Road Condition Assessment summary

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Artificial Intelligence & Information Analysis Lab

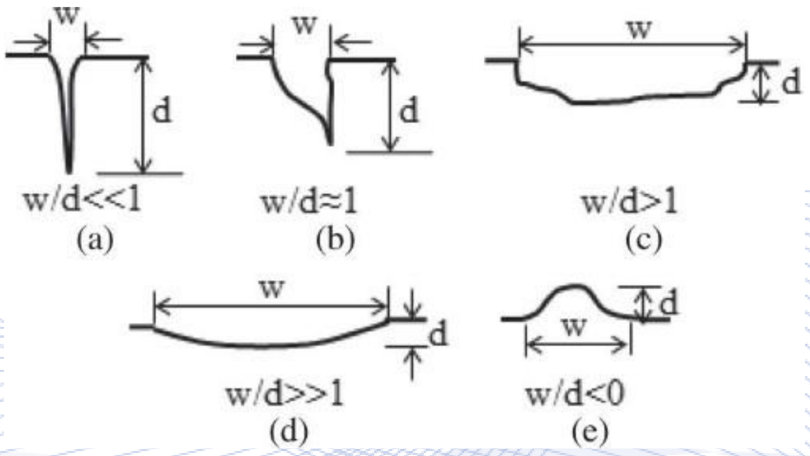
Road Condition Assessment

- Vibration sensing-based methods
- GPS-based methods
- Active sensing-based methods
- Passive sensing-based methods
- 2D image analysis-based methods
- 3D road surface modeling-based methods

Introduction

Q. How many different types of road damages?

A. There is an illustration of different road damage types:



Different types of road damages [2]; (a) crack; (b) spalling; (c) pothole; (d) rutting, and (e) shoving.

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Introduction

Q. Can you match the following figures with the five road damage types?

(a) (b) (c) (d) (e)

(a) crack; (b) spalling; (c) pothole; (d) rutting, and (e) shoving.

Introduction

The frequent detection of different types of road damage, e.g., road cracks and road potholes [3], is a critical task in road maintenance [2], because this can

- ensure traffic safety,
- allow governments to appraise long-term investment schemes, and
- help governments to allocate limited resources for road maintenance.

(a) (b) (c)

Road damage condition assessment; (a) road crack; (b) road pothole; (c) manual visual inspection.

State of the art

Over the past decades, various technologies, including:

- vibration sensing,
- active/passive sensing, and
- global positioning system (GPS),

have been utilized to acquire road data and aid personnel in localizing road damages [5].

Vibration sensing-based methods

Arduino vibration sensor: https://www.youtube.com/watch?v=IfP6UOsMZGE

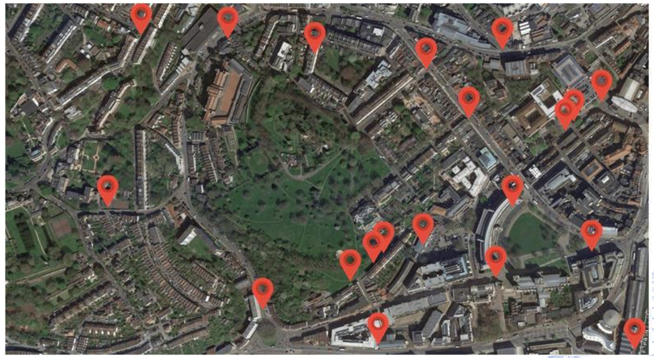
Advantages:

- small storage space,
- cost effectiveness, and
- real-time performance.

However, this kind of methods always cause road damage mis-detection [1].

GPS-based methods

Bristol online road damage report system:



Bristol online road damage report system.

However, the detection is not performed by certified inspectors, and the results are not quantitative.

Active sensing-based methods

Laser scanning-based method: Two laser scanners on a digital inspection vehicle (DIV) to collect 3D road surface data [6].

