Commentary: General Road Detection From a Single Image

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1. Introduction

The 2010 paper "General Road Detection From a Single Image" aims to provide a robust method of road detection in varying environmental and road conditions without the use of multiples sensors or image sets. The paper innovates by inclusion of a confidence score to texture region orientation estimations as well as a novel approach to a pixel-based voting system for vanishing point estimation called LASV (Locally Adaptive Soft-Voting algorithm). The paper succeeds in improving upon accuracy of prior techniques in the field of road detection while improving computational efficiency.

Road detection is an important area of computer vision as one of the most prevalent upcoming technologies that utilizes computer vision techniques are self-driving cars. This technology space represents a big opportunity for commercial and technological gain in the current technology era. Self-driving cars are highly reliant on the dependability and robustness of the vision and decision methods they use so addressing the generality of techniques in road detection is extremely beneficial to the technology space when improvements can be made on prior work, effectively the technology is reliant on extreme robustness.

This problem relates more generally to robotic vision problems and improving on generality and efficiency of vision techniques to the extent that they surpass human drivers or controllers is essential to the confidence in self driving technologies in such a safety oriented technology space as cars and robotics. The more generally these techniques can be applied efficiently and accurately the more potential there is to reduce injury or death by car accident, as robotic control has the potential to surpass human control in safety. Difficult road conditions are a focus of this paper's road detection and improvement of detection in these environments is especially useful to the improvement of the safe decision making of autonomous vehicles.

Achieving robust road detection using only the direct image space at one timestep (as this paper aims to) is also beneficial to the technology industry of autonomous vehicles, as requiring more sensors and faster processing speeds can add to costs of technologies significantly.

2. Methods

The paper proposes a method for road detection in varying environmental and road conditions that utilizes Gabor Filters to estimate texture orientations, a novel soft pixel voting system (LASV) to find the road's vanishing point, and finally a vanishing point constrained method of dominant edge detection for segmenting the road surface.

Gabor filters are gaussian kernel-based filters that analyze local image areas for specific frequencies based on orientation. 36 orientations are applied to pixel areas with 5 different scales, allowing for the most prevalent texture orientation of the local area around a pixel to become apparent. Gabor filters are claimed to behave as mammalian cortical cells and are like human perception in desirable ways for computer-based processing of localized orientations in images [1]. Texture orientations are given a confidence score that is based on based on image brightness. Texture orientation is highly useful for off-road surfaces and thus this methodology is appropriate for use in this problem space.

Once local orientations of texture regions of an image are determined, a novel adaptive voting (by pixel) method is used to determine a vanishing point candidate location. Different pixels are given varying voting weights that take into account their height in the image (only top 90% of image pixels), the confidence score in their Gabor based orientation estimate, and their location in a voting region around a vanishing point candidate defined by the intersection of the Gabor filter results and a half disk centered at the candidate point.

Road edges are then finally detected by constructing 29 rays around the estimated vanishing point decided by LASV that are evenly distributed and selecting the best road edge estimation ray based on color difference and OCR (orientation consistency ratio) within the ray. The second edge of the road is found the same way with the constraint that it must be 20 degrees apart from the dominant edge found first. The road edges found are used to segment the entire road.

This road detection method benefits from the assumption that the intersection of straight road edges will meet at or near a vanishing point, but it may not always be the case with road images on extreme hills or extreme curves such that are not present in the images shown in the paper. The paper achieves robust performance with different road textures utilizing orientation but does not give much consideration to curved orientations in road boundaries. Perhaps weighting alternate curved projections alongside straight rays should allow for a further generalized approach to edge detection. Also not considered is the effects of obstacles in the road on the results of texture analysis and vanishing point voting as the obstacles in the example images are sparse and usually near where the vanishing point would normally be.

3. Results

The paper uses a combination of 430 images taken along a possible Grand challenge route (DARPA), as well as 573 images taken from Google Images, and tests the proposed methodology against manually (human) marked versions vs previous methodologies comparing the vanishing point estimates and road segmentations. The implementation was tested on a Windows OS with a 1.8 GHZ CPU and 1 GB of memory.

The proposed method is able to process 17 240 × 180 resolution frames per second on the aforementioned architecture. This is more than fast enough to be practical for direct use in autonomous vehicles. And the paper proposes that the method could be made even more efficient with subsampling techniques.

The human marking of the test images was done by 5 individuals and a median filter was applied to these manual markings to reduce the effect of their subjectivity. An alternate approach to this would be to use more people however it is understandable that this was not feasible.

The soft voting strategy (LASV) proposed by the paper is compared in conjunction with previously used hard voting strategies to compare their performance against each other and demonstrate the improvements made.

Recall and accuracy are calculated based human marked ground truths for the final image segmentation results and are the predominant quantitative identifier of the success of the methodology overall. It is shown to perform better than a previous method (cvpr'09) in these metrics.

The paper states that curved roads cannot be fully encompassed by using their dominant edge technique, and as such my previous critique of this methodology is warranted. However, the paper should show more of these suboptimal performance images directly as only mostly positive results are shown in the figures.

Since desert roads make up 430 of the 1003 total images tested on, the road conditions and attributes of the southern California desert are overrepresented in the testing of this study if it is to be considered a general approach that could be applied to country roads across the world. This could result in biased choices made to cater to the DARPA competition rather than a useful general algorithm. Another factor that reduces the generalization of this method is the lack of lines in any roads tested on, a truly general approach should test on normal road conditions as well as off-road conditions as this may be a significant source of error in the edge detection methodology used.

4. Conclusions

The paper provides novel and robust improvements over previous methodologies with higher accuracy and improved computational efficiency but uses too focused a testing set and empirical decision making to really be called a general solution to the problem of road detection.

The methodology proposed provides novel proposals over previous methods and succeeds in improving on accuracy and computational efficiency of some previous techniques, but focuses on too specific a testing set and set of boundary assumptions to allow itself to be called a general solution to the road detection problem. Specifically, in the overrepresentation of roads from the southern California desert in the testing images and a lack of normal roads with lines or roads with significant curves or differences in elevation. Not considering these things will likely result in significant error in the ray-based edge detection method and vanishing point estimation.

The methodology needs to be extended to consider normal paved and lined roads as well as more extreme road geometries and more geographically diverse road sets for the solution to truly be considered a general approach to the road detection problem. The algorithm should then also be extended to consider handling lots of obstacles on roads (including other vehicles) which are a practical necessity in non-remote road conditions.

An immediate recommendation for improvement can be made in the use of convolutional neural networks which have progressed this problem space significantly since this paper was published in 2010 [2]. However, it is not reasonable to expect the paper itself to have taken these technological advances into account at the time. But this is where a significant amount of the work in autonomous driving solutions is conducted in the current day technology space.

The greatest strength of the paper is the improvements it made in direct comparison to some prior papers especially in computational efficiency vs accuracy. Its greatest weakness is its lack of generality in its testing sets, methodology setup and decision making. Overall, the paper makes a relatively useful contribution to research relating to autonomous driving.

References

[1] S. Marĉelja, "Mathematical description of the responses of simple cortical cells*", Journal of the Optical Society of America, vol. 70, no. 11, p. 1297, 1980. Available: 10.1364/josa.70.001297 [Accessed 20 August 2020].

[2] J. Kocić, N. Jovičić and V. Drndarević, "An End-to-End Deep Neural Network for Autonomous Driving Designed for Embedded Automotive Platforms", Sensors, vol. 19, no. 9, p. 2064, 2019. Available: 10.3390/s19092064 [Accessed 20 August 2020].