Campbell, and Nowatzyk, CMU, Deep Thought, Grand Master



1997 Chess World Champion Team (Top Image) and Chess Pioneers (Bottom Image) with Fredkin and Reddy
Top Image: Raj Reddy, Murray Campbell, C B Hsu, and Joseph Hoane Jr., Ed Fredkin
Bottom Image: Murray Campbell, Joe Condon, Raj Reddy, Ken Thompson, C B Hsu, Richard Greenblatt, Larry Atkin, Hans Berliner, David Slate, Andreas Nowatzyk, Thomas Anantharaman, Gordon Goetsch, Ed Fredkin, Joseph Hoane Jr

Beyond Chess: The Development of Gaming AI

Complexity of non-complete information games

Games

Number of information sets

Average size of individual information set

Heads-up limit poker

10^{14}

10^3

Heads-up no-limit poker

10^{162}

10^3

Contract bridge

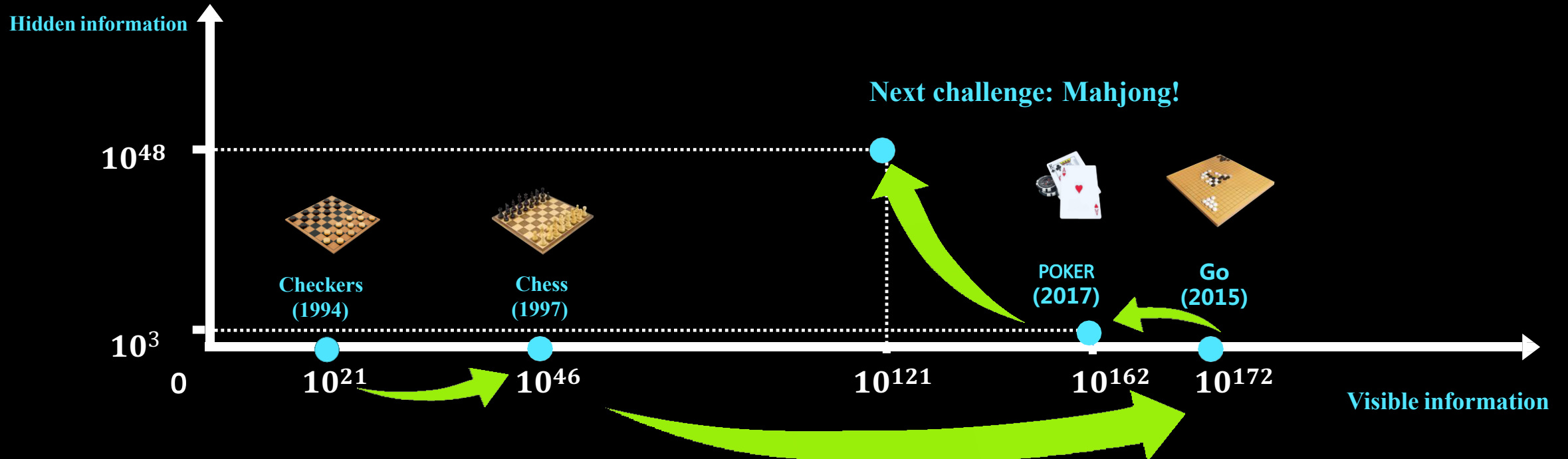
10^{67}

10^{15}

Mahjong

10^{121}

10^{48}



Accident Avoiding Car (Driverless Car) Challenge

- The Accident Avoiding Car (Driverless Car) challenge was decided in 2005 when Stanford's Stanley headed by Sebastian Thrun and CMU's Sandstorm headed by Red Whittaker were among the five cars to successfully complete the challenge

[https://en.wikipedia.org/wiki/DARPA_Grand_Challenge_\(2005\)](https://en.wikipedia.org/wiki/DARPA_Grand_Challenge_(2005))

