Off-Road Drivable Area Extraction Using 3D LiDAR Data

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***Abstract*— nothing.**

I. INTRODUCTION

nothing.

II. RELATED WORKS

nothing.

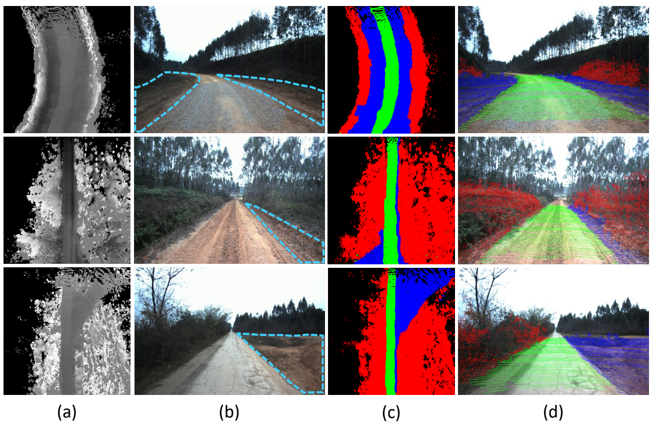

Fig. 1. The ambiguities in off-road drivable area extraction. (a) Input LiDAR data in bird's-eye view. (b) Image reference of input data. (c) Human annotation. (d) Projected point clouds in camera coordinate.

III. METHODOLOGY

A. Problem Definition

The origin data are point clouds from 3D LiDAR sensor, which are denoted as $PC = \{pt_i\}_{0 \le i < N}$, where N is the number of points. In order to get a bird's-eye view height map with denser point clouds, we aggregate point clouds from a few frames to one height map X as our networks' input. $X = \{x_{j,k}\}_{0 \le j < H, 0 \le k < W}$ is in the size of $H \times W$ and $x_{j,k}$ means the physical height of pixel (j, k).

We let $G = \{g_{j,k}\}_{0 \le j < H, 0 \le k < W}$ denote human annotated ground truth, where $g_{j,k} \in \{unknown, drivable\ zone, obstacle\ zone, gray\ zone\}$

B. Data Processing

C. Drivable Area Extraction / Network Architecture

$$L^{br} = -\sum_i y_i^{br} \log P(y_i^{br}|\Theta^{br}) \ , \quad br \in \{dri, obs\} \quad (1)$$

$$y_i^{br} = \begin{cases} \vec{br}, & if\ y_i = \vec{gre} \\ y_i & if\ y_i \in \{\vec{dri}, \vec{obs}\} \end{cases}$$

$$L_{semi}^{br} = -\lambda \sum_j \widetilde{y_j^{br}} \log P(y_j^{br}|\Theta^{br}) \ , \ br \in \{dri, obs\} \quad (2)$$

$$\widetilde{y_j} \in \widetilde{Y}, \quad \text{Auto-generated Labels}$$

$$S = \begin{cases} S_1, & if\ S_1 > \alpha_1 \\ 1 - S_2, & if\ S_2 > \alpha_2 \\ \frac{1-S_2}{1-S_1+1-S_2}, & otherwise \end{cases}$$

D. Cost Map Generation

E. Weakly and Semi Supervised Extraction

IV. IMPLEMENTATION DETAILS

A. Training Setup

B. Ground Truth Labeling

C. Evaluation

V. EXPERIMENTAL RESULTS

A. Data set

B. Proposed Method Results

C. Limitations

VI. CONCLUSION

nothing

APPENDIX

ACKNOWLEDGMENT

nothing.

REFERENCES

[1] G. O. Young, Synthetic structure of industrial plastics (Book style with paper title and editor), in Plastics, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 1564.

TABLE I
EVALUATION MEASURES

Drivable Zone		Obstacle Zone	
Definition	Explanation	Definition	Explanation
$Q_1 = TP(G_{dri})/\|Y_{dri}\|$	$TP(G_{dri}) = \|G_{dri} \cap Y_{dri}\|$	$Q_1 = TP(G_{obs})/\|Y_{obs}\|$	$TP(G_{obs}) = \|G_{obs} \cap Y_{obs}\|$
$Q_2 = TP(G_{dri})/\|G_{dri}\|$	$TP(G_{dri}) = \|G_{dri} \cap Y_{dri}\|$	$Q_2 = TP(G_{obs})/\|G_{obs}\|$	$TP(G_{obs}) = \|G_{obs} \cap Y_{obs}\|$
$Q_3 = TP(VP_{dri})/\|VP_{dri}\|$	$TP(VP_{dri}) = \|VP_{dri} \cap Y_{dri}\|$	/	/
$F_1 = 2Q_1Q_2/(Q_1 + Q_2)$	F_1 Measure	$F_1 = 2Q_1Q_2/(Q_1 + Q_2)$	F_1 Measure

dri: Drivable zone **obs**: Obstacle zone **G**: Ground truth **Y**: Prediction $\|$**X**$\|$: Pixel number in X

