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STAR Localization Aids Enhancement Final Report

A Call-Up Under the Noise Monitoring Standing Offer

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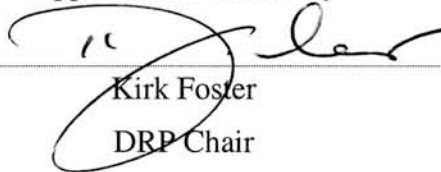
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Scientific Authority

Approved for release by

Kirk Foster

DRP Chair

Abstract

Recent multistatic trials have shown that contact assessment; echo association between receivers; and localization can be complex and confusing tasks, especially in the presence of multiple contacts. Dr. Joe Maksym, a Defence R&D Canada (DRDC) scientist, developed localization algorithms for use with multistatic data that may improve operator performance. This report documents the work done to integrate existing Interactive Data Language (IDL) localization software produced by Joe Maksym into the Software Tools for Analysis and Research (STAR) suite, along with enhancements that provide a quantitative assessment of algorithm performance against real data. Some of Dr. Joe Maksym's localization algorithms were incorporated into STAR. They analytically determine the ellipse-ellipse and ellipse-bearing crossing points, which are used as inputs into a clustering routine, providing an AOP and MPP overlay onto the tactical plot. It was found that the area(s) of probability (AOP) generated by the localization algorithm could produce a clear, deterministic assessment of a contact's location that can be rapidly interpreted by both a computer and a user. This in itself is a significant advantage over relying on an individual operator's qualitative assessment of contact. These localization aids could also prove useful as an operator fixing aid, contact prioritization tool and contact classification tool. They may also be used to support higher-level data fusion and data association algorithms in a track-before-detect paradigm. Though initial results are very promising, it was clear that other versions of the localization algorithm, such as one based on ellipse-hyperbola crossing points, might provide better localizations. A number of suggestions for follow-on work are provided in this document.

Résumé

Des essais multistatiques récents ont démontré que l'évaluation des contacts, l'association des échos entre les récepteurs et la localisation pouvaient s'avérer des tâches complexes et portant à confusion, tout particulièrement en présence de contacts multiples. Dr. Joe Maksym, un scientifique de R&D pour la défense Canada (RDDC), a mis au point des algorithmes de localisation destinés à être utilisés avec des données multistatiques et susceptibles d'améliorer le rendement des opérateurs. Ce rapport décrit le travail accompli pour intégrer le logiciel de localisation IDL (Interactive Data Language ou langage de données interactif) produit par Dr. Joe Maksym dans la suite STAR (Software Tools for Analysis and Research ou outils logiciels d'analyse et de recherche), ainsi que les améliorations qui permettent d'évaluer quantitativement les performances de cet algorithme lorsqu'il est appliqué à des données réelles. Certains algorithmes de localisation mis au point par le Dr Joe Maksym ont été intégrés à la suite STAR. Ces algorithmes déterminent par l'analyse les intersections ellipse-ellipse et ellipse-relèvement; ces points d'intersection sont entrés dans une routine de grappage et permettent de superposer à la visualisation tactique un calque avec la zone de probabilité (AOP) et la position la plus probable (MPP). On a constaté que les zones de probabilité générées par l'algorithme de localisation permettaient d'obtenir

une évaluation déterministe claire de la position du contact, pouvant être rapidement interprétée à la fois par un ordinateur et un utilisateur. En soi, ce résultat présente un avantage significatif par rapport à la situation dans laquelle on doit se fier à l'évaluation qualitative du contact effectuée par un opérateur individuel. Ces aides à la localisation peuvent également s'avérer utiles pour aider l'opérateur à faire le point, et également à titre d'outils de priorisation et de classification des contacts. On peut également s'en servir à l'appui d'algorithmes de fusion et d'association des données de niveau supérieur, dans un modèle de poursuite avant détection. Bien que les résultats initiaux soient tout à fait prometteurs, il est clair que d'autres versions de l'algorithme de localisation, par exemple une version qui serait basée sur les intersections ellipse-hyperbole, pourraient permettre d'obtenir une meilleure localisation. Ce document présente également un certain nombre de suggestions pour des travaux ultérieurs.

Executive summary

Introduction

Current acoustic displays can prevent the operator from intuitively associating contacts between individual receivers and a geographic position. In an ideal scenario, the sonobuoy and source positions would be exactly known and the bearing error would be negligible, so that the ellipses, hyperbolae, and bearing crossings from sonobuoys in contact would exactly correspond to the target position. However, in reality, sonobuoy and source position (as well as bearing) errors can make the tactical plot display a tangled web that is difficult for an operator to interpret. These problems are multiplied when there is more than one contact present.

The objective of this call-up was to attempt to improve operator assessment of multistatic contact through automatic localization and assessment of the contact area of probability (AOP) and most probable position (MPP).

Results

Some of Dr. Joe Maksym's localization algorithms were incorporated into STAR. They analytically determine the ellipse-ellipse and ellipse-bearing crossing points, which are used as inputs into a clustering routine, providing an AOP and MPP overlay onto the tactical plot. In addition, the AOP and MPP statistics are logged automatically to an ASCII file. Other software enhancements include a temporary display fix, a stand-alone tactical plot, a trial summary plot, and the capability to suspend the tactical analysis.

Significance of Results

Multistatic data analysis is a complex task and current information presentation methods can confuse even experience operators. The AOPs produced by localization generate a clear, deterministic assessment of the contact location that can be rapidly interpreted by both a computer and a user. This in itself is a significant advantage over relying on an individual operator's qualitative assessment of contact. Localization aids could also prove useful as both an operator fixing aid, contact prioritization tool and contact classification tool. They may also be used to support higher-level data fusion and data association algorithms in a track-before-detect paradigm.

