RESEARCH INTERNSHIPS WITH DST GROUP

INT - 0502

Defence Science Technology Group - Round 3

Note to Students & Supervisors
Projects are available in ACT, WA, VIC and SA. Start date, location and scope of the research project may be negotiated during the application stage. If you have any questions please contact the APR.Intern team to discuss at: contact@aprintern.org.au or 03 8344 1785

LOCATION: FAIRBAIRN, AUSTRALIA CAPITAL TERRITORY

1. Technology Foresighting

Division: JOAD | Duration: 5 months | Start Date: 2018

The DST technology foresighting approach developed by TFF consists of a series of activities beginning with horizon scanning and then a series of increasingly detailed analyses which inform a range of outputs. Technology Watches are short reports on a subset of the topics identified in the horizon scan, where potential benefits and threats are examined briefly, with deep dive activities such as the Emerging and Disruptive Technology Assessment Symposiums (EDTAS) conducted on particular themes or technologies assessed as being of particular significance.

DST is seeking someone with expertise in foresighting methodologies, which could include data analytics, expert elicitation and workshop design. The particular focus of the team is technology foresighting, implications analysis and future concepts research.

Research to be conducted - The research to be conducted under this program would be to build on the current expertise in expert elicitation and workshop design, data analysis as applied to technology foresighting to develop novel scientifically-based foresighting methodologies. This research will assist in continuing to develop worlds-best-practice futures and foresighting approaches which will be applied in the Defence and National Security domains.

The exact details of the project will be negotiated dependent upon the unique skills of the APR Intern recipient. However, depending on the particular skills of the successful applicant, the aim of the internship may be to develop a sound basis for the conduct of technology foresighting workshops. An alternative objective will be to assist in the development of the next version of the DST technology foresighting software which assists in the horizon scanning that seeks to identify potential technologies which may have a disruptive impact on Defence and National Security.

LOCATION: STERLING, WESTERN AUSTRALIA

2. Computational Underwater Acoustics

Division: Maritime | Duration: 4 months | Start Date: Prior to December 2018

Sonar is the primary sensor used by submarines and other maritime platforms to detect, classify and track undersea platforms. The Sonar Technology and Systems (STS) Branch of the Defence Science and Technology (DST) Group is the principal source of scientific and technical advice within the Australian Department of Defence on the acquisition, optimal employment and evolution of sonar systems for the Australian Defence Forces. The STS Branch operates out of DST sites in Western Australia (HMAS Stirling, Rockingham) and South Australia (Adelaide, Edinburgh) and undertakes collaborative R&D in sonar technology and systems, both nationally and internationally with a range of government, academic and industrial partners.

The DST STS Branch is seeking a PhD intern with skills and interests in the application of modern computational technologies and techniques to one of the following areas: a) Large Sensor Count Sonar Array Processing; or b) GPU (Graphics Processing Unit) - based Underwater Acoustic Propagation Modelling.

Research to be conducted – Large Sensor Count Sonar Array Processing: Improved understanding of the computational techniques available for making signal processing of large sensor-count sonar arrays possible, within the constraints of the submarine sonar application. Specifically, may answer questions such as:

- What parts of the sonar processing chain are best suited to parallel processing?
- How much computational efficiency improvement can be expected for various parallel processing techniques applied to the sonar processing chain?
- What techniques exist for avoiding ill-conditioning of large channel count cross-correlation matrices?
- Can the 'snapshot deficiency' problem be solved without loss of performance?
- Research into answering one or more of these questions is expected to be largely theoretical, however software and hardware resources exist at the DST HMAS Stirling

(Rockingham, WA) site sufficient to support implementation and experiment with signal processing and parallel/GPU computing.

GPU-based Underwater Acoustic Propagation Modelling: It is anticipated that the internship would achieve the following objectives:

- Further DST Group's understanding of ocean acoustic modelling
- Progress the state of the art in parallel computing implementations (GPU-based)of ocean acoustic model
- Demonstrate potentially increased situational awareness for the end-user/operator

PROJECTS IN FISHERMAN'S BEND, VICTORIA

3. Underwater Electric Signatures: Influence of sacrificial anode fits upon achievable signature levels

Division: Maritime | Duration: 4-5 months | Start Date: Flexible, preference between September-December 2018

The research program of the Advanced Vehicle Systems (AVS) group seeks to identify opportunities and develop solutions to improve the resilience and adaptability of critical services on Army's future land vehicles. AVS is interested in multi vehicle robotic/AI systems and distributed mechanisms of behaviour design. These systems need to exhibit situational awareness and autonomy by reacting appropriately to their environment which also includes enemy agents and other autonomous agents. In open environments this is challenging due to limited sensing capability of each agent, unpredictability of the environment and the other playing agents.

