Supplementary Material for "Self-Supervised Difference Detectionfor Weakly-Supervised Semantic Segmentation"

A.1 Details of the simple decision

In the proposed method, we select *advice* by inference results of difference detection. The confidence score is calculated from the viewpoint of how close the value of d^K to d^A. In the proposed method, if this difference is large enough, we ignore the *advice*. Therefore, if the inferences of the difference detection are too easy, the values of d^K for *advice* that is not true become close to d^A, and the proposed method does not work effectively. In particular, if the inference results of the difference detection are ($d^K = 1, d^A = 1, d^A = d^K$), we cannot distinguish whether the *advice* belongs to the set of true values $|S^{A,T}|$ or the set of false values $|S^{A,F}|$ based on the results of the difference detection. Therefore, we judge the typical failure examples of $advice$ and excluded them from the training sample so that the differences between d^K and d^A were large in the inference of the bad *advice*. To be concrete, when the number of differences in the pixels in each class of mask is obviously large, we assume that the *advice* has failed. We define the bad training samples as the pair of the masks for the difference detection that satisfies the following equation:

$$\forall c \in \mathcal{C}, \frac{|S_c^{m^A}|}{|S_c^{m^K}|} < 0.5, \tag{16}$$

where $\mathcal{C}$ is a set of image-level label of the input image. We decide the threshold 0.5 empirically.

A.2 Details of the bias in Eq.(3)

In Eq.(3), we use $bias$, which is a kind of hyperparameter. In this section, we discuss this $bias$. We define the $bias$ as follows:

$$bias_u = \begin{cases} b_{dd} \pm b_{class} & \text{if } m_u^A \textit{ or } m_u^k \textit{ belongs to } \hat{\mathcal{C}} \\ b_{dd} & \text{if } \textit{otherwise} \end{cases}, \tag{17}$$

where $\forall c \in \hat{\mathcal{C}}$ satisfy $\frac{|S_c^{m^A}|}{|S_c^{m^K}|} < 0.5$ and $c \in \mathcal{C}$. b_{dd} is a bias for the difference between *knowledge* and *advice*, and b_{class} is a bias for the class category. When the number of differences in the pixels in each class of mask is obviously large, it is assumed that the *advice* has failed, and to prioritize the label of that class over the results of the difference detection, we use the bias b_{class}. We defined the values of b_{dd} and b_{class} by using the grid search.

A.3 Values of hyperparameters

We explore good hyperparameters by a grid search and verify the effect of the hyperparameters. We change the values of the hyperparameters and measure the mean IoU scores. Table A-1 shows the hyper parameter values and the mean IoU scores. The hyperparameters (b_{dd}, b_{class}) are used in Eq.(17) as the bias values. In $b_{dd} = 0.4$, the mean IoU score becomes the maximum value. We also set the bias b_{class} for the missing categories. We observe that the setting $b_{class} = 1.0$ achieved a maximum mean IoU. It is expected that the class biases for the missing categories help to the train for robustness. In addition, we also verify the effect of hyperparameters for coefficients of losses in Eq.(11). Though we had expected that the value of α would affect the performance, the hyper parameter was not critical for the change of the mean IoU. The balanced setting, that is, $\alpha = 0.5$ showed the best score.

Table A-1. Experimental results with different parameters.

b_{dd}	0.0	0.1	0.2	0.3	**0.4**	0.5
mIoU	62.2	63.9	64.6	64.2	64.9	62.7
b_{class}	0.0	0.5	**1.0**	1.5	2.0	
mIoU	64.3	63.0	64.9	64.5	63.7	
α	1.0	0.75	**0.5**	0.25	0.0	
mIoU	63.1	64.4	64.9	64.3	63.2	

A.4 Detailed comparison with existing works on the PASCAL VOC 2012 *val* and *test* sets

Table A-2. Results on PASCAL VOC 2012 *val set* without additional supervision.

methods	bg	aero	bike	bird	boat	bottle	bus	car	cat	chair	cow	table	dog	horse	motor	person	plant	sheep	sofa	train	tv	**mIoU**
MIL-FCN [24]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	24.9
CCNN [23]	68.5	25.5	18.0	25.4	20.2	36.3	46.8	47.1	48.0	15.8	37.9	21.0	44.5	34.5	46.2	40.7	30.4	36.3	22.2	38.8	36.9	35.3
EM-Adapt [22]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38.2
DCSM [32]	76.7	45.1	24.6	40.8	23.0	34.8	61.0	51.9	52.4	15.5	45.9	32.7	54.9	48.6	57.4	51.8	38.2	55.4	32.2	42.6	39.6	44.1
BFBP [29]	79.2	60.1	20.4	50.7	41.2	46.3	62.6	49.2	62.3	13.3	49.7	38.1	58.4	49.0	57.0	48.2	27.8	55.1	29.6	54.6	26.6	46.6
SEC [16]	82.4	62.9	26.4	61.6	27.6	38.1	66.6	62.7	75.2	22.1	53.5	28.3	65.8	57.8	62.3	52.5	32.5	62.6	32.1	45.4	45.3	50.7
CBTS [28]	85.8	65.2	29.4	63.8	31.2	37.2	69.6	64.3	76.2	21.4	56.3	29.8	68.2	60.6	66.2	55.8	30.8	66.1	34.9	48.8	47.1	52.8
TPL [15]	82.8	62.2	23.1	65.8	21.1	43.1	71.1	66.2	76.1	21.3	59.6	35.1	70.2	58.8	62.3	66.1	35.8	69.9	33.4	45.9	45.6	53.1
MEFF [7]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PSA [1]	88.2	68.2	30.6	81.1	49.6	61.0	77.8	66.1	75.1	29.0	66.0	40.2	80.4	62.0	70.4	73.7	42.5	70.7	42.6	68.1	51.6	61.7
SSDD (ours)	89.0	62.5	28.9	83.7	52.9	59.5	77.6	73.7	87.0	34.0	83.7	47.6	84.1	77.0	73.9	69.6	29.8	84.0	43.2	68.0	53.4	64.9

Table A-3. Results on PASCAL VOC 2012 *test set* without additional supervision.

methods	bg	aero	bike	bird	boat	bottle	bus	car	cat	chair	cow	table	dog	horse	motor	person	plant	sheep	sofa	train	tv	**mIoU**
MIL-FCN [24]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25.7
CCNN [23]	68.5	25.5	18.0	25.4	20.2	36.3	46.8	47.1	48.0	15.8	37.9	21.0	44.5	34.5	46.2	40.7	30.4	36.3	22.2	38.8	36.9	35.3
EM-Adapt [22]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39.6
DCSM [32]	78.1	43.8	26.3	49.8	19.5	40.3	61.6	53.9	52.7	13.7	47.3	34.8	50.3	48.9	69.0	49.7	38.4	57.1	34.0	38.0	40.0	45.1
BFBP [29]	80.3	57.5	24.1	66.9	31.7	43.0	67.5	48.6	56.7	12.6	50.9	42.6	59.4	52.9	65.0	44.8	41.3	51.1	33.7	44.4	33.2	48.0
SEC [16]	83.5	56.4	28.5	64.1	23.6	46.5	70.6	58.5	71.3	23.2	54.0	28.0	68.1	62.1	70.0	55.0	38.4	58.0	39.9	38.4	48.3	51.7
CBTS [28]	85.7	58.8	30.5	67.6	24.7	44.7	74.8	61.8	73.7	22.9	57.4	27.5	71.3	64.8	72.4	57.3	37.0	60.4	42.8	42.2	50.6	53.7
TPL [15]	83.4	62.2	26.4	71.8	18.2	49.5	66.5	63.8	73.4	19.0	56.6	35.7	69.3	61.3	71.7	69.2	39.1	66.3	44.8	35.9	45.5	53.8
MEFF [7]	86.6	72.0	30.6	68.0	44.8	46.2	73.4	56.6	73.0	18.9	63.3	32.0	70.1	72.2	68.2	56.1	34.5	67.5	29.6	60.2	43.6	55.6
PSA [1]	89.1	70.6	31.6	77.2	42.2	68.9	79.1	66.5	74.9	29.6	68.7	56.1	82.1	64.8	78.6	73.5	50.8	70.7	47.7	63.9	51.1	63.7
SSDD (ours)	89.5	71.8	31.4	79.3	47.3	64.2	79.9	74.6	84.9	30.8	73.5	58.2	82.7	73.4	76.4	69.9	37.4	80.5	54.5	65.7	50.3	65.5

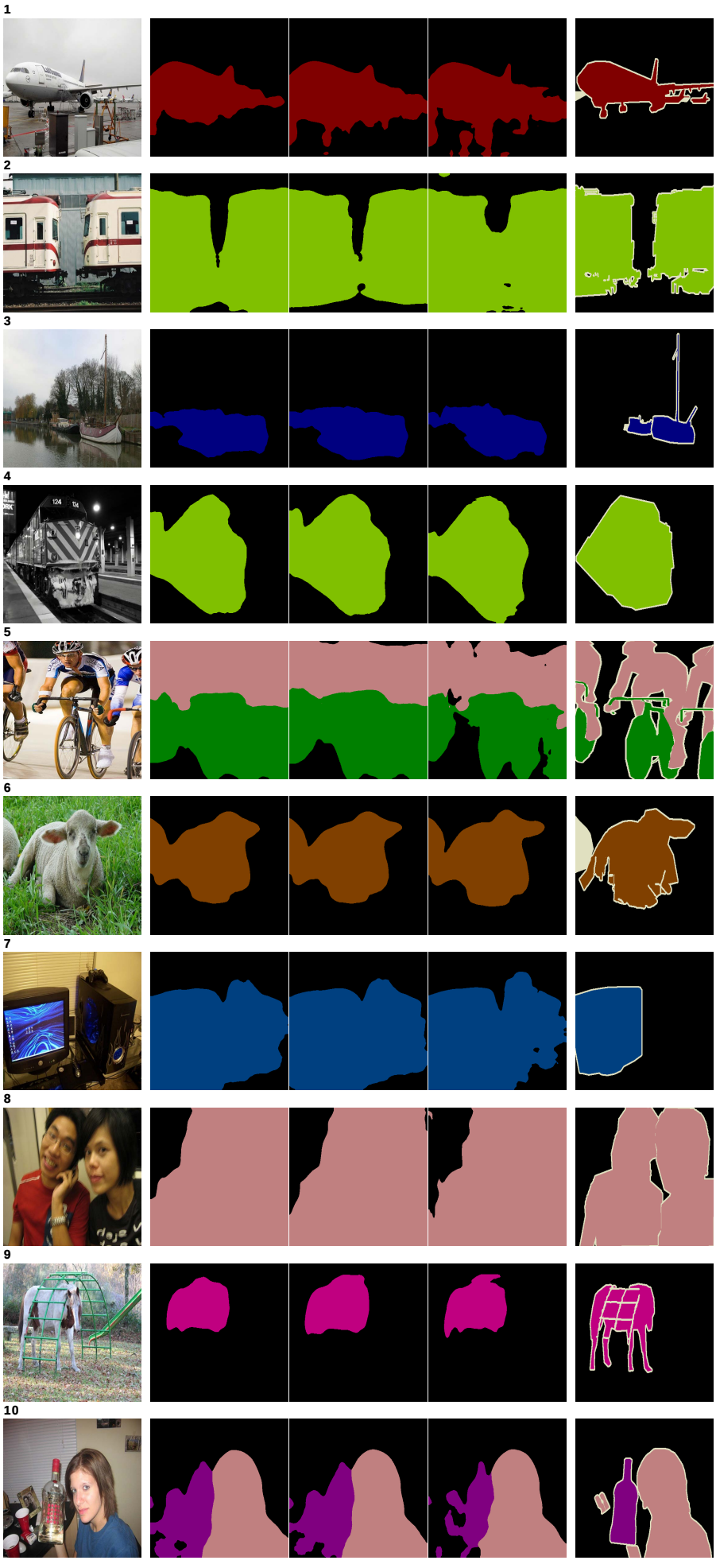
Table A-4. Results on PASCAL VOC 2012 *val set* with additional supervision.

methods	info type†	bg	aero	bike	bird	boat	bottle	bus	car	cat	chair	cow	table	dog	horse	motor	person	plant	sheep	sofa	train	tv	**mIoU**
MIL-seg [25]	S	79.6	50.2	21.6	40.6	34.9	40.5	45.9	51.5	60.6	12.6	51.2	11.6	56.8	52.9	44.8	42.7	31.2	55.4	21.5	38.8	36.9	42.0
MCNN [34]	WV	77.5	47.9	17.2	39.4	28.0	25.6	52.7	47.0	57.8	10.4	38.0	24.3	49.9	40.8	48.2	42.0	21.6	35.2	19.6	52.5	24.7	38.1
AFF [27]	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	54.3
STC [37]	S	84.5	68.0	19.5	60.5	42.5	44.8	68.4	64.0	64.8	14.5	52.0	22.8	58.0	55.3	57.8	60.5	40.6	56.7	23.0	57.1	31.2	49.8
Oh et al. [30]	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	55.7
AE-PSL [36]	S	83.4	71.1	30.5	72.9	41.6	55.9	63.1	60.2	74.0	18.0	66.5	32.4	71.7	56.3	64.8	52.4	37.4	69.1	31.4	58.9	43.9	55.0
Hong et al. [9]	WV	87.0	69.3	32.2	70.2	31.2	58.4	73.6	68.5	76.5	26.8	63.8	29.1	73.5	69.5	66.5	70.4	46.8	72.1	27.3	57.4	50.2	58.1
WebS-i2 [14]	WI	84.3	65.3	27.4	65.4	53.9	46.3	70.1	69.8	79.4	13.8	61.1	17.4	73.8	58.1	57.8	56.2	35.7	66.5	22.0	50.1	46.2	53.4
DCSP [3]	S	88.9	77.7	31.3	73.2	59.8	71.0	79.2	74.5	80.0	15.1	73.3	10.2	76.1	72.2	69.1	72.1	39.9	73.9	14.6	70.3	53.1	60.8
GAIN [18]	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	56.8
MDC [38]	S	89.5	85.6	34.6	75.8	61.9	65.8	67.1	73.3	80.2	15.1	69.9	8.1	75.0	68.4	70.9	71.5	32.6	74.9	24.8	73.2	50.8	60.4
MCOF [35]	S	87.0	78.4	29.4	68.0	44.0	67.3	80.3	74.1	82.2	21.1	70.7	28.2	73.2	71.5	67.2	53.0	47.7	74.5	32.4	71.0	45.8	60.3
DSRG [11]	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	61.4
Shen et al. [31]	WI	86.8	71.2	32.4	77.0	24.4	69.8	85.3	71.9	86.5	27.6	78.9	40.7	78.5	79.1	72.7	73.1	49.6	74.8	36.1	48.1	59.2	63.0
SeeNet [10]	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	63.1
AISI [6]	IS	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	64.5
SSDD (ours)	-	89.0	62.5	28.9	83.7	52.9	59.5	77.6	73.7	87.0	34.0	83.7	47.6	84.1	77.0	73.9	69.6	29.8	84.0	43.2	68.0	53.4	64.9

(† AS:Saliency mask, WV:web videos. WI Web images. IS Instance saliency mask.)

B. Five hundred results on the validation set.

The results are given in Table A-2. In each row, an input image, a result by PSA [1], a result by SSDD with only first stage, a result by SSDD with both the first and second stage (full results), and ground truth are shown in the leftmost column.


