NPS-MA-92-ØØ8

NAVAL POSTGRADUATE SCHOOL
Monterey, California

AUDIO DETECTION ALGORITHMS

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August 1992

Prepared for: Naval Postgraduate School
Monterey, CA 93943

NAVAL POSTGRADUATE SCHOOL
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Prepared by:

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188

1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED

1b RESTRICTIVE MARKINGS

2a SECURITY CLASSIFICATION AUTHORITY

2b DECLASSIFICATION / DOWNGRADING SCHEDULE

3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited

4 PERFORMING ORGANIZATION REPORT NUMBER(S) NPS-MA-92-008

5 MONITORING ORGANIZATION REPORT NUMBER(S) NPS-MA-92-008

6a NAME OF PERFORMING ORGANIZATION Naval Postgraduate School

6b OFFICE SYMBOL *(If applicable)* MA

7a NAME OF MONITORING ORGANIZATION Naval Postgraduate School

6c. ADDRESS *(City, State, and ZIP Code)* Monterey, CA 93943

7b ADDRESS *(City, State, and ZIP Code)* Monterey, CA 93943

8a NAME OF FUNDING/SPONSORING ORGANIZATION Naval Postgraduate School TRAC - Monterey

8b OFFICE SYMBOL *(If applicable)* MA

9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS *(City, State, and ZIP Code)* Monterey, CA 93943

10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO

11 TITLE *(Include Security Classification)* AUDIO DETECTION ALGORITHMS

12 PERSONAL AUTHOR(S) B. Neta and B. Mansager

13a TYPE OF REPORT Technical

13b TIME COVERED FROM 10/1 TO 7/31

14 DATE OF REPORT *(Year, Month, Day)* August 10, 1992

15 PAGE COUNT 8

16 SUPPLEMENTARY NOTATION

17 COSATI CODES

FIELD	GROUP	SUB-GROUP

18 SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)* acquisition sensors, audio cueing, emanating platform, Janus combat simulation

19 ABSTRACT *(Continue on reverse if necessary and identify by block number)*

Audio information concerning targets generally includes direction, frequencies and energy levels. One use of audio cueing is to use direction information to help determine where more sensitive visual direction and acquisition sensors should be directed. Generally, use of audio cueing will shorten times required for visual detection, although there could be circumstances where the audio information is misleading and degrades visual performance. Audio signatures can also be useful for helping classify the emanating platform, as well as to provide estimates of its velocity.

The Janus combat simulation is the premier high resolution model used by the Army and other agencies to conduct research. This model has a visual detection model which essentially incorporates algorithms as described by Hartman(1985). The model in its current form does not have any sound cueing capability. This report is part of a research effort to investigate the utility of developing such a capability.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS

21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED

22a NAME OF RESPONSIBLE INDIVIDUAL B. Neta

22b TELEPHONE *(Include Area Code)* (408) 646-2235

22c OFFICE SYMBOL MA/Nd

DD Form 1473, JUN 86 — *Previous editions are obsolete* — SECURITY CLASSIFICATION OF THIS PAGE

S/N 0102-LF-014-6603 — UNCLASSIFIED

Audio Detection Algorithms

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1 Introduction

Audio information concerning targets generally includes direction, frequencies and energy levels. One use of audio cueing is to use direction information to help determine where more sensitive visual direction and acquisition sensors should be directed. Generally, use of audio cueing will shorten times required for visual detection, although there could be circumstances where the audio information is misleading and degrades visual performance. Audio signatures can also be useful for helping classify the emanating platform, as well as to provide estimates of its velocity.

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In the next section we discuss visual detection and define the terminology. Section 3 will be devoted to an aural detection algorithm used in UCCATS. We suggest several modification to this algorithm to be incorporated in Janus. This modified aural acquisition algorithm is described in section 4. We conclude with remarks concerning parallel computation.

2 Visual Detection

The target acquisition combat process has been investigated for many years. Work on the physiology and psychophysics of vision began in the last century and continues today, (see J. K. Hartman, 1985). The seminal study of military target acquisition is the work "Search and Screening" by B. O. Koopman (1946). Almost all later work in modeling of target acquisition builds on the basic ideas of this report. Koopman defined detection as, "that event constituted by the observer's becoming aware of the presence and possibly of the position and even in some cases of the motion of the target". There are several levels of target acquisition (see e.g. Hartman, 1985).

Cueing Information provides the approximate location for further search (e.g. a gun flash or a noise).
Detection means that an observer decides that an object in his field of view has military interest (e.g. he distinguishes between a vehicle and a shrub).

Classification means that the observer is able to distinguish broad target categories (e.g. tracked versus wheeled vehicles).

Recognition means discrimination among finer classes of targets (e.g. tank versus armored personnel carrier).

Identification provides precise target identity.

Note that detection is used both to denote the entire target acquisition process (Koopman's definition) and as a level of acquisition. The intended meaning will be specified if it is not clear from the context.
The response to a target acquisition depends on the level of acquisition. Detection may cause the observer to look more closely or to use better sensors in order to identify the target.
Target acquisition is very complex and requires research in many areas, such as Physics, Meteorology, Electronics, Physiology and Psychology.
Hartman discusses several models of target acquisition using real time imaging sensors such as unaided vision, optically aided vision, and infrared scopes. All of these sensors present an image to the human observer, and target acquisition requires that the observer respond to the image displayed. There are also models for non-imaging sensors such as radar and sonar.
Koopman observed two significant characteristics of the visual detection phenomenon:

i. There is a certain set of physical requirements which must be met for detection, for example, line-of-sight to the target must exist; the target signature must be greater than the sensor threshold; the sensor must be pointing in the right direction.

ii. "Even when the physical conditions make detection possible, it will by no means inevitably occur". Thus detection models are stochastic. Examples of factors important in target acquisition are: target type, target fraction exposed, target movement, observed background complexity, atmospheric visibility, sensor device, sensor calibration and maintenance, observer training, observer alertness, observer motivation and many more.