We seek a PhD intern with relevant expertise in one or more areas of game theory, adaptive control, computational intelligence, symbolic AI, numerical optimization, systems design or similar to tackle problems in resilient and adaptive behaviour design in uncertain and adversarial conditions.

Research to be conducted - DST have already completed some basic studies into this area, however a number of questions remain, and so research is required in understanding:

1. How small variations from the optimal potential at the free flood openings affects signature levels?
2. How much variation between the potential at the free flood openings can be accommodated before signature levels become excessive?

4. Unlocking the Potential of Additive Manufacturing (AM) for Aircraft Fracture Critical Structures using Surface Enhancement Technology

Division: Aerospace | Duration: 4-5 months | Start Date: 2018

The cost of ownership and the operational availability of air capability are major concerns for the ADF [DST Strategic Plan 2013-2018]. Given fatigue failure of any of fracture-critical structures may result in loss of an aircraft, to maintain the fleet airworthiness and readiness, the new AD strategic plan has recently identified Innovation Sustainment (iSustainment) – one of the three new S&T themes [AD Plan – A catalyst for the Future 2018]. Titanium alloys such as Ti-6A1-4V forgings are widely used for aircraft fracture-critical components due to their high specific strength and fracture toughness. These fracture-critical components are conventionally machined out to die forgings and hand forgings, resulting in typical buy-to-fly ratios more than 10:1 with lengthy lead times and high costs [Kobryn et al/AFRL, 2006]. Although, in recent years, extensive R&D efforts have been devoted to achieving lower cost fabrication of Ti alloys using AM, the successes are so far tempered by challenges that fatigue durability of the today's AM manufactured parts can only match that of casting counterparts, but not that of the forged Ti alloys due to the AM process defects (such as lack-of-fusion voids and pores) and surfaces roughness [Airbus Additive Manufacturing 2017].

Research to be conducted

1. To apply deep surface rolling (DSR) to enhance fatigue durability of AM Ti-6A1-4V for the applications of aircraft fracture-critical structures; and
2. To understand the mechanics of DSR introduced beneficial compressive residual stresses at the surface, but more importantly, the mechanisms how DSR can induce nanocrystallization, and microstructural solid-state transformation for fatigue strength enhancement.

5. Synchronisation of Real and Virtual environments

Division: Aerospace | Duration: 5 months | Start Date: 2018

This project will advance the state of our science supporting integrated Live, Virtual and Constructive (LVC) environments for training and experimentation.

The AOSC XR lab conducts applied Human-Computer Interaction research on Augmented/Mixed/Virtual Reality, supporting projects for Army, Navy and Air Force. The lab has leading edge equipment for immersive visualisation, including eye/head/body tracking and 3D environment scanning and ready access to advanced manufacturing workshops.

Integrating real word objects with virtual worlds is challenging. IR optical marker tracking (e.g. Optitrack, VICON), laser multilateration (lighthouse) and accelerometers are functional for tracking discrete points in indoor spaces, but perform poorly outside, and are incapable of capturing the appearance or tracking natural objects (trees, clouds) or untracked participants, and require considerable effort to attach and calibrate the fragile trackers.

Photogrammetry techniques allow real-time capture of shape and textural information. Multi-View Stereo Structure-from-Motion (MVS-SfM) is a method to incorporate the information from multiple cameras, generating a 3D point cloud. The point cloud can be used to build a 3D polygonal model, or to track the motion of known objects through the scene.

Research to be conducted –The goal of this project is to employ MVS-SfM techniques to capture complex dynamic scenes in real time, track known objects, and update environmental scenery (traffic, pedestrians, clouds and shadows). Existing open source and commercial for MVS-SfM will be used where possible, with a focus on real-time processing and tracking.