Input image
PSA 59.0 %
(re-implementation)
SSDD(1st) 61.4 %
(only 1st stage)
SSDD(full) 64.9 %
(both stages)
Ground truth
1
2
3
4
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8
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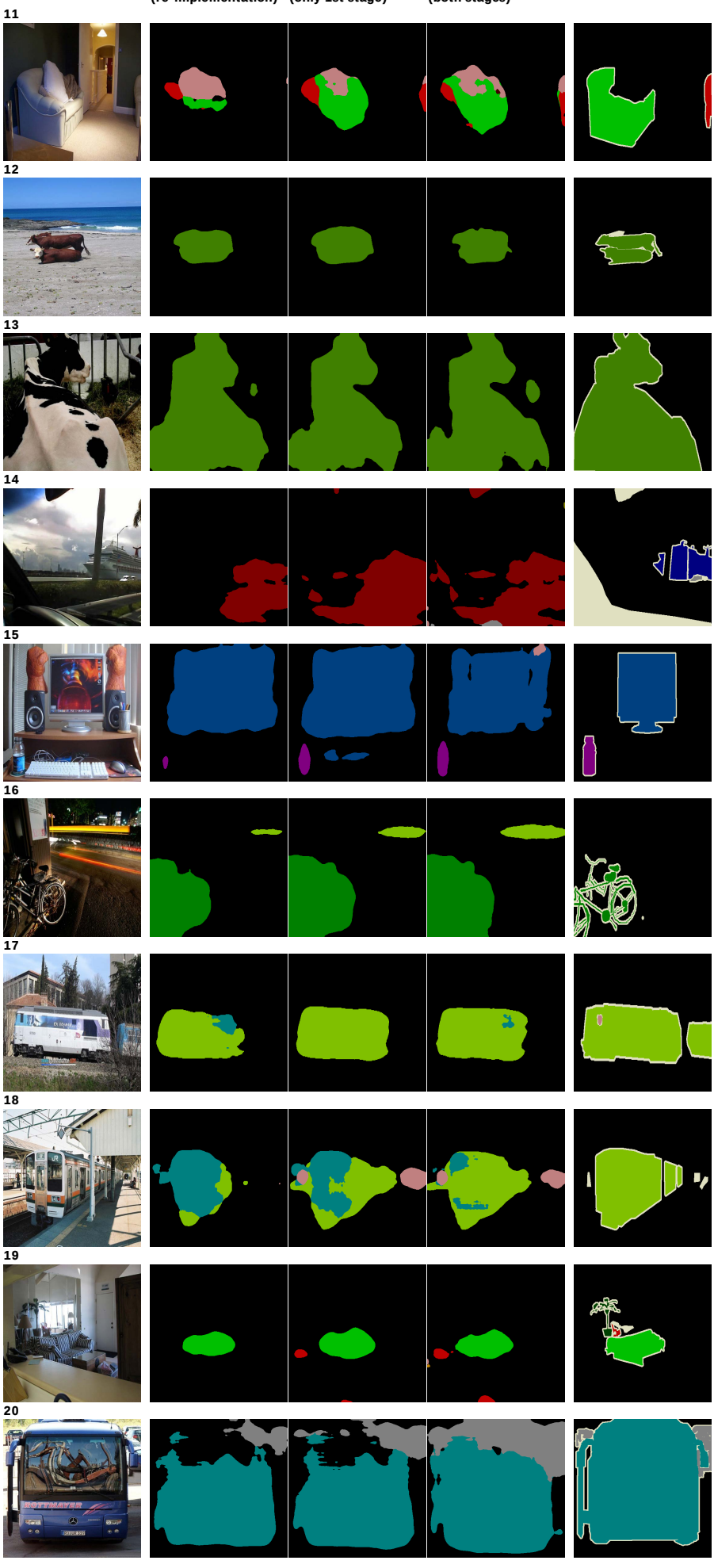
10


