Lane Detection based on Object Detection and Image-to-image Translation

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Background

- Many vision-based lane detection methods have been proposed for advanced driver assistance system or autonomous driving system
- Most of these methods detect lane markings such as white lines drawn on the road surface
- Traffic lanes are divided by various roadside objects
- The proposed method detects various types of lane markings and road boundaries simultaneously from a monocular camera image

Lane markings
(Solid line, Dashed line)

Curb

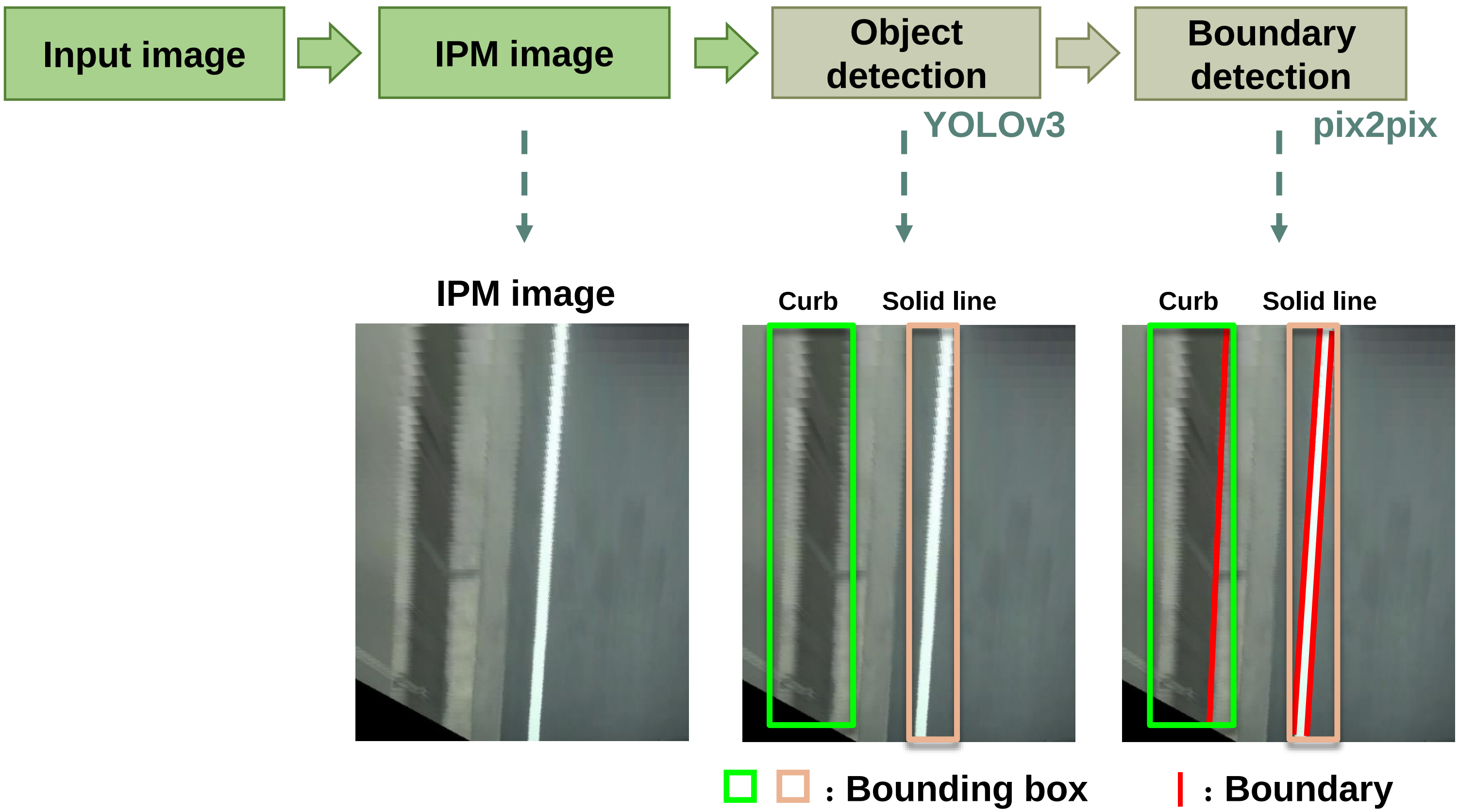
Grass

Snow sidewall

Wall

Outline of the proposed method

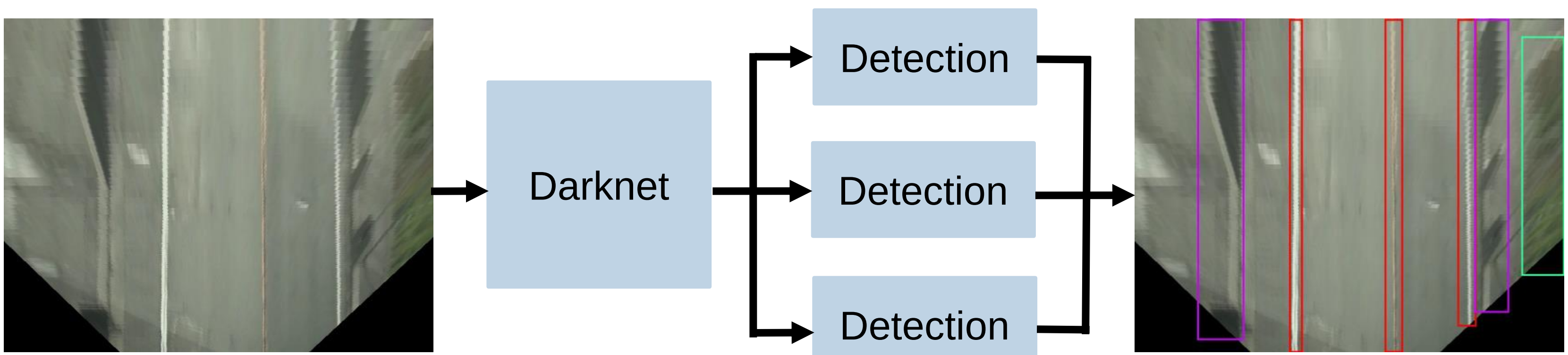
- Processing flow



Detection of lane boundary object

- Object detection network
  - YOLOv3

Darknet: Conv layer + residual block
Detection: Conv layer + Upsampling
Conv layer: filter + Batch Normalization + Leaky ReLU



