Worldwide AI

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Artificial Intelligence Research in Singapore: Assisting the Development of a Smart Nation

Artificial intelligence (AI) research in Singapore is focused on accelerating the country's development into a smart nation. Specifically, AI has been employed extensively in either augmenting the intelligence of humans or in developing automated methods and systems to improve quality of life in Singapore. AI research has been mainly conducted at research institutes (universities and labs), including the National University of Singapore (NUS), Nanyang Technological University (NTU), Singapore Management University (SMU), Singapore University of Technology and Design (SUTD), and the Agency for Science, Technology, and Research (A*STAR).

■ *In this column we summarize Singapore's major research efforts involving AI, which are mostly funded by government agencies and mainly conducted at the National University of Singapore, Nanyang Technological University, Singapore Management University, Singapore University of Technology and Design, and the Agency for Science, Technology, and Research. Our focus in this column is primarily limited to the efforts of Singapore to become a smart nation. The key areas of AI research summarized here include mobility, security, manufacturing, and health care.*

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Most AI research in Singapore is funded by government agencies, such as the National Research Foundation (NRF), the Ministry of Education (MOE), and the A*STAR Science and Engineering Research Council (SERC). In addition, there are also translational research projects that are funded by ministries (Ministry of Home Affairs and Ministry of Defense), defense research centers (Defense Science and Technology Agency [DSTA] and Defense Science Organization [DSO]) and also industry.

Historically, AI research in Singapore has been focused on applications to health care and robotics, with research directions focused on graphical models, neural networks, and fuzzy systems. AI research in Singapore is for the most part a phenomenon of the the last two decades. Owing to the focus on becoming a smart nation, Singapore has seen a surge in applications related to mobility, security, manufacturing, health, and sustainable, resilient systems. In this column, we primarily describe the research that has focused on assisting the development of a smart nation. While there are many other domains where researchers in Singapore are currently conducting AI research, we focus on the key areas of mobility, security, manufacturing, and health care.

Mobility

Due to limited land availability, Singapore has always been interested in developing efficient transportation models for people and freight. AI research in this domain has taken a number of interesting directions. The first of these is offline and online probabilistic machine-learning methods to model and predict (with confidence intervals) spatiotemporally varying mobility patterns, demands, and traffic flow. A second direction that has received significant interest is in devising active learning and sensing algorithms. Static traffic sensors or direct mobile probes are placed in a road network where they gather the most informative data and observations for learning a predictive model given a sampling budget. Another area of interest has been in building simulators at various levels of granularity to evaluate the impact of common control strategies and improve efficiency in mobility patterns on roads, attractions, and even large buildings. A fourth research focus is in developing offline and online decision models to support novel mobility concepts such as pervasive use of real-time information, mobility on demand, and sustainability. A fifth research direction has focused on harnessing and enhancing automated systems to

improve safety and efficiency (for example, intention-aware motion planning and pedestrian avoidance for driverless vehicles). A final research thread has focused on the optimal placement and pricing of public services such as EV charging stations to satisfy users and minimize traffic congestion.

Researchers at Singapore Management University, the National University of Singapore, and the National University of Singapore in collaboration with faculty at the Massachusetts Institute of Technology (MIT) have made significant contributions in methods and systems in the context of not only public transportation and mobility-on-demand systems, but also for private automobile, bicycle, and pedestrian traffic under the SMART-FM initiative.[1] In addition, some new initiatives on urban mobility at Singapore Management University have focused on crowd and freight management.[2]

Contributions addressing mobility issues have focused on machine learning, planning under uncertainty, robotics, game theory, and multiagent systems (including agent-based simulations).

Security

Given recent incidents around the world, security of people and cyber and physical infrastructure (for example, airports, ports) is of critical concern to most people. In Singapore, research in security has focused specifically on the problem of securing important targets given limited resources — a key constraint in most security problems. Specifically, the focus problems are (1) security in both cyber and physical space, especially for critical infrastructures (such as ports and airports) and endangered species; (2) interdiction of the illegal flow of drugs, weapons, and money; and (3) suppression of urban crime.

Computational game theory for security (also called security games) is a new research area that has attracted increasing attention recently. The research area is based on computational and behavioral game theory and incorporates elements of AI planning under uncertainty and machine learning. Various security games-based decision aids have been deployed for protecting ports, airports, metro trains, and wildlife.

