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GRAPHICALLY ENHANCED VISUAL CONCEALMENT OF LARGE OBJECTS

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ABSTRACT

Inexpensive, flicker free, flat, large, extremely bright LCD panels can be effectively used to conceal very large objects both stationary and moving. CCDC (Charge Coupled Device Camera) may capture the surrounding environment and reproduce it on the LCD screens. LCDs may easily be installed on the surface of the objects. It is also possible to use the video cards of personal computers and laptops to digitally process the image captured with the CCDS and obtain patterns to disguise the real appearance of the object or the way it is moving. The visual CCD (Camouflage, Concealment, and Deception) system so obtained is extremely effective. In this paper, it is demonstrated that the digital image processing techniques necessary to obtain a successful concealment are elementary and already embedded in the hardware of video card for real time image processing. It is also possible to superimpose patterns at defined frequencies that will obscure the image to the human observer especially in case of use of magnifying optics. The CCD effect in the visual and ultralight field is extremely effective. An example of active CCD of the Ariete MBT (Main Battle Tank) is shown in this paper.

Keywords: visual concealment, graphically enhancement.

INTRODUCTION

LCDs (Liquid Cristal Display) and in general, flat visual devices for home and public entertainment have been introduced in the market in recent years. The improvement of these devices is continuous with a decrease in costs. The brightness, the available angle of view and the resolution are continuously improved. It is now possible to see highly contrasted colored images even in daylight and at shallow angles between the screen and the observer. Therefore, it is possible to install LCDs on large objects with the purpose to conceal them from the observer's view. This can be made by installing CCDCs (Charge Coupled Device Camera) to capture the images of the environment and to reproduce them on the screens. Digital image processing hardware is usually embedded in the hardware of many common devices from smart handhelds to PCs (Personal Computers). This hardware and software can be easily used for CCD (Camouflage, Concealment, & Deception) purposes. In this paper, it will be demonstrated that elementary digital image processing techniques are sufficient to obtain optimum CCD effectiveness in the visual and ultralight EM (Eletro Magnetic) frequencies. Patterns may be superimposed at specific frequencies to impair the visual processing of humans observing the objects. This active technique is particularly effective when the observer use magnifying optics. This paper will introduce this active CCD technique and it will discuss the effectiveness of the concealment with the different sensors actually available. Then the application of the traditional and natural concealment techniques to LCD aided camouflage will be discussed. Finally, an example of concealment of the Ariete MBT (Main Battle Tank) is introduced as an example. The LCD based CCD technique introduced in this research work will be referred with the acronym ALCDC (Active LCD Camouflage).

Active visual concealment

CCD techniques, effective in the visual portion of the EM spectrum, are extremely important. With the large commercial availability of extremely luminous, large and flat LCD panels, it is possible to conceal even large targets just by reproducing the background on the panel (Figure-1).

Figure-1. The MBT Ariete equipped with flat LCD "active" camouflage panels for CCD.

As it can be seen, the ALCDC static camouflage with LCD panels is extremely effective. Even if the pattern depicted on each panel is not the exact portion of the rear landscape, it is extremely difficult to detect the very large Ariete Main Battle Tank. The vision is realistic; in fact, the panels are perfectly installable on the vehicle. For comparison, see the original image of Figure-5. The rear background can be captured by commercial CCDCs. the crew can also use these sensors for the outside vision. The effect can be improved by the reverse shadowing of the cannon.

The blending effect is clear as the alteration of target's appearance. The Ariete becomes partially a part of the background. The application of the LCDs on the corners is difficult. Therefore, a frame was left around the panels. Moreover, it is unavoidable to have difference of the background from the pattern on the panel. Without a frame, this discontinuity would have been a clear anomaly. This framework disguises the true shape and size of the Ariete. The target's appearance resembles something of lesser significance. The framework disrupts and eliminates the regular patterns and alters the MBT shape. The background pattern graphical representation, nearly identical to the pure transparency, contributes to the camouflage effect. Modern LCD sensors cannot effectively shadow NIR (Near Infra-Red) or IR (Infrared) sensors. Different is the UV (Ultra Violet) effectiveness, since some LCDs can work in this EM field, even if the LCD effectiveness is reduced. In any case, it is possible to apply transparent protective panels that will be effective also to reduce the IR image. These panels are necessary also to protect the LCD from impact damage and dirt. The LCD panels make it possible to choose several different patterns optimized for the specific situation. Several techniques are available from animals and from military experience. All these techniques can be easily implemented with the schema of Figure-1. The best solution can be adopted for different environments, velocity and available concealments.

