Stereo cameras with applications to traffic scenarios, traffic light detection

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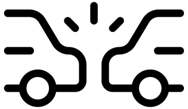
MOTIVATION



SAFE DRIVING WITHOUT ACCIDENTS

The disregard of traffic lights by drivers is one of the major causes of traffic accidents

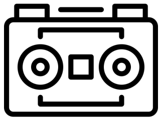
SELF DRIVING CAR BECAME THE PART OF HUMAN ROAD TRAFFIC

Report forecasted that roughly 33 million autonomous cars will hit the road by 2040

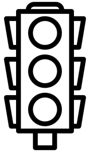
Nearly 43% of people in the US don't feel safe in a driverless car. But with a save robust algorithms providing non-crash driving, people are expected to get used to driverless cars.


coop
coop
60
TESLA FAIL !

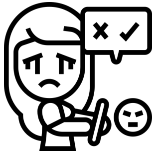
Why traffic detection is challenging?



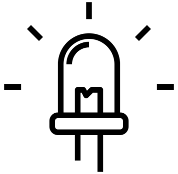
Traffic lights have to be detected in advance before passing the stop line. Camera needs to cover a high field of view.



The colours of traffic lights can be easily over-saturated and appeared to be white. Thus it's hard to distinguish red and green.



False detection of color (like green light in shining sun through trees) can lead to an incorrect action and humans' death.



New LED lights blink at a high frequency and can appear all turned off on camera frames.

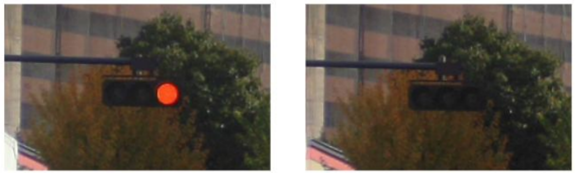
3D position and orientation estimation is not enough to make a decision.

Additional information such as shape or position is required for correct detection.

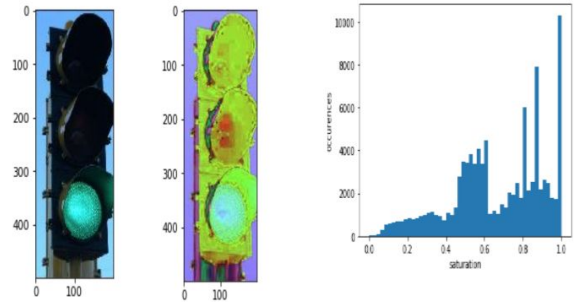
Report Structure

- What is stereo vision
- Traffic lights as a special perception problem
- CNN for object detection
- Traffic light mapping
- Color pixels detection
- Shape, texture and color detection
- Color saturation approach
- High frequency detection

(a) Over-saturated pixels



(b) Blinking light



(a) Original (b) Saturation (c) Saturation Plotting

About a Stereo Camera

To be able to drive autonomously a vehicle has to have eyes, not real eyes, but cameras.

The stereo camera s a type of camera with **two or more image sensors.**

By using the difference in image location of an object seen by the left and right cameras can be calculated using the cameras' horizontal separation.

