University Defence Research Collaboration in Signal Processing, Phase 3 Application Theme: “Acoustic Signal and Information Processing in the Underwater Environment”

Call for proposals

Overview

Closing date: 19th August 2019

Funding Available: Up to £1.2M

How to apply: Full proposals (not more than 30 pages), sent to udrc@dstl.gov.uk.

These must include:

- Detailed description of the approach(s) and how it addresses the Call
- CVs of each member of the team, team structure and team roles
- Plan and cost breakdown
- Risks (technical and programmatic)

Assessment Process: Applications will be sent to expert reviewers selected by Dstl. Proposals will be reviewed under the assessment criteria detailed in this document and all applications must provide the necessary information requested in this document.

Reviewers will be referred to this document as part of their assessment.

Key Dates:

Activity	Date
Deadline for proposals	*Monday, August 19th 2019*
Funding decision	*Monday, September 16th 2019*
Award start date	*Monday, October 14th 2019*

Additional information: The project is expected to be of up to three years' duration. There is no limit on the number of submissions from individual organisations; institutional statements of support are not mandatory for this Call.

Contacts:

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1 Summary

The UK Ministry of Defence (MOD) is seeking to fund research at UK universities on the topic of *Acoustic Signal and Information Processing in the Underwater Environment.* Indicative funding and timescales for the project are £1.2m for a single project of up to three years duration. If not already so, the successful applicant will become a member of the University Defence Research Collaboration in Signal Processing (UDRC) and is expected to participate in, and benefit from, that research community. More detail on the UDRC can be found at http://mod-udrc.org.

The Defence Science and Technology Laboratory (Dstl) will nominate reviewers to undertake peer review assessment of proposals.

2 Background

This Call is part of the third phase the UDRC. This programme proceeds in stages (see Figure 1). The first stage, for which funds were assigned in May 2018, was the *Underpinning Signal Processing* (USP) consortium grant to undertake research into fundamental principles and coordinate wider activities under the title "**Signal Processing in the Information Age**". The USP consortium has a role in coordinating the community, and applicants to the current Call are expected to work with that consortium (see http://mod-udrc.org). In addition to the USP research there are several *Application Theme* projects. This call solicits proposals for one of those Application Themes.

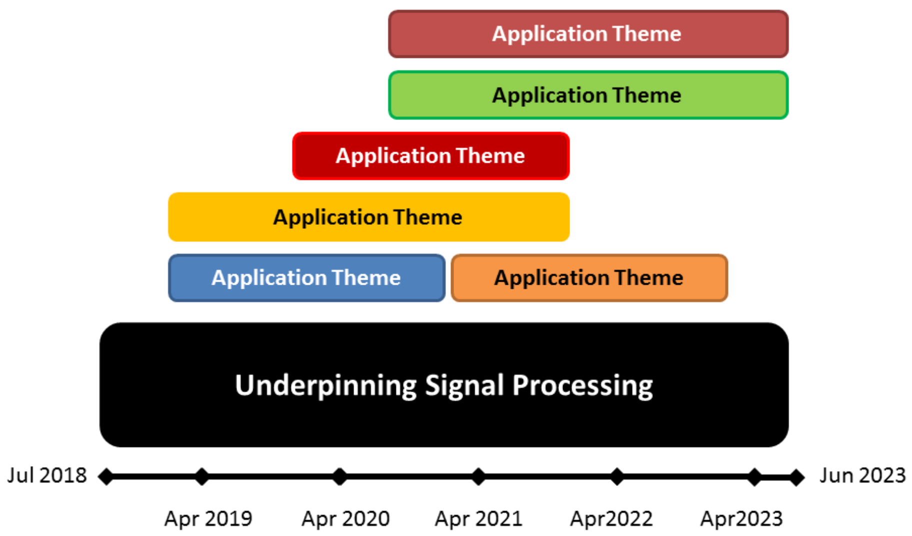

Figure 1: The UDRC phase 3 model showing the relationship between application themed projects and the underpinning consortium (actual timelines may differ depending on number funded and timings of Calls). Note that while the start and end dates for the Underpinning Signal Processing block are broadly correct, those for the Themes are purely illustrative.

3 Scope of the Call

This Call invites applications on the topic of active and passive signal and information processing in the underwater environment. Up to £1.2m is available for a project of up to three years duration. The Award is expected to start and end within the lifetime of the USP consortium grant and may have a role in exploiting research from it.

