Making Shadows Visible: A Hybrid Methodology for Restituting Shadows from Natural Scenes

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ABSTRACT
This paper presents a framework for efficient shadow –free image reconstruction from casually captured images. This research focuses the shadow restitution methodology from images and videos, to improve the scene visibility and understandability. The proposed hybrid technique combines the physical, geometric, textural, spatial and photometric features for shadow detection. Using feature importance statistics the appropriate criteria is chosen and applied. The experiments over wide benchmark dataset prove that the proposed hybrid technique outperforms peer research proposals with the expense of computational cost and time.

Keywords
Shadow removal, Shadow detection, Shadow reconstruction, De-Shadowing, Shadow Enhancement, Hybrid Technique, Texture, Gradient, Chromaticity, Shadow Enhancement, Image Reconstruction.

1. INTRODUCTION
In the golden era of digital world, one of the interesting, rapidly developing and proven to be more attractive than many competing technologies, is Computer Vision and Artificial Intelligence. The potentially useful vision / graphics task in computing machinery is to perceive the information from the surroundings [1]. Humans see a world full of objects that interact with each other and with themselves. Human vision is a wonderfully complex system that analyzes the world, and under normal circumstances, it is able to make sense of it. Though, human vision has evolved over millions of years, there is no particular advantage in evolution giving any indication of the difficulties of the task perception. When humans are asked to describe a picture, they generally give a list of objects within the picture as well as their shape of each object, its distance to the observer, its material, lighting, color, motion, and texture [2].

Images (scenes) are the input to the visual system, providing a constant stream of information about the world surrounding us. One of the most fundamental tasks for any visual system is that of separating the changes in an image which is due to a change in the underlying imaged surfaces from changes which are due to the effects of the scene illumination [3]. The problems caused by the effects of illumination include shading, inter-reflections from multiple surfaces, mirrored surfaces that show objects not present in the scene, and lastly shadows. Shadows are often one of the largest problems and have become a topic worthy of much research. Such processes largely rely on similarities within natural scenes, whether natural is taken to mean scenes with no manmade structures, or natural in the more general sense of scenes that exist in the real world [2]. These similarities are indeed striking at once images are analyzed with suitable tools. The area of natural image statistics provides a set of criteria for quantitatively analyzing natural scenes and the regularities that appear among them. Shadows in images are typically affected by several phenomena in the scene, such as lighting conditions, type and behavior of shadowed surfaces, occluding objects etc [4]. Additionally, shadow regions may undergo post-acquisition image transformations, e.g., image contrast enhancement, which may introduce noticeable artifacts in the shadow-free images.

Shadows are crucial for enhancing realism and provide important visual cues. This can be beneficial for the purposes like revealing information about the object's shape, orientation, size, position, intensity, physical characteristics of the screen and even about the light source, type and behavior of shadowed surfaces. Often spurred but the tremendous increase of computational power and capabilities of graphics hardware, much progress has been made concerning visual quality and speed by making high-quality real-time shadow free images a reachable goal [5]. But with the growing wealth of available choices, it is particularly difficult to pick the right solution and assess shortcomings. Because, currently, there is no ultimate approach available, algorithms should be selected in accordance to the context in which shadows are produced.

Despite many attempts, the problem remains largely unsolved and this is due to several inherent challenges [6]. Dark regions are not necessarily shadow regions, since foreground object or background can be dark too. A commonly used assumption is that shadow falls only on ground plane, but it is not valid for all the general cases. The possibilities range across a wide spectrum from very approximate but really efficient and accurate, methodology for shadow interpretations [7]. This research tries to serve as a guide to better understand limitations and failure cases, advantages and disadvantages and suitability of the shadow rectification algorithms for any kind of application scenarios. At the same time, a large set of algorithms within the areas of computer graphics and image processing aim to produce images that will eventually be viewed by the human visual system [2]. Even in algorithms focusing on artistic representations of scenes, some degree of realism is desired.

The main focus is on real-time automatic solutions for the shadowing problem but also approaches scene for a better understanding of natural scenes by the analysis of various visually plausible scene reconstruction methodologies. This research provides a concise, yet comprehensive review of the literature on shadow perception from across the cognitive sciences, including the theoretical information available, the perception of shadows in human and machine vision, and the ways in which shadows can be used [8].