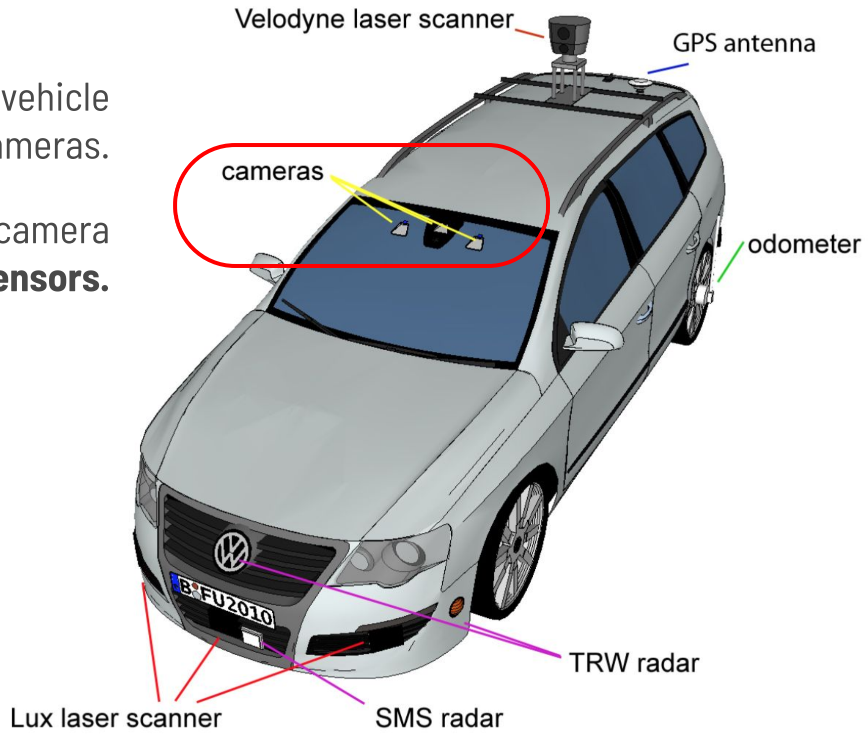


Image: https://autonomos.inf.fu-berlin.de/vehicles/made-in-germany/

About a Stereo Camera

Triangulation is used to estimate the position of an object.

Cameras look at an image **from different angles**, the difference between the two point of view can be computed and a distance estimation established.

We have to distinguish the distance to the traffic lights since only the near traffic light is important for determining the next maneuver.

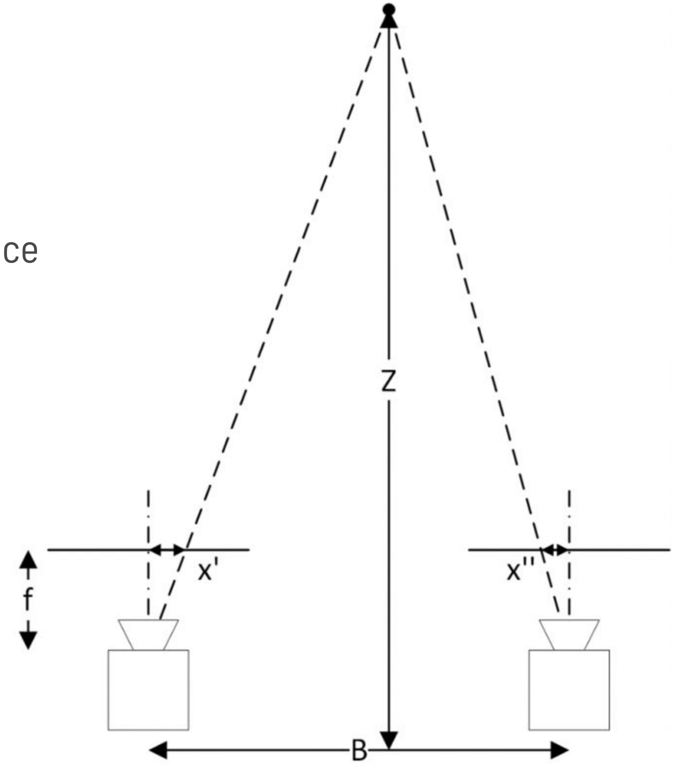


Image: https://murmotorsports.eng.unimelb.edu.au/news-and-events/news-and-events/mur-blog-getting-started-with-stereo-vision

Camera Setup

The camera's parameters must be first calibrated.

