Adaptive Camouflage Techniques for a Light Armoured Vehicle

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ABSTRACT

Camouflage has historically been an important survivability technique for battlefield platforms, installations and personnel. In World War I, camouflage was developed as handcrafted disruptive patterns, unique to each soldier, platform or installation. World War II saw the development of industrially produced patterned camouflage textiles for uniforms and nets. The modern battlefield presents new challenges for the traditional methods of camouflage. Modern sensors are able to resolve very small differences between targets and background, and a traditional static camouflage solution will only maintain a close enough match to its environment if the environment also remains static. To maintain low detectability in a changing environment, camouflage systems must adapt.

This research demonstrates concepts of adaptive camouflage for a light armoured vehicle (a Canadian Coyote) in a desert environment. Three techniques are investigated. A heat shield cover to reduce thermal signature and solar heat transfer into the vehicle, electro-chromic cells to simulate a chameleon-like behaviour in the visual spectrum, and active thermal cells to create dynamic disruptive thermal patterns on the heat shield. The overall objective is to create a system to reduce conspicuity across the visual and infrared spectrum by disrupting the vehicle silhouette and minimising the difference between the background and vehicle characteristics. This paper presents results from recent proof-of-concept testing.

1. Introduction

The goal of camouflage systems is to reduce the vulnerability of platforms, installations and personnel to detection and identification. This task has become increasingly difficult as sensors on the modern battlefield become more sophisticated and able to image targets with increasing sensitivity in multi-spectral bandwidths. Land vehicle camouflage is a particular challenge. The range of different types of sensors land vehicles may expect to encounter requires that camouflage systems be multi-spectral in effect. The need for mobility limits the obstruction of certain readily identifiable characteristics such as wheels and engine exhaust. Additionally, expected engagement ranges can be quite short for many modern operations, therefore it is more and more common to see performance goals for vehicle camouflage systems setting desired detection ranges of less than 1 km. For camouflage systems to be effective against modern imagers at these close ranges, they must very closely match their environment. This means reducing the contrast of the vehicle against the background to very low levels.

Maintaining a low enough contrast is difficult for traditional static camouflage systems, due to the fact that the environment of a vehicle is constantly changing while the camouflage material properties are fixed. A vehicle will move from place to place, changing its background as it goes. But, even when stationary, changing solar and weather conditions create a constantly varying background, which limits the effectiveness of static camouflage solutions[1]. Static camouflage systems are unable to respond to these changes well enough to consistently remain below the maximum acceptable contrast. Therefore, to meet this challenge, camouflage systems for the future must become more adaptive, responding actively to changes in their environment. Responding appropriately to maintain low detectability against common sensors requires being able to change the apparent surface characteristics individually in both visual and thermal domains. This means that new camouflage system concepts are required that can actively alter their temperature characteristics and their colour separately in response to their environment. This paper describes a prototype adaptive desert camouflage system for a light armoured vehicle and presents some sample results from recent proof-of-concept field trials.

2. Prototype adaptive system concept

Adaptive camouflage techniques must combine visual features with thermal properties without compromising the vehicle conspicuity level. This section presents three different types of material developed to improve the signature of the vehicle in arid region: the heat shield covering the whole vehicle, and different patches (heating panels and electro-chromic cells) to create an adaptive camouflage kit.

2.1 Heat shield

The heat shield's first requirement is to keep the thermal inertia of the material as low as possible, and to have an optimal solar absorptivity on the surface layer. This aims to reduce the crew heat stress and the vehicle thermal signature. Figure 1 shows the heat shield installed on the Coyote vehicle (prototype) and the Leopard tank (fielded in theatre).

Figure 1: Heat shield on the Coyote light armoured vehicle (top) and the Leopard tank (bottom).

The inner layer is a three-dimensional knitted mesh. This material lets air circulate between the surface of the vehicle and the outer substrate, enabling convective cooling of the vehicle. Heat generated by the vehicle escapes by convection. The knitted mesh is covered with an aluminum layer that provides a barrier to infrared energy radiation towards the vehicle, and retains energy on the outer substrate. The outer layer is chosen to be compatible with the arid desert environment: a sandy beige coloured layer of polyvinyl chloride which also mimics the thermal behaviour of desert sand. The heat shield is resistant, designed to last in the harsh operational environment.

