Contract No. DASG60-00-M-0201
Purchase request no.: Foot in the Door-01
Title Name: Artificial Neural Network Analysis System
Company: Atlantic Engineering Company
1779 S. Lakeshore Drive
Louisa, VA 23093
Phone 540-967-5005
Email: bpowell@usa.com

Technical Report-Study/Service
Final Report
Due Date February 27, 2001

Distribution:

Space & Missile Defense Technical Center
P. O. Box 1500
ATTN: SMDC-TC-A/Smith
Huntsville, AL 35807-3801

Space & Missile Defense Technical Center
P. O. Box 1500
ATTN: SMDC-CM-CT/Callahan
Huntsville, AL 35807-3801

Defense Technical Information Center
ATTN: DTIC (Pat Mawby)
Suite 0944
FT Belvoir, VA 22060-6218

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
27-02-2001	Final Report	28-10-2000 27-02-2001

4. TITLE AND SUBTITLE

Artificial Neural Network Analysis System

5a. CONTRACT NUMBER
DASG60-00-M-0201

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Powell, Bruce C

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Atlantic Engineering Company
1779 S. Lakeshore Dr.
Louisa, VA 23093

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Space & Missile
Defense Command

P.O. Box 1500
Huntsville, Al 35807-3801

10. SPONSOR/MONITOR'S ACRONYM(S)
SMDC

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Target detection, multi-target tracking and threat identification of ICBM and its warheads by sensor fusion and data fusion of sensors in a fuzzy neural network system based on the compound eye of a fly.

15. SUBJECT TERMS
Sensor fusion; data fusion; fuzzy; neural; network; threat identification; multi-target; tracking; target detection

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Bruce C. Powell
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED		8	19b. TELEPHONE NUMBER *(include area code)* 540-967-5005

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

Form SF298 Citation Data

Report Date *("DD MON YYYY")* 27-02-2001	**Report Type** N/A	**Dates Covered (from... to)** *("DD MON YYYY")* 28-10-2000 27-02-2001

Title and Subtitle Artificial Neural Network Analysis System	**Contract or Grant Number** DASG60-00-M-0201
	Program Element Number
Authors Powell, Bruce C	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Atlantic Engineering Company 1779 S. Lakeshore Dr. Louisa, VA 23093	**Performing Organization Number(s)**
Sponsoring/Monitoring Agency Name(s) and Address(es) U.S. Army Space & Missile SMDC Defense Command P.O. Box 1500 Huntsville, Al 35807-3801	**Monitoring Agency Acronym**
	Monitoring Agency Report Number(s)
Distribution/Availability Statement Approved for public release, distribution unlimited	
Supplementary Notes	
Abstract Target detection, multi-target tracking and threat identification of ICBM and its warheads by sensor fusion and data fusion of sensors in a fuzzy neural network system based on the compound eye of a fly.	
Subject Terms Sensor fusion; data fusion; fuzzy; neural; network; threat identification; multi-target; tracking; target detection	
Document Classification unclassified	**Classification of SF298** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** unlimited
Number of Pages 8	

Title Name: Artificial Neural Network Analysis System
Report prepared by: Bruce Powell, Atlantic Engineering Co, Phone 540-967-5005

Table of Contents:

Section I
Introduction Page 1
Summary Page 1
Conclusion Page 2
Section II
Method to arrive to Conclusion Page 2
References Page 4

Introduction

The purpose of the study is to examine the issue of target detection, multiple target tracking and threat identification from ICBMs and their warheads. The study is to propose how to perform sensor fusion and data fusion in a biological equivalent system using fuzzy neural networks. Matlab is to be considered, as it is a rapid development tool.

Summary:

The biological equivalent system identified is the compound eye of the housefly. Entomologists believe that the compound eyes are adapted to seeing swiftly moving objects. The housefly lacks a cortex so the system performs object recognition and tracking without high level computation. The housefly performs sensor fusion that is highly noise tolerant and the fly reacts to movements of less than 2/10 of a degree even though the calculated angle for each lens of the compound eye would be for two degrees of movement. By mimicking the housefly using several infrared detectors in an overlapping manner, the ability to tolerate noise and detect targets is increased and the angle of resolution should be improved by ten times.

