PAMGuardIV: Final Report from SMRU Ltd

Prepared by SMRU

E&P SOUND & MARINE LIFE PROGRAMME

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Report

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PAMGUARD IV Final report

Doug Gillespie, SMRU, April, 2008

Report from SMRU Ltd under Schedule No 02 (07) to the letter agreement dated 5 January 2007 between SMRU Ltd and the International Association of Oil & Gas Producers (OGP).

1 Summary

The PAMGUARD IV proposal and work schedule contained three work packages

- WP1 Core Architecture
- WP2 Maintenance
- WP3 Workshop

As part of PAMGUARD IV SMRU Ltd were contracted for a total of 4.5 months of Doug Gillespie's time to work on WP1 (3 months) and WP2 (1.5 months) and agreed to assist and participate at the workshop using time allocated to WP1 and WP2.

This final report to JIP details the work conducted at SMRU under each of the above tasks. All of this work will have previously been reported in monthly reports to JIP. The purpose of this document is to provide a single clear overview of accomplishments at SMRU and to show how the various tasks come together to enhance the overall operability and functionality of PAMGUARD at the close of this phase in its development.

As part of WP1 SMRU have added considerable functionality to the core architecture of PAMGUARD, making it easier for the user to configure modules and inter-module dependencies (section 2.2.3). SMRU have also added a number of enhancements to core modules such as hydrophone configuration which now more accurately predicts the locations of hydrophones based on vessel movement and also contains software 'hooks' for the use of data from depth and other location sensors (section 2.2.2). A number of improvements have also been made to the displays (section 2.3) including a more accurate depiction of the vessel location, pop up comments and a key of symbols used to a display of the airgun location and the mitigation zone around the guns.

Also under WP1, a number of new modules have been written (section 2.4). The database interface has been rewritten to make selection of different database types possible and to simplify the database interface to the programmer. Four new sound processing modules have also been added.

Under WP2, as the primary author of most of the PAMGUARD core software (the parts which configure PAMGUARD and move data between the various modules) as well as the click and whistle detectors and the graphic displays, and also as a key user of PAMGUARD software (see below) SMRU have uncovered and fixed large numbers of bugs in the software.

Also under WP2, a number of improvements have been made to the click and whistle detectors, particularly for support of multi channel operation and improved species identification (section 3.2).

SMRU are heavily involved in acoustic marine mammal research and as a result, have had the opportunity to use PAMGUARD on a number of other projects. The PAMGUARD click detector was used in preference to IFAW's RainbowClick for the analysis of data from the CODA survey. PAMGUARD was also used to detect beaked whales in acoustic recordings made during line transect surveys for beaked whales in the Bahamas. The simple act of processing many hundreds of hours of acoustic data through PAMGUARD detectors has been essential in uncovering bugs in the software and improving the overall ruggedness of the software and it's usability by non-expert users.

SMRU projects using PAMGUARD in 2007 primarily used it for offline data analysis. Already in 2008 a SMRU researcher, Rene Swift, has used PAMGUARD during a survey on board the Norwegian ice breaker RV Lance in the high Arctic around the island of Svalbard and along the coast of Greenland. In May, we plan to use PAMGUARD for real time detection, location and tracking of beaked whales during cruises in the Bahamas and the Canary islands. In short, PAMGUARD has now become our software of choice over the old IFAW software.

As well as becoming our software of choice for field studies, the PAMGUARD framework is providing us with a flexible tool for the rapid implementation of new modules. Whistle and click classifiers being developed under a JIP funded project "Odontocete Classification" are being integrated into PAMGUARD easily and efficiently using the data management functions, database functions and the PAMGAURD graphics modules. As part of our beaked whale project, a PAMGUARD module has been written which sets a ships track at a pseudo random distance from sighted whales. The PAMGUARD displays and database options again made PAMGAUARD the ideal framework for the simple and rapid implementation of this software. This demonstrated the suitability of the PAMGUARD framework for handling for all types of data (i.e. not just acoustic data).

To summarise, the functionality implemented into PAMGUARD at SMRU now more than replicates that of the IFAW software, providing us with an important field and offline analysis tool and a flexible framework for future developments. However, testing at sea during 2007 was minimal and no sea trials were conducted by members of the core PAMGUARD development team. It is highly likely that there are still bugs in the code which will only be uncovered through further use in the field. Further field testing should be conducted in 2008 to ensure software reliability.

2 WP1 Core Architecture

The main tasks laid out in the proposal under WP 1 were

1. Adaptations to support offline re-analysis
2. Advanced Configuration utilities
3. Advanced Displays (3D, airgun/vessel/sound field, etc)

As well as making substantial contributions to all three of these areas, a number of additional modules have been written, as detailed below in section 2.4.

2.1 Adaptations to support offline re-analysis

2.1.1 Viewer and Mixed mode operation

PAMGUARD now has three main modes of operation, Normal mode, Viewer mode and Mixed mode.

During normal operation, PAMGUARD collects data from the outside world (through sound cards, GPS's etc.) processes those data and stores summary information in a database.

In Viewer mode, PAMGUARD reads data back from the database and re-displays it on the map. This enables operators to review data following a cruise, prepare maps for reports, etc. In viewer mode, the 'start' and 'stop' menu commands have been replaced with a dialog where the user sets the times for which they wish to display data.

In mixed mode, data are travelling in two directions at once – both into the database and out of it. GPS data and other data which does not derive directly from sound (e.g. depth data) are read back from the database. Sound data are reprocessed, generally from file. The output of detectors analysing that data is written back into the database. A main motivator behind mixed mode is the re-analysis of CODA / PAMGUARD field trial data during which the operator is re-analysing data as though in the field. During mixed mode, from the operators perspective, PAMGUARD operation looks and feels (apart from the lack of motion sickness) exactly as it does during real time operation. Mixed mode will also be useful in any other re-processing of data where detections and localisations are being reprocessed and need to be correctly linked with GPS and other non-sound data.

