With shadow elimination towards effective foreground extraction

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Abstract—very important process in the area - image processing, is the task of foreground extraction. To learn a computer to distinguish between foreground objects and background scene is non-trivial. Further, if foreground is extracted, a question can be set: is the foreground credible? What if significant part of detected foreground is unimportant information? Shadow is in most cases as noise considered. Our goal is to analyze possibilities shadow elimination and next to provide improved inputs of detected foreground for more efficient traffic surveillance system.

Keywords – surveillance system, shadow elimination, umbra, penumbra, foreground, background subtraction

I. INTRODUCTION

Image processing tasks are in progress in recent years. Application can be used in surveillance, secure, recognition system etc. Common problem in those areas is designing an efficient foreground extraction algorithm. In this paper we perform experiments with method for shadow noise reduction, which could improve efficiency of foreground extraction process in later image processing phases. A general aimed shadow finding and elimination method is proposed.

There are many reasons of finding and elimination of shadows in images and also many methods exist. Approaches differ in used algorithms, ability to work in real time, noise and illumination changes resistance or in efficiency aspect. Some of them are useful just in indoors, the others require strong light source where umbra is strong, better ones can cope also with penumbra (see Figure 1). Some methods require specific background (textures), others try to be more-less generally used. Differences can be found also in approaches used just in single frames or video sequences. All those aspects have to be considered and suitable model has to be chosen. Our goal is to provide a general aimed method.

Many methods working with video sequences are using a reference image as background model. For example first frame is taken, where foreground objects are not visible and then any next frame is compared to this first reference frame. It is clear that such approach is not too robust for noise or when strong illumination changes occur. Therefore different methods for background modeling are designed, where background is learnt sequentially. To be able work in real time a simple method was chosen. It is based on background subtraction with weighted learning [1]:

\[ r_{ft} = (1 - \alpha). r_{ft-1} - \alpha. f_t \]  

\( \alpha \) – is learning constant; \( r_{ft} \) – is reference image in time t; \( f_t \) – is image in time t.

It is also important to consider the static shadows. They are not intended to be removed, because they are not part of foreground, but they have properties as other foreground shadows so some color based method do not have to work properly. The static shadows are not considered because of using foreground extraction. In next section an overview of existing methods is summarized. In third section our method is presented and next section outlines some experimental results. The 5th section concludes this paper and some feature steps are discussed.

Figure 1. cast shadow can create umbra and penumbra.

We are designing system for traffic surveillance; therefore our method should meet in next text listed requirements, or get close to them. For more details see [1]:

- Must be resistant against noise, light changes etc.
- Must be as universal as possible (methods used in various outdoor systems).

Video sequences will be used as inputs for our method. Shadows are found and eliminated due next main reasons:

- Shadows deform a true shape of objects, when considering shadows as part of foreground. Then object recognition or classification is more difficult.
- Shadows cause objects linking into one.

The goal of this paper is to analyze possibility of shadows finding and elimination to propose improved foreground extraction process in different outdoor surveillance tasks.
II. AN OVERVIEW

A shadow finding and eliminating methods could be separated into different groups according their properties. In [2] authors recognize statistical and deterministic methods.

A. Statistical methods

A probability function is used for decision making for different membership groups (is shadow or not). These methods could be further separated into parametrical or non-parametrical.

B. Deterministic methods

Some shadow properties are used when deciding about group membership. Further, they can be branched into model or non model approaches. Model methods require more acknowledge about environment (e.g. type and direction of light) and they are computationally more demanding. But model methods provide generally better results. Strong disadvantage is their not universal character – for different environments a new model must be set. Non-model methods stand opposite the model ones. The non-model methods can assume some conditions:

- The light source is strong.
- The light is not point source.
- The camera position is always the same; background is static and has the same texture.
- The surface is flat.

When some assumption is set then a condition can be supposed:

- If a) is true then illumination changes of moving shadow are significant.
- If b) is not true then there could be a penumbra.
- If c) is true, then shadows have the same texture as background, it can be distinguishable from object.
- If d) is true then also light changes caused by shadow are flat.

Other conditions can be found if necessary. Before an overview of some methods is presented, a workflow of all processes needed for efficient shadow processing is shown (see Figure 2).

![Figure 2. A general workflow for shadow processing.](image)

Preprocessing – resizing, noise reduction, color transformation, contour extraction, etc. are the most common operations.

Processing – Pixels or groups of pixels are labeled with class (pixel of umbra, penumbra, background or object). It is simpler to detect umbra than penumbra. In this phase more steps could be implemented (an iterated election of shadow candidates).

Shadow elimination – if a shadow candidate is found, it could be:

- Eliminated from region of interest (object of interest).
- Substituted with background.

In [3], [4] a simple method based on edge features is presented. In [5] authors present non parametric, statistical method which maps each pixel of input frame into four groups: background, shadow or dark background, lighter background and object. The background model is computed from N first frames. Each background pixel is modeled with four parameters (mean, variance, movement of dispersion brightness and color). Previous methods used just single shadow property (edges and some color attributes). If object has the same texture or color of background, results are not satisfactory. In [6] a combination can be found, where a shadow is market just when it has the same color and texture as background. Other approaches can be found in [7], [8], [9]...In [7] a shadow elimination in traffic system is presented. This method provides real time computation and it uses property e.g., that shadow is linked with his parent object. There is also presented model, where time information during day is exploit. In [8] is used information, that shadow does not change surface color, just decrease brightness. This method uses the YUV color scheme. In [10] a normalized RGB color scheme is used. Properties those are used: the shadow decrease values of RGB, the shadow does not change values in normalized RGB, with the change of material, the RGB values also change. In [8] is modified [10] about shadow tracking. Although the shadows segmentation and elimination problem has been increasingly studied during last time period, there is no a method, that could be generally accepted. In next section our model is discussed.

