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Coupled Electrochemical Modeling and Transient Thermal Analysis of a Lithium-Ion Battery Pack comparing different cooling solutions in STAR CCM+

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Abstract: Li-Ion batteries are rapidly becoming the technology of choice for the next generation of Electric Vehicles, Battery Electric Vehicles, Plug-In Hybrid and Hybrid Electric Vehicles (EVs/BEVs/PHEVs/HEVs).
Li-Ion battery, so far, is the technology that best fits for the need of these vehicles, due to their large specific energy density and specific power, making these cells ideally suited for high rate-of-discharge applications such as acceleration of electric vehicles.
Lithium-ion cells performance depends on both the temperature and the operating voltage. Lithium-Ion cells work well when cells operate within limited voltage and temperature. Otherwise, damage will occur to the cells and will be irreversible. This paper presents a computationally efficient modeling approach to characterize the internal temperature distribution within a Li-Ion battery pack. This would be as a tool to design models characterizing the thermal behavior of Li-Ion battery cells to be used in order to perform thermal management studies for battery pack cooling systems.

Keywords: Electric Vehicles, Hybrid, Lithium-ion, Connected component labelling.

I. INTRODUCTION

Image inpainting is a method for repairing damaged pictures or removing unnecessary elements from pictures. It recovers the missing or corrupted parts of an image so that the reconstructed image looks natural. In real world, many people need a system to recover damaged photographs, designs, drawings, artworks etc. damage may be due to various reasons like scratches, overlaid text or graphics etc.
This system could enhance and return a good looking photograph using a technique called image inpainting. Image inpainting modify and fill the missing area in an image in an undetectable way, by an observer not familiar with the original image. The technique can be used to reconstruct image damage due to dirt, scratches, overlaid text etc.
Some images contain mixed text-picture-graphic regions in which text characters are printed in an image. Detecting and recognizing these characters can be very important, and removing these is important in the context of removing indirect advertisements, and for aesthetic reasons. There are many applications of image inpainting ranging from restoration of photographs, films, removal of occlusions such as text, subtitle, logos, stamps, scratches, red eye removal etc.
The concept of image inpainting was first introduced by Bertamio et al. [1]. The method was inspired by the real inpainting process of artists. The image smoothness information interpolated by the image Laplacian is propagated along the isophotes directions, which are estimated by the gradient of image rotated by 90 degrees. Exemplar Based method proposed by Criminisi et al. [2] used a best exemplar patch to propagate target patch including missing pixels. This technique uses an approach which combine structure propagation with texture synthesis and hence

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produced very good results. In [3], the authors decompose the image into sum of two functions and then reconstruct each function separately with structure and texture filling-in algorithms. Morphological technique is used to extract text from the images presented in [4]. In [5], the inpainting technique is combined with the techniques of finding text in images and a simple algorithm that links them. The technique is insensitive to noise, skew and text orientation. The authors in [6] have applied the CCL (connected component labelling) to detect the text and fast marching algorithm is used for Inpainting.

The work in this paper is divided in two stages. 1) Text- Detection 2) Inpainting. Text detection is done by applying morphological open-close and close-open filters and combines the images. Thereafter, gradient is applied to detect the edges followed by thresholding and morphological dilation, erosion operation. Then, connected component labelling is performed to label each object separately. Finally, the set of selection criteria is applied to filter out non text regions. After text detection, text inpainting is accomplished by using exemplar based Inpainting algorithm.

Paper is organized as follows. Section II describes automatic text detection using morphological operations, connected component analysis and set of selection or rejection criteria. The flow diagram represents the step of the algorithm. After detection of text, how text region is filled using an Inpainting technique that is given in Section III. Section IV presents experimental results showing results of images tested. Finally, Section V presents conclusion.

II. RELATED WORK

Sometimes an image may contain text embedded on to it. Detecting and recognizing these characters can be very important, and removing these is important in the context of removing indirect advertisements, and for aesthetic reasons.

Our system aims at the automatic detection of text. This is done by the algorithm. Fig. 1 shows the flow diagram of text detection algorithm. The algorithm steps are summarized as follows.

1. An efficient edge detection scheme is applied to the greyscale image. The image I is blurred (to reduce false edges and over-segmentation) using open-close and close-open filters. The final blurred image Ib is the average of the outputs of these filters. The 3 x 3 8-connected structuring element of type 'square' is used here. Next, the morphological gradient operator is applied to the blurred image Ib resulting in an image G as follows:

   G = Dilation (Ib) – Erosion (Ib)

   The Morphological gradient is an edge-strength extraction operator that gives symmetric edges between foreground and background regions.

   The resulting image is then thresholded to obtain a binary edge image. Global thresholding technique is used for that.
2. Closed edges in the binary edge image are grouped by dilation using eight- connected structuring elements. Then small connected components in the dilated image are filtered using erosion. The output is a binary image that contains text candidate regions.
3. Connected component labelling is performed to label each object separately.
4. After applying connected component labelling, the first set of criteria is applied which eliminate all objects whose area is greater than 10000 and filled area is greater than 8000. One more criteria namely major axis length is used which is used to retain the text region alone. All objects, whose major axis lengths are in between 20 to 3000, are considered to be text. To eliminate small objects, connected component labelling is applied to the resultant image and the second set of criteria is applied which eliminates all the objects whose area is less than 300 and filled area is less than 500.

After applying all these 4 steps, we get a filtered image that contains only text regions.