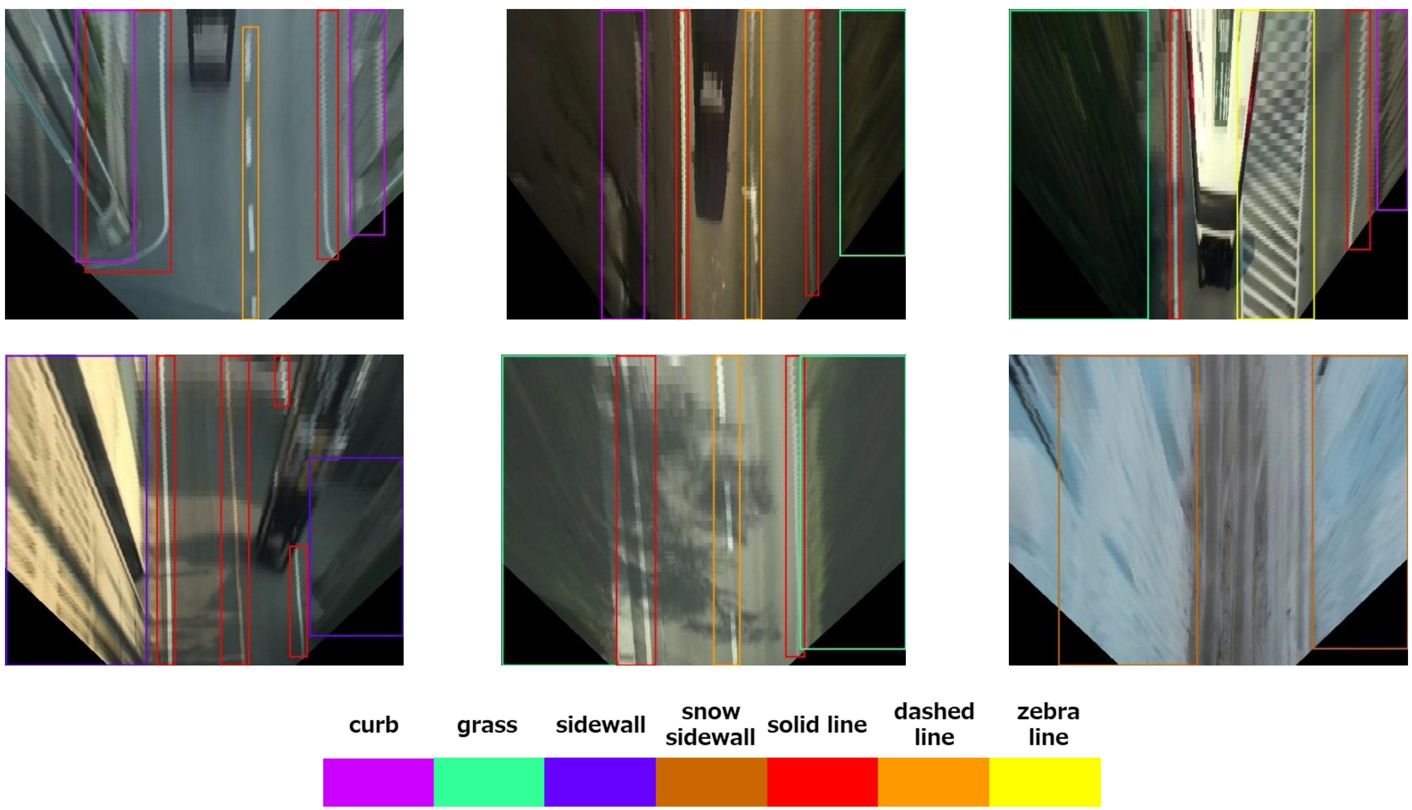
IPM image **Output**

Bounding box Category
- Solid line
- Curb
- Grass

8 categories are identified by the object detection network
Lane marking: Solid line, Dashed line, Zebra line
Road boundary: Curb, Grass, Guardrail, Sidewall, Snow sidewall

Datasets for object detection

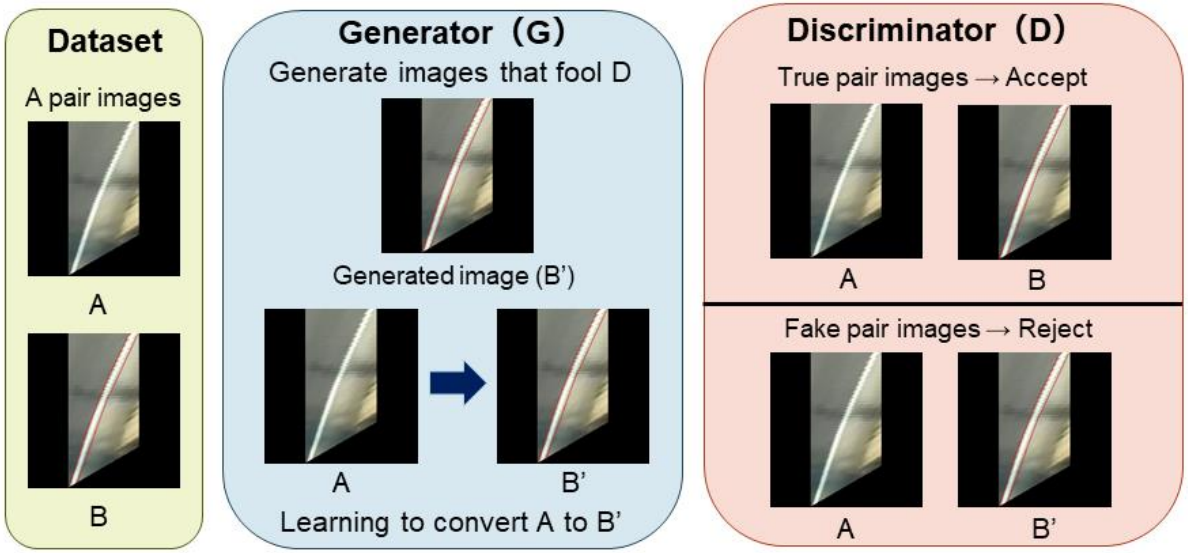
- New datasets in which bounding boxes are annotated in the IPM image are built and used for training



