VEHICLE IDENTIFICATION IN TUNNELS BY USING THE TRACE TRANSFORM

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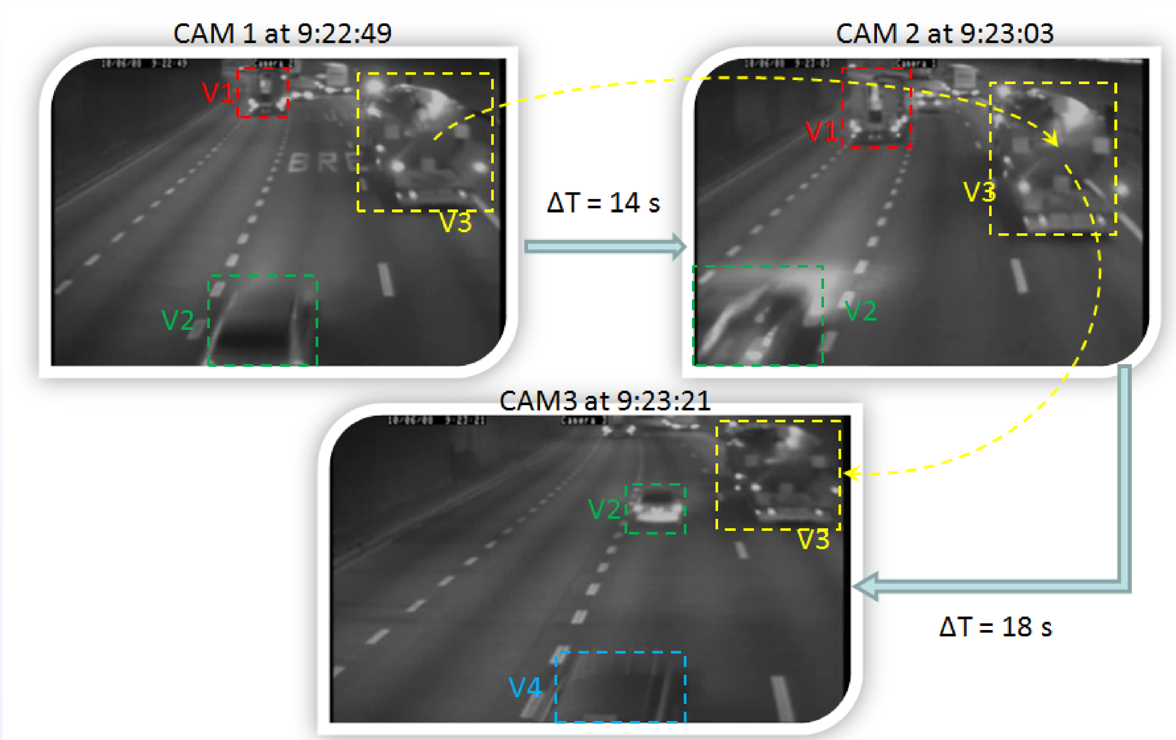
Abstract

This work presents a vehicle identification approach for a multi-camera tracking setup distributed along a tunnel. Salient features, called signatures, are extracted through the *Trace Transform* by applying geometrical invariant functionals to the vehicle images. These sorts of affine-invariant features outperform interesting point detectors under challenging illumination conditions and low resolution images.

Multi-camera Tracking



Scene Conditions in Tunnels

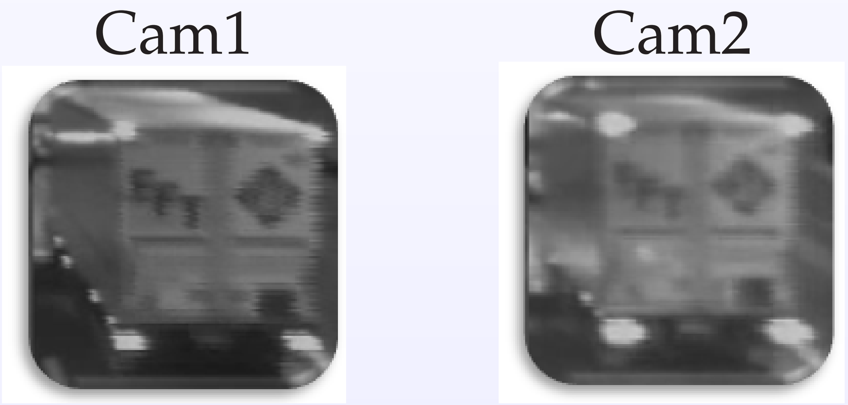
Photometrical Variations:

- Strong uneven illumination.
- Reflections on the road and over the vehicle bodywork.
- Rear tail lights are not always turned on.

