International Journal on Artificial Intelligence Tools
Vol. 23, No. 6 (2014) 1460024 (7 pages)

DOI: 10.1142/S0218213014600240

# Artificial Intelligence Basic Research Directions at the U.S. Air Force*

Peter Z. Revesz
*Department of Computer Science, University of Nebraska-Lincoln*
*348 Avery Hall, Lincoln, NE 68588-0115, USA*
*revesz@cse.unl.edu*

Received 1 September 2014
Accepted 26 September 2014
Published 26 December 2014

This survey gives a review of recent artificial intelligence-related research directions that are considered priority areas by the U.S. Air Force and targeted for basic research funding by Air Force Office of Scientific Research. These research areas include space situational awareness, autonomous systems, sensing and information fusion, surveillance, navigation, robust decision making, human-computer interfaces, and computational and machine intelligence. The possible contributions of artificial intelligence to these topics will be described and illustrated whenever possible by recently awarded grants.

*Keywords*: Artificial intelligence; autonomous systems; information fusion; navigation; surveillance; unmanned aerial vehicles.

## 1. Introduction

Each year the Department of Defense (DOD) spends about two billion dollars on basic research, primarily through the following top five offices in terms of decreasing budgets for basic research: the Office of Naval Research (ONR), the Air Force Office of Scientific Research (AFOSR), the Army Research Office (ARO), the Defense Advanced Research Projects Agency (DARPA), and the Defense Threat Reduction Agency (DTRA). These offices fund an increasingly larger number of artificial intelligence projects. However, neither the DOD nor these offices have a clear budget item for "artificial intelligence." The National Science Foundation (NSF) is relatively easy to navigate for academics because NSF is organized into subject areas similar to how universities are organized into colleges and departments. In contrast, the DOD funding offices are organized along various missions.

*This work was originally presented while the author was an *AAAS Science and Technology Policy Fellow* at the U.S. Air Force Office of Scientific Research. The views expressed in this paper are those of the author and do not necessarily reflect the views of the US federal government or its agencies.

For example, to better understand the organization of the Air Force Office of Scientific Research, it has to be recognized that it is only one of the nine Air Force Research Laboratories (AFRLs), which are: (1) Air Force Office of Scientific Research (AFOSR), (2) Air Vehicles and Propulsion, (3) Directed Energy, (4) Effectiveness, (5) Information, (6) Materials and Manufacturing, (7) Munitions, (8) Sensors and (9) Space Vehicles. The Air Force Office of Scientific Research (AFOSR) is the only one of the nine Air Force Research Laboratories and the only office within the Air Force that is charged with overseeing basic research. The mission of AFOSR is to discover, shape and champion basic science of Air Force interest through collaboration with the scientific community. AFOSR accomplishes these by funding basic research through grants and contracts, supporting technical conferences and workshops, and providing assistance for scientists to engage the other Air Force Research Laboratories, usually by funding short-term visits.

This survey is organized as follows. Section 2 describes the AFOSR research directorates and special programs and their interests in artificial intelligence basic research. Section 3 reviews some special educational and outreach programs. Finally, Section 4 provides some remarks on future prospects.

## 2. Directorates and Special Programs with Artificial Intelligence Interests

The Air Force Office of Scientific Research has six directorates as shown in Figure 1. As can be seen, no directorate name mentions explicitly "artificial intelligence." Hence a potential principal investigator needs to look carefully at the directories to find out where his or her research fits in best. The most interdisciplinary office is the International Office, where I served as a Program Officer and an AAAS Science and Technology Policy Fellow from 2012 to 2014 and used my database expertise[1] to conduct several

