The Partial Cartoon Central Vision Compensation Technique: Subjective Evaluation

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Abstract

The “partial cartoon central vision compensation technique” involves partially superimposing the entire surrounding image in the form of a cartoon layer to the immediate left and right of the visible/truncated image. This research has been inspired by the increasing demand in EVES (electronic vision enhancement techniques) for various low-vision and industrial applications. A previous publication has reviewed this technique from an analytical perspective, while this paper addresses the subjective evaluation of this method for five different daily-life scenarios. Images remapped using different cartoon (or superimposition) factors and gray shades were evaluated through surveys performed on 115 subjects, where image quality was relatively assessed using measures of image detail and distortion. It is concluded that the partial cartoon technique is most suitable for daylight, outdoor conditions at a cartoon factor of 30% with a black shade.

Keywords
eye, compensation, enhancement, image, warping

1. Introduction

Quality vision lies mostly in the macular photoreceptor region of the retina, which roughly corresponds to a measure of 15 degrees on a visual eccentricity scale, or 7.5 degrees from either side of direct vision (Lewis, 2003; Rodieck, 1998; El-Sherbeeny et al, 2006). This has inspired the initiation of the “partial cartoon” technique, which is based on introducing the invisible image to the immediate left and right of the truncated image as a partially superimposed cartoon into respective sides of the truncated image, without disrupting the view of the central, quality vision (El-Sherbeeny, 2006; El-Sherbeeny, 2014). Images are warped according to predefined parameters including the cartoon (or superimposition) factor and grayscale level. Remapped images have been evaluated through surveys performed on 115 subjects, where viewing quality was assessed using measures of image detail and distortion. First, the technique is further illustrated, followed by various practical applications. Methods are then described regarding how the technique was tested subjectively, followed by practical results, conclusions, and future recommendations.

1.1 Electronic Vision Enhancement Systems (EVES)

The EVES (Electronic Vision Enhancement Systems) technology strives to achieve an application-dependent optimization, addressing the factors governing geometric warping (or compensation) to produce the desired shape, versus the realistic appearance and minimized distortions in the output image. Consequently, this balance of variables, also referred to as image optimization, involves the challenge of dealing with both analytical (or geometric) and physical (or physiological) aspects of the human perception to images. Central vision optimization involves achieving both an optimized geometric warp having a good match with minimal distortion, as well as visibility within the region of the highest spatial resolution (Lewis, 2003; Rodieck, 1998; El-Sherbeeny et al, 2006).

Applications of EVES are numerous, and have traditionally included those related to low-vision applications (such as for macular degeneration patients) (Peterson, 2003; Wolffsohn, 2003; Peli, 2007; Culham, 2009), as well as selective area magnification of an image (such as in remote sensing or surveillance) (Wolberg, 1990). Other examples have also included removing optical distortions introduced by a camera or a particular viewing perspective, to register an image with a map or template, or to align two or more images (Glasbey, 1998).

More recent EVES applications include investigating the use of new technologies for improving reading speed (Calabrèse, 2016) and writing performance (Matchinsky, 2016; Haji, 2015). Other educational applications include those used for students with visual impairments (Mulloy, 2014), with particular examples involving the use of portable EVES (or p-EVES) (Taylor, 2014). Other recent research involves EVES as low vision aids (Moshteal, 2015), and for generally improving the quality of life (Lancioni, 2014).

1.2 The Partial Cartoon Technique

The partial cartoon technique has been previously introduced and analytically evaluated using various image quality parameters (El-Sherbeeny, 2006; El-Sherbeeny, 2014). It involves compensating a minified field of view (local FOV) for that of a larger, global FOV, whereby the source image is truncated down solely to its central, undeformed portion, with the integration of a contour superimposition (or cartoon) of the image periphery onto the truncated image. Unlike previous research on the topic (Peli, 2007), only the invisible image to the left and right of the truncated image is superimposed on the respective sides of the truncated image. Furthermore, the two cartoons are introduced only partially, leaving the central portion of the original truncated image clear for maximizing the central (quality) view.

