Gazi University Journal of Science
GU J Sci
24(3):425-435 (2011)

GUJS
www.gujs.org

Estimation of Target Size on the Infrared Image Taken from Different Distances

Yalçın ATA[1♠], Cem NAKİBOĞLU[2]

[1]*Defense Industries Research and Development Institute (TÜBİTAK SAGE)*

[2] *Gazi University, Faculty of Engineering, Department of Chemical Engineering, 06570, Ankara, Turkey*

Received: 01/06/2010 Revised: 26/11/2010 Accepted:13/01/2011

ABSTRACT

In this study, it is aimed to calculate the target size from its infrared (IR) image. Target is decomposed from background and target size is calculated depending on its pixel number on the thermal image. By using horizontal and vertical angular field of view (FOV) of thermal camera and distance between thermal camera and target, target size is estimated. Comparing obtained results with real target size show that this model has a good accuracy. Model can be used for target size calculation on the infrared image

Key Words: Infrared image, thermal image, target size etc.

1. INTRODUCTION

Any target's size can be calculated with the help of thermal image processing on the thermal image taken from definite distance. By decomposing target and background on the thermal image, target size is estimated and so that a parameter of target identification is defined easier.

In our study we developed a model to calculate target size from its thermal mage. Target size calculation steps for developed model are given in the Figure 1.

♠Corresponding author, e-mail: yalcinata@gmail.com

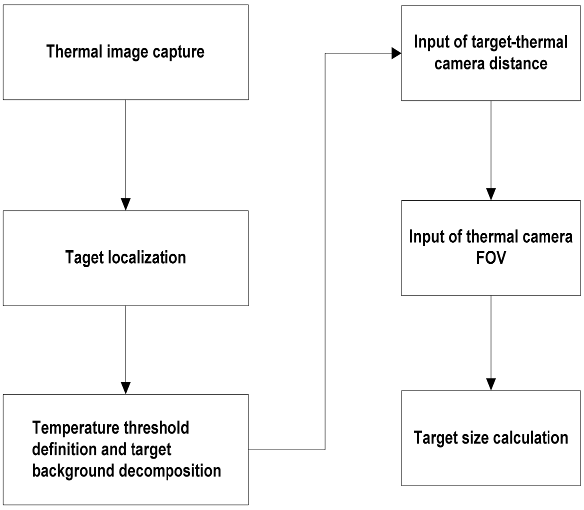

Figure 1.Target size calculation steps

In model after capturing thermal image, target boundaries are defined on the thermal image and target is localized. The temperature threshold value is defined so that elimination of effects of pixels which are belonging to background in the localized area. The pixels which have temperature over the temperature threshold value are used to calculate target size. The distance between thermal camera and target is included to the model. Then horizontal and vertical angular FOVs of thermal camera are inputted to the model. After providing those parameters target size is calculated and model is approved by comparing the obtained results with the real target sizes.

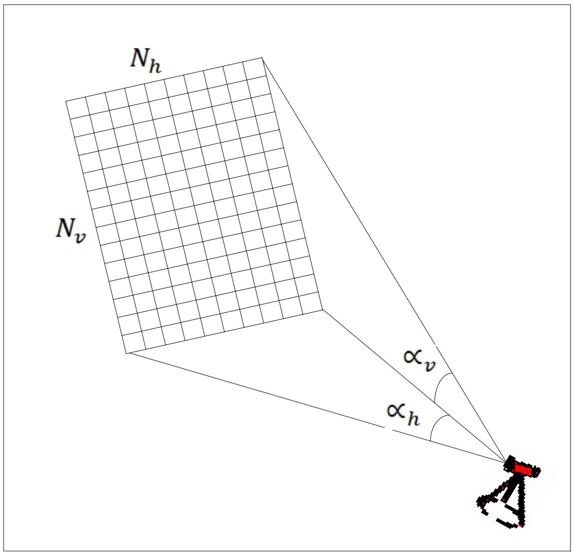

Figure 2. Thermal camera FOV

As seen from Figure 2, any thermal camera takes thermal images depending on its horizontal and vertical angular FOVs α_h and α_v. Horizontal and vertical pixel numbers in the taken thermal image can be stated as N_h and N_v. Thus horizontal and vertical angular resolution of any pixel in the thermal image can be given as in Eq. 1 and Eq.2.