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6. Wave Estimation Using Autonomous Vehicles

Division: Maritime | Duration: 5 months | Start Date: 2018

DST is assisting the ADF with enhancements to ocean modelling tools and also concepts for improving the performance of military crewed and uninhabited vessels. Better characterization of the ocean surface conditions can provide the opportunity for the ADF to adapt their behavior and planning in order to improve their overall effectiveness in the maritime environment. In the case of vessels at sea, adaptive control approaches may allow for crewed and uninhabited vessels to improve their seakeeping performance. In the case of planning, the sparsity of observational data for data assimilation schemes that correct ocean model continues to be a limiting factor in ocean modelling skill, especially in littoral and regional modelling. Wave-buoy data that can provide a direct characterisation of the sea surface is particularly sparse.

The concept being investigated with this project is the use of a small, uninhabited craft to substitute for a wave-buoy sensor. The dynamic behaviour of a small vessel can be highly non-linear and so the project will combine vessel dynamic modelling with prediction tools. There is also a possibility that there will be full-scale at-sea data and model-scale tank test data available for validation purposes. This is part of a larger research program intended to improve the modelling and seaway performance of small military vessels.

Research to be conducted:

1. Review key problems related to the use of a small craft as a wave-buoy.
2. Formulate an analytical approach to resolving the problem
3. (If possible) validate the approach using model-scale and full-scale data Co-author findings

LOCATION: EDINBURGH, SOUTH AUSTRALIA

7. Advanced C2 ISR Information management and Dissemination in the Land Tactical Battlespace through Knowledge Representation of and Reasoning over Dynamic Mission Context

Division: Land | Duration: 5 months | Start Date: Flexible

In contested, complex warfighting environments, Army requires highly resilient information systems and networks in order to gain information advantage over its adversaries and ensure 'decision superiority' in the tactical battlespace. Currently tactical information networks are often disrupted, intermittent, and of low bandwidth (DIL), so Army is looking to DST Group for science and technology (S&T) support and innovation to enhance the resilience of information, in order to provide tactical commanders with the tools to make informed decisions, faster, more effectively and more reliably.

There are multiple approaches to address this challenge and the Systems Integration and Tactical Networking (SITN) Science and Technology Capability (STC) is engaged in a multi-year collaborative research programme known as SMARTNet that aims, through an intelligent middleware solution, to provide dynamic tactical information prioritisation and dissemination based upon the operational and network contexts in a given tactical environment.

SITN is currently engaged in research using computational intelligence to capture, represent and reason over mission, platform, environmental, human and network contexts in order to facilitate dynamic, context-based prioritisation of information. SITN is working on this problem in collaboration with academia and industry and is looking to augment its research team with PhD-level expertise.

Research to be conducted – The project will be developed using appropriate software development and modelling and simulation environments with the SITN research programme.

- Conduct an exploration of alternative techniques that may be applied to the problem space, based on current literature, and develop a framework for measuring the utility of these techniques.
- Develop a prototype implementation of a mission context inference engine utilizing one of the techniques explored and conduct experimental analysis and evaluation in a simulated environment.

8. Distributed Contextual Awareness

Division: Land | Duration: 5 months | Start Date: Prior to November 2018

The research program of the Advanced Vehicle Systems (AVS) group seeks to identify opportunities and develop solutions to improve the resilience and adaptability of critical services on Army's future land vehicles. These vehicles will implement self-managing, adaptive software systems as a key component of their mission systems. An important consideration here is the development of contextual awareness amongst multiple vehicles.

Each military land vehicle needs to be aware of its context based on policy that is provided to it and data that it senses. A challenge is to exchange data with other vehicles in order to update each vehicle's contextual assessment for itself, for others and for the group, and in how this information stored, disseminated and combined. Data networks that support land vehicles are generally characterised by low data rates, and intermittent connectivity. While vehicles with good network connections may have the ability to exchange more detailed context related data, those with poorer connections may only be able to exchange very limited data. In order to exchange the contextual data of greatest value it is important to develop appropriate representations of the data types, data properties and their interrelationships.

The Advanced Vehicle Systems (AVS) team expects that contextual data can be structured using appropriate ontologies and that the use of agent-based mechanisms can facilitate the exchange of appropriate data to make best use of the available networking resources. This context-related data should be represented in a distributed knowledge base.

Research to be conducted
The research project will explore and identify:

1. appropriate mechanisms for the representation of context related data.
2. agent-based mechanisms for exchanging context related data.

The research will include an analysis of the technologies that would support the establishment of a distributed knowledgebase for the purpose of supporting decentralised contextual awareness in a federated land vehicle deployment.

The research will include a simulation that demonstrates the implementation of the contextual awareness mechanisms responding autonomously to the changing communications environment.