Semi or fully automatic data analysis for damaged road area detection. Such systems ensure personnel safety, but also reduce manual interventions to produce pothole detection results [6].

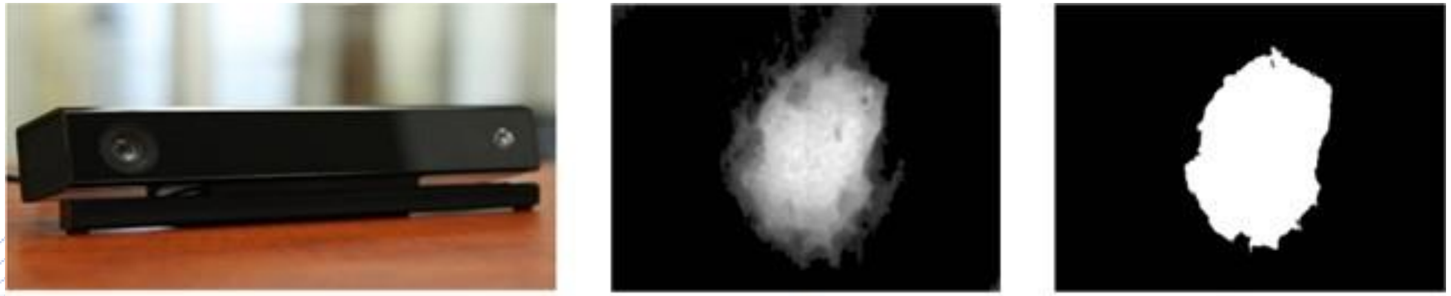
Digital inspection vehicle from the Georgia Institute of Technology.

Active sensing-based methods

Microsoft Kinect-based method:

Jahanshahi et al. [7] utilized a Kinect to acquire depth maps, from which the damaged road areas were extracted using image segmentation algorithms.

The Microsoft Kinect sensors were initially designed for indoor use. Therefore, they greatly suffer from infra-red saturation in direct sunlight [8].



(a) (b) (c)

Figure: Pothole detection using Microsoft Kinect sensor; (a) Microsoft Kinect; (b) depth image; (c) detection result.

