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A Mobile Decision Aid for Determining Detection Probabilities for Acoustic Targets

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ABSTRACT

The Army Research Laboratory (ARL) has developed a physics based Acoustic Battlefield Aid (ABFA) for acoustic sources and sensors. This application computes numerous output parameters (e.g., probability of detection, transmission loss, signal-to-noise ratio, etc) for a number of acoustic sources and sensors (if required). Probability of detection (POD) output would seem to be particularly of interest to lower echelon units, e.g., in determining how close enemy tanks could approach before being heard (by either the human ear or some other acoustic sensor). As a result, a prototype application has been developed that allows the POD for a user specified target/sensor pairing given the direction and distance between the two. Commercial wireless communications are used to link the mobile device (a Compaq 3650 personal digital assistant) to a remote laptop server. The server consists of a set of dynamic linked libraries written in C that contain several functions that access an acoustic propagation table. This table is a function of the environmental conditions, and for the prototype, is simply a static table. Eventual dynamic creation of the table from an existing gridded prognostic meteorological database (residing on the Army's tactical command and control system for weather) is anticipated. Tactical wireless comms would also replace the short-range commercial comms.

INTRODUCTION

While military ground targets have traditionally been detected via their visible and infrared emissions, detection of their acoustic signatures can also be used for target acquisition. For example, the Brilliant Anti-Armor Technology Submunition (BAT) uses an acoustic sensor to seek out armor targets, and an infrared sensor to engage the vehicles. As with visible and infrared signatures, the atmosphere can attenuate the transmission of the acoustic signal. Realizing the requirement for providing information regarding the acoustic source propagation through the environment and its effects on the ability of sensors to detect the signal, ARL researchers have developed an Acoustic Battlefield Aid (ABFA) [1]. ABFA is a physics based model that can provide numerous outputs regarding the acoustic signal transmission through the atmosphere. Some of the outputs available include probability of detection, direction finding accuracy and signal-to-noise ratio. Inputs include the meteorological conditions, underlying terrain type (forest, gravel, sand, etc) the acoustic source (target – T62 at 19 mph, generic tank, stationary HMMWV, etc) and receiver (sensor – human listener, generic single microphone, microphone array, etc). It is currently available on Windows based platforms although an effort is underway to provide the ABFA functionality on the Army's fielded tactical command and control system for weather, the Integrated Meteorological System (IMETS). Figure 1 is a capture of a recent ABFA graphical user interface and display showing the detection probability for a generic tank by a microphone array. The interface also shows a pull down source menu that can be used to select a specific acoustic source. Weather data can currently be entered manually, downloaded from the internet or the user can choose pre-defined meteorological cases, e.g., "clear night, moderate wind". When integrated into the IMETS, the weather data can be automatically retrieved for the specified location by accessing a gridded database containing the output from a prognostic fine scale weather model.

As can be seen from Figure 1, the ABFA GUI is rather involved and contains numerous menu items and options that must be set by the user. This is beneficial in terms of providing a powerful and highly configurable modeling environment, however, for lower echelon users the computing platform that they have access to may not be amenable to this level of detail. In this case, when the majority of the meteorological and terrain data can be maintained on a server platform (e.g., an IMETS at battalion level), a simple GUI on a handheld computing device may suffice. This GUI would provide the user with enough flexibility to specify the basic input parameters (e.g., source and sensor as well as azimuth and range between them) that can then be sent to the server (over wireless comms, for instance) for computation of probability of detection (or some other output parameter). Thus, critical quantitative detection related information could be provided to lower echelon users on the local device. The remainder of this paper discusses such a prototype application that has been developed and demonstrated by ARL.