The fuzzy neural network has the ability to track an unlimited number of multiple targets. Tracking is accurate even when the targets have a very complex movement and there is crossover in motion. The combination of a fuzzy neural network, which is also highly tolerant to noise, with the housefly's sensor fusion, should yield a system that is very precise. The system should perform multi-pixel object recognition in addition to single pixel tracking. The fusion of many radar sensors into the system will produce a radar system that is highly noise tolerant and adds the radar's abilities of ranging, Doppler and chaff penetration. Radar enhances the system's target identification and tracking ability. Data fusion of remote sensor is inherent to the system.

Conclusion:

The fuzzy neural network system based on the housefly's compound eyes visual system promises a fast and highly accurate system for target detection, multiple target tracking and threat identification from ICBMs and their warheads. Sensor fusion and data fusion are inherent to the system and give the high performance of the system.

Section II: Method to arrive to Conclusion:

The conclusion is based on information gained from written material from newspapers, technical journals, technical papers and books. Following this section are the references. The knowledge gained from the references to arrive to the conclusion is summarized below.

To identify, track and intercept an ICBM the characteristics and methods of sensing the ICBM need to be known. The launch of an ICBM has a large and bright rocket plume. The plume can be detected by the characteristic of infrared absorption due to the H2O and CO2 in the plume. The plume also has metal particles and the Doppler of the plume is in the opposite direction of the ICBM. The body of the ICBM has a high temperature from air friction. At the height of the trajectory the ICBM's warhead will separate form the ICBM's body. The warhead is much smaller and is surrounded by chaff and decoys. There is also jamming radar. The decoys can be distinguished from the true warheads as the decoys lack the mass of the warheads. There are methods for dealing with chaff and jammers.

The warhead must be detected quickly and intercepted prior to the warhead reentering the upper atmosphere. NORAD may have 15 minute warning of a launch and an interceptor may only have 100 seconds of flight time. The actual time for making the decision that the launch is a threat is after the payload separates and takes an angle and velocity to come down on the US.

For most of the time the target appears as a single infrared pixel. The combination of Doppler with single pixel can fix the target's coordinates. Time of the coordinate must also be accounted for. The time of the reception of the data and correcting for time delay from receiver electronics and propagation delay of the wave from the target to the receiver must be done.

The difference of radar from infrared is that search radar can quickly find an object and find its range and tracking radar is good at following the target. Radar has a large angle that the target may be in. Infrared can track a target to a smaller angle but can not measure the target range.

To quickly detect and track multiple targets, all the available radar, infrared and laser data needs to be organized and processed in as few steps as possible. A biological comparison is the housefly's compound eye with 4000 individual hexagon shaped image-forming elements. Also, the fly does not have a cortex so there does not exist a high computation of vision. The fly is able to organize and process data in a simple system. Each hexagon element has a directional view of two degrees in its vision. The output of the hexagon element is to eight receptors. The receptors do not receive the same view of space from the eight hexagon elements, but an overlapping offset from the elements. Another issue is that the input is adjusted for intensity. This setup allows the fly to react to movements of less than 2/10 of a degree. Entomologists believe that the compound eyes are adapted to seeing swiftly moving objects.

The fly's model implies that the issue of different location of radar, infrared and laser sensors can be dealt with by organizing the sensors with overlapping field of view. The result is a system tolerant to noise and the detection ability of locating the object to an angle is more accurate.

As a general-purpose detection and tracking computer, not all resources of radar and infrared may be available in a search area. The "Artificial Neural Network Analysis System" must be able to use what is available and produce an accurate detect or tracking. This ability to adjust for the unavailability of a sensor has the added benefit if the unavailability was due to malfunction or lost by military action. To account for the difference in sensor input timing difference, the last input needs to be held and given a life, the data can expire at the end of its life. When there is not an input the life is zero.

