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Detection and Extraction of Sky Regions in Digital Images based on Color Classification

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Abstract

In many applications of image processing there is a need to extract the solid background which it is usually sky for outdoor images. In our application we present this solution. We developed an automatic algorithm for detection and extraction of sky regions in the color image based on color classification. In which the input image should be in the RGB color space and the blue color is detected and classified. Then the color image is transformed to the binary form and the connected regions are extracted separately. The connected regions are then sorted in a descending order according to the biggest area and the biggest region is identified. Then we merged all objects that have similar sky properties. Experimental results showed that our proposed algorithm can produce good results compared to other existing algorithms.

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1 Introduction

Color extraction is quite important in image processing field since it can be used in the extraction of different kind of objects. There are many applications based on color classification such as, in satellite images to extract specific vegetation type using color information that this vegetation has the same color [15], in alpine ecosystem for monitoring snowmelt and estimating the influence of future climate change [9], in computer vision for recognize objects in real time [1,2], in video recognition systems for tracking of facial region [8], in medical field to detect the homogeneous regions for pathology study [3].

In our particular application, we aim to detect the background of the buildings since our main task is to extract buildings. It is difficult to define buildings since they have different shapes, different windows, different types of roofs and many details so it is hard to define them but we can define everything else and when we extract everything from image only the buildings will remains. In this research study, we will use color classification for one specific application which always has a sky for a background. The images that will be used to test the proposed algorithm are provided by the research team.

Sky is usually occupying a large area in outdoor and landscape images. In which these area needs to be identified and extracted since act as a disturbing factor for building extraction application. The basic problem is that the sky is quite hard to define because it has a quite big range of intensity values and in different weather, the sky tones are different. For instance in a sunny day the sky has blue color but in a cloudy day the sky has a bluish gray color so the most characteristic in sky is the color variable, which it is usually bluish to bluish grey. Usually sky present in the upper part of images and occupying a large area, this keep us on track that we need to look to the biggest area in the image. Sometimes there are other objects having almost the same properties of the sky. For instance road signs, cars and other objects in the image in which they all have the same sky bluish color, so they should be excluded.

Our problem is how to extract a background of sky regions, so many of situations need to keep in mind about the definition of the sky and how the algorithm identify that these regions are belonging to the sky or belong to other objects having the same color properties. Also we need to think about if the sky region belong to one big area or belong to smaller areas in the image. The usage of color classification is needed in this particular case to detect the sky and thus exclude other objects such as building, road signs and cars that these objects have almost the same sky range of the bluish to bluish gray color. These problems have been solved earlier for instance in the following papers; Saber *et al.* [12] used color pixels classification for sky region extraction. The major drawback of this type of algorithm is that it cannot differentiate between objects that have blue color in the image and the sky blue color. Lately, Luo *et al.* [10] took the advantage of using physics model technique in the extraction of sky region. However it is not convenient to follow this technique since it need a lot of technical work on the sky validations model. More recently, Han *et al.* [6] developed a technique which is able to extract automatically objects of user first foci of attention that is around the center of the image combined by seed growing region. However the technique extracts objects in a good manner but it is not convenient to our case since usually the sky is not in the foci of attention. Phung *et al.* [11] present an algorithm for face detection in color images using mainly edge information. Hanmandlu *et al.* [7] present color classification of natural images based on a clustering approach.

1.1 Background

In this chapter we will present a background of color definition, image processing techniques that used in this thesis and literature survey about earlier work of the proposed field.

1.1.1 Color definition

Color is a visual perceptual property to the human's eye where the color is created inside our brains system and thus there is little difference of the perceived color among the human beings. Color is perceived according to the combination of biological phenomena regarding to our visual system, psychological phenomena regarding to brain light interpretation and physical phenomena to different objects. In order to see color, you must have a light which has a measure in wavelength. The light wavelengths visible to our retina are from 400 nm to 700 nm [4]. When light strikes on an object some of the colored light rays are absorbed by it and others will be reflected from it, in which our eyes see only the reflected colored light rays. For instance when light strikes a white object, it absorbs no color and reflects all color and thus looks white to us but when light strikes a black object, it absorbs all colors and reflects nothing and thus appear black to us. The importance of color is that it differentiates between objects according to their physical properties such as light absorption, diffusion and reflection, so the usage of color concept is an efficient way to differentiate and extract between different objects.