2.1.2 Bulk file analysis

File folder analysis functionality for bulk processing of audio files. The user can now select a single file for analysis, a complete folder of many files (including those in sub-folders if desired) or a selection of any number of files from within a single folder. There are options to either analyse all sound as though it were one long recording not stopping between files, or to stop and restart detectors at the end of each file.

2.2 Advanced Configuration utilities

2.2.1 Save Settings options

PAMGUARD now has the facility to export configuration settings into different files. When PAMGUARD starts, the user is presented with a drop down list of recently

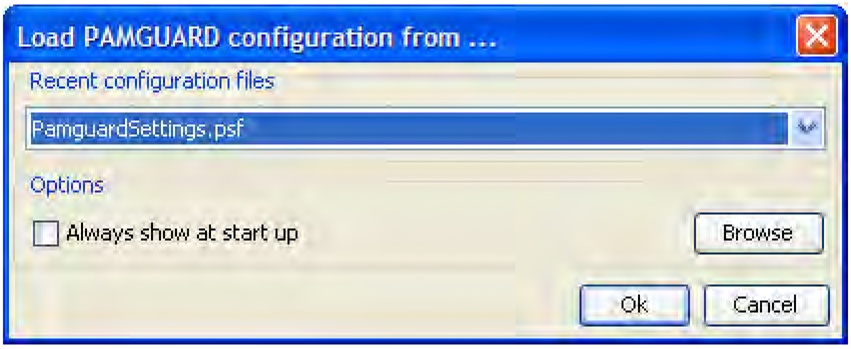


Figure 1 : Save settings options dialog presented to the user at start-up

loaded configurations (Figure 1), or they can browse their computer for settings files. Settings files can be easily emailed between users as small attachments.

2.2.2 Hydrophone configuration, location and display

Hydrophone configuration options have been modified to cater for static (e.g. bottom mounted) hydrophones. If a static array is selected, hydrophone positions are referenced to a latitude and longitude entered by the user.

Framework code has been added to locate hydrophones streamed behind a vessel using either predicted positions, based on vessels recent track, rate of turn, etc, or using data from sensors or using a combination of predicted and measured location. Java classes have been written for a simple locator which assumes the hydrophone is sticking straight out the back of the boat and a "threading" locator, which assumes that the hydrophone is following the exact track of the vessel as well as for static hydrophones. The type of locator can easily be selected by the user from a drop down menu. Developers can use the framework to easily implement alternative locators if required in the future.

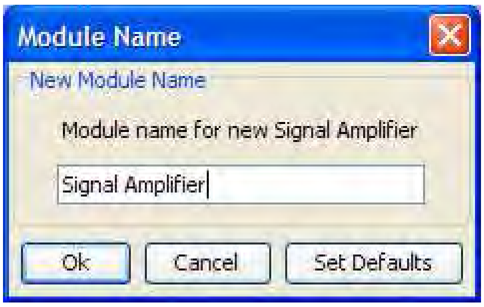


Figure 2. New module name dialog.

2.2.3 New module creation and inter module dependencies

A key feature of PAMGUARD is the way in which the user and add and configure modules for different signal processing, detection and localisation tasks depending on the type of work being undertaken.

The PAMGUARD user creates new modules from the PAMGUARD file menu. Previously, the user always had to type in a name for each new module. Names are now assigned automatically, although the user still has to confirm. Module names are now also required to be unique, for instance if you have two instances of the click detector, it is not possible to name them both 'click detector', you'd have to use 'click detector' and 'click detector 2', or better, 'sperm whale detector' and 'beaked whale detector', etc. The new dialog for entering module

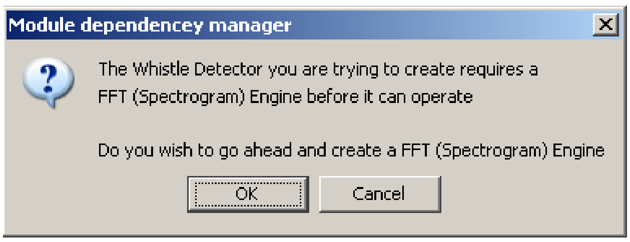


Figure 3. Message from the dependency manager indicating that additional modules need to be created.

names is shown in Figure 2.

Many PAMGUARD modules require other PAMGUARD modules to be present before they can function correctly. For instance, the click detector requires some kind of sound input, the whistle detector requires a FFT (spectrogram) Engine, which in turn requires sound input, etc. When a module is added by the user, PAMGUARD checks that any dependencies are satisfied, and where necessary prompts the operator to create additional modules. Figure 3 shows a typical information panel which pops up if dependencies are not satisfied.

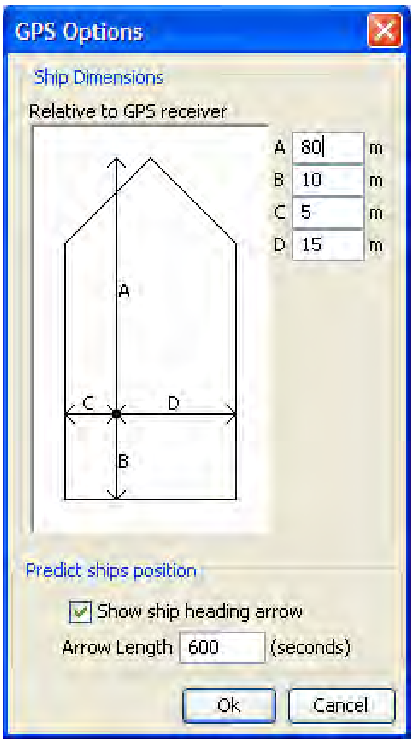


Figure 4 Vessel display options

2.3 Advanced Displays

2.3.1 Vessel Display

A vessel dimensions dialog allows the user to enter the length and breadth of the vessel as well as the relative position of the GPS receiver on the vessel so that the vessel is correctly drawn on the map relative to the GPS receiver antenna (Figure 4). The 'predict ships position' options can be used to show the likely position of the vessel in the near future (based on current speed and heading info.)