Passive sensing-based methods

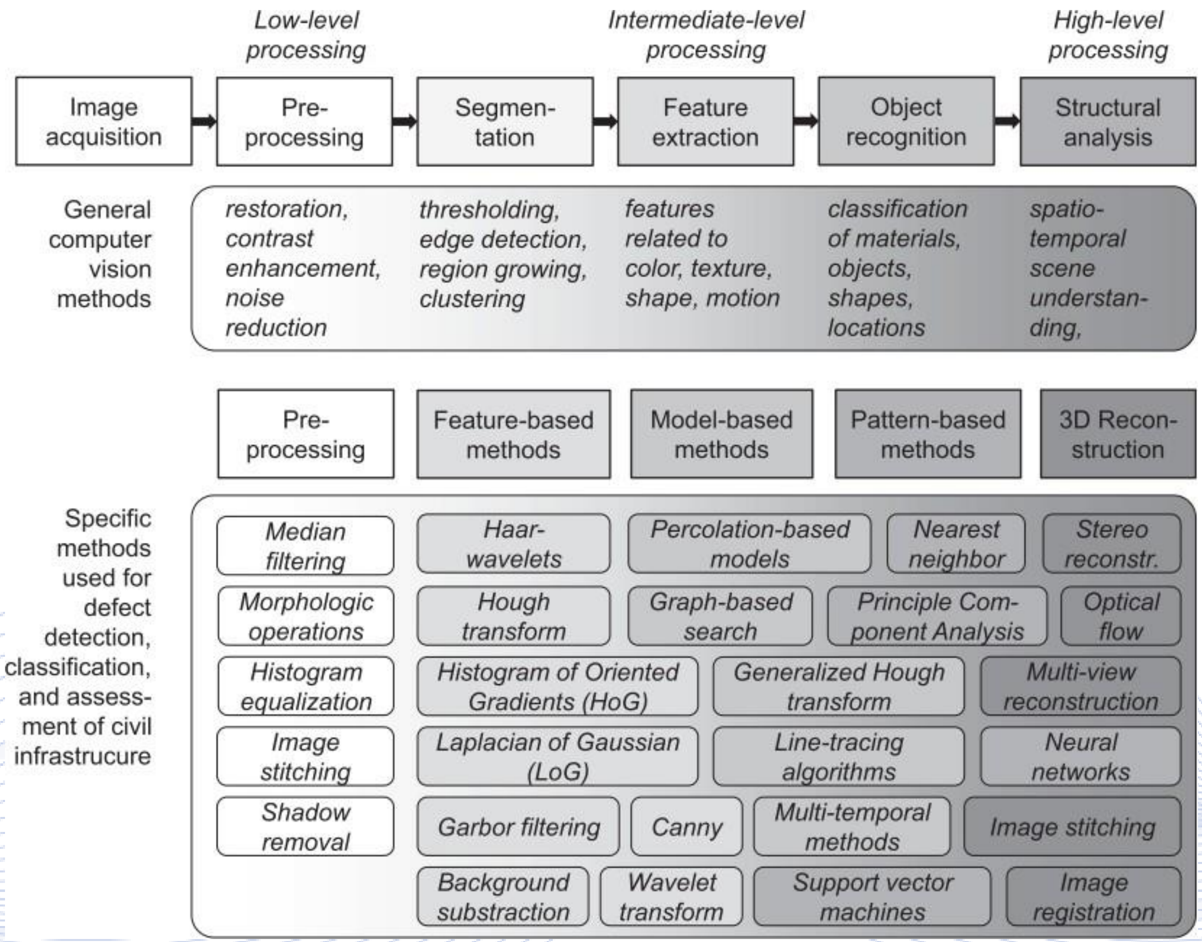


Figure: Categorizing general passive sensing-based methods [9].

2D image analysis-based methods

They typically consist of four main steps:

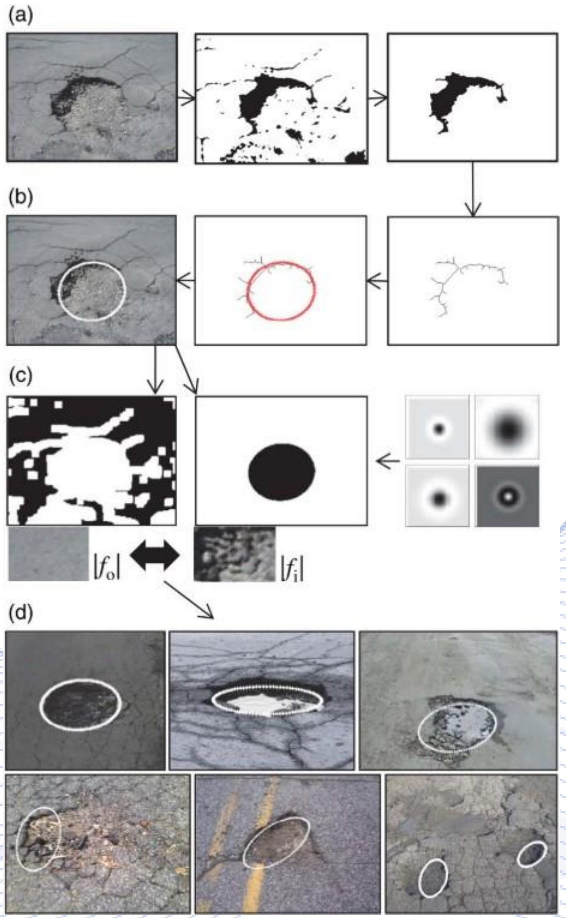
1) Image pre-processing: reduce noise and enhance the target region outline, before image segmentation.