The RGB color model is the standard color model for representing colors in image processing, computer graphics and computer monitors. It consists of 3 channels and represents the colors from combination of the Red, Green and Blue colors as in Figure 1 below.

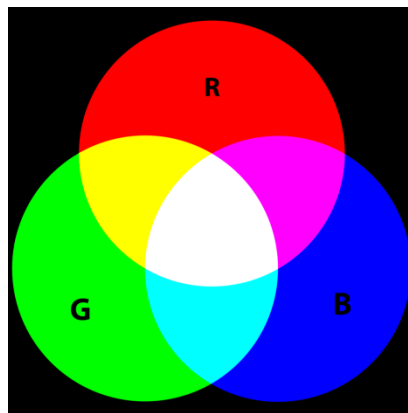


Figure 1 RGB color model component [13]

Usually each channel use 8 bits ($8 \times 3 = 24$ bit image) or may be reproduction of more color by using 16 or 24 bit per channel [4]. Each channel under 8 bit have integer value from 0 to 255, eventually 256 discrete levels of colors for each channel thus a range of $256 \times 256 \times 256 = 16.7$ million possible colors [4]. For instance light sky blue has an R value of 135, a G value of 206, and a B value of 250. The white color is produced when the intensity values of all components are 255, while the black color is produced when the intensity values of all components are 0 and if all components are equal result in the gray color. The RGB model shows the transition between cyan, magenta and yellow color by respectively the complement of the red, green and blue color.

1.1.2 Image processing techniques

In this part we will present a background of the techniques that is going to be used in this research problem.

1.1.2.1 Conversion to binary image

The conversion to the binary image is done from a grayscale image using a threshold value. The output of the binary image replaces all the pixels from the input image that are greater than the threshold with value 1 (displayed as white region) and replaces all the rest that below the threshold to value 0 (displayed as black region). The range of the threshold is between 0 to 1 [5]. If the input image in the color space, first it should be converted to a grayscale image and then converted the grayscale image to the binary image using a threshold for all the R , G and B channels.

1.1.2.2 Clustering

It is an approach for classification of objects in the images that organizes the relationship among the pixels of the data by differentiating them into groups or clusters [5]. The image that is used must be in the binary form which contains pixels values of 0 and 1. It is used to find the connected regions in the image whose pixel values belong to 1. It is done through scanning the entire image pixels that have only the value 1, to find the connected regions according to the selection of 4 or 8 connected neighbors as in Figure 2. By using 4 connected neighbors, it checks only the 4 main directions (up, down, right and left) around the current pixel and if there are pixels with 1 value in these positions, it will be underlying on the same connected region. Otherwise it starts another connected region as shown in Figure 3. While using 8 connected neighbors, it checks all the 8 directions (up, down, right, left and the four corners) around the current pixel and if there are pixels with 1 value in these positions, it will be underlying on the same connected region. Otherwise it starts another connected region and continues till scanning all the entire image pixels that have 1 value as shown in Figure 3. It labels all the connected regions and stores them in an array.

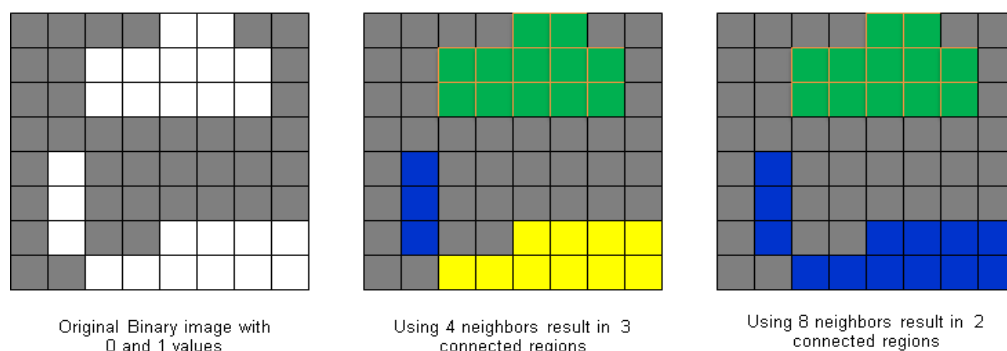
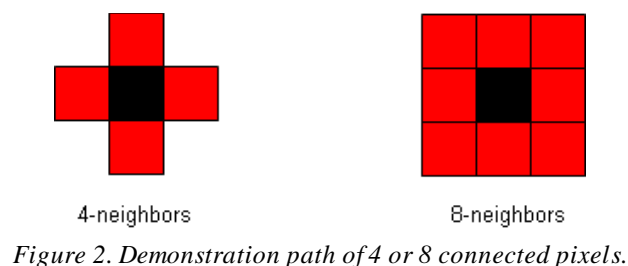