$$\Delta\propto_h = \frac{\propto_h}{N_h} \qquad (1)$$

$$\Delta\propto_v = \frac{\propto_v}{N_v} \qquad (2)$$

The edge of the area seen by a pixel is as in Figure 3 depending on angular FOV and distance.

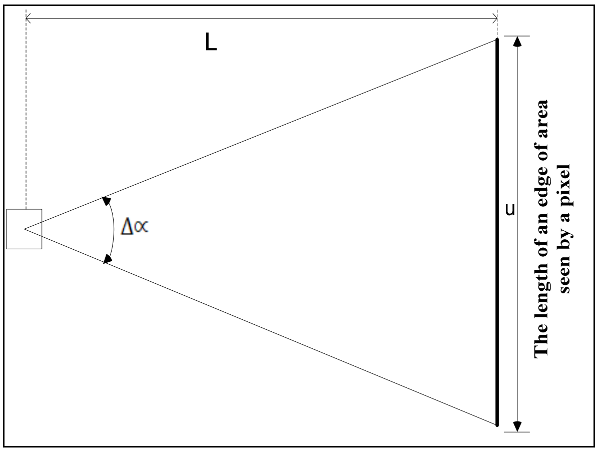

Figure 3. The edge seen by a pixel

The area seen by a pixel has a rectangular shape and is related with the distance (L) and angular FOVs (α_h,α_v). By using trigonometric relations, lengths of horizontal and vertical edges of the rectangular area seen by a pixel can be calculated as in Eq. 3 and Eq.4 [[1],[2]] :

$$u_h = 2L\tan\left(\frac{\Delta\alpha_h}{2}\right) \tag{3}$$

$$u_v = 2L\tan\left(\frac{\Delta\propto_v}{2}\right) \tag{4}$$

The rectangular area seen by a pixel can be written as in Eq. 5 depending on the lengths of horizontal and vertical edges:

$$A_p = u_h x u_v$$
$$= 4L^2\tan\left(\frac{\Delta\alpha_h}{2}\right)\tan\left(\frac{\Delta\propto_v}{2}\right) \tag{5}$$

Pixel numbers (N_p) which are belonging to target are defined depending on selected temperature threshold value are calculated. Depending on the ambient and background temperature on the time of image capture, the highest temperature value in the background section of the thermal image is selected as threshold value (T_e).

On the infrared image, pixels belonging to target are defined as Eq. 6 depending on the selected threshold value where N is the pixel number of infrared image

$$T_{tar} = \begin{cases} T_t, & \sum_{t=1}^{N} T_t \geq T_e \;\; lse \end{cases} \tag{6}$$

Target pixels decomposed from background is calculated by using Eq. 7. Initial value of N_0 is 0. By scanning all pixels of infrared images, when target's pixel is caught (Eq. 6) then value of N_0 is increased by 1.

$$N_{tar} = \begin{cases} N_0 + 1, & \sum_{t=1}^{N} T_t \geq T_e \;\; lse \end{cases} \tag{7}$$

As a result total area can be calculated by using Eq. 8.

$$A_t = N_{tar} x A_p \quad (m^2) \tag{8}$$

The user interface of the software of our model which is used to calculate target size is given in Figure 4.

