International Journal of
Science and Engineering Investigations vol. 10, issue 117, October 2021
Received on October 12, 2021 ISSN: 2251-8843

Concealment, Detection, Recognition, and Identification of Target Signature on Water Background under Natural Illumination

Anowar Hossain
School of Fashion and Textiles, RMIT University, 25 Dawson Street, Brunswick, Melbourne, Vic 3056, Australia
Department of Textile Engineering, City University, Savar, Dhaka, Bangladesh
(engr.anowar@yahoo.com, s3820066@student.rmit.edu.au)

Abstract- Natural illumination is a common attribute and uncontrollable intimidation for concealment, detection, recognition, and identification (CDRI) of defense surveillance. Every research outcome of camouflage engineering needs to conduct field experimentation under natural illumination. CDRI versus natural illumination necessitates considering for every combat location such as woodland, marine, desert land, stone land, snow land, sky and ice land. The intensity of natural illumination and surveillance technique determine CDRI due to irrepressible illumination angle and intensity among sunlight, object-background (OB) environment and detector in ultraviolet, visible, and infrared spectrum. Camouflage field assessment of real OB environments, different weather conditions, season and its variation in natural illumination is also cost involvement and achievement headache for continuous improvement of research. Natural illumination versus CDRI has been investigated in visible range (400-700 nm) using different universal conditions of OB environment in winter season such as foggy morning light (FML), morning sun light (MSL), noon sun light (NSL), evening sun light (ESL), dusk evening light (DEL). A simulation of CDRI of marine target signature was experimented by using "animal object (*Anas Platyrhynchos*)" as target signature. "Water background in water reservoir" was selected for controlled features of background environment as alternative of marine zone. Natural illumination of CDRI has been methodically explained in terms of Lab (L*, a*, b*) color intensity, key factors of water background and its surrounding in OB environment. The partial protection factors of target signature against marine surveillance were signified based on key rudiments of water background environment such as illumination of sun-position/sunlight-angle, weather condition in winter season, wind speed, target detection angle, shadow, wave of water surface, the chromatic intensity of OB and its surrounding background. The illumination of FML-MSL-NSL-ESL-DEL was indicated as CDRI factors in OB environment. MSL-NSL was remarked as predominant effect of target concealment. The experimental concept and procedure can be implemented for design and assessment of marine camouflage objects in different areas of camouflage engineering in terms of natural illumination against water background. The investigation proposed a model named CDRI for target OB in natural illumination.

Keywords- *Natural Illumination, Concealment, Detection, Recognition, Identification*

I. INTRODUCTION

Recently concealment, detection, recognition, and identification (CDRI) represents the most important natural behaviours for preventing target signature in object-background (OB) environment, the assumption has attracted the attention of visual psychology and surveillance [1]. Natural illuminations such as sun and sky are stimulated from above and animals are darker from their backside which is a strategy for animal CDRI, the concept is most vibrant for every target signature in marine backgrounds [2]. Most species of duck are counter shaded to sunlight when the birds are in their natural characteristic position like vertical habitat [3]. Dark dorsa and light on animals are often attributed to an adaptive effect of shape-obliteration when illumination is from above [4]. Colors of different animals seems adapted to their purpose of concealment such as background matching, disruptive coloration and countershading [5, 6]. Target detection is more difficult to identify when color intensity of OB are similar [5]. Object detection and countershading changes under cloudy and sunny environments, [7] luminance distribution of the sky depends on the condition of weather [8]. Luminance of distribution changes with the position of the sun, [9] even detection is complicated in winter [10]. Darker pigmentation on animals exposed to the lighting, which reduces detectability of prey [11] Detection and countershading vary with natural lighting [2]. Optical information, optic flow, which breaks camouflage and specifies target locations as optic flow is responsible for image structure of OB [12]. Light reflected from a surface depends on the scene geometry, the incident illumination, and the material surface [13]. In addition to natural illumination; water waves, shadow are the illumination features for water background, those hamper target detection [4, 14-16] and concealment [17]. Lighting effects on water and shadow enhances the visibility and detection [18, 19]. In different lighting conditions, animals protect from predation by compensating their own shadows [20]. Shadow generates a brightness contrast between the dorsal and ventral surfaces [21]. OB depicts contrast or conceal as a function of viewing angle,[14] size, texture, color [22]. Natural illumination and target properties of animals were experimented with a computational model [23] but digital photography was considered an efficient method for recording luminance intensity and achromatic contents of target signature [20, 24]. Therefore, a hypothesis of this investigation was depicted that sunlight, shadow, wind on water background has an impact for CDRI mechanism. Natural illuminations are key characteristics for CDRI and defence surveillance. Luminance and illumination of sun, sky and cloudy environments have been experimented and reported in the literature. Currently, natural illumination of OB of a specific daylight in time intervals have not been investigated in terms of CDRI, chromatic and achromatic intensity of color imaging. CDRI investigation on target object-duck (TOD) has been undertaken for natural illumination of foggy morning light (FML), morning sun light (MSL), noon sun light (NSL), evening sun light (ESL), dusk evening light (DEL) that have not scientifically been reported in the literature.

