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METHODS FOR DERIVING OPTIMUM COLOURS FOR CAMOUFLAGE PATTERNS

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1. SUMMARY

The majority of camouflage patterns have been designed subjectively with only the colour aspect conforming to certain constraints such as average colour and luminance. Given the power of modern computing it should be possible to design scenario specific camouflage from calibrated colour imagery. The Defence Clothing and Textiles Agency is at present working on such a system. This capability will allow us to design and test patterns in a digital environment before field trials are carried out. This system will allow us to design patterns for specific scenarios such as coniferous treelines, deciduous treelines, summer, winter etc. It should also lead to highly effective patterns, as early validation can be carried out using a target detection model followed by photosimulation using a digital implantation technique. Once validated in the digital environment, a field trial using live observers can be carried out.

In the design of a pattern, there are two major factors to take into account: the multi-level structure of a background and the many colours present. A method of designing scenario specific patterns needs to reduce the many hundreds of colours to a workable number of colour centres, usually between three and six. There is also the need to assess the structure present and produce a structure for the pattern, which should be multi-level to allow the pattern to be effective at various ranges.

In this paper, we will review the results obtained from the initial study on reduction of the number of colours and colour centre choice.

Keywords: Colour choice, patterning, optimisation routine

2. INTRODUCTION: TRADITIONAL METHODS OF CAMOUFLAGE DESIGN

Traditionally methods of camouflage design for materials have been mainly subjective with the only constraints being the colours used and the average luminance of the overall pattern.

The methods of traditional design involve the designer viewing a background and using their skill and judgement to devise a pattern which will be effective. This pattern must then be trialled to assess its effectiveness and may also undergo further validation techniques such as photosimulation. Any validation routines have by necessity to take place over various scenarios and compare several camouflage schemes. The personnel and time needed for such validation makes the costs very high. The pattern designed often has to be applicable to several theatres of operation i.e. temperate zones, jungle environments, arctic and desert and must be a good average to account for the diversity within each background.

3. THE GENERATION OF PATTERNS USING A COMPUTER BASED METHODOLOGY

The generation of patterns from digital images using computers gives the capability to design scenario specific patterns, relatively quickly and cheaply. There are three discrete parts to the design of a new camouflage pattern using a digital methodology.

1. A method of texture analysis and generation
2. A method of optimising the choice of colours from those found in a background so the pattern is most effective either against a specific background or over a wide range of scenarios.
3. A target detection model which will allow us to measure the relative effectiveness of camouflage schemes

Parts 1 and 3 can be carried out using either colour or monotone images but, for an effective visual camouflage part 2 is a highly important factor.

A methodology which allows us to carry out textural analysis could also be used to design a pattern which has first and second orders statistics that resemble those of the background. The in-service U.K. pattern has an average colour which resembles an average colour of a set number of treelines. The design only incorporates the first order statistics of a series of backgrounds. Second order statistics are used to describe the textural elements of the particular region being analysed. This ability to design the first and second order statistics of the pattern and the use of target detection models allows us to predict the relative effectiveness of several patterns in a digital environment. This reduces the initial costs, as we do not have to go through such a large-scale trial and do not have the expense of making life-size uniforms or designs for vehicles. The use of colours in a pattern can determine its effectiveness. A method of optimising the limited number of colours used is highly desirable.

4. HOW ARE COLOURS USED IN A CAMOUFLAGE SCHEME?

The colours in a camouflage pattern or scheme are ideally used to allow the target to blend in to the background. This is done on two levels. Firstly, the colours used are those found in the background. For rural camouflage, these are browns, greens and black resembling those found in a natural scene. Secondly, the colours form a pattern which, it is hoped match that of the background and reduces any visual cue given by the outline. It may be said that the colours and textured pattern used in a camouflage scheme are equally important from a detection point of view. A good pattern's effectiveness will be reduced by bad colour choice and good colours will be ineffective if the patterning is poor. It should be noted that no matter how good the colours or pattern at very long ranges

both are inconsequential e.g. at long ranges where the background appears monochromatic and atmospheric effects dominate¹. At closer ranges, the better the patterning choice and colours used, the shorter the detection range. However, for vehicles in particular, there are ranges where the vehicle just cannot be disguised.

5. COLOUR CHOICE

The human eye can see all the colours in a specific background but has a problem if asked to reduce these colours to a given number for a best fit. The human eye tends to blend the colours it sees where as a digital image taken at close range will only average over a very small area, depending on how the digitisation is done. In addition, humans tend to have a bad visual memory for exact colours, whereas a calibrated digital image will contain exact data for a specific scene at a given moment in time. As a result, choosing the colours to be used to optimise the effectiveness of a pattern is a task more suited to digital calculation than to human judgement.