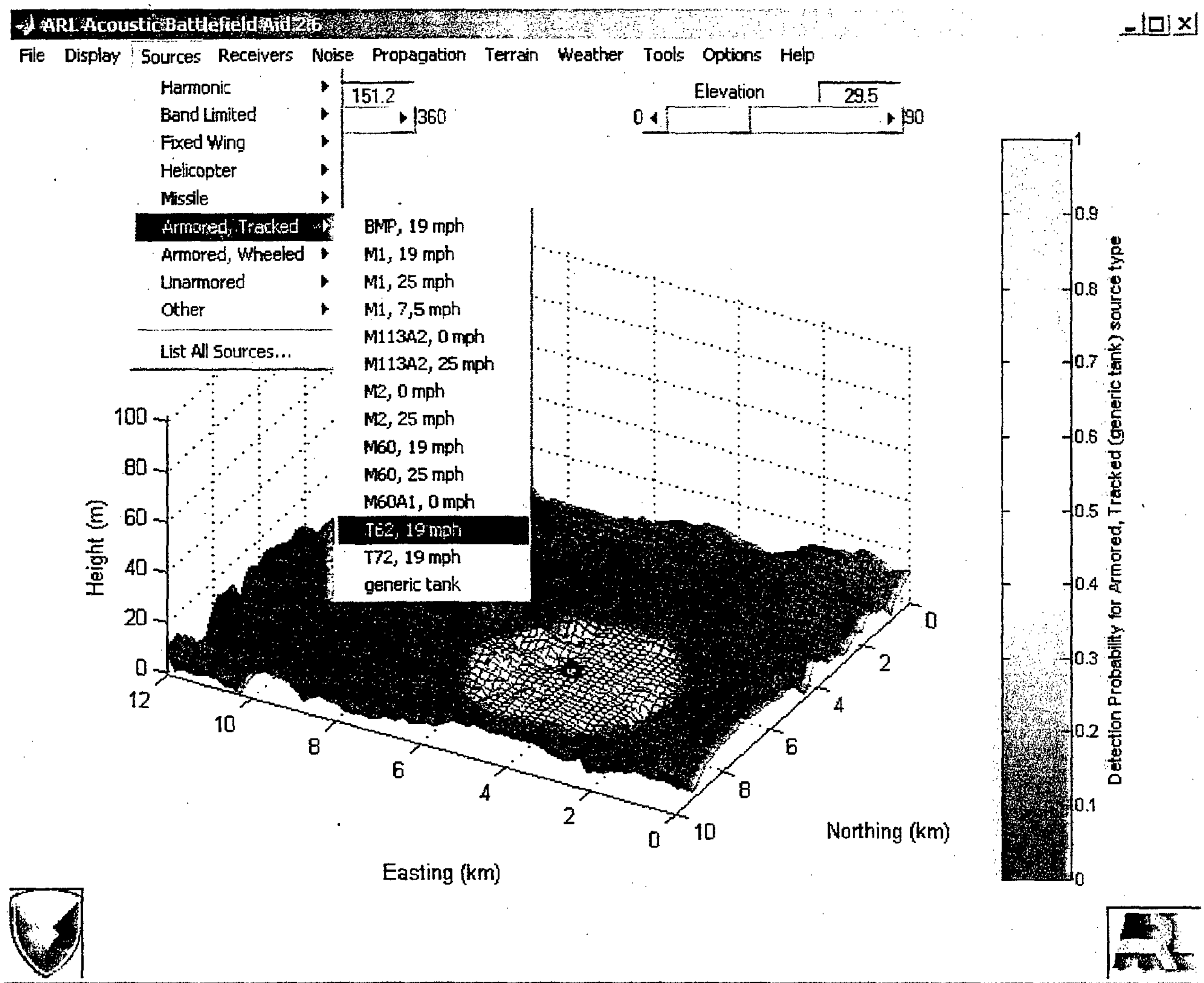

Figure 1 - ABFA Graphical User Interface

REQUIREMENT

The Army's Objective Force will emphasize highly mobile and independent fighting units. To enable the Objective Force, information and situational dominance will be required at all echelons. This will require providing critical information to the lower echelons via small computing devices (e.g., handheld computers) over wireless communications. Although an IMETS will be fielded at battalion level via a light version on an Intel based hardware platform, there are currently not any plans to field an IMETS at echelons below this. In an effort to address this requirement, the Army is developing prototype hardware and software environments to provide a lower echelon computing capability on handheld or mobile computing devices. For example, there are ongoing efforts at the Dismounted Battlespace Battle Lab (Ft. Benning, GA), the Land Warrior Program (Ft. Belvoir, VA) and the Objective Force Warrior (Natick, MA) related to mobile computing applications. ARL is involved in developing prototype applications specifically related to weather and weather impacts on weapon systems and military operations, of which acoustic propagation is one.

Even though there have been numerous technological advances in the mobile computing environment, it is not yet feasible to make all of the required computationally intensive calculations on the mobile device, thus a client-server environment was chosen to develop and demonstrate our prototype Mobile Acoustic BattleField Aid (MABFA). The specifics of both the server and client are discussed briefly in the following section.