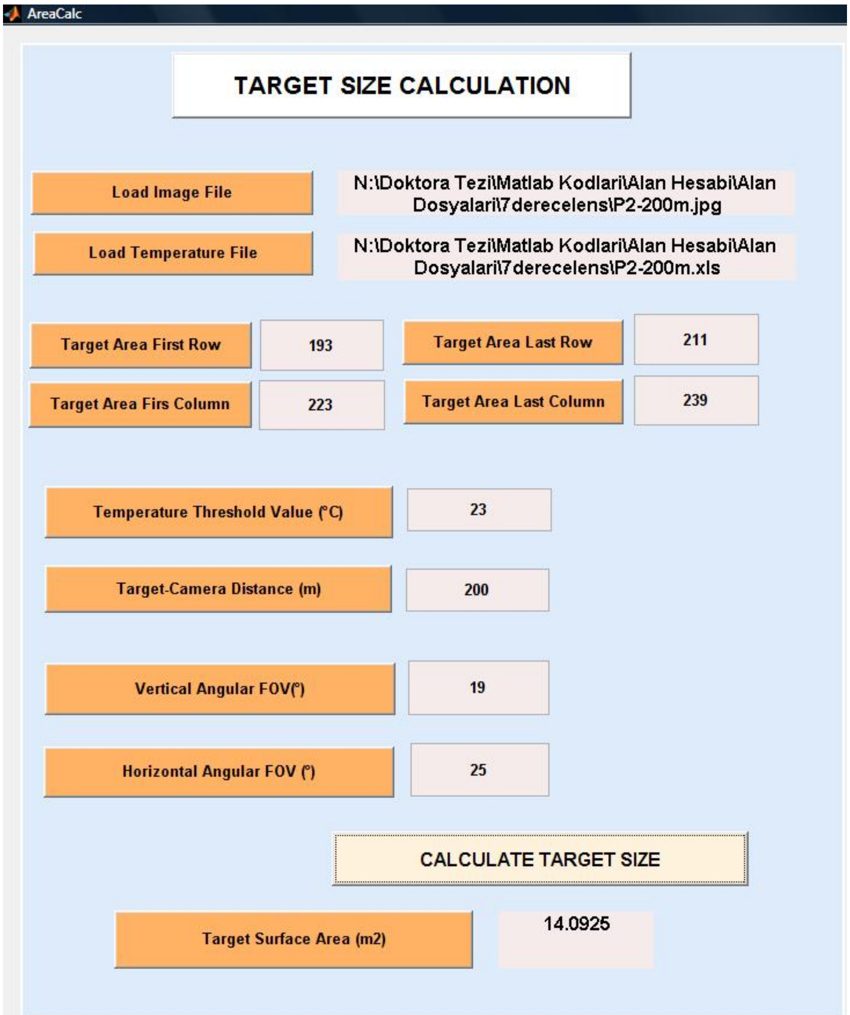

Figure 4. Target size calculation software user interface

2.EXPERIMENTAL RESULTS

2.1.Temperature plate captured by standard camera lens

FLIR ThermaCAM S65 LWIR thermal camera which works between 7,5-13 µm wavelengths was used to take thermal images. Its angular vertical and horizontal FOVs respectively are $\alpha_v = 18°$ ve $\alpha_h = 24°$. Focal length of the camera is $f_1 = 35$ mm [[3]].

Thermal images of a temperature controlled plate (Figure 5) with 60 °C temperature were taken from different distances. The dimensions of the plate are 105 cm x 110 cm and its area is 1,155 m^2.

Figure 5. Temperature controlled plate

Captured IR images of the temperature controlled plate are given in Figure 6.