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9. Adaptive Automation in next Generation Human Robot Teaming

Division: Land | Duration: 5 months | Start Date: Flexible

If the Australian Defence Forces are to exploit the technical capabilities provided by Robotic and Autonomous Systems (RAS), then such systems need to be perceived as trustworthy partners. Two key elements of this are that 1) the system is trusted to undertake military tasking, and 2) trusted by operators to perform as expected. The second element might be further clarified by framing the statement as 'trusted by team members to perform as expected' since this more accurately reflects the problem framing and relationship that would be investigated under this research.

A foundational research and technology development requirement is to develop ways for an autonomous robotic system to sense and classify the intentions and actions of human team members and use this information to adaptively respond to changes in the ability of humans to effectively complete required tasks. An additional and related requirement is that the human team member will have appropriate, or calibrated, trust in what the RAS is doing and how it can augment and support them in completing his/her mission.

A key to classifying human intentions and actions is machine learning and related computational intelligence approaches. The development and exploitation of classification approaches will be critical in supporting the development of machines that are able to adapt their behaviour in ways that assist in sustaining appropriately calibrated trust. Failing to get this right will lead to technology rejection and/or inappropriate dependence on the technology, which in turn will lead to human-robot team failure or substantial reductions in team capability.

Research to be conducted – Building on extant research, the objectives of this Intern Project are to:

- Apply ML or related approaches to classify tactical plans developed by military personnel
- Apply ML or related approached to classify dynamic human state and actions drawing on cognitive, behavioural and physiological data
- Evaluate and refine classification approaches either developed by the Intern and/or by extant research partners.

Preliminary data sets already exist to support the first objective, with additional data related to objective 2 expected to be captured in the next 3 to 6 months.
The simulation infrastructure and associated data collection tools are also available as needed to support additional development of classifiers, as are software tools for ML.

10. Autonomous System Control under Adversarial Action

Division: Land | Duration: 5 months| Start Date: Prior to November 2018

The research program of the Advanced Vehicle Systems (AVS) group seeks to identify opportunities and develop solutions to improve the resilience and adaptability of critical services on Army's future land vehicles. AVS is interested in multi vehicle robotic/AI systems and distributed mechanisms of behaviour design. These systems need to exhibit situational awareness and autonomy by reacting appropriately to their environment which also includes enemy agents and other autonomous agents. In open environments this is challenging due to limited sensing capability of each agent, unpredictability of the environment and the other playing agents.

We seek a PhD intern with relevant expertise in one or more areas of game theory, adaptive control, computational intelligence, symbolic AI, numerical optimization, systems design or similar to tackle problems in resilient and adaptive behaviour design in uncertain and adversarial conditions.

Research to be conducted - The research will explore and identify the most successful approaches in the literature relating to the design of behaviours for intelligent tactical systems in the context of adversarial enemy actions and/or system faults. Techniques and applications will be investigated to address the design of appropriate distributed decision making and adaptive control behaviour to enhance survivability of fleets of land vehicles via semi-autonomous management of their distributed tactical systems.

In light of enemy intent and adversarial actions, investigation will be conducted into intelligent distributed decision-making techniques. These may include:

- Situation, risk, vulnerability and damage assessment under conditions of imperfect, incomplete, misleading or irrelevant information
- Multi-objective decision making
- Reciprocal interaction, game theory, complex adaptive systems, theory of mind, red-teaming, irrationality, redundant functionality
- System behaviour modelling for non-linear environmental effects (e.g. in terms of tipping points, cascades, chaos and instability)
- Other topics relevant to the objectives as uncovered in the investigations

This role will work within the Advanced Vehicle Systems Group which will provide the resources and facilities to conduct this research.

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11. Capturing Uncertainty in Machine Learning for Automated Airborne Video Surveillance

Division: National Security & ISR | Duration: 6 months | Start Date: Flexible

DST Group is the Australian government's lead agency responsible for applying science and technology to safeguard Australia and its national interests. Within the Intelligence, Surveillance and Reconnaissance (ISR) space, a key focus is automated processing that provides accurate high level cues to human decision makers. An outstanding challenge is that while airborne video surveillance data is becoming increasingly common with the growth of sensor systems, there is not a corresponding growth in the Image Analysts that would be required to analyse this data.

