DEVELOPING A PROCESS TO EVALUATE THE EFFECTIVENESS OF INFRARED CAMOUFLAGE UNIFORMS IN JUNGLE-MOUNTAINOUS TERRAIN

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Abstract

Developing methods to evaluate the effectiveness of camouflage against thermal reconnaissance devices reliably and close to reality is an urgent requirement today. Therefore, applying camouflage solutions against thermal reconnaissance equipment has been developing rapidly in many countries. However, to reach the target, it is essential to develop a process and method to evaluate the properties of camouflage materials and means in the laboratory, simulate targets in the virtual environment, and asset the effectiveness of camouflage directly at the scene. In Vietnam, research in the field still needs more information and has only recently been implemented.

To deal with the target above, the research team conducted studies to develop and evaluate the effectiveness of thermal camouflage. This article focuses on developing a complete procedure for the field method to evaluate the effectiveness of thermal camouflage. The result can be applied to evaluate and select the thermal camouflage material and facilities in jungle - mountainous terrain.

Keywords: *Thermal imaging; thermal camouflage; TTP model.*

1. Introduction

Nowadays, optical and thermal infrared sensor technologies are increasingly developing rapidly with lower suitable prices. Hence, they have been making a great challenge and high pressure on Army forces in different countries. In the Ukraine-Russia conflict, the appearance and wide application of reconnaissance and suicide UAVs equipped with thermal optical cameras have been affecting military tactics and strategy [1-3]. In Vietnam, because of lacking camouflage proper documents, the research and proposing procedures to evaluate the effectiveness of thermal camouflage solutions are still confusing and there are only some specific studies in this field. Therefore, it is so necessary to build up a research method and a procedure to evaluate the apparent thermal contrast of the target and the background. The difference should have been performed based on the variety of spatial and weather conditions closely and appropriately.

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DOI: 10.56651/lqdtu.jst.v5.n02.547.sce

The article is aimed to show and propose a new method to evaluate the effectiveness of thermal camouflage. The results have been conducted based on observation on the real field and applying Johnson's criteria.

2. Theoretical basis and experimental method

2.1. Methodology and principle for evaluating thermal camouflage effectiveness

Evaluating the thermal camouflage effectiveness for static ground targets are to evaluate the DRI (Detection, Recognition, Identification) ranges [4, 5]. DRI refers to the distance and probability at which a target is Detected, Recognized, or Identified based on specific universally accepted parameters [5-7].

Johnson's model provided definitive criteria for calculating the maximum range at which "Detection, Recognition, and Identification (D, R, and I)" could occur, with a 50% probability of success. The meaning of detection, recognition and identification can be clarified below:

2.1.1. Detection

Detection refers to the distance at which a target initially appears in the image. This "target" is something out of the ordinary that is warmer or cooler than the ambient environment. Specifically, it will be visible on at least two pixels, so there will not be enough information to confirm what the target is at this distance, just that something is there.

2.1.2. Recognition

Contrary to what might be expected, recognition does not mean that you can recognize an individual. Recognition refers to the distance at which you can determine an object's class (is it human, animal or vehicle).

2.1.3. Identification

Identification refers to the distance at which you can differentiate between objects within a class. For example, identifying the type of vehicle (truck, SUV, or car) or whether the human is a soldier or civilian.

Note that these distance measurements are based on a 50% probability and do not take any atmospheric conditions into consideration. Weather is almost never ideal so in real use these distances are almost always shorter than specified.

2.2. Selecting survey background

The typical topographical background in Vietnam includes rain forests and hilly areas with subtropical climates. The selected background for the experiment needs at least two main elements: Tropical forest and mountainous terrain. The terrain also has to

combine high trees, bushes and pasture. The canopy of trees can cover the target and provide the background for the target. To archive experiments, we recommend conducting experiments with mixed topographic and geomorphological features. The environment needs to be carefully selected and can be applied to multiple targets at the same time. Hence, the researchers can conduct the comparison of DRI for many targets at one time [7].

The surrounding needs to be divided into several sub-areas. The number of sub-areas must be more than the number of targets to make certain objectivity in observing. The observers are not allowed to know which sub-areas have targets or have not. To adapt to the requirement above, the research team selected the Dong Roi (Yen Bai, Ba Vi, Ha Noi) location to experiment.

Target locations in observed areas should not be changed during all tests. It is important for the test performance to show obvious signals or markings that lead to false estimation or attract the attention of observers.