3 Aural Detection

One of the limitations of visual detection is the necessity of existence of line-of-sight to the target. Military platforms can be noisy, especially when they are moving. If the movement is on the other side of a hill or, in urban setting, obscured by buildings, an aural detection algorithm can be useful. It is, of course, to be used in conjunction with visual detection. For example, the noise eminated by a military platform can give cueing information. The detection and classification can be done by recognizing the type of noise heard. For example rotary wing aircraft can be distinguished from wheeled or tracked vehicle. Other characteristics such as sound pressure level can help in classification.

Cueing information obtained by sound will be given to observers so they may point their video sensors in that direction.

The only available algorithm for aural acquisition known to us can be found in UCCATS. UCCATS is a model combining features of Janus and the SEES model and still retains many of the Janus features. Therefore, it is an appropriate model to look to for possible improvements to the Janus simulation. In the following we describe that algorithm. We conclude the report with our modifications to it and with ideas for future research.

The Conflict Simulation Laboratory at Lawrence Livermore has developed sound cueing as a part of the Urban Combat Computer Assisted Training System (UCCATS). We now describe this model as it is given in The UCCATS Algorithms Manual (see S. Wang, 1991).

UCCATS attempts to simulate the detection of mechanical vehicles based on sound cueing. Sound cueing is determined by the mechanical vehicle and the distance between the vehicle and the detecting unit. Units report the detection of mechanical vehicles to the player. UCCATS provides the player the capability to turn the reporting of units detected by sound on or off.

The sound cueing model computes the perceived sound level for a given listener based on the inherent sound level of the platform and its distance from the listener. The attenuation of the generated sound level of the platform depends only on distance.

Other assumptions and dependencies associated with sound cueing are:

i. Each listener can be surrounded by sound wherever it goes. For example, a human driving a truck will always be surrounded with the noise generated by the truck. We would say that the listener is surrounded by an inherent sound that is generated at an inherent sound level. In the UCCATS simulation the inherent sound level of each platform takes on one of two values depending on whether or not the listener is moving.

ii. The only sound that can mask the sound of an enemy platform is that inherent sound that surrounds the listener. This implies that the listener mounted on the noisiest platform will not be able to hear any other platform.

iii. Each platform is considered in isolation. For example, a thousand tanks moving between a listener and a truck will not mask the sound of the truck.

iv. Listening has no blind spots, i.e. any platform close enough to the listener may be heard.

v. Listeners can only hear platforms that do not belong to the same side as the listener. This fits in well with the notion that the units on the same side know the location of each other.

vi. A unit will not report hearing any platform that it has already acquired visually.

vii. When a unit hears something that should be reported, the simulation causes the listener's symbol to blink to alert the work station operator.

viii. Each increase of 10 db in the intensity of a sound stimulus, no matter what the frequency component, doubles the sensation of the loudness.

ix. The propagation of sound is modeled as a wave front that expands in a spherical fashion from the platform with the pressure varying inversely proportional to the volume of the sphere with the given radius".

4 Modified Aural Acquisition Algorithm

The aural acquisition algorithm in UCCATS is clearly a simple model, a demonstration of which can be seen at CSL at Lawrence Livermore National Laboratory. There are many possible modifications to be considered. Some of these are simple enough and can be included in an implementation of sound cueing in Janus combat model. The others will lead to a deterioration of the response time and will not be possible to include unless a version of Janus for a parallel computer is developed.
The following can be incorporated in a version of Janus on serial computers:

i. Eliminate the third assumption in the sound cueing algorithm implemented in UCCATS. Thus the noise generated by platform near the listener will be incorporated with the inherent sound level of the listener.

ii. Add an assumption that noise resulting from shooting in a proximity of a listener must also be incorporated in the inherent sound level.

iii. Another platform should be modelled in Janus, this is a listening - capable unit called TUGV (Tactical Unmanned Ground Vehicle). This unit is now under development. It has an Integrated Acoustic Sensor (IAS) and an Acoustic Detection System (ADS). The IAS was developed to provide the remote operator the capability of acoustically monitoring the vehicle surroundings. The IAS can also be steered electronically to find the direction of acoustic sources. The ADS provides listening capabilities for two frequency regions - 100 Hz to 11 KHz (sonic) and 11 KHz to 20 KHz (ultrasonic). Since humans have their greatest hearing sensitivity for frequencies in the range 1000-5000Hz, the ADS provides for enhanced listening capability at the higher frequency range, see Tromel (1992).

iv. Initially one should be able to draw circles around each platform showing how far it can hear any type of platform assuming inherent sound level of zero. Since circles are drawn, this means that reflections, refractions and attenuation due to any effect but distance are not taken into account.

Factors that are harder to include in a serial computer version of Janus are: The attenuation of a generated sound level should depend on topography and terrain features, vegetation, weather and atmospheric conditions. For these effects one can consult Attenborough (1988), Pierce (1988), Larson et. al. (1988) and Huisman (1990).

Parallel computers have been used to solve problems in many application areas. The first author has developed several algorithms for the solution of systems of ordinary differential equations and for the solution of the shallow water equations on the INTEL iPSC/2 hypercube available at the Mathematics Department. The hypercube was also used to predict the orbit of satellites. The authors believe that the response time of Janus will deteriorate by the introduction of the one-meter terrain and by the more sophisticated sound cueing algorithm. Therefore it is recommended that parallelization of Janus will be considered.

Acknowledgement
The authors acknowledge the support of TRADOC Analysis Command in Monterey.

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