Future Work

This call-up started the implementation of localization aids into STAR, focusing on ellipse-ellipse and ellipse-bearing crossings. The AOP and MPP generation tools in the STAR can be improved by integrating ellipse-hyperbola, bearing-bearing, and hyperbola-hyperbola crossings. Other ideas for future work include improving error modelling, supporting multiple contacts, automating echo detection, and including tracking algorithms.

Sommaire

Introduction

Les visualisations acoustiques actuelles peuvent empêcher l'opérateur d'associer intuitivement des contacts entre des récepteurs individuels et une position géographique. Dans un scénario idéal, on connaîtrait exactement la position de la bouée acoustique et de la source, et l'erreur sur le relèvement serait négligeable, de sorte que les ellipses, les hyperboles et les intersections de relèvement des bouées acoustiques en contact correspondraient exactement à la position de la cible. Cependant, dans la réalité, les erreurs sur la position de la bouée acoustique et de la source (ainsi que sur le relèvement) peuvent provoquer l'affichage sur l'écran tactique d'un réseau de points confus que l'opérateur a de la difficulté à interpréter. Ces problèmes s'amplifient en présence de plusieurs contacts.

Cette commande subséquente avait pour objectif de tenter d'améliorer l'évaluation par l'opérateur de contacts multistatiques, grâce à la localisation et l'évaluation automatiques de la zone de probabilité (AOP pour area of probability) du contact et de la position la plus probable (MPP pour most probable position).

Résultats

Certains algorithmes de localisation mis au point par le Dr. Joe Maksym ont été intégrés à la suite STAR. Ces algorithmes déterminent par l'analyse les intersections ellipse-ellipse et ellipse-relèvement; ces points d'intersection sont entrés dans une routine de grappage et permettent de superposer à la visualisation tactique un calque avec la zone de probabilité (AOP) et la position la plus probable (MPP). En outre, les statistiques sur l'AOP et la MPP sont journalisées automatiquement dans un fichier ASCII. Parmi les autres améliorations apportées au logiciel, citons l'affichage d'un point temporaire, un tracé tactique autonome, un tracé sommaire d'essai, et la capacité d'interrompre l'analyse tactique.

Importance des résultats

L'analyse des données multistatiques est une tâche complexe, et les méthodes actuelles de présentation de l'information peuvent créer de la confusion, même chez les opérateurs expérimentés. Les zones de probabilité produites par la localisation génèrent une évaluation déterministe claire de la position du contact, qui peut être rapidement interprétée par l'ordinateur et l'utilisateur. En soi, ce résultat présente un avantage significatif par rapport à la situation dans laquelle on doit se fier à l'évaluation qualitative du contact effectuée par un opérateur individuel. Ces aides à la localisation peuvent également s'avérer utiles pour aider l'opérateur à faire le point, et également à titre d'outils de prioritisation et de classification des contacts. On peut également s'en servir à l'appui d'algorithmes de fusion et d'association des données de niveau supérieur, dans un modèle de poursuite avant détection.

Travaux ultérieurs

Cette commande a amorcé la mise en œuvre d'aides à la localisation dans la suite STAR, axées sur les intersections ellipse-ellipse et ellipse-relèvement. Les outils de génération de l'AOP et de la MPP ainsi intégrés à la suite STAR peuvent être améliorés, en prenant en compte les intersections ellipse-hyperbole, relèvement-relèvement et hyperbole-hyperbole. Des travaux ultérieurs pourraient également porter sur l'amélioration de la modélisation des erreurs, la prise en charge de contacts multiples, l'automatisation de la détection des échos, et l'intégration d'algorithmes de poursuite.

Hood, J. and B. Glessing. 2005. STAR Localization Aids Enhancement Final Report. DRDC Atlantic CR 2005-099, Defence R&D Canada - Atlantic.

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1.   Introduction

This final report outlines the work done under Noise Monitoring Software Regional Individual Standing Offer (RISO) No. W7707-032293/A, STAR Localization Aids Enhancements Call-up Requisition No. W7707-04-2604. This work was performed at DRDC Atlantic under the direction of the Scientific Authority (SA), Nicole Collison, from approximately June 2004 to October 2004.

1.1   Overview

Multistatic data analysis is a complex task. Current acoustic displays prevent the operator from intuitively associating contacts between individual receivers and a geographic position. Echoes from different contacts can arrive in varying orders as the receiver positions change. This is due to the complex geometries involved and the often dispersed nature of acoustic receivers, such as sonobuoys. Also, if many contacts are present at one time, it can be very difficult to interpret the web of ellipses, hyperbolae and bearings that appear on a tactical plot as potential contacts to be entered for analysis.

The objective of this call-up was to attempt to improve operator assessment of multistatic contact through automatic localization and assessment of a contact's AOP. This was done using the STAR suite and localization algorithms developed by Joe Maksym, a DRDC Scientist. Dr. Maksym provided IDL code segments to MacDonald Dettwiler and Associates Ltd. (MDA) for integration into STAR, and technical consultation services to ensure that the algorithms were correctly implemented.

This report is broken into five main sections. The remainder of this section provides background on the software used during the call-up. Section 2 provides an overview of the call-up requirements and work performed to meet those requirements. Section 3 documents the data analysis and unclassified results and recommendations. It also provides a high level description of the localization algorithm. Section 4 details software configuration management processes and the versions used for this call-up. Section 5 provides a summary of current software issues.

1.2   Background

The data processing and analysis work was performed using two software suites: STAR and Signal Processing Packages (SPPACS). An overview of the two software suites is provided in the following subsections.