2. SHADOWS: AN OBSTACLE TO LIGHT PATH

Shadow occurs when an object partially or totally blocks the direct light source [9]. Shadow can take any size and shape. In general, shadow can be divided into two major classes viz., self and cast shadows. A self shadow occurs in the portion of an object that is not illuminated by direct light [10]. Cast shadows are the areas projected on a surface in the direction of direct light. Cast shadow can be further classified into umbra and penumbra. The region where the direct light source is totally blocked is called the umbra, while the region where it is partially blocked is known as the penumbra [11]. Shadow in image is generally divided into static and dynamic shadows. Static shadows are shadows due to static objects such as building, parked cars, trees, etc. Object detection methods do not suffer from static shadows, since static shadows are modeled as a part of background [12]. In contrary, dynamic (moving) shadows are harmful for moving object detection methods. These appear due to moving object such as animals, vehicles, pedestrians, etc. The shadow can be either in contact with the object, or disconnected from it [13]. In the first case, shadows distort the object shape and make the use of subsequent shape recognition methods less reliable.

In the second case, the shadows may be wrongly classified as an object in the scene. For example, typical problems caused by shadows in surveillance scenarios, shadows may cause merging of multiple vehicle objects. An indoor scenario, shadows are projected on the floor and on the wall. In this case, a false positive foreground (shadow casted on the wall) occurs and a long shadow causes a severe object shape distortion in an outdoor scenario [11]. Clearly, in many image analysis applications, the existence of shadows may lead to inaccurate object segmentation. Consequently, a task such as object description and tracking are severely affected and thus induces an erroneous scene analysis. (.75”). The text should be in two 8.45 cm (3.33") columns with a .83 cm (.33") gutter.

More precisely, investigation is on shadow detection and extraction methodologies are suggested by many researchers with the experimental conditions of multiple visual cues and multiple physical, statistical, geometrical & analytical features [14]. Despite the existence of abundance of research on individual techniques, efforts have been made to investigate the integration of environmental changes and shadow effects [15]. With that specific goal in mind, a framework has been developed for automatic reconstruction of shadow-free images from the natural scenes. Thus, the proposal has to operate under the following conditions: (i) for indoor as well as outdoor scenarios; (ii) detect both umbra and penumbra; (iii) detect chromatic and achromatic shadows; and (iv) recognize shadows even in the presence of camouflage. Thus, the main objective of this research is to explore the possibilities of the scene analysis, to solve the problem of missing information caused by shadows in the natural scenes and to eliminate them in a systematic way.

Shadows are the major concern in today’s intelligent systems performance, because they have made the classification task more difficult. [14] Furthermore, other application domains also benefit from the advances in the research of this domain. Some privileged applications that use the proposal are satellite image segmentation, Non photorealistic rendering, medical imaging, bio metric analysis, virtual rendering, 3D photographic and robotics [16].

3. LITERATURE REVIEW

Shadow detection has long been considered a crucial component of scene interpretation. But despite its importance and long tradition, shadow detection remains an extremely challenging problem, particularly from a single image. There is no single robust shadow detection technique and it is better for each particular application to develop an appropriate technique according to the nature of the scene. Scanlan et al., [17] have presents a shadow removal algorithm that employs a simple histogram modification function on the image intensity. Jiang et al., [18] have presented a shadow identification and classification method for real images, the shadow intensity and shadow geometry are analyzed. Although satisfactory results are achieved in their simple indoor images with a single colored flat surface background and a single light source, these assumptions would likely restrict the method from being applicable in outdoor environments where complex lighting and unstructured background surfaces are both common. Salvador et al., [19] have presented a method that is based on the use of invariant color models to identify and classify shadows in color images. the application of their method is restricted by its assumptions that shadows are cast on a flat and non textured surface, objects are uniformly colored, and a single light source illuminates the scene. If Times Roman is not available, try the font named Computer Modern Roman. On a Macintosh, use the font named Times. Right margins should be justified, not ragged.