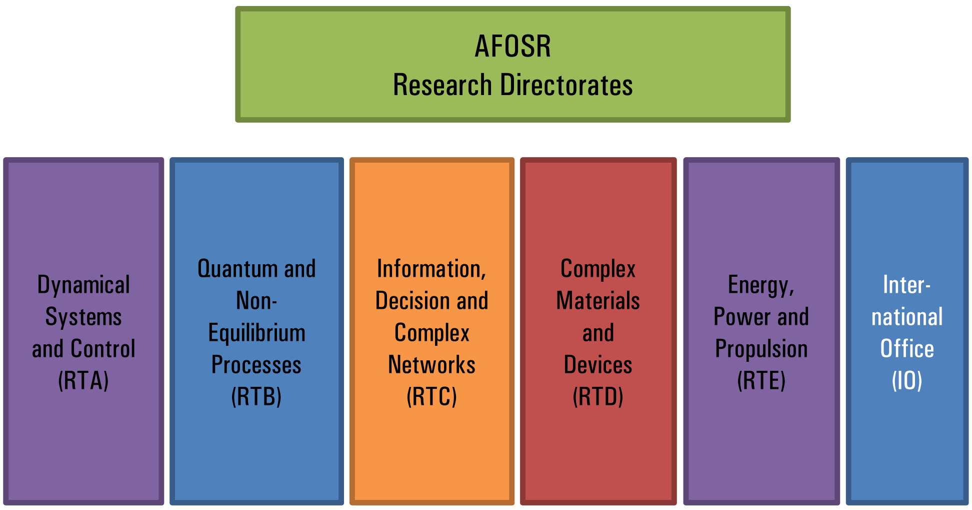


Fig. 1. The organization of the Air Force Office of Scientific Research.

studies regarding predicting emerging research leaders[2] and testing whether there is any unexpected regional bias in research funding.[3] The International Office often facilitates interaction among domestic and foreign researchers, and many projects are co-funded by the International Office and one of the other AFOSR directorates. Hence the possibility of international collaboration also should be considered.

AFOSR International Offices are located in Arlington, VA, London, UK, Santiago, Chile and Tokyo, Japan. Since the time of its founding in 1951, AFOSR funded over 74 Nobel Prize winners, including Francois Englert and Peter Higgs, the winners of the Nobel Prize in Physics in 2013. Within computer science and artificial intelligence, AFOSR also funded several Turing Awardees. In particular, AFOSR funded Douglas Engelbart's breakthrough research on "Augmenting Human Intellect" which proposed the computer mouse, and Edward Feigenbaum's seminal research expert systems.

Today's AFOSR continues to fund novel research in artificial intelligence in several areas, as shown by the following examples, taken from the AFOSR Broad Agency Announcement (BAA)[4] and concrete projects cited by various program officers in their annual reports. Each AFOSR Program Officer gives a public review of their programs, usually in March. These Spring Reviews are publicly available[5] and contain brief example funded projects that could be further inspiration for potential grant proposers. Prospective principal investigators are welcome to contact the AFOSR Program Officers whose interests they think overlap with theirs.

### 2.1. *Dynamical systems and control*

Dynamical Systems and Control (RTA): The AFOSR BAA describes the RTA directorate as being interested in "Optimization and Discrete Mathematics" and "Sensory Information Systems" among other topics. The BAA also mentions for "Optimization and Discrete Mathematics" the following details: "Areas of interest include resource allocation, planning, logistics, engineering design and scheduling. Increasingly, the decision models will address problems that arise in the design, management and defense of complex networks, in robust decision making, in performance, operational efficiency, and optimal control of dynamical systems, and in artificial intelligence and information technology applications." Here as well as in later quotations the italics are added to the original BAA text to emphasize the artificial intelligence connections.

For the "Sensory Information Systems," the BAA elaborates that: "This program coordinates multi-disciplinary experimental research with mathematical, neuromorphic, and computational modeling to develop the basic scientific foundation to understand and emulate sensory information systems. Emphasis is on (a) acoustic information analysis, especially in relation to human auditory perception, and (b) sensory and sensorimotor systems that enable 3D airborne navigation and control of natural flight, e.g., in insects or bats, especially in relation to capabilities of autonomous biological systems not yet emulated in engineered flight."

Sample AI projects in this area include "Optimal learning and approximate dynamic programming" by Warren B. Powell, PI, Princeton University, and "Optimal persistent surveillance through cooperative teams" by C. G. Cassandras, PI, Boston University. The former project aims to create a single general-purpose tool that will solve sequential decision problems, and the second projects at optimal movement of sensors to survey an environment that is too large to be covered by a set of stationary sensors.

### 2.2. *Information, decision and complex networks*

Information, Decision and Complex Networks (RTC): This directorate is interested in at least four topics that are AI-related, namely the following: "Computational and Machine Intelligence", "Dynamic Data Driven Applications Systems (DDDAS)", "Mathematical and Computational Cognition" and "Robust Decision Making in Human-System Interface." The BAA mentions that the "Computational and Machine Intelligence" program supports "innovative basic research on fundamental principles and methodologies of computational intelligence necessary to create robust intelligent autonomous systems."

