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Shadow Detection, Methods and its Evaluation

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***Abstract* - Tracking is one of the main activities of applications like navigation, surveillances, traffic control etc. The success of these applications depends on how successfully tracking services are implemented.**

Tracking is affected by number of factors like visibility, environmental conditions, motion of objects, nearby similar type of objects and their shadows. The target objects shadows being closely related to the target is tapped as the most important factor to be detected and eliminated.

Shadow detection for it elimination started as a pre processing step in tracking but looking at the advantages and its importance, it has now become a independent field of research having its own taxonomy as shadow detection techniques which maps I its own different methods .These methods are further evaluated by different measurable evaluation metrics.

This paper aims to target shadow detection methods in its taxonomy framework. It further selects statistical parameters based techniques as the most appropriate and discusses its various methods based on the properties like intensity, colour, geometry and texture.

This paper concludes with a analysis of various techniques at a measurable level using evaluation metric.

***Keywords* - Tracking, Foreground, Background, Subtraction.**

I. Introduction

Tracking is a process by which a moving objects like car, airplane, ship etc is identified and its route is mapped on the screen by detecting its image as the object of interest. Shadows are integral part of a image. They can be detected and classified as shadow and non shadow regions when seen by eyes. When a image is detected by the computer there are problems in its detection like region forming, region defining, knowledge expression etc. [1][9] The effect of shadow regions on object are reduction of light intensity, shadow being the dark region of the image, gray variance of shadow region being smaller.[1][3][9]

All these effects can be considered as parameters and can be used to detect the shadow regions either independently or in combination. This results in the development of taxonomy which maps the shadow detection techniques as SP(Statistical Parametric), SNP (Statistical Non Parametric), DNM(Deterministic Non Model Based) and DM (Deterministic Model Based)[2][8]

The one which is exploited is statistical parametric technique because of its measurability, count ability and generalization. The statistical technique of shadow detection can be further implemented by using methods for parameters like edges, colour, intensity and texture [8][5].

Section II classifies the shadow detection algorithms into four classes which is called as its taxonomy. Of the four classes SP, SNP, DMB and DM the most appropriate for shadow detection is SP i.e. statistical parametric

Section III taps the four main parameters which are prominently used in shadow detection. The subsection further elaborated the design conditions used in each of these methods.

Section IV suggest the evaluation metrics to be used followed by a comparative analysis in section V of all the four techniques of the shadow detection taxonomy.

II. Taxonomy of Shadow Detection

Shadow detection algorithms are associated with techniques which are grouped into four classes. Each class is selected as per the requirements of its applications and the parameters exhibited. The formation of these for classes leads to the formation of shadow detection taxonomy. The taxonomy is defined in form of layers.

Layer one tells whether the decision process has deterministic (D) or statistical(S) approach.

Layer two further subdivides the statistical approach as parametric (SP) or non parametric (SNP) where as the deterministic approach as model based (DMB) or non model based (DNMB).

The DM uses ON/OFF decision process supporting model based knowledge. This gives best results, but to form the model is complex and time consuming. As the model depends on the prior information and environment changes any variation in this respect makes the model invalid.[2][8]

This approach cannot be generalized as it can be used for specific environmental conditions.

DNM is the deterministic approach which is not model based and the output and input parameters are mapped close to human perception of colours. This gives more accuracy in shadow detection.

Form all the colour models, HSV colour model closely maps to human perception. The parametric changes observable are only in V (Intensity value) where as H (Hue) and S (Saturation level) are invariant to colour i.e. they show very less change between non shadow to shadow regions[5][4].

The first approach, which deals with umbra region is called as DNM, Where as the next approach which is more complete and deals with penumbra is called as DNM2. It accounts for, dark uniform region of shadows, relationship between actual value and reference value of pixels in presence of cast shadow and luminance differences.

SNP, the statistics of shadow and non shadow are generated without considering any parameters, so it may depends on colour consistency ability of human eye taking the light model for the relationship between irradiance and reflectance and exploiting distortion between chrominance and brightness.

SP, the statistical information based on parameters is collected to form shadow and non shadow. The region can be grown or segmented or edge detected. For this horizontal or vertical scanning can be used [2] or between pixel and within pixel invariant [7].