The other approaches are based on inter-frame or reference-frame approach. Prati et al.,[20] have compared and evaluated some of these existing methods, and proposed a general categorization based on the decision making process. These four categories are namely: “deterministic model-based”, “deterministic non-model-based”, “statistical parametric”, and “statistical non-parametric” approaches. As a secondary classification, the authors have mentioned the type of features used by each method among three broad classes: spectral, spatial and temporal features. Sanin .A et al., [21] have observed that the choice of features have greater impact on shadow detection results compared to the choice of algorithms. Therefore, they present a feature-based taxonomy. Furthermore, they divide spectral features into intensity, chromacity and physical properties and they divide the spatial features into geometry and textures. Yet, methods within a single category under this categorization can be very different in their assumptions and the approach taken owing to the use of different image information (e.g. color, edge, geometry), while methods in different categories may share a similar approach. Al-Najwadi et al., [22] have classified the methodologies based on object/environment dependency and implementation domain.

4. PROPOSED METHODOLOGY

This section enumerates the various problems and challenges related to the task of shadow detection, extraction and compensation. It is worth, noting that a given shadow image does not necessarily include all the phenomena mentioned. Indeed, in many of the images only a subset of phenomena occurs. However, in order to develop a robust shadow restitution methodology which can effectively handle shadow images taken under different conditions and of different scene types, any shadow restitution algorithm should account for the various types of possible phenomena [23]. The researcher applies a multi-stage approach inspired by the use of color and gradient information, together with known shadow properties [24]. In this research, the properties of shadow (spatial, geometrical, photometric, statistical and textural) are analyzed in a scene and prominent features are selected for the processing.

The stages of the proposed approach for shadow detection has stated in the following five important steps:

- Applying a TAM intensity model to identify shadows in the input scene [25].
- Combining scene adaptive feature selection and successive thresholding to improve the detection of shadows [21].
- The shadow tracking stage is improved with gradient, boundary, edges, smoothness and invariant properties which are used for accurate shadow refinement [26].
- Extending the shadow detection to cope with the categories, fuzzy support vector machine and hybrid classifier based clustering techniques are applied. The shadow map produces a refined shadow [27].
- The shadow classification stage segregates hard/soft shadow and umbra/penumbra regions with the automatic adaptation of scene knowledge.
- Finally, the shadow reduction is done with natural shadow matting or Gradient Similarity patch in-painting approach based on the category of soft or dark shadow [26].

Unlike other approaches, this method does not make any assumptions about camera location, surface geometries, surface textures, shapes and types of shadows, objects and background. In order to enhance the shadow detection, a post processing is presented. To improve the shadow-free image quality, several image enhancement techniques such as gamma correction, contrast stretching, histogram specification, unsharp masking and smoothness transfer are therefore applied [25].

5. EXPERIMENTAL RESULTS

Several real life scenario shadow images were experimented and their resulting shadow-free scenes and videos produced by the proposal are in good quality. The obtained shadow-free images are able to recover the effects, from both hard and soft shadows [28]. The textural and boundary information is preserved by this approach. To show the supremacy, the approach is tested under benchmark datasets [29] and various shadow-illness criteria are tested in qualitative and quantitative metrics.

6. CONCLUSION

In this paper, the authors presented a de-shadowing method that can handle images containing shadows, cast on different kind of surfaces under different environmental conditions. The proposal result in a high-quality shadow-free image, in which the textural and boundary information of the original