II. METHODOLOGY

CDRI was experimented in natural OB environment against water background. Water reservoir was considered as alternative to marine background to keep the constant feature of water background. Animal objects were selected for CDRI in replacement of a marine target signature such as a marine ship. The movement of each TOD was simulated as an uncontrolled movement of a marine ship. The photographic illumination/surveillance angle (35°-45°) was implemented as target detection from a land area beside the marine zone (simulated as a water reservoir).

Natural illumination of birds was experimented based on Thayer theory and discoveries [3, 4] of lighting and background contributions to countershading. A few black colored and almost similar colored bird scenes, Australian duck, scientific name: *Anas Platyrhynchos*, were used to investigate CDRI behaviours in a water reservoir, Princes Park, melbourne with capacity of water 38 ML, water height 35 cm, construction: semi-circular with brick wall and two water pumps. A digital camera, 13 MP, F 1.8, phase detection auto focus (PDAF) was used as observer to view from one side in the visible range 400-700 nm at 45° angle. TOD and water surface was considered as background in ambient illumination of day light [25]. Digital photography [20] is a convenient method for chromatic information and achromatic content of animals. According to the opinion of researcher Stevens, few TOD movements in a reservoir were observed under specific natural illumination.

Figure 1 illustrates the phenomenon of image capture for CDRI mechanism under natural illumination. TOD-CDRI was observed in “five phases” of day light illumination for chromatic matching of TOD with water background. FML, MSL, NSL, ESL, DEL were used for demonstrating the optical influence of sunlight for CDRI. The angle between observer (digital camera) and TOD was kept almost 35°-45°. Photographs were captured at distances ranging from 4 to 5 m. TOD scenes were captured using the camera on the same day in winter during June 2020. The whole day had no visible clouds in the sky. Photographs were captured with the digital camera under different conditions of natural illumination for observations of lighting effect on TOD-CDRI.

The experiments were performed in a water reservoir at Princes Park, a public park at Melbourne, Australia. There were few trees beside the water reservoir at different distances such as 2, 5, 7, 10 m. The results and discussion have been included without considering the exact length of tree shadow, since trees of varying height were located at different distances. During photo capture, the TOD movements were unpredictable due to the natural behavior of ducks. The photographic distances between TOD and camera were kept almost constant without causing any disturbance of the ducks in their natural and relaxed movements. So, all images of TOD did not show the same number of TOD. Similarly, the direction of TOD was not constant due to their tendency for unpredictable movement.

Lab (L^*, a^*, b^*) of TOD and water background for color intensity, three dimensional surface plot of water background for water waves were presented using an image analysis process and it was performed by imageJ software (Fiji Is Just) developed by National Institute of Health (NIH), USA [26].

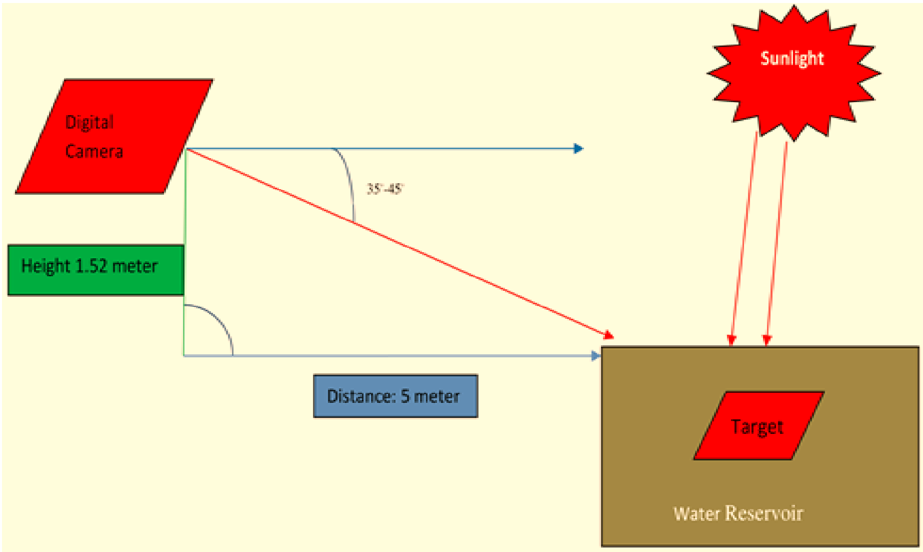


Figure 1. Schematic of CDRI-OB-TOD mechanism in natural illumination against water background and color imaging in OB environment