1.3 Objectives

The current paper seeks to subjectively evaluate the partial cartoon technique in order to determine,

- The variability of the warping for different images and scenes. A landscape scenery, as well as those of a close-up, text, obstacle, and home scenes were investigated.
- Optimal central viewing factors including the "cartoon" factor, as well as the gray shade of the superimposed cartoon.

2. Methods

Grayscale images were chosen to eliminate bias that may arise due to the presence of color in the subjective studies. A white, black, and image-mean grayscale value was chosen for the cartoons.

The cartoon factor can range between 0 and 50% starting at the extreme respective left and right sides of the local FOV. Creating a compromise between the fact that when the cartoon is small (< 25%), the surrounding is less identifiable, and conversely when the cartoon is too large (>40%), the center of the truncated image is less identifiable, 30% and 40% cartoon factors were selected for practical purposes.

Each image was shown for five to ten seconds (on an LCD screen) by which time the participants were asked to respond to a measure of detail and distortion of each warped image (scaled from 0 to 10) versus the control (truncated) image. Questions were randomly ordered to prevent a predictability pattern in the answers.

First a pilot study was conducted on 23 participants on a first set of images (image set one), followed by an improved (main) survey applied on 115 volunteers (image set two). Figure 1 shows the original (not shown) and truncated (local FOV) images, partial-cartoon black images at 30% and 40% cartoon factors, as well as white and image-mean warped images (at the default 30% cartoon factor) for the obstacle image. This was similarly repeated for the remaining four images.