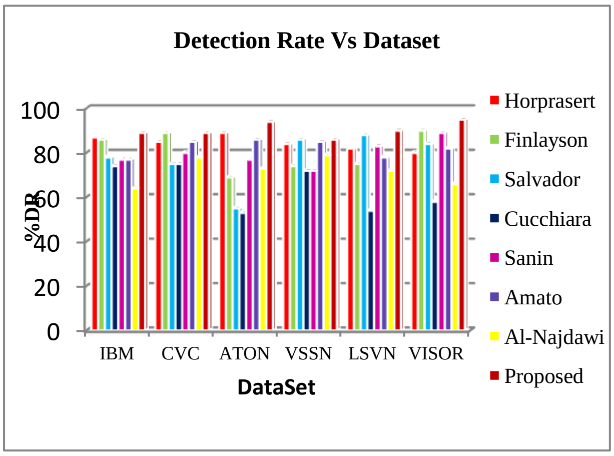

Fig 1. Shadow Detection Accuracy

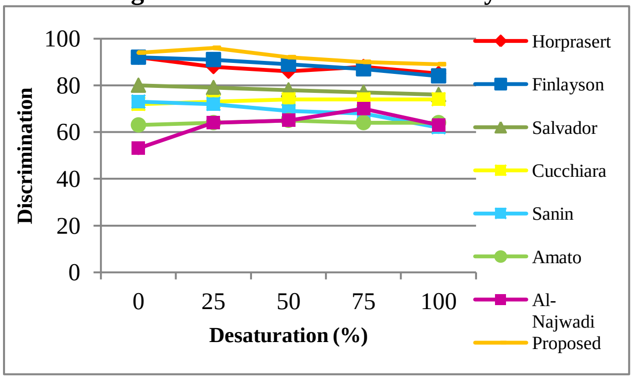

Fig 2. Shadow Discrimination Accuracy

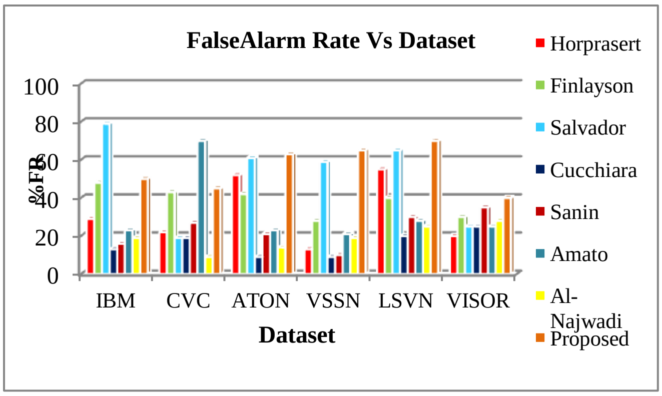

Fig 3. False Detection Rate

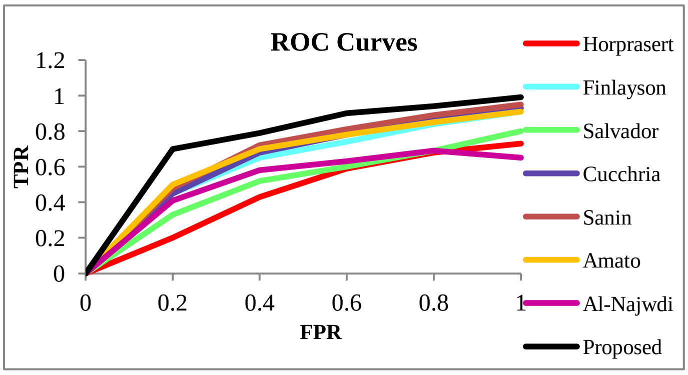

Fig 4: ROC Curves

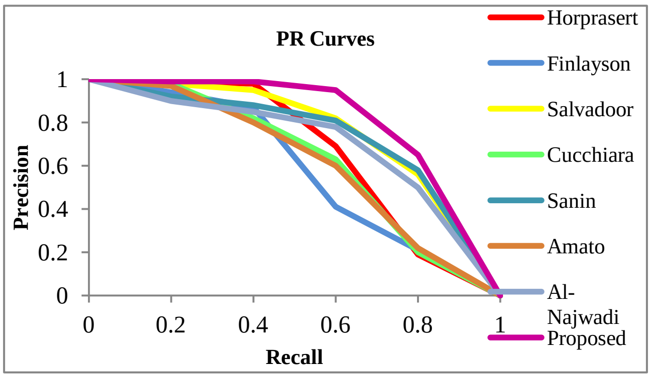

Fig 5. PR Curves Vs Recall of different Algorithms proposed by Significant Authors