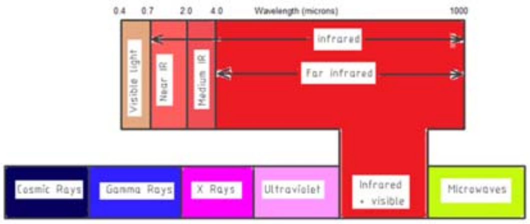

Figure-2. EM spectrum divided into segments by wavelength.

General concepts

A large variety of sensors is used to detect and identify persons, equipment, vehicle and supporting installations. These sensors may be visual, near infrared (NIR), Infra-Red (IR), ultraviolet (UV), acoustic, or multispectral/hyperspectral. The specific sensor systems or combination of systems that is employed for that purpose is rarely known by the victims. The former Soviet long-standing battlefield doctrine of maskirovka is a living legacy in many, human assisted or fully automated detection systems. Maskirovka is conceived to optimize the interaction between all elements of CCD into a cohesive and effective system. Even in recent times, elementary, low technology, maskirovka was used to effectively in the face of the most advanced detection systems. Sensors are usually identified by the part of the EM spectrum in which they operate. Figure-2 shows the EM spectrum and some common bandwidth of sensors operating within specific regions of the spectrum. Active sensors emit energy that reflects from targets and is recaptured by a nearby sensor, indicating the presence of the target. In some cases, the receiving sensor system outputs an image sufficient to identify the nature of the target. Searchlights, NIR and radar are examples of active sensors. Passive sensors do not emit energy; they collect the EM energy in a way that may indicate the presence of a target. Human eye, Night-Vision Devices (NVDs), IR imaging devices, microphones, and photographic devices are examples of passive sensors. Visual sensors are the principle and most effective sensors available. They work in the parts of the EM spectrum that are visible to the human eye. They may be aided by binoculars, telescopic sights, and image intensifiers. However all these devices have shortcomings; they improve a characteristic but reduce the other performances. Image intensifiers are visual sensors. They are passive night-observation devices. They amplify the low-level light that is present on even the darkest environments. Low-light television (LLTV) combines image intensification with television technology. Visual sensors may be interfaced with digital devices CCD for remote image transfer, record and automated target identification, aerial recon, remote sensing, and imagery. NIR sensors operate at a wavelength immediately above the visible light wavelength. NIR energy reflects well from live vegetation and even better reflects from dead vegetation and most man-made materials. NIR sights allow the human eye or the computer software to detect targets based on differences in their reflection of NIR energy. NIR sensors are interfered by fog, mist, and smoke although they are less "blocked" than visual sensors. These sensors are rapidly being replaced with image intensifiers and IR sights. IR sensors detect the contrasts in heat energy emission of targets and display the contrasts as different colors or shades. IR sensors are less affected fog or "normal" smoke since the longer wavelength of IR radiation less susceptible to atmospheric absorption than NIR radiation, IR contrast levels change dramatically over a daily cycle. For example, operating vehicles, heated buildings and tents, stressed materials and warm bodies are usually hotter than their background. In addition, items exposed to direct sunlight appears hotter than most natural backgrounds. At night, however, the same item might appear cooler than its background if it is treated with heat conductive paint. In other words, objects, especially thermally conductive ones, generally heats up and cools off more quickly than its background. Several different IR sensors have been developed. They vary in sensitivity, linearity and tolerance to saturation. The UV area is the part of the EM spectrum immediately below visible light. UV sensors are extremely effective in snow-covered areas, because snow reflects UV energy well and most white paints and opaque man-made objects do not reflect UV energy very well. Radar uses high-frequency radio waves to penetrate fog, mist, and smoke. Radar works by transmitting very short and intense burst of radio waves and then receiving and processing the reflected waves. In general, electrically conductive objects reflect radar waves well, while radar waves are either weakly reflected by or pass through most other objects. The shape and size of the conductive part of the object determine the strength and the size of the reflected signal. In Moving-target indicators (MTIs) a radar EM wave hits the moving target. For the Doppler Effect the reflected wave changes its frequency. The faster the target moves, the larger the changes in frequency. Multispectral and hyperspectral sensors are the result of the continuous research activity in sensor acquisition and information-processing. A common multispectral sensor scans simultaneously the visual and thermal IR portions of the EM spectrum. Hyperspectral sensors scan many channels across a relatively narrow bandwidth and provide detailed information about target spatial and spectral patterns. Absorption and emission bands of different materials at different temperature occur within very narrow bandwidths. Hyperspectral sensors distinguish the properties of the substances to a finer degree than an ordinary broadband sensor. None of the available camouflage materials or techniques provides complete broadband protection. The more closely a target resembles its background, the more difficult it is to distinguish between the two. Tracking of the surroundings and the ability to identify target EM signatures that sensors will detect is then fundamental.