Examples in datasets for object detection

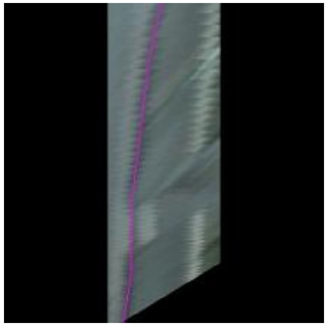
Boundary generation

- Image-to-image translation network
  - In each bounding box extracted by the object detection network, boundary lines with a lane markings or a roadside object are generated by pix2pix
  - Different generators are created for each category
  - Boundaries are generated using a generator that corresponds to the category of the bounding box

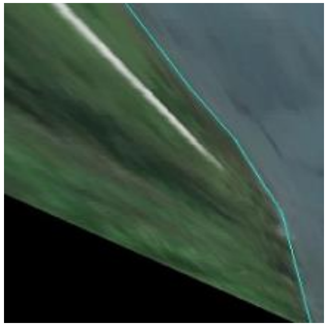


Datasets for boundary generation

- A pair images
  - Original image: a bounding box image obtained from object detection network
  - Boundary image: an image adding line borders to an original image manually
    - In solid line and dashed line, line borders are drawn on both sides of a white line
- Zero padding
  - The image size input to pix2pix is 256 x 256 pixels
    - When the height and width of the cut-out image are less than 256 pixels, the periphery of the image is filled with pixel value 0

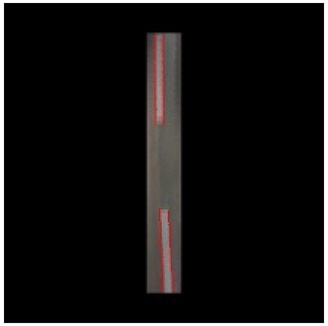


Curb



Grass

Solid line



Dashed line

Boundary image of each class

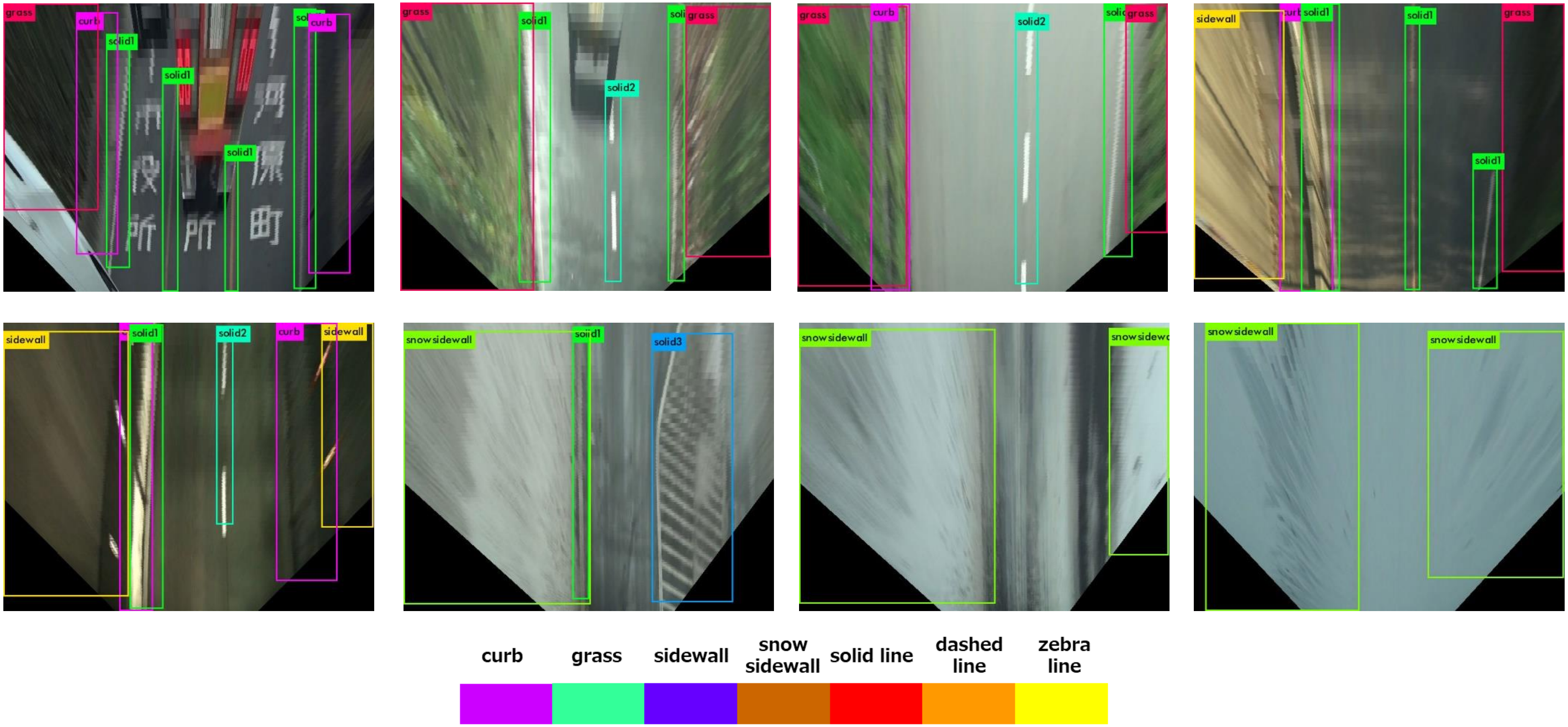
Experiments (1)