The STAR and SPPACS suites are configuration controlled using the concurrent versioning system (CVS), and issue and enhancement idea tracking is affected using the Bugzilla issue tracking software. CVS is a repository that allows developers to check-in revisions to software and documentation where they are archived in a common database. The tool allows all previous versions of the software to be maintained and aids resolution of new issues, while ensuring that current builds of the software are readily accessible to users and developers alike. Bugzilla is a web accessible database that offers both user and developer input to issues, priorities and solutions. It provides coherent tracking and recording of an issue over its entire lifecycle.

STAR and SPPACS components are documented in a combination of formats, each with their own purpose. Microsoft Word documents are maintained, which describe functionality and algorithms of components. These are primarily intended for the end user. Enterprise Architect (EA) files are maintained, which document software design, interaction and dependencies. EA design information is intended primarily for developers. Hypertext Markup Language (HTML) library documentation is being developed that provides automatic extraction of the routine's Application Programming Interface (API), purpose and description. This documentation is maintained to assist developers in familiarizing themselves with the existing libraries and components, and is intended to support and encourage software reuse. Some users may also wish to refer to this information for use in their own custom applications. SPPACS also provides HTML and main page user documentation for each module.

The most current status of the SPPACS and STAR suites can be found at https://star.iotek.ns.ca. Users are also encouraged to refer to the electronic documentation provided with the software distribution for up-to-date information.

1.2.1 STAR

The STAR suite was developed to support general research and analysis objectives at DRDC Atlantic. The primary objectives of the STAR suite are:

- Provide scientific grade analysis tools that allow for efficient, detailed quantitative and qualitative analysis of a data set.

- Support synergy between DRDC groups and the Department of National Defence (DND) by providing a common software base for analysis. This synergy encourages inter-group communication and simplifies user training, analysis process development, documentation and data portability.

- Support cost and analysis efficiency by providing software reuse and common tools and data formats. Examples of efficiency would be using the output of analysis from one group to feed the inputs of another, or using common software components to lower development cost of several custom analysis tools.

All STAR components are currently implemented using IDL, though the design is not restricted to IDL. The name STAR reflects the generic nature of the software. Applications in the STAR suite are built using a combination of reusable and custom components that meet the requirements of each application. The layered design and common components allow for rapid and logical development of new capabilities. Though currently focused on sonar data processing and analysis, the tools are capable of expanding to meet other analysis and research requirements.

1.2.2 SPPACS

SPPACS is a group of software programs that are based on the C programming language and is implemented on Linux-based Personal Computers (PC). Each program provides a specific processing function and a series of programs can be chained together to create a custom-processing stream using the command line or scripts. The output from SPPACS is stored in DREA formatted data files. SPPACS has slowly evolved to its present day state due to the efforts of several MDA personnel over the last 4 years.

SPPACS has been used to perform a number of mid-trial and post-trial processing functions, such as the post-trial study of multistatic trial data and the mid-trial analysis of the Q265 sonobuoy test trial. SPPACS only performs data manipulation and does not provide an interface to examine the results. The processed data output is often imported into other applications that enable data display and are used to perform the detailed analysis of the results. One example of such an application is the STAR suite.

The SPPACS software suite consists of two types of software. One type is runtime executables that can be used to process DRDC Atlantic data files in a number of ways, including data management and signal processing. Each program performs a specific function and the programs are designed so that they can be used in conjunction to perform more complex processing tasks. The software has proven to be very useful in simplifying data management and sonar processing tasks by providing a set of tools from which to build the necessary processing streams. These streams can be run from the command line or assembled into scripts to perform batch-processing tasks allowing for large amounts of data to be automatically processed. The second form of the software is a group of library functions that can be used by other programs to efficiently perform standard tasks. These library functions are extensively used by the runtime software, but can also used for other applications. There are now three types of libraries. The first are utility routines for performing tasks, such as header manipulation and command line parsing. The second are signal processing modules termed signal processing library (SPLIB). These are low-level modules, each performing a low level signal-processing task. A new SPPACS module typically consists of one or more SPLIB modules linked together with an SPPACS user interface. The final library type is a sonar processing module termed sonar library (SONLIB). These are more complex modules that combine several SPLIB modules to create a complex sonar module, such as passive processing. Separating the SPLIB and SONLIB modules from SPPACS generated more generically reusable software. SPLIB and SONLIB are independent of the data header format, timestamping method, etc. and are suitable for integration in real-time processing systems.

SPPACS is also supported by a set of signal processing libraries known at the Fastest Fourier Transform in the West (FFTW). These free, open-source libraries provide optimized signal processing functions helping to ensure that the SPPACS software runs as efficiently as possible, while providing a significant reduction in coding effort.

2. Work Overview

This section presents an overview of the tasked work and a summary of the work that was completed. The development requirements for this call-up are listed in Table 1. Some data processing and analysis was also performed during this call-up. A summary of the unclassified portions of that work is provided in Section 3. The work completed under this call-up was included in STAR Release 4.5.1.

A detailed description of the technical aspects related to the work performed under this contract can be found in the primary STAR reference, "The Software Tools for Analysis and Research Data Analysis and Technical Manual - Revision 1" [R-1]. This document is located at (/usr/local/atools/acoustics/src/analysis_tools/ documents/STAR_analysis_technical_manual.doc) on Whale. This document provides details, such as the algorithms used to perform the various analysis measurements, and recommends a complete analysis process that can offer significant improvements in efficiency to DRDC Atlantic. Each complex program (i.e., Energy Time Indicator [ETI] analysis, power spectra analysis display, automatic reanalysis, etc.) is started using a script. These scripts provide a quick and easy way of launching the analysis applications. See "The Software Tools for Analysis and Research Data Analysis and Technical Manual – Revision 1" Section 7.6 [R-1]for more information on how to use and customize these scripts.