Input image
PSA 59.0%
(re-implementation)
SSDD(1st) 61.4%
(only 1st stage)
SSDD(full) 64.9%
(both stages)
Ground truth
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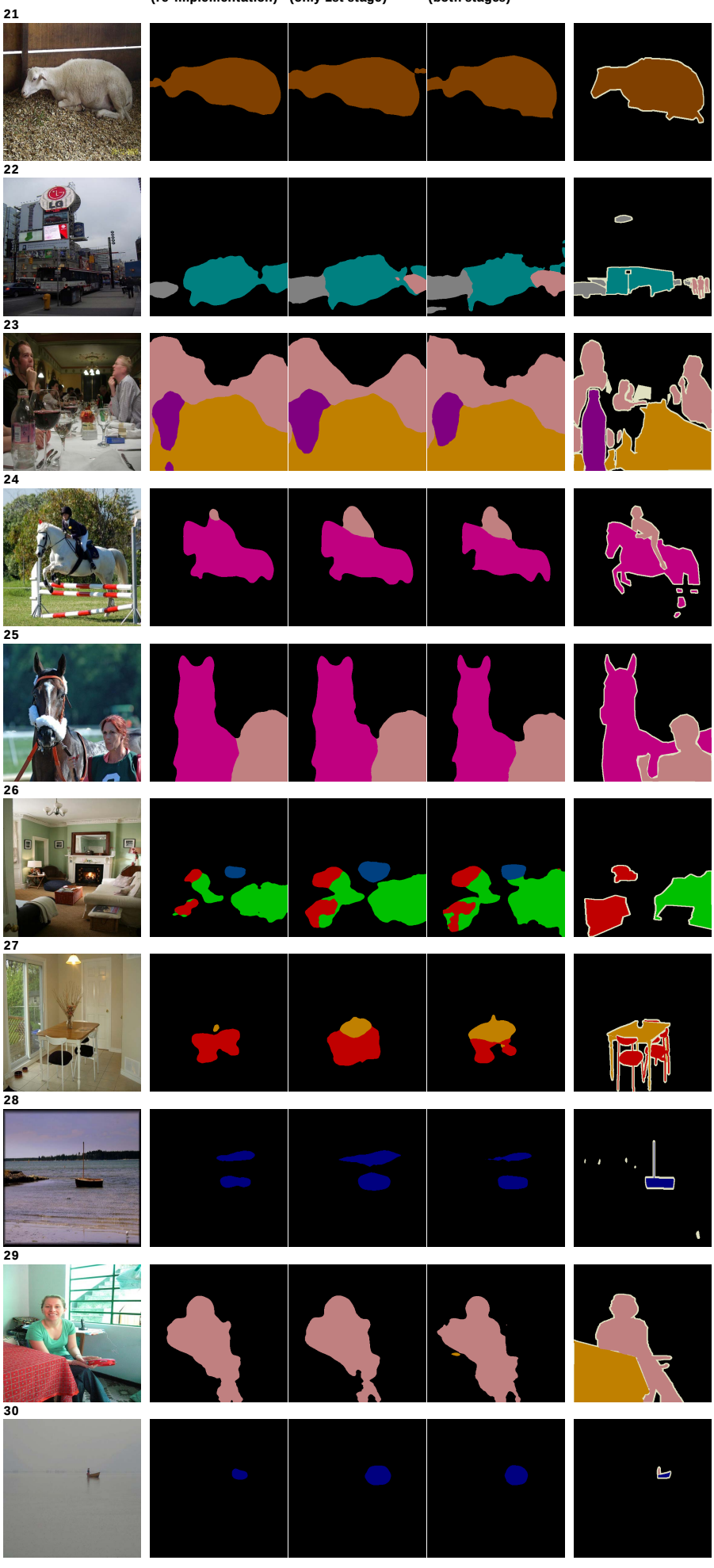
Input image
PSA 59.0%
(re-implementation)
SSDD(1st) 61.4%
(only 1st stage)
SSDD(full) 64.9%
(both stages)
Ground truth
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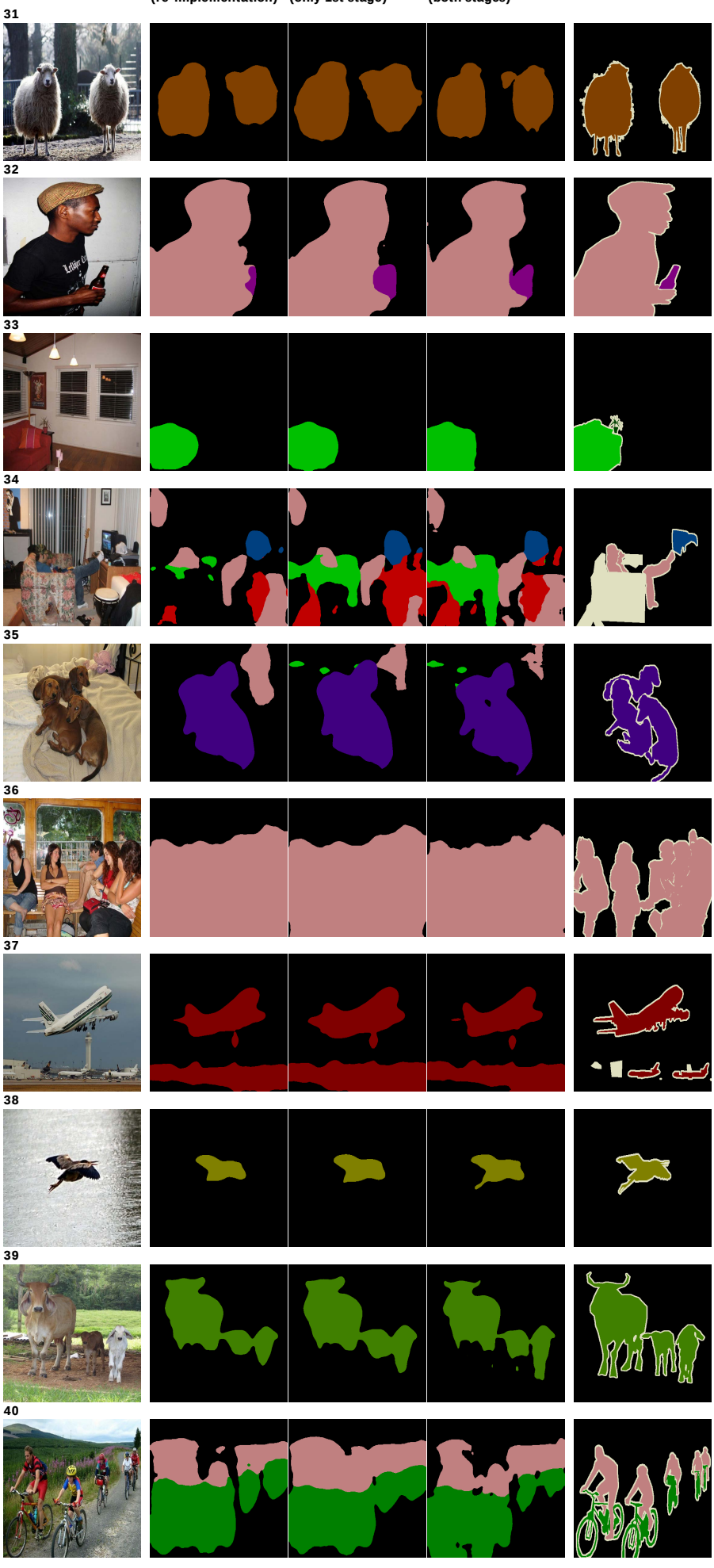
Input image
PSA 59.0 %
(re-implementation)
SSDD(1st) 61.4 %
(only 1st stage)
SSDD(full) 64.9 %
(both stages)
Ground truth
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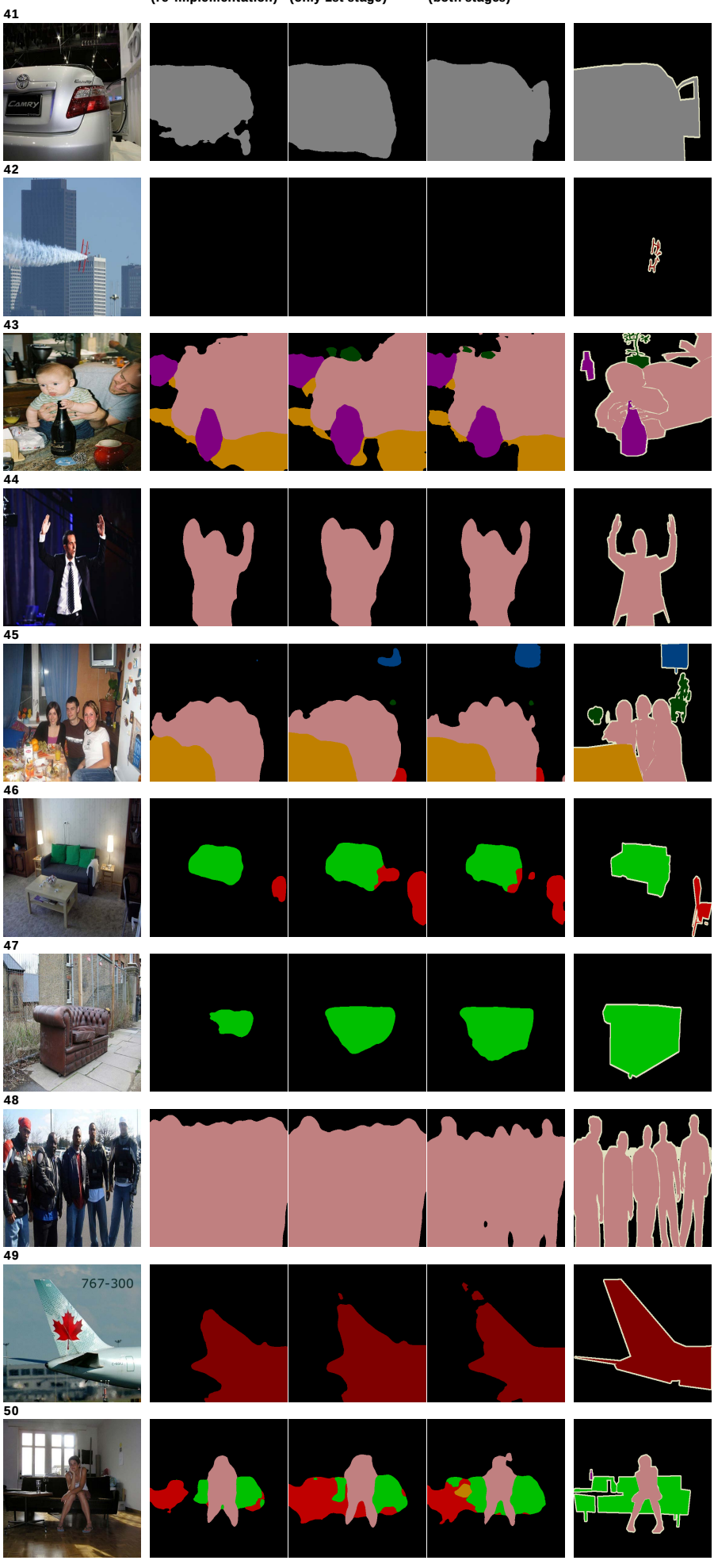
Input image
PSA 59.0% (re-implementation)
SSDD(1st) 61.4% (only 1st stage)
SSDD(full) 64.9% (both stages)
Ground truth
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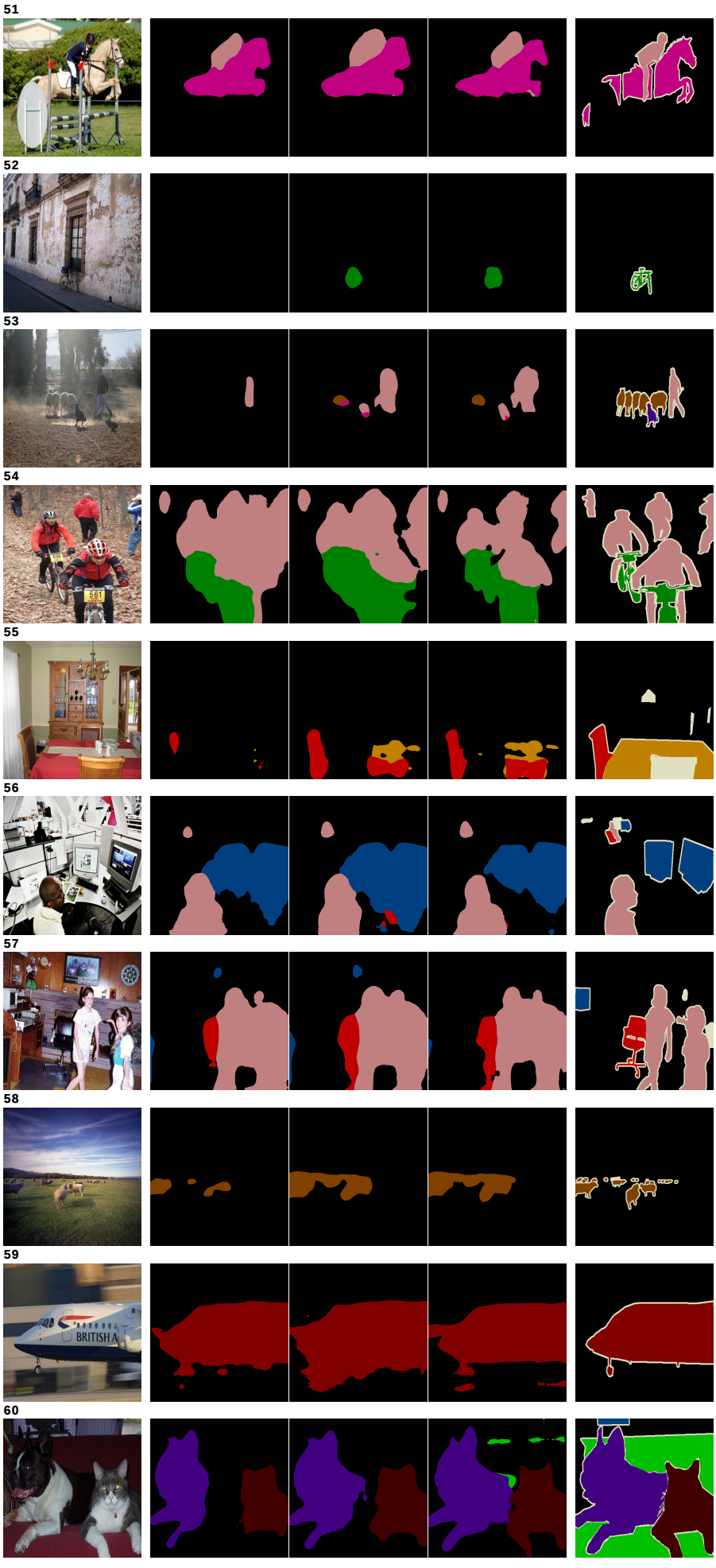
Input image
PSA 59.0% (re-implementation)
SSDD(1st) 61.4% (only 1st stage)
SSDD(full) 64.9% (both stages)
Ground truth
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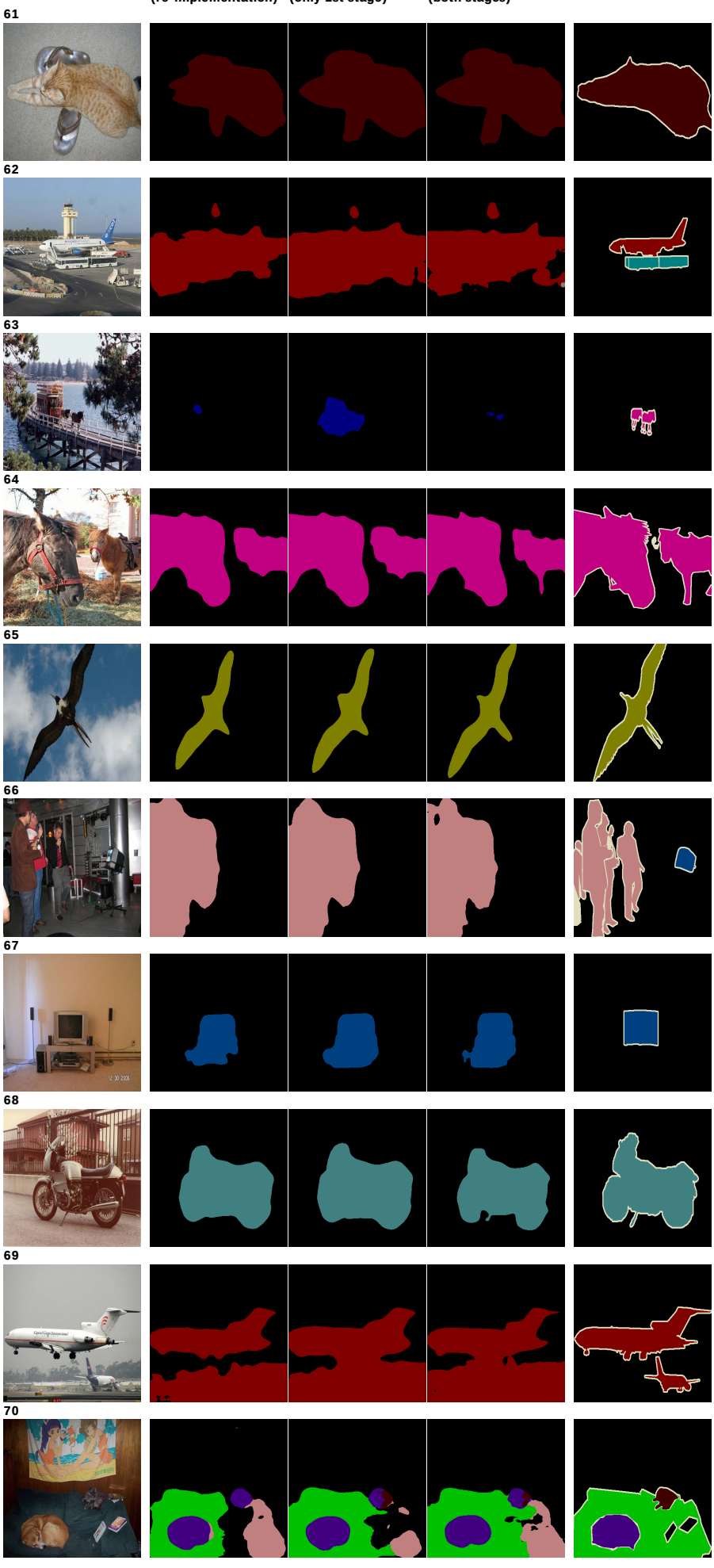
Input image
PSA 59.0% (re-implementation)
SSDD(1st) 61.4% (only 1st stage)
SSDD(full) 64.9% (both stages)
Ground truth
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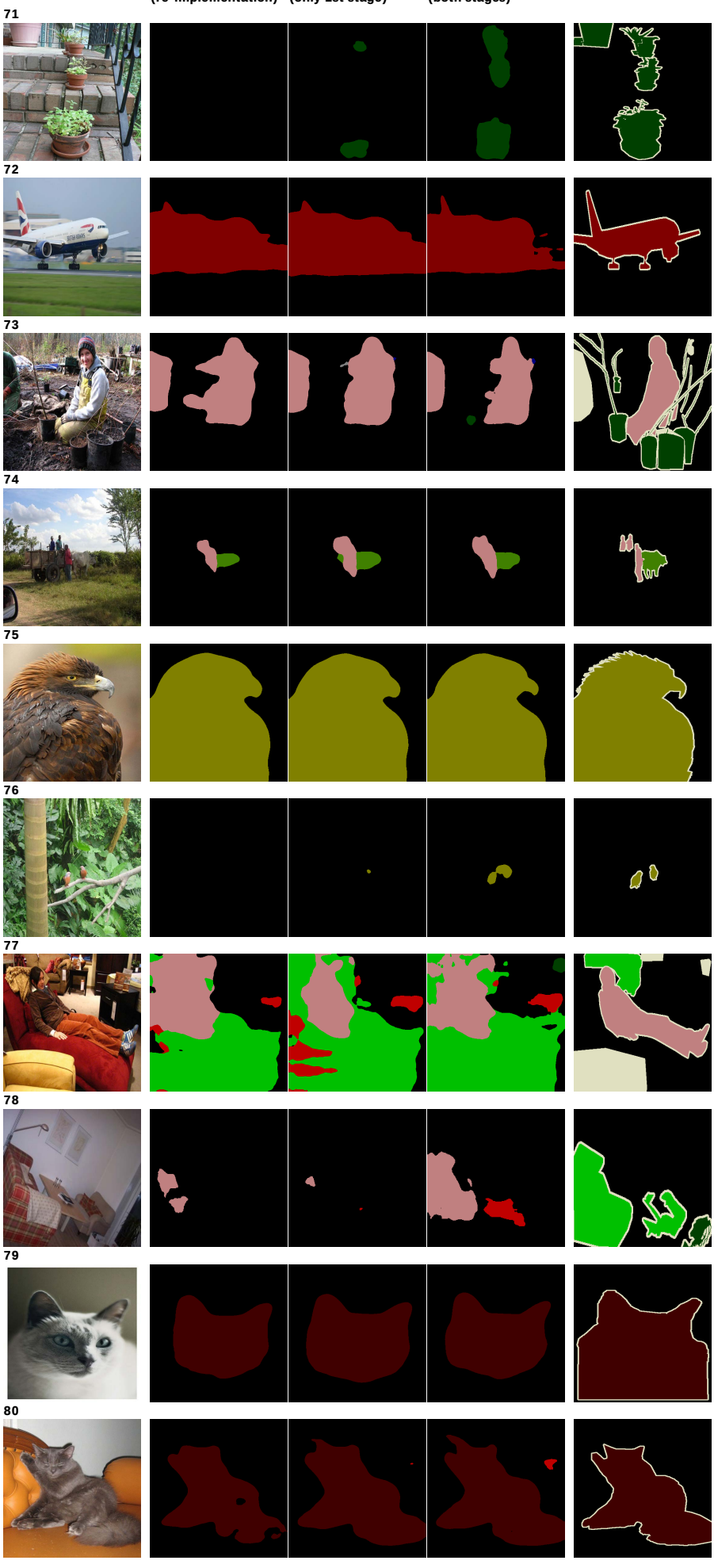