It is important to recognize the type of features shown by images so as to select the required parameters for shadow detection.

These features are mapped in three domains, spectral, where the features can have parameters like Intensity, Hue, and Saturation Level in colour or gray images.

Spatial, these features are grouped from pixel level to region level and from region to frame level.

Temporal features are used to integrate and improve the results.

III. Statistical Parametric Technique

The various parameters which can be obtained statistically are colour information, intensity information, edge information and texture information. Each set of information is now tapped with a different set of methods .these methods depend on various conditions which are discussed within.

III.1) *INTENSITY BASED METHODS*

The brightness level of a pixel can be represented as intensity for objects or background. It is high intensity and for shadows and dark objects it is low intensities. Intensity level of the pixel being a function of light is represented as:-

$I=F(S)$…………………………………1

Case1: This function F(S) can be modeled from the light model as

$I=E(x\ y)\ \rho\ (x\ y)$……………………….2

ρ (x y): reflectance of the object; E(x y): irradiance or illumination of the object

$E(x\ y) = Ca + Cp\ angle\ (N(x\ y), L)$… .3

This is the irradiance value for illumination i.e. object, and

$E(x\ y) = Ca$……………………… … 4

This is the irradiance for shadow, where

Ca: intensity of ambient light; Cp: intensity of light source; N(x y): object surface normal; L: direction of light source [1][10]

The model can be also used for detecting vague shadows. Vague shadow do not have clear boundaries and their intensities also change gradually .This retinex problem is solved by separating the illumination component from reflectance.

$S=R.L.$…………………………………...5

S: reflectance of image pixel; L: illumination of image pixel; S: intensity of the image.

$s=\log S;\ r = \log R\ ;\ l=\log L$…………… 6

$s= r + l$ ……………………………….….7 (from 6 and 5)

l represents smooth changes and r represents sharp details, so by passing this from high pass filter reflectance image is obtained[6].

Case 2: The function is now modeled using various components of light.

There are two types of light sources, direct and ambient. Similarly environmental light is from reflection of surrounding light and direct light comes from the source. The intensities of these light components are related as

$Ii = (Ti \cos \Phi\ Ld + Le)\ Ri$ ………………....5

Where Ti=1 for sunshine region and Ti=0 for shadow region

II: value of the ith pixel; Ti: attenuation factor of direct light; Ld: intensity of direct light; Le: intensity of environmental light; Ri: surface reflectance of the pixel; Φ: angle between the direct lighting direction and surface normal [1][6]

Case 3: Smooth change in intensities at the boundaries of shadow and non shadow regions.

Matting function is used with energy function

$Ii=Ki\ (Ld\ Ri + Le\ Ri) + (1-Ki)\ Le\ Ri$……………..6

Where $Ki=Ti\cos \Phi i$

III.2) *COLOR BASED METHODS*

Colour is one of the important components of any scene/image. At pixel level there are different methods of representing the colour which gives different results for shadow detection. These methods are colour model based and colour invariance property based[2]

Colour model based uses the basic colour model, RGB. It detects gray value distance and colour distance. It can detect shadow under vehicle object but cannot detect their boundaries.

The pixel can be modeled in RGB space as

$Id[\ i\ ][\ j\ ] =F\ (R[\ i\ ][\ j\ ],G[\ i\ ][\ j\ ],B[\ i\ ][\ j\ ])$

Function F can be maxima, modulus, compare etc.

RGB method works properly for indoor images as light conditions are stable. In case of outdoor scenes where light sources may consist of direct sunlight, diffuse light scattered by the sky and other coloured light from nearby surfaces, as all these light sources may have different spectral power distribution, RGB value of shadow pixels may not attenuate linearly.[5][6]

HSV colour space approaches the human perception model. It reflects the brightness information directly so it can qualify the difference between the shadow and vehicle better then RGB colour space.

HSV stands for Hue, Saturation level and value (intensity).

$M=\max(R, G, B)$

M=maximum component value of R, G, B.

V = M this is the largest component of colour

As the change in H and S component is significantly less, V component is mainly used for shadow detection.