The "Dynamic Data Driven Applications Systems (DDDAS)" program is interested in "autonomous systems (e.g. swarms of unmanned or remotely piloted vehicles); autonomous mission planning; complex adaptive systems with resilient autonomy; collaborative/cooperative control; autonomous reasoning and learning; sensor-based processing; ad-hoc, agile networks; multi-scale simulation technologies and coupled multi-physics simulations; decision support systems with the accuracy of full scale models (e.g. high-performance aircraft health monitoring, materials stresses and degradation); embedded diagnostics and V&V for complex adaptive systems; automated software generation; cognitive modeling; cognitive performance augmentation; human-machine interfaces.

The "Mathematical and Computational Cognition" program is interested in formal models of human cognition. In particular, "the program welcomes work that (1) creates a statistical and machine learning framework that semi-autonomously integrates model development, evaluation, selection, and revision; (2) bridges the gap between the fields of cognitive modeling and artificial general intelligence by simultaneously emphasizing important improvements to functionality and also explanatory evaluation against specific empirical results.

Finally, the "Robust Decision Making in Human-System Interface" program is interested in projects that "produce cognitive systems that are capable of communicating with humans in a natural manner that builds trust, are proficient at condensing intensive streams of sensory data into useful conceptual information in an efficient, real-time manner, and are competent at making rapid, adaptive, and robust prescriptions for prediction, inference, decision, and planning."

Sample AI projects in this area include "Neurocognitive information processing" by A. Lazar, PI, Columbia University, "Robust planning of autonomous systems" by B. Williams, PI, MIT, "Robust intelligence in complex problem solving" by L. Kaelbling, PI, MIT, and "Application of DDDAS principles to command, control and mission planning for UAV swarms" by M. B. Blake *et al.*, PIs, University of Notre Dame. The first project aims to build a brain-inspired information-processing machine. In particular, it tries to reverse engineer insect flight control in order to design nano-sized air vehicles.

The second project develops a "calculus of risk" that enables autonomous systems to operate within specified risk bounds. The third project integrates logical and probabilistic reasoning to allow autonomous agents to plan long-duration tasks in complex and uncertain environments. The fourth sample project considers cooperative sensing by a large set of UAVs in coordination with other aircraft and ground resources that control the overall mission.

### 2.3. *Complex materials and devices*

Complex Materials and Devices (RTD): This directorate supports "Adaptive Multimode Sensing" among other topics. The BAA mentions that: "future U.S. Air Force universal situational awareness needs include near real-time detection, tracking, and identification of low-contrast and complex targets in broad areas and highly-cluttered dynamic environments, integrated with near real-time communication of resultant actionable data to battlefield commanders. Resulting near instantaneous sensor-to-shooter capability will require remote and autonomous real-time-closed-loop-controlled target spectra sensing, data fusion and processing, knowledge objective exploitation, and communications." Energy-efficiency is an important consideration in UAV-related projects in order to reduce the size of UAVs and enable longer-term use. Increased energy-efficiency could be achieved by a combination of improved materials and devices and energy-aware optimization algorithms. A sample project that is focused on the algorithmic side is "Energy-aware aerial systems for persistent sampling and surveillance," which is a collaborative project by PIs from the University of Colorado-Boulder, the University of Nebraska-Lincoln and Texas Tech University.

### 2.4. *Multidisciplinary research program of the university research initiative*

Multidisciplinary Research Program of the University Research Initiative (MURI): The MURI program is another program listed by the BAA that can be considered by AI researchers. The MURI program supports basic research in the science and engineering areas intersecting more than one traditional discipline. The program is focused on multidisciplinary team efforts. Instead of being permanent, the MURI topics change each year. For example, the recent MURI topic, "Control of Information Collection and Fusion," had a strong AI-component and led to funding of many AI-related projects. Two sample projects are "Consistent vision-aided inertial navigation system" by S. Roumeliotis *et al.*, PIs, University of Minnesota, and "Multi-robot team to find targets and avoid hazardous areas" by V. Kumar *et al.*, PI, University of Pennsylvania. The first project aims at inertial navigation, which is important because GPS-based systems are easily disabled during war fighting, while the second project is a robotics project that is focused on sensing and multi-target detection.