As this contract was restricted by a limitation of expenditure and the contract objectives were ambitious, not all requirements were completely implemented, though substantial progress was made. MDA worked with the SA to ensure that the call-up deliverables were satisfactory allowing trade-offs to be made, as required.

Several accomplishments described in this contract rely on work conducted under other contracts. By sharing a common code base, several contracts were able to reduce the amount of effort required to meet their individual requirements and realise more overall benefit with the available funds.

The following work was completed to address the requirements listed in Table 1:

Table 1. Contract Requirements

REQUIREMENT TITLE	ASSOCIATED REQUIREMENTS
Localization Overlay Generation	The contractor shall enhance the Tactical Plot module in STAR to compute and plot an Area of Probability (AOP) and most probable position based on multistatic contact data that produces bearings, ellipses and hyperbolae. The SA will supply the algorithms and prototype software for integration. This may include localizations from single and multi-sensor contact. The activation and deactivation of the overlays and the software computations shall be user selectable.

Table 1. Contract Requirements

REQUIREMENT TITLE	ASSOCIATED REQUIREMENTS
Localization Comparison	The contractor shall automatically compute the difference between the target of interest's position and a computed localization position and some SA/Technical Authority (TA) defined measure of the target position relative to the computed AOP. Log entries shall be created for all available contacts using a non-interactive script. Log entries shall be able to be parsed into the in memory database. A query shall be generated that allows the user to search for localizations within a given time range for a given processing method.
Tacplot Enhancements	The contractor shall implement a zoom-in and zoom-out option for the tactical plot that allows the user to zoom based on a mouse-selected point. The available zoom factor will be defined by the SA during the requirements analysis. The contractor shall implement a restore function that restores the tactical plot area to the default. The contractor shall implement a re-center function that re-centers the tactical plot on a user selected position. The contractor shall implement a measurement select function that pop-ups a window that displays the selected position along with the bearing and distance to the source and the target of interest. The user shall have the option to log a manual fix based on the automated localization log entry from this selected position. The contractor shall implement a measurement select function that pop-ups a window that displays the bearing and distance between two user selected positions. The user shall have the option to select which targets have fix information displayed for them. This shall be implemented in the contact model to ensure that all displays reflect this change.
Fixing Enhancements	The contractor shall change Echo and False alarm measurement to temporarily display a fix on the tactical plot before the contact is confirmed. If the contact is not confirmed then the temporary contact shall be removed. The contractor shall implement the option to display all false alarms in the database for the requested data time range using a dashed line or different color, as directed by the SA. The contractor shall implement the option to pad the time range used to query for fix information allowing a small amount of time to be displayed on an acoustic display with fixes beyond that time range displayed on the tactical plot.
Stand Alone Tactical Plot	The contractor shall implement a stand-alone version of the tactical plot with appropriate data navigation features (receiver, time [ping], etc.). This plot will function as the main analysis window and shall only require access to the tactical database and not the processed data files. The tactical plot shall be enhanced to show the current time range used for the plot.
Trial Summary Plot	The contractor shall implement a trial summary plot that plots the track of all sources, targets, receivers, wrecks, clutter and tracks (for example radar contacts) between two user selected times.

Table 1. Contract Requirements

REQUIREMENT TITLE	ASSOCIATED REQUIREMENTS
Tactical Suspend Analysis	The contractor shall implement a tactical suspend analysis function that copies the current tactical database into a temporary user variable for manual or non-STAR application use.

2.1   Localization Overlay Generation

An overlay was added to the tactical plot to display the AOP and most probable position (MPP), as shown in Figure 1. Rather than just show the AOP and MPP, the user can select from any or all of:

- Fixes: Bearing – Ellipse crossing points and a fix AOP for each crossing point generated from the modeled bearing error and range error. The crossing point is shown in red with the AOP shown in light green.

- Crossings – Selected Ellipse-Ellipse crossing points shown as a green dot. Ellipse crossings are filtered by probability, which is computed using each echo Signal-to-Noise Ratio (SNR) and the computed bearing.

- Clusters – Red dot and AOP, shown in light green, identifying the computed MPP and computed error estimate.

The details of these algorithms remain as provided by Joe Maksym, except that STAR adds a sonobuoy bearing variance of 7.5 degrees. This models the sonobuoy induced errors, such as the compass crossings, removing bearings that are below a certain probability threshold. Algorithm details will not be documented in this report, though a high-level description of the algorithm is provided in section 3.1.