In recent years Deep Learning techniques based on Artificial Neural Networks have set new benchmarks within Computer Vision for areas such as image classification, object detection and scene understanding. The machine learning algorithms that underpin these methods leverage large data sets and parallel processors and are able to adapt their behaviour when trained on new examples. This data-driven technology is employed by DST Group to enhance the automated processing and analysis of airborne surveillance imagery.

Research to be conducted - Working under close supervision with a range of PhD-qualified experts in Computer Vision and Machine Learning, the project requires developing new algorithms and empirical methods to capture the uncertainty in neural networks. There are three main facets to this work:

- Familiarization with deep learning techniques for image classification and object detection;
- Development of algorithms for propagating uncertainty in deep learning models;
- Development of methods to measure and calibrate uncertainty in model predictions.

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12. Anomaly Detection in Track Data

Division: National Security &ISR | Duration: 5 months | Start Date: Prior to November 2018

Over the last few years, the rate at which information is being collected in every domain has increased exponentially. This gives us greater opportunity to observe normal patterns of behaviour; however, the volume and rate of information collected makes it very difficult for a human operator to find something that may be considered a threat amongst all the normal traffic. Automated anomaly detection would be of great assistance to a human operator trying to find something that may be a threat. There are many systems available now, which collect kinematic data about a vehicle's position, course and speed, with updates every few seconds so that a track can be formed. This project considers the problem finding anomalies in track data, which may indicate threats, when there is little or no labelled data available.

Track data could be obtained from vehicles (land, sea or air) with a device that reports location over time (e.g. GPS or AIS). Other data sources may also be available to augment the information for each track, such as vehicle type and local weather conditions.

DST Group has been exploring the use of two different machine learning techniques for anomaly detection in track data but would like an intern to help progress this work and explore other machine learning techniques, which may be applicable.

Research to be conducted - DST Group is seeking assistance to explore alternative/improved techniques for implementing an anomaly detector for track data, along with a methodology for testing anomaly detection performance when there is little or no labelled data available. Example track data will be provided by DST Group, but the methodology for finding anomalies should be applicable to any types of track data with the option to include additional data sources.

There are three main facets to this work:

1. Familiarisation with work already undertaken by DST Group in this area and a focused literature survey of other techniques which could be considered
2. Implementation of an anomaly detector, including feature selection and pre-processing of data
3. Exploration of results, particularly methods to measure anomaly detection performance in the absence of labelled data and explaining why something has been labelled anonymous.
4. If time permits, consider methods to improve performance, including ensemble methods.

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13. Use of reactive non-equilibrium chemical kinetics in hydrocode modelling of reactive materials

Division: Weapons & Combat Systems | Duration: 6 months | Start Date: 2018

Structural Reactive Materials (SRMs) present an opportunity to advance warhead design options previously not achievable. While qualitative performance outcomes have been demonstrated, there is little understanding of how the effects are achieved, how to measure them, and how to utilize them efficiently.

Warheads Effects Group in the Weapons and Combat System Division of Defence Science and Technology Group (DTS Group) is interested in developing that required deeper understanding through the application of computational fluid dynamics (CFD) techniques. The CFD simulations will require development of multi-phase materials models that need the individual mechanical and chemical characteristics of the phase species of the SRMs applicable to the warhead effectiveness and design problems. The successful candidate would therefore require an appreciation of material shock loading characteristics, high strain rate material response, and computational physics.

Research to be conducted – During the project term DST Group hopes:

- To specific chemical reaction kinetics that could be associated with the processes occurring in SRMs at high strain rate conditions typical of warhead detonation and target impact; and
- To apply the kinetics to multi-phase material models implemented in modern hydrocodes for simulation of scenarios typical for the warheads involving SRMs.

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14. Surrogate Seeker interface definition

Division: Weapons & Combat Systems | Duration: 4 months | Start Date: 2018

We are in the planning stages of procuring a new commercial missile seeker which will be modified to be used as a 'surrogate' or general-purpose IR imaging seeker. The seeker will be used in the future to test response to a range of countermeasures as part of a development and validation program. An interface will be required between the seeker and our custom-built processing unit which contains the target tracking system and associated image processing algorithms. The interface will pass real-time imagery and data between the seeker and the processing unit.

Due to the reduction in staff numbers we have limited capability to do this work in-house. To meet strict timelines, we need to design the integration before the seeker hardware is delivered. The seeker interface specification document has been provided and with this and knowledge of the processing unit it is possible to design the electronics interface. We do not have staff available to undertake this work, but we do have the required funding (under the CMD&V MUL project).

