Automated Tire Footprint Segmentation

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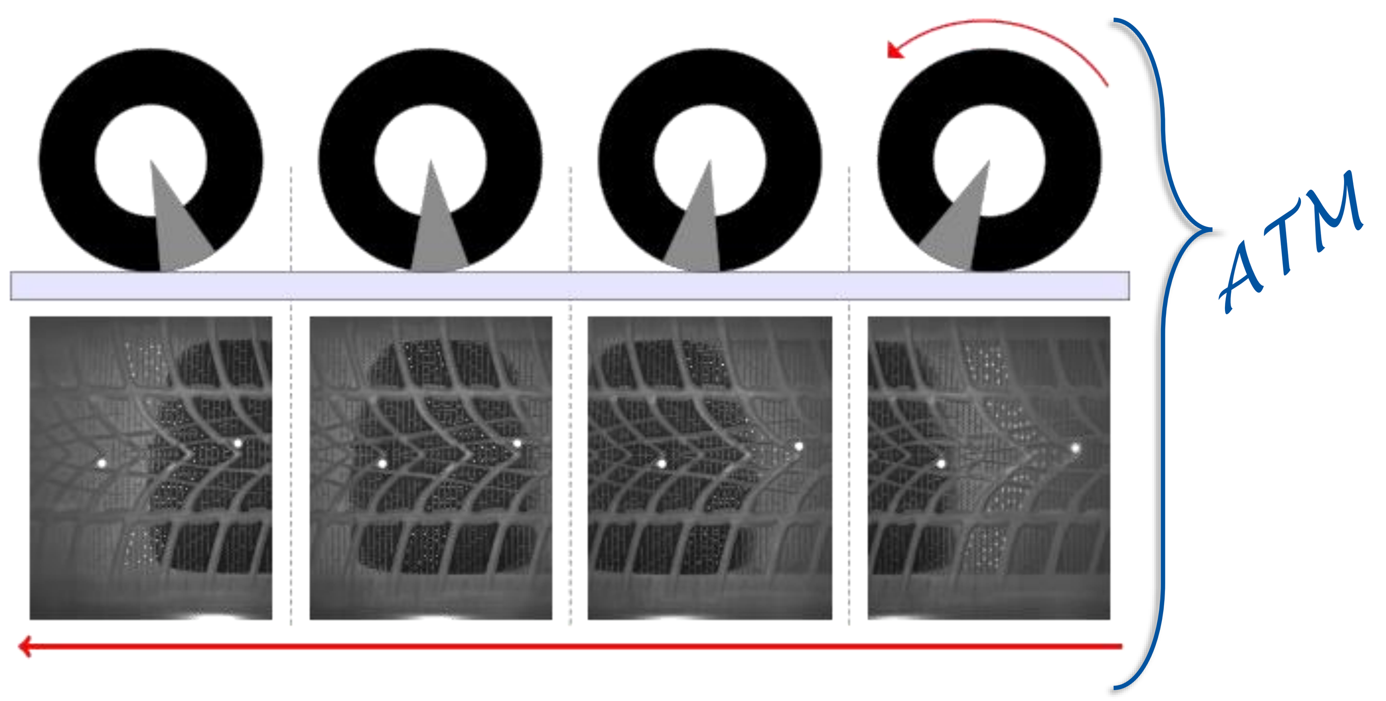
INTRODUCTION

The area of contact between the tire and the road surface, commonly named **tire footprint**, plays an important role in tire performance. However, its inspection is a time consuming task and a simple geometric model is used generally.