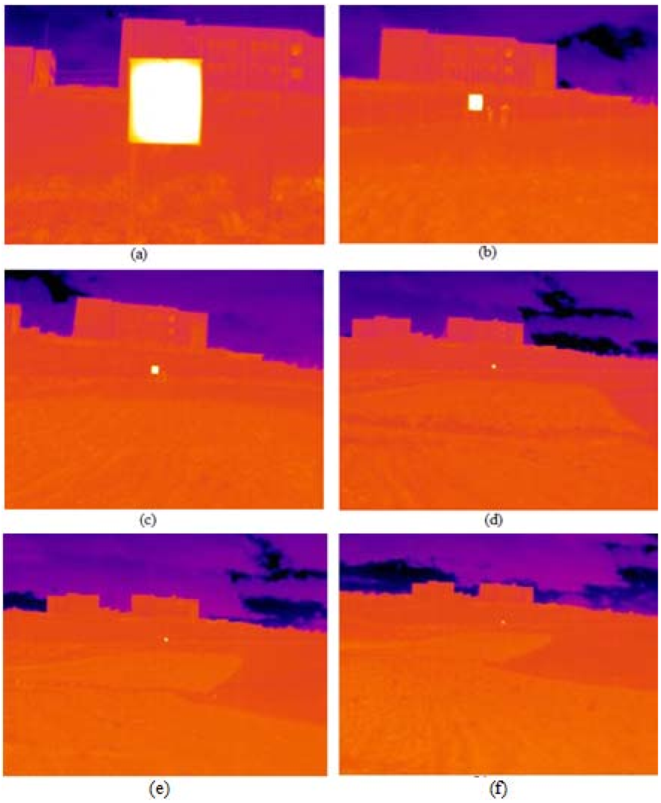

Figure 6. Thermal images of the temperature controlled plate with 60 °C from different distances (a- 10 m, b- 50 m, c- 100 m, d- 250 m, e- 300 m, f- 400 m)

Obtained results from our model for different distances are given in Table 1.

Table 1. Area values of the temperature controlled plate with 60 °C

Distance (m)	Calculated Area (m^2)	Error* (%)
10	1,185	2,59
50	1,2208	5,69
100	1,2508	8,29
250	1,178	1,99
300	1,0795	6,53
400	1,0966	5,05

*Error values are absolute

Calculated values variations depending on distance is given in the Figure 7.

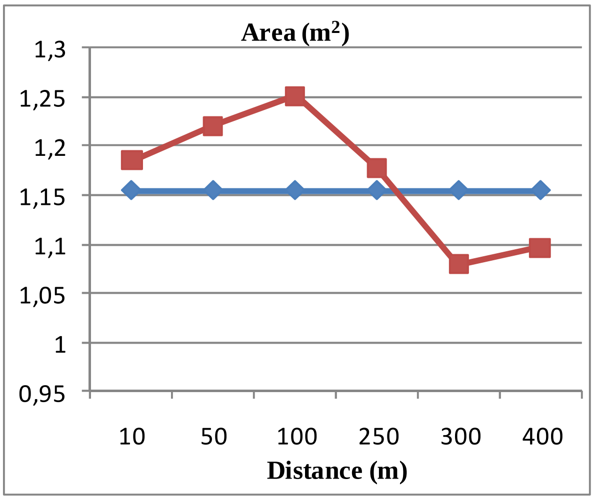

Figure 7. The area-distance variation of temperature controlled plate with 60 °C

The variation of the errors occurred during area calculation depending on the distance is given in the Figure 8.

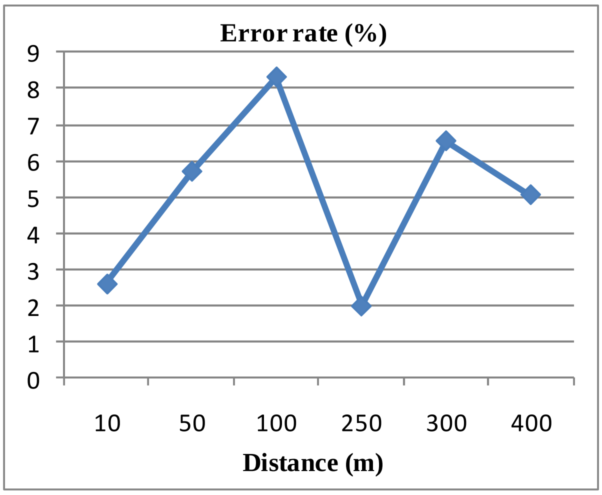

Figure 8. The error-distance variation of the temperature controlled plate with 60 °C

In this experimental study maximum occurred error is about 8.3%.