Understanding of Science Textbooks

By Taking An Exam

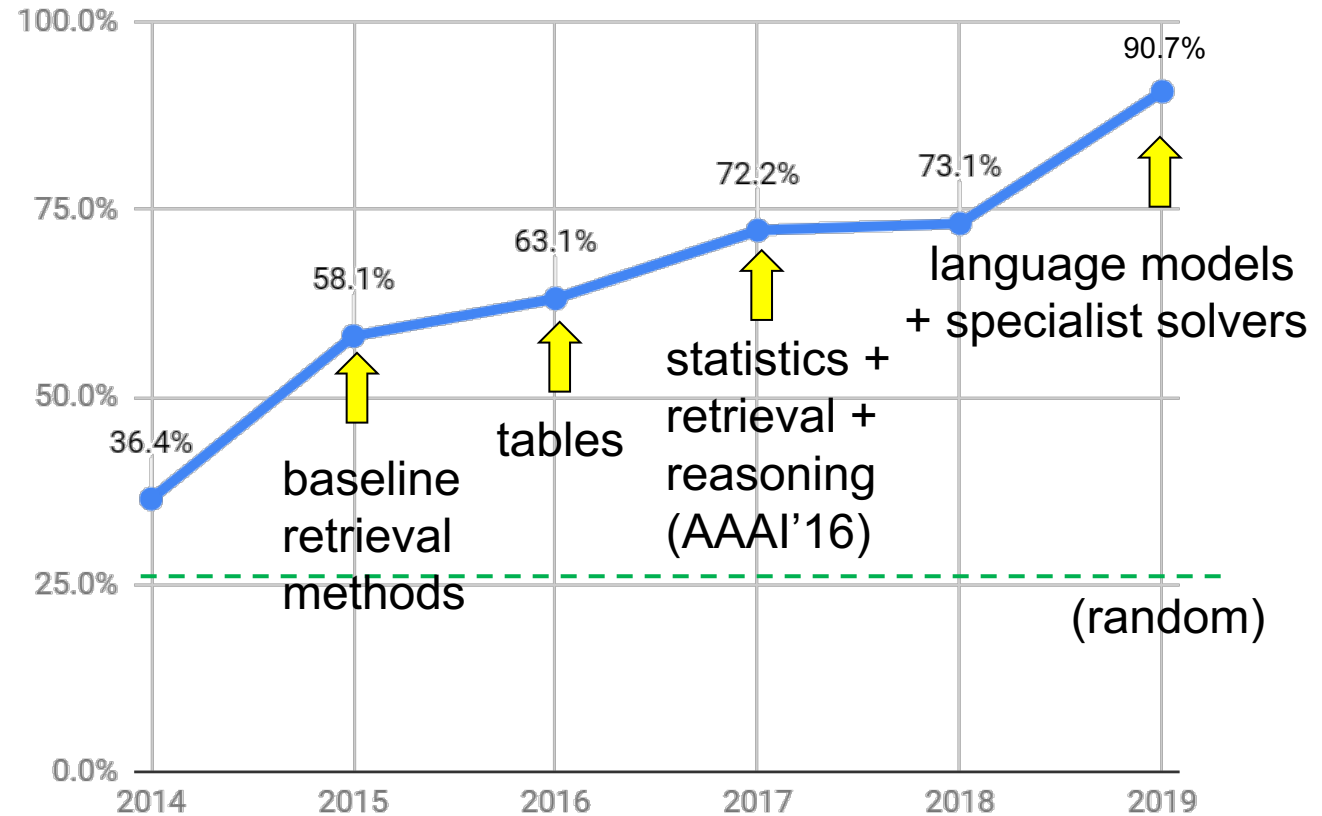
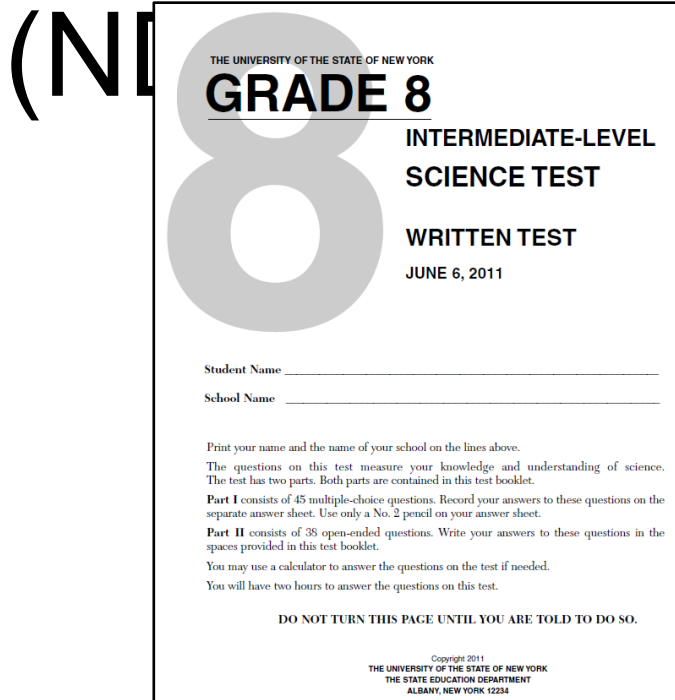
- The Challenge to demonstrate Understanding of Science Textbooks by taking an Exam was successfully demonstrated recently in 2019.
<https://www.wired.com/2016/02/the-best-ai-still-flunks-8th-grade-science/> and <http://bit.ly/aristo90>.
- Starting from a failing performance in the 8th Grade NY Regents Science Exam in 2016, Peter Clark, Oren Etzioni and team at Allen Institute for AI developed a system that answered over 90% of the questions correctly.