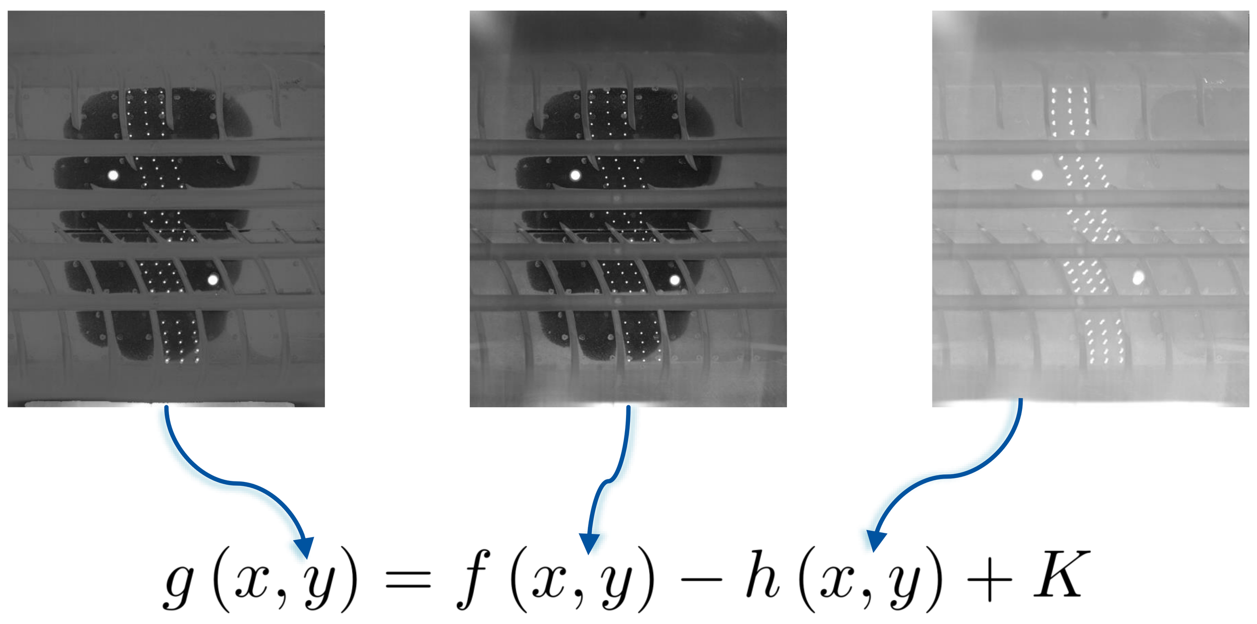
We propose a novel technique to segment dynamic tire footprint. This represents a new approach in tire mechanics.

- Acquisition of video sequences with an automatic test machine (ATM).
- Contrast enhancement via Illumination compensation.
- Superpixels and Graph cuts to segment the tire contact patch.
- Refinement of boundaries and rolling circle filter to generate a binary mask.
- Quantitative analysis with an estimated average tire footprint.



1 - ILLUMINATION COMPENSATION

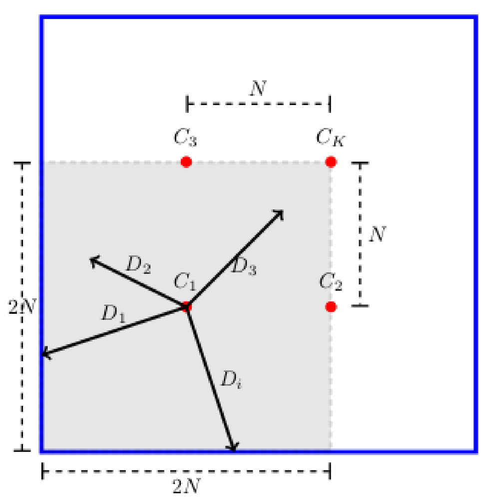
Gray levels constitute the main source of information that can be used for estimating the tire footprint. However, intensity values are affected by noise and non-uniform illumination conditions. We use a **retrospective model** to enhance the tire footprint from the background.