CLIENT-SERVER ENVIRONMENT

Surrogate Server

Detailed acoustic propagation information is computed as a function of the environmental conditions (wind velocity, temperature profile, etc) and stored in tables on a surrogate IMETS server (a Pentium 450 MHz Windows 2000 based laptop computer in this case). These tables are computed from algorithms written in the C programming language and derived from the ABFA code. Currently the tables are static for demonstration purposes. However, they will eventually be derived from the gridded meteorological database that is resident on the IMETS. This database is both temporally and spatially dependent and provides relatively high fidelity (10 km in the horizontal) prognostic (48 hours) data from which the propagation tables can be computed. These tables will be dynamically updated twice daily when the gridded meteorological database is refreshed. Depending on the compute time for the tables, they will either be computed a priori and stored for each grid point or they will be computed on the fly for a specific grid point that is nearest the location of the mobile user requesting acoustic propagation information. The IMETS gridded database is typically valid for a 500x500 km domain, thus there are 2601 grid points (51x51) in the horizontal.

Client Environment

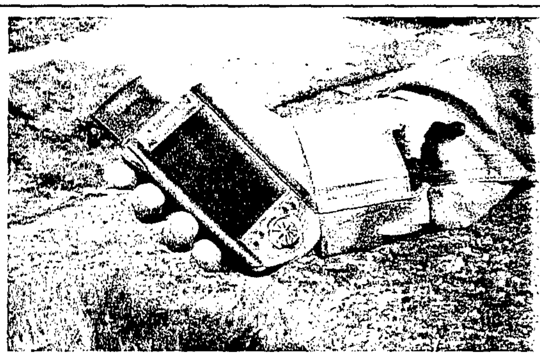

Figure 2 – Compaq 3650 with 802.11 PC Card

The client device is a Compaq personal digital assistant, specifically model 3650 (see figure 2). Although the device weighs just over 6 ounces and has approximate dimensions of 5" x 3.3" x 0.6", it is a fairly capable platform with a 206 MHz processor, color display, integrated microphone and speaker, and 32 Mb of memory (newer versions have 64 Mb). Enhancing the device's capability is the PCMCIA[1] expansion pack option. This allows either one or two PC cards to be integrated with the mobile platform. Current cards supported include 802.11 based wireless comms[2], GPS, additional memory via compact flash cards or micro drives (up to 10 Gigabytes!), and VGA output to an external display. Of primary interest is the wireless capability which is currently being used to transmit and receive information from the surrogate IMETS server over distances of up to 1000 feet via a small antenna plugged into an external wireless access point connected to the server. The wireless comms utilized for the prototype application could be replaced with tactical comms for fielding, e.g., possibly the emerging Joint Tactical Radio System (JTRS) which will be able to transmit/receive both voice and data. The GPS capability can be integrated with the acoustics application to pass the geographic location of the mobile device and then query the propagation tables nearest to that point. For more detailed information regarding the mobile computing device and the software environment utilized see a recent journal article by Sauter and Torres [2].

The client application is written in Java for portability and potential transition to a fielded system. The code as written and compiled on a Windows 2000 operating system machine runs *without recompilation* on the Compaq device as well as Windows 95 and Solaris based platforms. Java's remote method invocation (rmi), a set of protocols to allow Java objects to communicate with each other remotely, is used for the client-server interaction. Since it was stated above that the server software is written in the C programming language, another interface is required on the server end to allow the Java client to access the propagation tables. This interface is the Java Native Interface (JNI) and allows Java objects to interact with C functions. RMI and JNI are both relatively straightforward to work with and did not pose any challenges to the implementation of the acoustic propagation mobile application.

[1] Personal Computer Memory Card International Association, an organization of some 500 companies that has developed a standard for small, credit card-sized devices, called PC Cards (from www.webopedia.com).

[2] 802.11 refers to a family of specifications developed by the Institute of Electrical and Electronics Engineers for wireless LAN technology. 802.11 specifies an over-the-air interface between a wireless client and a base station or between two wireless clients (from www.webopedia.com).