6. COLOUR REDUCTION/OPTIMISATION ROUTINE

For our colour reduction/optimisation routine, we decided on a methodology which concentrated on a particular Region Of Interest (ROI). The values which describe the colour of each pixel, in a 3D colour space, are run through a mathematical routine which finds the best fit colour centres for the colour population of the ROI.

Before using the routine, decisions have to be made as to how its various capabilities are going to be utilised. It is necessary to decide how many colour centres are to be used, and whether a number of those centres are to be predetermined or all are to be optimised.

The first step in the use of the actual program is the section of a ROI from the image. If we use the whole image, which might be up to 4000x4000 pixels, the length of time needed to run the routine may extend into a number of weeks. A good size for a ROI is up to 200x200 pixels (although this will have to be run overnight if a large number of colour centres is to be used). The size of the ROI is up to the individual user, but it should contain a good cross-section of the colours found in the background as well as some of the textural elements. Figure 1 shows a region which is 100x100 pixels in size and contains good information on the type of background we want to be camouflaged against.

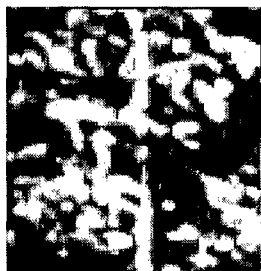


Fig 1: ROI taken from original image 100x100 pixels

As stated, once the region of interest has been chosen, the routine then converts the RGB values for each pixel to the Lab values. The conversion to Lab colour space allows us to describe the colours in a colourspace which resembles how the colours are actually perceived by humans². This conversion is described in more detail in Houlbrook³. Once the conversion has taken place the values are plotted as in Figure 2. This plot allows the operator to view the most populated volumes and so place the initial colour centres near these population

centres. This allows the routine to run quicker and ensures that in the later stages all of the colour centres are interrogated.

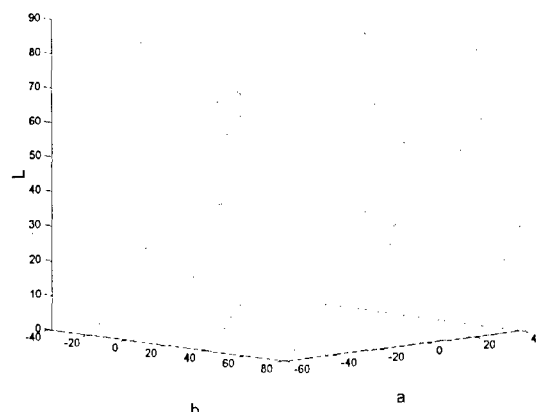


Fig 2: Plot of the Lab values of the population of the pixels found in Fig 1

The next step of the routine is an iterative step, which ceases when the best colour centres are found. During the initial step of the iteration process, each of the pixel points interrogates the initial colour centres and assign themselves to their respective nearest colour centre. Figure 3 shows a simplification of this initial assignment process.

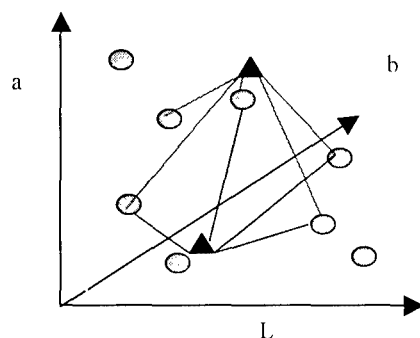


Fig 3: Showing an example of Pixel co-ordinates (●) in colourspace being assigned to colour centres 1 (▲) and 2 (▲)

Once the co-ordinates of the pixels have all been assigned to the most appropriate colour centre an average is taken of the population to find the centre point. This centre point is assigned as the new colour centre (See Figure 4)

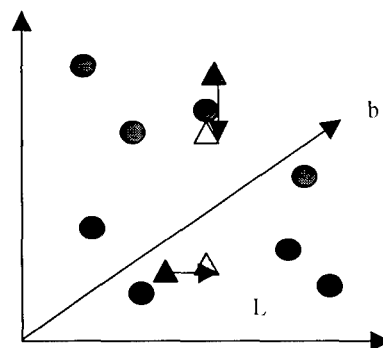


Fig 4: After step one the colour co-ordinates are assigned to their respective colour centres (● and ●) and the colour centres relocated to the average of the population (colour centre 1'▲ and colour centre 2'▲).