With ALCDC, it is possible to work in the reproduce images to disguise the object and to actively mask movement to the MTIs. In this case, it is possible to obtain a clutter effect by producing virtual movements scattered in random direction or to maintain the image still at slow speeds. It is also possible to create patterns that will deceive the movement direction and velocity both to the human eyes and to the sensors. These techniques will be discussed in the following part of the paper.

Static camouflage techniques

In the WWII, the British zoologist Hugh Cott introduced very effective camouflage techniques, including countershading. Countershading can be effectively used for the Ariete cannon. Large military aircraft traditionally have a disruptive pattern with a darker top over a lighter lower surface as a form of countershading.

Camouflage can be achieved by different methods: crypsis, mimesis and motion dazzle. These methods may be applied on their own or in combination. Crypsis means blending with the background, making the target difficult to spot and recognize. Visual crypsis can be achieved in many different ways; some animals' colors and patterns resemble a particular natural background. The closer the background is to the natural one the better. This is an important component of camouflage in all environments. On the contrary, disruptive patterns use strongly contrasting, non-repeating markings such as spots or stripes to break up the outlines of the target or to conceal revealing features. Disruptive patterns may use more than one method to defeat human and software visual systems such as edge detection (see Figure-3). The disruptive contrast approach was used for the framework of the Ariete in Figure-1. The effect of Figure-3 can also be easily obtained with elementary digital image processing techniques already embedded in the firmware of many video cards. It is then possible to combine the real framework of the LCD mounting with a virtual-computer-generated framework to actively disguise the object. In the case of Figure-1, the LCD image was adapted to the olive green framework by increasing the contrast and reducing the luminosity near the edges of the LCD. The frame is then disguised to the naked eye. It is also possible to add olive green bands inside the “background image” shown on the LCD.

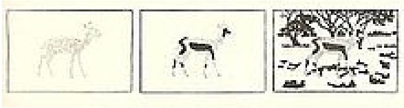

Figure-3. The "maximum disruptive contrast" [1].

Some animals hide by decorating themselves with materials such as twigs, sand, or pieces of shell from their environment, to break up their outlines, to conceal the features of their bodies, and to match their backgrounds. Similar principles is currently been applied for military purposes, for example the sniper's "ghillie suit" is designed to be further decorated with materials from the surrounding environment.

This technique can be also adopted in the LCD image. For example, flowers from the background can be added to deceive the recognition process of the human eye-brain-network.

The digital camouflage helps to defeat observation at a range of distances. This is due to a disruptive effect with pixelated patterns at a range of scales and of distances. Uniform pixellation can be obtained by changing the resolution of the LCD panel. Non-uniform disruptive pixellation can be obtained by software. Random position, random resolution pixellation algorithm can be easily implemented with modern computers.