MOBILE ACOUSTIC BATTLEFIELD AID

Once the client and server environments were chosen, it was relatively easy to develop the client application. A graphical user interface (GUI) was developed Java on a laptop computer and then copied to the Compaq mobile device (although Java code can be run on the mobile device, there is not a development environment on it, thus code must be compiled elsewhere and transferred). While the full Acoustic Battlefield Aid (ABFA) application has numerous inputs and possible outputs, it was felt that for a mobile application, the interface and number of output parameters should be kept simple. Thus, an application that would provide the probability of detection of an acoustic source by a sensor given the range and azimuth between the two was coded. Figure 3 displays the actual mobile ABFA GUI as it appears on the mobile device. Pull down menus allow the user to choose one acoustic source and one sensor. The Java programming environment for the mobile device is rather versatile and allows for error trapping of invalid inputs (e.g., a character entry for a numeric input field or an azimuth value > 360 degrees). In turn, the user cannot submit the request for the server computations until all inputs contain valid entries. A text area is used to display pertinent information to the user as is displayed in the GUI in the figure. Sound can also be added to the client application to alert the user of invalid entries, problems with the server or successful retrieval and display of information from the server.

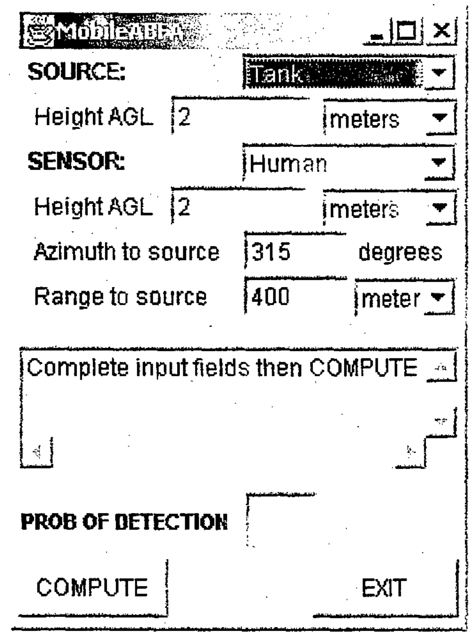

Figure 3 – Mobile ABFA GUI

For the prototype application the source and sensor are actually fixed on the server. Once the user has entered the range and azimuth and clicks the "COMPUTE" button shown in the lower left portion of the GUI, the information is transmitted to the surrogate IMETS server over the wireless comms. The computations are then made using the static propagation tables and the probability of detection information is sent back to the client and displayed. The time from "COMPUTE" to the display of the information on the mobile device is typically a few seconds. Depending on the meteorological scenario, the probability of detection can vary greatly depending on not only the range between the source and sensor but also on the azimuth. Acoustic signals can be transmitted longer distances along the downwind direction than in the upwind direction. Thus, if the azimuth is aligned in the same direction as the wind direction and the sensor is downwind of the source, the probability of detection can be much larger than would otherwise be expected.

The Mobile ABFA application should provide useful information to the mobile user regarding detection probabilities/distances not only for enemy vehicles, but also for estimating possible avenues of approach for friendly vehicles on enemy positions. For example, because of terrain or other features there may exist two potential avenues of approach upon an enemy location. If one is more vulnerable than the other to acoustic detection by enemy forces, a decision could be made to use the approach with the lower probability of acoustic detection. Depending on mobile user requirements, it would be relatively simple to add output parameters to the Mobile ABFA application other than the probability of detection. As was stated earlier, there are multiple parameters that are available from the ABFA program. Thus, if the user wanted to see transmission loss that value could be computed on the server and transmitted back to the mobile application for display.

FUTURE CAPABILITIES

2-D/3-D Displays

The full ABFA application relies heavily on 2-D and 3-D displays to display spatially dependent output information to the user (see Figure 1). It should be possible in future versions of the Mobile ABFA to display some of this information for the mobile user. This would be possible via two separate methods. Both would involve the computation of the spatially dependent information on the server. In the first method, the actual 2-D or 3-D display would also be created on the server and saved as a graphics image in the Joint Photographic Experts Group format (jpeg or jpg for short). As the mobile device has an image viewer to display jpg images, the file could be transmitted to the mobile user over the wireless comms and then loaded and displayed. The drawback to this approach is that the bandwidth for the existing wireless comms is relatively small (1 megabit per second in theory, but in practice typically significantly less) and some of these images could be relatively large (over 1 megabyte). Thus, if there are several mobile users requesting multiple images the transmit times could be long. In addition, in a fielded version there would be competing applications requiring use of the wireless network effectively decreasing the bandwidth even more. A second option would involve transmitting the spatially dependent information to the mobile user and then composing the image on the mobile device. Commercial mapping software solutions for the Compaq 3650 do exist (e.g., ESRI's ArcPad), so in theory, this information should be able to be rendered on the mobile device. The amount of information required to be transmitted would vary with the domain of interest and the resolution of the grid points but should result in a lesser amount of data transferred between server and client. Benchmarking tests would need to be performed to determine the tradeoffs/benefits of each method.