This stage is repeated with all of the pixel points interrogating each of the new colour centres and the averaging process repeated. The iteration process ceases when the difference between the newest colour centre and the previous colour centre is within a predefined limit. These final colour centres are then written to file for retrieval later. The final step of the routine is to change the pixel co-ordinate values to those of the colour centre to which it is assigned. So the whole population of that colour centre has the same Lab values. The routine will then show a visual representation of the original image with the new Lab values. This allows the operator to do a visual comparison as a check. Although the human visual system is not good at remembering exact colours when asked to compare two images, it can judge quite effectively if the colours chosen appear to be correct or not. Figure 5 gives an example of this phenomenon, in that although there are approximately 9000 fewer colours used than in Figure 1, the overall impression is not greatly diminished in the reduction to 10 colours.

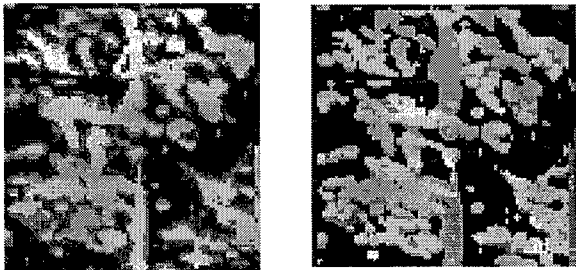


Figure. 5: Visual representation of results of the routine (i) shows optimisation to 10 colours (ii) shows optimisation to 4 colours.

7. RESULTS OBTAINED USING SYNTHESISED IMAGES

As an initial test of the routine, it was decided to use simple images constructed in Adobe PhotoShop. The rationale behind using images synthesised in PhotoShop is that images will be initially viewed using this software. Using PhotoShop we can create images with known Lab and RGB values. This allows us to compare the Lab values in PhotoShop to the values obtained from the routine when digital RGB is the only input. This gives us a good insight to how good the routine is at calculating Lab's from RGB.

The image in Figure 6 consists of 66 pixels and was created so we could carry out calculations both manually and using the routine to check that the initial conversion was correct.



Fig 6: Image constructed to check conversion from digital rgb to Lab (i) and image obtained at end of routine (ii)

	PhotoShop			Routine		
	L	a	b	L	a	b
C1	77	-34	18	77.8	-32.5	18.0
C2	63	-28	15	63.5	-27.0	15.1
C3	9	3	4	8.9	1.8	3.3
C4	0	0	0	0	0	0
C5	33	-1	27	33.0	-1.8	26.4
C6	84	-6	76	83.4	-7.8	78.0

Table 1: Comparison of the Lab's quoted in PhotoShop and those obtained as results from the routine

As can be seen from Table 1 the results obtained from the routine are similar to those quoted in PhotoShop. The differences can in part be accounted for by rounding errors.

8. RESULTS USING REAL IMAGERY

In addition to the synthesised imagery, the colour reduction routine has been successfully applied to real imagery. The results when applied to real imagery are shown in Table 1. The original image is shown in Fig 1. (The printing process has degraded these images to a certain degree.)

It may be asserted however that the colour-reduced imagery of real scenes is, by eye, a good match for the original imagery. Where we allow 10 colour centres, the scenes are barely discernible from the originals. This fidelity naturally falls with the number of allowed colour centres.

This match to the background is not, however, the purpose or test of the routine. That will come with the application of chosen colours in the creation of new camouflage schemes. These will be tested for their ability to blend into the background - by detection modelling, photo-simulation and ultimately, test in the real world

9. USE OF THE COLOUR REDUCTION ROUTINE

As mentioned there are several variations which can be carried out using the colours reduction routine. Firstly we can carry out the optimisation routine which will allow us to reduce the number of colours in an image to a given number. These colours will also be optimised to best describe the colours in the original image. Secondly, when inputting the starting colour centres we can choose to lock these centres so that the colour reduction takes place to these colour centres. This is particularly useful if the colours have been pre-determined and it is these colours you want to use. You can now see how those colours compare to those in the background. We also obtain information on the proportion of each colour in the background.

10. CONCLUSION

We have described in this paper a routine, which can be used to derive optimum colours for a camouflage pattern using calibrated digital imagery. It has been recognised that the optimisation of colours for a pattern is desirable. Optimised colours used in a pattern can reduce the ranges at which targets become visible in specific scenarios.

Colour as has been described is an intrinsic part of a camouflage pattern. In the rush to devise a digitally based method for pattern design, the use of the best colours has been largely overlooked. This work addresses this oversight and represents an important step in the development of a more complete digital pattern design tool. A routine such as this allows the optimisation of colours for a scenario without the need for extensive field trials and so cuts the time needed for the design of an effective pattern for that scenario.

11. REFERENCES

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