- Detection of lane boundary object
  - Datasets
    - IPM images annotating bounding boxes around the lane markings and road boundaries
    - Image size: 720 x 560 pixels ➡ 608 x 608 pixels (resize)
    - Train: 3,240 images, Test: 1,172 images
  - Quantitative evaluation
    - True positive (IoU > 0.5 and Category reliability > 0.25)
  - mAP for testing: 92%
  - Processing time: 16ms

	curb	grass	guardrail	sidewall	snow sidewall	white line	white line (dashed)	white line (zebra)	mAP
train	98.9	99.2	98.2	98.5	99.1	99.5	99.1	99.7	**99.0**
test	91.7	97.1	93.3	87.2	92.4	95.4	96.4	82.8	**92.0**

Experiments (2)

- Detection of lane boundary object
  - Examples of true positive detection

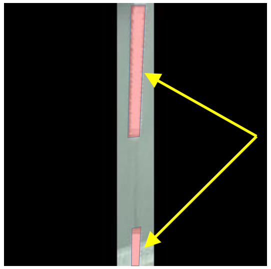


Experiments (3)

- Boundary generation
  - Three generators for a curb, grass and a white line (solid line and dashed line) were created and evaluated.
  - Datasets
    - Curb: train 1,000 images, test 110 images
    - Grass: train 800 images, test 100 images
    - White line (Solid line and dashed line): train 3,200 images, test 1,060 Images
    - Image size: 256 x 256 pixels

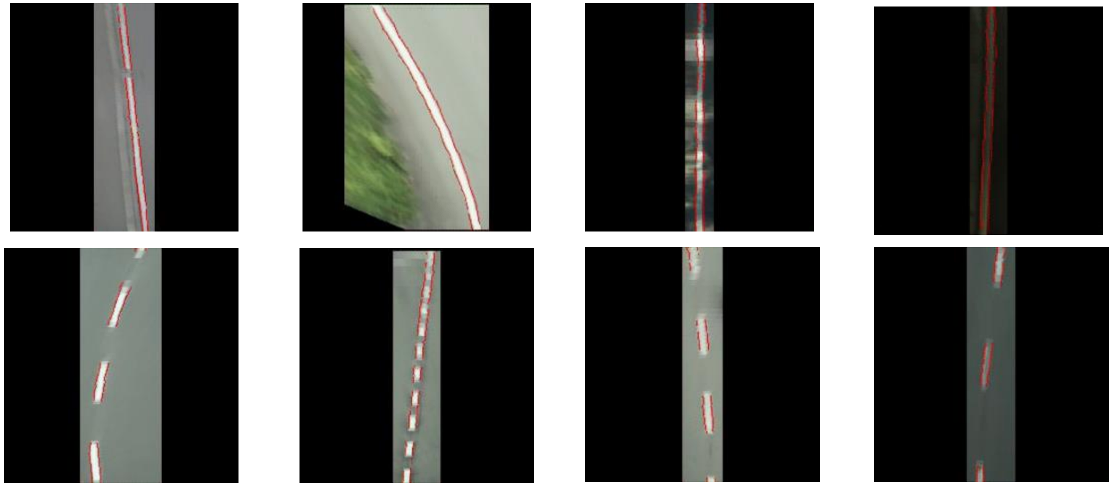
Experiments (4)