Input image
PSA 59.0%
(re-implementation)
SSDD(1st) 61.4%
(only 1st stage)
SSDD(full) 64.9%
(both stages)
Ground truth
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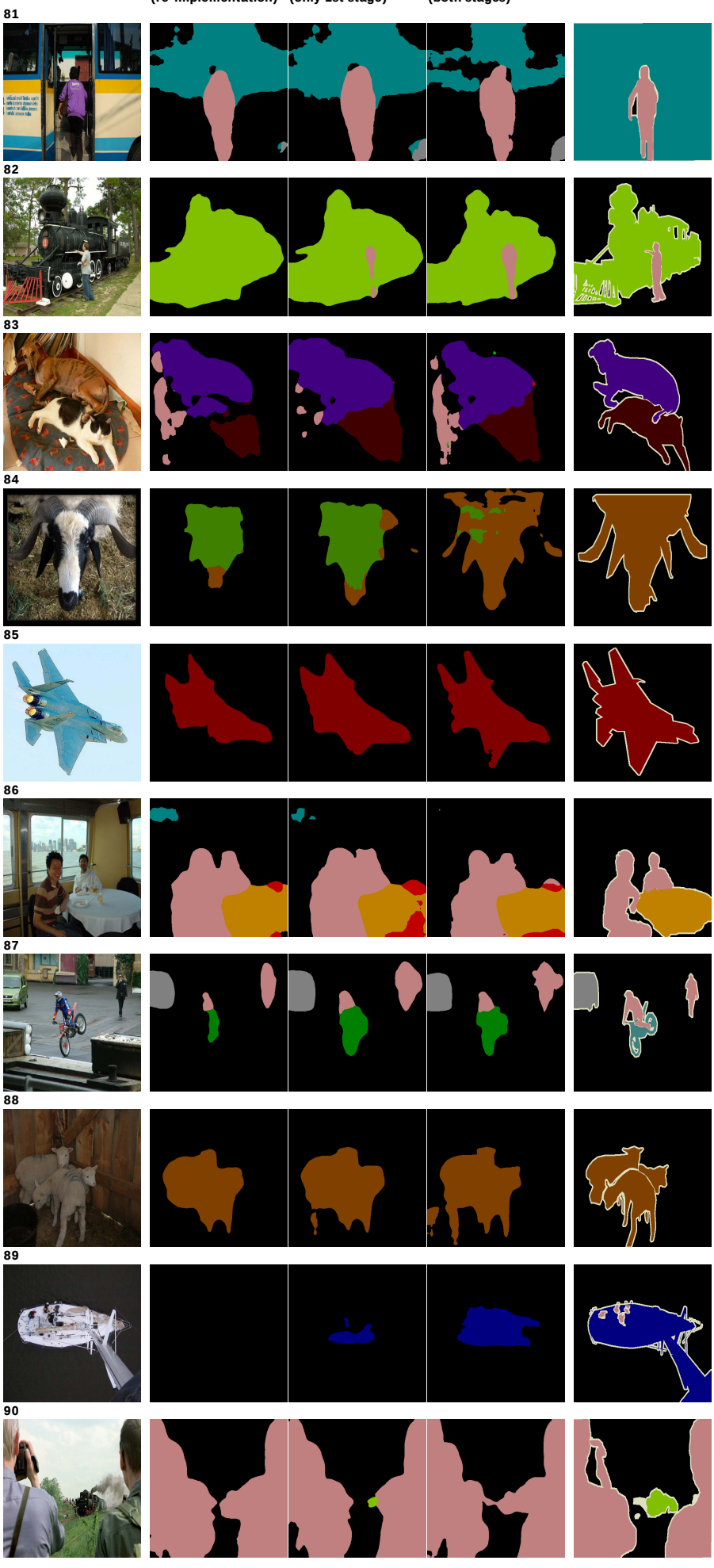
Input image
PSA 59.0%
(re-implementation)
SSDD(1st) 61.4%
(only 1st stage)
SSDD(full) 64.9%
(both stages)
Ground truth
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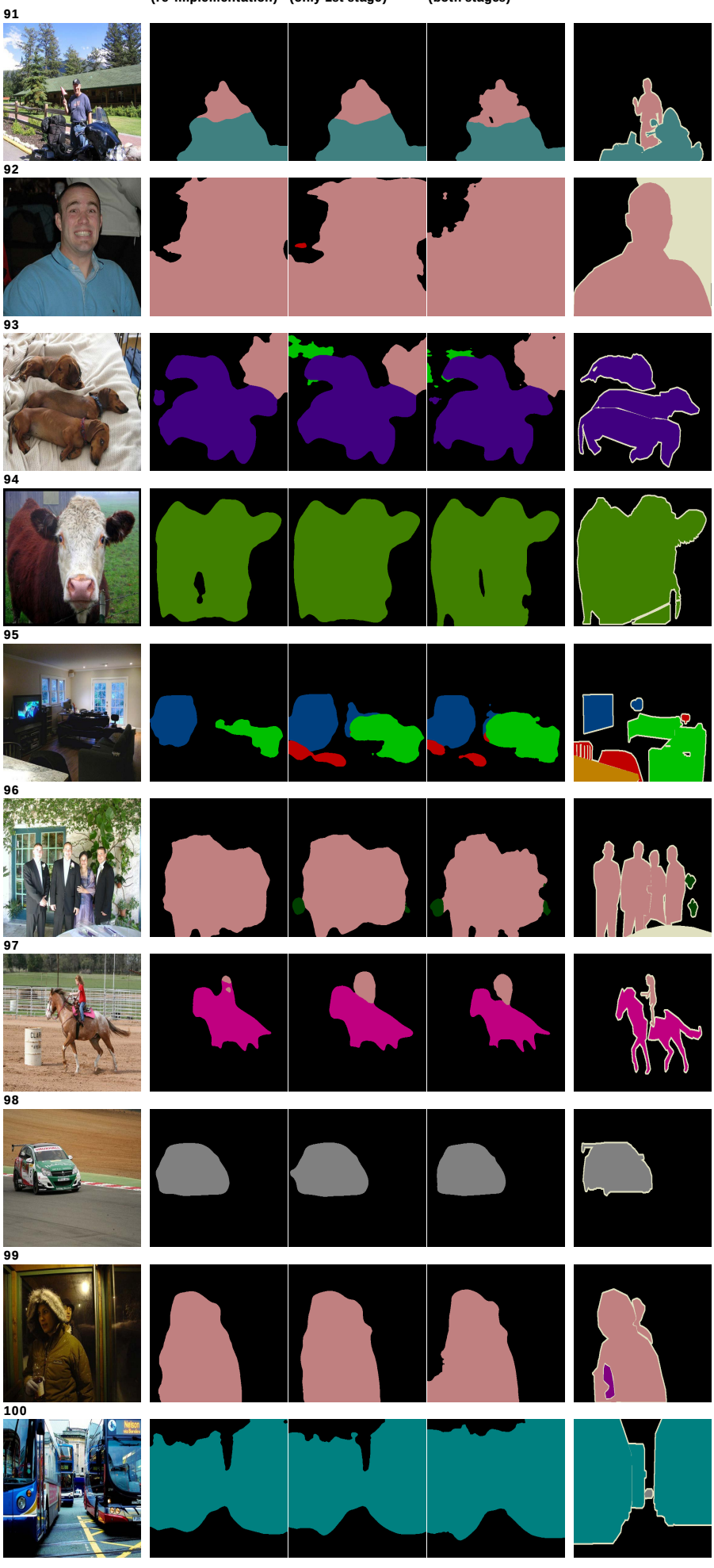
Input image
PSA 59.0% (re-implementation)
SSDD(1st) 61.4% (only 1st stage)
SSDD(full) 64.9% (both stages)
Ground truth
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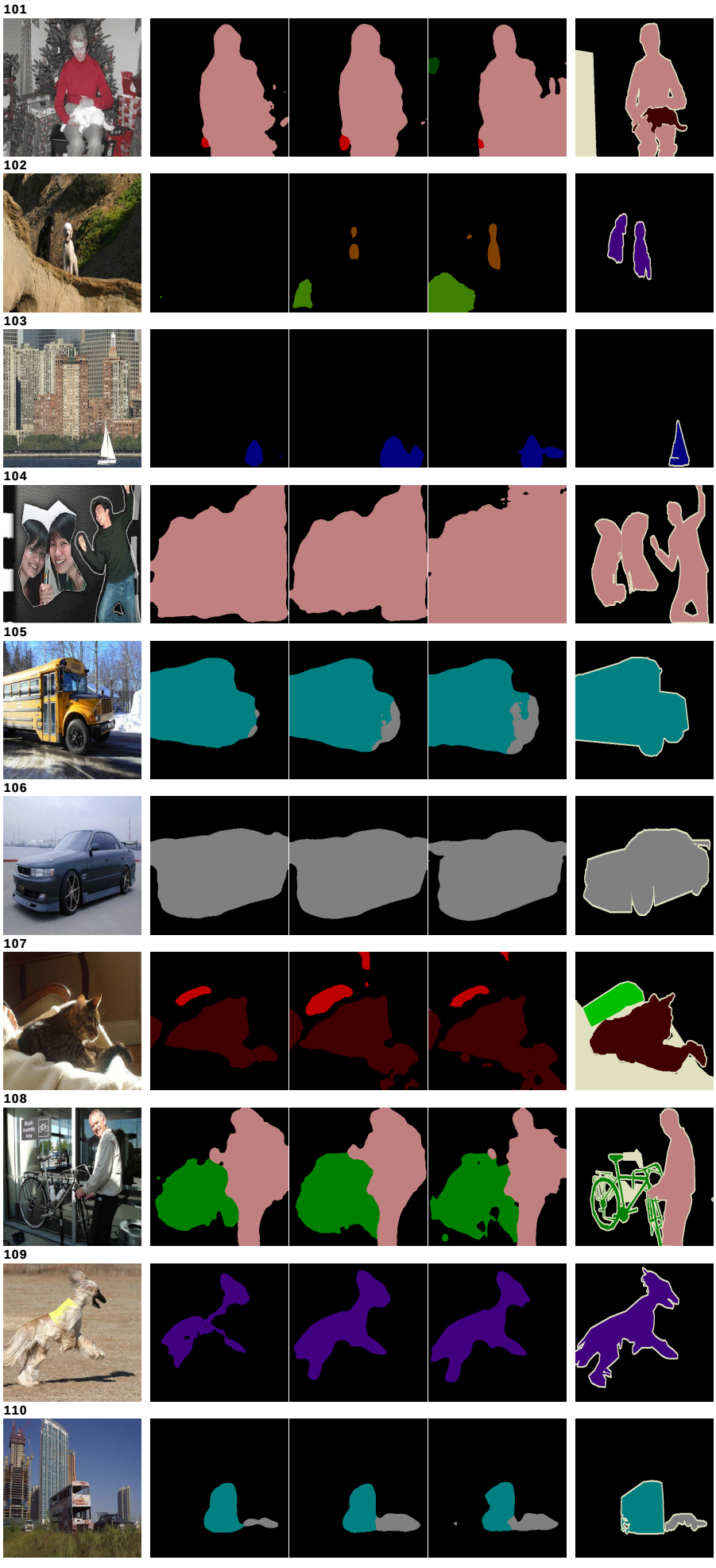
Input image
PSA 59.0%
(re-implementation)
SSDD(1st) 61.4%
(only 1st stage)
SSDD(full) 64.9%
(both stages)
Ground truth
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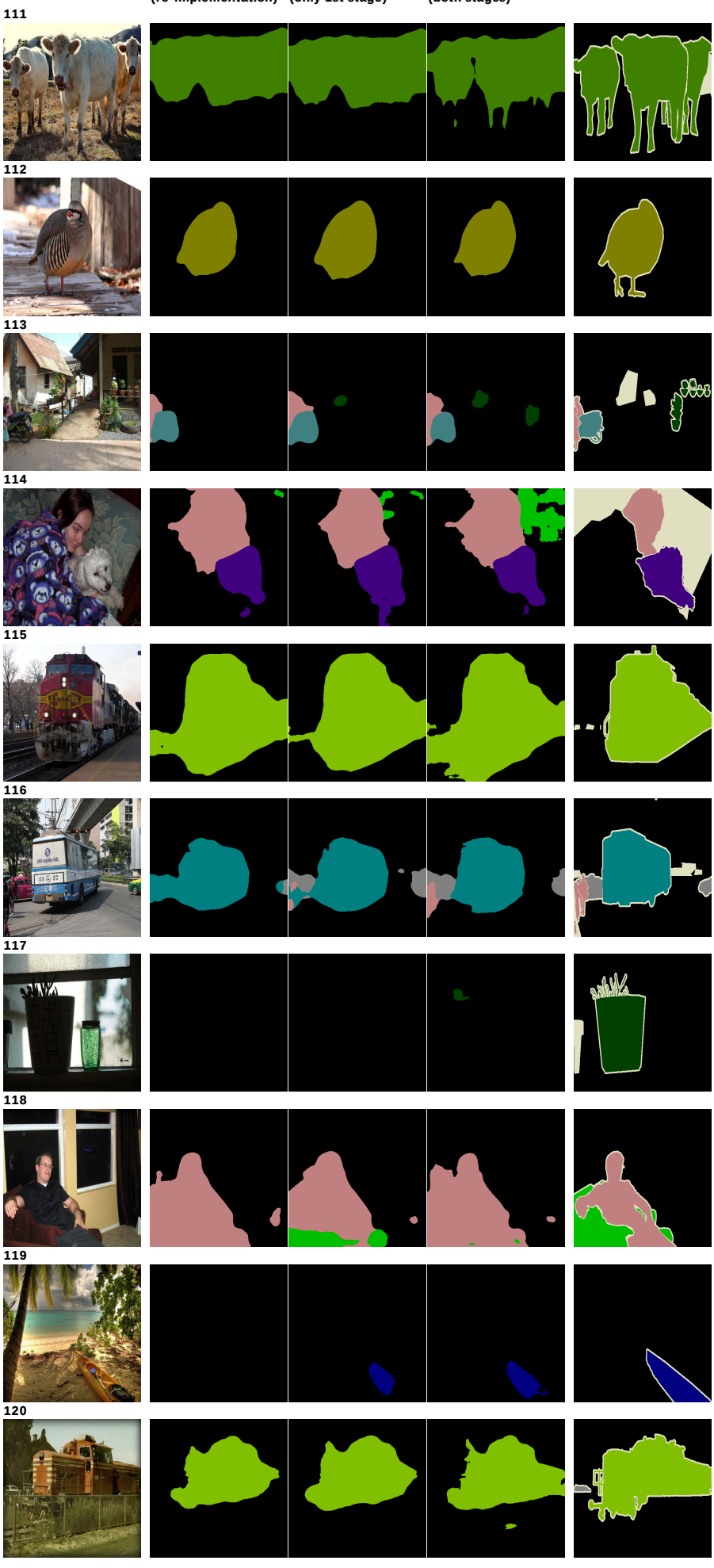
Input image
PSA 59.0%
(re-implementation)
SSDD(1st) 61.4%
(only 1st stage)
SSDD(full) 64.9%
(both stages)
Ground truth
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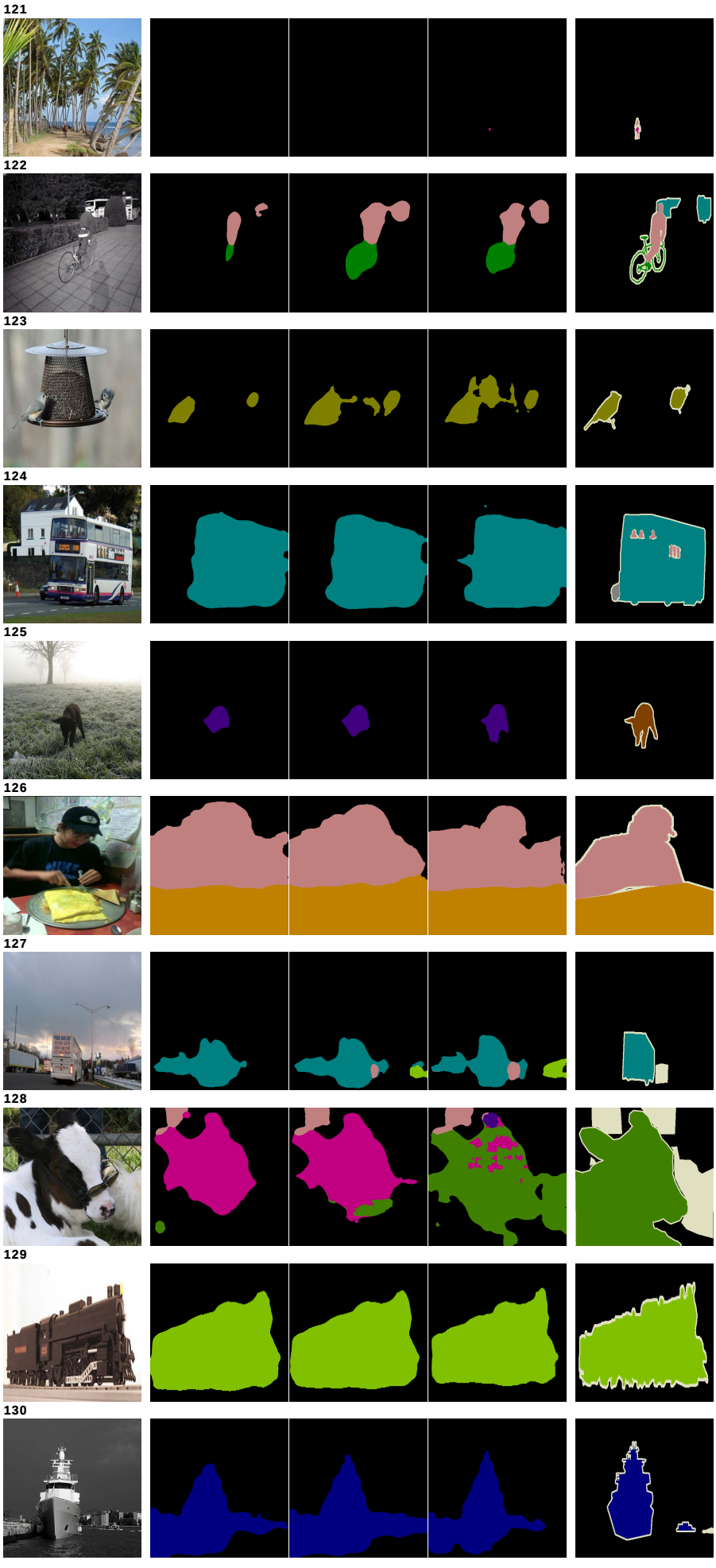
Input image
PSA 59.0% (re-implementation)
SSDD(1st) 61.4% (only 1st stage)
SSDD(full) 64.9% (both stages)
Ground truth
121
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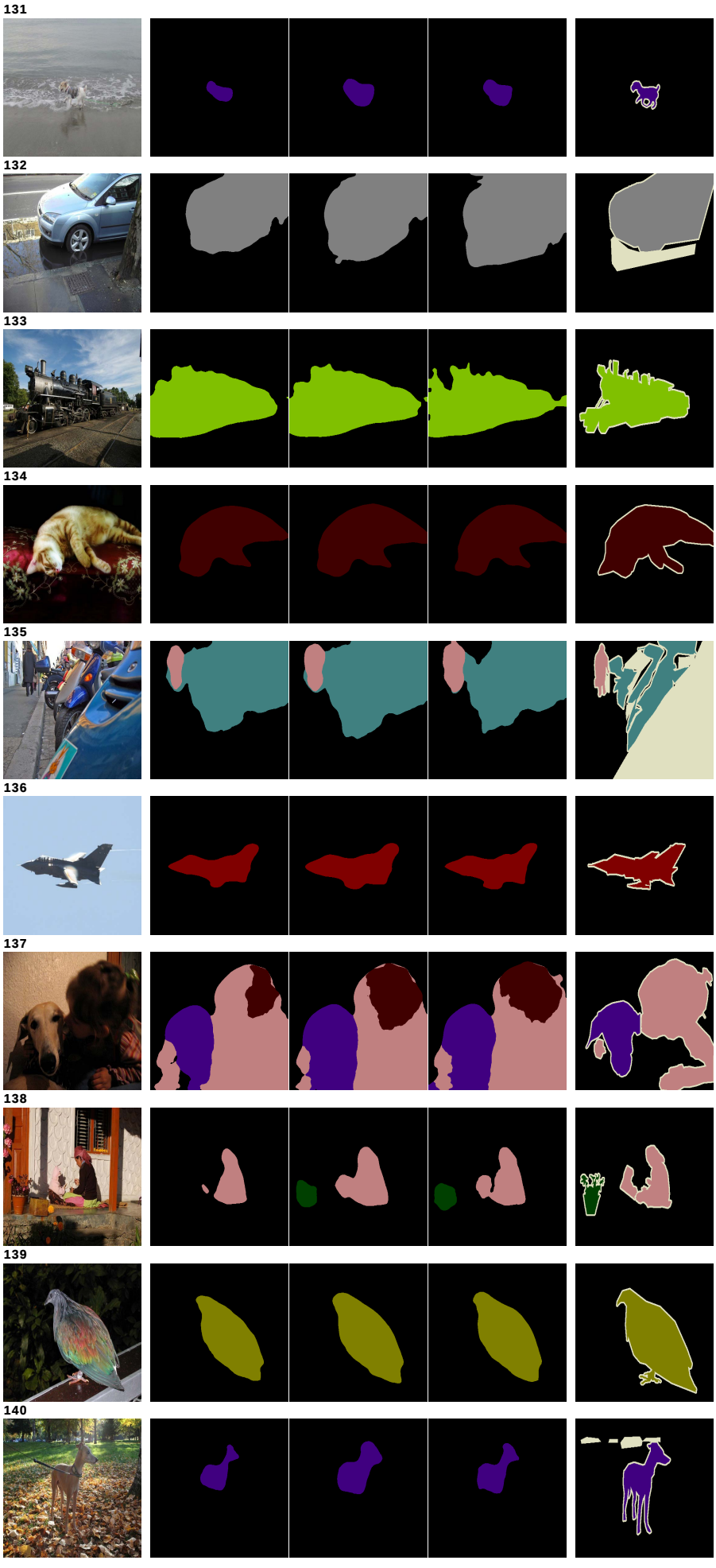
129
130