Research to be conducted – The objectives are:

- Examine the interface documents and, in consultation with local expertise and the manufacturer (MBDA), become familiar with the interface requirement.
- In consultation with the user, develop an interface hardware design and provide recommendations on the way forward.

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15. Investigation of real-time dynamic thermal prediction models applicable to the Visible & Infrared Scene Generation Suite (VIRSuite) software

Division: Weapons & Combat Systems | Duration: 5 months | Start Date: February 2019

VIRSuite is a real-time electro-optical (visible and infrared) and LADAR (Laser Detection and Ranging) synthetic scene generation system that has been conceived, developed and improved by the Defence Science and Technology researchers over the last 10 years. VIRSuite development was initially driven by the need for hardware-in-the-loop (HWIL) simulation, benchtop test and evaluation of guided weapons and closed loop all digital simulation.

Recently DSTG formed an industry partnership for the sustainment and continuous development of the capability along with providing on-going responsive support to a broad range of VIRSuite users. Activities under the partnership have included a reimplementation of VIRSuite in the commercial game development system, UnrealEngine 4.0., driven by the need to have a maintainable and evolving industry standard codebase. Consilium are also developing a commercial offering and a marketing strategy in order to seek new commercial opportunities for the capability.

A key aspect of the system is the capability to predict real-time infrared signatures of the objects of interest and the background when the "real life" (trial data) is unavailable. VIRSuite has been limited in the past due to the static nature of the thermal signature of targets. A rudimentary thermal dispersion model was developed in the legacy VIRSuite but has not been implemented in the UnrealEngine based re-implementation.

To generalise target signatures, significantly improve the quality of scenes in simulations spanning extended time periods and to maximize the commercial prospects of the package the legacy thermal dispersion modelling needs to be reviewed, improved and implemented within the constraints of the Unreal Engine architecture.

Research to be conducted

1. Familiarisation with the existing thermal dispersion model implementation and its limitations.

2. Research, development and testing of improvements that meet an agreed set of requirements.
3. Investigate methods/techniques for integrating and optimizing the performance and work-flow aspects of the developed capability within the VIRSuite/ UnrealEngine 4.0 architectural framework.

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16. Multi-target tracking for low contrast objects in a cluttered environment

Division: Weapons & Combat Systems | Duration: 5 months | Start Date: 4 February 2019

Following a number of objects of interest in a cluttered environment is a challenging that has not fully been solved. Many unmanned systems use low cost, low resolution sensors, which has potential to pose more technical issues for object detection and recognition.

Current techniques rely on a range of image segmentation and pre-processing techniques, but the process can be largely characterised as memory-less. Objects can be obscured, easily confused, lost and re-acquired without any additional properties or time-history attached. Adding some cognitive aspects to image processing (using multi-mode, multi-band sensors, and forming and maintaining a database of recognised objects against a characterised background) can contribute to more systematic multi-target tracking, with better in-built self-learning.

There is a growing interest in UAVs supporting the target recognition and designation process. DST/WCSD has industry partnership agreements with the aim to develop swarm-like UAV operations. This work would support the advanced image processing required for such operations.

DST is seeking a candidate with expertise in electrical/electronic or mechanical engineering with a strong background in mathematics and computer science.

Research to be conducted

- Familiarisation with the existing techniques applicable to the problem as well as the research environment and resources used within WCSD/WST.
- Research and development of the proposed cognitive methods resulting in tests and experiments.

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17. Accuracy Prediction for Over-the-Horizon Radar

Division: National Security & ISR | Duration: 4-5months | Start Date: 2018

Skywave over-the-horizon radar (OTHR) uses refraction of radio waves in the earth's atmosphere to achieve coverage ranges well beyond line-of-sight. This technology is a key surveillance asset for Australia. Models of detection and accuracy performance can be used as tools to design future network enhancements and to validate the achieved system performance against expectations. However, the atmospheric ionisation that supports skywave propagation is highly variable over daily, seasonal and multi-year solar cycles, and characterising radar performance is challenging.

DST is seeking an early career researcher with expertise in statistics, signal processing, or physics to help design an OTHR system model to forecast achievable accuracy with high enough fidelity to be practically relevant.

Research to be conducted - The overarching aim of the program is to derive a Cramer Rao Lower Bound on estimation accuracy, which is to say a theoretical measure of the best performance achievable for the system. This is already possible if we over-simplify the system, the challenge is to extend this to be more realistic. The first research objective would be to incorporate numerical methods to estimate the statistical properties of the propagation path and transforms to combine this with modelled radar measurement accuracy. The second objective would be to explore marginalisation techniques to allow evaluation over large volumes in achievable time.