To observe definitely in various climatic conditions and to minimize the influence of atmosphere and weather on the results, the experiment should be carried out under good weather conditions. It means that, the weather is good with cloudy sky, visibility over 10 km, cloudy to eliminate irregular irradiation from the path of the Sun in the test on day. With the test in the night condition, avoid testing at the full moon.

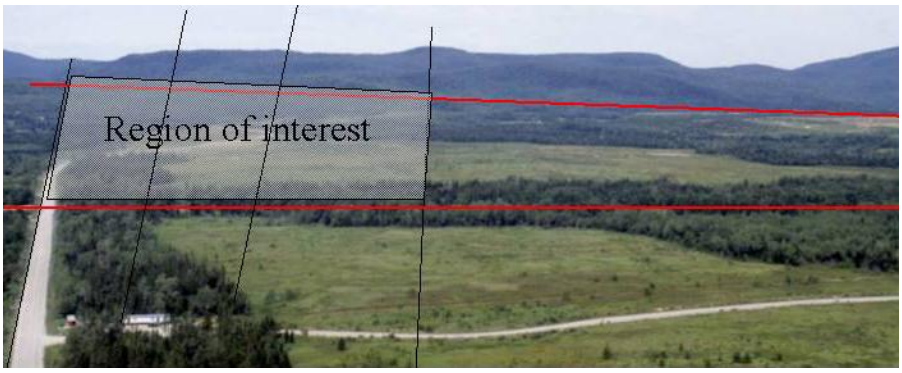


Fig. 1. Area for evaluating thermal camouflage effectiveness.

2.3. Measuring equipment

Field experiment has been conducted with the thermal camera Moskito TI.

Moskito TI is a specialized camera of Vectronix that is applied by infantry with 3 observation modes: daylight optical mode; low light imaging; thermal imaging mode.

Visible imaging: Monocular, 5x magnification;

Thermal imaging: 640 × 480 resolution; Spectral range: 8 ~ 14 μm; field of view 12°;

Fig. 2. Camera Moskito TI.

Low-light optics: 1280 × 1024 resolution; Spectral range: 0.4 ~ 1.1 µm;

Distance measuring capacity: 10 m ~ 10 km;

Telemetry accuracy: ±2 m, wavelength 1,550 µm.

2.4. Measurement processing and evaluating thermal target

2.4.1. Camouflage suit samples

The experiment used 5 camouflage costumes provided by TECOTEC company. The above models are being offered in Vietnam by companies around the world. These suits are also introduced in the table below.

Tab. 1. Camouflage suit samples

Number	Name code
1	Multicam Jungle
2	Multicam Dessert
3	Poncho
4	Sniper (French)
5	Ghillie suit

The figure of five samples from left to right are number 1 to 5 presented in the visible image below:

The camouflage uniforms above are worn by soldiers and were observed with the thermal camera Moskito TI. After wearing suits, waiting at least 30 minutes to reach thermal equilibrium.

The soldier location deployment is predetermined and the observer never got it. Soldiers in the background are required to deploy in standing postures. Besides, the requirement of diversity of survey background should be satisfied.

Fig. 3. The figure of five samples.

2.4.2. Environmental parameters

The experiment should be conducted to measure the climatic parameters:

- Humidity, temperature, weather, wind velocity;

- Experimental time.

The purpose of collecting data is used to compare experimental results in various weather conditions or setting a database used for predicting thermal camouflage effectiveness by numerical simulation method.

2.5. Experimental procedure

To take the thermal photos of targets at many distances, the device has to move slowly toward the targets. There are two methods of moving the camera: using a drone or vehicle. The field of view of the reconnaissance has to contain the targets. Take photos or record video with every 100 m step. In case of using drones, the UAV could fly at a fixed altitude with the ranges from far to near.

The device and the observer are located far enough beyond the reconnaissance range of the device. The initial distance for human detection is 500 m. Slowly move closer to the target with step 100 m. Observe the image on the thermal camera or on the screen. Save the entire process data.

2.6. Evaluating method

The most objective assessment is to use AI computers to automatically identify and analyze the ability to detect, recognize or identify the target. Due to limited experimental time conditions and lack of application and budget, the method will be introduced in the future.

