Seasonal Adaptation of Vegetation Color in Satellite Images

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SEASONAL ADAPTATION OF VEGETATION COLOR IN SATELLITE IMAGES

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ABSTRACT

Remote sensing techniques like NDVI (Normal Difference vegetative Index) when applied to phenological variations in aerial images, ascertained the seasonal rise and decline of photosynthetic activity in different seasons, resulting in different color tones of vegetation. The rise and fall of NDVI values decide the biological response, either the *green up* or *brown down* [1]. Vegetation in *green up* period appears with more vegetative vigor and during *brown down* period it has a dry appearance. This paper proposes a novel method that identifies vegetative patterns in satellite images and then alters vegetation color to simulate seasonal changes based on training image pairs. The proposed method first generates a vegetation map for pixels corresponding to vegetative areas, using ISODATA clustering, morphological operations and vegetation classification. It then generates seasonal color adaptation of a target input image based on a pair of training images, which depict the same area but were captured in different seasons, using image analogies technique. The vegetation map ensures that only the colors of vegetative areas in the target image are altered and also improves the performance of the original image analogies technique. The proposed method can be used in flight simulations and other applications.

Index Terms— pattern recognition, satellite images, image analogies, texture synthesis, vegetation identification, ISODATA, seasonal adaptation, color tone, flight simulation, texture color transfer.

1. INTRODUCTION

Satellite images are routinely used as ground textures to simulate Earth surface and 3D features on Earth in terrain visualization, flight simulations and many other similar applications. Texture mapping is a standard and powerful rendering technique used in modern computer graphics and it enhances realism and details with only a modest increase in computational complexity. However, it is common that satellite images of different regions were not captured in the same season and they exhibit substantial variations due to seasonal color changes of vegetation on the ground. Thus if satellite images captured in different seasons are used in flight simulations, the trainee would witness widely differing and constantly changing level of fidelity. In such systems, training effectiveness is compromised since the suspension of disbelief cannot be fully maintained. Therefore in many applications such as flight simulations it is desired that, satellite images captured in the same season are to be used, the images based on different seasons.

This paper proposes a novel method that identifies vegetative areas in satellite images and then alters vegetation colors to simulate seasonal changes based on training image pairs. It is also a matter of fact that, non-vegetative regions also change their content (so color) based on seasons. For example, in frigid zones the non vegetative regions are covered by snow for most of the time in a year. Some regions experience snow fall in winter, which covers the land and vegetation areas in random amount. The proposed algorithm's scope is confined to generating seasonal adaptations for vegetative regions, due to uncertainty in snow fall and hence difficultly involved in acquiring training data. This method generates a vegetation map for pixels corresponding to vegetative areas in satellite images, using ISODATA clustering, and classification techniques. It then generates seasonal color adaptations of a target image Q based on a pair of training images P and P', using image analogies technique [2]. The training images P and P' are images of the same area, but captured in different seasons. The final image Q' has seasonal appearance that is similar to that of the training image P'. The vegetation map ensures that only colors of vegetative areas in Q are altered. The remainder of this paper is organized as follows. Section 2 describes the proposed algorithm; Section 3 includes some experimental results and discussions. Finally conclusion is drawn in Section 4.

2. PROPOSED METHOD

2.1. Vegetation Map

Satellite images usually consist of vegetative and non vegetative patterns. The proposed algorithm first generate a vege-