The fly's eye does take information from separate lens as single pixel detection and fuses the single detection with other single detection from other lenses. This has a natural offset and overlap. Due to the ICBM's great distance from sensors, the fusion of separate sensors can mimic the process of the fly's system. When one sensor is off to the side of the ICBM the model has a dramatic change. This can be compared to an object that is close and between the eyes of the fly. Another ability of the fly is to go from single pixel movement detection to feature recognition when the image becomes a multi-pixel image

without having to include additional steps. In the same subclass as the housefly is the dragonfly. The dragonfly is territorial and hunts flies as prey. The dragonfly performs detection, tracking and interception as a hunter. However the study [4] is on houseflies. The ability to identify, track, and avoid obstacles needs an ability for short term memory and an instinct (memory recall) to recognize objects. The fly's organization of data is forced by the precise construction of its compound eyes and the connection from the eyes to the neural system. To mimic the fly's system by various sensors at different locations require a communication system. The sensor data needs to be organized for input into the "Artificial Neural Network Analysis System". Having a fixed system with sensors gives the advantage of ease in organizing the data. However, data from a remote sensor that will be fused will also need to be organized. Data from remote sensors that does not relate to the areas being monitored needs to be ignored.

The above information was found in various books and papers listed in References following this section. The "Artificial Neural Network Analysis System" proposed is to be written using the Neural Network Toolbox and Fuzzy Logic Toolbox by MathWorks Inc and the simulation of radar and infrared input to the system will use Matlab products.

Reference:

[1] Bradley Graham, "Countdown to Collision", The Washington Post Magazine, December 10, 2000, pages 10-15, 24-28.

[2] Microsoft 1998 Encarta Encyclopaedia.

[3] Gan Wang, "A Parallel System for Single-Pixel Target Detection and Tracking Based on Trajectory Continuity Theory" A dissertation Presented to The Faculty of the School of Engineering and Applied Science, The University of Virginia. August 1991.

[4] Michael J. Wilcox, Donald C. Thelen, Jr., "A Retina with Parallel Input and Pulsed Output, Extracting High-Resolution Information", IEEE Transactions on Neural Networks, Vol. 10, No. 3, May 1999, pages 574-583.

[5] Haimovich, Yosko, Greenburg, Parisi, Becker, "Fusion of Sensors with Dissimilar Measurement/Tracking Accuracies", IEEE Transactions on Aerospace and Electronics Systems, Vol. 29, No. 1, Jan 1993, pages 245-249.

[6] Maybeck, Herrera, Evans, "Target Tracking Using Infrared Measurements and Laser Illumination", IEEE Transactions on Aerospace and Electronics Systems, Vol. 30, No. 3, July 1994, pages 758-767.

[7] Richard Alan Peters, II, James A. Nichols, “Rocket Plume Image Sequence Enhancement Using 3D Operators”, IEEE Transactions on Aerospace and Electronics Systems, Vol. 33, No. 2, April 1997, pages 485-498.

[8] Radar Systems Analysis and Design Using Matlab, Bassem R. Mahafza, Chapmam & Hall/CRC, 2000

[9] Lawrence Klein, “A Boolean Algebra Approach to Multiple Sensor Voting Fusion”, IEEE Transactions on Aerospace and Electronics Systems, Vol. 29, No. 2, April 1993, pages 317-325.

[10] Siouris, Chen, Wang, “Tracking an Incoming Ballistic Missile Using an Extended Interval Kalman Filter”, IEEE Transactions on Aerospace and Electronics Systems, Vol. 33, No. 1, Jan 1997, pages 232-239.

[11] Steven M. Sassman, “Track grouping to enhance moving target exploitation”, Proceeding of SPIE Vol. 4048, 2000, pages 156-167.

[12] Xu, Tso, Fung, “Fuzzy reactive control of a mobile robot incorporating a real/virtual target switching strategy”, Robotics and Autonomous Systems, Vol. 23, 1998, pages 171-186.

[13] Park, Ryu, Lee, “Multiple Target Angle Algorithm Using Predicted Angles”, IEEE Transactions on Aerospace and Electronics Systems, Vol. 30, No. 2, April 1994, pages 643-648.