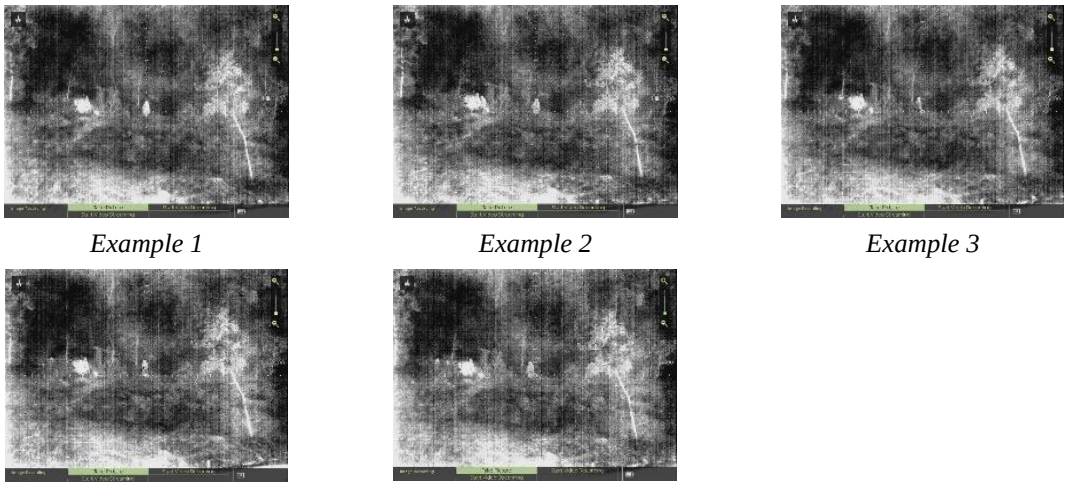
The evaluating method in our experiment is to use the direct observation and analysis ability of the observers. From taken image collection in different distances (including random images without targets to distract observers' attention), the survey to evaluate the probability range of detection, recognition and identification of human targets has been conducted.

After observing, the observers need to fill in the data form to determine the distance where the targets have been detected, recognized or identified. Camouflage efficiency of detection, recognition and identification target is the distance at which there is a 50% probability of observers detecting, recognizing and identifying the target.

3. Experimental results and evaluation results

3.1. Experimental results

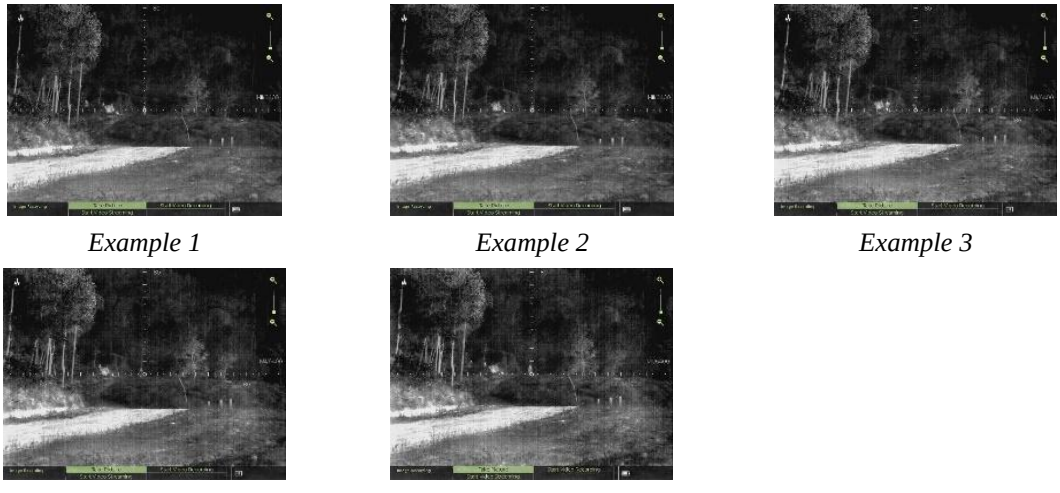
Experiments were conducted in the Dong Roi area on June 10th, 2022. The weather is clear sky, cloudy, and temperature 35^{o}C. The five experimental samples were taken by the MOSKITO TI camera at different distances. The observed image results are shown in the following figures:



Example 1 *Example 2* *Example 3*

Example 4 *Example 5*

Fig. 4. Observation results at the distance 100 m.



Example 1 *Example 2* *Example 3*

Example 4 *Example 5*

Fig. 5. Observation results at the distance 200 m.

Example 1

Example 2

Example 3

Example 4

Example 5

Fig. 6. Observation results at the distance 300 m.

Example 1

Example 2

Example 3

Example 4

Example 5

Fig. 7. Observation results at the distance 400 m.

Using twelve observers to observe the obtained thermal images of the above image samples and record the results of the target detection assessment by distance. The results are shown in the figure below.