2.2.Temperature plate captured by 7° camera lens

In this experimental study FLIR ThermaCAM S65 LWIR thermal camera was used to take thermal images. Thermal camera lens was changed with new one which has 7° FOV.

Image size on the thermal image is directly proportional to focal length [4]. So image size of 7° lens relative to the image size of standard lens will be the result of focal lengths ratio. The focal length of 7° lens is $f_2 = 122$ mm. This means that images taken with this lens will be larger than the images taken with standard lens by n times in one axis. Where:

$$n = \frac{f_2}{f_1} = \frac{122}{35} = 3{,}48 \qquad (9)$$

So, for rectangular area in horizontal and vertical axes magnification factor will be $Z = n^2 = 12{,}15$.

Temperature controlled plate was set 70 °C and thermal images were taken as shown in the Figure 9-Figure 10.

The lengths of the horizontal and vertical edges of the area seen by a pixel given in Eq. 3 and Eq. 4 will be as in Eq. 10 and Eq. 11 depending on the zoom factor. The values of the area seen by a pixel will be as in Eq. 12.

$$u_h = Z 2L \tan\left(\frac{\Delta\alpha_h}{2}\right) \quad \text{(m)} \qquad (10)$$

$$u_v = Z 2L \tan\left(\frac{\Delta\alpha_v}{2}\right) \quad \text{(m)} \qquad (11)$$

$$A_p = Z^2 4L^2 \tan\left(\frac{\Delta\alpha_h}{2}\right) \tan\left(\frac{\Delta\alpha_v}{2}\right) \quad \text{(m)} \qquad (12)$$

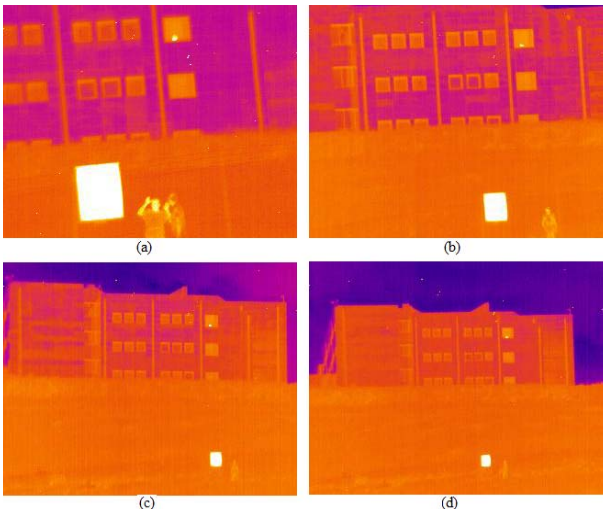

Figure 9. Thermal images of the temperature-controlled plate with 70 °C (a- 50 m, b- 100 m, c- 200 m, d- 250 m)

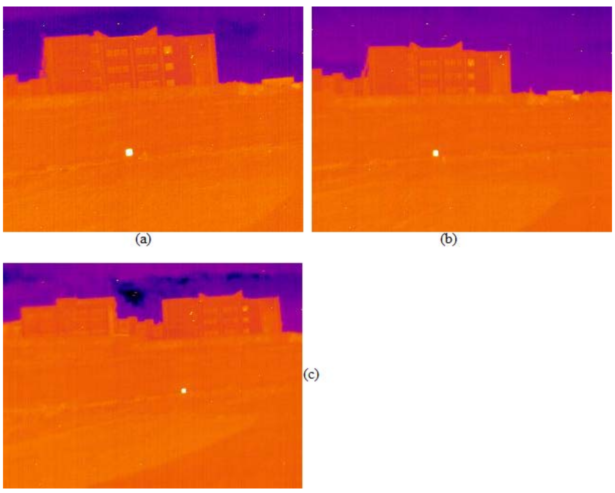

Figure 10. Thermal images of the temperature-controlled plate with 70 °C (a- 400 m, b- 500 m, c- 650 m)

Calculated results were normalized by dividing Z^2 to obtain the approximate real results.