2) Image segmentation: e.g. using some histogram-based thresholding methods, such as Otus [10], triangle [9] or watershed [11].

3) Shape extraction: the segmented road image consists foreground (road damage) and background (undamaged road surface). The foreground outline is modeled by an ellipse.

4) Object recognition: within-ellipse image texture comparison with the one of the undamaged road area texture. Potholes have grainier and coarser image texture [5].

2D image analysis-based methods



2D image analysis-based pothole detection [12].

2D image analysis-based methods

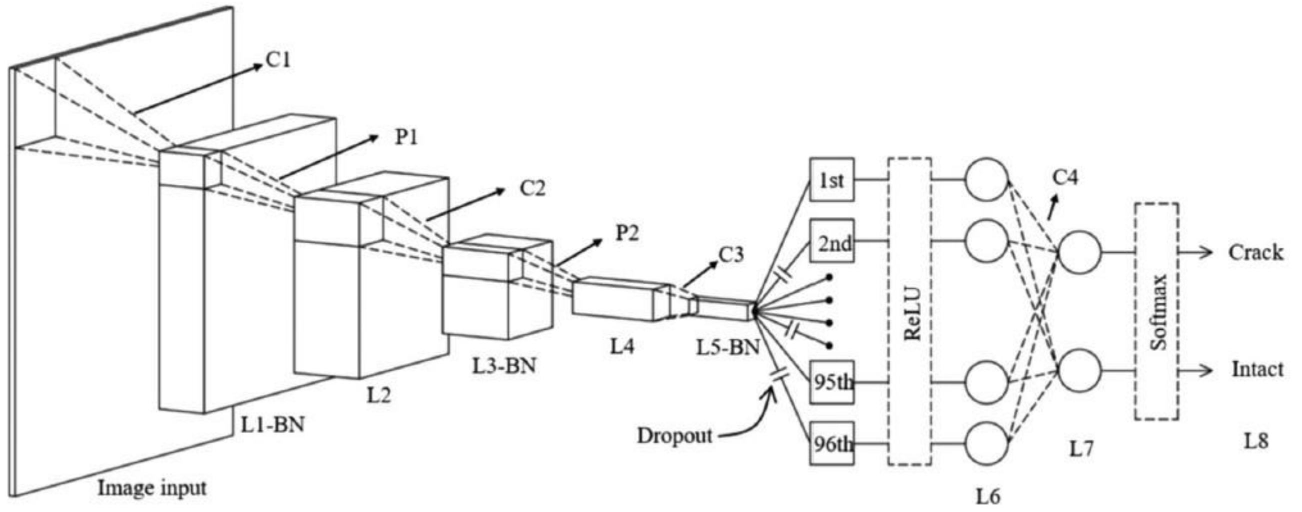
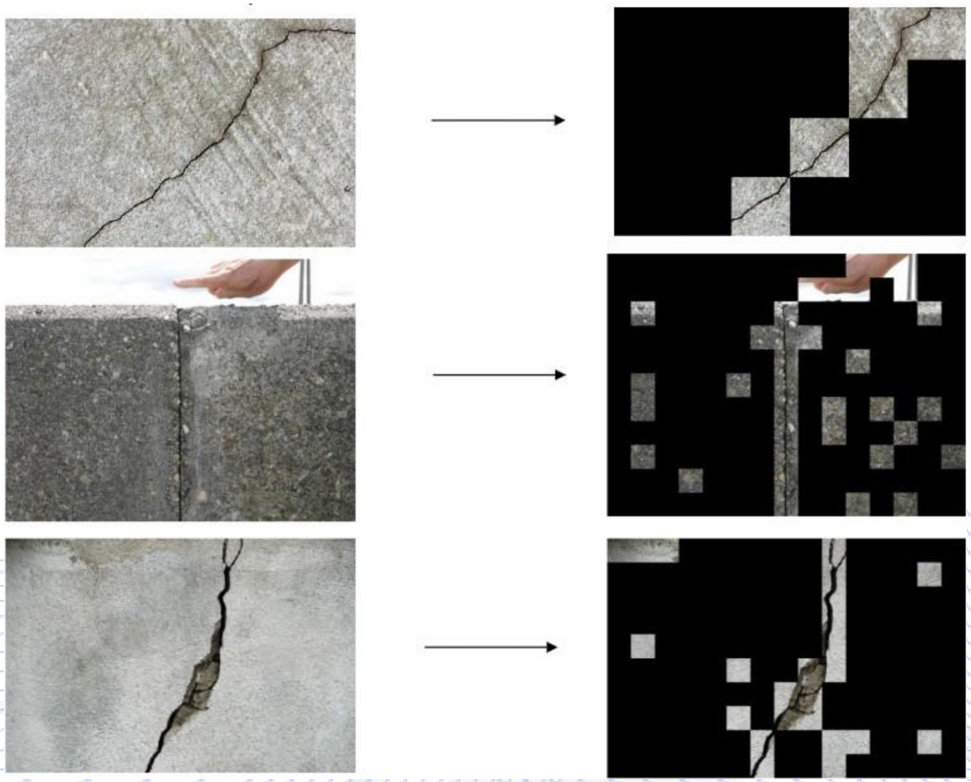