Input image
PSA 59.0%
(re-implementation)
SSDD(1st) 61.4%
(only 1st stage)
SSDD(full) 64.9%
(both stages)
Ground truth
131
132
133
134
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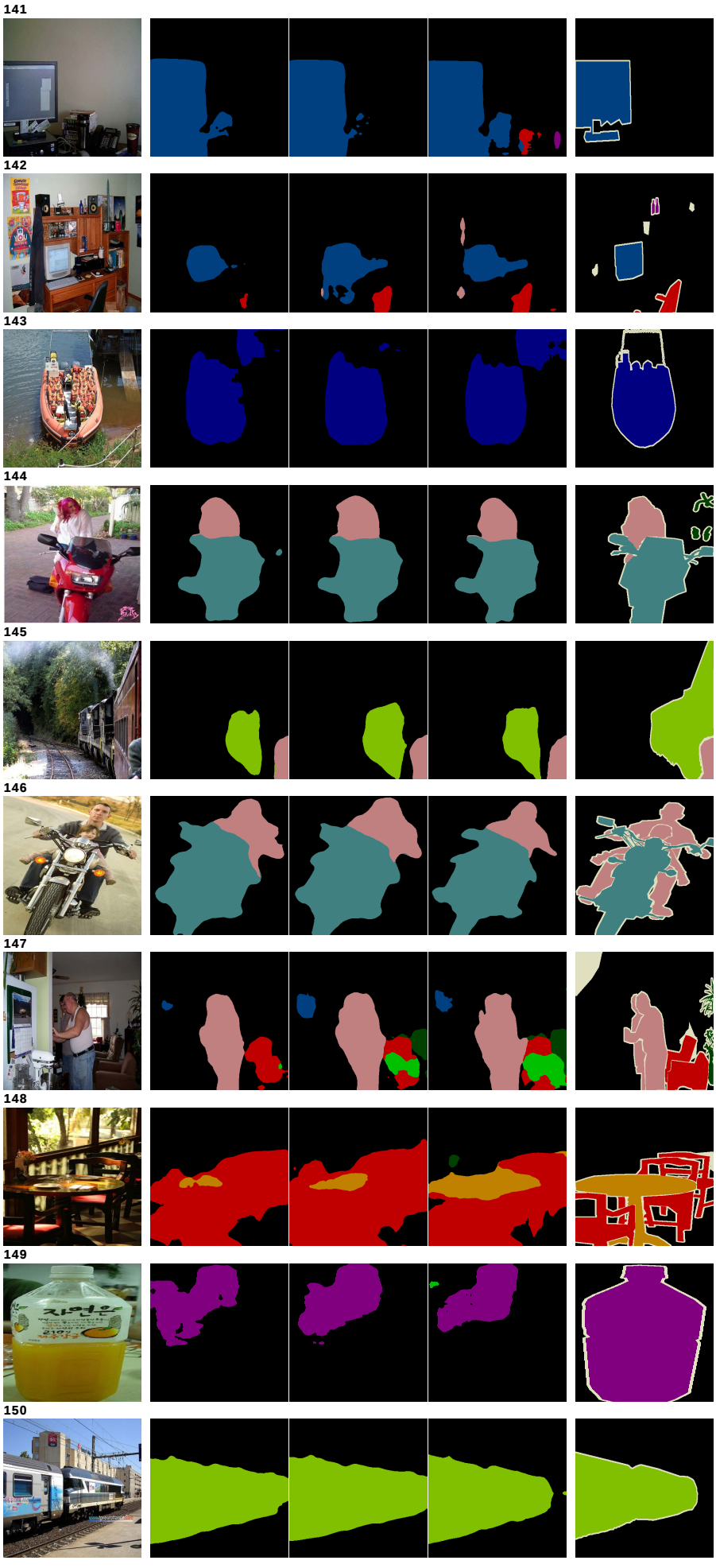
140