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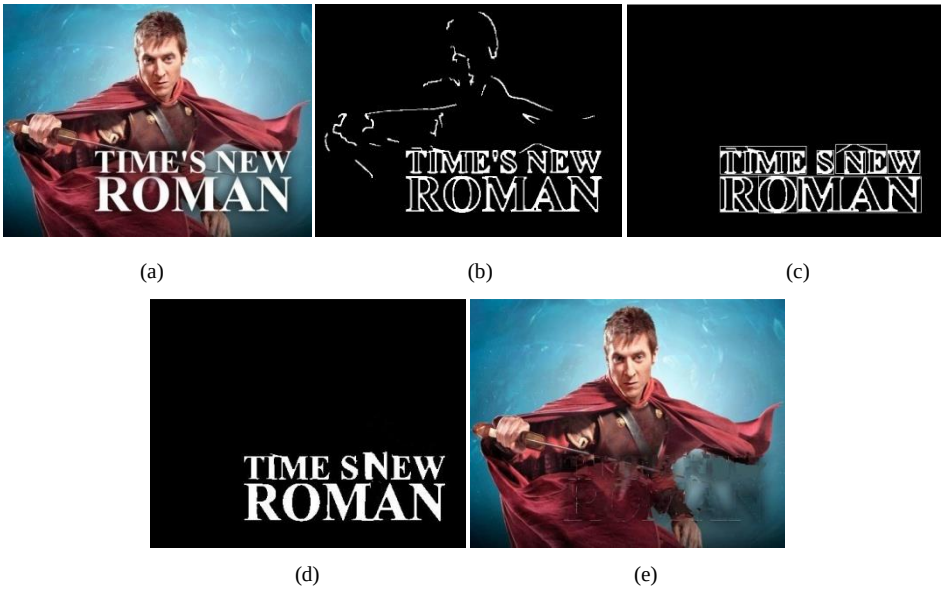
III. TEXT INPAINTING

Exemplar based Inpainting technique is used for inpainting of text regions, which takes structure synthesis and texture synthesis together. The inpainting is done in such a manner, that it fills the damaged region or holes in an image, with surrounding colour and texture. The algorithm is based on patch based filling procedure. First find target region using mask image and then find boundary of target region. For all the boundary points it defined patch and find the priority of these patches. It starts filling the target region from the highest priority patch by finding the best match patch. This procedure is repeated until entire target region is inpainted.
The algorithm automatically generates mask image without user interaction that contains only text regions to be inpainted.

IV. EXPERIMENTAL RESULTS

Figures shows the results of text detection from an image and inpainting by using exemplar based Inpainting algorithm. Figs. 2, 3, 4 (a) shows the original image. (b) is the image obtained by applying first set of criteria. All objects whose area greater than 10000 and filled area greater than 8000 are eliminated and major axis lengths are in between 20 to 3000 are considered to be text. Still, some small non-text objects are detected.



(a) (b) (c)

(d) (e)

Fig. 2. Text Detection and Inpainting (a) Original image (b) Image after applying first set of criteria (c) Image after applying second set of criteria (d) Image mask (e) Inpainted image using patch size 4 x 4 and search window size 81 x 81

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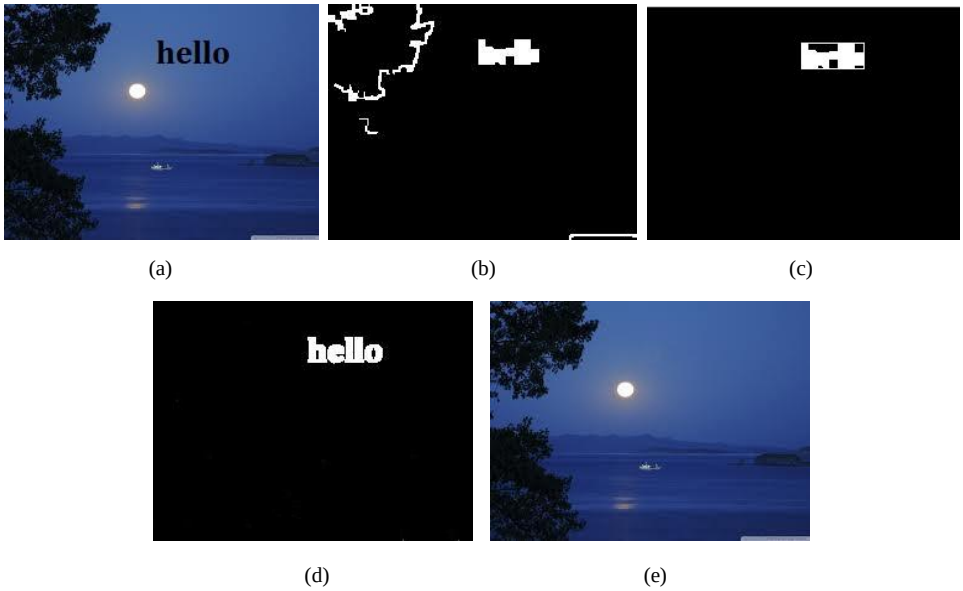

(a) (b) (c)

(d) (e)

Fig. 3 Text Detection and Inpainting (a) Original image (b) Image after applying first set of criteria (c) Image after applying second set of criteria (d) Image mask (e) Inpainted image using patch size 5 x 5 and search window size 81 x 81

(a) (b) (c)

(d) (e)

Fig. 4 Text Detection and Inpainting (a) Original image (b) Image after applying first set of criteria (c) Image after applying second set of criteria (d) Image mask (e) Inpainted image using patch size 5 x 5 and search window size 81 x 81

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To eliminate small objects, connected component labelling is applied to the resultant image.(c) represents text detection by applying second set of criteria which eliminates all the objects whose area is less than 300 and filled area is less than 500.

VI. CONCLUSION

We have implemented an automatic text detection technique from an image for Inpainting. Our algorithm successfully detects the text region from the image which consists of mixed text-picture-graphic regions. We have applied our algorithm on many images and found that it successfully detect the text region.

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