III. PROPOSED METHOD

In our model casted shadows are eliminated. Static and self shadows are not considered. An algorithm for the separation of video objects and their shadows is based on color information and next spatial verification is proposed. Our method is similar to the one used in [10]. For shadow detection information in RGB and normalized RGB is used. In our work we avoid shadow tracking part, because we suppose, that this part is not so informative compared to its computational costs. This tracking part is replaced with improved spatial analysis, where additional conditions are laid on shadows region. A shadow is connected with an object with less part of its perimeter than any other object. Also there are set limits for the size of shadows and objects.

The processing phase consists of two main steps (see Figure 3):

- Color analysis.
- Spatial analysis.
A. Preprocessing

Background model is maintained as mentioned in introduction. It should be able to learn small changes in environment, but this should be improved later (see Figure 4). Gauss filter is used to decrease a noise effect. Foreground and background model are transformed into normalized RGB for further processing. The normalized RGB is used for discounting local illumination variations. On the Figure 4 are shown foreground objects, those were detected. Shadows are also considered as part of foreground.

B. Color analysis

For efficient shadows finding pixels with low values are skipped, where according [10] these values are not usually shadows. The color analysis works with single pixels, areas are not considered. Extracted mask, after color analysis, contains pixels, where also part of foreground objects is taken (see Figure 5). The shape of objects is not considered at all. The color analysis is based on these assumptions:

- The order of RGB color components in the shadow and background is the not changed.
- When shadows occur, each color component of foreground pixels has lower value then the background ones (they are darker) and the photometric (normalized RGB) values do not change.

To improve result spatial analysis is processed.

C. Spatial analysis

This part finds shadow areas by eliminating foreground parts considering spatial properties. This stage is region based. Contours are extracted from detected foreground. An empirical assumption can be made:

- A candidate region belonging with its whole area into foreground is eliminated – this eliminates “stand alone” shadows.
shadow is not connected with object – then the proportion is equal to 0. Problem occurs when a shadow of one object is connected to other object or shadow. In this phase are eliminated also small shadows, but this depends on the size of tracked objects, this parameter can be estimated automatically. An example of spatial analysis can be seen at the Figure 6.

D. Shadow elimination

The way of shadow elimination depends on system deployment. As was described in section 2 shadows could be deleted from image or just skipped from area of interest. When shadows cause e.g. improper object bordering, the shadow elimination lays just in resizing region – subtracting the shadow area. In our method we deleted shadows. The pixels in shadow area were replaced with background pixels at the same position (see Figures 7,8).

IV. EXPERIMENTS

The goal of experiments was to verify our method for shadow finding and elimination. If shadow is deleted in an efficient way, more proper object shape is obtained and classification process of foreground objects is executed with less noise. On the other side the whole process has its own computational cost. In next experiments some results are shown. It is difficult to provide comparative study with other similar methods, because non effective evaluation technique exists, that can adequate evaluate quality of found shadows. Some shadows were detected very well (almost 100% of the area), some were detected partly, detected with an object or the worst case - detected just as part of foreground object (see Figures 6,7).

Figure 6. Spatial analysis. Regions are chosen detected as shadows in spatial analysis.

Figure 7. An example of shadow detection and elimination with satisfactory results. First row: original frame. Second row detected pixels after color analysis, original image with eliminated shadows after color analysis. Third row: found shadow regions after spatial analysis, original images after spatial shadow elimination.

Figure 8. An example of shadow detection and elimination with not satisfactory results. First row: original frame. Second row detected pixels after color analysis, original image with eliminated shadows after color analysis. Third row: found shadow regions after spatial analysis, original images after spatial shadow elimination.
All experiments have been executed with videos used in [10] at the PCs with configuration: AMD Sempron 1.61 GHz, 512 MB RAM, Win XP; Intel Pentium 2,2 GHz, 3GB RAM, Win 7 and Intel Core 2 Duo 2,00 GHz 64 bits, 4GB RAM, Win 7. Computational time can be considered as able to work in real time. The number of frames processed per second moved from 7 up to 18 frames/s depending on configuration, when the size of frames was around 320x240 pixels.

For better imagination an estimation of elimination results was done. Average positive shadow elimination was done with efficiency around 46%. Indoor and outdoor videos were used with the same initially set parameters. For videos with outdoor scene better results were achieved, they moved around 65% of positive shadow elimination. Measurements were done by counting all shadows in the sequence and positives. For positive shadow elimination we considered (see Figure 7):

- When shadows were eliminated properly as a whole.
- When shadow was eliminated partly (most of it).
- When shadows were eliminated with small part of an object (not significant part of object).

It is important to mention also false positives, when some parts of foreground objects were considered as shadows. In outdoor conditions an average rate of false positive was around 50% compared to positive cases. A lot of objects were discarded, when shadow was eliminated (see Figure 8).

CONCLUSION

The task of shadow elimination is challenging. Our model combined color with spatial properties for efficient shadow finding. For accessible input data satisfactory results were obtained. Most false positives occurred when objects on video sequences were too small and with the same color as umbra (strong umbra). These were discarded very often, because they were considered as shadows. When the object was small, the background and its texture does not play role. Some failures occur also in foreground detection system. If the umbra (penumbra was weak), it was not detected by background subtraction model. Despite not high final result score of the shadow elimination process, a valuable experiments and conclusion has been introduced, those can be used in further research.

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REFERENCES