Calculated area results and error values are given in the Table 2. Results show that calculated values are close to the real area value. Error is increasing with the distance increase. Maximum value is 17% and is occurred at the farthest distance in our study. Because the number of pixels which are belong to target is reduced significantly far away. Thus elimination of the pixels which aren't belonging to target is getting harder. By taking thermal images with a higher focal length lens, the target size on the thermal image will increase and error will be reduced.

Table 2. Area values of the temperature controlled plate with 60 °C

Distance (m)	Calculated Value (m^2)	Error* (%)
50	1,2193	5,62
100	1,1531	0,10
200	1,1602	0,50
250	1,0346	10,37
400	1,064	7,83
500	1,0258	11,13
650	0,9564	17,14

*Error values are absolute

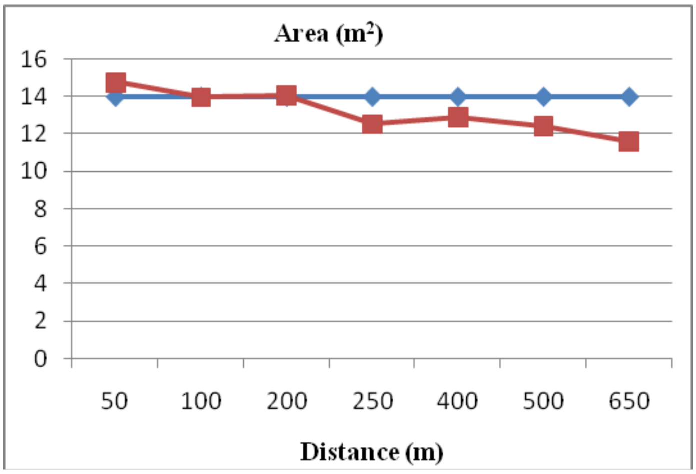

Figure 11. The area-distance variation of temperature controlled plate with 70 °C

The error-distance variation of the temperature controlled plate with 70 °C is given in Figure 12. The error-distance variation of the temperature controlled plate with 70 °C

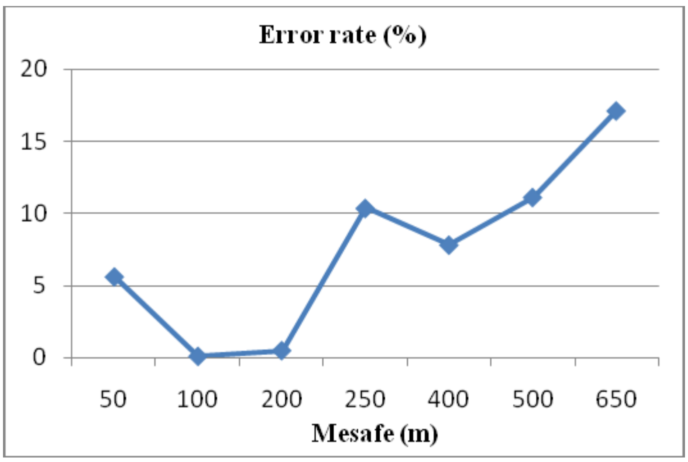

Figure 12. The error-distance variation of the temperature controlled plate with 70 °C

2.2.1.Blackbody captured by thermal camera with standard lens

Thermal images of a blackbody (Figure 13) with 100 °C and ± 0,001 accuracy were taken by using Indigo Systems MERLIN Mid InSb MWIR thermal camera. Thermal camera works in 3-5 µm IR spectrum. Horizontal and vertical angular FOVs of thermal camera are respectively $\alpha_h = 16°$ and $\alpha_v = 22°$ [[5]].