[X,Y,Z] → [X,Y]

3D point from the world coordinates

pixel coordinates going through camera coordinates

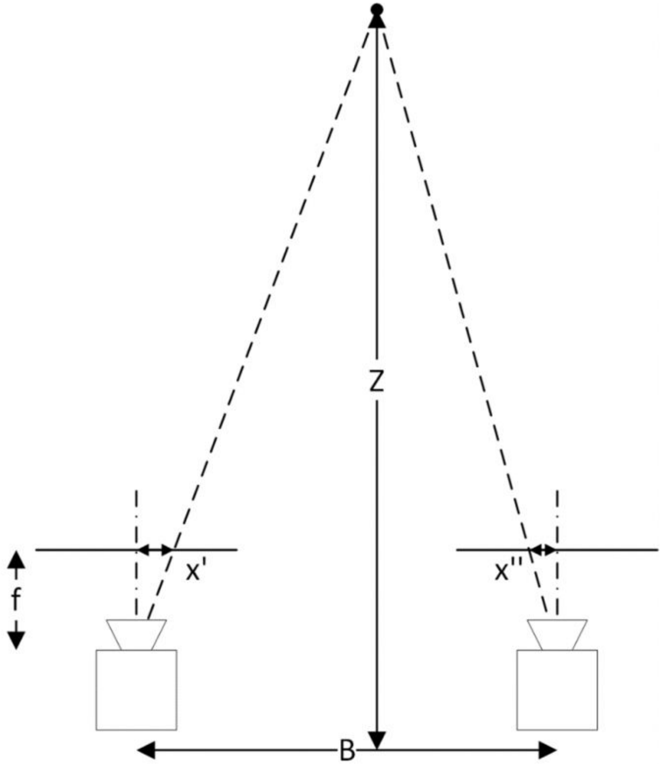


Image: https://autonomos.inf.fu-berlin.de/vehicles/made-in-germany/

CNN for object detection

Faster R-CNN

Consists of two CNNs and can detect 20 types of objects including humans and vehicles.

Traffic lights as are commonly a small part of the image what makes the detection task more difficult even for R-CNN

YOLO CNN

Has two stages of detection and classification separately

Great performance as a detection rate. The computational and processing result is slower with two stages.

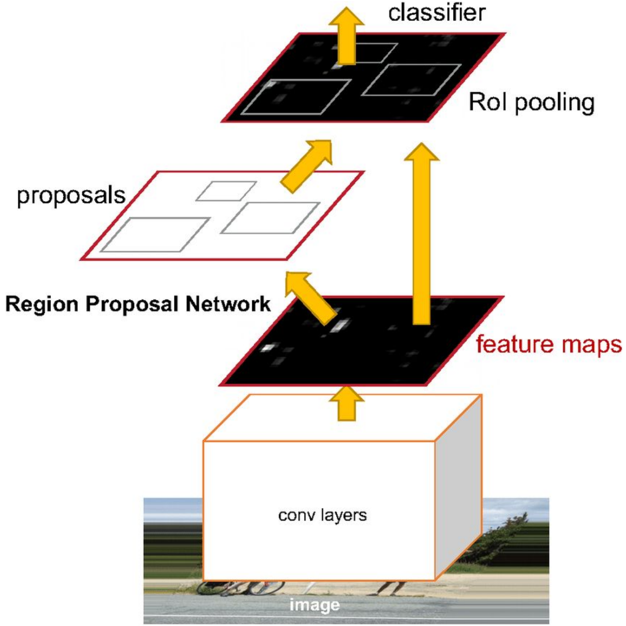


Image: https://www.researchgate.net/publication/324549019_Towards_Real-Time_Smile_Detection_Based_on_Faster_Region_Convolutional_Neural_Network/figures?lo=1&utm_source=google&utm_medium=organic

TRAFFIC LIGHT MAPPING

- The precise position of traffic lights is not generally available
- Prior map indicates when and where a vehicle should be able to see a traffic light.
- Traffic lights will mostly occur at intersections.
- To reduce dataset we can discard images taken when no intersections are likely to be visible

Image: Nathaniel Fairfield, Chris Urmson. Traffic Light Mapping and Detection.