- White line (solid line, dashed line)
  - Quantitative evaluation
    - The degree of overlap between white line area of the ground truth image and white line area of the generated image are evaluated by IoU
    - The ground truth areas of the white line is created manually.
    - F-measure: 99.3% (IoU > 0.3), 96.4% (IoU > 0.5)



White line area

  - Qualitative evaluation



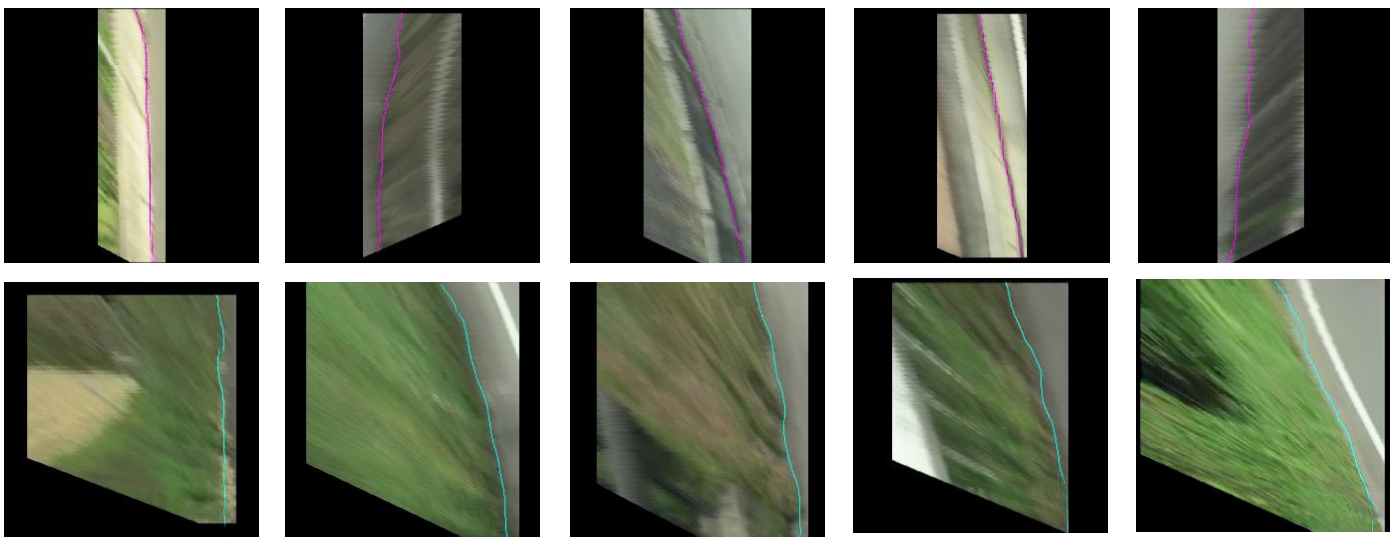
Solid line

Dashed line

  - Processing time: 3.0ms

Experiments (5)

- Curb and Grass
  - Quantitative evaluation
    - When the average error in the horizontal direction between the generated boundary and the ground truth is less than about 5 pixels, It’s determined as the true positive
    - True positive: 80% of 110 images for curb
      93% of 100 images for grass
  - Qualitative evaluation



Curb

Grass

  - Processing time
    - Curb: 2.8ms Grass: 2.9ms

Conclusion

- We proposed a method to detect various types of lane markings and road boundaries simultaneously from monocular camera image
  - First, the object detection network detects bounding boxes surrounding a lane marking or the boundary with roadside object
  - Next, in each bounding box, lane marking boundaries and road boundaries are drawn by the image-to-image translation network
- Experimental results using our own dataset show the effectiveness of the proposed method for detecting lane markings and road boundaries