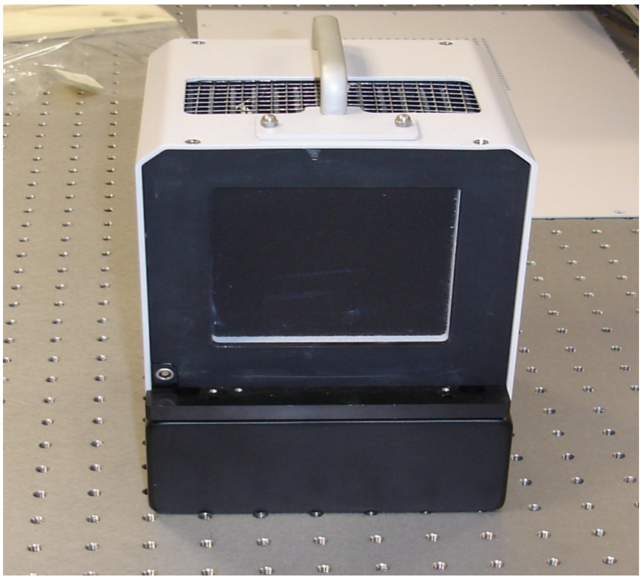

Figure 13. Blackbody 100 °C

Thermal images were taken are shown in Figure 14. The dimensions of blackbody are 16 cm x 16 cm and its area is 256 cm^2.

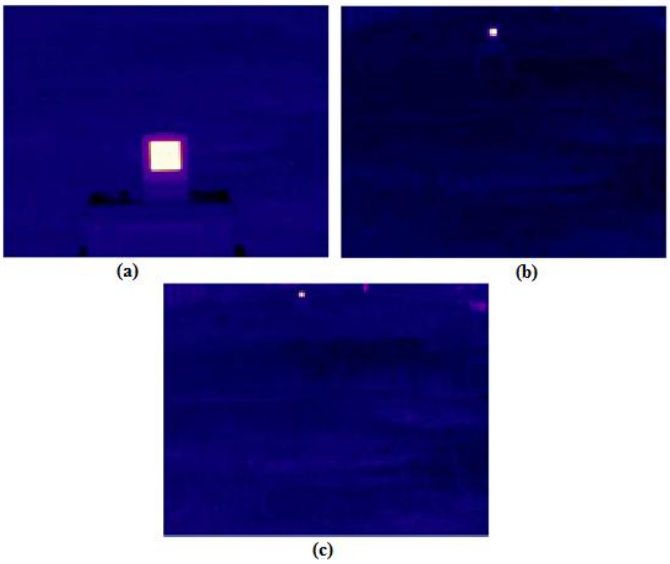

Figure 14. Thermal images of blackbody with 100 °C from different distances (a- 6 m, b- 30 m and c- 60 m)

Calculated results are given in the Table 3. Maximum error value is approximately 6,7%.Error is increasing with the distance. Area values-distance variation is as in Figure 15.

Table 3. Calculated area values for blackbody with 100 °C

Distance (m)	Calculated Value (m^2)	Error (%)
6	0,0263	2,73
30	0,0270	5,46
60	0,0273	6,64

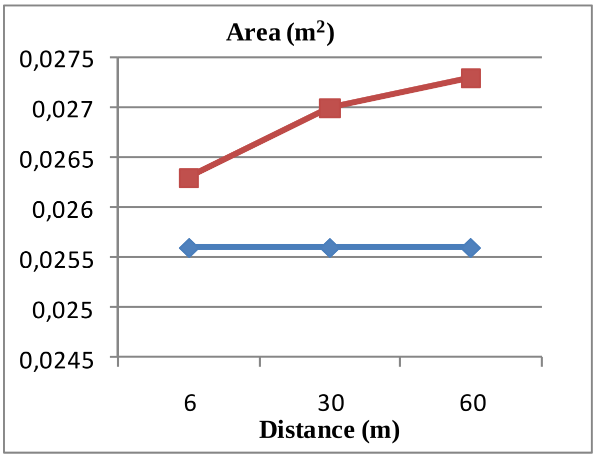

Figure 15. The area-distance variation of blackbody 100 °C

The error-distance variation of the blackbody with 100 °C is given in Figure 16. Error rate is increasing with the distance.