Input image
PSA 59.0%
(re-implementation)
SSDD(1st) 61.4%
(only 1st stage)
SSDD(full) 64.9%
(both stages)
Ground truth
141
142
143
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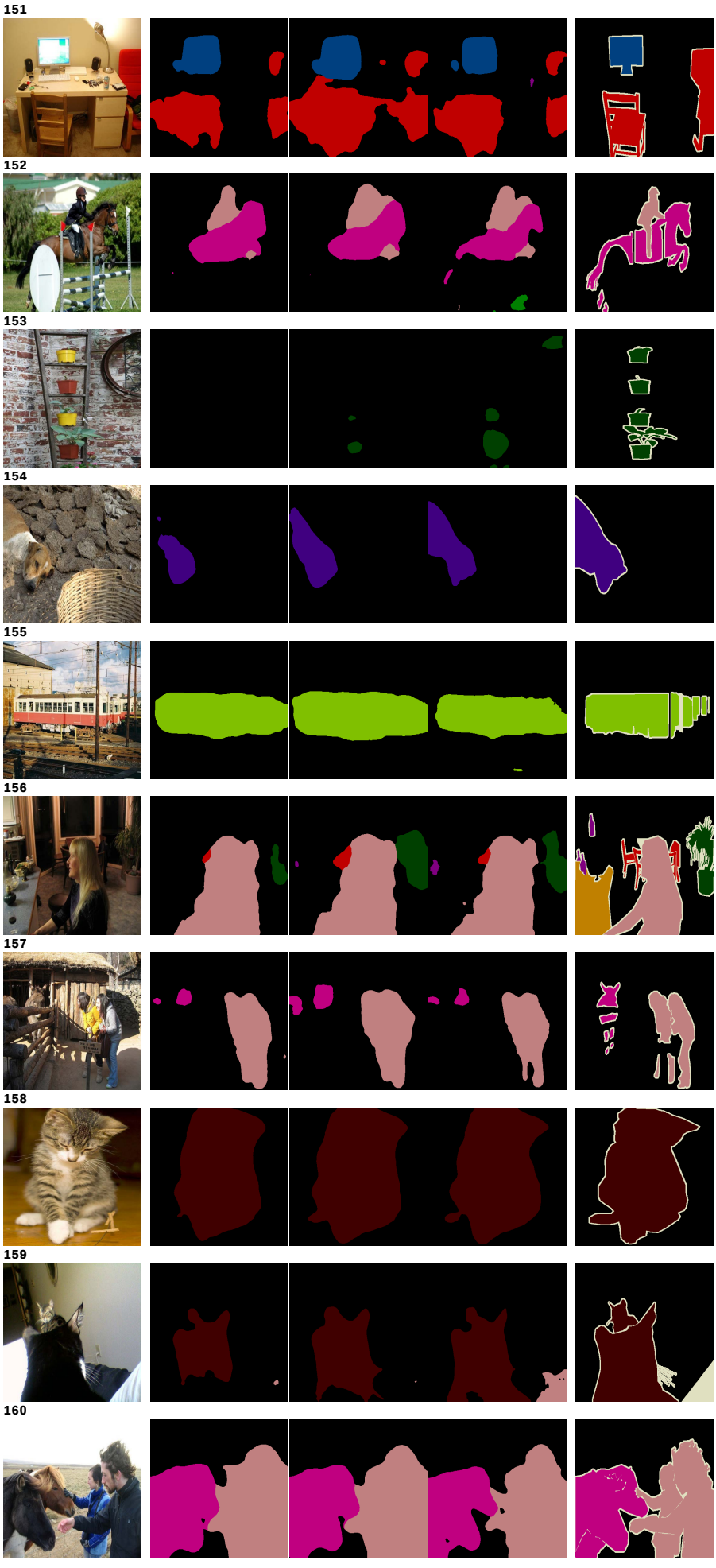
Input image
PSA 59.0%
(re-implementation)
SSDD(1st) 61.4%
(only 1st stage)
SSDD(full) 64.9%
(both stages)
Ground truth
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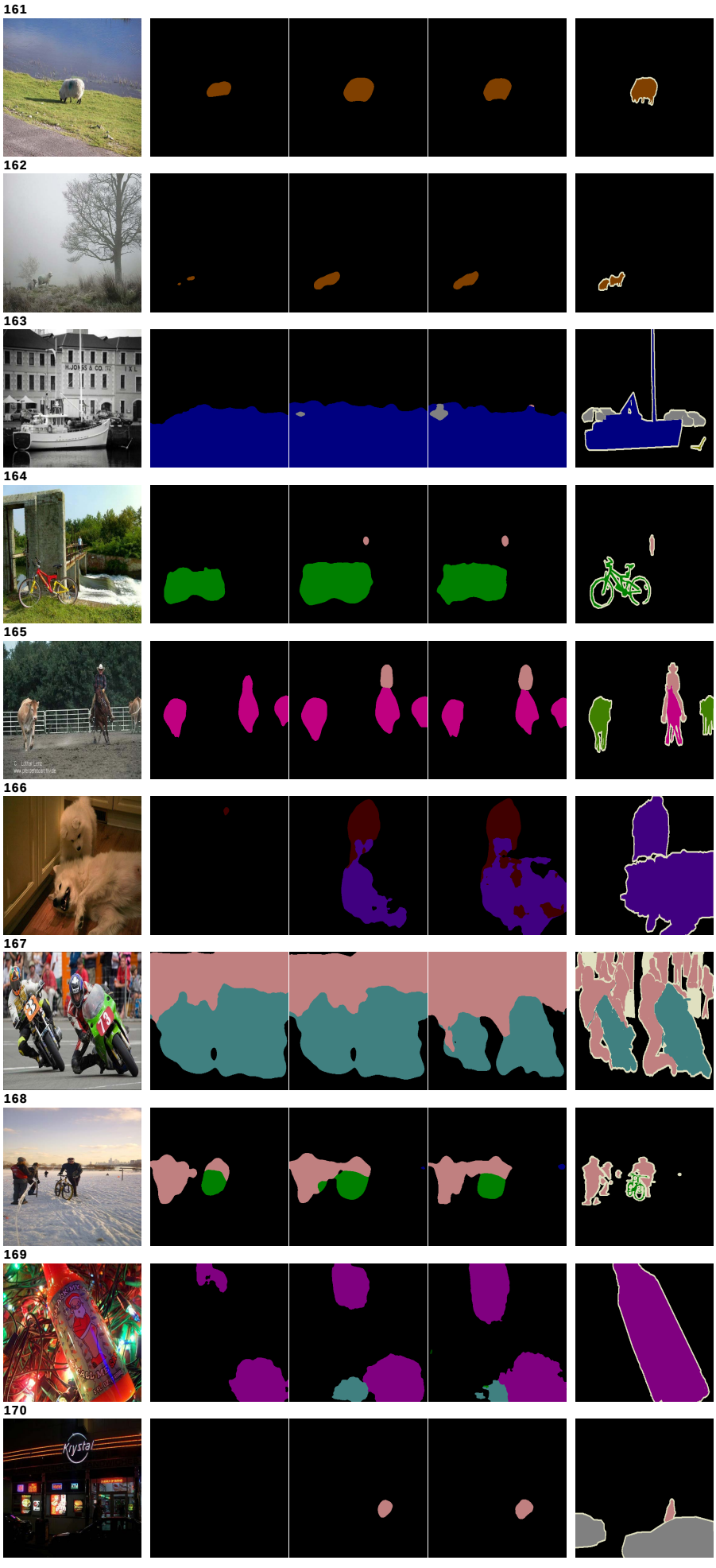
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(re-implementation)
SSDD(1st) 61.4 %
(only 1st stage)
SSDD(full) 64.9 %
(both stages)
Ground truth
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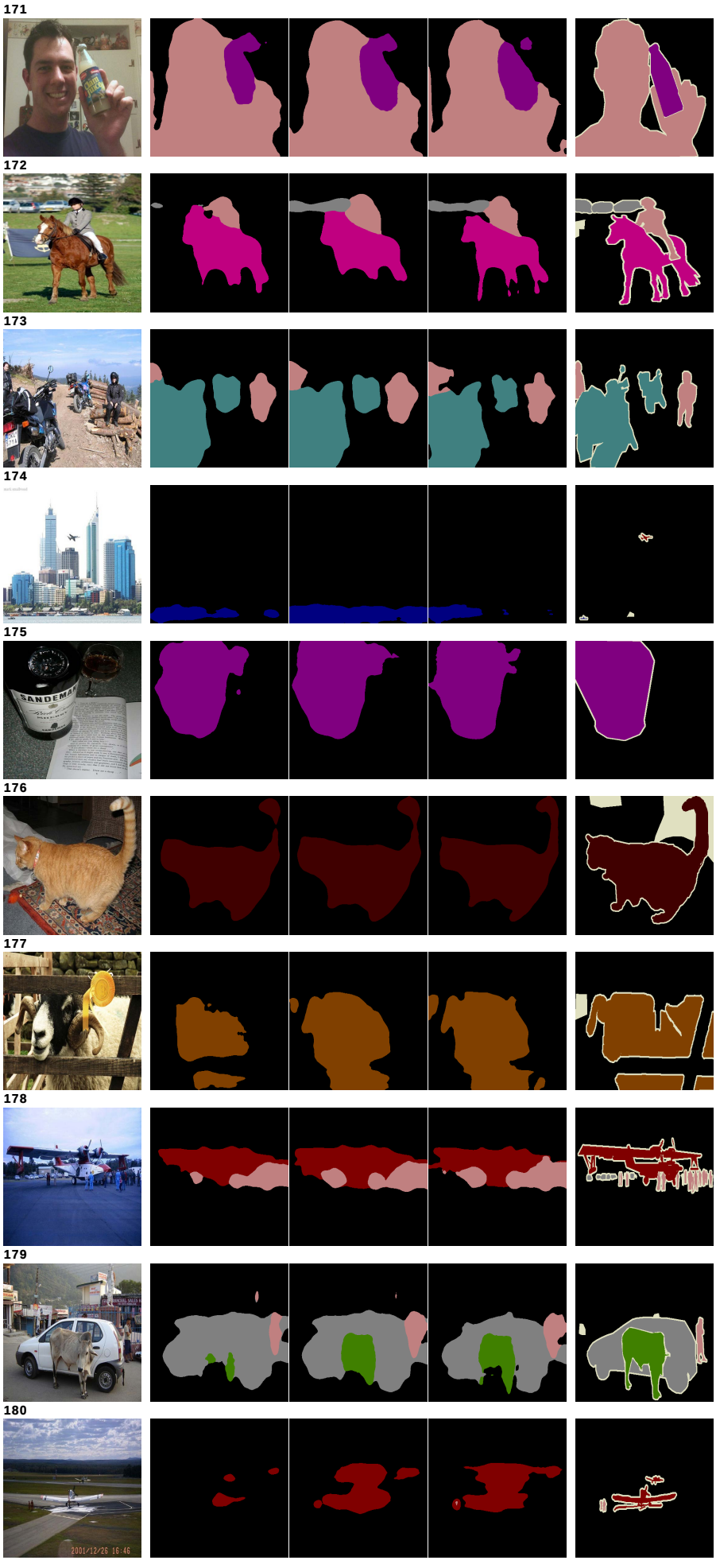
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SSDD(full) 64.9% (both stages)
Ground truth
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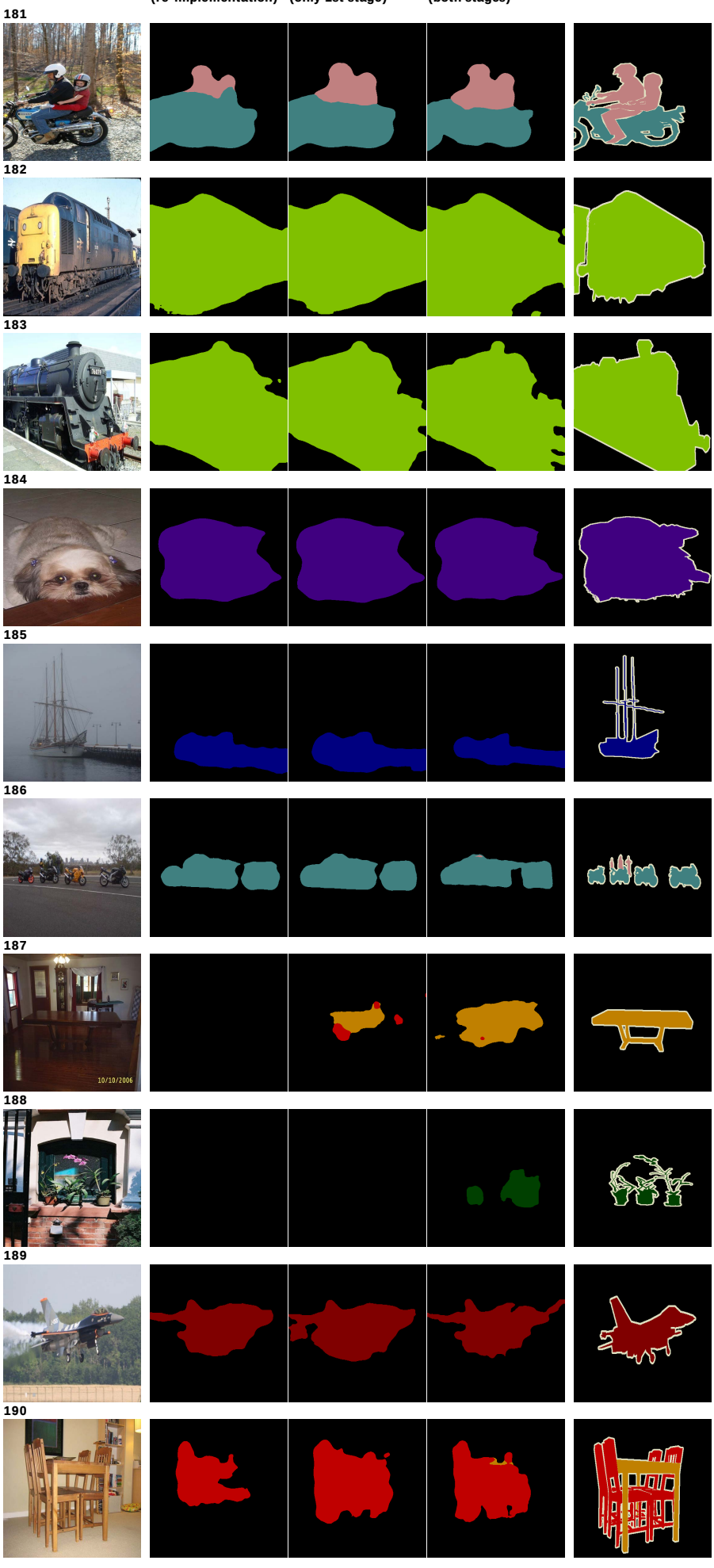
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(both stages)
Ground truth
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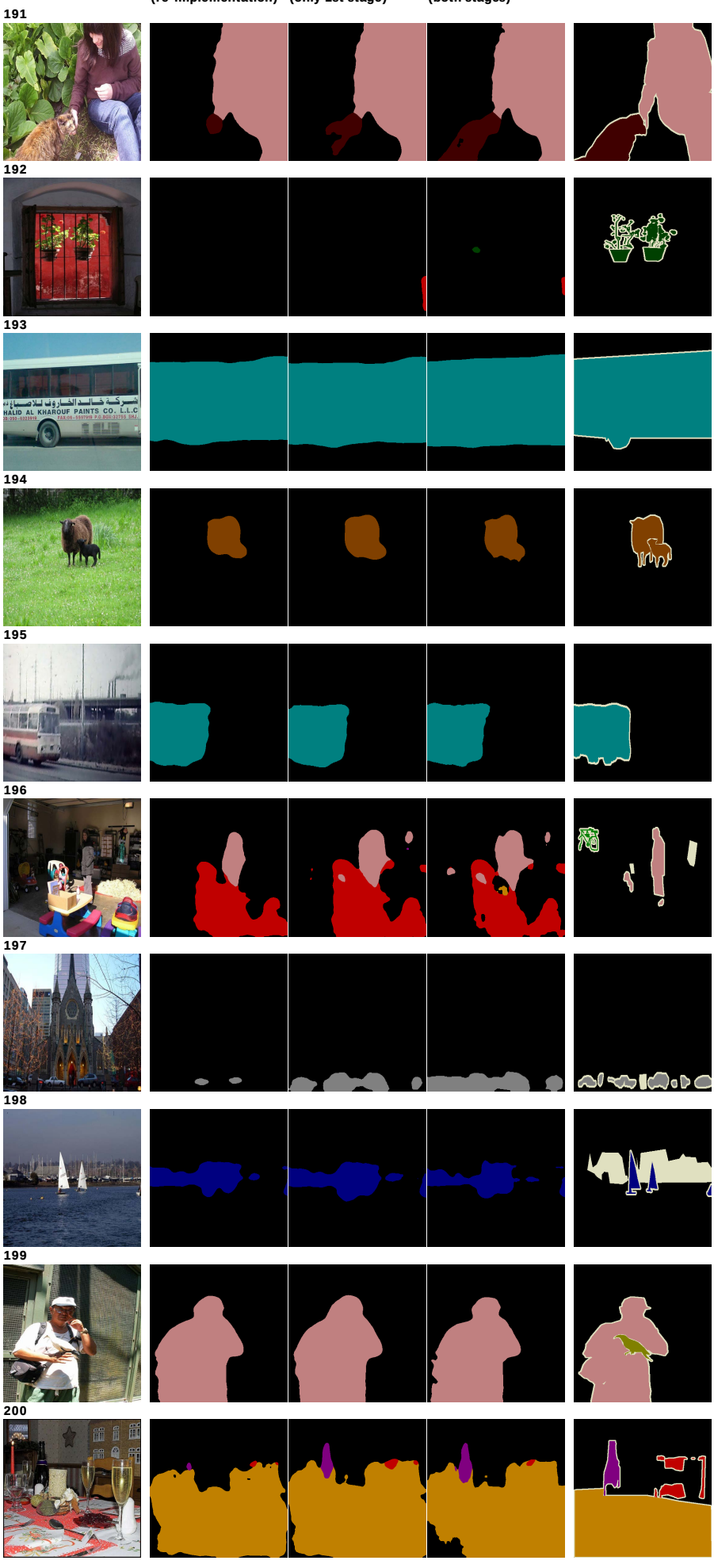
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(re-implementation)
SSDD(1st) 61.4 %
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SSDD(full) 64.9 %
(both stages)
Ground truth
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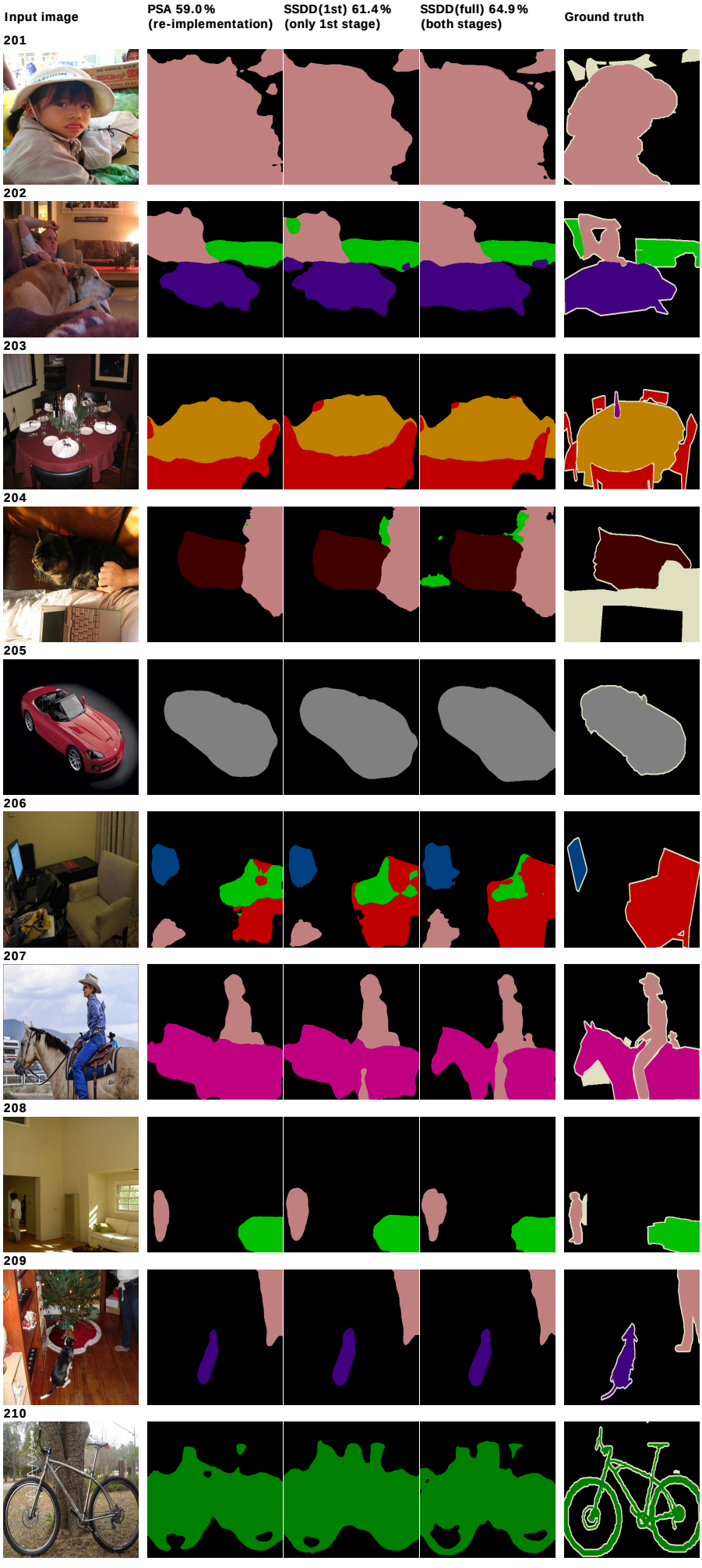
Input image
