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Evaluation of Cyclops Automatic Target Detection and Comparison with Human Capabilities

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ABSTRACT

An evaluation is presented on the performance of the detection and tracking algorithms used in a DSTO developed experimental air to air threat warner (Cyclops). The simulations of the Cyclops routines were performed using the Generic Track Processor software. It was found that human observers with limited training, who were aware of the approximate target location, reliably detected the target at ranges significantly greater than the automatic target acquisition system. The limitations of the data set and implications of the results are discussed.

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Evaluation of Cyclops Automatic Target Detection and Comparison with Human Capabilities.

EXECUTIVE SUMMARY

Images sequences obtained during the trial of Cyclops (a DSTO developed experimental air to air threat warner) were processed using a suite of algorithms - referred to here as the Generic Track Processor, or GTP, to evaluate the Cyclops tracking algorithms. The parameters in the Generic Track Processor were optimised for the sequences. The detection ranges were recorded and compared to the detection ranges of a trained operator and four observers of a previous experiment who were not trained with the imagery.

In general, the trained operator detected the target at least three nautical miles earlier than the Generic Track Processor and two nautical miles earlier than the average observer. This was due to the poor quality of the imagery which was caused by sensor imperfections and made all aspects of the tracking difficult. However, when the imagery was of a good quality the automatic target detection improved. The time spent looking at the imagery also gave the trained operator an advantage over the average observer (the four observers of the previous experiment) and the Generic Track Processor.

The tracking procedures for the Cyclops data are inadequate due mainly to the poor quality of the images; however the performance of the automatic target detection process on good quality images cannot be judged.

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1. Introduction

Cyclops was an experimental air to air threat warning system based on a 128 by 128 mercury-cadmium-telluride focal plane array. The Cyclops development program culminated in airborne trials in April 1991, in which detection and tracking of a distant aircraft approaching head-on with engine plume not visible, was investigated.

The aim of this experiment was to evaluate the performance of the Cyclops tracking algorithms on the Cyclops data and to compare these results with those obtained by human operators. The simulation of the Cyclops routines was performed using the Generic Track Processor software. Results are presented and comparisons and explanations are discussed.

2. Procedure

The procedure used to process the Cyclops data follows the algorithm as originally proposed for the Cyclops trial, but which was not evaluated due to equipment malfunction. The results obtained here do not duplicate the results that would have been obtained using the exact Cyclops processing chain. The size of filter windows and other parameters have been chosen to give the best performance.

2.1 Image Sequence Selection

Eleven sequences, each consisting of 90 frames obtained during the Cyclops trials, were extracted from the Honeywell HD101e magnetic tape drive at ranges where a human operator could detect the targets. In each sequence, the aircraft was at a different location (eg. Tindal or Richmond) and at varying altitudes and speeds. These sequences were run through the Generic Track Processor so that the parameters of the process could be optimised. None of the targets was detected automatically in these sequences and the parameters were modified to allow for maximum sensitivity, without having an excessive amount of false detections. The number of false detections were too high for an operational threat warner, however the detections were not so numerous that they obscured a valid detection when it occurred.

Failure to detect the target meant that extra image sequences from each run had to be obtained in which the target was closer to the sensor. Using this approach, the target was eventually detected in each run. The trained operator detection range, tracker detection range and the number of tracks in the initiated frame were recorded.

2.2 Processing Chain

The data was first spatially filtered by means of a low pass non-linear filter to remove low frequency components from the image, such as those arising from illumination variation within the image, or changing backgrounds. A binary threshold was applied to the image to select areas which are different to the background. The resultant points were formed into clusters. The cluster centres were then either associated to existing tracks, using a nearest neighbour association technique, or formed into new tracks using an *m-out-of-n* track initiation process. Temporal filtering of the track data used a Kalman filter.