The AOP overlay can be enabled/disabled from the tactical plot settings dialog. In addition, the various localization options previously discussed can be enabled/disabled from the localization settings dialog shown in Figure 2. The localization settings dialog is accessible from the tactical plot settings dialog.
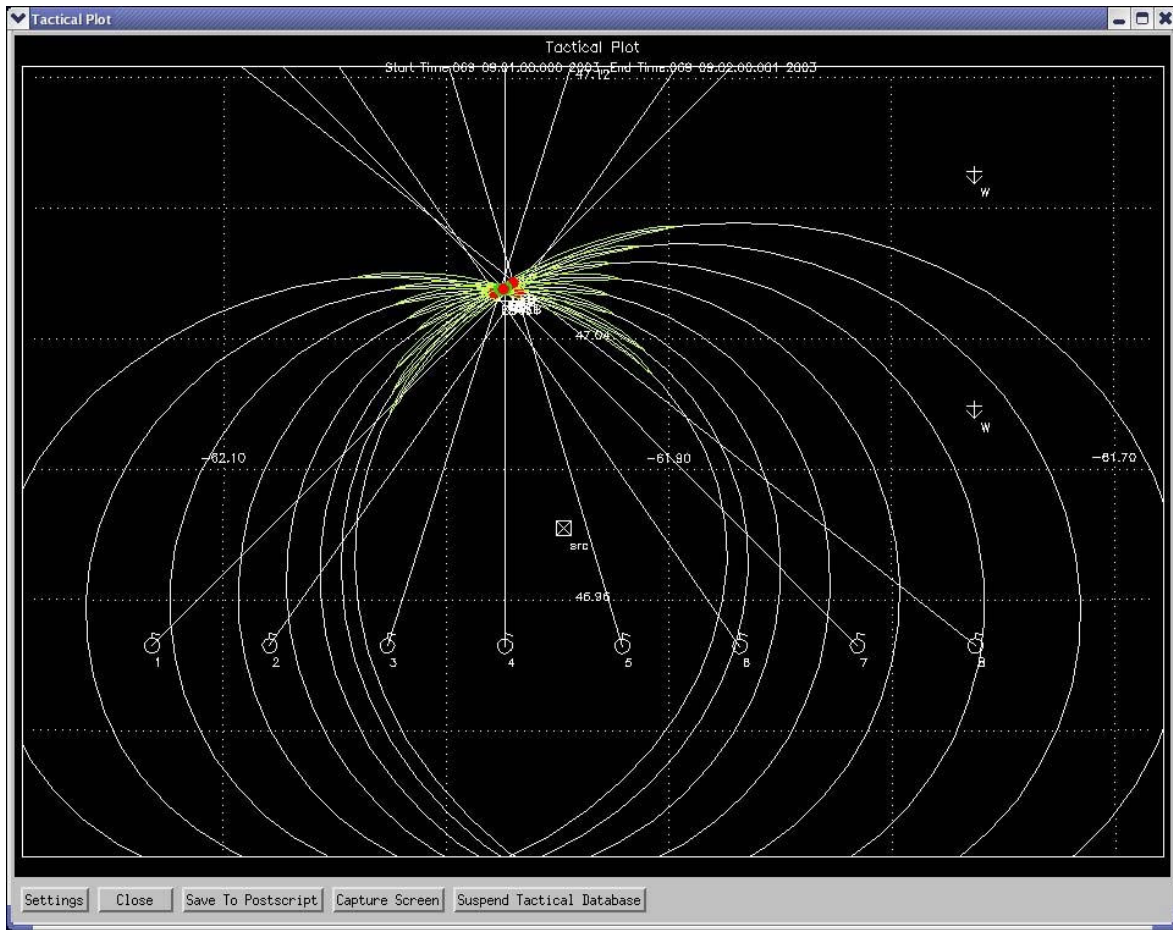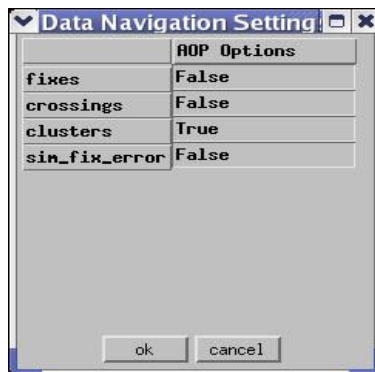
Figure 1. Localization Overlay

Figure 2. Localization Settings Dialog

2.2 Localization Comparison

An analysis application called "AOP Calculate" was created to log AOP information to an American Standard Code for Information Interchange (ASCII) based file similar to the trial logs. This application can be run several times with different settings to help assess AOP performance and determine optimal algorithm settings. During execution, AOP fix error and the ratio of the fix error to the AOP size is logged amongst other parameters to provide a quantitative assessment of AOP performance. Parsers were created to read the AOP information from the log files into the tactical database. Detailed information on the log entry contents and format can be found in [R-1].

Query routines were not written to allow the user to search for localizations within a given time range for a given processing method. This functionality was not required given the operation of AOP Calculate.

2.3 Tacplot Enhancements

As call-up funding was less than initially estimated, the SA and Project Manager (PM) agreed that all tactical plot enhancement requirements would not be implemented.

2.4 Fixing Enhancements

A temporary display fix for echo and false alarm data was added to the analysis windows. This feature allows the user to mark a fix that becomes visible on the analysis window and tactical plot, if open at the same time. These temporary markings occur before the user is cued to confirm the fix, so that they have the opportunity to prevent insertion in the database, or improve on the classification.

False alarms have been added to the tactical plot and are shown as dashed lines. Only bearings and hyperbolae are shown as false alarms and are not associated, preventing hyperbolic computation.

Functionality was added to the data models to allow them to pad extra time on either end of the data request. This allows the tactical plot to display more fix information than is on the boundaries of the data request. This is especially useful when zooming in, as it can be used to prevent loss of neighbouring fixes and main blasts, which are needed for ellipse drawing.

2.5 Stand-Alone Tactical Plot

A stand-alone tactical plot was created to allow the user to view only tactical information for a specified time range. The data navigation toolbar was integrated with the stand-alone tactical plot to allow the user to navigate through the data by time, main blast and receiver. In addition, the tactical plot was enhanced to display the current time range used for the plot.

