Computers Play Chess, Computers Play Go...Humans Play Dungeons & Dragons

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In July 2006, one of us (Hendler) was the editor in chief of IEEE Intelligent Systems and wrote an editorial celebrating the 50th anniversary of the famous Dartmouth summer school, entitled “Computers Play Chess: Humans Play Go.” The central thesis was that, while computers are capable of massive computation and rapid processing of complex data on scales that leave human brains floundering, they really aren’t very good at the abstract, intuitive, pattern-matching side of intelligence, the forte of human reasoning. The article talked about some of the complexities of Go as they related to these issues and suggested that it would be a long time before computers could handle that level of abstract pattern recognition. The challenge to AI research was posed: How could we get a computer to play Go?

Today, not quite 10 years since that editorial was published, an AI system has successfully beaten one of the top human Go players. AlphaGo, a system developed by a team at the Google-owned company DeepMind, demonstrated that deep-learning techniques, coupled with reinforcement learning and Monte Carlo simulation, and running with the massive computer power available today, could play Go at a human level. In March, it beat Lee Sedol, the fourth best human player, four wins to one in a standard five-game Go tournament. It’s official: computers now play Go. (In AI, 10 years is a long time, but the aforementioned editorial implied it would take much longer than that.)

This isn’t the first time this decade that humans’ game-playing prowess has been challenged. In 2011, IBM’s Watson program, designed from the ground up to handle extremely complex and sometimes contradictory pieces of general knowledge, not only played a game that had until then been seen as “humans only” but resoundingly beat its two human competitors, the best of the best, at the language-based trivia game.
Jeopardy! Watson used a combination of techniques and a novel architecture to “connect the dots” between hints in the clues and a wide range of textual sources that had been made available to the computer. (An entire issue of IBM Journal of Research and Development [May/June 2013] focused on explaining the basics of Watson.) Summing up some of its features, Watson was essentially a memory-based reasoner that made use of a large number of separate heuristic techniques (annotators) trained by a learning algorithm about which techniques to apply when. Watson, thus, was essentially a demonstration of a cognitive computing system that demonstrated the power of a combination of weak methods advocated by Herb Simon and Allan Newell in the early days of the AI field and the “society of mind” approach advocated by Marvin Minsky in the 1980s.

What can we take away from the fact that Jeopardy! and Go, bastions of human “superiority” in the face of ever-encroaching AI ability, have fallen? Should we, as AI researchers, kvell over our recent successes? Can we, as some seem to think, believe we’re now on the threshold of superhuman AIs that could threaten humanity’s existence?

Clearly, there are ethical dimensions our field must consider. In recent times, a steady stream of articles have examined the theme of AI systems—robots, in particular—challenging humans in the job market, with administrative and production jobs being the most under threat. In the US, President Obama’s white house sounded a cautionary note in 2016 about the large number of people who could be put out of work by robots and AI in the coming decade and asking for an investment in education and training to make sure we won’t end up with nearly an entire generation out of work.

While we must consider these issues, it’s also clear that AI still has a long way to go. For example, in the automotive industry, a field where automation has long been embraced, we see something of a countertrend emerging. Specifically, the massive variation of customization options for the Mercedes S-Class has overwhelmed the robots, forcing the company to hire some humans to do the job for them.

It’s telling that the reason for the company’s return to human labor is that robots weren’t able to cope with the complexity of the situation in the plant—programming all possible combinations was beyond current capability—and even with new learning technologies, people are, at least for now, the cheaper alternative. The flexibility and adaptability of the human brain—it’s ability to learn to cope with new situations on the fly and, in doing so, make intuitive leaps that apparently defy logical explanation—are the reasons why. Even AlphaGo, using DeepMind’s deep-learning-based system, is stuck doing the one thing it was created to do: play Go. Thus, the dream of many (and the nightmare of some), a generalized AI that can transfer its knowledge across domains, remains a challenge for AI. “We’ve no idea how to do that,” Demis Hassabis, co-founder of Google DeepMind, admits. For all its power, for all its ability to be trained to detect patterns in complex sources, deep learning still doesn’t give AI the ability to reason in differing contexts or to apply appropriate skills at appropriate times; the “metareasoning” required in many situations is still beyond what today’s AI can handle. (Of course, one human and a team of robots still represent fewer jobs than a team of humans, so the social problem remains, even as the AI challenge is ongoing.)

Going beyond Go
Winning Jeopardy! was a tour de force for question answering, but Go is more typical of the sorts of games that AI systems have been attacking for much longer. Thus, beating a top human player at Go is clearly a major milestone in AI. The complexity of the game, the size of its search space, the temporal nature of the emerging patterns, and the subtlety of board evaluation necessary to win at Go have kept it on the forefront of AI research for many years.