Camouflage in motion

Patterns can provide more effective crypsis than solid colors when the camouflaged object is stationary. However, any pattern, particularly the ones with high contrast, stands out when the object is moving. Jungle camouflage uniforms were issued during WWII, but both the British and American forces found that a simple green uniform provided better camouflage when soldiers were moving. After the war, most nations returned to an uncolored uniform for their troops. Similarly, modern fast fighter aircraft often wear gray overall. Most forms of camouflage are ineffective when the camouflaged animal or object moves, because the motion is easily seen by the observing predator, prey or enemy. Movement catches the eye. This is the reason way most military vehicles use a simplified camouflage with a nearly uniform color. This is because moving spots or edges attire the attention of the observer. Cryptic behavior, such as lying down and keeping still avoiding being detected, or moving slowly and quietly, watching the prey is common among predators. In line frontal moving or behind the sun approach are common among animals. In frontal moving, the effect is a progressively enlarging of the predator in the view of the prey. This effect disorientates the prey giving precious advantage to the hunter. The behind the sun approach is common in aerial attacks. With LCD panels, it is possible to differentiate the motion depicted on the panel from the one of the vehicle. This technique is particularly effective at slow speed. The result is similar to the mole that moves under the terrain surface. It is also possible to keep the framework still while the object is moving.

The motion dazzle disguising technique of the Zebra requires rapidly moving bold patterns of contrasting stripes. Motion dazzle degrades predators' ability to estimate the prey's speed and direction accurately, especially when the predators’ eye uses the Doppler Effect. Motion dazzle distorts speed perception at high speeds. Fast moving irregular stripes also distort the perception of size and consequently the perceived range to the target. Motion dazzle had been proposed for military vehicles, but never applied. This is because dazzle patterns make animals more difficult to locate accurately when moving, but much easier to see when stationary. Dazzle patterning is extremely easy to implement on LCD. Since the background may be the true one, the dazzle disguising effect is enhanced and the true direction of the object and its speed are difficult to evaluate. This system works for humans and for computer-assisted tracking. It is particularly effective when magnifying systems are used.

Active Camouflaging

Counterillumination means producing light pattern to match a background. This is common when the background is brighter than the animal's body. The example of Yehudi Lights is depicted in Figure-4. This effect is particularly easy to obtain with LCDs.

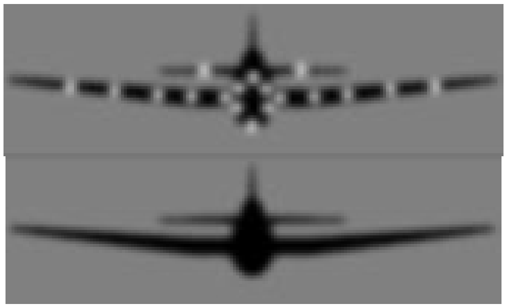

Figure-4. Yehudi Lights raise the average brightness from a dark shape to nearly the same as the night sky for a "Grumman Avenger TB strike fighter”.

Where transparency cannot be achieved, it can be obtained effectively by making animal's body highly reflective. For example, at medium depths at sea, the light comes from above. Therefore, a mirror oriented vertically makes a fish invisible from the side. Sardine and herring are camouflaged by silvering (also called mirroring). In mimesis or *masquerade*, the camouflaged object looks like something else. This tactic has occasionally been used in warfare, for example by the Graf Spee during WWII. In addition, this effect can be obtained with virtual LCD imaging.

Compromises

No single camouflage pattern is effective in all terrains and in all conditions. The effectiveness of a pattern depends on contrast, shapes and color tones. Forests, where the play of light and shade is prominent, require strong contrasts with disrupt outlines low contrasts are better suited to open terrain.

Seasons may play a critical role in some regions. A dramatic change in color and texture is created by seasonal snowy conditions in northern latitudes, necessitating tens of repainting of vehicles in the same winter season. Tonal changes are embedded in virtual LCD imaging.

Active camouflage for binoculars, telescopic sights, and image intensifiers

Active frequency masking can be obtained by summing to the usual visual pattern displayed and additional fictional image at an output frequency tuned to disorientate the viewer and give a false neurological response to the visual stimulus. In fact, pattern vision is conceived of as a process in a network of interconnected units (mechanisms). Foley [1] proposed a mathematical model of the human pattern-vision mechanisms and a proposition that links the response of these mechanisms to target thresholds.

Figure-5. The original image of the Ariete (see Figure-1 for comparison).