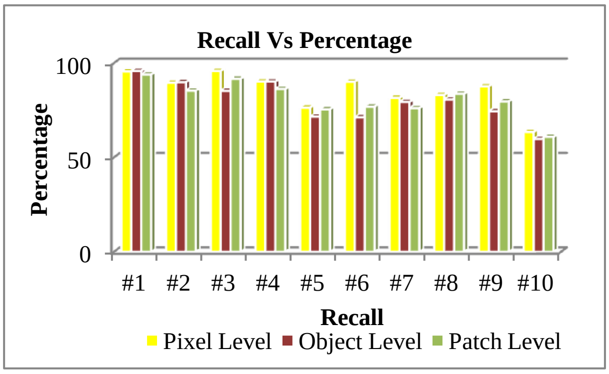

Fig 6. Performance Measure of Pixel, Patch and Object Level Recall

image is preserved. The approach performs well, even for images containing shadows with wide penumbra and dense hard shadows. The authors have taken multi-colored, multiple shadows and moving dynamic shadows, for the future analysis. The presented outcome of this research, definitely support the prospective researchers and open further avenues for many interdisciplinary research domains.

7. REFERENCES

[1] Serences, John T., and Steven Yantis. "Selective visual attention and perceptual coherence." Trends in Cognitive Sciences 10, no. 1 (2006): 38-45.

[2] Pouli, Tania, Douglas W. Cunningham, and Erik Reinhard. "Image statistics and their applications in computer graphics." Eurographics State of the Art Report, STAR (2010).

[3] Finlayson, Graham D., Steven D. Hordley, Cheng Lu, and Mark S. Drew. "On the removal of shadows from images." Pattern Analysis and Machine Intelligence, IEEE Transactions on 28, no. 1 (2006): 59-68.

[4] Arbel, Eli, and Hagit Hel-Or. "Shadow removal using intensity surfaces and texture anchor points." Pattern Analysis and Machine Intelligence, IEEE Transactions on 33, no. 6 (2011): 1202-1216.

[5] Eisemann, Elmar, Ulf Assarsson, Michael Schwarz, and Michael Wimmer. "Casting shadows in real time." In ACM SIGGRAPH ASIA 2009 Courses, p. 21. ACM, 2009.

[6] Joshi, Ajay J., Stefan Atev, Osama Masoud, and Nikolaos Papanikolopoulos. "Moving shadow detection with low-and mid-level reasoning." In Robotics and Automation, 2007 IEEE International Conference on, pp. 4827-4832. IEEE, 2007.

[7] Soares, Luciano Pereira, José Miguel Salles Dias, Joaquim A. Jorge, Alberto Raposo, Bruno R. De Araújo, and Rafael Bastos. "Designing multi-projector VR systems: from bits to bolts." In Eurographics 2010-Tutorials, edited by Maria Roussou, and Jason Leigh, pp. T1-undefined. The Eurographics Association, 2010.

[8] Dee, Hannah M., and Paulo E. Santos. "The perception and content of cast shadows: an interdisciplinary review." Spatial Cognition & Computation 11, no. 3 (2011): 226-253.

[9] Shehata, Mohamed S., Jun Cai, Wael M. Badawy, Tyson W. Burr, Muzamil S. Pervez, Robert J. Johannesson, and Alireza Radmanesh. "Video-based automatic incident detection for smart roads: The outdoor environmental challenges regarding false alarms." Intelligent Transportation Systems, IEEE Transactions on 9, no. 2 (2008): 349-360.

[10] Prati, Andrea, Ivana Mikic, Rita Cucchiara, and M. Trivedi. "Comparative evaluation of moving shadow detection algorithms." In IEEE CVPR workshop on Empirical Evaluation Methods in Computer Vision. 2001.

[11] Prati, Andrea, Ivana Mikic, Costantino Grana, and Mohan M. Trivedi. "Shadow detection algorithms for traffic flow analysis: a comparative study." In Intelligent Transportation Systems, 2001. Proceedings. 2001 IEEE, pp. 340-345. IEEE, 2001.

[12] Jaynes, Christopher, Stephen Webb, R. Matt Steele, Michael Brown, and W. Brent Seales. "Dynamic shadow removal from front projection displays." InProceedings of the conference on Visualization'01, pp. 175-182. IEEE Computer Society, 2001.