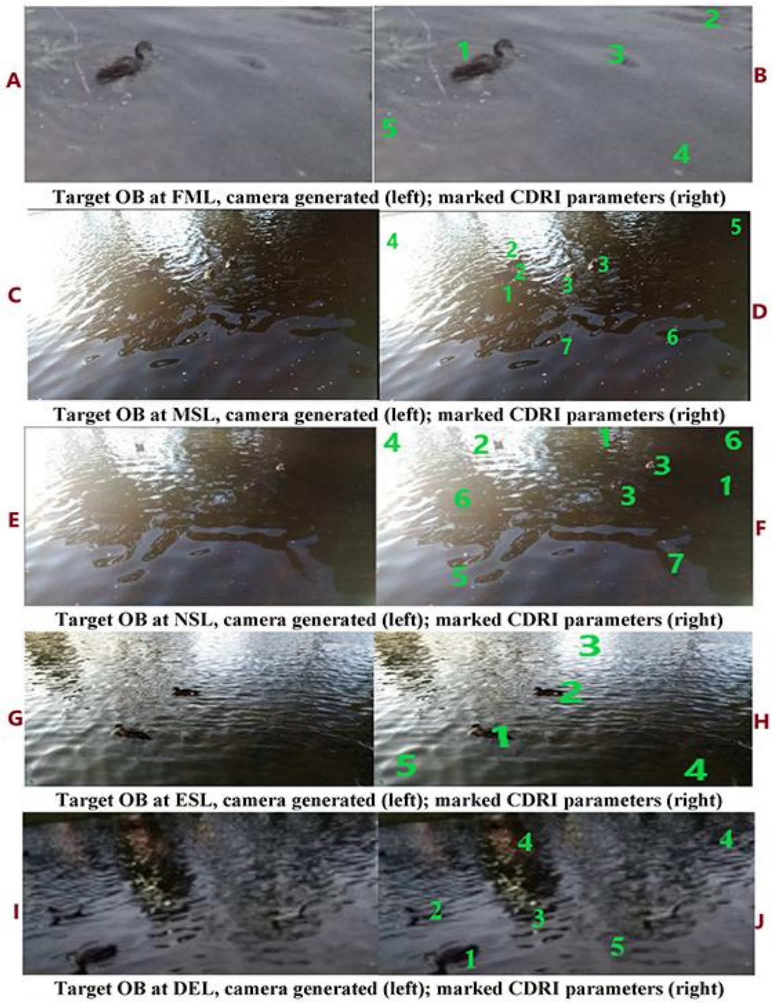


Figure 2. CDRI-TOD at five-dimensional natural illumination under water background

A global thresholding method (mean), Lab was used to distinguish foreground and background under natural illumination Figure 3. Red color thresholding was selected to identify intensity of sunlight. For Lab of OB, original captured photographs were uploaded into imageJ by file and open selection process; and converted into 8-bit depth, wavelength 400-700 nm. TOD and water background was separated by polygon and rectangular shapes. Every CDRI object under different illumination were selected by plugins and color inspector 3D individually for generating diagrams in Lab. Similarly, every background at FML, MSL, NSL, ESL and DEL were selected for background Lab, Figure 3. Water backgrounds at five-dimensional illumination were chosen by "analyze" and three-dimensional water surface plot. "3D surface plots" of water background was exported by selection of background area, Figure 5.

III. INVESTIGATIONS OF TOD FOR CDRI IN WATER BACKGROUND

Detection (ability to distinguish TOD from the background), recognition (ability to classify TOD class) and identification (ability to describe TOD in detail) technique [27]; and camouflage-TOD, detection-TOD, and identification-TOD theory [4] were implemented for CDRI of TOD in water background. Color imaging versus CDRI technique was applied under natural illumination such as FML, MSL, NSL, ESL and DEL. TOD was investigated on water background for CDRI in terms of five-dimensional illumination. The distinctiveness of CDRI were investigated by color imaging in terms of CDRI parameters of TOD such as natural illumination, shadow, angle of water wave, water bubbles.

A. Investigation-01, Figure 2 (A & B) shows FML for CDRI-TOD

In figure 2, A and B are similar photograph of FML. A signifies the captured photograph in natural illumination of FML and B illustrates the symbol for identifications of target CDRI parameters on water background. Marking with "1" demonstrates the identification of TOD. "2", "3", "4", "5" depicts the minor proportion of shadow on a foggy morning, minor water wave, whitish effect of foggy morning environment in winter and water bubbles on water background, respectively. In this condition, the TOD was observed to be almost motionless.

B. Investigation-02, Figure 2 (C & D) shows MSL for CDRI-TOD

In figure 2, C and D are unchanged photograph of MSL. C denotes the captured photograph under natural illumination of MSL and D demonstrates the marker identifications of target CDRI and its background. Marking with "1", "2" and "3" indicates the concealment, recognition, and identification of TOD. "4" indicates the sun illumination when the sun is rising from east side of the water reservoir, "5" defines the shadow of an outside tree and "6" specifies water wave and "7" mentions water bubbles on water background.

C. Investigation-03, Figure 2 (E & F) shows NSL for CDRI-TOD

In figure 2, E and F illustrates an alike photograph of NSL. E mentions the captured photograph in natural illumination of NSL and F illustrates the mark identifications of target CDRI and its background, water surface. Marking with "1", "2", "3" states the concealment, detection, and recognition of TOD. "4" reveals the effect of sunlight, "5" demonstrates water bubbles, "6" signifies shadow of outside tree, "7" generates a CDRI effect of water wave.

D. Investigation-04, Figure 2 (G & H) shows ESL for CDRI-TOD

In figure 2, G and H shows an unchanged photograph of ESL. G implies the captured photograph under natural illumination of ESL and H means the pointer identifications of target CDRI and its water background. Marking with "1" and "2" indicates identification of TOD. "3" identifies sunlight directly falling on the surface of water background. The ESL illumination signify whitish/shiny stimulus. Marking "4" shows the shadow and "5" indicates water waves at different angles.

E. Investigation-05, Figure 2 (I & J) shows DEL for CDRI-TOD

Figure 2, I and J shows same photograph of DEL. I signify the captured photograph under natural illumination of DEL and J illustrates the marker identifications of target CDRI and water background. "1" indicates identification of TOD, "2" remarks recognition of TOD, "3" implies concealment of TOD, "4" indicates the shadow of an outside tree and marking with "5" indicates water wave and the shadow free zone of water background.