Fig. 2. Overall architecture: L#: layers corresponding to operations (L1, L3, L5, and L7: convolution layers; L2 and L4: pooling layers; L6: ReLU layer; L8: softmax layer); C#: convolution; P#: pooling; BN: batch normalization.

Convolutional neural network for road crack classification1 [13].

1https://github.com/satyenrajpal/Concrete-Crack-Detection

2D image analysis-based methods



Road crack classification results; (a) true positive; (b) true negative [13].

The image classification accuracy is approximately 85%.

2D image analysis-based methods

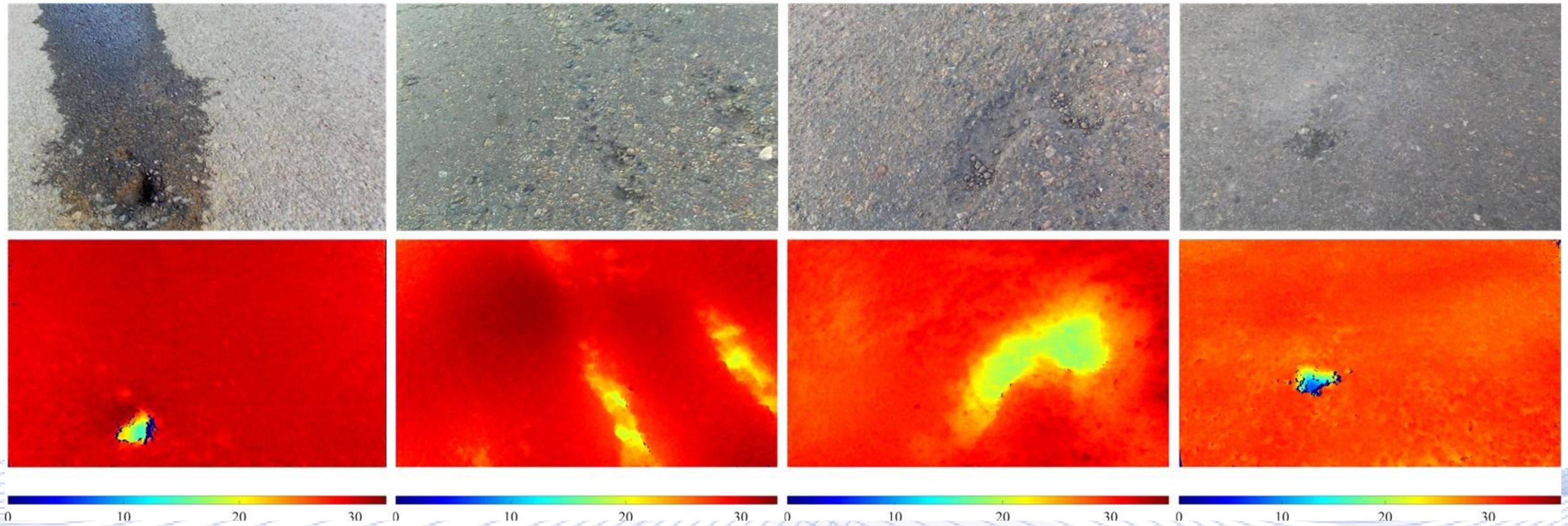
So, what if the road image looks like this?