Figure 3. An example of a binary image and the connectivity result using 4 or 8 connected regions.

1.1.2.3 Object properties

We can get a set of different properties from the connected regions in the binary image such as; calculating the shape measurements with *Area* which is used on the connected regions to counts the number of pixels in the desired region. Also we can get statistics from pixels to retrieve value measurements with *PixelList*, which is used to specify the pixels coordinates in the region.

1.1.2.4 Sorting element

Sorting property is used on the connected regions to arrange the regions in ascending or descending order according to the need. For instance if matrix $A = \begin{bmatrix} 7 & 2 \\ 5 & 3 \end{bmatrix}$ and we sort A in descend order then the answer = $\begin{bmatrix} 2 & 3 \\ 5 & 7 \end{bmatrix}$.

1.1.2.5 Mean value

It is the average value of array of elements. The mean value is calculated by the sum of all elements value divided by the number of elements [5]. For instance if array $Z = [1\ 3\ 2\ ;\ 1\ 5\ 6\ ;\ 4\ 7\ 7\ ;\ 1\ 9\ 8]$ then the mean of $Z = [2\ 4\ 6\ 6]$.

1.1.3 A Literature Survey

In color extraction application, a combination of more than one technique is used, for instance color pixel classification, region growing, edge classification, object texture feature and clustering approach. The proposed research problem has been solved in the following list of papers in which they are sorted according to their techniques:

1.1.3.1 *The following papers are based on techniques based mainly on color pixel classification*

According to Saber *et al.* [12] used color pixels classification for sky region extraction by using a 2D Gaussian probability density function followed by image threshold which based on the analysis of image histogram cluster to decide if the pixels belong to the desired class or not. The major disadvantage of this type of algorithm is that it cannot differentiate between objects that have blue color in the image and the sky. Another algorithm presented by Vailaya and Jain [15] detected the texture features of the image in addition to color based extraction. The image is divided to $16 * 16$ sub blocks then texture, color and position features extracted from each sub block resulting in an accuracies of extraction over 94%. The algorithm still have crucial problem when dealing with another objects in the image with the same sky color. More recently, Saini and Chand [13] proposed algorithm for skin color classification to differentiate between skin and non skin pixels by switching color model. They used filters to have the binary image in RGB color model or HSV color model and switch between them if skin pixels not visible also applied morphological operations and median filter to enhance image processing. They differentiate between the tested regions if it belong skin pixel or not according to geometrical knowledge properties of the human face.

1.1.3.2 *There is another approach dealing with extraction of objects which is described in the next paragraph. This approach is based on a seed growing region*

Another algorithm proposed by Shih and Cheng [14] which able to extract automatically region growing using color classification and the technique comprised in the following four steps. First the color image will be converted into YCbCr color space. Secondly the region will be automatically selected by using three criteria; the

seed region pixel should be with high neighbor similarity, at least one seed must be produced in order to generate the selected region and disconnected the seeds for different regions. Thirdly as each region is presented by at least a seed so the color image segmented according to each region. Finally merging between small region with similar properties to overcome over classification and then the objects extraction is done. They tested the algorithm and the result was good compared to some existing algorithms. In our opinion the most advantage of this algorithm is the ability to extract all objects from the image. Lately, Han *et al.* [6] developed a technique which able to extract automatically objects of user first foci of attention (FOAs) which is around the center of the image. The technique comprised in the following four steps. Firstly, found the area of foci of attention according to edge information and visual attention. Secondly the seeding area extracted using a Markov random field (MRF) model. Thirdly the extracted area is enhanced using two post processes; a “close” operation, to fill the holes in the attention area then a “merging” operation to the neighboring area attention incase only if color distributions are sufficiently close to each other. Finally the attention object extracted or if the extraction was failed, the process starts again from first step for another object extraction. The technique was tested on 880 general images from the Corel Image Gallery and proved the effectiveness of the proposed model. The most crucial in their work that the technique extracts object as in the same manner to the human eye and also their no need to complete understanding of image content.