4 Research Themes

Dstl have identified several *Technical Challenges* of interest, grouped into three *Research Themes*. Proposals should describe how their research will address each of these Research Themes. For convenience we also outline the Technical Challenges in Annex 1 to this Call. These describe specific issues faced by MOD in the area of underwater signal processing. The Technical Challenges can either be treated as the core problems to be addressed, or as indicative problem examples. Applications describing research based on either approach (or a mix) are all equally acceptable. The Research Themes are summarised in the following three sub-sections.

4.1 Research theme 1: information processing

This theme concentrates on fusion, performance metrics, automated tracking and the fundamental properties of signal processing techniques applied to problems associated with underwater targets and acoustic signals of interest.

Advances in acoustic sensor data and information fusion, registration and automated tracking, are sought in this theme. This research area is relatively mature so the advances should aim to be highly relevant to problems and difficulties encountered in the underwater domain. Some of the difficulties include: moving and dispersed fields of different types of sensor, intermittent and variable signals of interest, intermittent sensors and acoustically noisy conditions.

With new underwater acoustic signal processing may come novel ways of presenting sonar data to a naval operator. Research into developing metrics to quantify the performance of *traditional* and new sonar displays is required. The challenge is to find metrics that allow comparison of quite different display types, without including the operator as part of the ‘system’ being measured.

The range of signal processing techniques relevant to underwater acoustics is large, with new techniques being reported frequently. A try-and-see approach is usually the most common method of discovering the utility of a given algorithm or technique, to underwater acoustic signal processing. Rather than continue with this inefficient approach, research is desired to try to understand if there exists a reduced set of fundamental properties of a given set of techniques that make them either good or bad performers, for underwater acoustic signal processing.

4.2 Research theme 2: optimised and adaptive sonar

The principal focus in this theme is on-the-fly adaption of one or more aspects of a sonar system, in order to optimise performance. Most of the technical challenges related to this theme (in Annex 1) are concerned with adaption for the underwater acoustic environment. However, adaption and optimisation of multi-static sonar for anti-submarine warfare (ASW) is also of strong interest, as sensors move and/or become intermittent.

How can signal processing be developed to modify active transmission waveforms, adapted to environmental changes? How can the signal processing in sonar self-adjust in order to remove known but interfering signals? What else can Adaptive Beamforming (ABF) be used for other than just to select for the strongest (or second strongest) signal? Can ABF self-reconfigure to change its 'filtering' from one signal of interest to another, or change array gain? How can sonar first estimate the acoustic environmental conditions, then adapt so that some aspect of its function (e.g. transmit waveform, matched filtering detection etc.) is optimised for those conditions? These are some examples of the kind of questions that research under this theme, should address.

4.3 Research theme 3: detection, classification and localisation

Detection, classification and localisation (DCL) are the traditional underwater defence acoustic signal processing issues. Detecting a target with sufficient probability is usually the first task, very often undertaken when the acoustic conditions are challenging. Classification refers to the identification of the target, which may be as loose as 'threat' or 'non-threat', or as precise as the identification of a particular vessel. Localisation usually means finding the relative bearing, the range and, if possible, the depth. Geographical localisation rather than localisation 'relative' to the sensing platform may seem a tempting approach.

Particular issues of research interest are related to the constraints that make DCL such a challenge underwater, and to the targets of common interest in defence. These issues can be summarised as:

- extremely poor signal-to-noise ratio (SNR)
- very short duration signals of interest (SoI)
- short time SoI occurring as single events
- other signals confusing or obscuring the SoI, such as biological noise
- SoI that are a mixture of coherent and incoherent components originating from one localised source
- Changing the sonar settings (for active and passive) to values optimised for the scenario (e.g. time and bandwidth optimisation).
- any combination of the above
- the presence of other objects that may generate confusing returns in active sonar

5 Approach

MOD is looking for a well-rounded, coherent programme of work that consists of a good balance of innovative, challenging research and demonstration of potential applications of this research in defence and security applications. To this end active collaboration and close work with subject matter experts at Dstl and industry partners is strongly encouraged. Cross-disciplinary research is also encouraged. Collaboration between universities is welcomed.

The project is undertaken in pursuance of the advancement of learning through teaching and research. Therefore, publication and dissemination of results in accordance with normal academic practice is encouraged. Dstl will provide guidance throughout the research in the form of direction, critique, military and security state-of-the-art, national security matters, and available data or performance metrics. Whereas Dstl will endeavour to supply suitable data where possible, proposals should not be critically dependant on Dstl-supplied data. Dstl will also endeavour to provide review of publishable material, links to related work strands elsewhere, identification of opportunities for wider dissemination of results and collaboration.