2.6   Trial Summary Plot

An example of the trial summary plot is shown in Figure 3. It was created to display the track of all sources, targets, receivers, wrecks, clutter and tracks for the duration of the trial. This base functionality should be integrated into the Trial Summary application generated under another call-up. Integration would provide more control over time ranges as well as controlling which data items are shown on the screen.
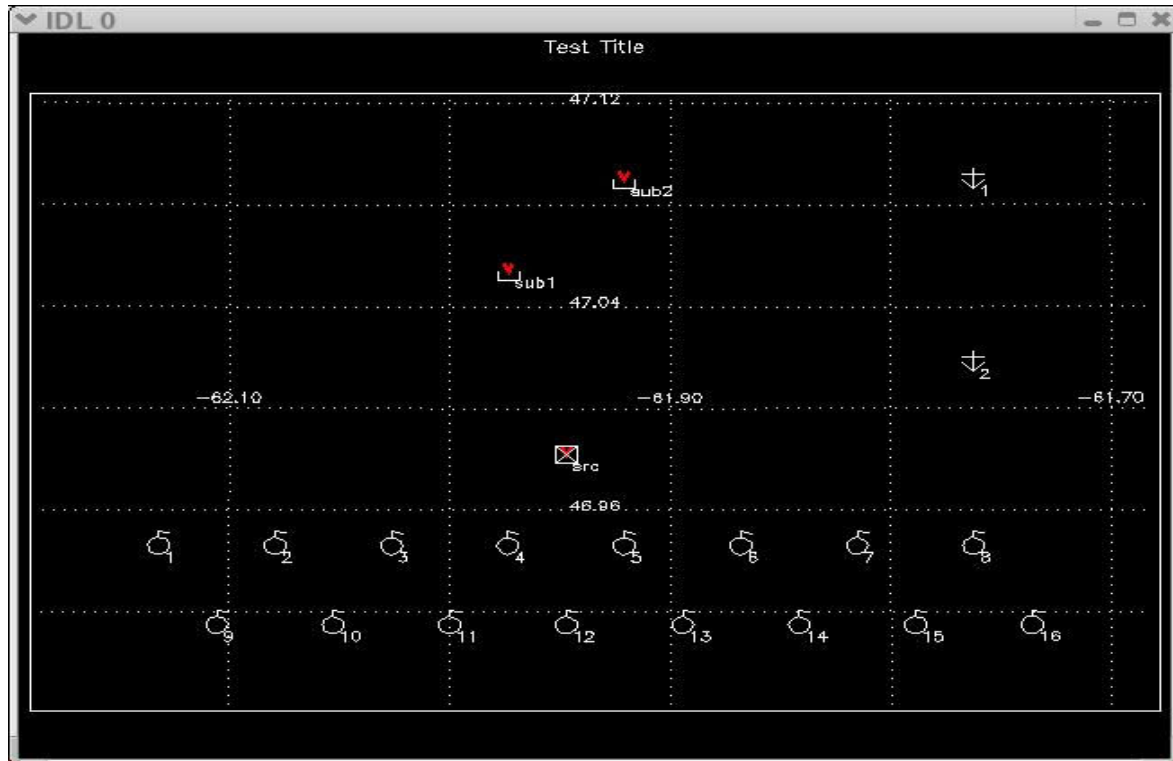
Figure 3. Trial Summary Plot

2.7 Tactical Suspend Analysis

A tactical suspend analysis feature was added to the tactical database to allow the user to save a snapshot of the tactical database to an offline cache. It is accessible from the IDL shell via a function call (i.e. data=get_tactical_db_data()). Users can then use custom applications or the command line to view and manipulate database information. The database is loaded as an IDL structure and its contents and substructure contents can be viewed using the IDL help command with the /structure keyword, such as:

help, <variable>, /structure.

3. Algorithms and Data Processing

This section provides a high-level description of the localization algorithm and describes processing that was performed on synthetic and real data. Synthetic data was used to confirm the correct operation of the software, while real data was used to evaluate algorithm performance under realistic conditions. Due to the security classification of the real data, only cursory information will be provided in this report.

3.1   Localization Algorithm

3.1.1 Original Algorithm

The localization software provided by Joe Maksym was implemented by performing a number of sub-tasks:

1. Main blast arrivals and echoes are automatically detected. The algorithm limits the number of detections permitted for each receiver (sonobuoy).

2. The bearing-ellipse crossing point and an AOP are computed for each detected echo.

3. The ellipse-ellipse crossing point is computed for each pair of echoes. Between zero and two crossing points can be computed for each pair. The probability that each crossing point is related to a valid fix is adjusted using the difference between the fix computed in step 2, and the ellipse-ellipse crossing point and the expected variance of the bearing, modeled as a function of SNR.

4. All ellipse-ellipse crossing points that exceed a specific threshold are passed into a clustering algorithm that returns the N-most probable clusters and their associated error. N is an integer defined by the user.

The user can optionally select a Monte Carlo simulation, which adjusts the sonobuoy positions by a given error and repeats the previously mentioned steps.

Steps 1 and 4 are generic steps that could be used for other localization cases, such as bearing or hyperbola crossings. Similar algorithms for other localization methods can replace steps 2 and 3. Bearing and hyperbola fixing methods may work equally well for passive and transient cases.

3.1.2 MDA Modifications

It was not the intent of this call-up to significantly modify the provided software, but rather to integrate it into an existing data analysis application for evaluation. Thus, the previously mentioned algorithm was only adjusted slightly. This section describes those adjustments.

Three minor algorithm modifications were made.

- First, step one of the algorithm was removed, as user selected echoes and main blasts were available and it was desirable to use those echoes for localization.

- Next, an additional 7.5 degrees was added to the computed bearing standard deviation to account for buoy error. Without this increase, many valid ellipse-ellipse crossing points were being ignored in real data, as the post probability of the crossing point was too low (note step 3). This change is realistic given the sonobuoy specification and performance on data.

- Finally, the probabilities output from step 3 were changed so that crossing probability was not normalized. As provided, the probability was the normalized probability that a crossing point was the crossing point of interest, given that one of the points was known to be of interest. This was changed to be the probability that the point was of interest. This change allowed both points to have low probability if the associated bearings were very far from both points. This seemed to work better for cases where non-target related echoes were included.