2.2 Heating panels

In the infrared spectral bands, the heat shield appears cooler than the sand because of its lower thermal emissive characteristics. In day time, the sand stores heat and it becomes hotter than the heat shield. In clear night conditions, the heat shield reflects the cold sky and offers also a lower thermal signature than the sand.

To regulate the vehicle thermal signature, patches with thin sheets of heating wires are attached to the heat shield in various locations. A patch consists of a heating fabric glued inside the heat shield material without the knitted mesh. The heaters used are thin wires of a metallic alloy laid in rows. Heat diffuser textiles spread the heat over the surface. Three heating textiles are studied: a fabric with woven conducting wires made in-house, the silicone rubber fibreglass insulated heater from Omegalux, and the Kapton® insulated flexible heater also from Omegalux. The resulting 30 cm by 60 cm patches can heat up to 100°C, with different power densities. By heating the different patches to different levels, it is possible to match the apparent temperature distribution of the background and blend in with the environment.

Figure 2: Heating patches in the visual (top) and infrared (bottom) bandwidths.

Figure 2 presents the vehicle with heating patches. In the left image, the patches have the same visual appearance than the heat shield. The advantage is in the infrared as shown in the right image. The patches have been heated to match the sand apparent temperature. For an observer located far away, the patches disrupt the shape of the vehicle, matching the apparent temperature and heat distribution of the background, thus making it difficult to distinguish the target in the environment.

2.3 Electro-chromic pixels

Some animal species, like chameleon lizards and octopus, have the ability to change their skin colours and blend in with their surroundings. The optimal visual camouflage of a vehicle would act similarly. The colour-changing ability would give the opportunity for a vehicle in operation to move across a variety of environments with the same camouflage kit. In comparison, conventional camouflages are appropriate in specific circumstances and a change of background can give away the vehicle.

Like chameleons, this project uses large pixels changing colours. The colour variation of the pixels results from the oxidation or reduction of a material by electrochemical means. The colour-change is triggered by a variation in the electric charge. The development of electro-chromic cells was undertaken with an academic partner, Université Laval (Canada), whose researchers synthesized basic electro-chromic cells[2]. The electro-chromic cells were prepared by spray-coating the copolymers onto ITO-coated glass or ITO-coated PET anodes using polymer gel as electrolyte. The fabrication of the 25 cm by 25 cm cells is a hybrid plastic/textile.

Figure 3: Electro-chromic pixels changing from yellow (left) to green (right).

For arid regions, the focus is put on developing yellow and green electro-chromic pixels, to blend in desert with and without vegetation. Figure 3 shows electro-chromic pixels developed for the adaptive camouflaged kit. Recent works[2] on multilayer electro-chromic cells are promising, but there are still important issues regarding stable packaging for large pixels.

3. Field Trial Method

The system concept was tested in a field trial in March 2010 in the desert environment of the US Marine Corps base in Twentynine Palms, California. A series of observations were conducted, comparing a camouflaged vehicle and a reference vehicle. The camouflaged vehicle was a Coyote (Canadian Light Armoured Vehicle) fitted with the adaptive camouflage system and the reference vehicle, another Coyote of the same model, was painted with in-service removable desert camouflage paint.

The background for the observations was a dark beige sandy plain, regularly vegetated with low-lying bushes, mostly dark green. Ambient temperatures were generally cool, and the soil slightly moist, presenting a generally cool background in thermal infrared.

Data captured consisted of imagery in visual and infrared bands. These images were analysed using the visual and radiometric analysis software CAMAELEON[3], which uses a range of image features to estimate a “detectability distance” for the target against the background in the image. This detectability distance is an estimate of the range at which probability of detection is 50%.

4. Results

Analysis using CAMAELEON produced detectability distance estimates for the reference vehicle and the adaptive camouflaged vehicle in observed scenarios. The performance of camouflage systems can be expressed by estimating how much the camouflage system reduced the detectability distance, as compared to an un-camouflaged vehicle. This result is shown here as *percentage reduction of detection range*, which is the percentage amount by which the detectability distance of the camouflaged vehicle is less than that of the reference vehicle.

Samples of the results obtained from the field trial are shown here to demonstrate the adaptive camouflage concepts.

4.1 Thermal Spectrum

In the thermal spectrum, observations were made to compare the reference vehicle to the adaptive camouflaged vehicle in two states: inactive, where the thermal panels are not heated, and active, where the panels are heated to display a temperature distribution similar to that observed in the surrounding environment. Figure 4 shows the reduction in detection range achieved for the inactive and the active states of camouflaged vehicle, compared to the reference vehicle in two scenarios. Scenario 1 is a morning observation, and scenario 2 is a night time observation. Both scenarios observed the vehicle from approximately 0.5 km, and against similar regularly vegetated background.