DST already has a numerical ray tracing engine for HF propagation and this could be combined with archived atmospheric sounder data to improve model fidelity.

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18. Using Systems dynamics modelling to identify potential levers for performance improvement in a Combined Arms Team

Division: JOAD | Duration: 6 months | Start Date: 2018

The Combined Arms Team, which combines combat, combat support and combat service support elements, is the core mechanism that delivers land combat fighting power to decisively win in close combat and realize success in contemporary conflict.

A key challenge in developing effective Combined Arms Teams is to understand the dependencies and interactions that exist between force elements involved in Combat, and how the individual performances of these elements combine to impact combat outcomes. This information can then be used to identify performance improvements that have the greatest potential to increase our chances of winning.

A systems dynamics model could be one way to capture the relationships between combat elements. This model can then be used to identify potential performance levers, i.e. potential systemic changes that could improve the Land Force's chances of winning.

Research to be conducted - The objective of this work is to identify opportunities for technology investment which will impact the effectiveness of combat. The PhD student will do this through:

1. Building a systems dynamics model of Land close combat.
2. Identifying the potential levers for impacting the dynamics of the system (for example through various technologies') to help identify how a force could change its chances of success.
3. Identify ways of quantifying changes in the systems dynamics as a result of technology insertion to assess the effectiveness of identified levers.

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19. Machine Learning and Data Fusion for Threat Object Detection

Division: Weapons & Combat Systems | Duration: 5 months | Start Date: 2018

A number of technology solutions are currently being used for IT detection. Operational teams in conflict situations must make near-real-time (NRT) decisions using sensor outputs. Weak target detection signals in dynamic and noisy environments, high false alarm rates and the evolving nature of threats and operational environments have become the biggest challenge in IT detection. It is highly desirable for any IT object detector to have high probability of detection and low probability of false alarms. In order to minimise casualties and maintain freedom of movement in ADF operations, modernisation of Counter-IT (C-IT) detection capability is an enduring requirement. The complex nature of operational scenarios makes it very difficult to design a universal detector. Advanced signal processing and machine learning techniques are therefore needed in order to develop a robust detection scheme, which can compensate for changes in the background conditions.

The project seeks to explore approaches to reduce these limitations by developing robust Automated Target Recognition (ATR) and advanced decision support systems. As the first step, advanced NRT ATR algorithms will be developed to detect IT objects using individual sensor outputs. Subsequently, new state-of-the-art computational intelligence approaches (deep learning artificial neural networks, fuzzy sets, and evolutionary computation) will be used to aggregate multi-sensor outputs at feature and decision levels.

Research to be conducted – Line of Effort (LOE) 1 – Validation/development of Real-time Automatic Target Recognition (ATR) algorithms for individual IT detection sensors.

The main objective of this LOE is to further improve GPR, MD and Non-Linear Junction Detector (NLJD) performance through novel ATR algorithms to real-time stand-off IT object detection applications.

LOE2 – Development of an advanced intelligent Multi-disciplinary Fuzzy Decision-making Support (IMFDS) system for IT object detection scenarios.

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20. Precision Photonic Sensing

Division: Maritime | Duration: 3-5months | Start Date: 2018

The Advanced Sensing Lab in DST's Maritime Division has world leading expertise in short cavity fibre lasers and their application to precision undersea sensing. The scope of our research includes the design and development of distributed feedback fibre lasers, basic laser physics, precision measurement techniques and development of novel undersea sensors. In the past, much of our focus has been on acoustic sensing technologies and their application to lightweight remotely deployable sonar for undersea surveillance. Recently we have been increasing interested in non-acoustic sensing techniques such as magnetometry.

We are seeking an experimental or theoretical physicist with a photonics background and an interest in precision measurement and sensing. Depending on the skills and interests of the intern a number of specific projects may be available including:

a) cavity-optomechanical magnetometry
b) feedback induced instability in distributed feedback fibre lasers
c) Relaxation oscillation noise suppression in ultra-high cavity-Q fibre lasers
d) Digitally enhanced frequency demodulation of fibre laser sensors.