Proposals should be primarily scoped to carry out cutting-edge research. Those which include a large proportion of time or budget on data collection or equipment procurement will be penalised.

While this call solicits defence and security research primarily, MOD also has a duty to provide value for UK prosperity generally. Proposals which identify significant and important exploitation routes in the civil sector will therefore not be penalised.

It is desirable not only to demonstrate, but also to quantify and compare the performance of any techniques or algorithms investigated. The performance subject (e.g. detection) and the metric (e.g. ROC analysis) should be appropriate and where possible, comparative to a suitable currently used approach.

6 Application Process

Eligibility: Applicants must be supported by a UK host university

Number of Awards: 1

Duration of Award: Awards are for up to three years

Funding: Awards are offered on a Full Economic Costing basis. There is no fixed amount awarded and the value of award will vary depending on the host institution. Awards cover the salary of Postdoctoral Research Associates to work full-time, small-scale research expenses, travel expenses, costs towards the time of the Principal Investigator (PI) and Co-Investigators (CoIs) and the host institution's estates and indirect costs. The funding does not cover PhD students or Industry partners.

Feedback: Proposals will go through a peer review stage and then be moderated at a decision conference. Occasionally there is specific feedback from this meeting which may be passed to the applicant.

Further information: For further information on this call, how to apply, and details of the review process please see the contact details at the front of this document.

7 Assessment Criteria

Proposals will be reviewed under the following assessment criteria and all applications must provide the necessary information requested in this call document.

Assessment criteria used to evaluate the proposal

All applications will be reviewed for technical relevance and quality prior to being considered further according to the Research Centre/Group and Linkages criteria.

Assessment Area	Assessment Criteria used to review the application
Scientific Quality and Innovation	The application will be assessed on the following: • The novelty of the proposed work in relation to the context, and the timeliness • Whether the proposed work is ambitious, adventurous, and transformative • How well the multidisciplinary elements of the proposal are integrated • The pathway to impact for the proposed research • How complete and realistic the proposed approach is
Academic Staff, Resources and Management	The application will be assessed on the following: • The CV(s) • Whether the team's expertise aligns with the topic of the call • The balance of skills of the team • The time and commitment proposed • If requirements for Government Furnished Equipment or Information (GFE, GFI) are realistic and whether any work involving human participation is being reasonably proposed

Assessment criteria used to review the Centre or Research Group

Only technically strong applications will be considered for funding. The Research Group/Centre and Linkages criteria will be used to further assess the quality of the application(s).

Assessment Area	Assessment Criteria used to review the application
The Research Group/Centre	The application will be assessed on the following: • The evidence provided of the international standing of the research of the group or centre, including evidence of significant research income and their contribution to the UK and international research landscape

	• The benefit MOD would obtain through funding research at the particular institution • The relevance of the broader research in the group or centre to MOD
Linkages	The application will be assessed on the following: • Applicants are encouraged to provide options that include significant alignment/contribution of other studentship support from the host university (e.g. from EPSRC, institutional funds, other funding sources).

8 Additional conditions

The research institutions within the funded consortium will be expected to claim title to the Intellectual Property resulting from the work and exploit the results. MOD shall have the right to free use of the results for defence purposes. For projects funded by this Award, the investigators may publish the results of the research in accordance with the normal academic practice. However, Dstl’s prior consent to publication must be obtained. There is also a Dstl requirement for quarterly progress reports from the Award, covering the work and successes of the project, together with an annual report.

Annexe 1: Technical Challenges

This annexe outlines some unclassified motivating examples of current MOD interest. By providing these examples we hope to set the context of the research by outlining some of the challenges faced by MOD which this Call seeks to address. These Technical Challenges have been collated by domain experts. A good understanding of the open source state of the art, plus close engagement with Dstl, is encouraged to ensure the proposed work addressing the research themes is new and relevant to these and future technical challenges. A mapping of all the described Technical challenges, into the three Research Themes is shown in the following table.

Information Processing Data fusion for multi-sensor target tracking Develop 'confidence value' metrics for Automatic Target Recognition (ATR) algorithms Autonomous Underwater Vehicle (AUV) navigation performance improvement Automated tracking in sparse, dispersing sensor fields Understanding the properties of the various Machine Learning, Signal Separation and Higher order Statistics techniques Measuring sonar display performance
Optimised and Adaptive Sonar New applications of Adaptive Beamforming (ABF), trade–offs in ABF Active/passive sonar processing/waveforms, adaptive to the environment New shape correction methods, for morphing/moving sensor fields/arrays Optimisation of Time-Bandwidth for multi-static sensing Temporal signal processing
Detection, Classification and Localisation Synthetic Aperture Sonar (SAS) signal processing: Mitigating SAS 'collapse' at low correlation coefficient values Weak signal detection (one—time detection) Iterative matched filter update from active-pulse (SoI) characterisation Measurement/estimation of sonar signal parameters Low Frequency (LF) Active, internal structure identification in the presence of scatterers SAS signal processing: 3D classification Change detection in side-scan sonar

Mapping groups of Research Challenges to the three higher level Research Themes.

