CNA
ANALYSIS & SOLUTIONS

AI, ROBOTS, AND SWARMS: OPPORTUNITIES AND CHALLENGES

A remarkable event took place in the early part of 2016: an artificial intelligence (AI) defeated an 18-time world champion in the game of Go, a game that is so much more "complex" than chess that, prior to this event, most AI experts believed that it could not be done for another 15-20 years. A notable number of groundbreaking AI-related technology announcements and/or demonstrations have been reported just since then:

GROUNDBREAKING AI-RELATED TECHNOLOGY

- AI learned—*on its own*—where to find the information it needs to accomplish a specific task.
- AI predicted the immediate future (by generating a short video clip) by *examining a single photograph* (and is also able to predict the future from studying video frames).
- AI automatically inferred the rules that govern the behavior of individual robots within a robotic swarm *simply by watching.*
- AI learned to navigate the London Underground *by itself* (by consulting its own acquired memories and experiences, much like a human brain).
- AI speech recognition reached human parity in conversational speech.
- An AI communication system *invented its own encryption scheme,* without being taught specific cryptographic algorithms (and without revealing to researchers how its method works).
- An AI translation algorithm invented its own "interlingua" language to more effectively translate between any two languages (*without being taught to do so by humans)*.
- An AI system *interacted with its environment (*via virtual actuators) to learn and solve problems in the same way that a human child does.
- AI poker-playing program defeated some of the world's best human poker players during a three-week-long tournament.
- An AI-based medical diagnosis system at the Houston Methodist Research Institute in Texas achieved 99% accuracy in reviewing millions of mammograms (at a rate 30x faster than humans).

These and other recent similar breakthroughs (e.g., IBM's Watson's defeat of the two highest ranked *Jeopardy*! players of all time in 2011) are notable for several reasons.

First, they collectively provide evidence that we, as a species, have already crossed over into an era in which seeing AI outperform humans—at least for specific tasks—is *almost routine* (perhaps in the same way that landing on the moon was "almost" routine after the first few Apollo missions).

Second, they offer a glimpse of how *different* AI is from human intelligence, and how inaccessible its "thinking" is to outside probes.

And third, they demonstrate the power of AI to surprise us (including AI system developers, who nowadays are closer in spirit to "data collectors" and "trainers" than to traditional programmers)—i.e., AI, at its core, is fundamentally unpredictable. In the second game of the Go match between the AI that defeated an 18-time world champion in Go, the AI made a move so surprising that the human champion had to leave the room for 15 minutes to recover his composure.

The breakthroughs listed above are also notable for a fourth—more subtle—reason. Namely, they portend a set of deep conceptual and technical challenges that the Department of Defense (DoD) must face, now and in the foreseeable future, as it embraces AI-, robot-, and swarm-related technologies to enhance (and weaponize) its fleet of unmanned systems with higher levels of autonomy. The subtlety lies in unraveling the true meaning of the deceptively "obvious" word, autonomy; indeed, as of this writing, there is no universally accepted definition (much less a well-defined framework for discussion).

As DOD prepares to cross-over into the "Robotic Age" (spurred on by the recent "Third Offset Strategy" innovation initiative), it faces four key technical gaps:

- **Gap 1**: A fundamental mismatch between the accelerating pace of technology innovation in commercial and academic research communities, and the timescales and assumptions underlying DOD's existing acquisition process.
- **Gap 2:** An underappreciation of the unpredictable nature of autonomous systems, particularly when operating in dynamic environments, and in concert with other autonomous systems.
- **Gap 3**: A lack of a universally agreed upon conceptual framework for autonomy that can be used both to anchor theoretical discussions and to serve as a frame-of-reference for understanding how theory, design, implementation, testing, and operations are all interrelated.
- **Gap 4:** A general disconnect between system design and the development of concepts of operations (CONOPS).

RECOMMENDATIONS

While not even AI experts can predict how AI will evolve in even the near-term future (much less project its possible course over 10 or more years, or predict AI's impact on the development of military autonomous systems), it is still possible to anticipate many of the key conceptual, technical, and operational challenges that DOD will face in the coming years as it increasingly turns to and more deeply embraces AI-based technologies. From an operational analysis standpoint, these challenges can also be used to help shape future studies. In particular, we recommend DoD invest in research and analysis that accomplish the following:

- Help establish dialog between commercial research and development and DOD.
- Develop an operationally meaningful conceptual framework for autonomy.
- Develop measures of effectiveness (MOEs) and measures of performance (MOP) for autonomous systems.
- Use nontraditional modeling and simulation (M&S) techniques to help mitigate AI/autonomy-related dimensions of uncertainty.
- Apply wargaming techniques to help develop new CONOPS.
- Develop new T&E/V&V standards and practices appropriate for the unique challenges of accrediting autonomous systems.
- Assess the data requirements for developing machine-learning-based autonomy.
- Explore basic human-machine collaboration and interaction issues.
- Explore the challenges of force-integration of increasingly autonomous systems.
- Explore the cyber implications of autonomous systems.
- Explore operational implications of ethical concerns over the use of lethal autonomous weapon.
- Examine the full spectrum of possible applications of expected near- to mid-term AI advances (not just those that pertain directly to the development of autonomous weapon systems).

https://www.cna.org/news/releases/2017-06-07

ABOUT CNA CORPORATION

CNA is a not-for-profit research and analysis organization with 75 years of experience providing government agencies with data-driven insights and real-world, actionable solutions grounded in our direct experience with the operational environments where these solutions are applied. CNA developed the foundational techniques for operational analysis to address complex challenges facing government programs. We have applied these techniques successfully in areas ranging from defense to aviation, education, justice, and homeland security.

For more information please contact:
Dr. Larry Lewis, Director, Center for Autonomy and AI
703-824-2020
Lewisl@cna.org

Dr. Andy Ilachinski, Principal Research Scientist
703-824-2045
Ilanchina@cna.org