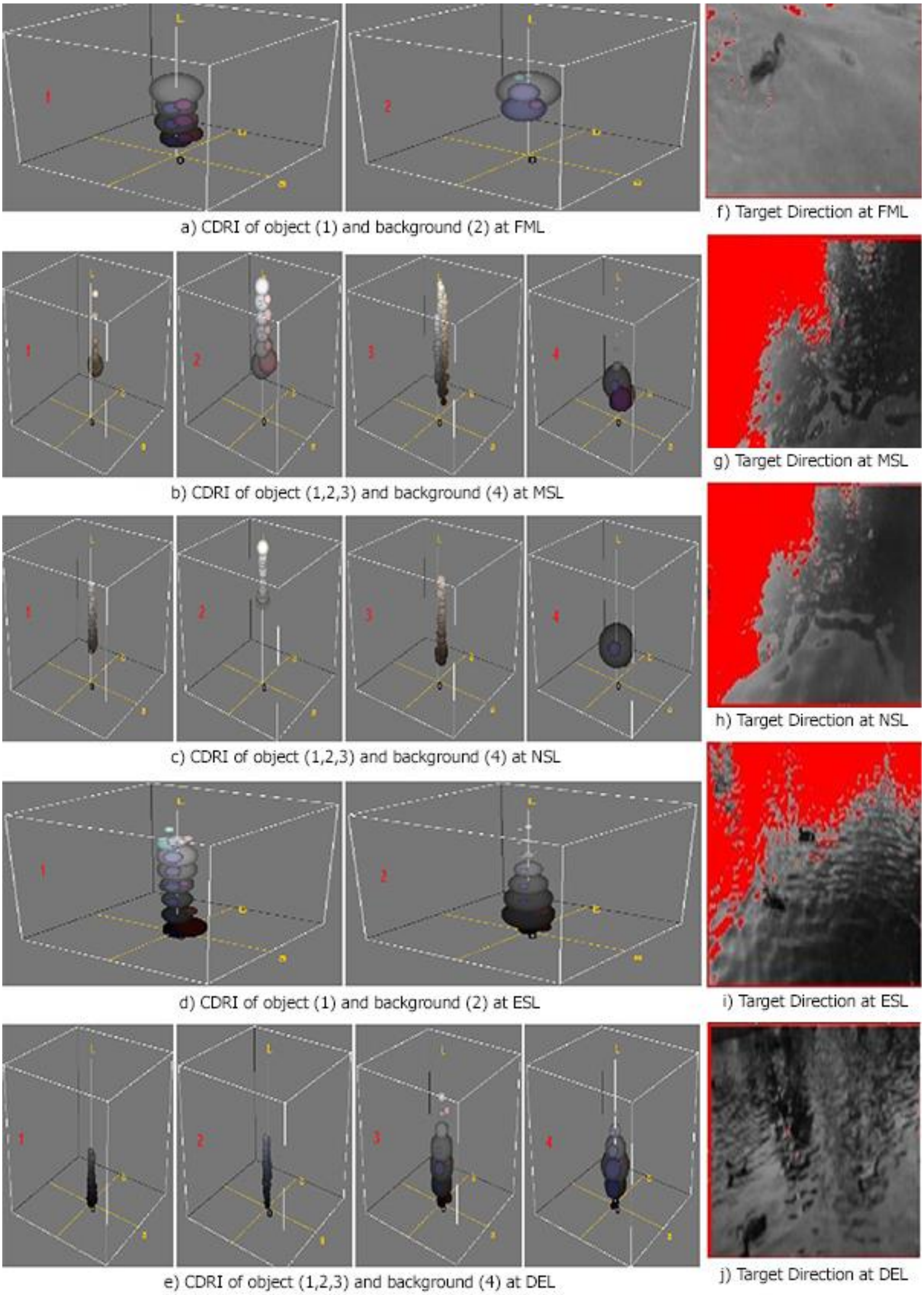
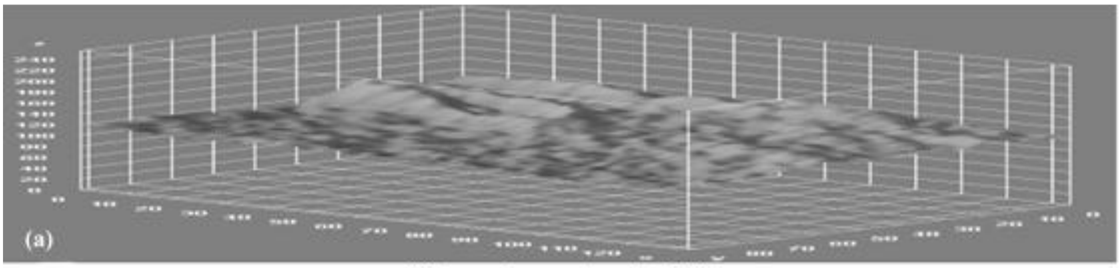
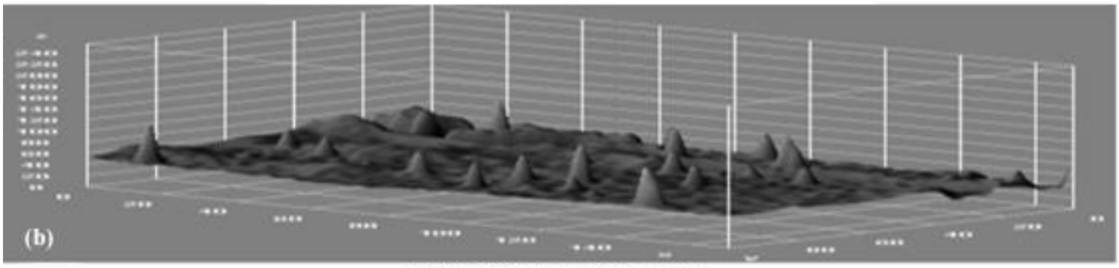