1.1.3.3 *There is a third solution method to this problem about sky extraction which based mainly on physics-motivated sky signature validation.*

According to Luo *et al.* [10] used color classification for sky region extraction combined with determination of the sky orientation in the image by using a physics-motivated sky signature validation to analyze the traces of the sky region. In which color classifier for the blue sky color was trained on different sky characteristic including 15 image of sky blue color, 15 images of sky gray color and 15 images of non sky using feed forward neural network with hidden layer of 2-3 neurons and single neuron in the output layer where result between 1 (for high likely sky for) and 0 (for non sky) followed by region extraction by using signature validation that satisfy the physics model for sky using 1D traces of color in the histogram and the result from histogram compared with sky models. They tested the algorithm on 1800 images with different quality and sky orientation resulting in a precision extraction rate of 98% and that is a good percentage. The algorithm built by using C++ code and takes few seconds for image processing under UNIX system.

1.1.3.4 *The below described paper used edge detection approach for region extraction.*

Another approach presented by Phung *et al.* [11] for face detection in color images using color and edge information by applying Bayesian model of the skin color to detect colored regions then the these regions refined by a region candidates that satisfy the human face homogeneity properties. They proposed that the main idea is to detect the boundary between the skin region and the background by using edge detectors and then removing the boundary pixels from the skin map.

1.1.3.5 *Also there are other techniques based on clustering approach for objects extraction which is described in the following paragraph.*

More recently, Hanmandlu *et al.* [7] presents color classification of natural images based on fuzzy co-clustering approach by simultaneous clustering of both object and feature memberships in which clustering in the color images gives better results since it carry more information than the gray scale images. The proposed method showed accurate color differencing compared with other classification methods as Mean-Shift,

NQJT, GMM, FCM. Since in this research problem dealing with color classification for one specific application which always has a sky for a background so this technique is not a good choice to follow.

1.2 Aims of the research

The aim of this research is to create an application for image processing which automatically detect sky regions in the images which contain big objects such as buildings, cars and others. We will show that such extraction can be beneficial for the future use of background extraction in more efficient way.

1.3 Research questions

In this thesis, we will concentrate on the following questions:

- Is it possible to create algorithm for automatic extraction of sky?
- Is it possible to develop application that automatically detect bluish region that don't belong to the sky but also bluish and can be excluded?
- Is it possible to define a sky as a part of background?

1.4 Problem delimitations

There are different kinds of blue objects in the tested images. For instance images can contain sky, road signs, cars and other objects. In this thesis, we will delimit ourselves to two cases where our algorithm is not able to successfully extract the sky region in a good way. Firstly, the images that contain sky region presented in gray tones without bluish color. Secondly, the images that contain sea regions especially a clear sea color beside the sky region.

2 Extraction of blue sky from images containing buildings

Experimental approach was used in our research thesis as first, we defined our problem about how to extract the blue sky region then, we formulated the proposed algorithm using image processing techniques and finally, we implemented the algorithm and tested under different type of sky images.

2.1 Data used in this research

The images that have been used in our research are provided by the research team and these images are taken privately with the same camera settings. The similarity of the images, that they all contain buildings and a quite big sky region as a background as in Figure 4 below.



Figure 4. A building with a sky region as a background.

We classify the dissimilarities among all the images into six types of classes: First type, the images contain other objects with blue color properties as road signs, cars or snow regions as in Figure 5 below. Second type, the images are captured with bad or high illumination conditions as in Figure 6 below. Third type, the sky region is presented in unusual position in the image as in Figure 7 below. Fourth type, the sky is presented in more than one area in which they are not connected to each other's as in Figure 8 below. Fifth type, the sky is presented in a grayish color as in Figure 9 below. Last type, the image contains a sea region beside the sky region as in Figure 10 below. Our aim in this research is to detect the background of buildings such as sky in our particular application and this will be solved in the following description.