2.3.2 Airgun Display

Airgun display options (Figure 5) can be used to display the exact location of the airgun array. The module supports airguns deployed from the same vessel that PAMGUARD is running on as well as airguns deployed from different vessels (for example, if monitoring were taking place from a guard vessel). If guns are deployed from a different vessel, then AIS (Automatic Identification System) data are used to obtain the location and heading of the source vessel.

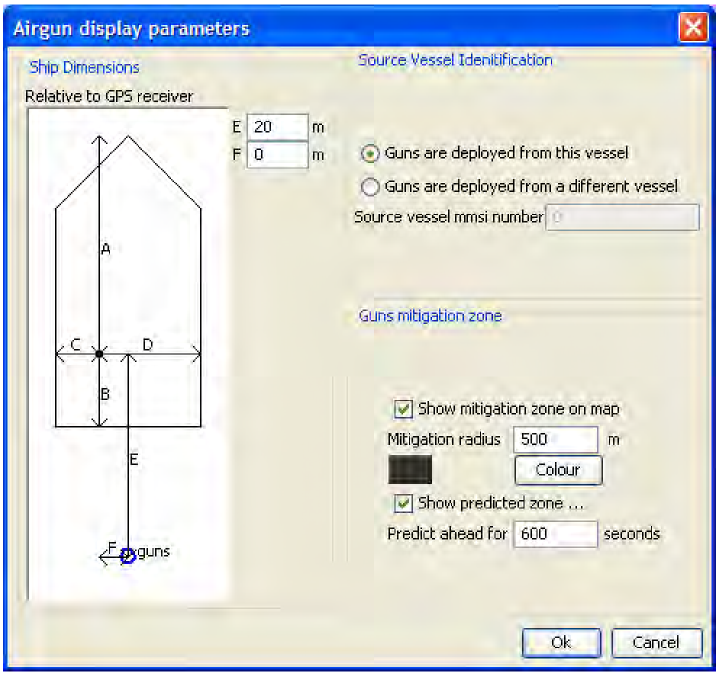
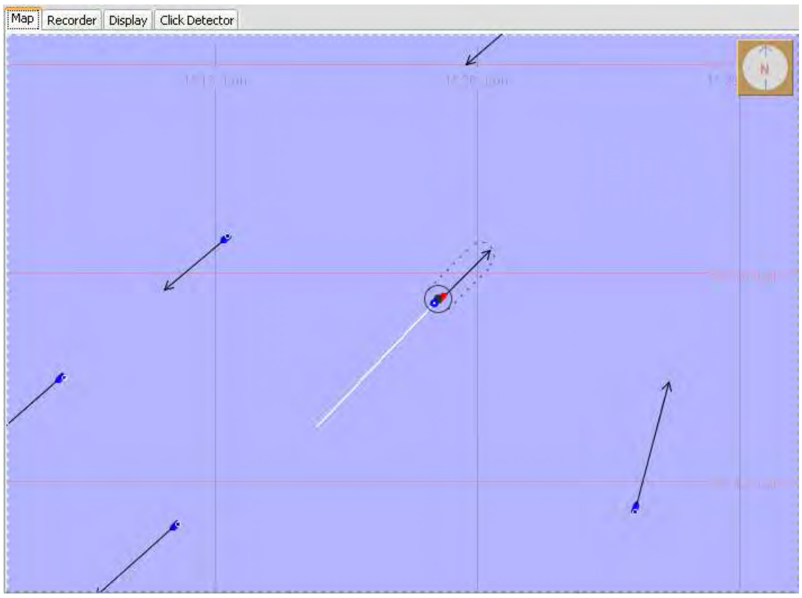


Figure 5 Airgun Display Options.

The airgun display shows the position of the guns, an optional mitigation zone, drawn as a circle centred on the guns and also an optional predicted zone, which will be ensonified by the guns in the near future (600s in the example in Figure 6).

The ship and airgun displays on the map are shown in figures 6a and 6b for airguns displayed on the monitor vessel and on a different vessel. Figure 6 uses archived AIS data (collected in the English Channel by Richard McLanaghan of IFAW) and simulated GPS data. International Maritime Organisation (IMO) regulations require AIS to be fitted aboard all ships of 300 gross tonnage and upwards engaged on international voyages, cargo ships of 500 gross tonnage and upwards not engaged on international voyages and all passenger ships irrespective of size. The requirement became effective for all ships by 31 December 2004. Presumably, most seismic

a)



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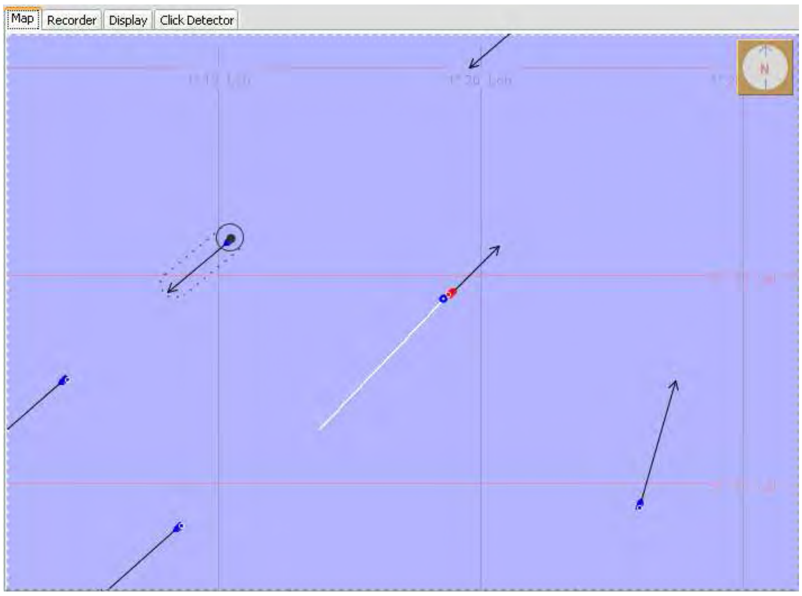

Figure 6 Vessel and airgun display. The monitor vessel is shown in red. Other vessels (from AIS data) are shown in blue. The blue circle just astern of the monitoring vessel is the position of the monitoring array hydrophones. Figure 6a shows the airgun display (black circle and dotted 10 minute prediction zone) for guns deployed from the monitoring vessel. Figure 6b shows the guns deployed from a different vessel

source vessels would therefore have AIS. AIS receivers can be purchased for a few hundred dollars.