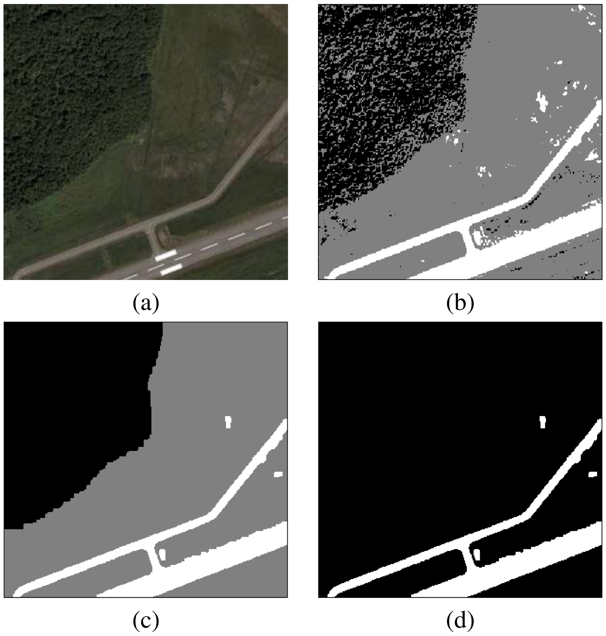


Fig. 1. (a) Input image (b) Initial clustering result produced by the ISODATA algorithm. (c) Improved clustering results by morphological operations. (d) Classification results produced by the MLP classifier, where black pixels represent the vegetation class and white pixels non-vegetation class.

tation map that represents pixels corresponding to vegetative areas in an image. Generation of vegetation map involves two steps: clustering and classification. The input images in the *RGB* (red, green, blue) color space are first converted to the *YCbCr* (luminance, blue, and red) [3] color space to reduce cross correlations between components. The ISODATA (Iterative Self-Organizing Data Analysis) algorithm [4] is then utilized to cluster pixels into groups, followed by morphological operations, such as opening and closing, and median filtering. The ISODATA algorithm is an unsupervised clustering method and it produces a number of unidentified clusters for vegetative and non-vegetative areas. A classifier then classifies the two clusters into a vegetative class and a non-vegetation class. The classifier utilizes a multi layer perception (MLP) which is trained by the back-propagation (BP) and output reset (OR) algorithms [4, 5]. Fig. 1 shows different stages of the vegetation map generation process. Fig. 1(a) shows the input image. Fig. 1(b) shows the initial clustering results, where three unidentified clusters were generated and represented by different colors. It can be seen that in Fig. 1(b) the initial clustering result has a lot of noise, for example, some pixels in the woods area (top-left) are assigned to the same cluster as are pixels representing grass. The non-uniform clustering is because the variations in the original input image and the imperfectness of the algorithms (ISODATA) used. Other conditions, such as mixels (mixed pixels) where one pixel may represent more than one type of object, can also result in wrong clustering. The initial clustering result can be improved by morphological operations [6]; the result is shown Fig. 1(c). The MLP classifier then classifies the three clusters into two classes: a vegetation class and a non-vegetation class by computing statistical values for all three channels *YCbCr*. The output from the classifier is shown in Fig. 1(d). For details about the ISODATA algorithm and the classifier used in our work, see our companion paper [4].

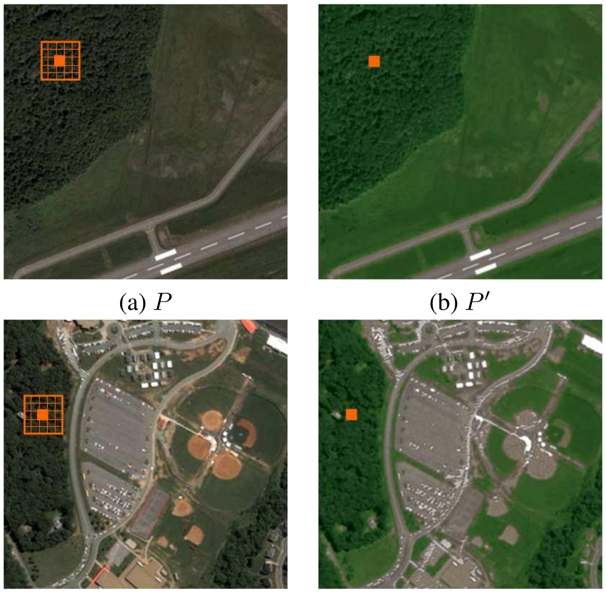
2.2. Seasonal Color Adaptation

After the vegetation map is obtained, the colors of the vegetation area can be adapted to other seasons utilizing the image analogies technique [2]. Image analogies generates an output image Q' that is related to an input image Q, imitating the relationship between a pair of training images P' and P. The image analogies process can be represented mathematically as:

$$P : P' :: Q : Q' \tag{1}$$

where the symbol :: denotes that the relationship between P and P' is similar to that between Q and Q'. P' and Q' can be thought of as filtered versions of P and Q, respectively. For the seasonal color adaptation in our work, the training pair P and P' are images of the same area but captured in different seasons, the target image Q is captured in the same season as is P, then the output image Q' would look as if it is captured in the same season as is P'.