Figure 5. First type of images.

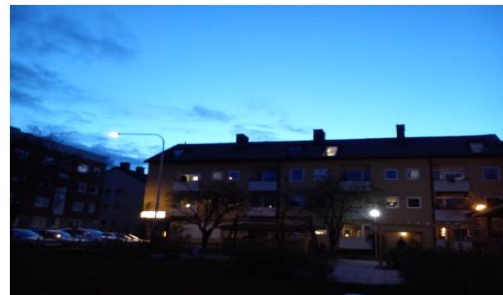


Figure 6. Second type of images.

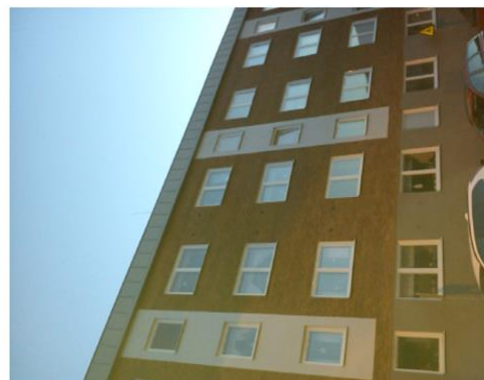


Figure 7. Third type of images.



Figure 8. Fourth type of images.



Figure 9. Fifth type of images.



Figure 10. Six type of images.

2.2 The Proposed Algorithm

As a first step, we check if the input image is in the RGB color space as in Figure 11 below. We are not interested in gray scale image in our research since we are working with color extraction. We used a check line in the code that really confirms that the images are in the RGB color space.



Figure 11. Color image with sky regions.

As a next step, we classify all objects that having a bluish color. This is done by creating an interval of color values in each of R , G and B channels that correspond to the blue color through scanning pixels value in all rows and columns of the R , G and B channels in the input images using a threshold for each channel that define the blue color in general respectively as follows 51 for R , 94 for G and 127 for B . This value is defined by visual examination on different types of sky regions images then we experiment this value and the algorithm showed a good result. We extract all the pixels that above defined range. After this step we have an image with all bluish features extracted and the rest is set to gray. The rest of image could be any color but we choose to set it to in a gray scale as in Figure 12 below.



Figure 12. Bluish color classification on the input image.

In the next step of the algorithm, we transform the bluish image to the binary image. This is done by creating a threshold value, which is 0.37. This value is defined by visual examination on different types of sky regions images then we experiment this value and the algorithm showed a good result. The result from this step will be a binary image of white regions with value 1 which have all bluish features that could belong to sky or other objects and black regions of value 0 to the rest of the image as in Figure 13 below.



Figure 13. Binary image of all objects having a bluish color presented in the white regions.

The following explanation concerns the processing of previous step, we extract all the connected regions that are related to the white regions in the binary image. We are interested only to the white regions that are belonging to the sky. We create a code to extract all the connected regions separately from the binary image through scanning the entire image pixels of 1 value and extracting the connected regions that follow the 8 connected neighbors. This is done by checking all the 8 directions (up, down, right, left and the four corners) around the current pixel and if there are pixels with value 1 in these positions, it will be underlying on the same connected region. Otherwise it starts another connected region and continues till scanning all the entire image pixels that have value 1. After this step we have data information that holding all the connected objects in an array.

As a next stage, we detect and define the biggest white region in the binary image. We use an assumption that the sky region is the biggest blue region in the image as an idea to get the sky regions since we are dealing with a sky image so after blue color classification, the biggest blue area will be the sky. For that purpose we need to sort the connected regions from the previous step in a descending order according to the biggest areas using a sorting method. The result of the sorting data is saved in an array where the biggest area is the first one and smallest area is the last one.

In the following step, we extract the main biggest bluish region from the color image. We will use it as a reference to compare other bluish smaller objects in the image. This is done by multiplying the biggest white region which has a 1 as pixel value from the binary image with the bluish image that contain only the bluish color. After this step, we will have the biggest bluish region from the image that it is belong to the sky.

As a following step, we develop a sky color reference from the biggest bluish region. This is done by creating a color mean value for each R , G and B channels of the biggest bluish region by using a mean value method. The result from this step will be the values of the sky color reference, in which these values are different according to each image.