The contract budget did not allow for a major rewrite of the scientific-grade software that was provided. Despite this, it was highly desirable to produce a localization module that had well designed external interfaces and was modular. This was done by wrapping the provided elelr_event handler and placing it into a subclass of a localization class. The following functionality was extracted from the main function:

- All error modeling was removed and handled externally. These models are dependent on the processing performed, receiver localization system used, etc. and are likely to change in ways unrelated to the localization itself. Examples of error modeling are bearing error, receiver position error, and time measurement error.

- The existing source position, receiver position, echo and main blast database entries were used to provide inputs to the localization algorithm.

- The localization module was changed to output a generic AOP. This structure can be used to describe any form of fix information.

- A settings dialogue was created and associated to the localization class to allow Graphical User Interface (GUI) modification of algorithm parameters.

This new design allows for other localization algorithms, both passive and active, to be quickly implemented and to leverage off of this initial work.

3.2   Data Processing

Much of the data processing had already been completed as part of other contracts. For this call-up, only synthetic data was fully processed to validate the software and algorithm. Previously analyzed data was browsed on screen to visually inspect the algorithm performance and make final tweaks to algorithm parameters. Once visually satisfied by the result, an automatic script was run to measure and log each individual fix and AOP for quantitative analysis. The details of these results cannot be discussed further due to the security classification of that information.

3.3 Suggestions for Improvement

As often occurs during call-ups of this nature, a number of questions and ideas were generated. The most significant ones are documented here in the form of suggestions for further improvement and study.

3.3.1 Compare Different Algorithm Variations

The localization algorithm used for this contract was limited in that it only considered ellipse-ellipse crossing points in generation of the AOP. Visual inspection of the results, on top of raw fix information, suggested that hyperbolae-ellipse crossing should also be included. In fact, inclusion of all crossing points may even prove useful though it could overwhelm the current clustering algorithm. The ellipse-ellipse and bearing-bearing localization methods are being implemented in STAR for passive processing as part of another call-up.

3.3.2 Improve Input Data Error Modeling

Algorithms, such as the localization algorithm discussed here, perform best when provided with accurate models of the input data, including error or variance in measurements. We should work to identify sources for accurate inputs or develop models appropriate for operational systems, such as the Modular VME Acoustic Signal Processor (MVASP). For example, the Sonobuoy Positioning System (SPS) will most likely be able to produce an estimate of buoy position error.

3.3.3 Improve Fix Error Modeling

Dr. Maksym provided a Monte Carlo simulation that provides an excellent visual representation of fix error due to sonobuoy position error. This could be expanded to include other elements of the fix error as part of a global AOP error estimate. It could also be further processed to output a quantitative analysis of fix error, rather than just a visual one. Quantitative AOP estimates provide much better information to tactical commanders than a simple fix position with limited error estimates.

3.3.4 Expand to Support Multiple Contacts

The current localization algorithm has been tuned assuming one significant contact. In many cases more than one contact will be present at a time. It may be possible to quickly refine the algorithm to iteratively exclude the most significant contact(s) and eventually localize many contacts. Other optimizations, such as an overlapping grid search, may help with multiple contacts. Regardless of the eventual effectiveness of this simple approach, lessons will be learned and ideas generated to produce a useful algorithm for many contacts, as would be seen in a high clutter environment.

3.3.5 Attempt Automatic Echo Detection

The subject localization problem could provide the most benefit if it was used to aid classification and automatic association of data on acoustic displays to a geographic position. Once a number of possible contacts are produced, they could be prioritized (by associating them with geological features, known contacts, etc.) and even tracked, reducing operator workload and improving the quality of fix output.

3.3.6 Track Contacts

Once localizations have been produced they can be assigned to tracks and used to generate tracks. These tracks can be used to improve classification of contacts by resolving motion. This is a critical contact versus geological echo classification feature, whose solution would permit better association with other intelligence data, such as radar contacts. Once again track information can be used to help prioritize contacts for investigation and rapidly provide better information to tactical commanders.

3.3.7 Improve Signal Processing and Feature Estimation

During replay on real data, a number of significant errors in data inputs affected the results. Some of these errors could possibly be reduced or mitigated by employing better signal processing and feature estimation methods. The errors that have a significant affect on operational outcomes should be improved. For example, in some cases the bearings could be significantly in error. A number of improvements to beamforming and bearing estimation have been suggested. This could be done very quickly using STAR.

3.3.8 Improve Software Design

Much of the current software is in the same state as provided by Dr. Maksym. This software is scientific grade and could be improved to provide better modularity and reuse, as other localization methods are implemented. This improved software design could also serve as a basis for operational implementation, should the requirement arise. The code should be changed to clearly separate the algorithm steps and define reusable interfaces.

3.3.9 Improve Summary Plot

As mentioned in section 2.6, this base functionality should be integrated into the Trial Summary application generated under another call-up. Integration would provide more control over time ranges as well as controlling which data items are shown on the screen.

3.4 Conclusions

Many of the significant conclusions are left to the SA to state in analysis reports, but some high-level statements are warranted here, while it is recommended that the reader discuss detailed issues with the SA, Nicole Collison and TA, Joe Maksym.

As discussed more thoroughly in section 1.1, multistatic data analysis is a complex task and current information presentation methods can confuse even experience operators.

The AOPs produced by localization generate a clear, deterministic assessment of the contacts location that can be rapidly interpreted by both a computer and a user. This in itself is a significant advantage over relying on individual operator's qualitative assessment of contact. Localization aids could also prove useful as both an operator fixing aid, contact prioritization tool and contact classification tool. They may also be used to support higher level data fusion and data association algorithms in a track-before-detect paradigm.