2.3.3 Pop-up hints

Added hints providing information on detection and other objects displayed on the map and other displays (Figure 7). This is an addition to the core architecture of the graphic overlay functionalities within PAMGUARD and can easily be implemented for all future additional detectors.

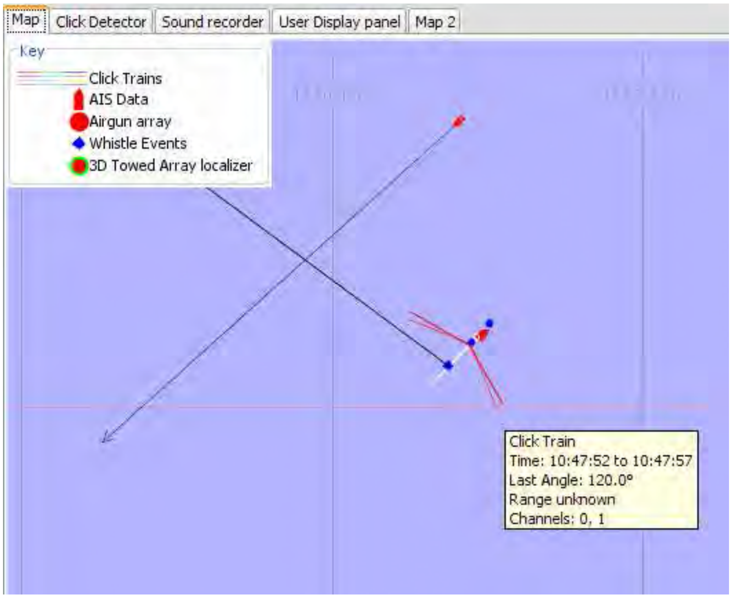

Figure 7 Example of a key in the corner of the map display and a hint which popped up when the mouse was hovered over a click train detection.

2.3.4 Symbol keys on displays.

Keys have been added to maps and other displays (Figure 7). This required infrastructure changes so that each graphics overlay can provide correct information for each display. Users can also now select different symbols for each graphics overlay using standard dialogs. This has become necessary due to the large number of detection and graphics options now available within PAMGUARD.

2.3.5 Map Comments

The user may double click anywhere on the map and a dialog pops up (Figure 8) with the time and lat / long of where the operator clicked. You may enter a comment or cancel. The date, time, lat, long and comment text are written to the database.

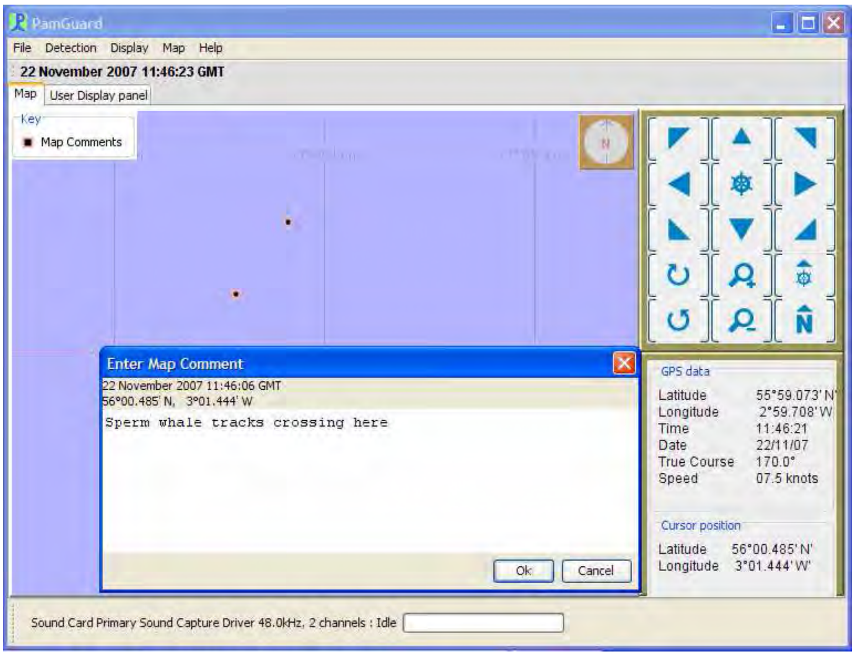

Figure 8 Dialog for entry of a map comment.

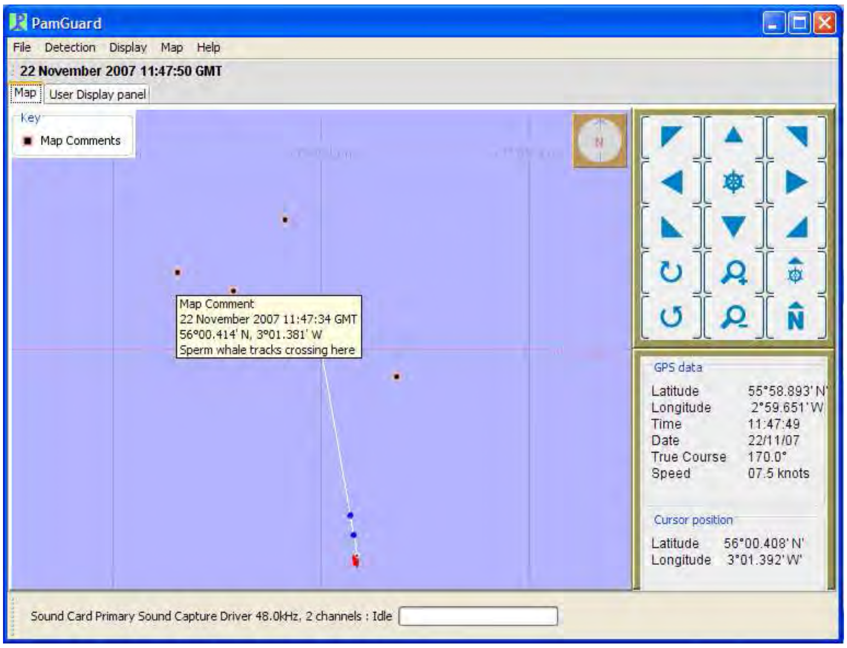

Figure 9 The map comment showing as a new symbol on the map, complete with pop-up 'hover' information.