Researchers from Nayang Technological University and Singapore Management University have done extensive work in the security game area, including designing algorithms for solving large-scale security games, handling significant adversarial uncertainty, and understanding spatiotemporal and coalitional dynamics. They have made contributions to different applications domains such as protecting public events (Yin, An, and Jain 2014), monitoring potential terrorists, protecting coral reef ecosystems, interdicting illegal network flow, patrolling for coast guard, and patrolling for securing rapid transit networks (Varakantham, Chuin, and Yuan 2013). They have also been involved in deploying the PAWS (protection assistant for wildlife security) system to protect wildlife in Southeast Asia.[3]

Recently, Singapore researchers have started to apply computational game theory and machine learning techniques to fight against cybercrimes such as spear phishing attack events (Yin, An, and Jain 2014), and different attacks on smart traffic control systems.

Manufacturing

Manufacturing has been identified as a key pillar of the Singapore economy. However, competition in manufacturing has increased dramatically across the entire Asia pacific region and the rest of the world. Therefore, it is not surprising that there is a growing demand for advanced information and communication technologies (ICT) to support massive transformation of various aspects of the entire manufacturing industry. This demand is reflected in the research, innovation, and enterprise (RIE) 2020 plan announced by the Singapore government. In the January 2016 announcement, the government proclaimed that 17 percent ($3.3 billion) of its entire $19 billion budget will be committed to research and development for advanced manufacturing and engineering (AME). The goal is to develop and strengthen technological capabilities to support continued growth and competitiveness of Singapore's manufacturing and engineering sectors. This, in turn, will achieve GDP growth, create good jobs for Singaporeans, and position the economy for the future.

Driven by the aforementioned industrial needs and government investment, some specific AI research focus areas include responsive supply chain, adaptive enterprise, and robust shop floor. The problems in these areas include the difficulty to accurately predict future demands, causing overstocking (responsive supply chain); multiple ad hoc changes in schedules causing nonoptimized resource allocation and inaccurate schedules (adaptive enterprise); and low overall equipment effectiveness due to high maintenance and setup time (robust shop floor). AI research that contributes to addressing these challenging problems includes machine learning and data analytics, agent-based simulation and optimization, verification, visualization, and sampling and fusion.

The Agency for Science, Technology and Research (A*STAR) is a primary driver of this type of research. A*STAR partners with local industries and collaborates with researchers at the National University of Singapore and Nanyang Technological University, as well as international experts. Specifically, they established the Advanced Remanufacturing and Technology Centre[4] — the first such center in Asia. The Singapore Institute of Manufacturing Technology and Nanyang Technological University set up the Joint Lab on Complex Systems to conduct research on

agent-based models for complex adaptive systems, large-scale multi-objective optimization, game theory for optimal solutions, heterogeneous data mining and machine learning, large-scale feature extraction and reduction.

Health Care

Providing smart health care is another area that receives significant interest among the researchers in Singapore. Specific research in this area has focused on multiple areas. Researchers have focused on developing graphical model–based methods to identify health state and design diagnostic tests for patients whose situation may deteriorate over time. There are also AI research efforts aimed at blocking the spread of communicative diseases through well-designed management guidelines. Another problem of interest has been in deciding on the placement and movement of emergency response vehicles to reduce response times in dealing with emergency incidents.

Finally, researchers have focused on building techniques at the intersection of artificial intelligence and operations research to design and schedule healthcare resources for efficient health care. Researchers at the National University of Singapore, the Singapore University of Technology and Design, and Singapore Management University have done extensive research in this area and are in the process of developing systems for specialized problems to improve efficiency of health care. AI contributions in addressing issues related to health care have focused on graphical models, machine learning, sequential decision-making under uncertainty, influence maximization, and operations research.

Conclusion

Because of focused funding for academic research as well as translational funding across most areas in AI that serve the building of a smart nation, Singapore has witnessed a surge in the number of research publications at top tier venues and also seen an increase in AI based translational projects, research centers, and startups.

Notes

1. See the Singapore MIT Alliance for Research and Technology (SMART) Centre on Future Urban Mobility (ares.lids.mit.edu/fm).

2. See the FUJITSU-SMU Urban Computing and Engineering Lab (unicen.smu.edu.sg).

3. A recent article on PAWS (PAWS — A Deployed Game-Theoretic Application to Combat Poaching) was published in the spring 2017 *AI Magazine*.

4. See the Advanced Remanufacturing and Technology Centre (www.a- star.edu.sg/artc).

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