Finally in the last step, we extract all the regions that are belonging to the sky and exclude other regions that are not belonging to the sky. We use the sky color reference mean value of each channels of the biggest bluish region and compare it with the other smaller regions mean value using a \pm variation interval since in general the sky is presented with little blue color variation and check if these other regions are belonging to the sky or not. This is done in a loop by scanning through all other smaller regions and comparing each one of them with the predefined reference of the mean value. This step is very important since sometimes the sky is divided into smaller regions by trees, buildings or other obstruction objects so we need to extract them and merge them to the main biggest sky region. In that way we exclude all the others smaller regions that may be having the same sky properties but they are not belonging to the sky. The result image is now containing only the regions that are belonging to the sky as shown in Figure 14 below only the sky regions is now extracted. We have been tested this approach on all of our images and in general we have extracted sky region in all of those tested images.



Figure 14. All sky regions.

3 Results

The evaluation of the resulting images is done visually, since the goal is to judge how well the obvious sky areas are extracted. That is why there is no need to present statistics in this case. The evaluation is done by testing 150 images; we found that the algorithm was successful in 94%. For the 6% that the algorithm was not successful the images contain sky of gray color or sea region. We have different types of images that have a sky as a background and the result of them will be explained below.

3.1 First type of images

In this type the images contain other objects that have the same sky color properties. As in Figure 15(a), the image contains two blue cars, a road parking sign and others smaller objects having the same sky color properties. You can clearly see that there are some objects have been detected with the sky after the bluish color classification as two cars, parking sign, windows, a balcony and some dots on the street as in Figure 15(b). in which these objects has been excluded after the image is completely processed to the whole algorithm and only the sky regions is extracted as Figure 15(c). While in Figure 15(d), the image contains snow regions with other objects as windows. After bluish color classification, snow region have been detected with the sky as in Figure 15(e). The result to this image was clearly satisfactory, as our algorithm extracts only the sky region and excludes the whole snow region and other objects as in Figure 15(f).



Figure 15. Result of first type of images.

3.2 Second type of images

In this type, the images are taken in high and bad illumination conditions. As in Figure 16(a), the image has been captured directly to sun light with high illumination. You can clearly see that there are some reflected blue light and other objects has been detected with the sky after bluish color classification as in Figure 16(b). The result in Figure 16(c) was satisfactory and showing the ability of our algorithm to extract the sky in high illumination. While in Figure 16(d), the image has been captured in bad illumination after the sunset. In Figure 16(e), there are still little small object has been detected with the sky after the bluish color classification. In Figure 16(f), the algorithm shows a good result for extraction of sky region in bad illumination image.