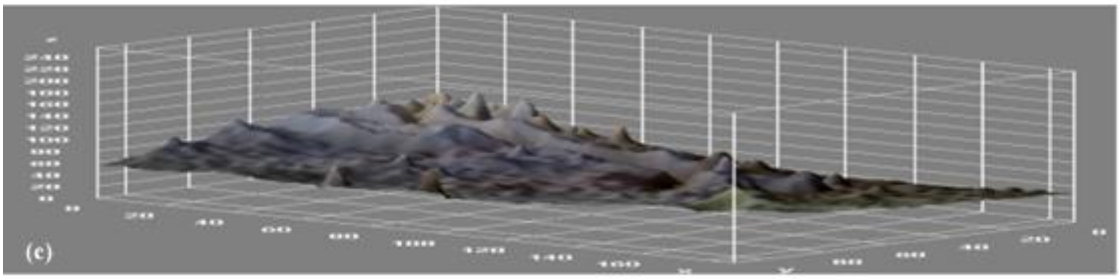
Figure 3. Lab (left) and color threshold (right) between TOD and water background at five-dimensional natural illumination



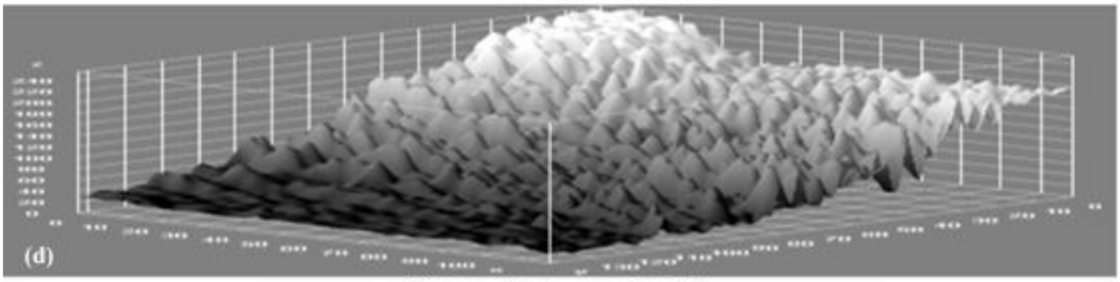
Water surface captured at FML



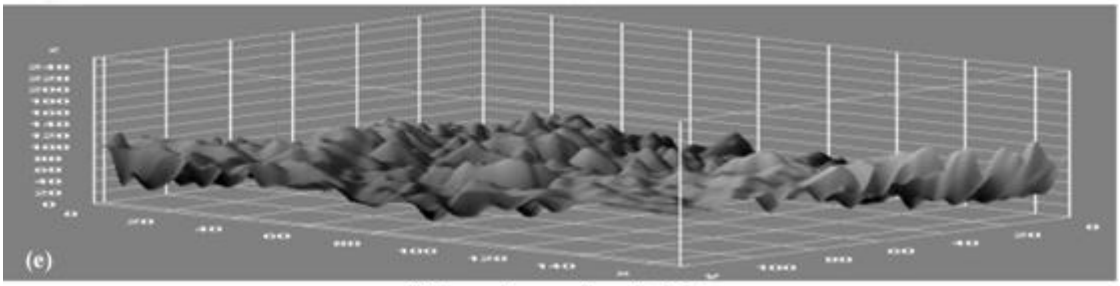
Water surface captured at MSL



Water surface captured at NSL



Water surface captured at ESL



Water surface captured at DEL

Figure 4. Three dimensional variations of water background captured at FML, MSL, NSL, ESL and DEL and represented with imageJ

IV. RESULTS AND DISCUSSION

Figure 3a, 1 = Lab of TOD, identification of TOD; 2 = Lab of water background; Figure 3b, 1 = Lab of TOD, concealment of TOD; 2 = Lab of TOD, recognition of TOD; 3 = Lab TOD, identification of TOD; 4 = Lab of water background; Figure 3c, 1 = Lab of TOD, concealment of TOD; 2 = Lab of TOD, detection of TOD; 3 = Lab of TOD, recognition of TOD; 4 = Lab of water background; Figure 3d, 1 = Lab of TOD, identification of TOD; 2 = Lab of water background; Figure 3e, 1 = Lab of TOD, identification of TOD, 2 = Lab of TOD, recognition of TOD; 3 = Lab of TOD , concealment of TOD; 4 = Lab of water background; Figure 3f, color threshold of OB at FML; Figure 3g, color threshold of OB at MSL; Figure 3h, color threshold of OB at NSL; Figure 3i, color threshold of OB at ESL; Figure 3j, color threshold of OB at DEL.