The image analogies technique assumes that the two training images are registered; that is, the colors at and around any given pixel p in P correspond to the colors at and around the same pixel p in P'. A similarity metric that is based on an approximation of a Markov random field is utilized by the image analogies technique [2]. Specifically, the joint statistics of small neighborhoods within the training image and target image are used to measure the relationships between them. Fig. 2 shows an example of the training image pair P and P', the target input image Q, and the output image Q'. For each pixel q in the image Q, the image analogies technique searches for a corresponding pixel p in the image P such that the small neighborhoods of p and q have similar statistics. The two orange squares surrounded by 5×5 windows in Figures 2(a) and (c) illustrate such matching pixels in P and Q, respectively. The pixel p in P' is then copied to the pixel q in Q', since the images P and P' are registered. That is, the pixel at the position labeled by the orange square in Fig. 2(b) is copied to the pixel at the position labeled by the orange square in Fig. 2(d). The pixels in Q are processed in a scan-line order; thus the pixels in Q' are generated in the same order.



(a) P (b) P'

(c) Q (d) Q'

Fig. 2. Image analogies. (a) and (b) are the training image pair P and P'. (c) is the target image Q. For each pixel q in the target image Q, a matching pixel p in P is found such that the neighborhoods of p and q (5×5 windows in (a) and (c)) have similar statistics; then the pixel that has the same location as p in P' is copied to the pixel in Q' in (d), which has the same location as q. The pixels in Q' are generated in a scan-line order.

The joint statistics of a small neighborhood centered at a pixel are concatenation of the feature vectors of all the pixels in the neighborhood. The feature vector of each pixel can consist of *RGB* color components, luminance (*YIQ* Color space) [7] , various filter responses, etc. In this work, only *RGB* color components are included in the feature vector. The efficient implementation of image analogies technique makes uses of multi-scale representation and fast neighborhood search methods [2]. The multi-scale representation first constructs Gaussian pyramids of images P, P', and Q with I levels; the synthesis then proceeds from coarsest to finest resolution, computing a multi-scale representation of Q', one level at a time. The pseudo code of the algorithm [2] is shown in Fig. 4.

Q'_I in the pseudo code is the finest resolution in the Gaussian pyramid and it is the final output. The Match() function in the pseudo code uses fast neighborhood search algorithms, including the approximate-nearest-neighbor-search [8, 9], coherence search [10] and tree structured vector quantization [11]. As noted in the original paper [2], although image analogies is an effective image synthesis method, it is not perfect. This can be clearly seen in the example output image

(a) (b)

Fig. 3. (a) Vegetation map of Fig. 2(c). (b) Final seasonal color adaptation of Fig. 2(c) based on the training pair in Fig. 2(a) and (b).

BuildImageAnalogy(P, P', Q)
  Construct Gaussian pyramids for P, P', Q
  Compute features for P, P', Q
    for each level i, do:
      for each pixel $q \epsilon Q'$ in scan-line order, do:
        $p \leftarrow$ Match(P, P', Q, Q', i, q)
        $Q'_i(q) \leftarrow P'_i(p)$
return Q'_I

Fig. 4. PseudoCode utilized in the Proposed Algorithm. Q'_I is the final output image. Match() function searches for the best matching pixels.