A road image example.

Even deep learning cannot perform well on this kind of images. Therefore, 3D information is very important for passive sensing-based methods.

2D image analysis-based methods

State-of-the-art disparity map transformation algorithm, which can better distinguish the damaged road areas. This algorithm is based on v-disparity map analysis.

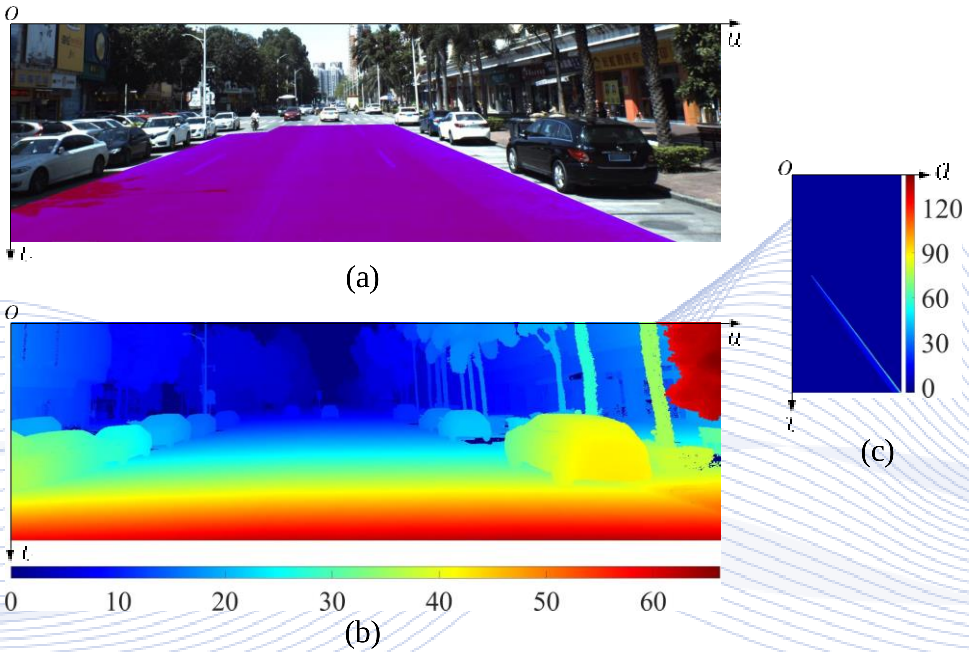


Transformed disparity map obtained using our method [14].