Go is, without a doubt, an extremely complex and richly subtle game. Even so, it’s of the same type of game as chess: a zero-sum, deterministic, sequential two-player game of perfect information. In other words, precisely the kind of game at which computers excel. Unless the game ends in a draw, there’s always one winner and one loser, players move in turn so there are no issues of preemption, and, except for the psychology of one’s opponent, nothing about the state of the game is concealed at any time. It’s as close to an ideal game as a mathematician, logician, or AI researcher could hope for.
However, some games don’t fall into this particular subtype—they aren’t nearly as clear-cut. Some of the variants of games that still challenge AI have features such as

- permitting more than two players playing individually or in teams (in the latter case, team psychology can require communication through rules that aren’t encoded in a hard and fast way, such as bidding in the card game bridge);
- employing, requiring, or relying on the concealment of information to greater or lesser degrees (Mafia, Risk, Battlestar Galactica);
- randomized or player-chosen starting positions (Arimaa), or boards whose configuration is determined on a game-by-game basis (Settlers of Catan) or can change during play (Infinite City); and
- rules that can change during play (this is usually within a predefined framework, although some modern games’ rules might not exist at all, such as Mornington Crescent).

Some games bring together many of these different aspects of gameplay and require the adaptability, flexibility, intuition, and creativity of a human to play them well. Perhaps the best known of these is Dungeons & Dragons, a game that’s played against the backdrop of a complex combination of rules and imagination.

Attacking Dungeons & Dragons

Dungeons & Dragons is a role-playing game set in a realm of fantasy, monsters, magic, and high and low adventure. Players take the roles of characters that they create to explore this strange world, choosing the type of character from a list including rogues, thieves, and wizards, and rolling dice to get various levels of strength, wisdom, and other talents.

In addition to the players, there’s an additional role in the game: the Dungeon Master (DM). The DM is a combination of manager, director, scriptwriter, knowledge base, and judge whose ruling truly is law. As the players’ characters navigate the world, it’s the DM who manages the plot, answers questions, acts for the entities the characters encounter whether good or evil, and determines the difficulty of tasks and the richness or paucity of players’ rewards. DMs must also manage the strands of the story through which the players are moving by pruning, adding, and inventing as required. Without a DM, there’s no game.

The setting of Dungeons & Dragons has evolved over the 40 years since its creation. Every so often, a new edition is released, providing core knowledge in the form of DM and player handbooks and steadily expanding the base with manuals on monsters, dungeon creation, treasure, new continents, and other planes of existence. The world the DM can define is complex, rich, and richly inventive. Although it’s constrained by the base rules laid down in the handbooks, there’s much latitude for creativity and creative interpretation, a fact rarely overlooked by the either players or the DM.

During a game, the DM keeps track of the scene and monitors the state of the world and the plot, reporting back to players the outcome of their actions and determining what happens next (see Figure 1). In the following (simplified) fragment, three players are exploring a dungeon:

DM: You’ve come to a T-junction. Corridors head off to your left and right, and there’s a door in front of you. What do you want to do now?
Fighter: I kick the door to knock it down.  
DM: Okay, you kick it down! And you barely even feel it! The door’s hinges were rotten, too, and you kicked so hard you stumble into the room. But as you do, you feel an oppressive presence, as though something truly evil was here. For a moment, you think you saw an old friend, but your will is strong enough that you realize it isn’t: there’s a thin humanoid corpse shambling toward you, its arms outstretched.

Rogue: Dungeoneering check, I want to see if I can work out what it is. (Rolls dice and gets a high score.)

DM (responding to the high roll): You’re pretty sure this is a wight. You remember hearing about them being buried as guardian servants to liches, and this is a lich tomb.

Ranger: A wight is classed as undead, right?
DM: Yes.

Fighter: So my normal sword won’t do much.
DM: Not against undead. Half-damage.
Rogue: Abh, but silver often affects the undead, so maybe my silver dagger will do the trick!

Ranger: It will do extra damage on top of the normal.
DM: But you have to hit it first...
Rogue: Good job I’m quick and fast, then!

Fighter, Ranger, back me up. I’m going in!

At Rensselaer, we’ve been thinking about the Dungeons & Dragons challenge for several years. We rapidly rejected many traditional approaches to game play and began exploring how a cognitive computing architecture, such as the one underlying IBM’s Watson, could be brought to bear on a game like this. We rapidly realized that this was a long-term, complex challenge, and that first we needed to explore whether cognitive computing could indeed be extended to playing games as an alternative to traditional game-tree-based approaches. We’re a long way from Dungeons & Dragons, but one of us (Ellis) recently published a thesis that shows how complex games can indeed be attacked using a Watson-inspired approach.10

So as we AI scientists begin to accept the new capabilities being offered by tools such as deep learning and cognitive computing systems, what are the next real challenges for playing games beyond Go? Just as Go outlined a research agenda that challenged us to look at temporal pattern recognition in new ways, thinking about games such as Dungeons & Dragons will encourage AI researchers to explore new directions in cognitive computing research. Attacking a game like this will push commonsense reasoning (in artificial worlds, which could be an interesting challenge in its own right), language, and storytelling, particularly as it relates to problem solving and creativity.

If we drew a map of the AI field today, we might find a demarcation line around the area claimed by games such as chess, Go, and even Jeopardy!. And what would we write in the space beyond? Our best bet might be to do as the early mapmakers did and write in large, determined print, the immortal words HERE BE DRAGONS. For, as in the days when sailors bravely set off to plumb the seas where the unknown was known to lurk, the really exciting challenges to AI, in game playing and beyond, remain to be explored.

References