Deeply shaded water background showed a dark bottom against TOD. Shadow and underwater substances created darker surface on water background. The black color of TOD on top was blended with deeply shaded water background and revealed as weak reflection in photographs of color imaging. Water caustic and sunlight position at FML-MSL-NSL-ESL-DEL critically replace the wavelength and illumination on TOD. Dappled light influence was also signified although there was no tree, wall or other obstacle remained close to the surrounding of OB during this experimentation.

Comparison of Lab of TOD and water background has been represented with imageJ at five-dimensional natural illumination. Color threshold (red) of OB environment was illustrated at FML, MSL, NSL, ESL, DSL. Reddish area of color threshold identifies the sunlight intensity at FML, MSL, NSL, ESL, DSL. Red thresholding signifies the intensity of natural illumination in natural OB environment. Red threshold clearly differs the significant area from water background due to intensity of sunlight at MSL, NSL and ESL. Therefore, the prominence of shadow was higher at MSL, NSL and ESL. Red threshold color did not appear at FML and DSL due to minor intensity of sunlight.

A. TOD in natural illumination at FML

Figure 3a, RGB grey value (L*) of TOD-1 (Lab-1) was lower than water background (Lab-2) grey value that seems in contrast due to remaining whitish effect in the water background at FML. Figure 4a depicts the minimum level of water surface changing at FML because of winding effect and surface water wave was poor and there was a minor proportion of water wave angle. Figure 3a illustrates the negligible effect of surrounding shadow due to absence of sunlight at FML. It can be signified that TOD was less impacted by shadow because of reduced intensity of sunlight. Water bubbles create a whitish caste, and a foggy morning generated a whitish reflection, so the water bubble effects were not visible, Figure 4a. TOD identification was slightly influenced by water wave by the reason of minimum effects of remaining natural wind. Therefore, the object may signify the trouble-free identification although TOD looked blurred at FML.

B. TOD in natural illumination at MSL

Figure 3b, the grey value sequence can be mentioned as TOD-1<TOD-2< TOD-3. The grey value of TOD-1 signifies almost similar proportion of grey value compared to water background. Hence TOD (Lab 1) remarked as concealed. TOD (Lab 2, 3) is lighter due to morning sunlight and shadow prominence. Figure 3b, 4b; the combination of shadow and water surface creates a darker TOD with less prominence to the water background. Therefore, TOD-2, 3 (Lab-2, 3) can be identified in terms of recognition and identification, but the TOD appearance is not as clearer as FML.

C. TOD in natural illumination at NSL

Figure 3c, the sequence of grey value can be identified as TOD-1<TOD-2<TOD-3<TOD-4. TOD-1 illuminates lower grey value which identify black appearance of TOD and water background. The shadow was more prominence at NSL due to higher degree of sunlight at noon. The combined outcome of shadow and noon sunlight was the mechanism of concealment of TOD (Lab 1). The grey value of TOD-2 (Lab 2) was higher because of whitish effect when sunlight was directly fall; and water wave was recorded as elevated because of air speed, Figure 4c. Consequently, same CDRI parameters were affected the third TOD (Lab 3). The target was less impacted by shadow and sunlight, created the TOD lighter with higher grey value to the water background and third TOD was identified as recognition of target object.

D. TOD in natural illumination at ESL

Figure 3d, the grey value of TOD was less than water background, the contrast mechanism of TOD and water background created the identification of TOD. Figure 4d, surface water movement at ESL was higher, it confirms that the airflow was elevated at evening. The grey value and TOD were not influenced by water wave as well as shadow was less affected the target at ESL.

E. TOD in natural illumination at DEL

Figure 3e, the grey value can be signified as TOD-1<TOD-2<TOD-3. Water background was lighter than TOD-1, hence the target was illustrated as identification. The shadow and underside ground of water background was generated a clearer water surface. Water surface movement was recorded at minimum level due to lacking intensity of air speed (natural phenomenon) at DEL, Figure 4e. The reflection mechanism of shadow and water background demonstrated the TOD-2,3 (Lab 2, 3) recognition and its concealment.

F. CIE, RGB stimulus of TOD in natural illumination

As per RGB-TOD theory of color science [1]; if red, green, and blue are the primary colors represented by the symbol [R], [G], [B]. Tristimulus values are denoted by symbol R, G, B, stimulus value is denoted by S, "matched by" is denoted by equal sign (=). So, it can be written for any matching condition of CDRI of target signature against background:

$$S= R[R]+G[G]+B[B] \quad (1)$$

In naked eye color assessment process or color imaging, the same theory can be applied for color comparison or photographic comparison or concealment comparison or TOD-CDRI for different color matching in different illumination of day light. Stimulus of FML is denoted by S_1, stimulus of MSL is denoted by S_2, stimulus of NSL is denoted by S_3, stimulus of ESL is denoted by S_4, stimulus of DEL is denoted by S_5.

$$S_1= R_1 [R]+G_1[G]+B_1[B] \quad (2)$$

$$S_2= R_2 [R]+G_2[G]+B_2[B] \quad (3)$$

$$S_3= R_3 [R]+G_3[G]+B_3[B] \quad (4)$$

$$S_4= R_4 [R]+G_4[G]+B_4[B] \quad (5)$$

$$S_5= R_5 [R]+G_5[G]+B_5[B] \quad (6)$$

Stimulus of S_1, S_2, S_3, S_4, S_5 are the dependable for the CDRI of TOD. The gradient of RGB increases the visibility of TOD. So, the simple formulation CDRI-RGB can be written as RGB of TOD for any concealment<RGB of TOD for any detection<RGB of TOD for any recognition<RGB of TOD for any identification. Thus, zero stimulus of RGB may create concealment of TOD to the sensor of detector in terms of digital camera or Lab, Figure 2, 3. In this experiment, RGB of S_2 and S_3 are more prominent for the response to the digital camera and S_1 shows less prominence. Therefore, the sequence can be formulated as $S_3>S_2>S_4>S_5>S_1$, Figure 2, 3, 4.