Positions of entered comments are displayed on the map and hovering the mouse will display the date, time, lat, long and comment information (Figure 9). This feature is useful for registering the results of manual tracking using crossing bearings from the click detector.

2.4 New modules

2.4.1 New Database interface

A new database interface, which is easily extendable to any SQL based database system has been written. This currently supports MySQL and MS Access databases

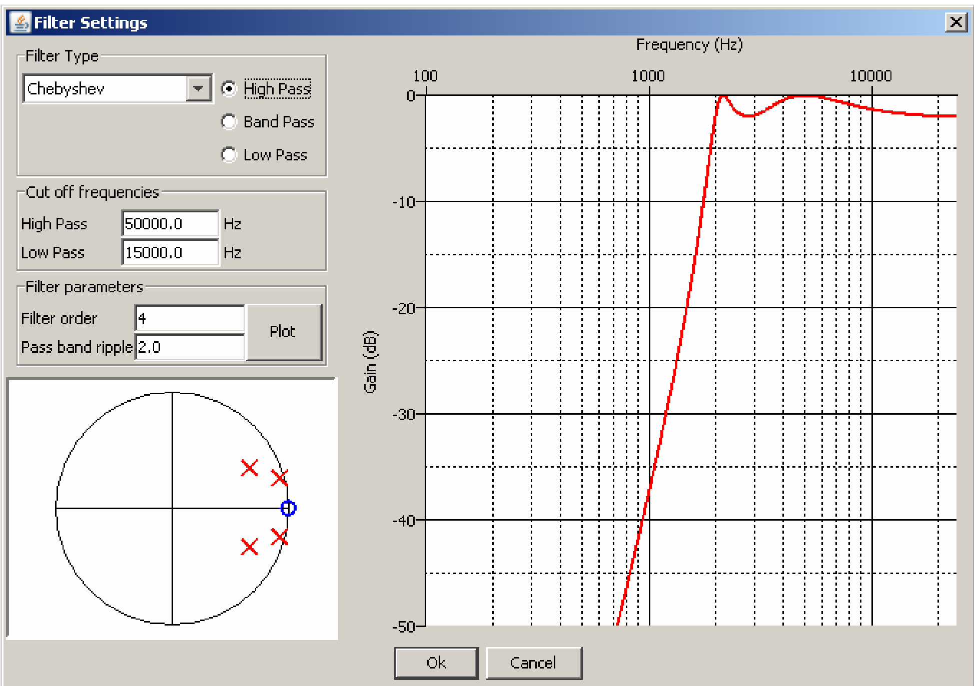

Figure 10 Filter configuration dialog

(tested with Access 2000 and Access 2003, but not Access 2007). The architecture has been written so that support for other database formats could easily be added if required. The database module will automatically configure a database so that it has the correct tables, with the correct columns for whichever PAMGUARD modules are in use at any one time.

Database tables have been added which record which modules within PAMGUARD are installed and how they are configured in the database every time PAMGUARD starts. The database therefore forms a single document, not only containing detection information, but also the PAMGUARD setup. This has two uses 1) auditing PAM operations and 2) aids data analysis since the configuration 'travels' with the detection data in a single document. Code has been written to read these data back into PAMGUARD. This information is used when running PAMGUARD in 'viewer' mode, since obviously the PAMGUARD configuration must match the data in the database tables.

Figure 11 Sound play back control dialog.

2.4.2 Filter module

A stand alone filter which can be inserted into PAMGUARD data pathways. The user can set up filters with a Chebyshev or Butterworth response for high pass, low pass of band pass filtering (Figure 10).

2.4.3 Sound playback

When re-analysing wav files, sound can be played back through the system sound card (Figure 11). Check boxes enable to user to select which channels to listen to in multi channel recordings. When combined with a patch panel (see below) it is possible for the user to listen to multiple channels in each ear.

Future plans are to extend sound playback to work when analysing sound from sound cards and other devices in real time.

2.4.4 Amplifier

A signal amplifier has been written (Figure 12). One of it's useful functions is the ability to invert the signal on individual channels since we have in the past found that hydrophones are sometimes inverting the signal incorrectly on some channels, thus making it difficult to accurately measure time delays between signal arrivals on different channels using cross correlations.

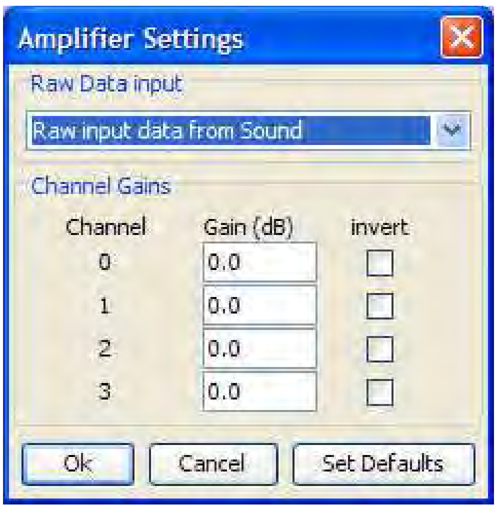

Figure 12 Amplifier control dialog.