[13] Amato, Ariel. "Environment-Independent Moving Cast Shadow Suppression in Video Surveillance", 2012.

[14] Joshi, Ajay J., Stefan Atev, Osama Masoud and Nikolaos Papanikolopoulos. "Moving shadow detection with low-and mid-level reasoning." In Robotics and Automation, 2007 IEEE International Conference on, pp. 4827-4832. IEEE, 2007.

[15] Muthukumar, Subramanyam, Ravi Subban, Nallaperumal Krishnan, and P. Pasupathi. "Real Time Insignificant Shadow Extraction from Natural Sceneries." In Recent Advances in Intelligent Informatics, pp. 391-399. Springer International Publishing, 2013.

[16] Hampapur, Arun, Lisa Brown, Jonathan Connell, Sharat Pankanti, Andrew Senior, and Yingli Tian. "Smart surveillance: applications, technologies and implications." In Information, Communications and Signal Processing, 2003 and Fourth Pacific Rim Conference on Multimedia. Proceedings of the 2003 Joint Conference of the Fourth International Conference on, vol. 2, pp. 1133-1138. IEEE, 2003.

[17] J. M. Scanlan, D. M. Chabries, and R. Christiansen, A shadow detection and Removal algorithm for 2-d images," in Proc. of IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), xpp. 2057-2060, 1990.

[18] H.Jiang and M.S.Drew, Shadow-resistance tracking in video, In ICME’03:Intl.Conf.on Multimedia and Expo. pages III 77-80-2003.

[19] Salvador, Elena. "Shadow segmentation and tracking in real-world conditions." PhD diss., Institut de traitement des signaux section d'électricité pour l'obtention du grade de docteur ès sciences par laurea in ingegneria elettronica, Università degli studi di Trieste, 2004.

[20] Prati, Andrea, Ivana Mikic, Mohan M. Trivedi, and Rita Cucchiara. "Detecting moving shadows: algorithms and evaluation." Pattern Analysis and Machine Intelligence, IEEE Transactions on 25, no. 7: 918-923, 2003.

[21] Muthukumar, S., et al., Fuzzy information system based on image segmentation by using shadow detection, Computational Intelligence and Computing Research (ICCIC), 2010 IEEE International Conference on. IEEE, 2010.

[22] Al-Najdawi, Nijad, et al. , A survey of cast shadow detection algorithms, Pattern Recognition Letters 33.6: 752-764, 2012.

[23] Kundu, M. K., and S. K. Pal. "Thresholding for edge detection using human psychovisual phenomena." Pattern Recognition Letters 4, no. 6 (1986): 433-441.

[24] J.-A. Beraldin et al., Virtualizing a Byzantine crypt by combining highresolution textures with laser scanner 3D data, In Proceedings of the VMMS 2002, pages 3–14, September 2002.

[25] Huerta, et al., Detection and removal of chromatic moving shadows in surveillance scenarios, Computer Vision, 12th International Conference, IEEE, 2009.

[26] Subban Ravi, Subramanyam Muthukumar and Pasupathi.P (2013): Image Restoration based on Scene Adaptive Patch In-painting for Tampered Natural Scenes, Recent Advances in Intelligent Informatics, Advances in Intelligent Systems and Computing, Vol. 235, Aug. 2013, pp. 65-72, Springer, LNAI, Switzerland, DoI: 10.1007/978-3-319- 01778- 5_7, ISBN: 978-3-319-01778-5.

[27] Muthukumar.S, Krishnan.N, Tulasi Nachiyar .K and Pasupathi .P (2011): Shadow Detection in an image using Fuzzy based Approach, International Journal on Information and Communication Technology, ISSN 0123-4560, DOI10.5120/502-819, Feb.’11.

[28] Hasenfratz, J-M., et al. "A Survey of Real- time Soft Shadows Algorithms." Computer Graphics Forum. Vol. 22. No. 4. Blackwell Publishing, Inc, 2003.

[29] Zhu, Guangyu, et al. "Detecting video events based on action recognition in complex Scenes using spatio-temporal descriptor." Proceedings of the 17th ACM international conference on Multimedia.ACM,2009.