[14] Cardillo, Mrstik, Plambeck, “A Track Filter for Reentry Objects with Uncertain Drag”, IEEE Transactions on Aerospace and Electronics Systems, Vol. 35, No. 2, April 1999, pages 394-408

[15] Lammers, Mark, “Doppler Imaging Based on Radar Target Precession”, IEEE Transactions on Aerospace and Electronics Systems, Vol. 29, No. 1, Jan 1993, page 166.

[16] Leonard Chin, “Application of Neural Networks in Target Tracking Data Fusion”, IEEE Transactions on Aerospace and Electronics Systems, Vol. 30, No. 1, April 1994, pages 281-286.

[17] Shetty, Alouani, “A Multi-sensor Tracking System With an Image-Based Maneuver Detector”, IEEE Transactions on Aerospace and Electronics Systems, Vol. 30, No. 1, Jan 1996, pages 167-181.

[18] Carlson, Evans, Wilson, “Search Radar Detection and Track with Hough Transform, Part I: System Concept”, IEEE Transactions on Aerospace and Electronics Systems, Vol. 30, No. 1, January 1994, pages 102-108.

[19] Carlson, Evans, Wilson, “Search Radar Detection and Track with Hough Transform, Part II: Detection Statistics”, IEEE Transactions on Aerospace and Electronics Systems, Vol. 30, No. 1, January 1994, pages 109-115.

[20] Carlson, Evans, Wilson, “Search Radar Detection and Track with Hough Transform, Part III: Detection Performance with Binary Integration”, IEEE Transactions on Aerospace and Electronics Systems, Vol. 30, No. 1, January 1994, pages 116-124.

[21] Arnold, Shaw, Pasternack, “Efficient Target Tracking Using Dynamic Programming”, IEEE Transactions on Aerospace and Electronics Systems, Vol. 29, No. 1, January 1993, pages 44-

[22] Hong, Lynch, “Recursive Temporal-Spatial Information Fusion with Applications to Target Identification”, IEEE Transactions on Aerospace and Electronics Systems, Vol. 29, No. 2, April 1993, pages 435-

[23] Hudson, Psaltis, “Correlation Filters for Aircraft Identification From Radar Range Profiles”, IEEE Transactions on Aerospace and Electronics Systems, Vol. 29, No. 3, July 1993, pages 741-748.

[24] Wei Li, “A Method for Design of a Hybrid Neuro-Fuzzy Control System Based on Behavior Modeling”, IEEE Transaction on Fuzzy Systems, Vol. 5, No 1, February 1997, Pages 128-137.

[25] Chang, Lee, Leung, “Radar Tracking for Air Surveillance in a Stressful Environment Using a Fuzzy-Gain Filter”, IEEE Transaction on Fuzzy Systems, Vol. 5, No 1, February 1997, Pages 80-88.

[26] Singh, Bailey, “Fuzzy Logic Applications to Multisensor-Multitarget Correlation” IEEE Transaction on Fuzzy Systems, Vol. 33, No 3, July 1997, Pages 752-768.

[27] Neural Network Toolbox User’s Guide, MathWorks Inc.

[28] Fuzzy Logic Toolbox User’s Guide, MathWorks Inc.

[29] Neural Network Design, Hagan, Demuth, Beale, PWS Publishing Company, 1996

[30] Brandon J. Bovey, "Target Tracking Prediction Through Group Correlation Analysis", A Thesis present to the Faculty of the School of Engineering and Applied Science, University of Virginia, May 2000.

[31] Radar Signal Processing and Adaptive System, Ramon Nitzberg, Artech House Inc, 1999

[32] Introduction to Random Signals and Applied Kalman Filtering with Matlab Exercises and Solutions, 3rd Ed, Robert Brown, Patrick Hwang, John Wiley & Sons, 1997.

[33] Bayesian Multiple Target Tracking, Lawrence Stone, Carl Barlow, Thomas Corwin, Artech House Inc, 1999

[34] Frederick Fergusion, Chandra Curtis, "A Hardware Design for Real-Time Multiple Target Tracking" IEEE 1999

[35] Hon Keung Kwan, Chi Kin Lee, "A Neural Network Approach to Pulse Radar Detection" IEEE Transactions on Aerospace and Electronics Systems, Vol. 29, No. 1, Jan 1993, pages 9-21