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

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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 the following research institutes (universities and labs): National University of Singapore (NUS), Nanyang Technological University (NTU), Singapore Management University (SMU), Singapore University of Technology and Design (SUTD) and Agency for Science, Technology and Research (A*STAR).

Most of the AI research is funded by government agencies: National Research Foundation (NRF), Ministry of Education (MOE) and 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 was focused on applications to healthcare and robotics, with research directions focused on graphical models, neural networks and fuzzy systems. AI research in Singapore is for the most part a recent phenomenon (in the last 15-20 years). In recent years owing to the focus on smart nation, there has seen a surge in applications related to mobility, security, manufacturing, health and sustainable, resilient systems. In this document, we primarily describe this research that has focused on assisting the development of a smart nation.

While there are many other domains where researchers in Singapore are currently pursuing AI research, we focus on the following key areas.

Mobility

Due to limited land availability, the focus in Singapore has always been on efficient transportation models for people and freight. In Singapore, research in this space has focused on multiple interesting directions. First of these has focused on development of 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/sensing algorithms to place static traffic sensors or direct mobile probes in a road network to gather the most informative data/observations for learning a predictive model given a sampling budget. Another research thread of interest has been in building simulators at various levels of granularity to evaluate the impact of common control strategies to improve efficiency in mobility patterns on roads, attractions and even large buildings. A fourth thread of 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 (e.g., intention-aware motion planning and pedestrian avoidance for driverless vehicles). The final 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 SMU, NUS and NTU in collaboration with faculty at 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 SMU have focused on crowd and freight management (2).

Contributions in addressing these mobility issues have focused on following research areas of AI: machine learning, planning under uncertainty, robotics, game theory and multi-agent systems (including agent based simulations).

Security

Given the recent incidents around the world, security of people, cyber and physical infrastructure (e.g., airports, ports) is of critical concern. In Singapore, research in this space 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 (e.g., ports, 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, which has attracted increasing attention in the recent years. It 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 NTU and SMU 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 (3), monitoring potential terrorists, protecting coral reef ecosystems, interdicting illegal network flow, patrolling for coast guard and patrolling for securing rapid transit networks (5). They have also been involved in deploying the PAWS (Protection Assistant for Wildlife Security) system to protect wildlife in Southeast Asia.

Recently, Singapore researchers have started to apply computational game theory and machine learning techniques to fight against cybercrimes such as spear phishing attacks (3) and different attacks on smart traffic control systems.

Manufacturing

Manufacturing is identified to be a key pillar of the Singapore economy. However, the competition is heating up across the entire Asia pacific region and the rest of the world, at a tremendous pace. Therefore, it is not surprising that there is a growing demand for advanced information and communication technologies (ICT) to support massive transformation in various aspects of the entire manufacturing industry. This is also reflected in the Research, Innovation and Enterprise (RIE) 2020 plan announced by the Singapore government on January 2016 where 17% ($3.3 billion) of the whole budget ($19 billion) will be committed to the R&D 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, so as to achieve GDP growth, create good jobs for Singaporeans and position the economy for the future.

Driven by aforementioned industrial needs and government investment, some specific research focus areas and problems are identified as follows:

(1) Responsive Supply Chain: It is difficult to accurately predict future demands, causing overstocking;
(2) Adaptive Enterprise: Multiple ad-hoc changes in schedules cause non-optimized resource allocation and inaccurate schedules;
(3) Robust Shop Floor: Low overall equipment effectiveness due to high maintenance and setup time.

AI research that contributes to addressing the above challenging problems includes: machine learning and data analytics, agent-based simulation and optimization, verification, visualization, sampling and fusion, etc.

A*STAR is a main driver of this type of research. They partner with local industries and collaborate with researchers at NTU and NUS as well as international experts. Specifically, they set up the Advanced Remanufacturing and Technology Centre [6], which is the first in Asia. Also, its Singapore Institute of Manufacturing Technology (SIMTech) and NTU 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, etc.

Health care

Another area that receives significant interest among the researchers in Singapore is in providing smart health care. Specifically research in this area has focused on multiple very interesting threads. The first thread has focused on developing graphical models based methods to identify health state and design diagnostic tests for patients whose situation may deteriorate over time. Blocking spread of communicative diseases through well-designed management guidelines is the second thread that has received a significant amount of interest from the AI community in Singapore. 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. The final thread has focused on building techniques at the intersection of Artificial Intelligence and Operations Research to design and schedule health care resources for efficient health care.

Researchers in NUS, SUTD and SMU have done extensive research in this area and are in the process of developing systems for specialized problems in this area to improve efficiency of health care.

Contributions in addressing issues related to health care have focused on following research areas: graphical models, machine learning, sequential decision-making under uncertainty, influence maximization and operations research.

Conclusion

Overall, due to focused funding for not only academic research but also for translational funding across most areas in AI that serve the building of a smart nation, Singapore has not only witnessed a surge in the number of research publications at top tier venues but also has witnessed AI based translational projects, research centres and startups.

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