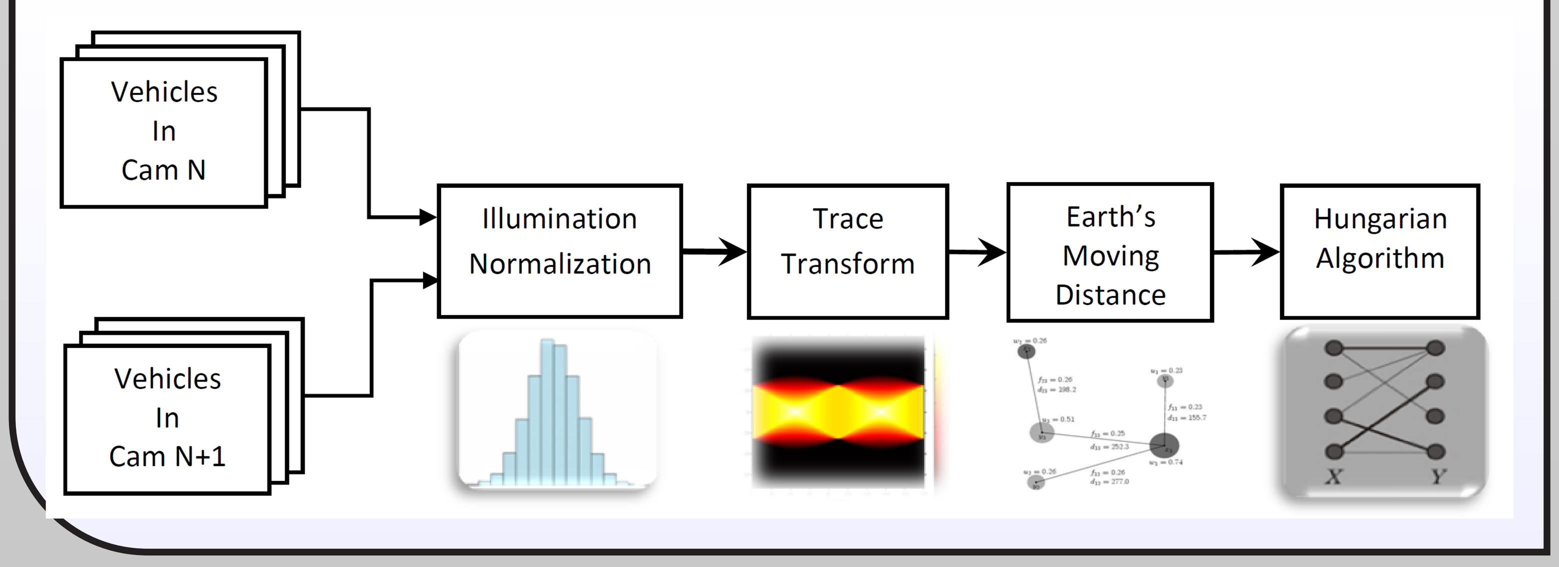
Geometrical Variations:

- Shift, scale, and projective variations.
- Position of the camera.

Cam1 Cam2



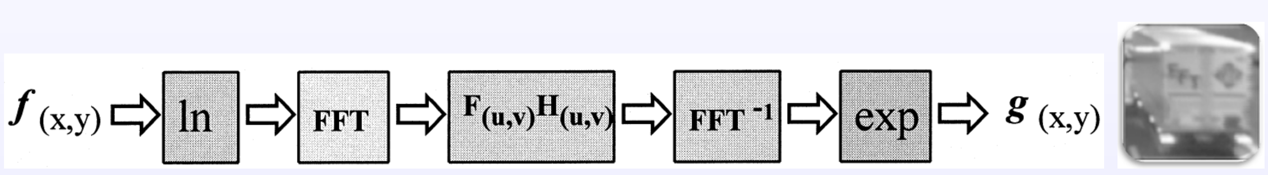
Proposed Method



Illumination Normalization

Illumination-Reflectance Model: $f_{(x,y)} = i_{(x,y)} * r_{(x,y)}$

Block Diagram of the Homomorphic Filtering:



Trace Transform

The Trace Transform

- Is a generalization of the Radon transform.
- Functionals are applied along batches of parallel lines tracing the image in all possible orientations.