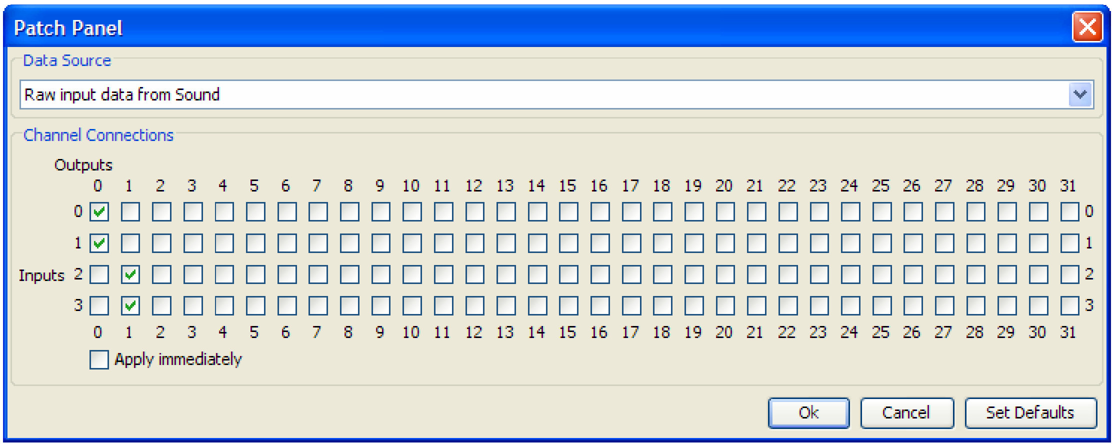

Figure 13 Patch Panel control dialog

2.4.5 Patch panel

A patch panel has been written (Figure 13) which allows the user to mix different channels together. The example in Figure 13 shows four input channels arranged so that they are mixed into just two output channels.

3 WP2 Maintenance

Maintenance work at SMRU has fallen into three main areas.

1. Debugging existing modules written by SMRU and by those at HWU
2. Adding additional or improving existing functionality to established modules
3. Assisting other developers in implementation of their modules into the PAMGUARD framework.

3.1 Debugging

Bugs have been reported in all PAMGUARD modules, mostly by Eva Hartvig who is working on analysis of CODA survey data using PAMGUARD and by Sebastian von Luders who ran PAMGAURD at sea during the CODA survey. Bugs have ranged from detectors crashing to small annoyances, such as settings not reloading correctly or incorrect distance being given in the GPS text area of the map. Most bugs were fixed in less time than it would have taken to write them down and there are no outstanding major bugs in the current PAMGUARD core.

3.2 Improved functionality

3.2.1 Click Detector

As one of the key components, and one which has now been extensively used at SMRU for analysis of our own survey data, a number of improvements have been made to the click detector module.

Better channel grouping in the click detector for multi channel analysis and better displays for multi pair channel configurations have been added. To further assist set-up by the user, trigger information can be displayed as a plug-in in the bottom of the spectrogram window.

Click detector performance has been improved by speeding up both the writing of clicks to file and the click detector graphics.

Improved time delay in correlation functions used to measure angles

A new algorithm has been implemented which uses parabolic interpolation between the integer sample numbers to improve the accuracy of delay (and therefore bearing) calculations in the click detector.

Improved manual tracking

A pop-up menu has been added so that when an operator clicks on a detected click, tracked clicks can be labelled / coloured (Figure 14).

Clicks which have been labelled in this way are added to grouped detections and a localisation calculated using target motion analysis (crossing bearings from multiple

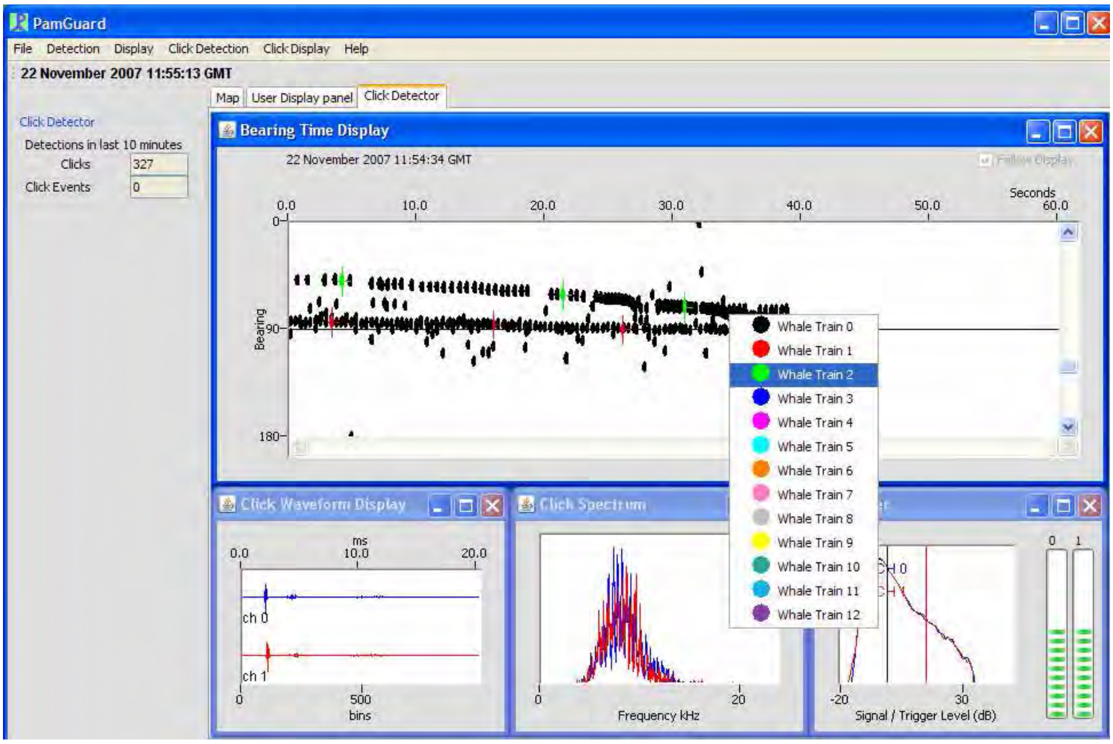

Figure 14. Manual tracking of multiple sperm whales. When the right mouse button is pressed, the display freezes, if the mouse is released over a click, a menu pop-s up and a train can be assigned a colour / whale number. The example shows tracks of two sperm whales.

points along the ships track). This can work either with a single hydrophone pair or with pairs of hydrophones some distance apart. In the latter case, it is possible to get a location from a single click since bearings from two widely separated points can be crossed accurately. If only a single hydrophone pair is used, then locations can only be accurately calculated once the vessel has progressed some distance along the track. These locations are only accurate if the animal movement is small compared to that of the vessel. It is good for estimating positions of sperm whales, but not so good with fast moving creatures close to the vessel such as dolphins.