TRAFFIC LIGHT MAPPING

- Thousands of human-labeled traffic lights are used as a base for a classifier training.
- Thousand intersections and over 4000 lights were mapped manually by researches.
- In the August 2020 Google has started testing a new feature that will show traffic lights in Google Maps on Android.

Image: Nathaniel Fairfield, Chris Urmson. Traffic Light Mapping and Detection.

COLOR PIXELS DETECTION

- The **position** of the red, yellow and red lights is **fixed** and can help to detect a right color.
- Using HSV color space the **color data** of the traffic lights results in **H channel**.
- The Saturation component signals how much the color is **polluted with white color**.
- Choosing the area with the high saturation and high hue values as the area to mask yielded a good result in detecting the traffic light color correctly

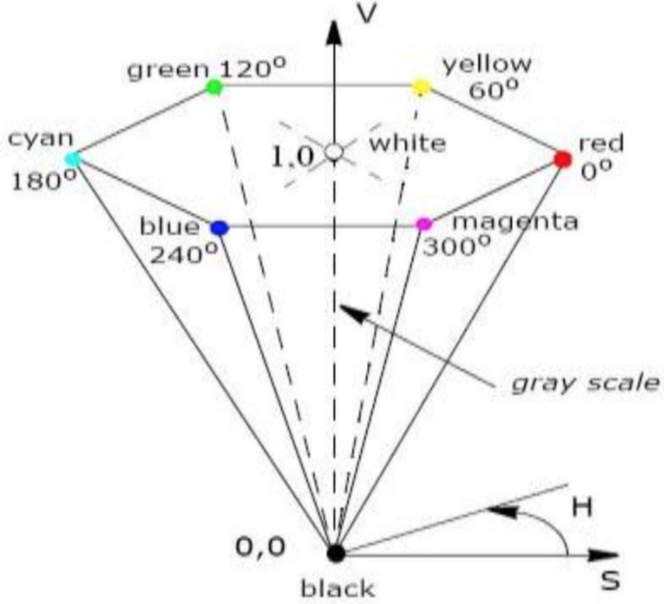
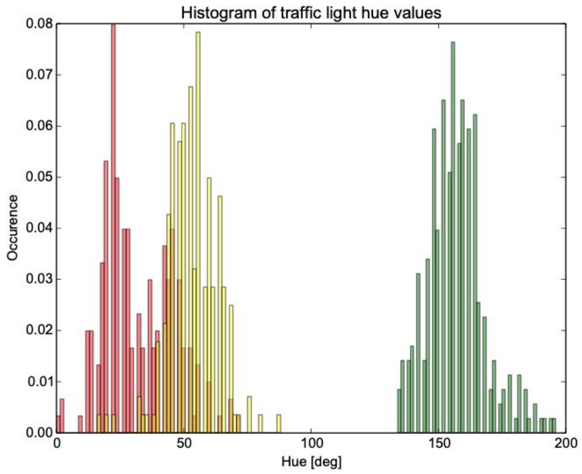


Image: Nathaniel Fairfield, Chris Urmson. Traffic Light Mapping and Detection.

COLOR PIXELS DETECTION

- Known geometry of traffic lights can be used to construct traffic-light entities consisting of one lit and two unlit circular light sources on a rectangular dark-colored frame

- Most of color-matching pixels can be rejected very fast because of the height of their position on the street or distance to the vehicle.



Distribution of hue angles for red, yellow and green traffic-lights.

Image: Tobias Langner, Daniel Seifert, Bennet Fischer, Daniel Goehring, Tinosch Ganjineh.

SHAPE, TEXTURE AND COLOR DETECTION

A robust detection approach using either color, shape or/and texture as key features.