Hess Mapping

$$x * cos(\phi) + y * sin(\phi) = \rho$$

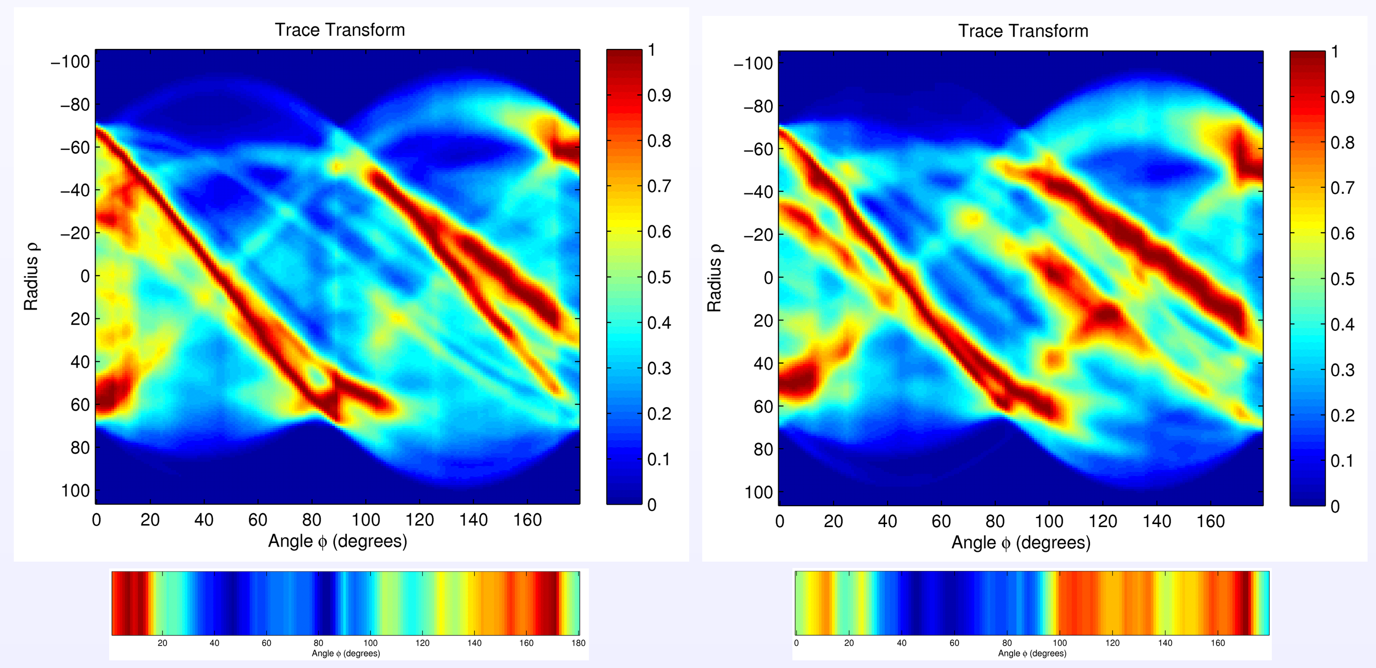
Functional:

$$T(f(x)) = \int \frac{f(r)dr}{r}$$

$$\text{where } r = x + \delta - c$$
$$\text{and } c = WM_X\{x, f(x)\}$$

Invariants:

$$T(f(x+\alpha)) = T(f(x))$$
$$T(f(\beta * x)) = T(f(x))$$
$$T(f(\beta * x)) = \beta^{\lambda} T(f(x))$$