More accurate spectrophotometric analysis can be performed for specific wavelength as per computational theory of color science [1]. If the tristimulus values are measured separately each wavelength of visible spectrum then the tristimulus R, G, B will be replaced by λ.

$$S =R(\lambda)+G(\lambda)+B(\lambda) \quad (7)$$

The same theory can be applied for the comparison of color or photographic or TOD-CDRI of different color matching in different illumination of day light. Stimulus of FML is denoted by S_1, stimulus of MSL is denoted by S_2, stimulus of NSL is denoted by S_3, stimulus of ESL is denoted by S_4, stimulus of DEL is denoted by S_5.

$$S_1 = R(\lambda_1) + G(\lambda_1) +B(\lambda_1) \quad (8)$$

$$S_2 = R(\lambda_2) + G(\lambda_2) +B(\lambda_2) \quad (9)$$

$$S_3 = R(\lambda_3) + G(\lambda_3) +B(\lambda_3) \quad (10)$$

$$S_4 = R(\lambda_4) + G(\lambda_4) +B(\lambda_4) \quad (11)$$

$$S_5 = R(\lambda_5) + G(\lambda_5) +B(\lambda_5) \quad (12)$$

Similarly, maximum color band of spectral and color imaging can be experimented by multispectral/hyperspectral imaging system due to having highest color response in a broader wavelength.

G. TOD versus CDRI assessment on water background

Figure 5 (a, b, c) illustrates the TOD assessment of water background under five dimensional natural illuminations such as FML, MSL, NSL, ESL and DEL in terms of CDRI. Comparison of major CDRI characteristics has been presented by scoring policy (1-4) based on partial assessment, Figure 2; chromatic (L*, a*, b*) analysis and color threshold analysis of sunlight intensity, Figure 3; wind effect on water surface, Figure (4). Figure 2, 3, 4 demonstrates the TOD versus CDRI characteristics such as shadow effects, sunlight intensity, wind effect (water wave) and accordingly summarized in Figure 5 (a, b, c). CDRI was graded as identification (1), recognition (2), detection (3), concealment (4) and CDRI parameters were also scored as zero (0), minor (1), moderate (2) and major (3). Illumination of sunlight moderated the target detection both in MSL and NSL. Reflection of sunlight at mid-day light was higher. It may be the reason for sunlight falling from top side at 90° angle on the surface of water and illumination of sunlight was distributed at multi-angle on water background. Shadow is more prominent when stimulus of sunlight is higher. The shadow effect of surrounding environment and the shadow of TOD was influenced the illumination and its target CDRI. Oppositely the surrounding shadow showed less prominent effect for target CDRI when observed at FML and ESL although FML showed minor effect in shadow. Sunlight creates shadow of TOD and the surrounding materials of water background. Both TOD-shadow and water background-shadow are responsible for CDRI. Wind effect has also been depicted as minor effect for CDRI.

H. An approach of TOD-CDRI model for camouflage assessment

The color intensity (*L**, *a**, *b**) of OB environment was represented for CDRI model of camouflage assessment. Figure 5d represents the symbolic amplification of CDRI. Striking with blue color illustrates the TOD on water background. Pink color demonstrates the concealment of TOD, orange color indicates the detection of TOD, green color depicts the recognition of TOD, red color shows the identification of TOD with water background. Color imaging of target signature have been impacted by CDRI parameters of TOD and its water background. Hence, altering of illumination versus CDRI effect of sunlight have been demonstrated at FML, MSL, NSL, ESL, DEL. Light falling angle on OB, detector, and target angle; its relationship with sun light direction, OB color matching, shadow of TOD, shadow of water background, shadow of surrounding OB environments is the natural mechanism for CDRI assessment.