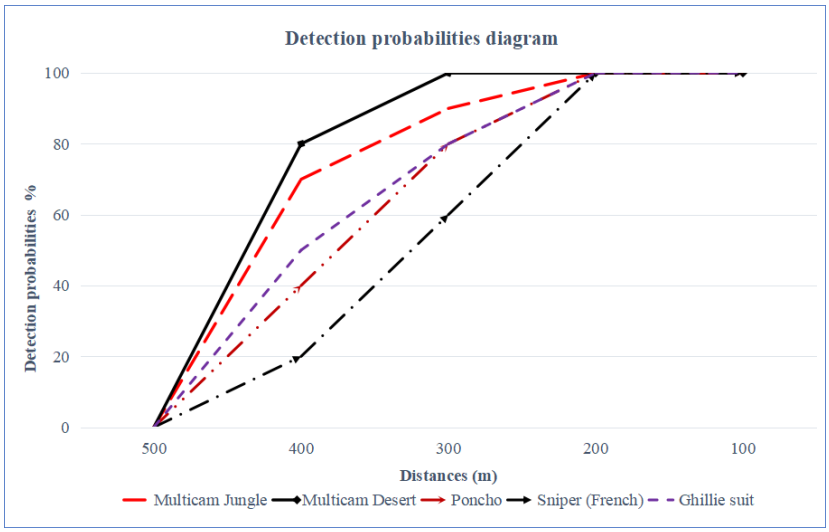


Fig. 8. The detection probability of uniforms.

3.2. Comments

The final result shows that the sniper uniform example has the highest camouflage efficiency in all examples. The detected range with 50% probability (R50) of Sniper kit can reach approximately 325 m.

The subsequent models, the Ghillie suit and the Poncho suit, also have R50 about 400 m. The rest of the group, the Multicam Jungle pattern and the Multicam desert pattern, have camouflage effectiveness reaching up to 430 m. These two models can be applied only for the regular infantry while the others are used for reconnaissance and sniper special forces. Hence, the designs and the prices also are different.

It can be concluded that the Sniper camouflage pattern gives the best camouflage effect in the experimental conditions at the field with the standing posture under the detailing background and climate conditions.

4. Conclusion

The article presents the intuitive method to evaluate and determine R50 for detecting, recognizing and identifying the ground targets, which are observed by thermal cameras. In addition, the article also gives some suggestions, recommendations on how to set up the background experiment model. Finally, the experiment procedure and the results of evaluating the effectiveness of camouflage of five examples were also performed and displayed. The result is the basis for evaluating the effectiveness of camouflage with different groups of materials. It is also the basis for comparing and proposing camouflage requirements.

However, evaluating results in the research is only the first step due to the lack of budgets, equipment. The more experiments in various experiment scenarios will be conducted,

the more accuracy will be achieved. On the other hand, to achieve objective results and reduce the cost, Appling AI computer and program in this test is our recommendation.

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XÂY DỰNG QUY TRÌNH ĐÁNH GIÁ HIỆU QUẢ NGỤY TRANG NHIỆT CHO MỘT SỐ BỘ QUÂN PHỤC CHUYÊN DỤNG TẠI ĐỊA HÌNH RỪNG NÚI

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Tóm tắt: *Xây dựng phương pháp đánh giá hiệu quả ngụy trang chống lại các thiết bị trinh sát nhiệt tin cậy, tiệm cận với thực tế là một yêu cầu cấp bách hiện nay. Vì vậy, nghiên cứu các giải pháp ngụy trang chống trinh sát và thiết bị ảnh nhiệt đang là trọng điểm đầu tư của các quốc gia. Để xây dựng được quy chuẩn và phương pháp đánh giá hiệu quả ngụy trang, cần phát triển được quy trình và phương pháp đánh giá tính chất vật liệu và phương tiện ngụy trang trong phòng thí nghiệm, trên mô phỏng số và đánh giá hiệu quả ngụy trang trực tiếp tại hiện trường. Tuy nhiên, các nghiên cứu chi tiết và chuyên sâu để xây dựng các quy trình vẫn còn thiếu và mới được triển khai tại Việt Nam. Trên cơ sở đó, nhóm nghiên cứu đã tiến hành các nghiên cứu để xây dựng và phát triển quy trình phương đánh giá hiệu quả ngụy trang nhiệt trong điều kiện địa hình rừng núi. Bài báo này tập trung vào việc mô tả một phương pháp tiếp cận để xây dựng một quy trình cho phương pháp đánh giá hiệu quả ngụy trang nhiệt trong khu vực rừng núi điển hình.*

Từ khóa: Ảnh nhiệt; ngụy trang ảnh nhiệt; mô hình TTP.

Received: 15/09/2022; *Revised:* 09/12/2022*; Accepted for publication:* 30/12/2022

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