Q' shown in Fig. 2(d). The original target image Q (Fig. 2(c)) has some ground objects with brown colors, but these objects' colors are changed to gray in Q'. This is an undesired effect since these ground objects don't change their colors in different seasons. To restrict color changes to vegetative areas only, the vegetation map generated in the previous section is utilized. The vegetation map of Q is shown in Fig. 3(a). Utilizing this vegetation map, non-vegetative regions in Q are copied back to Q' to form the final image shown in Fig. 3(b). Our current implementation utilized the code from [12]. Our future implementation will utilize the vegetation map in the neighborhood search process, i.e., the search is restricted to the vegetative areas of P and Q only. This will certainly improve the output image quality since the probability of erroneous neighborhood match is greatly reduced. The computational time will also be significantly reduced.

3. RESULTS AND DISCUSSION

Vegetation changes colors due to a number of chemical, physical, and biological processes that occur in different seasons. It is especially worth to note two phenomena, namely, *green up* and *brown down* [1]. In spring, leaves emerge and flourish and vegetative growth is rapid, resulting in an greenish appearance, known as *green up*. From mid-summer to late

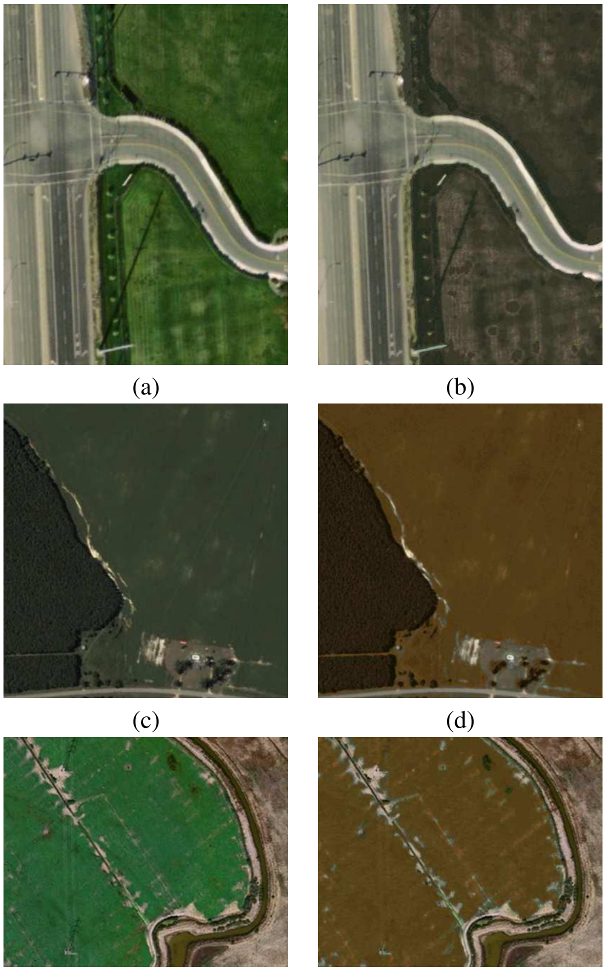


Fig. 5. *Brown down* effect simulation. (a), (c) and (e) are input target images, while (b), (d) and (f) are output images generated by the proposed method.

summer, plant tissues mature, dry, and are harvested, resulting in an brownish appearance, referred to as *brown down*. There are some other seasonal color changes as well. The images in Fig. 5 simulate the *brown down* effects. Images in Figures 5 (a), (c) and (e) are input images, while images in Figures 5 (b), (d) and (f) are output images produced by the proposed method. The images in Fig. 6 simulate the *green up* effects. Fig. 6 (a), (c), (e), (g) and (i) show the input images, while Fig. 6 (b), (d), (f), (h) and (j) are the output images generated by the proposed method. These results illustrated the effectiveness of the proposed method. In our current implementation, the vegetation map only contains vegetative areas (and therefore non-vegetative areas). To obtain even better results, the vegetation map needs to be refined, that is, it should indicate different types of vegetation, such as trees and grass. Currently the vegetation maps are generated from satellite images in the visible wavelength band. In order to obtain better vegetation maps or feature maps, images from other sources should also be used, such as infrared images in various wavelengths.