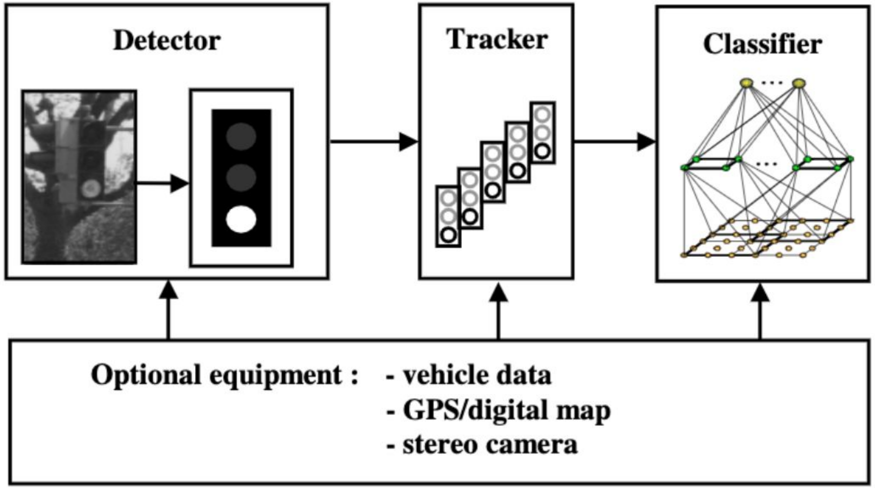
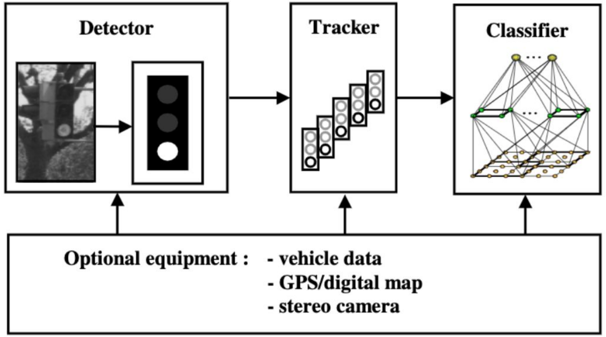


Fig. 1. System architecture for the traffic signal recognition system: detector, tracker, and classifier, supported by other information.

Image: Frank Lindner, Ulrich Kressel, Stephan Kaelberer. Robust Recog- nition of Traffic Signals.

SHAPE, TEXTURE AND COLOR DETECTION

- Detector scans each frame for traffic signal
- Tracker groups these candidates over several frames to form an hypothesis
- Classifier verifies whether candidate is a traffic signal or not, and classifies the status of the traffic signal (red, yellow or green)
- Detector could miss only very few traffic lights. Gaps can be filled by the tracker.



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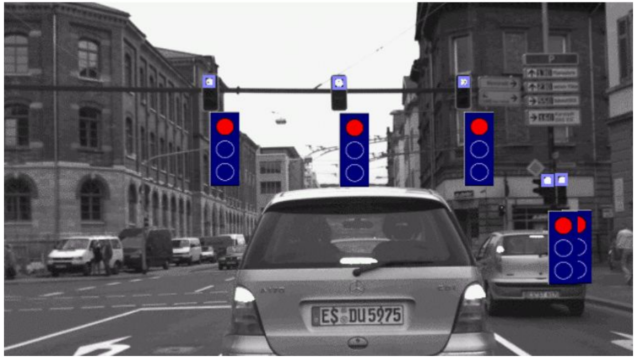
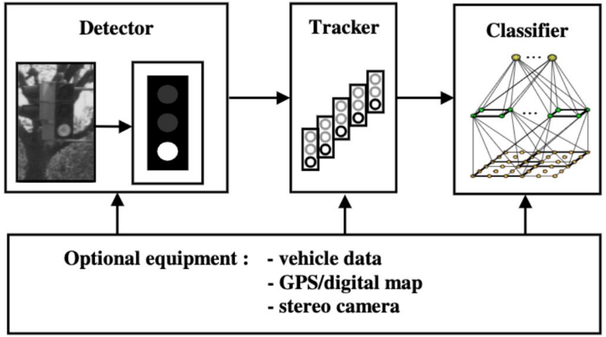


Image: Frank Lindner, Ulrich Kressel, Stephan Kaelberer. Robust Recog- nition of Traffic Signals.