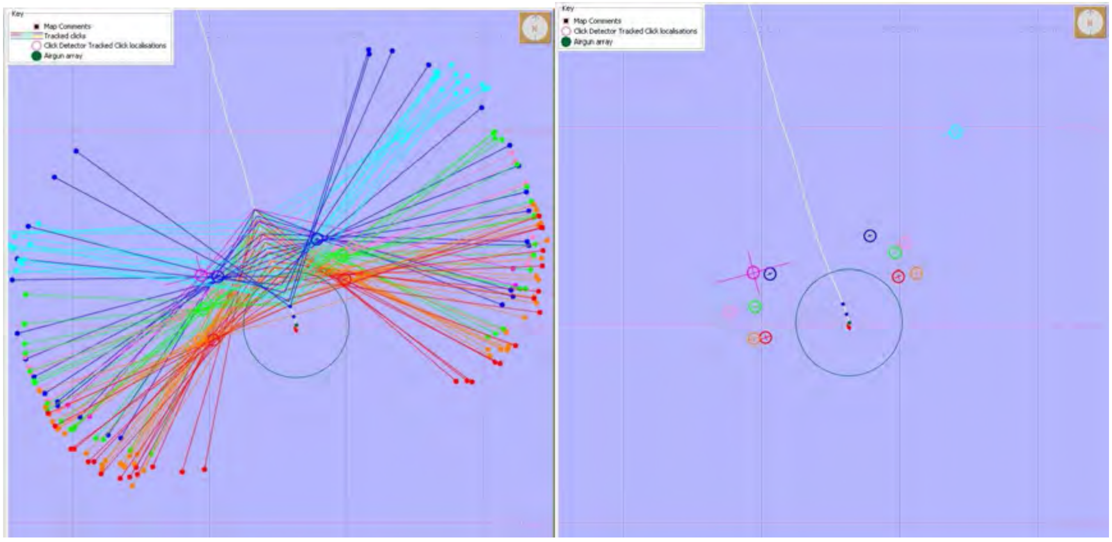

Figure 15 Plots of locations of multiple sperm whales. The left hand plot shows bearing lines to manually selected clicks. This right plot shows locations and errors on locations. The circle is a 1km circle around the airgun positions (see section 2.3.2).

The calculation computes a position along the vessel track line and the perpendicular distance from the track line. Errors are also calculated on both coordinates. Positions and errors are shown on the map (Figure 15).

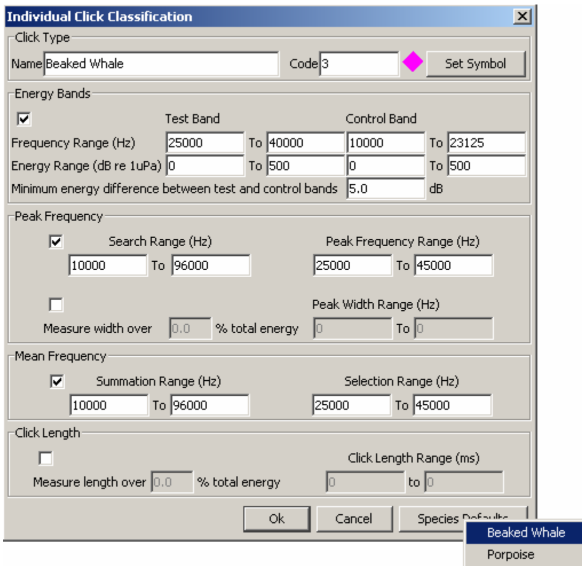

Figure 16. Click classification options dialog

Improved click classification

Improvements to the IFAW RainbowClick click classifier, which were developed for the detection of beaked whale clicks in 2007 have now been fully implemented in PAMGUARD (Figure 16). The click classifier contains functions for inserting default parameters for some species (small pop-up menu in lower right hand corner of Figure 16). This list can easily be added to by developers.

The click detector displays have also been improved giving options to only display clicks classified to a particular species if required. Although this classifier has proven useful and is still being used at SMRU for the detection of beaked whales and porpoise, it may be superseded later in 2008 by work being undertaken under the JIP funded Odontocete Classification project.

3.2.2 Whistle Detector

Another key detection component is the whistle detector which has also undergone considerable bug fixing and improvement during the past year.

Additional options have been added to the peak detection stage of the whistle detector to allow for more flexible configurations. In particular, options to limit the frequency

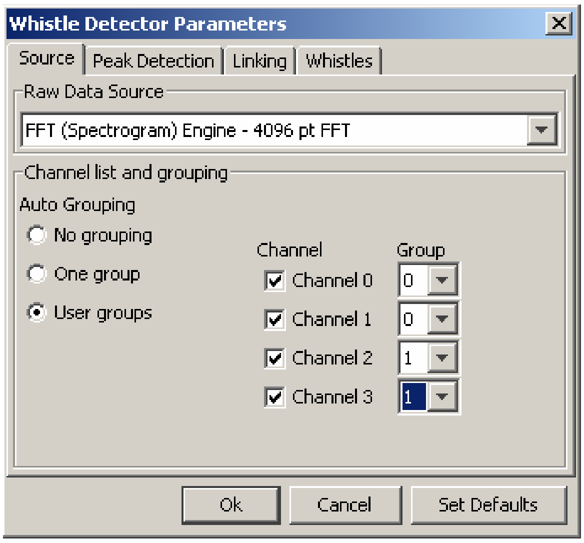

Figure 17. Whistle data source configuration. In the example, two pairs of hydrophones are used. Whistles will be detected independently on each pair, and a location, based on crossed bearings, will be calculated if whistles appear simultaneously on both hydrophone pairs.

band for whistle searching have been added and two alternative peak detection methods are now available.