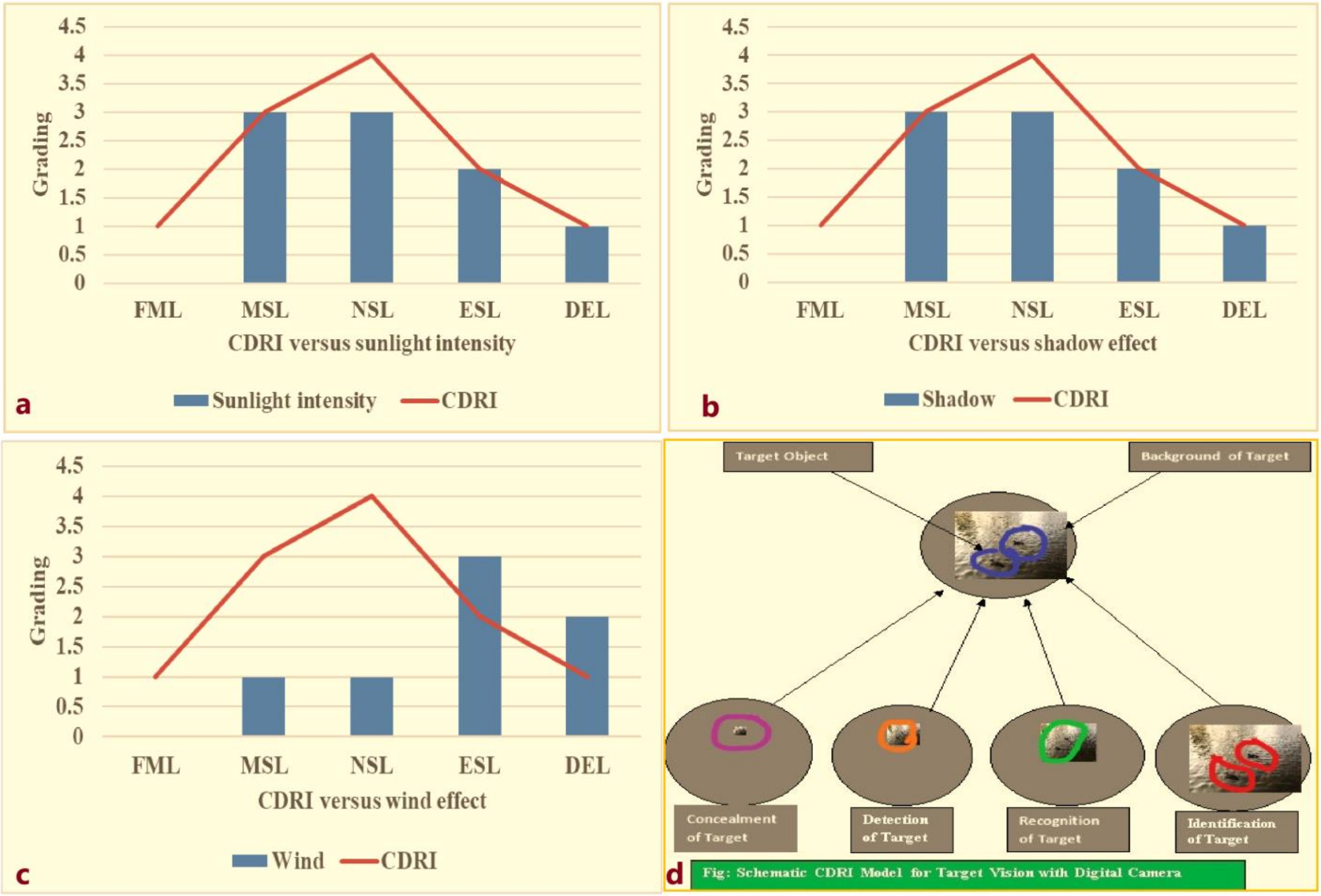


Figure 5. a) CDRI versus sunlight intensity, b) shadow and c) wind effect and d) an approach of CDRI model

V. CONCLUSION

It is recommended that TOD color, surrounding color and water background color are strongly influenced by lighting conditions of natural illumination at different time of a specified day. Therefore, natural illumination should be considered for every research and development of CDRI. It is also vital for CDRI in ultraviolet, visible, and infrared spectrum. Photographic investigation on natural illumination in different day lighting can clarify the effect of environmental conditions for decision making of CDRI. Therefore, known, and unknown features of OB may influence CDRI of target signature against combat background. Every target signature is affected by natural illumination. Major natural features of water background have been remarked for CDRI of target signature such as shadow, water wave angle and winding speed, and the movement of target signature. The concepts, technology, and applications of RGB and Lab color imaging, quantitative and qualitative image analysis in OB environment can be implemented at marine zone for every CDRI in OB environment.

TOD is a natural phenomenon for adaptation with water background because of cryptic coloration of animals. But natural illumination was remarked as uncontrolled parameters. Similarly, CDRI and natural illumination are the challenging task for all branches of camouflage engineering and protection of surveillance against modern remote sensing technology. For example, camouflage textiles, camouflage ship, camouflage vehicle for countershading of multidimensional illumination and its variation of color imaging for CDRI. Accordingly, modern surveillance technology for identification of target signature needs to be improved under the consideration of natural illumination and its related parameters for CDRI.

Abbreviations

Foggy morning light (FML); morning sun light (MSL); noon sun light (NSL); evening sun light (ESL); dusk evening light (DEL); concealment, detection, recognition, and identification (CDRI); red, green, blue (RGB), L^*, a^*, b^* (Lab); object-background (OB), target object-duck (TOD).

Declaration

Authors declare no conflict of interest to publish this article.

Acknowledgement

Author, Md. Anowar Hossain, acknowledges RMIT University and Australian Government for funding through RTP Stipend Scholarship. Author also thankful to Professor Robert Shanks, School of Science, RMIT University for his draft review.

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How to Cite this Article:

Hossain, A. (2021). Concealment, Detection, Recognition, and Identification of Target Signature on Water Background under Natural Illumination. International Journal of Science and Engineering Investigations (IJSEI), 10(117), 1-11. http://www.ijsei.com/papers/ijsei-1011721-01.pdf