SHAPE, TEXTURE AND COLOR DETECTION

- Tracker detects lights and fills the gaps using the relative location, speed and acceleration between the moving camera and the signal.
- Tracker suppresses detection of false candidates in inhomogeneous regions such green trees.
- True positive, hidden by traffic participants or other obstacles, can also be detected by analyzing last frame with positive detection.



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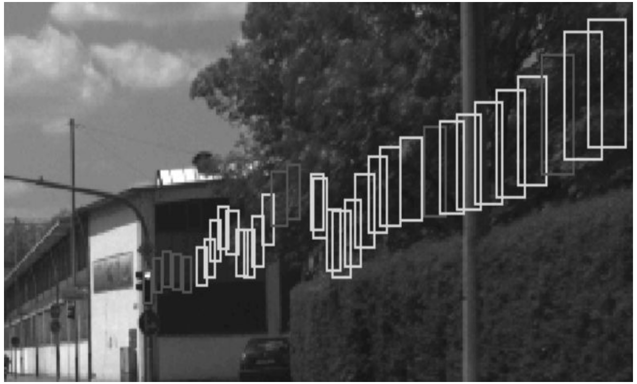
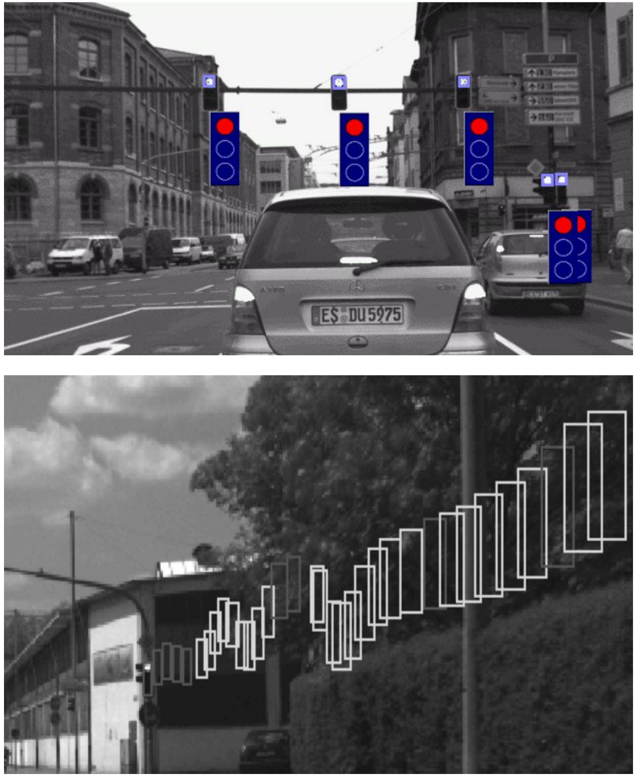


Image: Frank Lindner, Ulrich Kressel, Stephan Kaelberer. Robust Recog- nition of Traffic Signals.

SHAPE, TEXTURE AND COLOR DETECTION

- Generalized Hough transform using Sobel based gradient directions are used for circle finder.
- Traffic lights are detected if the diameter is larger than 6 pixels.
- Even slightly distorted lights can be detected
- Reached recognition rates for the complete system is of over 80%



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COLOR SATURATION APPROACH

- Digital camera can easily over-saturate in various condition captured luminous objects.
- The L*a*b* model is used in order to separate intensity and color information.
- Each region is compared to the standard size of a traffic light, and candidates are selected.
- Kalman filter is introduced to track the changing of position of the each candidate

(a) Cloudy, green bulb, 10×11

(b) Cloudy, yellow bulb, 13×14

Image: Hiroki Moizumi, Yoshihiro Sugaya, Masako Omachi, Shinichiro Omachi.

COLOR SATURATION APPROACH

- L*- component is the lightness and is used for detecting over-saturated pixels.