Target Detection via non-Acoustic Signals

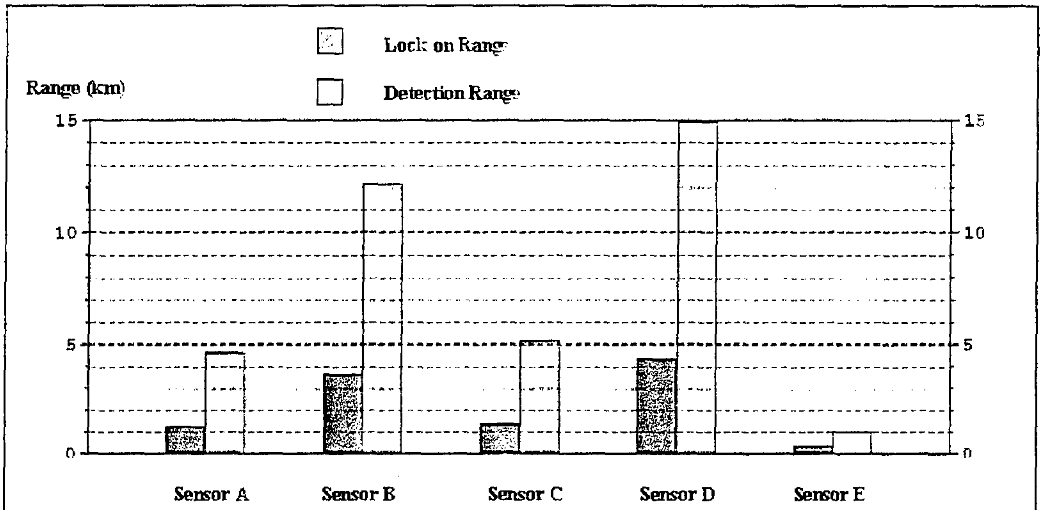

Figure 4 – TAWS Bar Chart of Lock On and Detection Ranges

The Target Acquisition Weapons Software (TAWS [3]) provides lock on and/or detection ranges for a wide variety of electro-optical sensors and military targets. Although this software is currently written in Fortran, it should be possible to develop a mobile client in Java that would display TAWS output parameters. This would compliment the Mobile ABFA application and allow the lower echelon user to obtain valuable information regarding target acquisition in the electro-optical wavelength spectrum. Currently a version of TAWS is implemented in the IMETS and has non-map graphics displays to represent the lock on and detection ranges as bar charts (figure 4). It is possible that at some point these bar charts could be displayed on the mobile device, but to start with it may be simpler to modify the existing Mobile ABFA GUI such that lock on and detection ranges can be displayed as numeric values in the current Probability of Detection text box. Work is being finalized on a TAWS map overlay capability in IMETS that will overlay the lock on and detection ranges on a map background over a 360-degree azimuth. This overlay will also incorporate the effects of terrain masking and will color code those areas in a separate color. The discussion in the section above related to providing a 2-D or 3-D display on the mobile device is pertinent to the overlay capability as well. At some point, it may also be possible to animate these graphics over time to allow the user to visualize the temporal variation in the transmission of the acoustic and electro-optical signals.

SUMMARY

Advances in computer hardware and software technology have made it possible to develop and demonstrate a prototype Mobile Acoustic BattleField Aid on a handheld computer. While the current GUI and outputs are rather simplistic, it is anticipated that continued advances in mobile computing technology will allow more advanced applications in the future. Replacing the existing commercial 802.11 wireless communications technology with the emerging Joint Tactical Radio System (JTRS) and rehosting the Java clients on fielded tactical command and control systems may soon allow a target detection capability at lower echelons. Weather information required as input for these clients is readily available (or will be soon) at echelons down to the battalion level via the fielded IMETS.

REFERENCES

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[2] Sauter, D., Torres, M., 2002, "Mobile Weather Technology for the Army", *Wireless Business & Technology*, February/March 2002, pp. 58-62.

[3] Gouveia, et al, 2000, "TAWS and NOWS: Software Products for Operational Weather Support", *Proceedings of the BACIMO 2000 Conference*, Ft. Collins, CO.