The limitation of this model is it cannot detect very low intensity pixels i.e. it cannot detect very dark objects. For this c1c2c3 colour model is selected [4]

S2(x y) = 1 for shadow and S2(x y) = 0 for non shadow pixel.

$S2(x\ y) = (MOD\ Pr(x\ y) – Ur < 1.5\ \sigma\ r,\ MOD\ Pg(x\ y) – Ug < 1.5\ \sigma\ g,\ MOD\ Pb\ (x\ y) – Ub < 1.5\ \sigma\ b,)$ [4]

III.3) *EDGE BASED METHODS*

Edge based methods for shadow detection can be used as it helps to compare the object shape and the shadow shape. If the object is not clear then form its shadow edge we can get the shape of the object. It also gives us the idea of the ground level of the object.

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The object edge map and the shadow edge map can be differentiated by the concept that objects have internal edges but shadow map do not.

In case of multiple object scenes, various edge maps are obtained for multiple objects and its shadows. These edge maps are merged to form the shadow and object regions. This can be done by comparing neighboring pixels. The common boundaries have to be first regrown so as to from sub regions which are later merged.

Edge based methods are not independent methods but are used as sub methods for region forming and segmentation

III.4) *TEXTURE BASED METHODS*

The basic idea to identify shadows from objects on the basis of its texture is that the shadow has a smooth texture where as the object has varying or rough texture. Shadows exhibits smooth textures because internal boundaries are not defined in it. [1]

Texture methods cannot be used in isolation as it requires edge detection of shadows and non shadow regions in multiple shadows in a image. Neighboring pixels are compared by using 8 or 4 neighborhood to grow the region. [1][2]

After the texture based regions are developed, texture histogram can be used for bases of comparison and region merging. [3]

The texture as a property for shadow detection cannot be relied completely as the change in texture is very less. In case of photometric certain colours models are texture invariant [3]

IV. Evaluation of Shadows

Two qualities of measures are defined, Good Detection and Good Discrimination. Good Detection specifies the low probability of miss classifying a shadow point [2] [8] where as Good Discrimination specifies the low probability of classifying non shadow points as shadows. It is also called as low false alarm rate [2] [8]

These quantities of measures are evaluated by using evaluation metrics, quantitative and qualitative [8]

The two quantitative measurable evaluation metrics defined are Detection Rate (DR) and False Alarm rate (FAR) where

$$DR = TP/(TP+FN) \ldots\ldots 1$$

$$FAR = FP/(TP + FP) \ldots\ldots 2$$

Where FAR =1- ρ where ρ is the precision. [4][8]

FN (False Negative): shadow points classified as background / foreground; FP (False Positive); TP (True Points) shadow points correctly identified [4][8]

As this being applied only to moving objects, this evaluation is generalized and modified evaluation metric of DR and FAR i.e., ή as Shadow Detection Rate and ξ as Shadow Discrimination Rate where

$$ή = TPs/(TPs + FNs) \ldots\ldots 3$$

$$\xi = TPf/(TPf + FNf) \ldots\ldots 4$$

S: Shadow; f: Foreground; TPf: Number of Ground Truth points of the foreground object minus the number of points detected as shadow but belonging to fore ground objects[2]

Along with this the qualitative metrics which can be attached to shadow detection are robustness to noise, flexibility to shadows strength, width and shape of shadow, object dependence, scene independence, computational load, detection of indirect cast shadows[8]

V. Analysis

Techniques	ή (%)	ξ (%)
SNP	L	L
SP	H	H
DM	M	L
DNM1	M	M
DNM2	H	H

H: High; L: Low; M: Medium

VI. Conclusion

Real time applications have different types of objects with different light conditions and parametric variations .The shadow available is of varying type within a single scene. Thus a single method is not able to satisfy the requirements of detecting different shadows.

This suggests the development of algorithms with combination of different methods where selection of methods depends on the parameters which are more prominent in that particular scene.

VII. Future Scope

The future scope with the backbone of this work done is to have algorithms for detecting different types of shadows with minimal number of dependent parameters with also reduction in number of steps in the algorithm.

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