Improved multi channel performance and configuration

The whistle detector has been altered so that multiple, independent detectors will run on pairs of hydrophone channels, each pair detecting whistles and calculating bearings independently. Figure 17 shows the new data source configuration dialog.

If detections on multiple pairs of hydrophones are detected simultaneously and overlap in both time and frequency, then the detection is assumed to be of the same whistle and the crossed bearing localisation is computed, stored in the database and displayed on the map.

3.2.3 Map Display

The third key PAMGUARD component which has undergone considerable revision in 2007 is the map.

As well as the map comments, keys and detection hints described above, the map graphics have been sped up. The map used to redraw every second and take approximately half a second to redraw each time, thereby rendering PAMGUARD almost inoperable. Sensible buffering of underlying map images and improved code now means that most of the map does not redraw at all (unless zoom settings are adjusted) and when it does completely redraw, it only takes about 1 millisecond to do so.

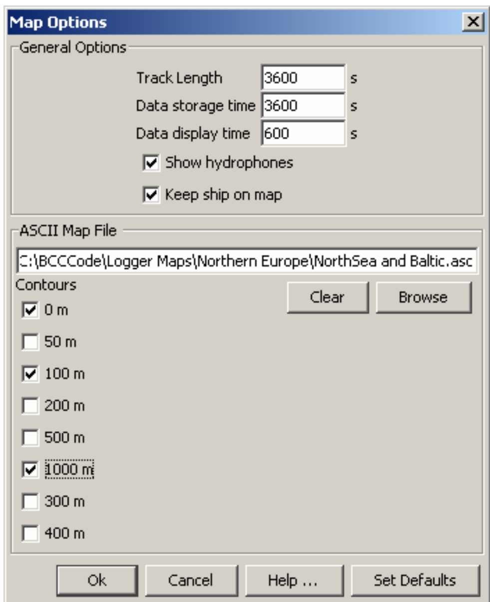

Figure 18 Map options dialog

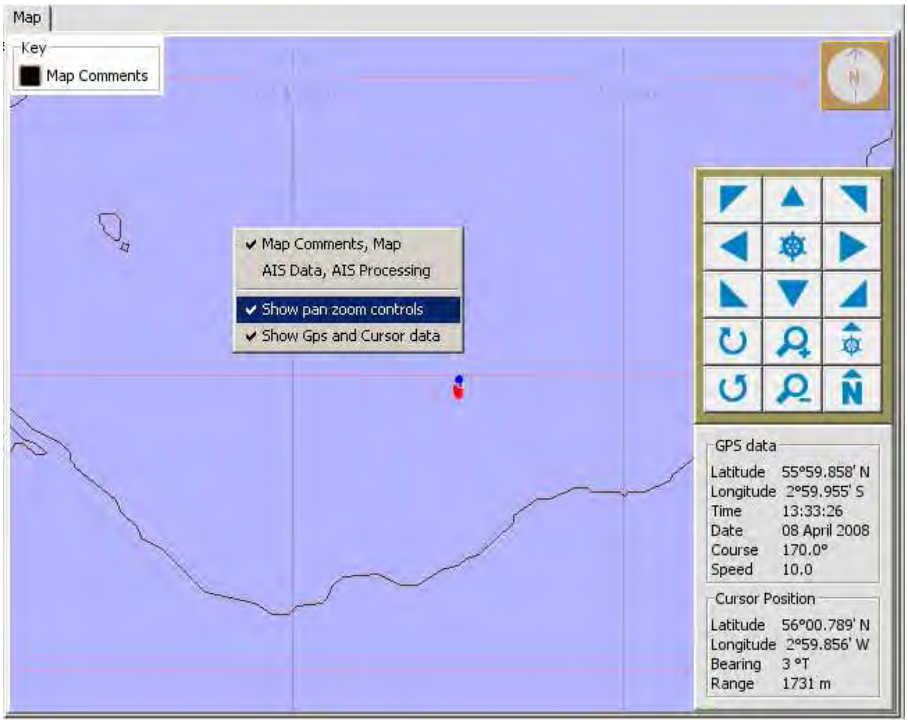

Figure 19. New position of Pan zoom and GPS text area and menu commands to remove them from the map if desired

Coastline images can currently be loaded as ASCII files from the Gebco digital atlas. Names of Gebco files are now correctly held in the PAMGUARD configuration options between runs (Figure 18).

The GPS text area in the bottom right of the display has been debugged so that it now shows the correct distance from the vessel to the cursor (this was not the case in earlier releases).

The pan/zoom buttons and the GPS text area have also been relocated slightly and there are options to remove them from the map altogether in order to increase the overall viewable map area (Figure 19).

3.3 Assistance

Much of the assistance given to other developers has been informal exchanges by email and by phone. To minimise travel and to deal with transatlantic time differences evening sessions (UK evening, Pacific Coast mornings) have been organised with Aaron Thode and Dave Mellinger whereby Gillespie has been able to offer help to Pacific coast developers. This primarily occurred every evening for a two week period in August 2007, although a number of other evening long calls have taken place since (the latest being in March 2008)

Gillespie also assisted Paul Redmond and Dave McLaren with writing C and Java code to read out ASIO sound cards (required for multi channel operation) and interfacing the ASIO module into PAMGUARD. Have since advised Xio Yen at HWU on how to adapt this code to support channel lists.

4 WP3 Workshop

Gillespie worked with Jonathan Gordon (Ecologic) and Dave McLaren and Paul Redmond (HWU) to provide training material and presentations for PAMGUARD workshop. Gillespie participated in workshop presentations, discussions and training of users and developers of PAMGUARD software.

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