- a* and b* components are used for detecting pixels of the typical red, yellow, and green colors.

- Using multiple images histograms for each color are constructed and normalized.

- After typical colors were selected, over-saturated pixels then can be detected.

(a) Cloudy, green bulb, 10×11

(b) Cloudy, yellow bulb, 13×14

Image: Hiroki Moizumi, Yoshihiro Sugaya, Masako Omachi, Shinichiro Omachi.

HIGH FREQUENCY DETECTION

- New installed traffic lights work with light-emitting diodes.
- LED displays are free of phantom images and use much less energy.
- LED lights blink at high frequency and seem to be turned off on photo.
- These frequencies are known and thus can be detected!

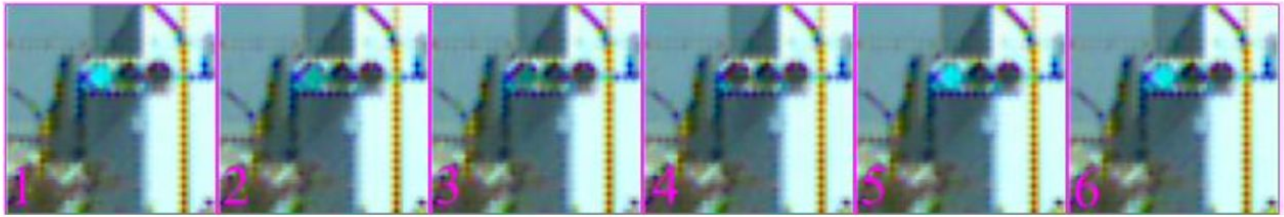
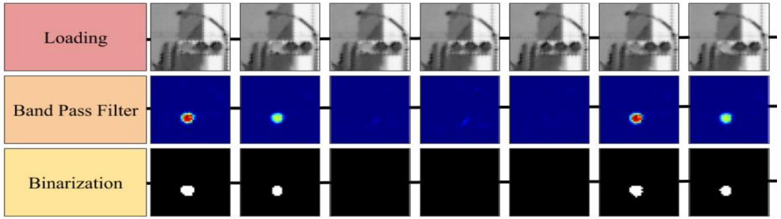


Figure 1. Example of the blinking of LED traffic light observed by a 500 fps camera. The time intervals are 2 ms.

Image: Real-Time Traffic Light Detection with Frequency Patterns Using a High-Speed Camera. Kento Yabuuchi

HIGH FREQUENCY DETECTION

- Standard band-pass filter fails with real-time calculations.
- Binarizing of the image before band-pass increases performance.
- Last five images are used to detect the blinking area



Example of the traffic lights with the same blinking phase.

Image: Real-Time Traffic Light Detection with Frequency Patterns Using a High-Speed Camera. Kento Yabuuchi

CONCLUSIONS

- The most important methods for detecting traffic lights is presented.
  - Detection of traffic lights using prior-created map
  - Using knowing shape, texture and positions of lights
  - Color detection using HSV and L*a*b* color spaces
  - Avoidance the over-saturated colors
  - Capture the color of high frequency LEDs

Traffic light detection remains a **difficult problem**
The captured images are overloaded with the objects in the urban environment.

The existing methods rather possible to use as a warning system for a driver and must me improved

Image: Real-Time Traffic Light Detection with Frequency Patterns Using a High-Speed Camera. Kento Yabuuchi

REFERENCES

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[2] Andreas Fregin,Julian Müller, Klaus Dietmayer. **Multi-camera system for traffic light detection: About camera setup and mapping of detections**

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[4] Nathaniel Fairfield, Chris Urmson. **Traffic Light Mapping and Detection.**

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[8] Kento Yabuuchi, Masahiro Hirano, Taku Senoo, Norimasa Kishi. **Traffic Light Detection with Frequency Patterns Using a High-Speed Camera**

Thank you for your attention!

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Do you have any questions?

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