In both of these cases, the camouflaged vehicle shows a shorter detection range than the reference vehicle. In scenario 1, the activation of the thermal panels reduces the detection range of the camouflaged vehicle by a further 10%. In scenario 2, the camouflaged vehicle already displays a large reduction in detection range, and only a small improvement is achievable when the thermal panels are activated.

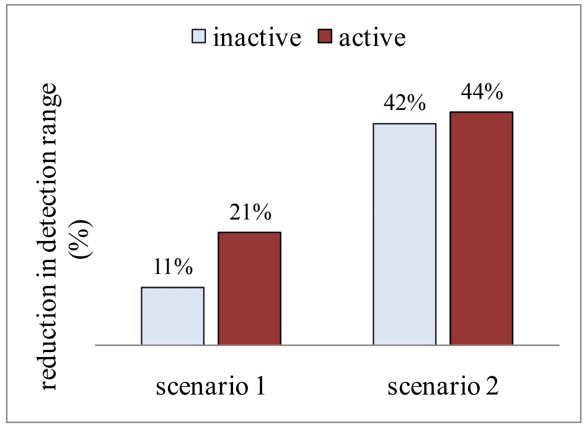

Figure 4: Thermal infrared spectrum percentage reduction in detection range for two sample scenarios. The heating of the panels improves the performance of the camouflaged vehicle, increasing the percentage reduction of detection range as compared to the reference vehicle.

4.2 Visible spectrum

In the visible spectrum, observations were again made to compare the reference vehicle to the adaptive camouflaged vehicle in two states: with the electro-chromic cells yellow or green. When the electro-chromic cells are switched to green, they better match the vegetated background. Figure 5 shows the reduction in detection range results for two scenarios observed employing the electro-chromic cells. Scenario 1 is observed in mid-afternoon from a range of about 0.5 km, and scenario 2 is observed at approximately midday, from a range of about 150m.

The percentage reduction in detection range results shown here are all negative, meaning that the adaptive camouflaged vehicle was observed to have a longer visual detection range than the reference vehicle in these two trials. This is a result of the colour of the heat shield fabric at the base of the adaptive camouflage system, which was a lighter beige than the observed colour of the sand in the trial environs during the testing of the electro-chromic cells. The reference vehicle, dark beige in colour, better matched the sand colour. A small improvement in performance of the camouflaged vehicle is observed in Figure 5 as the cells are switched to green. When the cells are green, the detection range of the camouflaged vehicle shortens a little, reducing the size of the negative percentage reduction in detection range. As only a small number of electro-chromic cells were deployed on the vehicle, it was expected that the effect would be small.

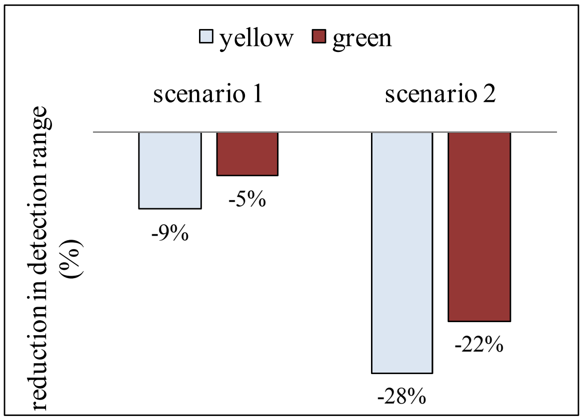

Figure 5: Visual spectrum percentage reduction in detection range for two sample scenarios. The green colouration of the electro-chromic cells improves the performance of the adaptive camouflage vehicle in the observed vegetated desert environment.

5. Conclusion

Field trials of a vehicle camouflage system prototype incorporating adaptive visual and infrared signature management concepts have shown that these concepts can be effective in realistic scenarios. Further work investigates the limitations of the current prototype, and seeks to determine how to improve the system for optimum operational effectiveness.

6. Acknowledgements

The work presented here was done at Defence Research and Development Canada (DRDC) – Valcartier. The prototype adaptive camouflage system discussed here is the property of DRDC.

This project was financed by the technological investment fund and the applied research program of DRDC from 2003 to 2010.

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