Research to be conducted - The intern would undertake one of the following projects depending on their skills and preference:

a) Cavity optomechanical magnetometry
b) Feedback induced instability in distributed feedback fibre lasers
c) Relaxation oscillation noise suppression in ultra-high cavity-Q fibre lasers
d) Digitally enhanced frequency demodulation of fibre laser sensors

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21. Swarm Decision Making - Act locally for global benefit

Division: Land | Duration: 5 months | Start Date: 2018

The research program of the Advanced Vehicle Systems (AVS) group seeks to identify opportunities and develop solutions to improve the resilience and adaptability of critical services on Army's future land vehicles. AVS is interested in multi vehicle robotic/AI systems and distributed mechanisms of behaviour design. These systems need to make decisions in environments in which communications is contested and information is not readily available. As such, the individual systems, which collectively work as a whole, require the ability to make decisions locally based on partial/incomplete information. The required effect of individuals making their own local decisions is that of an emergent globally beneficial behaviour, as per a swarm. Consider for example the manner in which fish school or birds flock; the individual entities make local decisions which lead to the desired global behaviour. AVS seeks to investigate whether the decision for a local agent to make such a decision can be learnt.

Research to be conducted - The research project will explore and identify the computational intelligence-based techniques which can be applied to enable an agent to learn the way it should behave based on the (incomplete) information it has at hand so as to benefit the swarm as a whole.

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22. Distributed Decision-Making Application to support Autonomous Systems in Military Land Vehicles

Division: Land | Duration: 5 months | Start Date: 2018

The research program of the Advanced Vehicle Systems (AVS) group seeks to identify opportunities and develop novel solutions to enhance the adaptability, tactical effects and resilience of critical services on Army's future land vehicles, which operate in contested and resource-constrained environments. This may be achieved through exploitation of redundant functionality afforded by distributed digital vehicle systems and utilisation of sensors and effectors on co-located vehicles in the land battlespace. To realise these capabilities, the AVS group is investigating the application of autonomic computing approaches and goal-driven software agents to achieve self-management of vehicle systems and services.

It is important that AVS understands key concepts that support the desired behaviour of our envisaged solution. This will provide awareness of relevant considerations and dependencies relating to their application in our environment. One such concept is the ability for goal-driven autonomous systems to respond to changes in their environment that require these systems to adjust their goals. That is, they are capable of goal reasoning. In cases of multiple vehicles operating collaboratively, this becomes a challenging task and requires coordination between agents. Agent-based decision-making methods have been investigated by AVS as a means to facilitate coordination for functions such as task allocation, resource management and maintaining state information. These techniques form the basis for decisions made by autonomous agents in our context. The potential for applying similar methods for coordination of goals between disparate autonomous systems is an outstanding area of research for AVS. Research in these areas aligns with the organisational focus on autonomy and is critical for enabling autonomous capabilities in the end product being developed by AVS.

Research to be conducted - Conduct research to enable distributed application of goal-based reasoning techniques in autonomous systems being developed by AVS. This will consider:

1. The inclusion of appropriate agent-based distributed decision-making methods to support distributed goal reasoning processes.
2. The application of distributed goal-based reasoning to facilitate alignment of goals within agent federations (e.g. conflict resolution).
3. Mechanisms for performing distributed goal-reasoning, enabling newly formed goals to inform task allocation (distributed action assignment) and resource management (distributed resource sharing) functions in a federation of agents.

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23. Develop methodology for creating 3D-printable solid fuel propellant geometrics with tailored progressivity

Division: Weapons & Combat Systems | Duration: 5 months | Start Date: 2018

3D printing has the potential to create step changes in performance for solid fuel propellants used in both guns and rockets. The geometry of the propellants plays a key role in their performance, and conventional methods of manufacture limit the geometrics able to be produced and therefore their performance. 3D printing will allow more complex and novel geometrics to be created leading to greater performance that can be specifically tailored for a given application.

Research to be conducted – There are two key areas of focus for this project:

1. Develop an understanding of propellant grain regression for the arbitrary geometries.
    a. Interior ballistic modelling has been performed for some candidate geometries, but the geometries are limited as analytical equations have been used for the propellant regression. More complex geometries required for greater performance necessitate a numerical approach to determining regression profile.
2. Research and propose methods for creating classes of propellant geometries for a given gas generation profile.
    a. Tailored gas generation rates can be determined via a deconvolution method for a defined gun/rocket system to achieve a desired performance objective. Translation of the gas generation rates into viable 3D printable geometries remains a key challenge in the optimal exploitation of this technology.