SONAR SIMULATION FOR SUBMARINE CONTINUATION TRAINING

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ABSTRACT

It has long been recognised that a man's performance deteriorates with time away from his operational task, and that the level of knowledge at any particular point can be related to time spent in the current activity. The Submarine Flotilla of the Royal Navy has for some years established Continuation Training schemes in order to maintain and improve the knowledge base of operators. This has proved to be particularly effective when men are landed during refits or routine harbour periods, and when drafted to support tasks in shore-side Naval Bases.

The provision of regular training schemes utilising aural tape and hard copy of contact signatures obtained from previous patrols still only partly satisfies the problem, as the training does not fully reflect the on-board situation. The ultimate solution would be to give each operator a complete sonar simulator suite into which pre-recorded signatures could be played. Besides the unacceptable costs, the size of the equipment precludes its installation in the shore training centres.

The Royal Navy has achieved real-time training for its sonar operators by creating a complex signature Toolbox programme loaded into a modified desktop AT PC. Contact signatures are created without the need for real recordings and new effects can be instantly demonstrated. The system, being of generic design, is not equipment specific. The sonar ratings therefore receive continuation training in analysis and classification on a high fidelity, real-time, low cost, part-task trainer.

The presentation will describe and demonstrate the technical innovations of the real-time training schemes.

INTRODUCTION

The Submarine Flotilla of the Royal Navy provides mandatory continuation training schemes for men of the Operations Branch at shoreside facilities throughout the United Kingdom. The training schemes have been developed over the years and have proved to be successful in maintaining and enhancing otherwise perishable professional skills. However, the training provided for the Sonar Ratings specifically did not include real-time Lofargram analysis techniques, as would be reflected in their professional role in using the operational equipment at sea.

LOFAR is the abbreviation for Low Frequency Analysis and Recording which enables submarines to achieve long range detection and classification of other vessels. All vessels produce broadband and discrete frequency noise in the low frequency spectrum, and it is mainly the discrete frequency sounds which are studied in Lofar analysis in order to classify contacts. These discrete components are produced mainly by propulsion systems (turbines and diesel engines) and auxiliary machinery (generators and pumps etc.) The vibrations produced by these sources emit via the vessels hull into the water as sound pressure waves. The pressure waves can be detected by passive sonar sets and hydrophones and the resulting electrical signals are processed before being fed into high voltage pen records and CRT monitors. The recordings obtained from the equipment are known as Lofargrams, and are colloquially referred to as just "grams".

Traditionally, lofargram analysis and classification training material utilises recordings taken from operational patrols. The recordings are catalogued and sections of both the aural and hard copy information are extracted by the Joint Acoustic and Anti-Submarine Warfare Analysis Centre (JAAC) and then distributed to the trainers with accompanying notes on special features. Short tests are included with the training material in order to evaluate individual performance, and additional training material is produced locally. The shortcoming of this approach is the non-availability of specific effects produced by vessels, which are known to exist, but of which recordings have not yet been obtained.

There was therefore a need to revise this philosophy of continuation training from one in which pure copies of recorded material were provided, to one where we could include information drawn from data held and manipulated to give effects of which we did not possess actual recordings.

Consequently the decision was taken to implement a project which would support this revised training methodology, independent of real recordings, and would be easy to administer and be cost effective. Equipment provided by the project would have to be installed at a sufficient number of locations to ensure easy access for all Sonar Submariners, thereby minimising the granting of exemptions to ratings from the mandatory training schemes.

Lofargram Analysis

In general, when a source produces a sound at a particular frequency, it will also produce harmonics of that frequency. To enable an analysis of which frequencies are harmonically related and which combinations of harmonic patterns are also related, a multipoint divider technique is used. These multipoints are either in a physical form for use with hard copy material, or they are electronically generated and controlled to facilitate measurement of on-screen data in the sonar displays.

The analysis involves the recognition of potential relationship patterns based upon the frequencies displayed and the spacing between them. The subsequent relating of this complex interpretation to likely plant/machinery sources and combinations of sources that might lead to platform classification involves using a knowledge base derived from intelligence gathering efforts.

In order to be successful, the analyst must have a detailed knowledge of marine propulsion systems and their associated sound effects which show as instabilities on the lines (eg An electric pump being switched on will create a noise noise that will appear as a line; the line will initially fade in as the sound increases in intensity while the pump is attaining operating speed, at the same time the changing speed will be dictating the line's change in fundamental frequency ie a frequency shift).

The initial object of analysing a lofargram is to classify the contact. Any and all information concerned with the propulsion and auxiliaries of a vessel is pertinent to this process. Acoustic data is held and updated in a variety of Service publications, but this data requires to be applied to the particular conditions in which the material was obtained. Consequently information that can be gleaned from a lofargram can yield further information on a contact's speed, depth and course. Contact manoeuvres will alter the received signals, and it is in this area that the skill of the analyser is most important in deducing the cause of lofargarm effects.