Understanding of Science Textbooks

By Taking An Exam

- ‘F’ to ‘A’ on the N.Y. Regents Science Exams: 2016 to 2019
 - Information retrieval methods 58.1%
 - IR Solver: question along with an answer option is explicitly stated in the corpus
 - PMI solver uses pointwise mutual information to measure the strength of the associations between parts of q and parts of a_i
 - ACME (Abstract-Concrete Mapping Engine) searches for a cohesive link between a question q and candidate answer a_i using a set of 5000 scientific terms in a term bank.
 - *Plus* Reasoning Methods 72.2%
 - The **Tuple Inference Solver** retrieves tuples relevant to the question, and constructs a support graph for each answer option
 - **Multee** retrieves potentially relevant sentences, then for each answer option in turn, assesses the degree to which each sentence entails that answer
 - Given a qualitative relationship (How does one increase/decrease affect another?), the **Qualitative Reasoning Solver** retrieves a relevant qualitative rule from a large database
 - *Plus* Large-Scale Language Model Methods 90.7%
 - Use of Context for Ambiguity Resolution:
 - *Banking on you to be at the Deutsche Bank by the River Bank*

Progression on NY Regents 8th Grade



(hidden test set, questions as written, NDMC, 5 years/119 qns)

21st Century Grand Challenges in AI

The Unfinished Agenda

21st Century Grand Challenges in AI

The Unfinished Agenda

- Any Language to Any Language Translation among the top 100 languages with less than 5% error and
- Any Spoken Language to Any Spoken Language (Speech To Speech) Translation among the top 100 languages with less than 5% error
- Summarization of Media (Books, Talks, Music and Movies)
- Encyclopedia on Demand
- Remote Repair in Space
- Self-Reproducing Machinery and Robots

21st Century Grand Challenges in AI

The Unfinished Agenda

- **Cognition Amplifiers:** Intelligent Agents that Help Humans to Do More Work in Less time.
 - Always On, Always Working, and Always Learning
 - Anticipate What You Want To Do And Help You To Do It
 - Help You To Do Tasks Faster and With Less Effort and
 - Help You To Do a Days Wok in an Hour
- **Guardian Angels:** Intelligent Agents that Enable Humans to Do Tasks They Cannot Now Do, Leading to Super Human AI
 - Always On, Always Working, Always Learning
 - **GA of Rights:** Provide the Right Information to the Right People at the Right Time in the Right Language at the Right Level of Detail
 - **GA of Safety:** Discover and Warn Humans About Unanticipated Events Impacting Safety, Security, and Happiness

In Conclusion...

- Grand Challenge Problems Usually Requires Major Breakthroughs and Fundamental Advances in AI and Other Areas of Computer Science and Technology.
- Adding a Prize and Duration Constraints Leads To Faster Progress Towards The Goal

Backup Slides

Understanding of Science Textbooks

By Taking An Exam

'Infections may be caused by (1) mutations (2) microorganisms [correct] (3) toxic substances (4) climate changes

as the corpus contains the sentence “Products contaminated with microorganisms may cause infection.” (for the **IR solver**), as well as many other sentences mentioning both “infection” and “microorganisms” together (hence they are highly correlated, for the **PMI solver**), and both words are strongly correlated with the term “microorganism” (**ACME**).