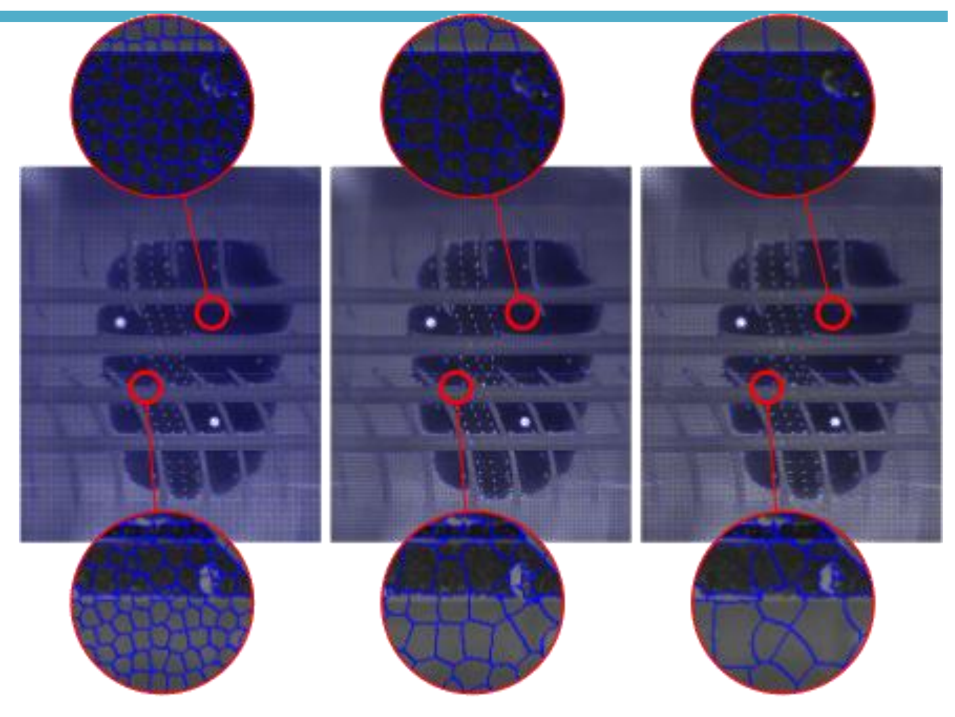
$$g(x,y) = f(x,y) - h(x,y) + K$$

2 - FEATURE EXTRACTION AND CLUSTERING

SLIC SUPERPIXELS



$$D = \sqrt{d_c^2 + \left(\frac{m^2}{N^2}\right) d_s^2}$$

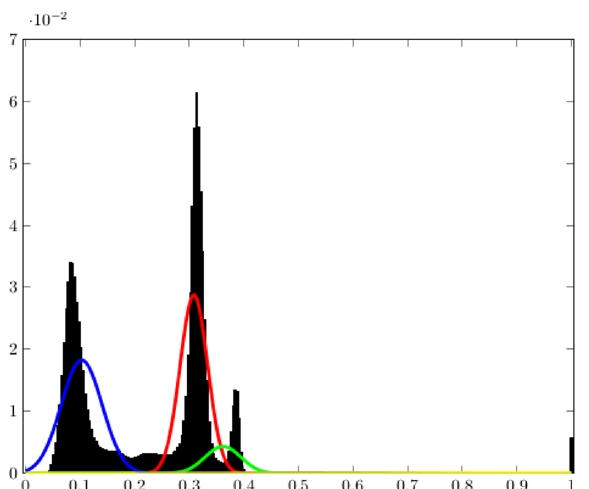


$$\boldsymbol{x}_p = [\mu_p,\ \max_p,\ \min_p,\ \mathrm{posx}_p,\ G_{p,\sigma_i}]$$

$$G_{p,\sigma_i} = \mathrm{mean}\left\{ g(x,y) * e^{-\frac{(x^2+y^2)}{2\sigma_i^2}} \Big|_p \right\}$$