A1) Data fusion for multi-sensor target tracking

Several naval platforms having quite different active and/or passive acoustic sensors may be cooperatively engaged in finding and locating a fleeting underwater target, in very low signal-to-noise (SNR) conditions. The data available to be used to find and locate the target can be comprised of quite disparate information, such as: acoustic time series signals, sensor geo-location information, transmission time, time-stamping, underwater propagation information etc. The challenge is to demonstrate a significant step-change in information processing in order to robustly register all the data to enable correct detection and track processing.

A2) Confidence value metrics for target recognition algorithms

Automated Target Recognition (ATR) algorithms exist and their ongoing development is a relatively mature area. However, a robust and widely applicable metric that ATR algorithms can use to quantify their own level of success in identifying a target, does not yet exist. Can an ‘identification success’ confidence value be developed to quantify the ATR performance?

A3) AUV navigation performance improvement

Unmanned underwater vehicles can sometimes exhibit significant offset in track, when repeatedly following the same set of pre-defined waypoints. These track uncertainties can be as much as a few metres, even when the water body is believed to be still (no tides or currents). Is it possible to find a more accurate means of on-board navigation while submerged, which reduces track offsets by a significant proportion?

A4) Automated tracking in sparse, dispersing sensor fields

A sparse and dispersing field of passive acoustic sensors is sometimes used in conjunction with an acoustic transmitter, to track a quiet underwater target. Using all the available information (for example: narrowband and broadband emissions plus active echo returns from the target plus any other suitable information), is it possible to significantly improve as well as automate the tracking, and even predict ahead where the target will be?

A5) Properties of Machine Learning, Signal Separation and Higher Order Statistical techniques

Methods and techniques that can be labelled as one or more of: Machine Learning (ML), Signal Separation (SS) or Higher Order Statistics (HOS), have been researched from time to time within the context of underwater defence acoustic signal processing. The previous approaches have tended towards trying a selected technique or algorithm on a data set and concluding whether it worked or not. Given that there are probably a great many different techniques, with variants and new ones being continually developed, it may be better to try to understand the properties of these techniques, in terms of their effect on performance. This approach might start to pay off if it turns out some properties are generic to groups of these techniques.

A6) Measuring sonar display performance

MOD requires new measures of performance for the new and emerging types of sonar display. Is it possible to find a metric that quantifies the performance of the displays, and can be used to compare performance of quite different display types? It may be necessary to evolve new criteria for performance comparison, in addition to the more traditional ones such as detection or localisation performance.

A7) New applications of Adaptive Beamforming

Adaptive beamforming (ABF) for sensor arrays is potentially a very versatile technique. In addition to current implementations, MOD is looking to understand how wide the range of possible uses of ABF might be. As a guide is it possible to configure ABF to perform any combination of the following?

a) Constant, but operator-selectable, in-beam gain,
b) Automated contact following,
c) Rejection of a user chosen incoherent or coherent signal type, selectable from a library,
d) Managing non-planar or wave-front curvature,
e) Managing a varying geometry array, such as a non-straight line array of sensors,
f) ABF for environmental information sensing (i.e. not for 'strong point source' detection).

In what other ways could ABF be used in the maritime domain?

A8) Active/passive sonar processing/waveforms, adaptive to the environment

The performance of sonar systems is strongly influenced by the properties of the underwater environment. Techniques can potentially be used to improve performance by adapting the sonar system to the properties of the environment. Research is required to investigate passive processing methods and/or active transmit waveforms, which are adapted by the environment to optimise their performance.

A9) New shape correction methods, for morphing/moving sensor fields/arrays

Some types of sensor arrays naturally change shape either through course change by a towing platform (towed arrays) or by sensor dispersal because of tides and currents. A number of challenges result. Beamforming under these changing conditions can be problematic if the sidelobe level and/or the beamwidth and/or the array gain is required to be fixed. It is assumed there comes a point when the array shape has changed so drastically from some assumed ideal that it is impossible to correct. The challenge here is two-fold. Firstly to understand just how far shape correction can be taken. Secondly, what new ways of generating any useful prior knowledge about the array geometry can be considered, to aid the correction algorithms?