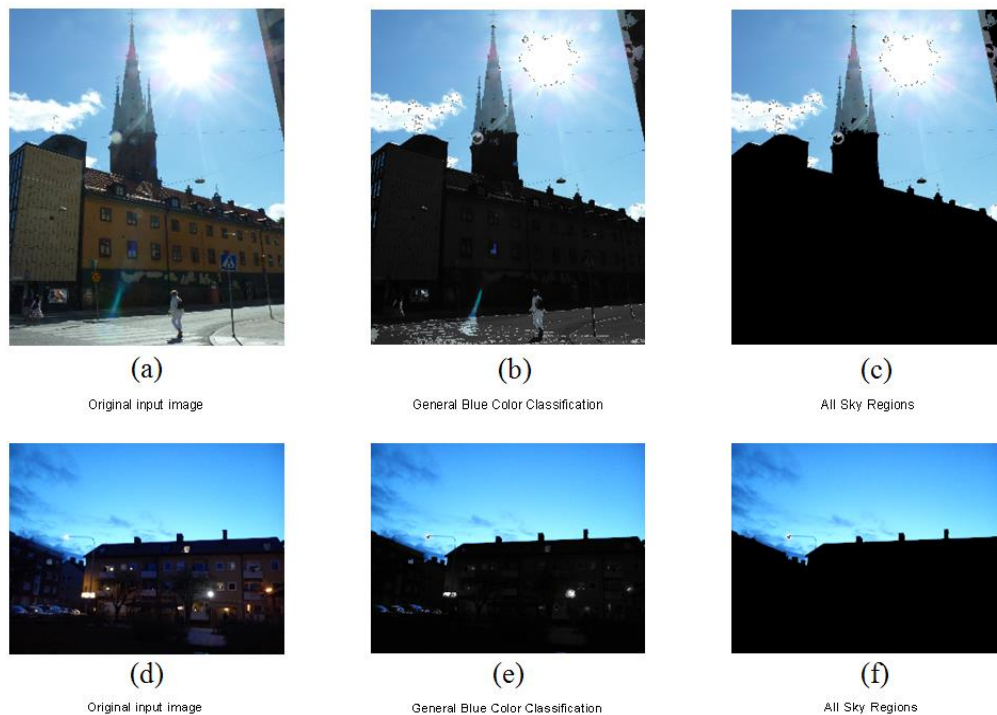


Figure 16. Result of second type of images.

3.3 Third type of images

In this type, the sky is presented in unusual position in the images for instance in the left side as shown in Figure 17(a), (d). After bluish color classification, some little objects still have been detected as shown in Figure 17(b), (e). While after the last step of our algorithm only the sky is extracted as shown in Figure 17(c), (f).

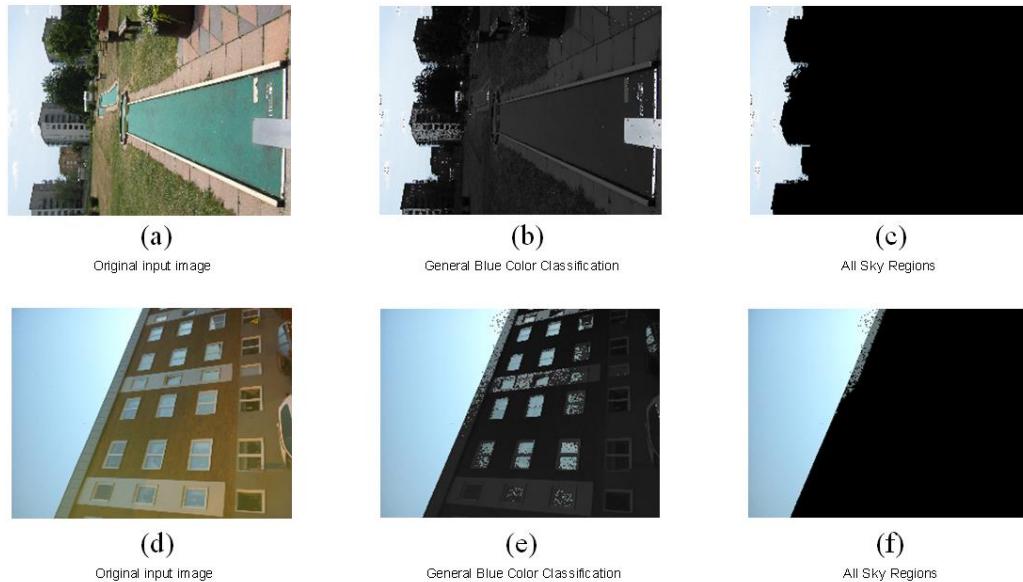


Figure 17. Result of third type of images.

3.4 Fourth type of images

In this type, the image contain an obstruction object as building that it splits up the sky region into two parts, a smaller and bigger parts in which they are not connected to each other and acts as a different objects as in Figure 18(a). After bluish color classification both areas are now detected with other small objects as shown in as in Figure 18(b). The final result shows the efficiency of our algorithm to detect all these areas that are belong to sky and extract all of them as shown in Figure 18(c).



Figure 18. Result of fourth type of images.

3.5 Fifth type of images

The images in this type contain sky regions presented in a gray color with very little bluish color as shown in Figure 19(a). After bluish color classification, the algorithm detect the parts that belong to some bluishness as in Figure 19(b). The result shows that the algorithm is not able to detect the whole sky region but it just extract only some parts in the sky region that belong to bluishness color as shown in Figure 19(c).