$$\sigma_i = \sqrt{1.5}^{\,i} \ \text{with}\ i = \{0, \ldots, 7\}$$

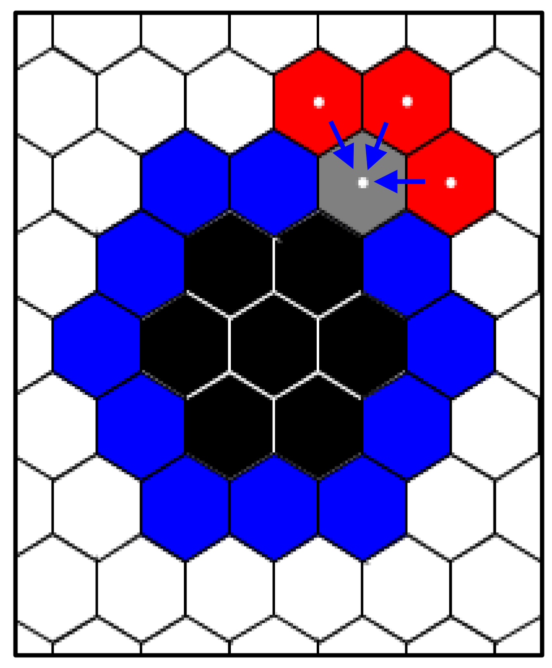
GRAPH CUT SEGMENTATION

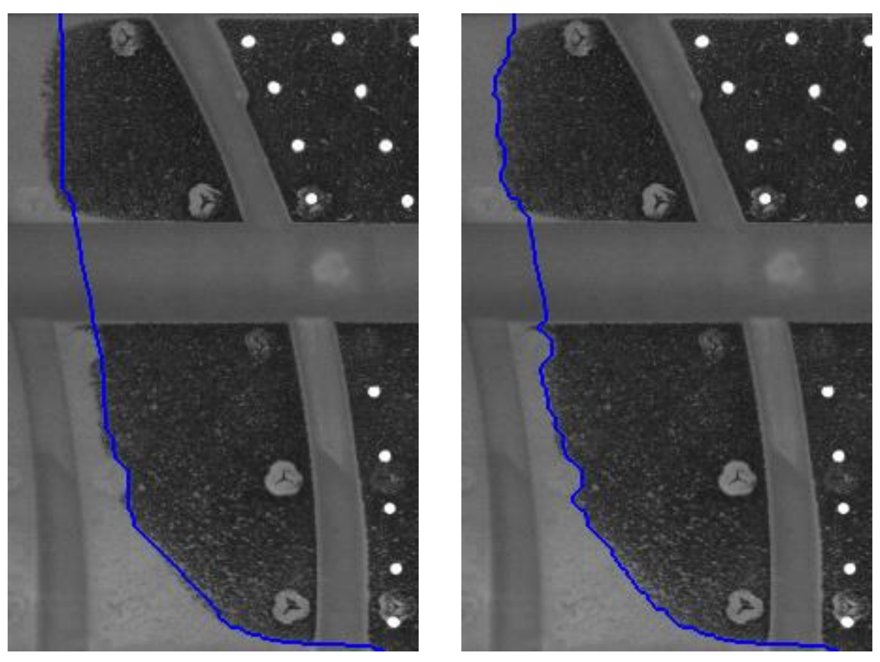


Graph cut is a powerful and suitable tool for segmentation in n-D images. They find the optimal segmentation with respect to an objective function that contains two terms: region-based and boundary term.

3 - BOUNDARY REFINEMENT

Due to the smooth transition between the **non-contact area** and the **slip region**, it is not clear where the segmentation should be stopped. The affinity between the contact area and the slip region leads Graph cut to fail in reaching the boundary of the tire footprint.





$$d(x,y) \leq k_d * d(\mu_j, y)$$

ROLLING CIRCLE FILTER

The **Total Area** of contact is defined as the elliptical contact area between the tire and the surface without considering any grooves. We designed a rolling circle filter to compute a mask that covers the segmented tire footprint.

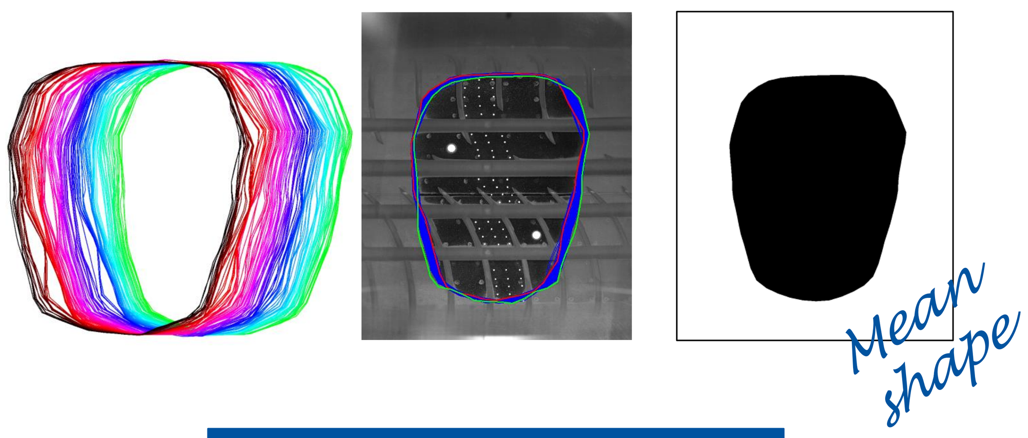
The algorithm uses a circle that rolls around the segmented tire footprint to calculate the contact points.

The implementation of the rolling circle filter is made by convolving a circle template with the segmented tire footprint. Then, the contact points are linked with a B-spline.