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SSDD(full) 64.9% (both stages)
Ground truth
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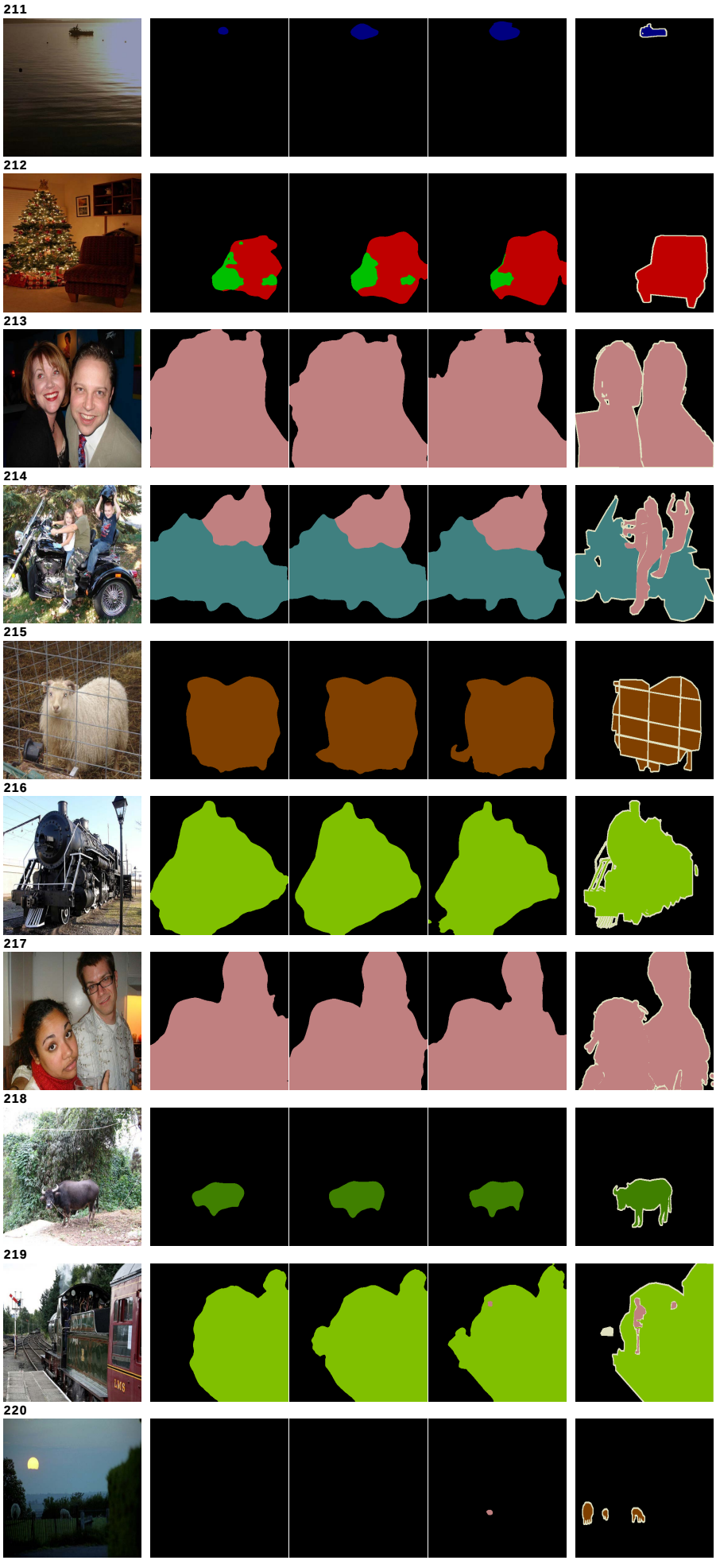
Input image
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Ground truth
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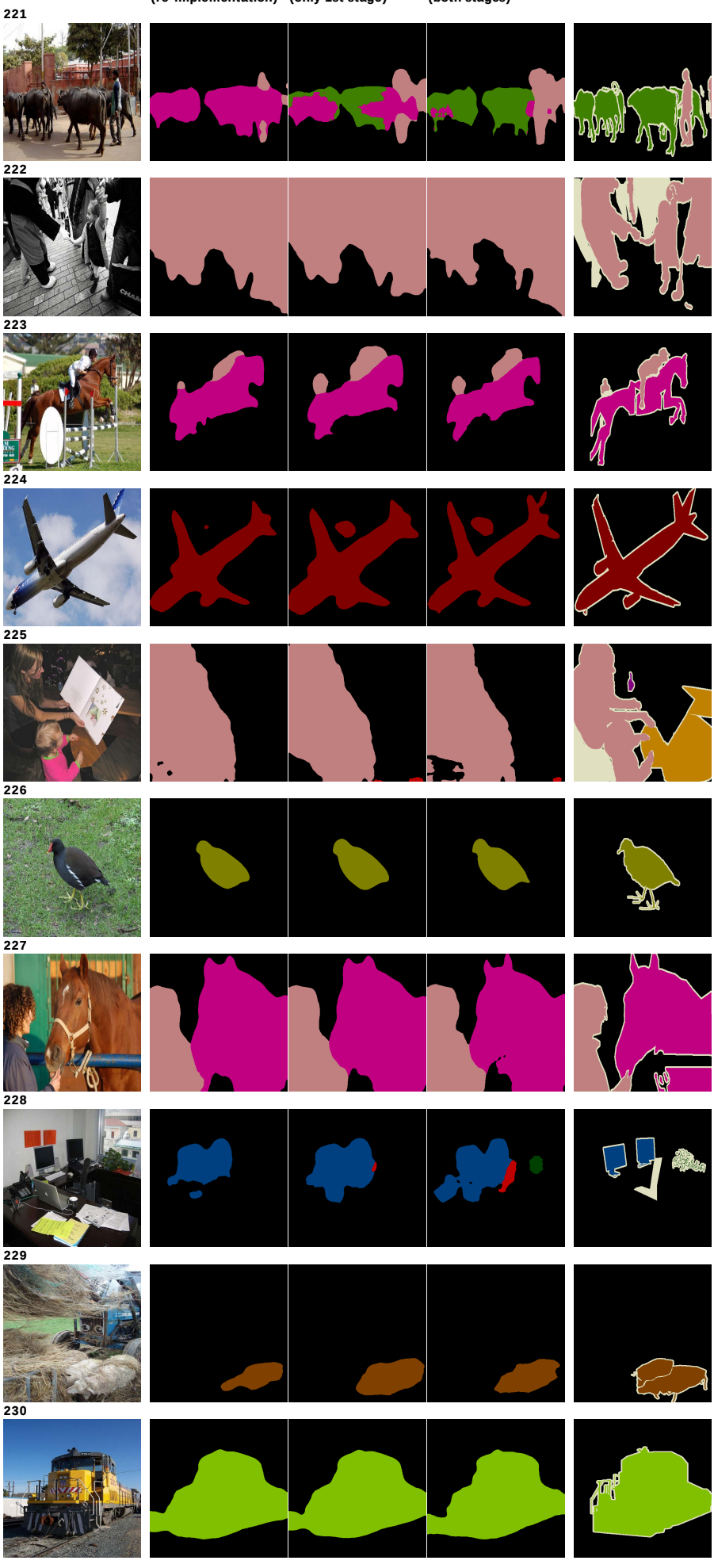
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SSDD(full) 64.9%
(both stages)
Ground truth
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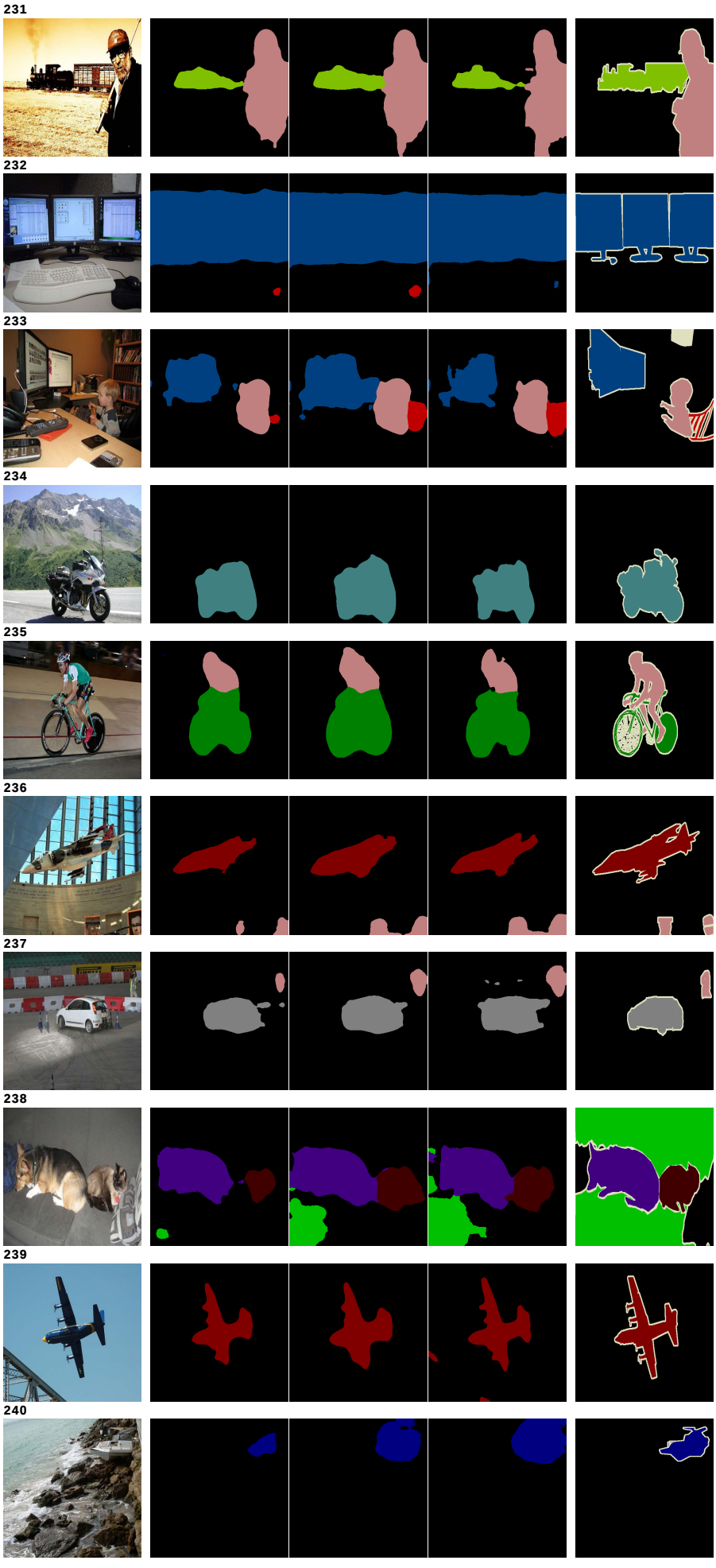
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SSDD(1st) 61.4% (only 1st stage)
SSDD(full) 64.9% (both stages)
Ground truth
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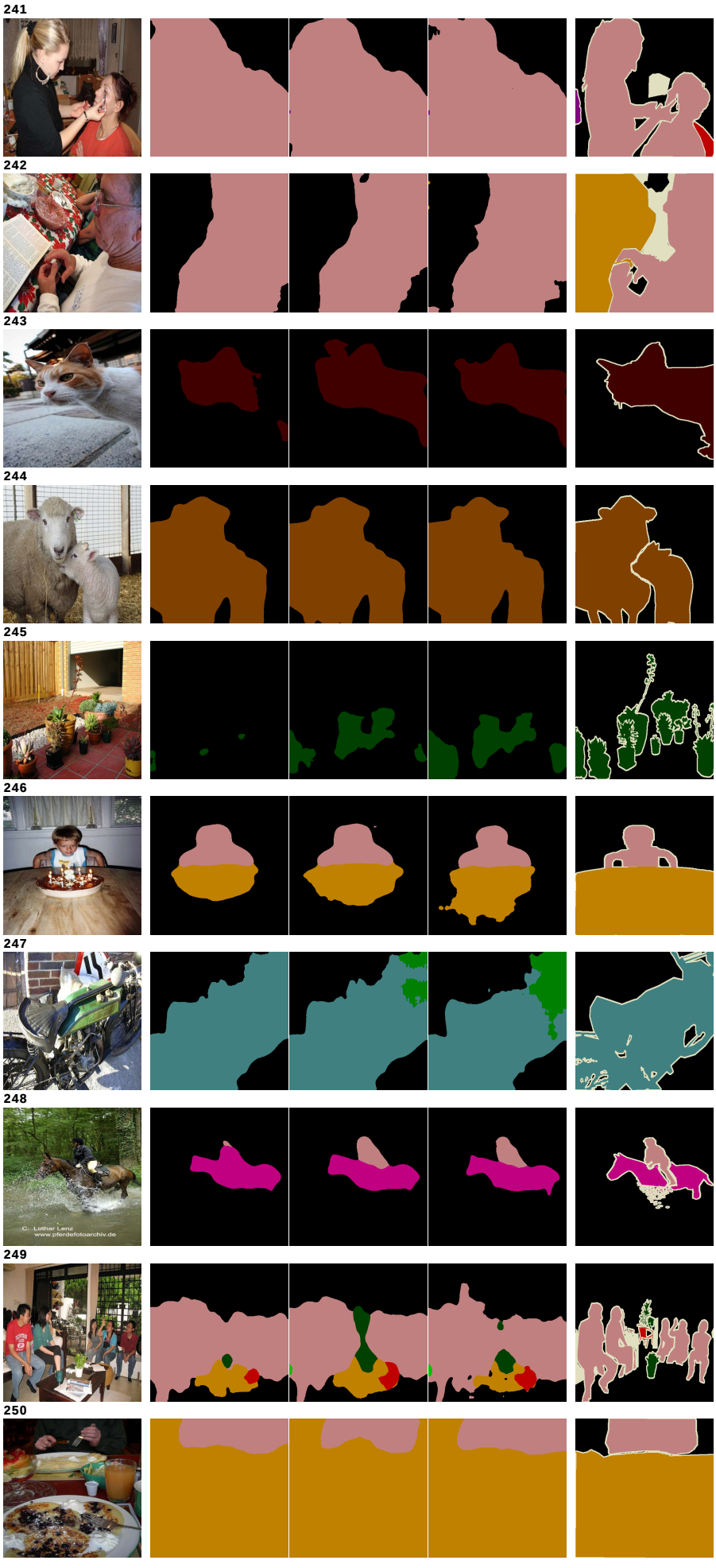
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SSDD(1st) 61.4%
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SSDD(full) 64.9%
(both stages)
Ground truth
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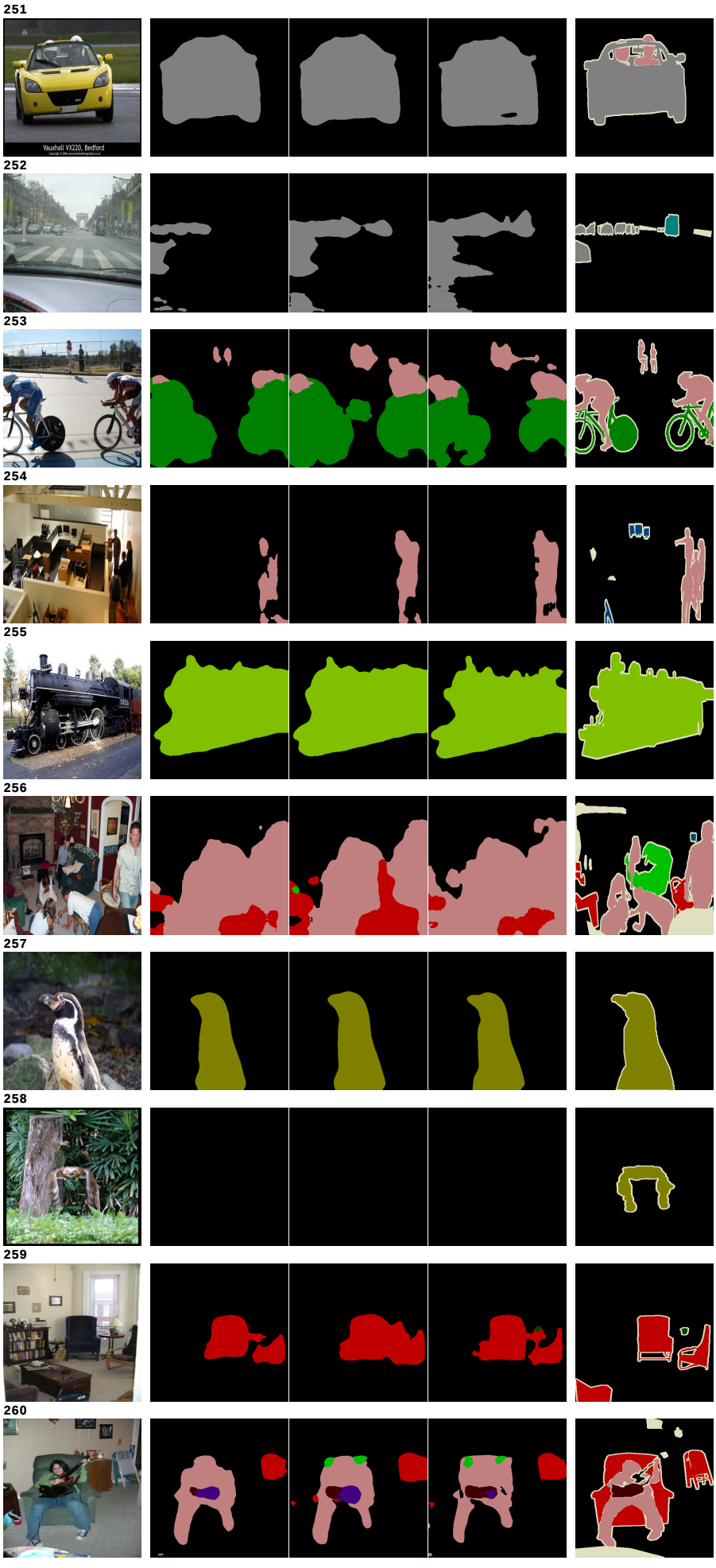
Input image
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(re-implementation)
SSDD(1st) 61.4 %
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SSDD(full) 64.9 %
(both stages)
Ground truth
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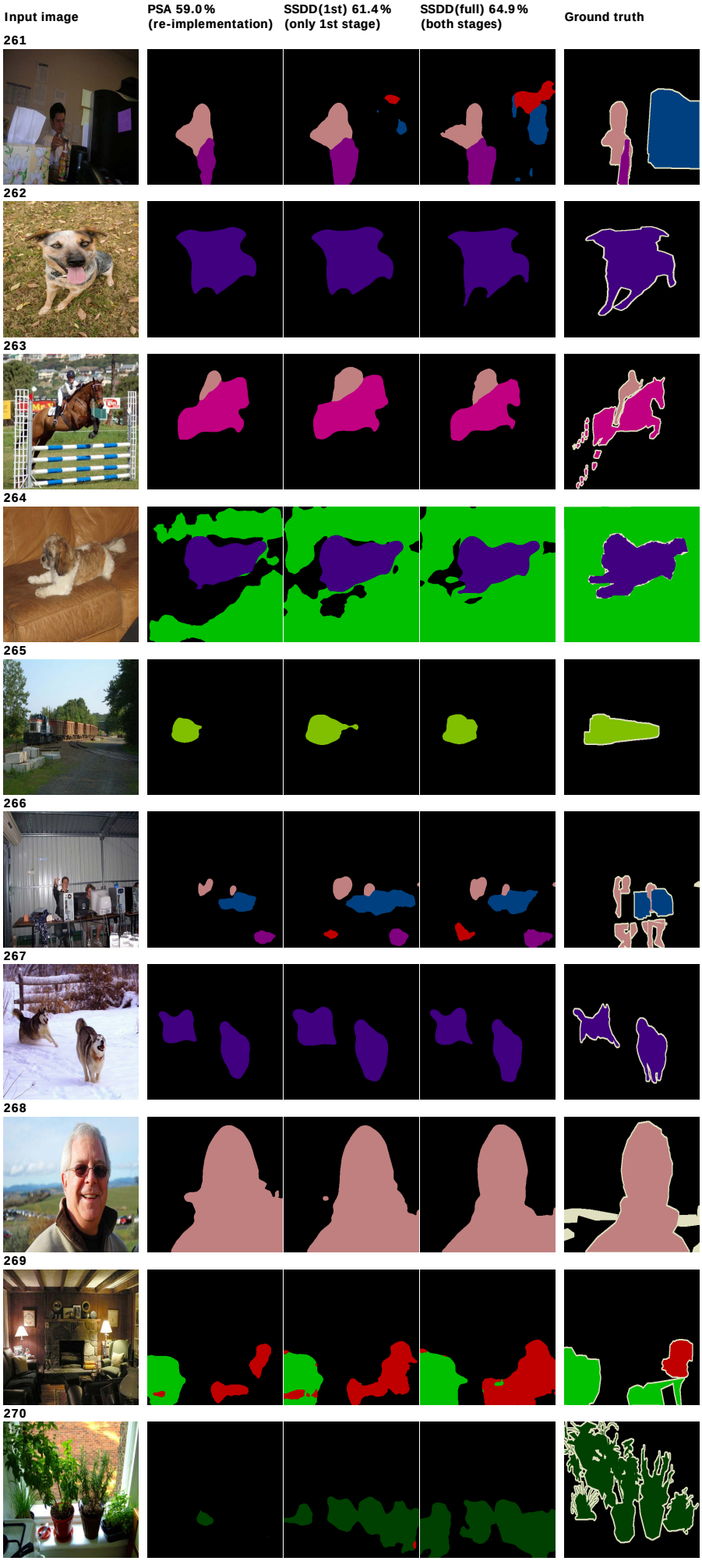
Input image
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SSDD(1st) 61.4% (only 1st stage)