A 7x7 pixel window was used for the low pass non-linear filter. Tests were run on a number of different size spatial filter kernels ranging from 3x3 to 9x9. The track was initiated in the same frame and the amount of tracks in the initiated frame was about the same in all these cases except for the 3x3. In this case, the track was initiated slightly later, the number of tracks in the initiated frame was lower and the track was not associated in as many frames as the larger kernels (track not at maximum likelihood) . The 7x7 kernel was a good mid range choice when these results were taken into consideration.

Nearest neighbour association was performed in a 5x5 window. Larger association windows were tried; however these resulted in the track being associated to the wrong plot. This could be quite a distance from the track position and resulted in the loss of the real track in the next frame.

The *m-out-of-n* track initiation parameters were set to 2-out-of-5. Although this resulted in a large number of false tracks, higher confidence initiation parameters such as 5 out of 5, resulted in extremely poor automatic detection ranges where the target was easily visible to a human observer.

The Kalman filter was detuned so that it did not form overly confident predictions of target motion. This was necessary because of the random manner in which the target would move around in the image due to the vibrations of the platform mount. For this report automatic detection is determined from initiation, and so the parameters of the Kalman filter do not affect these results. However, the parameters used produced the smoothest possible track without loosing track due to the jitter.

2.3 Human Performance

A previous experiment had been undertaken which involved a number of observers trying to detect the target in image sequences from the Cyclops trials. The observers were shown at least one trial run to demonstrate the type of images they would be looking at, and to familiarise them with the type of motion and approximate location of the target in the images. The image sequences were started at different lead times before the target was visible and therefore the observer did not know when to expect the target. Each observer saw 6 to 8 runs in a row, which were then repeated in the same order. Information from this experiment such as the average detection range, maximum detection range and minimum detection range was recorded where possible (This experiment was not carried out on sortie 4 and sortie 7 run 3).

3. Results

The results presented here list human detection ranges and automatic initiation ranges. The automatic target detection process is considered to have detected a track when a track, which will become a high confidence track, is initiated. A human observer will form a level of confidence in the track before signifying detection. The different measures are necessary because of the nature of the imagery, particularly the manner in which the lack of stabilisation causes the target to bounce. This makes it difficult for the Kalman process to establish a reasonable level of confidence in the track, while human observers need to establish confidence before they can indicate a detection. Due to random displacements in the image, the covariance of the plot estimates from the Kalman filter remain high. Therefore the covariance of the estimates is not a good measure of the track confidence.

A track management unit in the Generic Track Processor monitors the consistency of each track by incrementing a track confidence parameter if association occurs and reducing the confidence if no plots can be associated to the track. This confidence measure gradually grew for the target in question. However, the rate of growth or decay of this confidence measure is arbitrary, as is a threshold value which would confirm the track. Therefore, use of this parameter to measure detection would modify detection ranges arbitrarily. It should be noted that there were always objects with a higher track confidence than the real target (most of which were stationary in the sensor field, and consequently easily removed as sensor artefacts, but there were also other objects which could not be so easily removed.) The different measures are unfortunate because they reduce the apparent difference between the automatic target detection process and that of the human observer. Therefore, the automatic tracker is actually worse than it appears from *Table 1* .

Five human observers viewed the sequences. One individual, known as the trained operator whose detection ranges were not included in the average detection ranges of the other observers, was allowed to view the imagery as frequently as desired. The large amount of time spent viewing the imagery meant the trained human operator became skilled at the early detection of the target. The other four individuals, whose detection ranges were used to make up the average detection range by observers, were presented the sequences in a controlled manner [2]. They saw each sequence twice, but not immediately after the other run and not necessarily commencing at the same point. Both observations were recorded for each run from each of the observers. The maximum, minimum and average ranges of the resulting eight observations for each run are presented in Table 1. Unfortunately, the observations were not conducted on every run selected for processing. These results are presented more completely in [2]