### 2.5. *Basic research initiatives*

Basic Research Initiatives (BRIs): The basic research initiatives are other occasional topics and programs listed in the BAA. These exploratory topics also include some dimensions that are not normally considered by the AFOSR directorates. Recent BRI topics included "Perceptual and Social Cues in Human-like Robotic Interactions." As the BAA pointed out: "Future U.S. Air Force operations will heavily rely on autonomous systems.

One important class of such systems includes those with physical effectors and mobility that in some ways emulate human abilities, i.e. robots. In order to optimize performance and minimize errors in the eventual use of robots in U.S. Air Force applications, research is needed to better understand the dynamics of human interaction with these devices." Successful grant proposals to such initiatives usually bring in collaborators from new areas. For example, in this case, artificial intelligence researchers could collaborate with computer science, psychology and other researchers who study human-computer interaction and human trust.

## 3. Education and Outreach Programs

The Air Force Office of Scientific Research provides a large number of education and outreach programs that provide opportunities beyond the traditional research grants. These programs include:

(1) Air Force Visiting Scientist Program
(2) Awards to Stimulate and Support Undergraduate Research Experiences
(3) Engineer and Scientist Exchange Program
(4) National Defense Science and Engineering Graduate Fellowship Program
(5) US Air Force/National Research Council Resident Research Associate Program
(6) United States Air Force-Summer Faculty Fellowship Program
(7) Window on Science (WOS) Program
(8) Windows on the World (WOW) Program
(9) Young Investigator Research Program (YIP)
(10) Presidential Early Career Award in Science and Engineering (PECASE)

Graduate students can apply for a graduate fellowship (4). Junior artificial intelligence faculty members are encouraged to apply for the Young Investigator Research and the Presidential Early Career Award in Science and Engineering programs (9 and 10). Senior as well as junior artificial intelligence faculty members may consider visiting for longer or shorter terms one of the Air Force Research Laboratories mentioned in Section 1 (programs 1, 3 and 6). These visits could enable some researchers to help move basic research ideas into exploratory or advanced development. The AFRLs are some of the best-equipped laboratories in the world in their specialty areas. However, visiting most of these laboratories requires a U.S. citizenship and a security clearance that needs to be initiated well in advance.

## 4. Future Prospects

Several of the topics considered by AFOSR are also of interest to other DOD funding offices. In fact, the Assistant Secretary of Defense for Research and Engineering, ASD (R&E), identified six basic research areas as general thrusts throughout the DOD, as reviewed in the recent video.[6] Out of the six areas, two areas could be particularly interesting to artificial intelligence researchers, namely, "Cognitive Neurosciences" and "Computational Modeling of Human and Social Behavior." These areas could involve many artificial intelligence researchers who are interested in building brain-inspired robots and improving the interaction between war-fighting robots and humans. The computational modeling of social behavior area could also include research on understanding human conflicts that lead to war and terrorism. Armed with a deeper understanding of the development of human conflicts and methods of settling conflicts,[7] in the future we may fight wars by preventing their outbreak.

## References

1. P. Z. Revesz, *Introduction to Databases: From Biological to Spatio-Temporal* (Springer-Verlag, New York, 2010).
2. P. Z. Revesz, A method for predicting the citations to the scientific publications of individual researchers, *Proc. 18th Int. Database Engineering and Applications Symposium* (ACM Press), (Porto, Portugal, July 2014), pp. 9–18.
3. P. Z. Revesz, Testing scientific research grant funding fairness, *Proc. 5th Int. Conf. on Computing for Geospatial Research and Application* (IEEE Press), (Washington DC, USA, August 2014), pp. 93–94.
4. AFOSR Broad Agency Announcement (2014), http://www.wpafb.af.mil/library/factsheets/factsheet.asp?id=8127
5. AFOSR Spring Reviews (2013). https://community.apan.org/afosr/spring_review_2013/m/default.aspx
6. T. P. Russell, *Focus on the Future* (2013). http://afrl.dodlive.mil/2013/02/28/focus-on-the-future/
7. P. Z. Revesz, On the semantics of arbitration, *Int. Journal of Algebra and Computation* **7**(2) (1997) 133–160.