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An Infinitely Scalable Learning and Recognition Network

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14. ABSTRACT
Learning and recognition are fundamental process performed by animals, humans, robots and intelligent systems. Humans, for example, continually learn and recognize where they are in the world (place recognition), who is there with them (facial recognition) and what things are around them (object recognition). Recognition also plays a significant role in technology like smartphones, whether it be recognizing what you are saying (voice recognition) or what the consumer item in front of you is when using Google Goggles (object recognition). Google and other information aggregators perform recognition at a vast scale, recognizing and classifying billions of images in the cloud and house numbers in millions of kilometres of Google Streetview imagery. In security and surveillance, taskâ€•specific signatures (such as a specific person’s voice, a bombâ€•carrying back pack or a person’s face) must be automatically recognized amongst vast amounts of data. Common to all these artificial recognition processes are computational and storage requirements that grow with the magnitude of the task. Typically these storage and computational requirements grow linearly or worse with the size of the dataset, a critical problem in a world where data storage demand is outstripping capability (see Figure 1), and this gap is forecast to continue growing (1). There is currently no feasible solution to this problem – current techniques such as those used for video and image compression have plateaued in performance over the last decade, while the limits of hashâ€•based approaches are known and unlikely to provide an ultimate solution. This project combines modelling of and inspiration from the spatial memory encoding system in the mammalian brain with machine learning techniques to enable subâ€•linear storage growth; that is, as the number of “items” in the database (places, images, voice signatures etc.) that need to be encoded grows, the amount of storage space required per item continually decreases.

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An Infinitely Scalable Learning and Recognition Network

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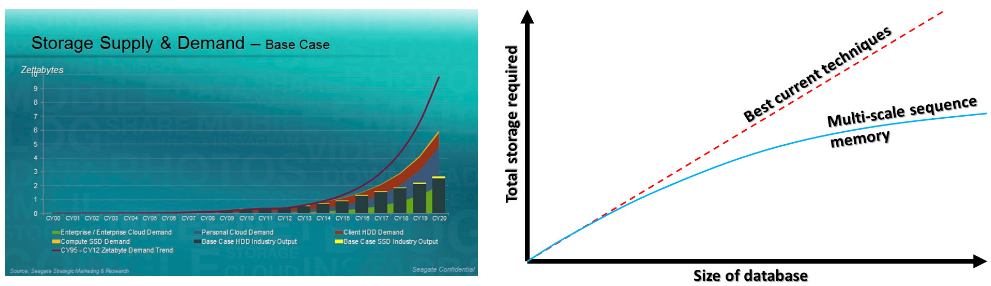
Final report for Period: June 22 2016 – Sep 30 2020 (non-continuous)

Proposed Total Cost (for each year)

Year	Amount in USD
Year 1	$90,034.62
Year 2	$90,322.62
Year 3	$92,937.62

Abstract (Publicly Releasable)

Learning and recognition are fundamental process performed by animals, humans, robots and intelligent systems. Humans, for example, continually learn and recognize where they are in the world (place recognition), who is there with them (facial recognition) and what things are around them (object recognition). Recognition also plays a significant role in technology like smartphones, whether it be recognizing what you are saying (voice recognition) or what the consumer item in front of you is when using Google Goggles (object recognition). Google and other information aggregators perform recognition at a vast scale, recognizing and classifying billions of images in the cloud and house numbers in millions of kilometres of Google Streetview imagery. In security and surveillance, task-specific signatures (such as a specific person's voice, a bomb-carrying back pack or a person's face) must be automatically recognized amongst vast amounts of data.



(a) (b)

Figure 1: (a) Data storage demand is rapidly outpacing storage availability (Source: Seagate Strategic Marketing & Research). (b) The proposed multi-scale sequence memory enables sub-linear storage growth.

Common to all these artificial recognition processes are computational and storage requirements that grow with the magnitude of the task. Typically these storage and computational requirements grow linearly or worse with the size of the dataset, a critical problem in a world where data storage demand is outstripping capability (see Figure 1), and this gap is forecast to continue growing (1). There is currently no feasible solution to this problem – current techniques such as those used for video and image compression have plateaued in performance over the last decade, while the limits of hash-based approaches are known and unlikely to provide an ultimate solution. **This project combines modelling of and inspiration from the spatial memory encoding system in the mammalian brain with machine learning techniques to enable sub-linear storage growth; that is, as the number of "items" in the database (places, images, voice signatures etc.) that need to be encoded grows, the amount of storage space required per item continually decreases.**

Enabler of Funding

The AOARD project has indirectly assisted in obtaining funding in the following schemes:

- US-Australian Multidisciplinary University Research Initiatives (MURI) bid, "Neuro-Autonomy: Neuroscience-Inspired Perception, Navigation, and Spatial Awareness". In brief:
    - 24 successful bids out of 295 proposals, 8% success rate.
    - a 3 year project extendable to 5 years
    - the U.S. side of the bid is worth approx $10M AUD over 5 years, the Australian side is about $5M over 5 years.
    - funded by ONR (US side) and DST (Australian-side).
    - collaboration between MIT, BU, Uni Melb, Macquarie, QUT and UNSW
- Advanced Terrain Detection (ATD) with Rheinmetall Defence Australia, https://research.qut.edu.au/qcr/Projects/rheinmetall-defence-australia-advanced-terrain-detection-atd/

The project and experience working in defence-related research has also formed a variable part of the foundation for funding proposals currently under review or in discussion with the following organizations:

- Australian Research Council (under review)
- Australian Department of Defence (under review)
- Amazon (confidential, under review)
- Ford (confidential, under review)

Students and Postdocs Funded by Proposal

The project has employed four postdoctoral research fellows, and also involved one PhD student.

- **Postdoc:** Dr Adam Jacobson, now working at Fortune 100 company Caterpillar in Brisbane, Australia (a long term collaborator). During Adam's PhD he also worked on some of the foundational research underlying the project.
- **Postdoc:** Dr Litao Yu, now working as a researcher at University of Technology Sydney, Australia, following a role at Griffith University, Brisbane, Australia.
- **Postdoc:** Dr Huu Le, now working as a researcher at Chalmers University, Sweden
- **Postdoc:** Dr Sourav Garg, now working as a Research Fellow at the QUT Centre for Robotics.
- **PhD student:** Mingda Xu, current second year PhD student at QUT, worked on the ICCV2019 paper and presented it in South Korea.

We would also add that the lead PI for this project, Professor Michael Milford, was during the project's duration first promoted from Associate to Full Professor at QUT, promoted to Deputy Leader of the Robotics Group (2016-2019) and then to Deputy Director and co-founder of the newly formed QUT Centre for Robotics. This project made a contribution towards this career development.

Other Dissemination of Project Outcomes

The project outcomes have been presented as part of approximately 40 presentations over the project duration: ranging from top international conferences, universities, and companies especially in the technological space. It's also been discussed in several dozen meetings with various defence departments from both Australia and the United States.

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