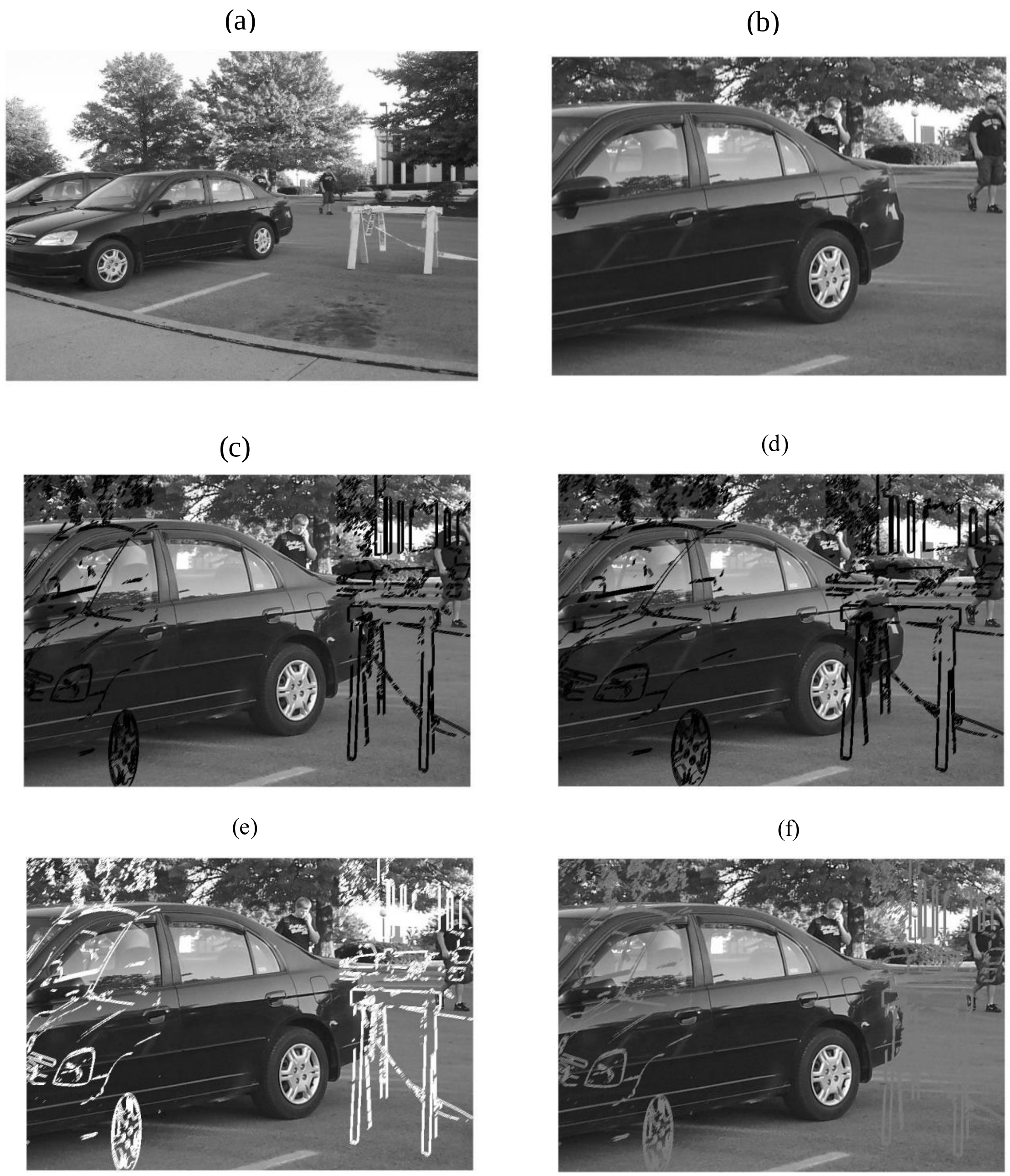
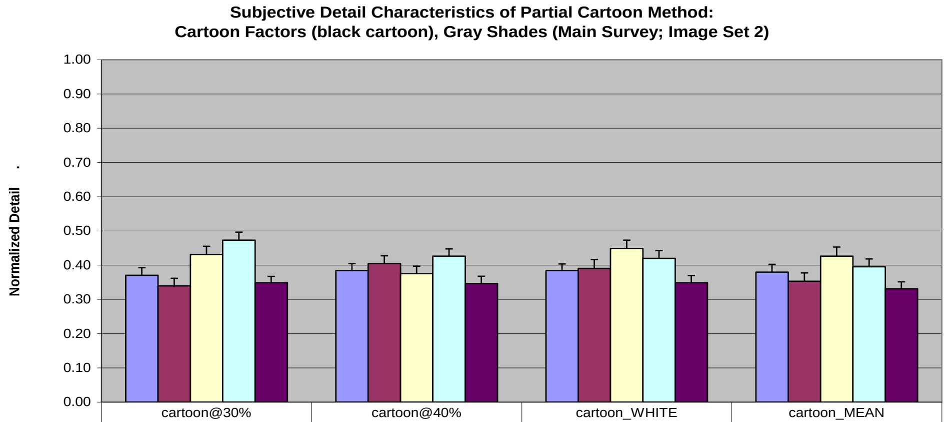
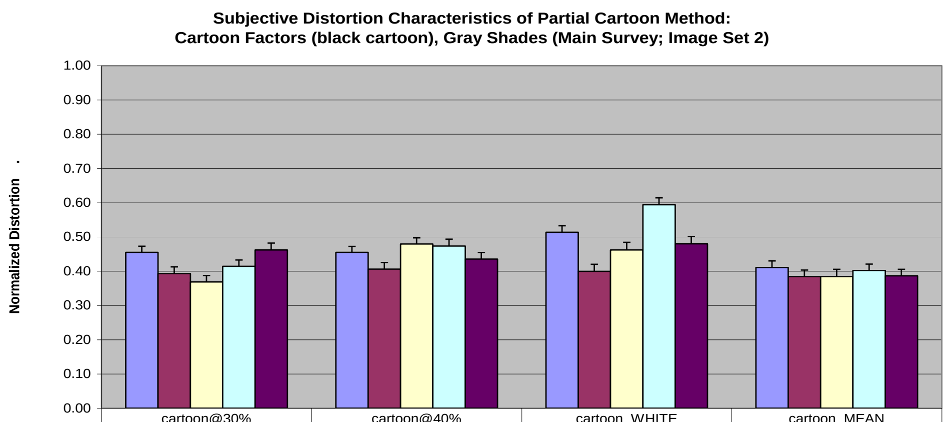