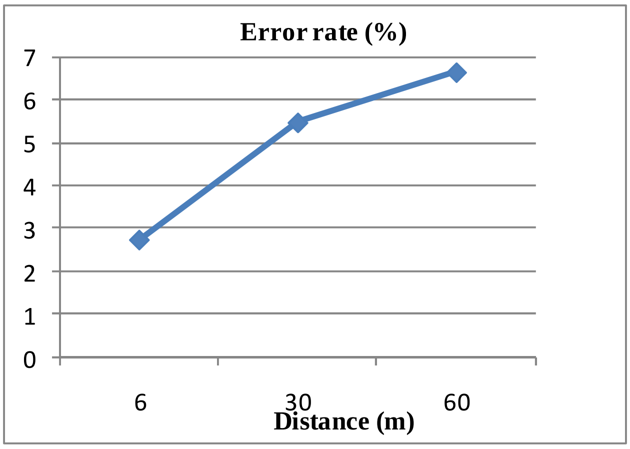

Figure 16. The error-distance variation of the blackbody with 100 °C

When results of 3 experimental studies are evaluated, the maximum error is approximately 18%. There are many factors which effects thermal image such as atmospheric conditions, target features etc. The most important issue is to decompose pixels which belong to the target. By distance increases it is harder to eliminate target's pixels. That's why error increases with the distance generally.

If also target size grows up on the thermal image, calculation will be easier and error will be reduced.

In our model it is possible to calculate surface area of a part of the target. Thus hot parts (engine, exhaust etc) on the target can be analyzed and their size can be calculated (Figure 17).

.

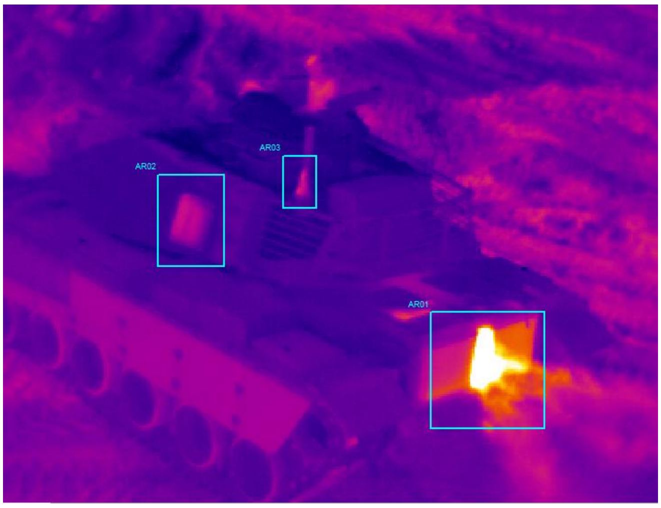

Figure 17. Target part localization

CONCLUSION

Results obtained from our model show that this model has a good accuracy. Accuracy can be improved by improving pixel elimination method and localizing the target on the thermal image more accurate.

It is possible to divide target into sections and calculate the size of sections separately. Thus target sizes of different geometrical sections can be calculated and results can be merged to obtain the total size.

And obtained results can be compared with the results in the database about the target, so one of the inputs of the target recognition, identification algorithms will be provided.

REFERENCES

[1] Jones, B.F., Plassmann, P., "Digital Infrared Thermal Imaging of Human Skin", ***IEEE Engineering in Medicine and Biology,*** 21(6):.41-48 (2002).

[2] Haren, R., "A Method of Determining Accurate Range Capability for Multispectral Infrared Sensors using Simple Modeling Techniques", ***Proceedings of the IEEE National Aerospace and Electronics Conference, NAECON,*** 287-294 (1998).

[3] ThermaCAMTM S65 User's Manual, ***FLIR Systems,*** Publ.No.1557990, Rev.a155, (2007).

[4] L. Stroebel, J. Compton, I. Current and R. Zakia, "Basic photographic materials and processes", ***Focal Press, 2nd ed.,*** Boston , 146-147 (2000).

[5] Merlin Thermal Camera Introduction Brochure, URL:www.spicatek.com/Support/Indigo_Merlin.pdf