PSYCHOPHYSICS OF HUMAN VISION AND CAMOUFLAGE PATTERN DESIGN

Baumbach, Johannes

CSIR, Defence Peace Safety and Security (DPSS), South Africa

ABSTRACT

The psychophysics of human vision describes how humans perceive and process information in a scene. The physiological aspects (e.g. spatial resolution and spectral resolution) as well as the psychological aspects of vision have been investigated. Camouflage patterns, having some specific properties, have been designed. These patterns were printed on fabric and camouflage uniforms were made, which were evaluated in the field, using the Analytic Hierarchy Process (AHP). The patterns with specific spectral and spatial properties performed as expected. However, effects like depth perception could not be observed in the field.

Keywords: Human vision, Psychophysics, Camouflage, Patterns, Analytic Hierarchy Process, Perception.

1. INTRODUCTION

Designing camouflage patterns, using today's modern computers and software, is very easy. However, designing an effective pattern for a wide variety of environments is a totally different story. The most important aspect to remember is that a pattern can only be regarded as effective once the probability of detection is low.

For the past 30 years Defence, Peace Safety and Security (DPSS), a business unit of the Council for Scientific and Industrial Research (CSIR) is involved in research and development of camouflage, concealment and deception. The current camouflage pattern of the South African National Defence Force was developed by DPSS.

In general, developers of camouflage patterns use basic principles (e.g. shape, edge masking, contrast) to develop these patterns, because they know what works and what not. However, first principle knowledge regarding the reasons for the effectiveness of patterns was not known. Therefore, a research project was established to better understand the human cognitive system.

2. SCOPE, CONSTRAINTS, ASSUMPTIONS

Two elements are always present during surveillance- and counter-surveillance missions: an observer and a target. The observer, in DPSS's case, is a human, with 20/20 vision, no colour deficiencies and using no optical aids (e.g. binoculars). The second element present is the target, which the observer is trying to detect. In this case it was assumed that the target is a human, standing in plain sight.

2.1. Physiological aspects of vision

The following properties of the human eye were investigated:

- Spectral resolution
- Depth of field (DOF)
- Contrast threshold
- Spatial resolution

It is widely accepted that the human eye cannot distinguish between colours if the difference between the colours is less than 1 delta E units (CIELAB). This is assuming adequate, controlled lighting, with a homogeneous background. However, for camouflage systems, the colours chosen are generally not close to each other. It was therefore assumed the spectral resolution would not play a major role in this investigation.

In photography, the depth of field only has a major influence when the object is very close to the sensor. The human eye behave in much the same way, therefore it was assumed that the DOF would have a minimal influence.

The spatial resolution and the contrast threshold (especially in low light and with a lot of shadows) were considered to have the largest influence.

The spatial resolution of the human eye is about one minute of arc [1]. If the Johnson criterion for vision is used, an object can be recognized if it comprises 7.5 line-pairs [2], i.e. 15 minutes of arc. This would determine the size of the patterns to be used.

The contrast threshold function (CTF) describes at what distance objects with known dimensions and contrast, could be differentiated. This would specify the lightness values of the colours to be used in the pattern.

2.2. Psychological aspects of vision

All psychological aspects of a human being are closely coupled to how the environment is seen and experienced. Upbringing, education and past experience plays a major role when visual imagery is processed.

Aspects of Gestalt psychology were also investigated in order to better understand the human cognitive system. For example, the principle of proximity (elements near each other appear to be grouped together) explains how humans would perceive printed patterns viewed at a distance. This also has a strong relationship with the spatial resolution of the eye.

3. PSYCHOPHYSICS OF HUMAN VISION

The combination of physical attributes as well as the psychological aspects is called psychophysics of vision.

The human visual system is very opportunistic. It analyses a scene/image, and then decides (based on past learning/experience/knowledge) what is presented to it. Visual illusions exploit this ability, and “impossible” figures could be generated.

Figure 1 is an example illustrating this effect: the same figure could be interpreted differently, depending on the combination of geometric- and illumination clues. On the left side it could be interpreted as two ridges and a valley, because of the geometric clues and shadows that suggest illumination from above. On the right-hand side it could be interpreted as three ridges and three valleys, as suggested by the geometric clues and the shadows created by illumination from the left. Other such illustrations are the Cornsweet effect [3] and the cube demonstrating simultaneous contrast, as developed by Purves [4].

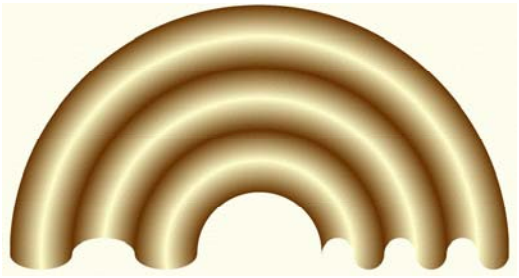

Fig. 1: Clues: geometry and illumination

APPLICATION IN CAMOUFLAGING

Targets that need to be camouflaged usually have flat surfaces (side of a vehicle, fabric printed with a pattern). Multi-coloured patterns are used to disguise the shape of the object and blend it with the environment. Flat surfaces are usually easy to identify in a three-dimensional world. However, three-dimensionality of surfaces (i.e. depth perception), could improve the camouflage effectiveness.

Several patterns were developed in order to evaluate the psychophysical aspects of human vision. The CTF was used to define the lightness values of colours to be used, and the eye’s spatial resolution was used to define the sizes of the different coloured patterns. The arrangement and distribution of the elements were determined by certain identified psychophysical properties. See Figure 2 for an example.

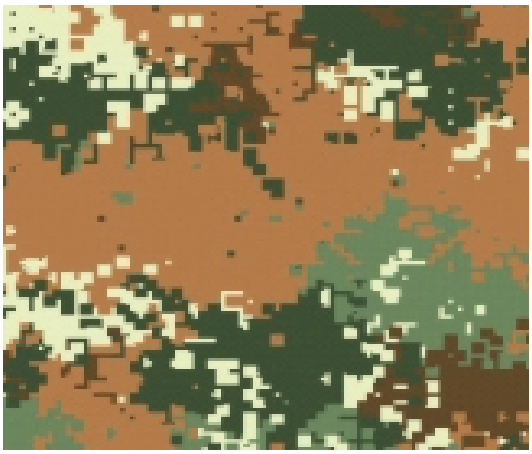

Fig. 2: Sample pattern

EVALUATION AND RESULTS

The sizes, colours and distribution of the camouflage pattern’s elements could be calculated, but it was much more difficult to produce a design that was aesthetical acceptable and was producible using the available manufacturing technology.

The patterns were printed on fabric, and camouflage uniforms were made. These uniforms were then evaluated in the field, using the Analytic Hierarchy Process (AHP) [5]. AHP is a forced choice, pairwise comparison method, and has been adapted for camouflage pattern evaluations [6].

Patterns with small elements (called texture-elements) performed as expected. At larger distances these small elements could not be resolved by the human eye, and blended to form larger elements. The “new” colour, after blending, was as predicted by theory.

CONCLUSIONS

Depth perception of a pattern, which would provide increased camouflaging capability, was not visible in the field, although it could be observed on a computer screen (i.e. when seen in isolation). This is because the uniform deployed in the field comprises only a small area in the field of view of an observer.

Although patterns and colours decrease a target’s probability of detection, the soldier’s skills, training and doctrine is still of utmost importance in the quest for survival.

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Johannes Baumbach
CSIR, DPSS
PO Box 395, Pretoria, 0001, South Africa
Tel: (+27 12) 841-2976
Fax: (+27 12) 841-4015
e-mail: jbaumbac@csir.co.za