TABLE II
QUANTITATIVE EVALUATION OF DIFFERENT METHODS

	Drivable zone				Obstacle zone		
	Q_1 (PRE)	Q_2 (REC)	Q_3 (ACC)	F_1	Q_1 (PRE)	Q_2 (REC)	F_1
3-class FCN (fully-sup.)	74.93	82.99	**98.92**	78.75	94.36	**98.44**	96.36
Ours (fully-sup.)	**76.01**	**86.72**	98.09	**81.01**	**96.20**	96.75	**96.47**
RG-FCN (weakly-sup.)	59.78	79.15	93.16	68.11	94.46	95.38	94.92
Oxford PP (weakly-sup.)	**97.00**	47.38	83.71	63.66	**98.40**	89.84	93.93
Ours (weakly-sup.)	72.38	78.83	95.21	75.47	96.31	94.84	95.57
Ours (semi-sup.)	81.73	**81.73**	**96.24**	**81.73**	95.60	**97.38**	**96.49**

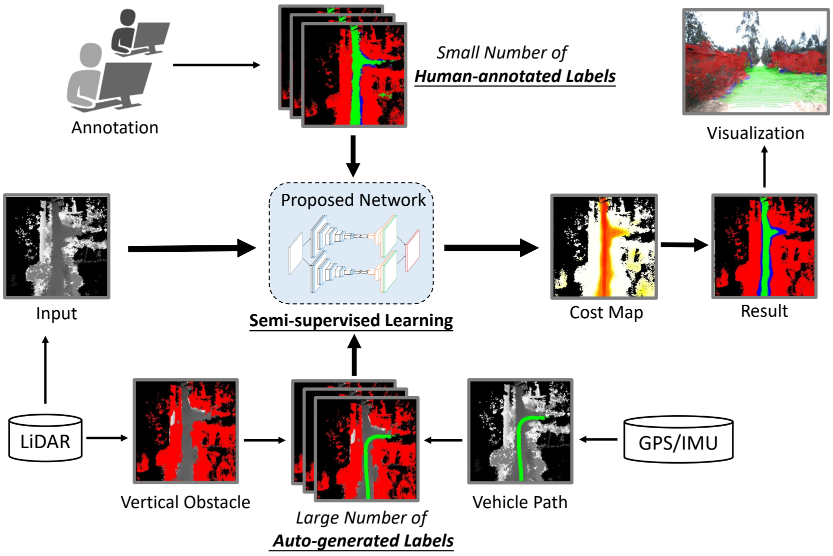

Fig. 2. Overview of the proposed off-road drivable area extraction framework

TABLE III
QUANTITATIVE COMPARISON OF F_1 MEASURE

-	6.25% semi-sup.	12.5% semi-sup.	25% semi-sup.	50% semi-sup.	Fully-sup.
F_1 measure	73.86	75.04	78.96	**81.73**	81.01