4. Maintain Configuration Management

STAR and SPPACS are maintained using CVS. The most recently released version is maintained and bug fixes are applied to that version, as required, ensuring that a stable release is always available. Simultaneously, software enhancements are applied to the development version and bug fixes are merged with this version. Once a call-up nears completion, or a release of the software is otherwise required, a new release version is branched off of the development stream for final integration, release testing and delivery.

STAR (includes SPPACS) release 4.5.1 (tag star_release_4_5_1) was created under this contract to serve as a baseline while the analysis work was being conducted. This allows development to continue on the trunk of the distribution. The trunk usually contains newly implemented software, which may not be stable enough to allow for operational use.

5. Track Software Issues

Defect Tracking Systems allow users to keep track of outstanding bugs in their product effectively. STAR and SPPACS issue tracking is performed using a web accessible tool called Bugzilla. This tool can be accessed using a secure web interface at https://star.iotek.ns.ca. Once the appropriate security procedures, detailed on the web page, have been followed, users and developers can use this site to add, view or modify issues related to the software packages.

A breakdown of the current issues for the STAR and SPPACS distributions are shown in Table 2. The total number of unresolved issues is shown in the NEW/ASSIGNED/ REOPENED column. The total number of opened issues is broken into two classes of severity. Issues classified as BLOCKER/CRITICAL/MAJOR are issues that should be addressed in the short term. Blockers are always addressed immediately to ensure that the user community can continue with their work. Issues classified as NORMAL/ MINOR/TRIVIAL are issues that can be dealt with in the long term.

Table 2. Distribution Issue Summary (07/02/2005)

PRODUCT	NEW/ASSIGNED/ REOPENED (TOTAL)	BLOCKER/CRITICAL/ MAJOR	NORMAL/MINOR/ TRIVIAL
SPPACS	35	1	34
STAR	53	4	49

The following gives a more detailed description of the SPPACS BLOCKER/ CRITICAL/MAJOR column:

- Issue # 284 (major) fails DAT32 byteswap case. The utility is attempting to read the extra gains using the original header, which may be in a different byte-order than the platform.

The following list gives a more detailed description of the STAR BLOCKER/ CRITICAL/MAJOR column:

- Issue # 193 (critical) tacplot does not cleanup before exiting. The work around for this issue is to run heap_gc after the analysis window has closed.

- Issue # 107 (major) problems capturing close button. A solution exists for this but has only been incorporated into the tactical plot.

- Issue # 295 (major) capture screen doesn't work correctly. The Capture Screen button does a screen capture on the analysis window and not the tactical plot. If the tactical plot is closed and reopened this will work. A fix is available in the next release.

- Issue # 329 (major) overlays need to be optimized. The tactical plot is too slow (on Bender). To load on Bender (dual P4- 1GHz), it takes approximately 20 seconds the first time and 15 to 20 seconds thereafter.

6. References

1. The Software Tools for Analysis and Research Data Analysis and Technical Manual – Revision 1, (Whale: /usr/local/atools/acoustics/src/analysis_tools/documents/ STAR_analysis_technical_manual.doc) STAR Release 4.5.1

List of symbols/abbreviations/acronyms/initialisms

AOP	Area of Probability
API	Application Programming Interface
ASCII	American Standard Code for Information Interchange
CVS	Concurrent Versioning System
DND	Department of National Defence
DRDC	Defence R&D Canada
DREA	Defence Research Establishment Atlantic
DRP	Document Review Panel
EA	Enterprise Architect
FFTW	Fastest Fourier Transform in the West
GUI	Graphical User Interface
HTML	Hypertext Markup Language
IDL	Interactive Data Language
MDA	MacDonald Dettwiler and Associates Ltd.
MPP	Most Probable Position
MVASP	Modular VME Acoustic Signal Processor
PC	Personal Computer
PM	Project Manager
RISO	Regional Individual Standing Offer
SA	Scientific Authority

SNR	Signal-to-Noise Ratio
SONLIB	Sonar Library
SPLIB	Signal Processing library
SPPACS	Signal Processing Package
SPS	Sonobuoy Positioning System
STAR	Software Tools for Analysis and Research
TA	Technical Authority

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Recent multistatic trials have shown that contact assessment; echo association between receivers; and localization can be complex and confusing tasks, especially in the presence of multiple contacts. Dr. Joe Maksym, a Defence R&D Canada (DRDC) scientist, developed localization algorithms for use with multistatic data that may improve operator performance. This report documents the work done to integrate existing Interactive Data Language (IDL) localization software produced by Joe Maksym into the Software Tools for Analysis and Research (STAR) suite, along with enhancements that provide a quantitative assessment of algorithm performance against real data. Some of Dr. Joe Maksym's localization algorithms were incorporated into STAR. They analytically determine the ellipse-ellipse and ellipse-bearing crossing points, which are used as inputs into a clustering routine, providing an AOP and MPP overlay onto the tactical plot. It was found that the area(s) of probability (AOP) generated by the localization algorithm could produce a clear, deterministic assessment of a contact's location that can be rapidly interpreted by both a computer and a user. This in itself is a significant advantage over relying on an individual operator's qualitative assessment of contact. These localization aids could also prove useful as an operator fixing aid, contact prioritization tool and contact classification tool. They may also be used to support higher-level data fusion and data association algorithms in a track-before-detect paradigm. Though initial results are very promising, it was clear that other versions of the localization algorithm, such as one based on ellipse-hyperbola crossing points, might provide better localizations. A number of suggestions for follow-on work are provided in this document.

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Software Tools for Analysis and Research (STAR), TMAST02, localization, multistatic, frequency modulated, tactical plot

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