Free-Space Segmentation based on Online Disparity-supervised Color Modeling

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Abstract

This work contributes to vision processing for Advanced Driver Assist Systems (ADAS) and intelligent vehicle applications. We propose a color-only stixel segmentation framework to segment traffic scenes into free, drivable space and obstacles, which has a reduced latency to improve the real-time processing capabilities. Our system learns color appearance models for free-space and obstacle classes in an online and self-supervised fashion. To this end, it applies a disparity-based segmentation, which can run in the background of the critical system path, either with a time delay of several frames or at a frame rate that is only one third of that of the color-based algorithm. In parallel, the most recent video frame is analyzed solely with these learned color appearance models, without an actual disparity estimate and the corresponding latency. This then translates into an improved response time from data acquisition to data analysis, which is a critical property for high-speed ADAS.

1. Introduction

At present, vehicles are becoming increasingly intelligent with so-called Advanced Driver Assistance Systems (ADAS). This development is expected to significantly reduce traffic accidents, traffic congestion and fuel consumption. In this context, color-camera systems are shown to be a reliable source of information for appearance-based analysis [1]. Additionally, stereo-vision camera-systems are employed, since they can provide a dense estimate of the 3-D geometry of a scene in real time and at a more affordable price point than high-end systems that rely on lasers, often accompanied with RTK-GPS. Recently, promising frameworks have been presented that segment traffic scenes into ground and obstacle regions by exploiting the stereo 3-D information (the stereo disparity signal), either as the single source of information [2], or fused together with the corresponding color signal [3]. The fusion method increases the robustness to difficult imaging conditions that lead to erroneous disparity analysis. Both systems require the availability of the disparity signal to analyze the most recent frame.

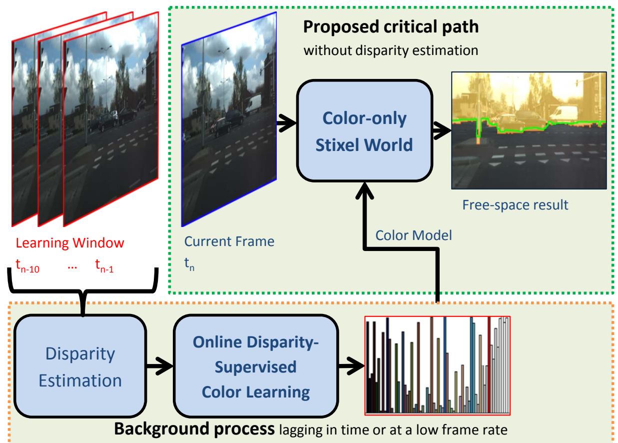

Figure 1. Our proposed framework without disparity estimation in its critical path [4], in contrast to previous systems such as [2].

In our current system, this requirement is avoided, so that the disparity estimation can be removed from the critical path to reduce the system latency without decreasing the system performance. This then translates into an improved response time from data acquisition to analysis, which is a critical property for high-speed ADAS.

2. Method

Our proposed method is depicted Fig. 1 and consists of two processes, executed in parallel: (a) the color-based free-space segmentation in the current frame and (b) the online disparity-supervised color modeling using previous frames.

2.1. Color-only free-space segmentation

The color-only analysis of the current frame consists of several steps: (a) perform histogram equalization on the color frame; (b) reduce the color space using minimum-variation quantization; (c) calculate the first and second mode in 11×11 windows; (d) employ our distance-aware color-only Stixel World, which is a MAP optimization that is solved efficiently using Dynamic Programming.

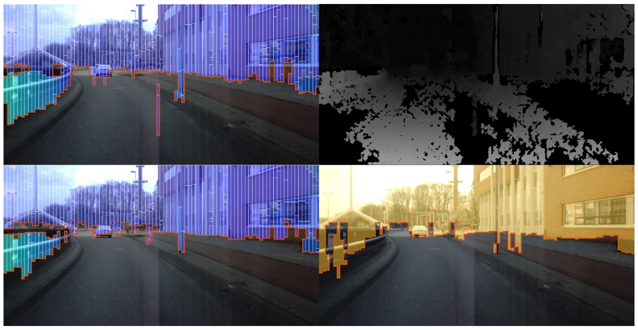

Figure 2. Results with low-light conditions and camera reflections for the disparity-only method [2] (top left), the fusion method [3] (bottom left) and our distance-aware color-only result with the same improvement [4] (bottom right). Top right: noisy disparity.

Figure 3. Results under low-light conditions: the brightened left camera image with a region of interest (top left), the results of [3] with partially undetected cars (bottom left), our color-only result (top right) and our distance-aware color-only result (bottom right).

2.2. Online color-modeling

In the background of the critical path, we employ an online color-modeling process to capture relevant and discriminative information of the current traffic scene. This process consists of several steps: (a) estimate the disparity of several preceding frames; (b) segment each image into *ground* and *obstacle* regions using an improved version of the disparity-only Stixel World of [2]; (c) with these regions, calculate color histograms using real-world pixel surfaces to balance image regions nearby and far from the camera; (d) translate the histograms into class-posteriors with Bayes' rule.

3. Experiments

We have evaluated our algorithm on publicly available stereo RGB data EHV-road-ITSC15 [4]. The data consists of a large variety of relevant traffic situations, such as dark roads with cyclists and cars, road repair sites, highway scenes, etc. The data is focused on scenes under dim, clouded or rainy conditions, leading to many low-contrast regions that are difficult for disparity-based methods.

Two figures illustrate the qualitative contribution of our method. Fig. 2 shows that the fusion method resolves a false obstacle that is caused by erroneous disparity on light reflections, and that the new color-only method achieves the same improvement with less processing. Fig. 3 provides an example where the fusion method partially misses several cars, due to the high uncertainty of the disparity at that distance and the low contrast of the color signal, an issue that is resolved with our proposed color modeling.

The quantitative results are summarized in Table 1, where we show the percentage of image columns for which the free space was detected correctly. First, note that our current metric is more strict and covers a larger distance than in [3], which is not in favor of the fusion method. Second, our proposed color method grows the percentage of correct free-space detections by 3.6%, as shown in the third row of Table 1. The bottom row illustrates that our method provides comparable results, even when the color modeling runs at a lower frame rate.

method	score
Disparity [2]	74.39 %
Disparity+Color fused [3]	60.9 %
Color (full FPS color modeling) [4]	78.01 %
Color (1/3 FPS color modeling) [4]	77.86 %

Table 1. Quantitative results: the percentage of image columns where the free space is correctly detected.

4. Conclusion

We have presented a framework for distance-aware color-based free-space segmentation that learns color appearance models for free-space and obstacle classes in an online and self-supervised fashion. Our algorithm outperforms previous systems under difficult imaging conditions, while we simultaneously facilitate an improved system latency.

References

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