Table 1: Table of Results

Image Sequence	Trained Operator Detection Range (naut.miles)	Tracker Initiation Range (naut.miles)	Average Detection Range by Observers (naut.miles)	Maximum Detection Range by Observers (naut.miles)	Minimum Detection Range by Observers (naut.miles)	Tracks at Initiated Frame
Sortie 8 Run 5	10.1	7.4	9.3	11.3	7.2	120
Sortie 7 Run 1	7.0	2.7	5.2	6.1	3.8	31
Sortie 7 Run 2	10.7	7.9	8.8	9.8	6.6	19
Sortie 7 Run 3	8.2	5.1	Not obtained	Not obtained	Not obtained	33
Sortie 7 Run 4	14.2	8.7	8.5	10.7	7.5	36
Sortie 7 Run 5	5.3	2.6	4.6	5.5	3.9	112
Sortie 4 Run 1	12.5	5.9	Not obtained	Not obtained	Not obtained	18
Sortie 4 Run 3	16.9	11.7	Not obtained	Not obtained	Not obtained	117
Sortie 4 Run 4	17.9	17.9	Not obtained	Not obtained	Not obtained	49
Sortie 4 Run 5	11.4	8.6	Not obtained	Not obtained	Not obtained	32
Sortie 4 run 6	11.6	7.5	Not obtained	Not obtained	Not obtained	34

4. Analysis of Results

The trained operator performed better than the inexperienced operators by an average of about 2.2 nautical miles. All human operators performed better than the automatic detection algorithm with the trained operator obtaining detections of the target at least 3 nautical miles before the tracker in all cases except one.

In sortie 7 run 4, the tracker performed better than the average human observer. In sortie 7 run 2, the tracker's detection occurred shortly after the average human response. It should be noted that only 4 people were used to obtain the average detection response and the results obtained on the same run by the same person at different times could differ by 3 or 4 nautical miles.

Detection by the tracker was hampered by the poor quality of the imagery. The target at times moved into areas of sensor imperfections like streaking, stationary bright pixels (dead pixels) and noise.

The contrast between the target and the background and the poor sensor mount stability also contributed to making early target detection by the tracker difficult.

The lack of stabilisation on the sensor mount caused the image to appear to bounce around, and made it difficult to track and associate points from successive frames.

The numerous dead pixels, which remained stationary in the image despite the bouncing around, are consequently easy to associate and form high confidence tracks. The dead pixels also provide other points for the tracker to associate to the target track instead of the real target, and this caused valid tracks to go astray. The dead pixels and their tracks could have been eliminated using additional processing, which relied on the knowledge that false tracks due to sensor imperfections have a zero velocity component, but this was outside the scope of the analysis.

Streaking caused by different gain and offset parameters in the pixel read out amplifiers (each line of pixels was read through the same amplifier) of the sensor caused the target intensity to fluctuate. This also confused the spatial filtering front end. This resulted in numerous false clusters. A simple de-streaking algorithm, which removed the offset but did not allow for the variation in amplifier gain, was added in an attempt to minimise the problems associated with the streaking. This proved to be moderately successful at removing many of the false clusters generated during the spatial filtering.

All these imperfections hampered the preprocessing of the image, track association and track initiation. An example of the image quality can be seen in Figure 1.

The image quality in sortie 7 run 5 and sortie 7 run 1 (which was described as having poor focus) was particularly poor. In sortie 4 run 4, the operator detection range and the tracker detection range are identical. This is because the image quality is much better in this sequence and the bright target was contrasted against a darker background. The image sequences taken from sortie 4 run 3 and sortie 4 run 6 detected the target earlier in the sequence but lost the target before regaining it later in that sequence.