Because of the infinite number of combinations of contact parameters, recordings have yet to be accumulated of all possible effects. For example, the analyser may have information on the lines that a particular vessel generates when proceeding at 12 knots and altering course through a 40 degree turn to starboard; if the gram shows some similarities then it may be due to a different rate of turn coupled with either an increase or decrease in speed.

Development

Initial research revealed that the key to the success of the project would depend on the physical size and cost of any equipment used. The available space in the already established main Squadron training centres was at a premium and the additional sites proposed would more readily accept new equipment if there was no requirement for building modifications. Overall cost was a major consideration as the funds available were limited.

Cost alone ruled out the procurement of operational sonar sets, not only because their physical size and cooling requirements precluded their installation at the shore sites, but also because additional complex and costly stimulation equipment was necessary in order to provide meaningful signals for the generation of screen data. It was out of the question to fund operational military specification equipment for a purely off-line training facility, especially when the associated costs for 25 year life cycles were taken into account. Due to the proliferation of different sonar sets and modification states it would be a problem to decide which particular set should be used for a Flotilla wide training scheme. It was for all of these reasons that the conclusion was reached that the delivery system would have to be of generic design. The idea therefore formed to produce synthetic lofargram signatures which could be manipulated to demonstrate desired effects, which would have an enormous training potential and cost/complexity benefits.

One of the advantages of using a generic design was the ability to display information completely independently of specific sonar analyser equipments. The training could encompass analysis and classification techniques rather than particular equipment associated skills. However it was decided that certain features found in the majority of sonar sets should be incorporated into the screen design as a familiarity aid to the students. Coupled with the cost and size limitations already explained, it appeared feasible, after an initial investigation, that the approach could be taken of producing synthetic material on a powerful desktop computer.

CBT Study

In 1985 the Ministry of Defence had commenced a pilot project in Computer Based Training as it was considered to be a medium with the potential for achieving improvements in the productivity and effectiveness of shore based training. (1). The project had selected six areas representing a range of training against which the efficiency potential of CBT could be examined. All the projects were put out to commercial tender for both the supply of hardware and software.

A common evaluation philosophy was established in order to assess the impact of CBT on trainee performance, training organisation, and human training resources. One of the areas trialed was Passive Sonar, where the courseware specification required maximum use of CBT capabilities for the provision of both still and animated graphics and equipment emulations - facilities which were not previously available; the system was however capable of producing simplified Lofargrams.

The MOD study results had found positive trainee and instructor attitudes towards the strategy of animation and graphics, and the lofargram presentation made the application potentially fruitful for the future. The results also encouraged the use of CBT as a low cost alternative to conventional high fidelity simulator configurations. It was thought that as analysis performance needs continuous practice, CBT could provide the answer for continuation training.

Requirements

It was therefore decided to expand and modify the parameters of one of the CBT authoring systems trialed in the Ministry of Defence sponsored study previously mentioned. Screen resolution was of prime importance if the simulated signatures were to appear realistic and approach the same fidelity found in the operational equipments. The Senior Rates of any submarine sonar department are required to meet both the mandatory training scheme objectives and also provide guidance, instruction, and management to the Junior Rates. Therefore screen displays must be credible and leave no room for doubt or confusion. Processing power available would have to cater for displaying and manipulating animated waterfall lofargrams in real-time. The proposed system utilised a high resolution graphics card of 768 x 576 pixels and could be installed in an IBM PC clone in conjunction with a 14 inch monitor. Hardware selected was an 80386 based PC running at 20 MHz with a 387 Math Co-processor, 2 Mb of RAM and a 40 Mb hard disk; this was the fastest hardware available at the time of raising the commercial contract.

Approach

The production of a software programme to display acoustic signatures was undertaken by the manufacturers of the authoring system. To enable the software to produce realistic sonar effects, the information required on the screen had to be broken down into its prime component parts. Thus the Royal Navy had to specify exactly what effects were to be produced, and how each tonal could be created from mixing various characteristics. By employing a "Toolbox" approach, software could be written such that the manufacturers did not require to have access to any classified information, even though they were actually MOD approved contractors. The utilisation of mouse selectable menu drivers was considered to be a useful training aid in its own right. The younger students were more adaptable to computer systems, and the older but more experienced sonar operators would find selection of functions by "point and click" more acceptable than having to type in commands. In order to display some of the effects associated with contact movement, it was found necessary to separate the signature building facility from a "Scenario Generator" which would define the vessels relative positions and motions.