Figure 1. Comparison of various partial cartoon warped images for different cartoon factors and gray shades; *(a)*: base, undeformed image (not displayed); *(b)*: control, truncated image (displayed); *(c)*: warped image at 30%, black cartoon; *(d)*: warped image at 40%, black cartoon; *(e)*: warped image at 30%, white cartoon; *(f)*: warped image at 30%, image-mean cartoon.



	cartoon@30%	cartoon@40%	cartoon_WHITE	cartoon_MEAN
Image 1	0.370	0.384	0.384	0.380
Image 2	0.339	0.404	0.391	0.353
Image 3	0.431	0.375	0.449	0.426
Image 4	0.473	0.426	0.420	0.395
Image 5	0.348	0.346	0.348	0.331

Images: 1. Landscape, 2. Close-Up, 3. Text, 4. Obstacle, 5. House



	cartoon@30%	cartoon@40%	cartoon_WHITE	cartoon_MEAN
Image 1	0.455	0.455	0.514	0.411
Image 2	0.393	0.406	0.400	0.384
Image 3	0.368	0.479	0.462	0.384
Image 4	0.414	0.473	0.594	0.402
Image 5	0.462	0.435	0.480	0.386

Images: 1. Landscape, 2. Close-Up, 3. Text, 4. Obstacle, 5. House

Figure 2. Subjective characteristics (with standard error) of the partial cartoon method (image set 2); *top*: data and plot for normalized detail values; *bottom*: data and plot for normalized distortion values.

3. Results and Discussion

The surveys were conducted mainly on students in the age group of 17 to 22. The partial cartoon method was analyzed for all 5 images (image set 2) at different cartoon factors (30 and 40%) as well as different gray shades (black and white). The subjective results are divided into detail and distortion measures for images used in the main survey. Detail and distortion experimental measures were normalized (out of one). The average mean values and standard error (SE) were also computed for all participants. As the SE values are always positive, they are plotted above the detail and distortion bars for the subjective results. Results are displayed in Figure 2.

The results indicate that the black partial cartoon (at 30%) scores the highest detail (as high as 0.47 in the obstacle image), except in one image, while scoring the lowest distortion among most images. This is in exclusion of the mean cartoon due to its offering very little contrast from the surrounding image, as indicated from survey evaluation responses, making it hard to identify. In addition, the white partial cartoon has much higher relative distortion measures.

Furthermore, the partial cartoon method at the default criteria of 30% superimposed black cartoon has the lowest distortion measures of the majority of warped images (at a lowest of 0.37). The exception to this appears with the home and other images with an average luminance of less than 128; this is justified by the low contrast between the cartoon and the truncated image, consequently deeming it unsuitable for this particular application. There does not, in general, seem to be a direct correlation between image detail and distortion data. This is expected and is justified by the fact that a detailed image is not necessarily less distorted, and vice versa.

4. Conclusions

The partial cartoon technique digitally involves introducing the immediate right and left of the surrounding (invisible) image to its respective location in the truncated image, at a custom “cartoon factor” and a specified gray shade (white, black, gray, or image-mean) values. The optimum evaluated technique parameters (or method defaults) were generated as a black cartoon at 30% superimposition.