A10) Optimisation of Time-Bandwidth for multi-static sensing

A widely separated and moving field of a small number of passive sensors plus one active sensor can be used to detect a quiet target. Assuming the environment is optimal and not part of the problem is it possible to adapt the time and bandwidth parameters to optimise the search task at hand, given the sensing field geometries and sensor capabilities?

A11) Temporal signal processing

Much of the work on ABF is related to adaptive spatial processing to optimise signal-to-noise-ratio (SNR) in the presence of the spatial noise, which is usually assumed to have a Gaussian distribution and to be 'white'. Similar ideas could be applied to the temporal characteristics of the noise, but more realistically assuming the noise is spectrally coloured, partially correlated across the sensor array and non-Gaussian. Is it possible to develop new ways of significantly improving the SNR using adaptive temporal processing?

A12) Synthetic Aperture Sonar (SAS) signal processing

Synthetic Aperture Sonar (SAS) tends to fail dramatically when the ping–to–ping correlation coefficient falls below a threshold because micro–navigation then fails. This is likely to be worse at higher SAS gains (ratio of synthetic to real aperture length). In the limiting case where there is no SAS gain (i.e. just using the physical aperture), the ping–to–ping coefficient has no effect on beamforming. Is it possible to mitigate the sudden onset of failure as the ping–to–ping correlation reduces? One approach might be to gradually reduce SAS gain as the ping–to–ping correlation coefficient decreases to avoid catastrophic failure.

A13) Weak signal detection (one—time detection)

This challenge would normally be regarded as one of the constraints present for many of the other challenges in this call. In underwater acoustics the label “weak” normally refers to a very low signal-to-noise ratio. The additional challenge here is that not only is the SNR very low but the signal of interest (SoI) may be a short time event that occurs only once. Under the assumptions of Gaussian background noise, and a single sinusoidal tone as the SoI, then matched filtering is known to be the optimal detector. However, dispensing with those assumptions may open up research to other ways of detecting weak signals that may perform well enough, whether they are sub-optimal or not. This challenge can be scoped further by focusing on a SoI comprised mainly of narrowband tonals that may or may not have some harmonic relationship.

A14) Iterative matched filter update from active-pulse characterisation

Active sensor systems often use a specific transmission waveform and employ replica correlation on echo returns, with thresholding, as the detector. Adaption of the detection replica in order to improve the correlator output is an attractive signal processing optimisation. Is it possible to develop a method of achieving significant improvements in detection performance by such on-the-fly adaption, in the face of disadvantageous situations such as passing through temperature fronts, extended range (weak echo returns), multi-path and variable noise corruption on the echo returns.

A15) Measurement/estimation of sonar signal parameters

This challenge is a collection of outstanding issues related to obtaining measurement (or estimation) of signal parameters from processed acoustic data, as part of the classification process. The main constraint is that the estimation of these parameters must be made without altering the standard sonar display configurations from those set-ups presented to a sonar operator. Three challenges are of interest to MOD:

1) Is it possible to significantly improve the precision and accuracy of the quantification of narrowband tones?
2) Can a method of quantifying the energy (power) in a broadband signal be developed, where the “broadband” noise originates from a single source and all other noise has been removed from the calculation (including any narrowband tones)?
3) Can interference effects such as Lloyd’s mirror be removed from the narrowband and/or broadband quantifications, to further improve accuracy?

A16) Low frequency active, internal structure identification

Active transmissions are sometimes used to detect small unmoving manmade objects underwater. Is it possible to develop a means of discerning the internal structures of such objects from the echo returns, using low frequency transmissions? The scenario of interest to MOD allows for multiple transmissions, variable transmission type, broadband or narrowband and from multiple aspect angles. The essential constraint is the transmissions must be low frequency.

A17) SAS signal processing: 3D classification

Using the data obtained from a SAS, develop a means of building a 3D image of a given static target. The platform on which the SAS is mounted would be manoeuvred in a circular path around the object in order to obtain the data. This issue has been referred to as "coherent acoustic tomography".

A18) Change detection in side-scan sonar

The challenge is to develop a method of geo-referencing and also geo-rectifying both SAS and side-scan sonar data at the resolution/precision of the sonar image pixels. Subsequent data collection over the same ground can then easily reveal changes, for example subsequent placement of new objects. Sonar images may be subject to shear, rotation, scaling and other morphisms, relative an earlier data set. The 'rectification' process must be capable of rendering a standard projection so that changes can easily be revealed.