2D image analysis-based methods

Q. What is a v-disparity?

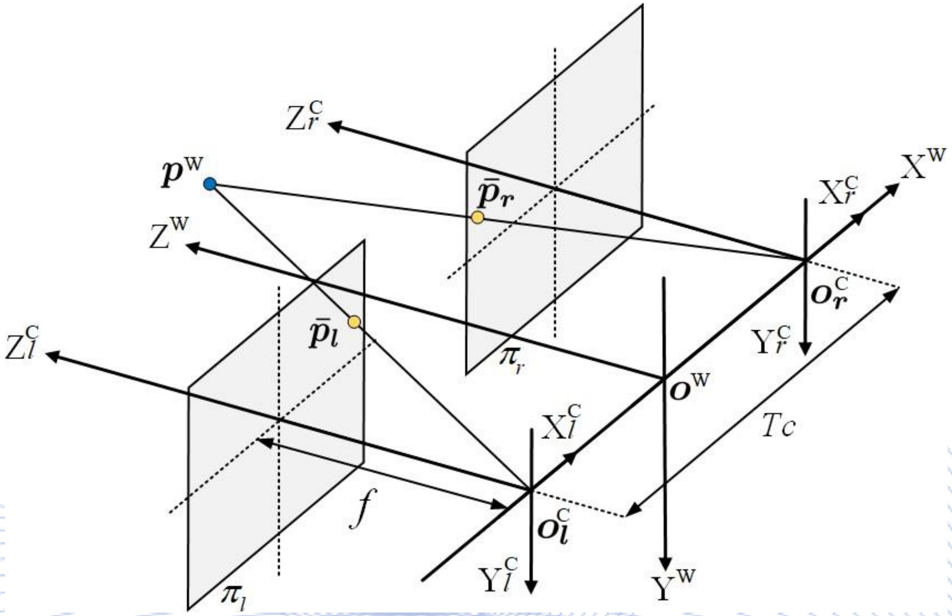
A. V-disparity map is a 2D image created by accumulating the 1D disparity histogram of each row.



V-disparity map example.

2D image analysis-based methods

An example of basic stereo vision model:



Basic stereo vision model.

$$v_l = v_r = v, \quad (1)$$

$$d = u_l - u_r = f\frac{Tc}{Z}, \quad (2)$$

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2D image analysis-based methods

2. Oblique plane:

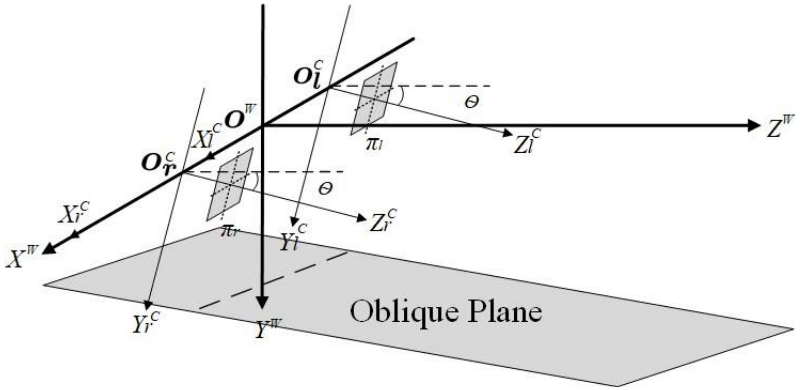

Figure: Basic stereo vision model.

An oblique plane can be simply described as follows:

$$Z^W = a_0 Y^W + a_1 \quad (12)$$

Plugging (12) into (7), (8) and (9) results in:

$$d\frac{a_1}{Tc} = f(\cos\theta - a_0\sin\theta) - V(\sin\theta + a_0\cos\theta) \quad (13)$$

3D road surface modeling-based methods

Road scene reconstruction reuires multiple camera views[4] to be capturedusing either: 1) a single movable camera or 2) an array of synchronized cameras.

1) structure from motion (SfM) [18], and
2)stereo vision [19]: two demo videos can be found here:
https://www.youtube.com/watch?v=_-YmlxojVMI&t=2s.
https://www.youtube.com/watch?v=pypPI7fsctg&list=_PLSsD3AXVRPMXuK1PM-5OlhItgNEClCKB3

The first category of methods can only provide sparse point cloud; the second category of methods can provide dense point cloud, however, they are typically very computationally intensive.

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Q & A

Thank you very much for your attention!

More material in
http://icarus.csd.auth.gr/cvml-web-lecture-series/

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