The spatial contrasted pattern of the target is superimposed upon other briefly presented spatial contrast patterns (maskers). The masker could differ from the target in spatial frequency, orientation, and other pattern dimensions. The aim is to avoid the discrimination of the target plus masker from the masker alone [1]. The excitation produced by pattern component *i* is

$$E_i^n = C_i s_{Di} \tag{1}$$

Where C_i is component contrast and s_{Ei} is the sensitivity of the mechanism to the normalized luminance profile of component i. Excitation is linearly summed across pattern components to yield total net excitation, *E'*:

$$E^i = \sum_i E_i^{''} = \sum_i C_i s_{Di} \tag{2}$$

and it is half-wave-rectified:

$$E = \max(E^{'},0) \tag{3}$$

The response is given by

$$R = \frac{E^p}{E^2 + Z} \tag{4}$$

where *p* and *Z* are parameters that are constant for this model. The term "response" defined by this equation is the ratio of the mean to standard deviation. In fact, the variability of neural signals is known to vary with the mean. The response will persist through the time and the wrong optical sensation will last from a few fractions of seconds up to seconds, blinding the observer. This is particularly true for observation through magnifying optics that will increase the energy in input to the eye or to the sensor. The high frequency agility of modern LCD screens is ideal for active masking.

Automated image analysis

Automated image analysis and object detection is a time-consuming activity that requires huge calculation capabilities. In the followings part of this paper a few up-to-date techniques are described. It will be clear that the most effective technique is to hide by decorating the LCD with materials such as twigs, sand, or pieces of shell from their environment, to break up their outlines, to conceal the features of their bodies, and to match their backgrounds. Visual virtual decoys may be added to the images to increase the computer-time required and to fool the common recognition algorithms. Since computers are “stupid” and “brilliant” algorithms have only the intelligence of the programmer, a good knowledge of the recognition and detection algorithms is fundamental to improve the effectiveness of the ALCDC technique. The automated recognition deception is the field where ALCDC is most effective. In fact, countermeasures are by several orders of magnitude less computer-intensive than recognition. In this case, not only real time detection capabilities may be impaired, but also off-line batch detection algorithms may be fooled with relative ease.

The problem of within-class object variation may be solved by combining machine learning techniques and local image features (or "interest points"). This is due by remarkable success of many methods using histogram based image representation. Information within different object regions varies in terms of discriminative power. For this purpose, histograms of image gradients are discretized in a few orientations. During training, the histograms are computed for rectangular object regions with several possible positions, sizes and shapes. Fisher’s type “weak learner” is then applied to select a histogram feature and an associated classifier at each round of the training. The objects are detected by classifying densely sampled fixed-size subwindows of a given test image. Multiple detections with similar positions and sizes are grouped by clustering. The size of these clusters is considered as the detection confidence. After the training, the most popular approach is the bag-of-visual-word (BoV) representation of images. The spatial information re-introduced as a post-processing step to re-rank the retrieved images, through a spatial verification. Since the spatial verification techniques are usually computationally expensive, they can be applied only to the top images in the initial ranking. The approach is highly parallel because the occupancy probability of a particular geometric primitive at each location is an independent computation. The algorithm extends to multiple cameras without requiring significant bandwidth increase. Another technique is the Conditional Random Field (CRF). The CRF is based on object-based image segmentation. CRFs typically have edges only between adjacent image pixels. To represent object relationship statistics beyond adjacent pixels, prior work either represents only weak spatial information using the segmented regions, or encodes only global object co-occurrences. Traditional inference methods, such as belief propagation and graph cuts, are impractical in such a case where billions of edges are defined. The assumption that the spatial relationships among different objects only depend on their relative positions (spatially stationary is then necessary. Other detection methods work by exploring the image-words co-occurrences in the neighborhood areas. Fast object detection can be obtained through the Hough transform. Various methods have been proposed to achieve discriminative learning of the Hough transform. In any case, “learning” is required. LCD computer generated images are ideal to produce images that deceit automated detection software through continuously changing virtual decoys, boundary morphing and false images generation.

CONCLUSION

ALCDC (Active LCD Camouflage) is becoming an increasingly effective option to mask stationary and moving objects to visual observation, detection and classification. The larger is the object the better. Crypsis by transparency can be easily obtained with large LCD panels and CCDC cameras. Fake objects and decoration may disguise the real object behind the LCDs and may easily fool the computer-based automated detection system. The extreme flexibility of this solution makes it possible to find the best-suited pattern for every situation and for every environment. Computer based optimization of the CCD system can be easily implemented to graphically improve the camouflaging of large objects.

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