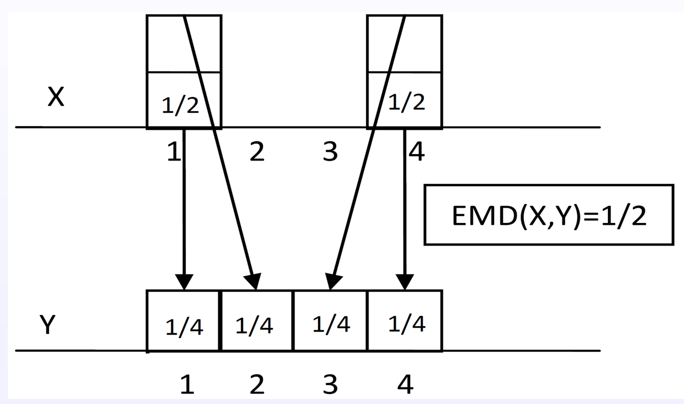


Earth's Moving Distance (EMD)

The Earth Mover's Distance (EMD) reflects the minimal work needed to transform one signature into the other by moving the "distribution mass"around.

Features:

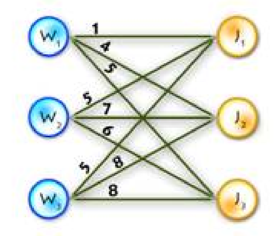
- Robust against different quantization of the signatures.
- Partial matching is allowed, and with signatures of different size.
- EMD is a *true* metric.



Hungarian Algorithm

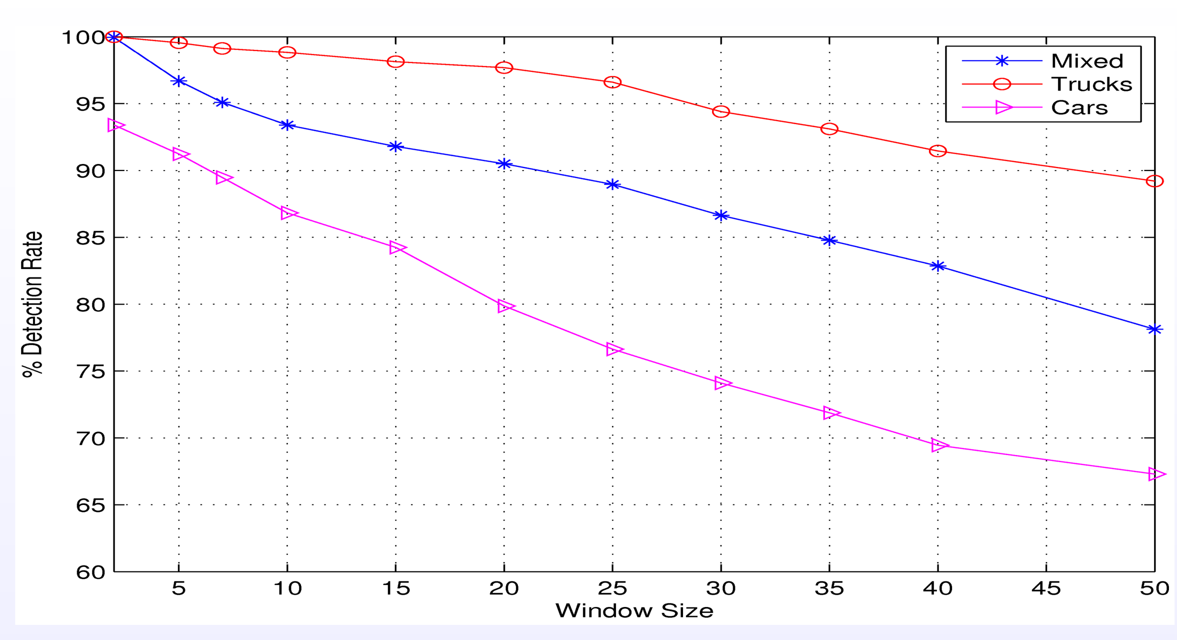
The Hungarian algorithm optimally assigns n vehicles in Cam 1 to m vehicles in Cam 2, assuming a numerical costs for each possible assignment resulting from the EMD metric.

$$\begin{pmatrix} 1 & 4 & 5 \\ 5 & 7 & 6 \\ 5 & 8 & 8 \end{pmatrix} \Leftrightarrow$$



Results

- A total of 480 vehicles were tested (149 trucks and 331 cars).
- 4 signatures were used.
- Trucks are better recognized due to their size and inherent distinctive features.
- Car detection can be improved by using context information and multiple vehicle templates.



Conclusions

The proposed method performed fairly well considering the challenging illumination conditions and geometrical variations of the images. A robust illumination normalization technique along with context information and multiple template are the key to improve current results.