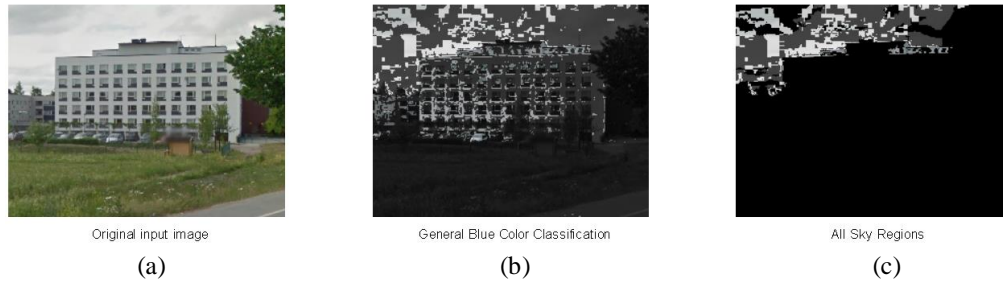


Figure 19. Result of fifth type of images.

3.6 Six type of images

In this type the images contain a sea region as shown in Figure 20(a), (d). After bluish color classification both the sea and the sky have been detected as shown in Figure 20(b), (e). Unfortunately after the last step from the proposed algorithm, it was not able to extract only the sky region. In some image the algorithm extracts only the sky region as in Figure 20(c) while in other images it extracts both the sky and the sea regions as in Figure 20(f). That is due to the similarity of sea pixel values to sky pixel values.



Figure 20. Result of six type of images.

4 Discussion

Our algorithm is working well with images that contain at least some bluish color of sky. The most advantage in this algorithm how it can deal with the type of images that contain snow regions, in those cases the algorithm shows a very good result and this can take part in industrial proposes for this kind of application especially in countries that have a cold and snowy weather. We was satisfied from that result as it was not expected from beginning but after fixing the whole algorithm in a proper way and especially after the last step of comparing the mean value of all the objects to the biggest one the result was very good. We can see as in Figure 15(e) that if we didn't use this step the result will be very bad especially in that type of image since snow region usually occupy a big area in the image and need to be fixed. Another type of images that the algorithm shows a good result with it is the type of image that contains different objects having almost the same sky properties as shown in Figure 15(c). The

algorithm showed a good result and proved the ability to handle this kind of situations that may be present in the sky image. Also the algorithm showed a satisfactory result to rest of all other types of images which have a blue sky as background and that was expected for this kind of application.

There are mainly two types of images that our algorithm is not able to successfully extract the sky regions. Firstly, the algorithm is not able to detect the whole sky region with images that are partially grayish or miss of bluish as shown in Figure 19(c). This kind of problem can be fixed by using a combination of other image techniques but it requires more time consuming approach and thus we could not fix it in thesis. Secondly, although we are using a very little range of blue color mean values as a reference in the last step, the algorithm fail to generate a good result for images that contain a sea region because the sea region has in general the same sky color properties and it is difficult to extract the sky region based only on the color classification. In this situation, the extraction will succeed with some images that have a dark sea color as shown in Figure 20(c) and will not succeed with images that have a clear sea color Figure 20(f). This problem can be improved in the future work by classifying the sky region according to the position in the image.

The performance of the algorithm was good according to the results. In which some parts in the code are very good and others need improvement respectively as follows. The last part in the code about the extraction of all sky regions should remain unchanged as it is key point in our algorithm. However the parts in the code about how to define the connected regions need to be modified. The result will be better by detecting only the regions that belong to the upper part of the image and exclude all other regions that do not belong to the upper part in the image and hence the algorithm will be able to handle images containing sea region. However it is quite unlikely to have building in the sea and the main goal of this application is to extract sky regions in images containing buildings. So this will be a good to fix it for general purpose but for our general purpose, this algorithm can be used to extract sky region in most of the images that containing buildings.

In this stage, this algorithm is already working very well and no matter what images we are dealing with as long as it contain sky regions, these regions should be extracted by our algorithm.

5 Conclusion

Color acts as an important factor in human visual perception. Many approaches use color classification to obtain the desired homogeneous regions. In this paper and according to our research questions; firstly, we have been developed an algorithm for automatic extraction of sky region using image processing techniques. Secondly, we clearly show in the result part that our application is able to detect all the bluish regions and extract only the sky region. Finally, our application is able is define the sky as a background by detecting the biggest area in the image since our assumption about this research that we are dealing with images that contain a quite big area of sky.

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