MASTER COPY KEEP THIS COPY FOR REPRODUCTION PURPOSES

AD-A284 891

[DOCUM]ENTATION PAGE

Form Approved OMB No. 0704-0188

[...]estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, [...]g and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this [...]g this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson [...] to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

[2.] REPORT DATE: 7/22/94

3. REPORT TYPE AND DATES COVERED: Final 1 Jun 92 - 31 May 94

4. TITLE AND SUBTITLE

New Algorithms for the Reduction of Image Degradation due to Atmospheric Turbulence

5. FUNDING NUMBERS

DAAL03-92-G-0209

6. AUTHOR(S)

B. Roy Frieden

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

Optical Sciences Center
Univ. of Arizona
Tucson, Arizona 85721

DTIC ELECTE SEP 27 1994 S B D

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U. S. Army Research Office
P. O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

ARO 30411.5-MA-SDI

11. SUPPLEMENTARY NOTES

The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

94-30709

402821

13. ABSTRACT (Maximum 200 words)

The problem of removing the deleterious effects of clear-air turbulence from images has been formally solved. As a spinoff, the method also allows wind velocity/shear to be measured along the optical line of sight. The overall approach uses two short-exposure images as inputs. These are divided in Fourier space. The division data is independent of the object (since it is the same in both images), and depends upon parameters that specify the two point spread functions. A neural net allows these parameters to be found, with good accuracy. The twoimages are then inverse-filtered, using the p.s.f. information. The average of the two inverse-filtered outputs is then the final reconstruction. Because of the neural net implementation, the entire algorithm can be emplaced upon a logic chip and used in quasi-real time. Future development would seem topromise real-time operation.

94 9 26 004

DTIC QUALITY INSPECTED 3

14. SUBJECT TERMS

image reconstruction; clear air turbulence; smart camera

15. NUMBER OF PAGES: 2

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

FINAL REPORT

NEW ALGORITHMS FOR THE REDUCTION OF IMAGE DEGRADATION DUE TO ATMOSPHERIC TURBULENCE

B. Roy Frieden
(602) 621-4904
fax: (602) 623-9034
e-mail: friedenr@ccit.arizona.edu

PROBLEM UNDER STUDY:

Limited-area defense from incoming missiles requires adequate lead time for effective countermeasures to be taken. If optical imaging sensors are used, atmospheric turbulence is an important obstacle to quick identification of an incoming missile. Another obstacle is image jitter due to random motion of the camera, both between and during image exposures.

Digital image processing permits efficient processing of image data. The overall objective is to reduce the deleterious effects to imagery of these well-known sources of image degradation, by using digital techniques. The general aims are to effect good reconstructions from a minimum number of data images, and in real time.

SUMMARY OF ACCOMPLISHMENTS

1. Atmospheric Turbulence Problem.

In this problem, multiple short-exposure images of one incoherent object are given as data. The aim was to process these to give a reconstruction of the object scene that would have existed without the presence of turbulence. For this purpose, the 'image-division' algorithm was developed.

The image-division algorithm works from two input spectral images. It uses a superposition model for the random atmospheric point spread function in each image. It solves for the parameters of the model by a least-squares fit to the quotient of the two images in Fourier space. The approach was tested to the presence of additive, circular Gaussian noise in the image inputs. It was found that up to 10% such noise (standard deviation of 10% of maximum modulus in image spectrum) can be well-tolerated in the reconstruction. This is a significant noise level, and bodes well for the approach.

Next, we attempted to further improve the algorithm's robustness to noise, by adding object power spectrum information into the algorithm. Specifically, a reconstruction is sought which least-squares satisfies both the quotient of the data and (additively) the average object power spectrum. It was found that the approach achieves its goal. Even if the inserted power spectrum is only a crude approximation to the true object power spectrum (which cannot be known, in any real problem scenario), the reconstruction quality increases.

Finally, with the aid of visiting professor Y. Wang, we strongly sped up the reconstruction algorithm by using a neural network in place of the Newton-Raphson search procedure previously used. A typical image now takes the order of a minute to process, and on a desk top pc. The goal is to produce the output in real time.

2. Wind velocity/shear mensuration

Since the image-division method (described above) has as intermediate outputs the two point spread functions forming the two observed images, it appears that vital information on wind speed is known as well. After all, these are the p.s.f.'s through the existing atmospheric turbulence, and the latter is directly caused by the prevailing wind situation. In particular, the more smeared out in a given direction a p.s.f. is, the stronger the wind must be in that direction. Since the method is purely passive as well, it offers a distinct advantage over the current use of radar imagery to accomplish the same goal. It also is cheaper to implement, and may prove to be a more effective measurer of wind speed and wind shear. This should be a promising area of new research.

3. Further development work

The main problem, number 1 above, has nearly been completely solved. It would require about 2 more years of research to reach full payoff. The spinoff to problem number 2 is fortuitous and suggests that this important problem may be soluble as well. However, if ARO or some other agency does not offer further support, this research will cease and a great opportunity will have been lost. In effect, past support of this research will have been wasted, as well.

SCIENTIFIC PERSONNEL

B.R. Frieden, principal investigator
David Graser, graduate student
Shan Jin, research assistant
Yiping Hu, research assistant
George Cipperly, Ph. D. 1992

REPORTED INVENTION

A patent disclosure for a 'smart camera for reducing atmospheric turbulence' was filed with ARO in 1993.