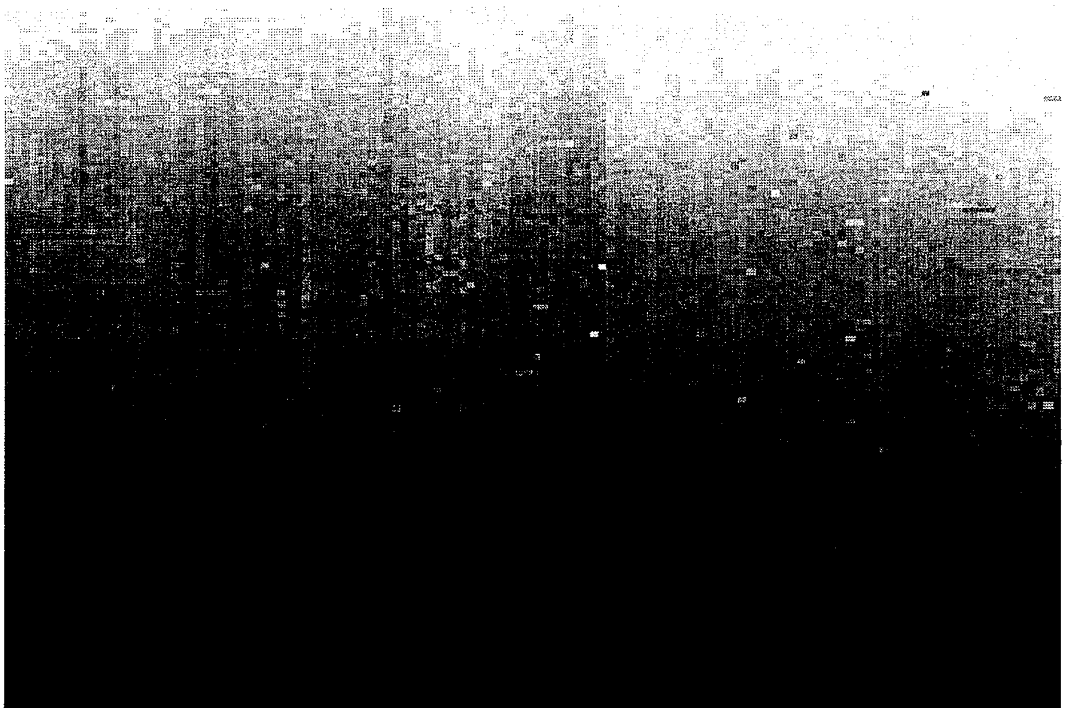

Figure 1. Example of image quality at approximate time of automatic detection.

Detection range by the trained operator was probably better than the average detection range due to the experience of the operator and knowledge of the expected target's motion, appearance and position in the image. The average observer would have had problems in detecting the target in the early stages of the sequences due to the poor contrast of the target with respect to the background.

5. Conclusions

The trained operator detected the target at least 3 nautical miles earlier than the GTP. This was due in part to the poor quality of most of the imagery. Sensor imperfections, such as image streaking, dead pixels and noise, coupled with the sensor mount instability made spatial filtering and all tracking aspects (track association and track initiation) difficult. The ability of the human observer to disregard stationary points and look for motion of the target within the image, accounts for the superior performance of human operators when compared to the automatic detection process.

When good quality images were available, the automatic tracker performance improved markedly. It is believed that the tracking procedures proposed for the Cyclops data are inadequate. This is due mainly to the poor image quality. The performance of the automatic detection process on good quality images cannot be inferred from this data set.

6. Acknowledgments

This work could not have been performed without the work of Michael Royce who managed to resurrect the Honeywell HD101e and its interface and William Cirillo who carried out the human observer experiments.

7. References

1. G. V. Poropat "Airborne Infrared threat-warning technology demonstrator trial: Conduct and Preliminary Results", SRL-0088-TM, February 1992.

2. William Cirillo, "Visual Target Detection of Cyclops Data", Unpublished note, April 1993.

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19. Abstract

An evaluation is presented on the performance of the detection and tracking algorithms used in a DSTO developed experimental air to air threat warner (Cyclops). The simulations of Cyclops routines were performed using the Generic Track Processor software. It was found that human observers with limited training, who were aware of the approximate target location, reliability detected the target at ranges significantly greater than the automatic target aquisition system. The limitation of the data set and implications of the results are discussed.