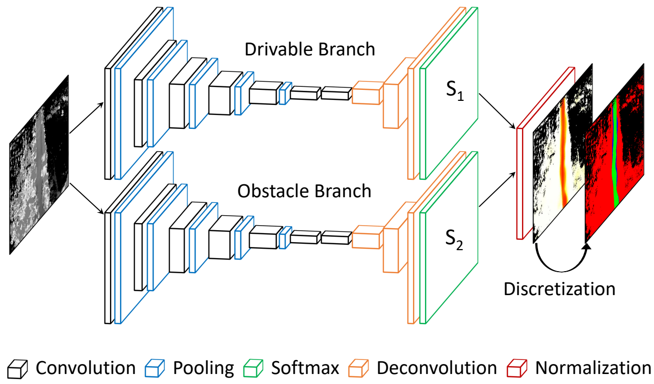

Fig. 3. Framework

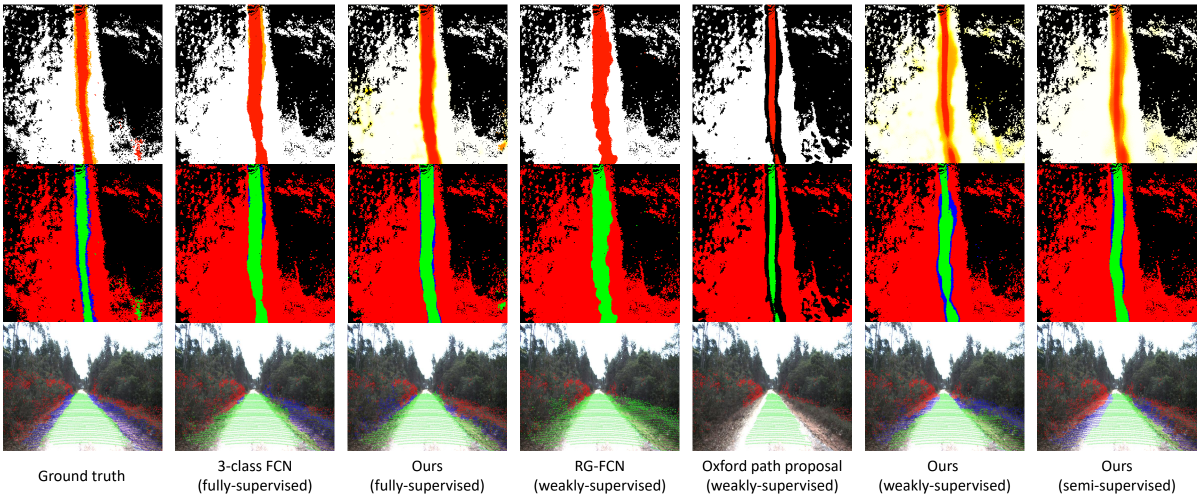

Fig. 4. Qualitative results at straight road scene.

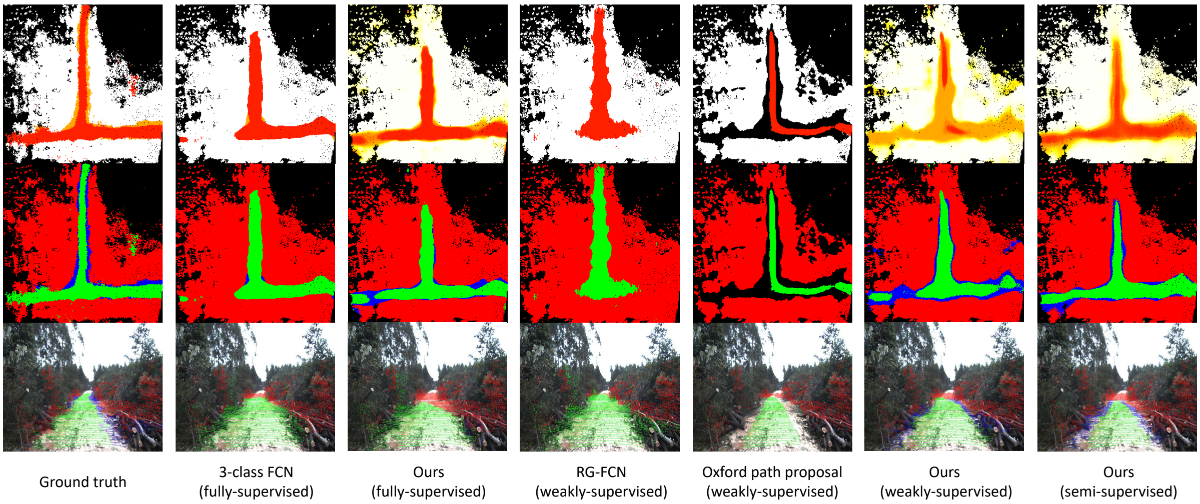

Fig. 5. Qualitative results at cross road scene.

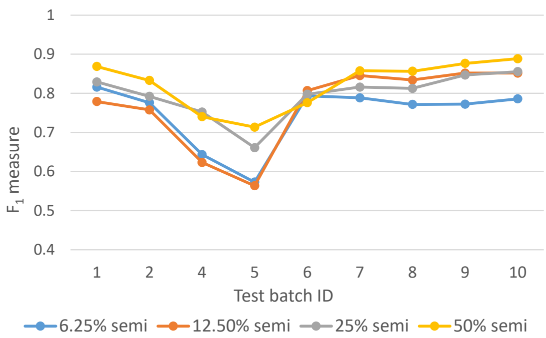

Fig. 6. Quantitative comparison on test set.