PUBLICATIONS

(total of 13 refereed papers during the grant period; the following 6 had direct bearing on the area of support)

B.R. Frieden, "Integral logarithmic transform: theory and applications," Appl. Opt. 31, 1138-1145 (1992).

B.R. Frieden and C. Oh, "Multiple-filter approach to phase retrieval from modulus data," Appl. Opt. 31, 1103-1108 (1992)

B.R. Frieden and C. Oh, "Turbulent image reconstruction from a superposition model," Optics Comm. 98, 241-244 (1993)

B.R. Frieden, "Turbulent image reconstruction using object power spectrum information," Optics Comm. 109, 227-230 (1994)

B.R. Frieden and R.J.Hughes, "Spectral 1/f noise derived from extremized physical information," Phys. Rev. E 49, 2644-2649 (1994)

B.R. Frieden and Y. Wang, "Minimum entropy-neural network approach to turbulent image reconstruction," Appl. Opt. (under review, 1994)

FINAL REPORT

NEW ALGORITHMS FOR THE REDUCTION OF IMAGE DEGRADATION DUE TO ATMOSPHERIC TURBULENCE

B. Roy Frieden
(602) 621-4904
fax: (602) 623-9034
e-mail: friedenr@ccit.arizona.edu

PROBLEM UNDER STUDY:

Limited-area defense from incoming missiles requires adequate lead time for effective countermeasures to be taken. If optical imaging sensors are used, atmospheric turbulence is an important obstacle to quick identification of an incoming missile. Another obstacle is image jitter due to random motion of the camera, both between and during image exposures.

Digital image processing permits efficient processing of image data. The overall objective is to reduce the deleterious effects to imagery of these well-known sources of image degradation, by using digital techniques. The general aims are to effect good reconstructions from a minimum number of data images, and in real time.

SUMMARY OF ACCOMPLISHMENTS

1. Atmospheric Turbulence Problem.

In this problem, multiple short-exposure images of one incoherent object are given as data. The aim was to process these to give a reconstruction of the object scene that would have existed without the presence of turbulence. For this purpose, the 'image-division' algorithm was developed.

The image-division algorithm works from two input spectral images. It uses a superposition model for the random atmospheric point spread function in each image. It solves for the parameters of the model by a least-squares fit to the quotient of the two images in Fourier space. The approach was tested to the presence of additive, circular Gaussian noise in the image inputs. It was found that up to 10% such noise (standard deviation of 10% of maximum modulus in image spectrum) can be well-tolerated in the reconstruction. This is a significant noise level, and bodes well for the approach.

Next, we attempted to further improve the algorithm's robustness to noise, by adding object power spectrum information into the algorithm. Specifically, a reconstruction is sought which least-squares satisfies both the quotient of the data and (additively) the average object power spectrum. It was found that the approach achieves its goal. Even if the inserted power spectrum is only a crude approximation to the true object power spectrum (which cannot be known, in any real problem scenario), the reconstruction quality increases.

Finally, with the aid of visiting professor Y. Wang, we strongly sped up the reconstruction algorithm by using a neural network in place of the Newton-Raphson search procedure previously used. A typical image now takes the order of a minute to process, and on a desk top pc. The goal is to produce the output in real time.

2. Wind velocity/shear mensuration

Since the image-division method (described above) has as intermediate outputs the two point spread functions forming the two observed images, it appears that vital information on wind speed is known as well. After all, these are the p.s.f.'s through the existing atmospheric turbulence, and the latter is directly caused by the prevailing wind situation. In particular, the more smeared out in a given direction a p.s.f. is, the stronger the wind must be in that direction. Since the method is purely passive as well, it offers a distinct advantage over the current use of radar imagery to accomplish the same goal. It also is cheaper to implement, and may prove to be a more effective measurer of wind speed and wind shear. This should be a promising area of new research.

3. Further development work

The main problem, number 1 above, has nearly been completely solved. It would require about 2 more years of research to reach full payoff. The spinoff to problem number 2 is fortuitous and suggests that this important problem may be soluble as well. However, if ARO or some other agency does not offer further support, this research will cease and a great opportunity will have been lost. In effect, past support of this research will have been wasted, as well.

SCIENTIFIC PERSONNEL

B.R. Frieden, principal investigator
David Graser, graduate student
Shan Jin, research assistant
Yiping Hu, research assistant
George Cipperly, Ph. D. 1992

REPORTED INVENTION

A patent disclosure for a 'smart camera for reducing atmospheric turbulence' was filed with ARO in 1993.

PUBLICATIONS

(total of 13 refereed papers during the grant period; the following 6 had direct bearing on the area of support)

B.R. Frieden, "Integral logarithmic transform: theory and applications," Appl. Opt. 31, 1138-1145 (1992).

B.R. Frieden and C. Oh, "Multiple-filter approach to phase retrieval from modulus data," Appl. Opt. 31, 1103-1108 (1992)

B.R. Frieden and C. Oh, "Turbulent image reconstruction from a superposition model," Optics Comm. 98, 241-244 (1993)

B.R. Frieden, "Turbulent image reconstruction using object power spectrum information," Optics Comm. 109, 227-230 (1994)

B.R. Frieden and R.J.Hughes, "Spectral 1/f noise derived from extremized physical information," Phys. Rev. E 49, 2644-2649 (1994)

B.R. Frieden and Y. Wang, "Minimum entropy-neural network approach to turbulent image reconstruction," Appl. Opt. (under review, 1994)

Codes
/or
Dist Special
A-1