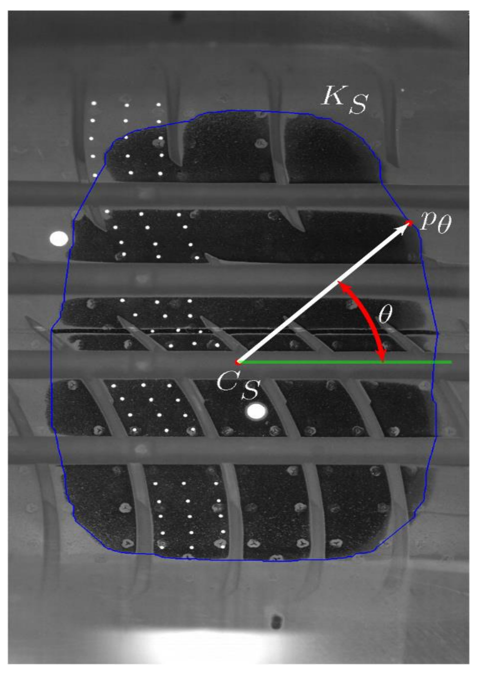
4 - EVALUATION WITHOUT GROUND TRUTH

Another **contribution is** a novel methodology to compare segmentation performance even if a ground truth is not available.

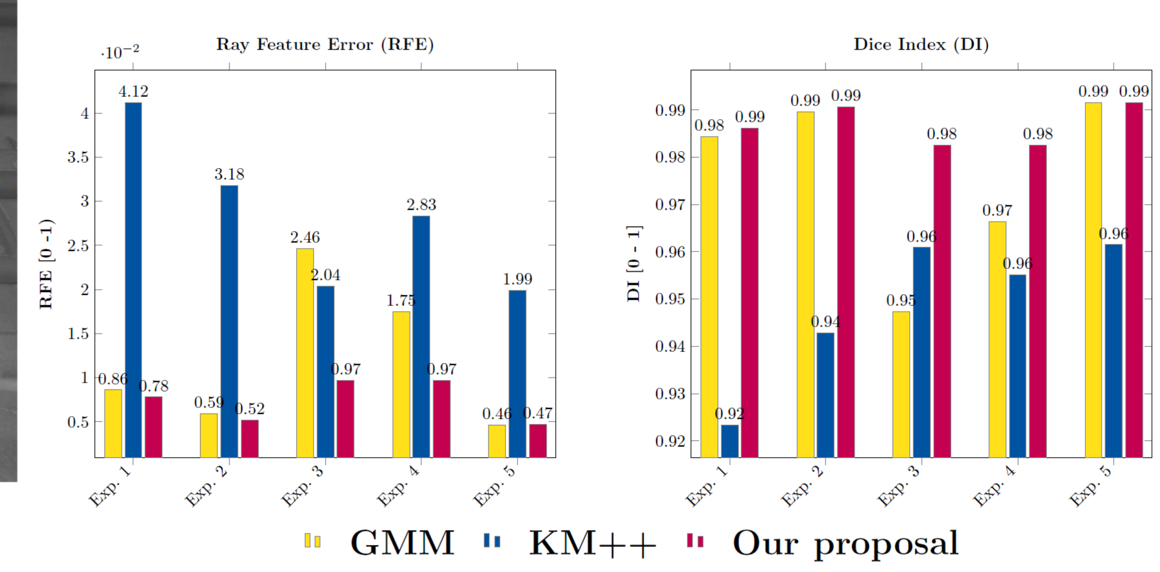
SEGMENTATION – ALIGNEMENT – AVERAGE MASK



RAY FEATURE DESCRIPTOR



EXPERIMENTAL COMPARISON



CONCLUSIONS

- We developed a **new method** for tire footprint segmentation. Since no ground truth is available, we also proposed a method of creating an estimated ground truth that can be used to assess the quality of the segmentation algorithms.
- The main difficulty is the non-uniform illumination. We **included a step that minimizes** the effects of the lighting conditions. The inclusion of superpixels improved the coherence of the segmentation. Further research is needed to improve background estimation.
- As far as we know, **our work is the first method** of analyzing quantitatively different approaches for tire footprint segmentation by estimating the ground truth. Extensions of this approach can be applied to other image modalities and domains.

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