4. CONCLUSION

This paper proposed a novel method that alters vegetation color in satellite images to simulate seasonal changes. The proposed method first generates a vegetation map for pixels corresponding to vegetative areas in satellite images, using ISODATA clustering and vegetation classification. Morphological techniques are also utilized to eliminate the unwanted clusters. It then generates seasonal color adaptations of a target input image using image analogies technique. The vegetation map ensures that only the colors of vegetative areas are altered. The proposed method can be used in flight simulations and other applications.

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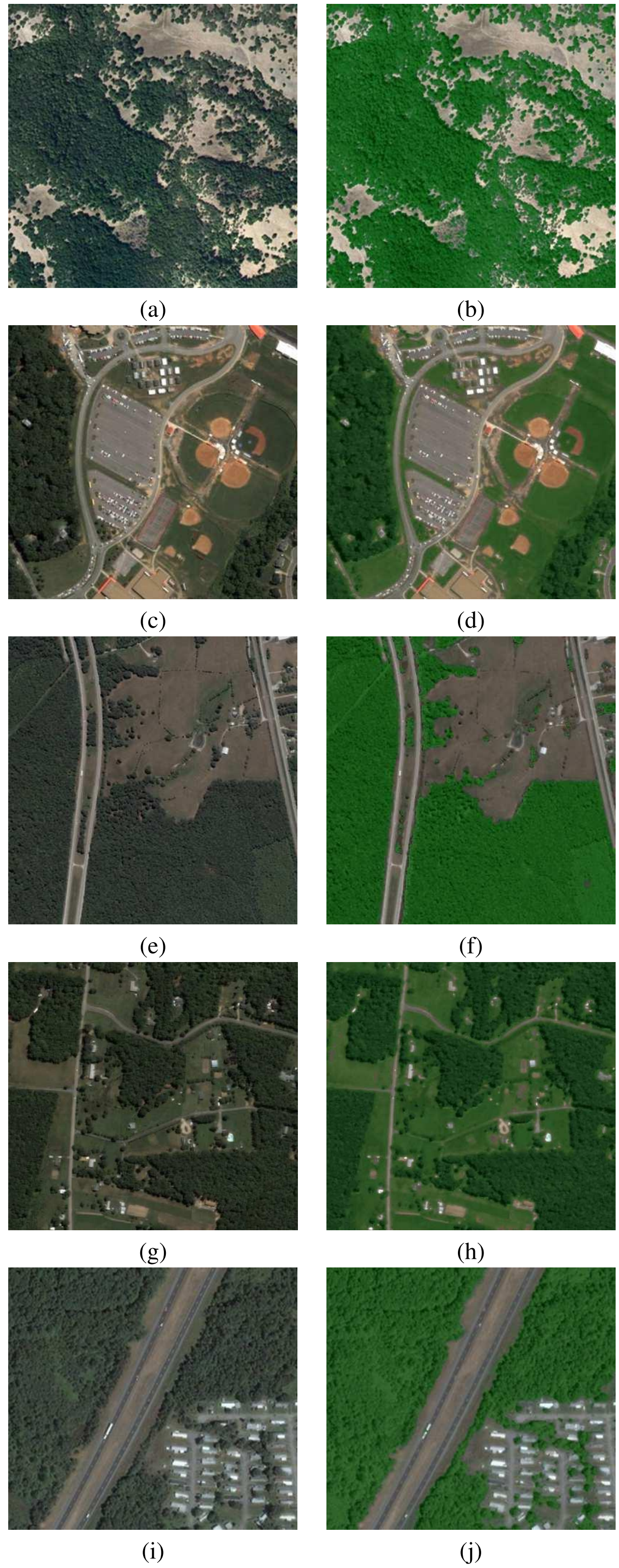

Fig. 6. *Green up* effect simulation. (a), (c), (e), (g) and (i) are input target images, while (b), (d), (f), (h) and (j) are output images generated by the proposed algorithm.