The technique was shown not to be subjectively suitable for an indoor, home, or low illumination environment. It is, however, best suited for daylight, outdoor conditions, especially for such scenes as signs, obstacles, or mixed layout environments. Potential applications of the partial cartoon method, therefore, may include areas such as low-vision and surveillance.

Further testing is recommended to verify the subjective efficiency of the partial cartoon method in its present form, including a larger, more diverse subject group, also including different races, and possibly people with varying vision conditions, including the variation with and without vision correction. Electronic testing is also proposed to further increase the participant (population) size, and the speed and automation at which data can be collected and analyzed.

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Biography

Ahmed M. El-Sherbeeny is an assistant professor at the Industrial Engineering department (since 2010) and head of the Alumni and Employment Unit (since 2013) at the College of Engineering, King Saud University. He completed both his PhD (2006) and Master's (2001) degrees in Mechanical Engineering from West Virginia University (WVU), where he was a graduate teaching and research assistant. He holds a BSME from the American University in Cairo (AUC, 1998). El-Sherbeeny's research interests include Human Factors Engineering and Engineering Education. His teaching interests include basic courses in Human Factors Engineering, Manufacturing, introductory Engineering design, Engineering problem solving and programming (with C, C++, and Matlab), Engineering drawing (with both AutoCAD and manual drawing), as well as Mechanical Engineering courses such as Statics, Dynamics, and Thermodynamics.

Mohammed Alkahtani is an Assistant Professor in Industrial Engineering Department at King Saud University. He is also the chairman of the Industrial Engineering Department and has recently been elected as chairman of the Industrial Engineering chapter of the Saudi Council of Engineers (SCE). Dr Alkahtani has collaborated on various Industrial and research projects. He has experience in teaching wide range of IE courses, is involved with several administrative duties, and has developed a network of industrial and academic collaborators across the world. Research areas and specialties: 1) Design and analysis of manufacturing systems, logistics, and supply chain. 2) Lean/Agile based approaches for performance improvement of SMEs. 3) Application of simulation, operations research and optimization techniques to solve supply chain and logistics problems.

James V. Odom is a professor at the West Virginia University Eye Institute. His current research investigates higher order visual perception in older patients with low vision. Dr. Odom's research has been supported by grants from several governmental agencies, including the National Institutes of Health, the Department of Defense, the National Science Foundation, Center for Medicare and Medicaid Services, and the Social Security Administration. He was awarded the Francqui International Interuniversity Chair in 1996 by Belgium's Franqui Foundation. Dr. Odom holds three patents with several others pending. He is a former member of the Board of Directors of the International Society for Clinical Electrophysiology of Vision (ISCEV), and has twice chaired the ISCEV VEP Standardization Committee. Currently, he serves regularly on National Institutes of Health grant review panels related to Low Vision. He currently serves as a Board Member of the Smith-Kettlewell Eye Research Institute in San Francisco, the world's only translational research institute devoted to diseases affecting binocular vision and to the rehabilitation of low vision and blindness. He also serves on the selection committee of the Pisart Award, awarded annually by the Lighthouse International of New York City.

James E. Smith is currently the Director of the Center for Industrial Research Applications (CIRA) at West Virginia University where he is a Professor in the Mechanical and Aerospace Engineering Department. He has taught at the University since 1976, before which he was a Research Engineer for the Department of Energy (DOE). During his 30+ year scientific career, he has been the principal and/or co-principal investigator for many millions of dollars of research (exceeding $20 million) for various projects funded by federal agencies (TACOM, DOD, HEW, DOT, US Navy, DARPA, and DOE), international corporations, and numerous US corporations. Dr. Smith has been involved in transferring technology from academia into the commercial sector. To date, he has helped form eleven companies that now market commercial applications of technology developed at and/or through West Virginia University. The work in these projects has resulted in the publication of over 200 conference and journal or bound transaction papers, in addition to many project final reports and unrefereed publications. This work has resulted in the granting of 29 US patents and numerous foreign patents on mechanical and energy related devices.