Functionality

Some of the main features of the system are now outlined:

a. The Lofargram Editor

After specifying the number of harmonic series required, an author will specify each series by defining the number of harmonic lines, the fundamental frequency and any associated instabilities. Instabilities can be displayed as one of six different standard types, and it is possible to also specify the bandwidth, repetition period and duration of that instability. Each fundamental tonal can be manipulated to show intermittancies, with fade ins and outs, and dynamic effects such as frequency shifts are also available from the menus. The overall diffuseness of the fundamental is then specified and then the intensity of each line in the harmonic series can be adjusted to correspond with known data. A "merge" utility enables authors to merge two separate sets of data to create a single complex gram. An author can then decide whether a student will see the lofargrams displayed on a large single window running in real-time or some factor faster than real-time. This feature provides for demonstrating particular effects where it would be unneccessarily time consuming for students to wait for those effects to appear. The students can toggle through a bandwidth selection menu and can call up cursors and multi-points for on-screen measurements. Access to an annotation menu is also available and can act as a "scratch-pad" feature for identifying particular tonals during analysis. An alternative display provides a multi-window mode, running in real time only, but where the student has full access to defining his own requirements for each window regarding the update period, bandwidth and centre frequency. Again, cursor and multi points are available in all windows for on-screen measurements. Both displays also feature a freeze facility to help the students with closer examination of the tonals.

b. The Scenario Editor

The main display grid reprsents an area 20 nautical miles square, divided up into 2 nautical mile square boxes. The stippling within the boxes indicates the depth of water; the less the stipple the greater the sea depth. The sea bed depth can be altered by menu selection for each box area and thus provides a simple method of building topographical features over the scenario area. Tracks of up to four contacts are indicated by different coloured lines, each contact can have up to seven waypoints programmed. Range, bearing and CPA information is displayed concurrently when an author is programming the tracks. The total scenario length is also displayed. Oceanographic effects are also available on the menu; bathtub fringes can be specified for a particular contact and will automatically be correct at CPA, having been simulated for a contact both closing and opening. The overall environmental noise can be selected from seven different levels. Each noise level is produced using a random pattern generator.

Once an author has created a databank of signatures and scenarios, it is then possible to assign signatures to contact tracks and save them to disk as complete setup files. The computer records the students personal details and also the time it has taken for the exercise to be completed as a measure of operational performance. Thus no classified data is stored on the hard disk. Security is protected as the floppy disks only hold line parameters, there is no reference to the contact. The JAAC maintain records of student results, as they are responsible for marking all the training schemes. Breakdowns are readily available for type of submarine in which the students are serving, and recent squadron history.

The system incorporates a screen dump facility together with a printout of signature specifications so that training libraries can be created for incorporation in other aspects of sonar operations.

Expansibility

The potential of low cost CBT simulation can be seen in many other areas where individual trainees need to practice operational tasks. Team training using networked microcomputers is no longer a pipe-dream, but only requires development to become reality. Most cost benefit can be obtained where microcomputers provide the same levels of training as conventional simulator configurations. The Submarine Flotilla is already pursuing real-time training for its Tactical Branch personnel in the area of Action Information using the same hardware equipment as that described in this paper. By building on the fundamentals already established in the creation of the scenario generator, additional mathematical outputs become available for incorporation in tactical simulators.

CONCLUSION

1. The desktop acoustic trainer provides a method for creating realistic facsimiles of Sonar Lofargram images without a requirement to inject real recordings.

2. The training emphasises analysis and classification skills and is totally equipment independant.

3. The use of bespoke Toolboxes enables authors and students to easily interface with the embodied mathematical modelling.

4. Virtually all conceivable sonar effects can be generated by the lofargram editor.

5. The scenario generator produces comprehensive contact tracks, and when linked to stored lofargrams gives unlimited possibilities for testing.

6. The cost and size of the systems enables a wide distribution to diverse locations.

By adopting the stance that "seeing is believing", it has been possible to present realistic sonar data on a computer monitor, as any sonar analyser display is a mixture of tonals and oceanographic effects. Ultimately, what a student sees can be broken down into a series of graphical images; in other words, the production of a complex line drawing facility will simulate whatever the author requires of it.

References

1. Computer Based Training - Hit or Myth? Directorate of Naval Education and Training Support. Proceedings, I/ITSC, November 1988.

ABOUT THE AUTHOR

Lieutenant Commander Hall currently holds the appointment of the Submarine Flotilla Computer Based Training Projects Officer. He has been on the Flag Officer Submarine's staff for over three years, initially being based at Command Headquarters in Northwood prior to specialising in computer training projects. An Instructor Officer, Lt. Cdr. HALL has spent over 11 years involved in Naval technical training. He has held appointments specialising in weapon systems training as well as operational deployments. Prior to joining the Royal Navy, he spent 9 years in industry as an electronic engineer.