SSDD(full) 64.9% (both stages)
Ground truth
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Input image
PSA 59.0 %
(re-implementation)
SSDD(1st) 61.4 %
(only 1st stage)
SSDD(full) 64.9 %
(both stages)
Ground truth
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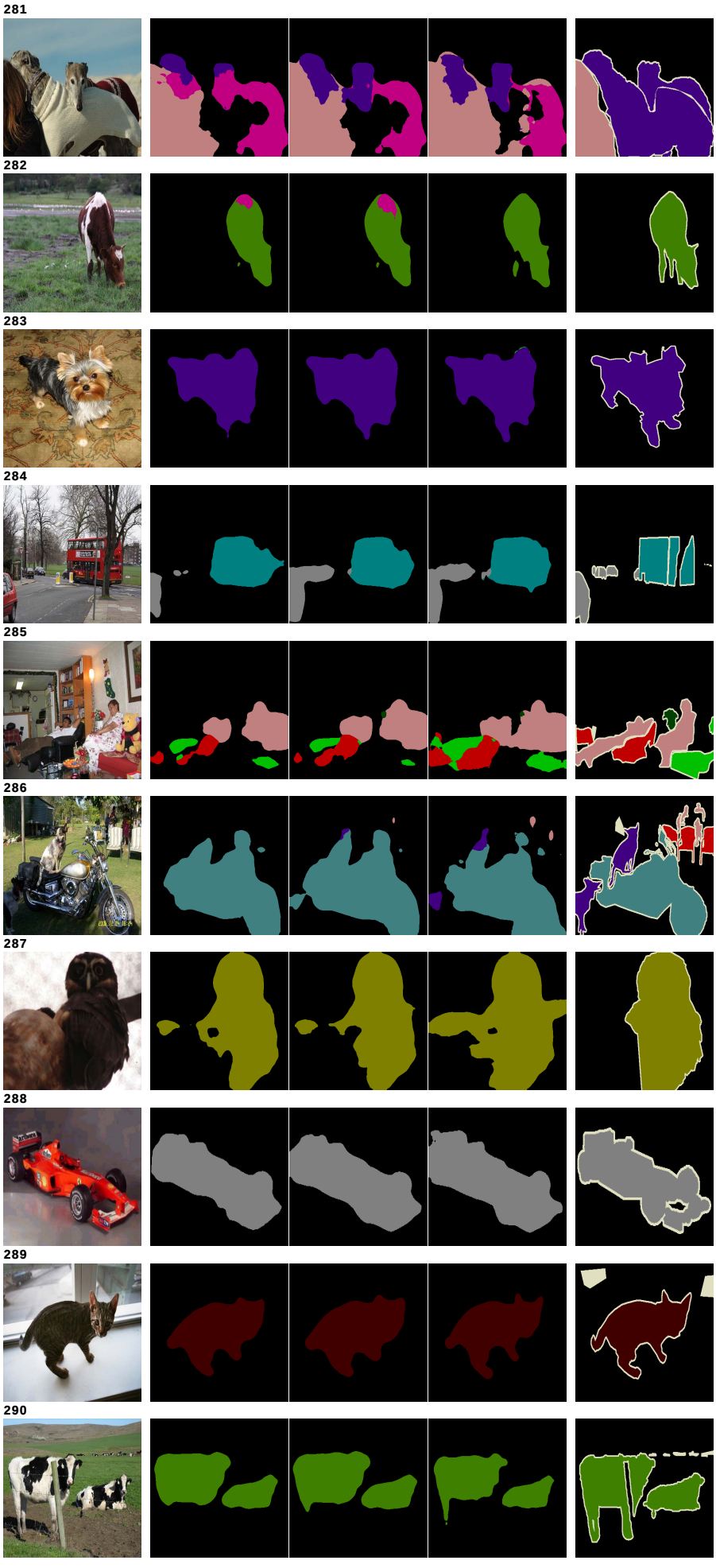
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SSDD(1st) 61.4%
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(both stages)
Ground truth
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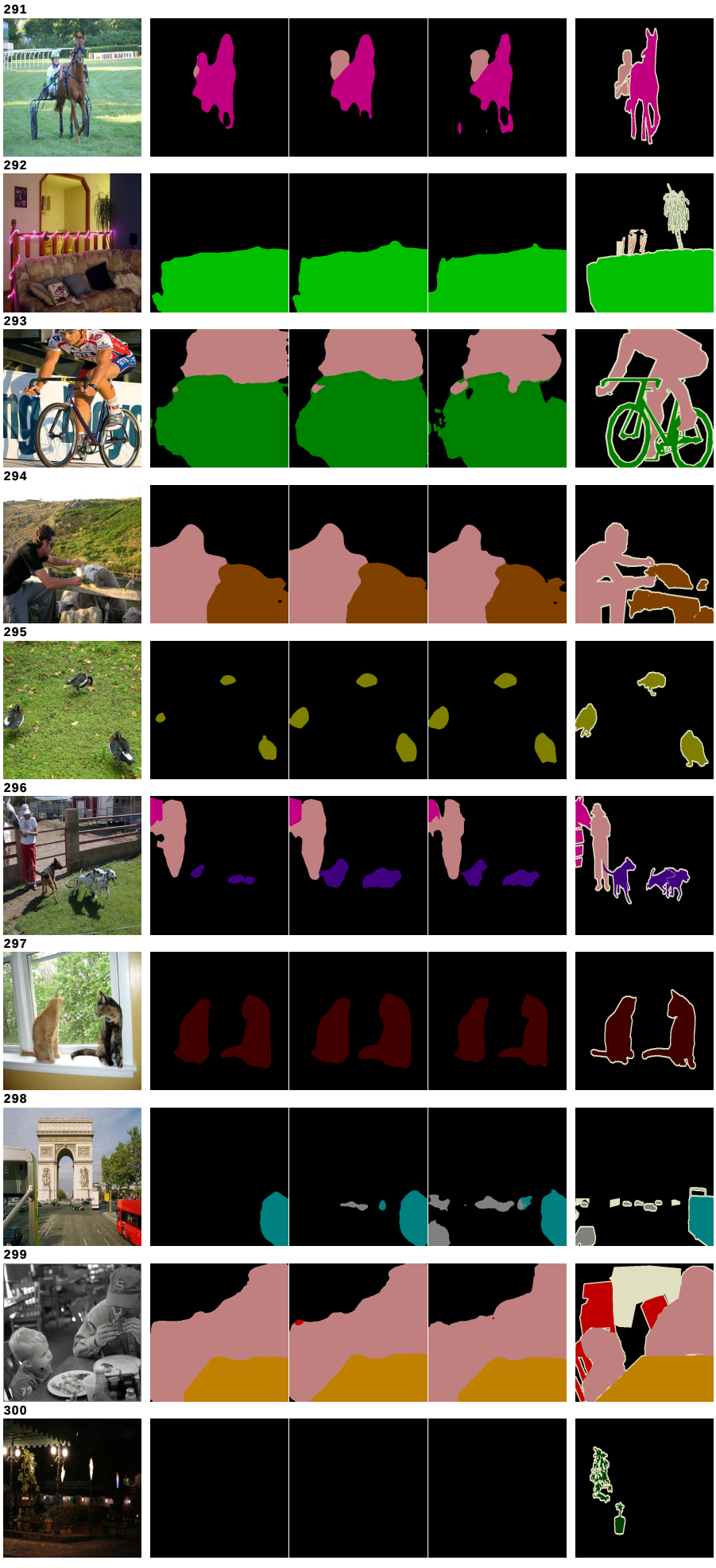
Input image
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SSDD(1st) 61.4% (only 1st stage)
SSDD(full) 64.9% (both stages)
Ground truth
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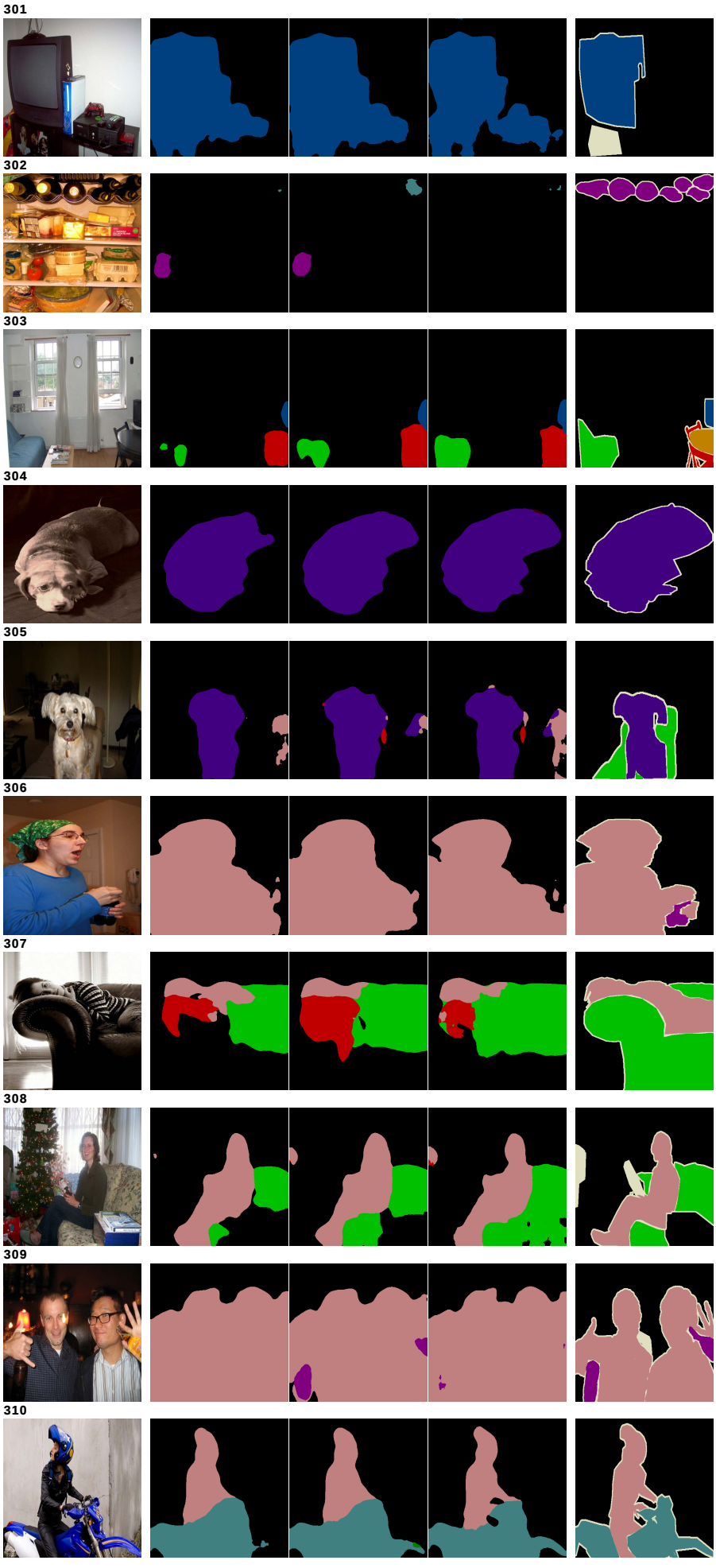
Input image
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(re-implementation)
SSDD(1st) 61.4%
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SSDD(full) 64.9%
(both stages)
Ground truth
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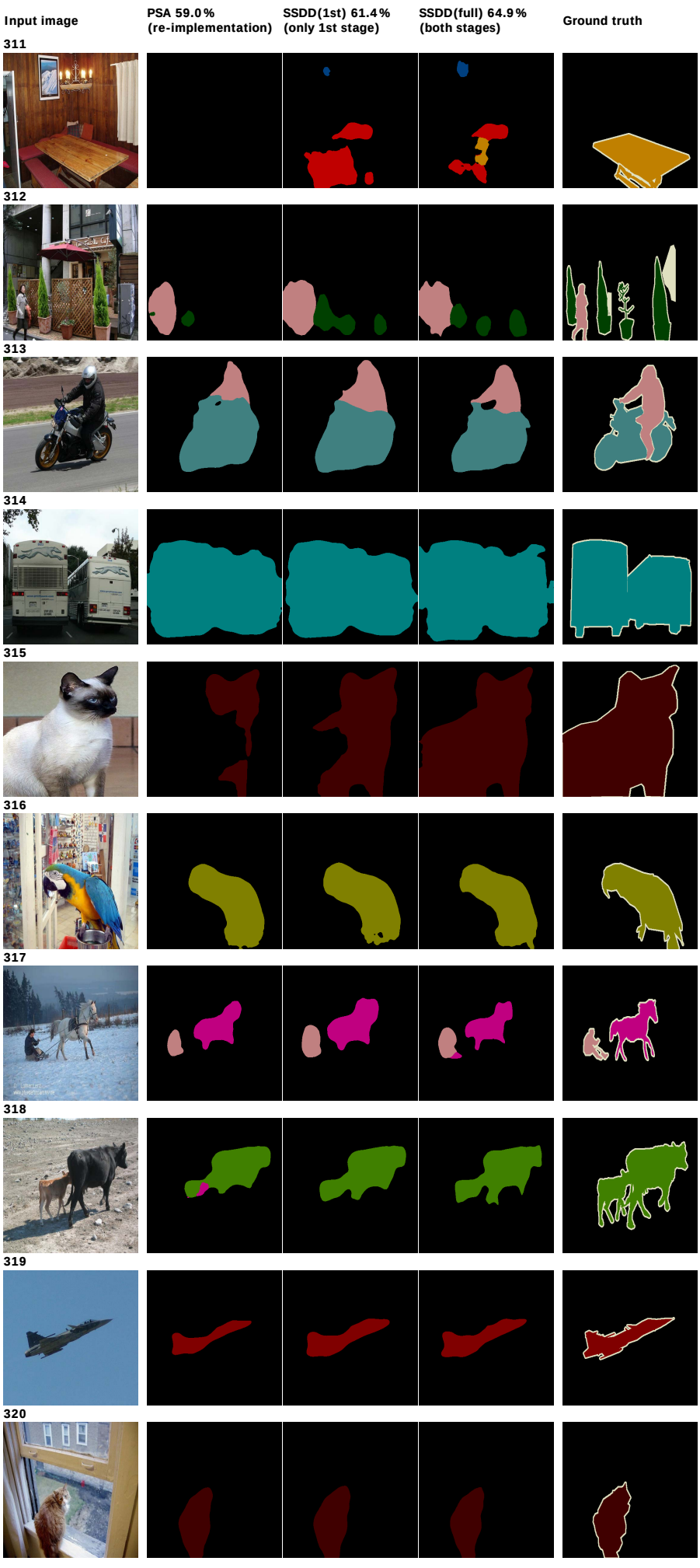
Input image
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Ground truth
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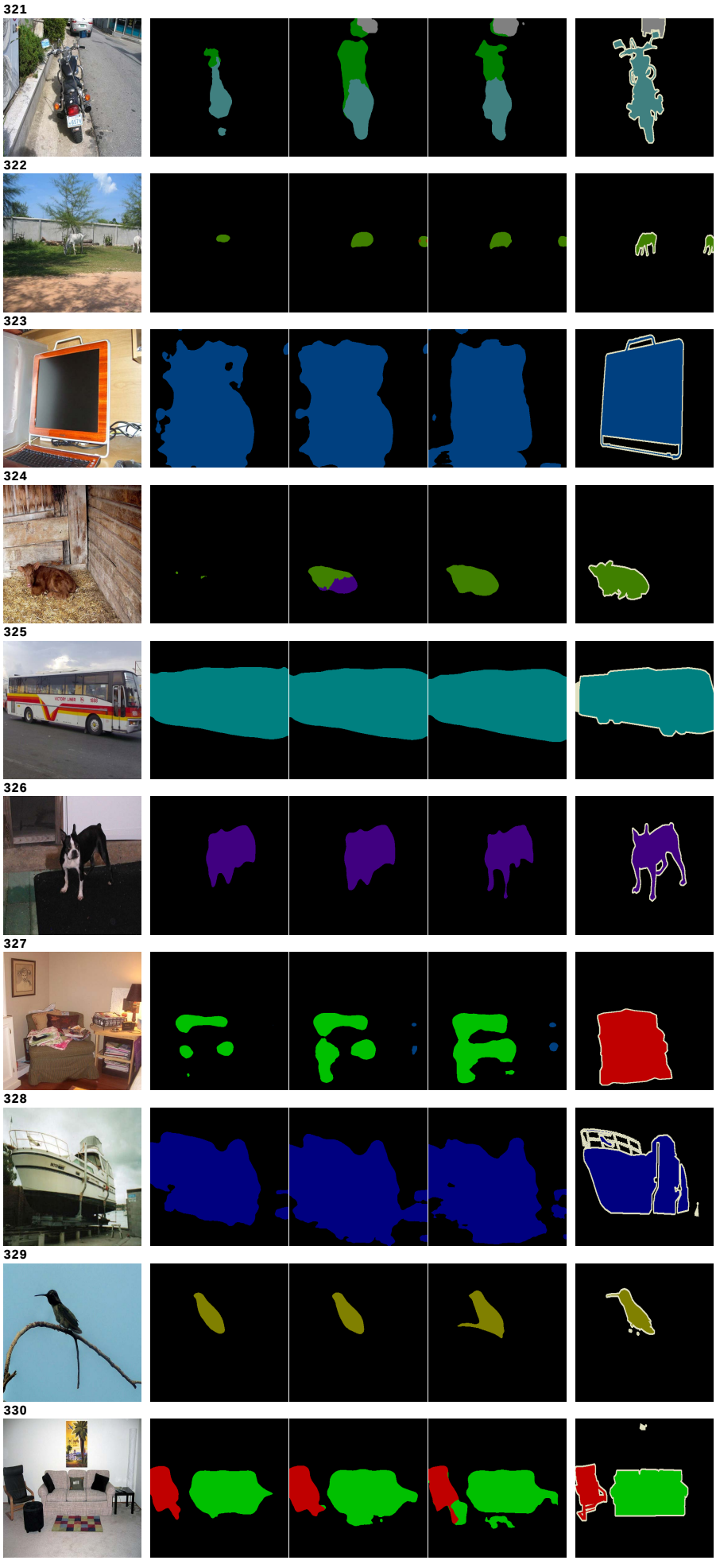
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Ground truth
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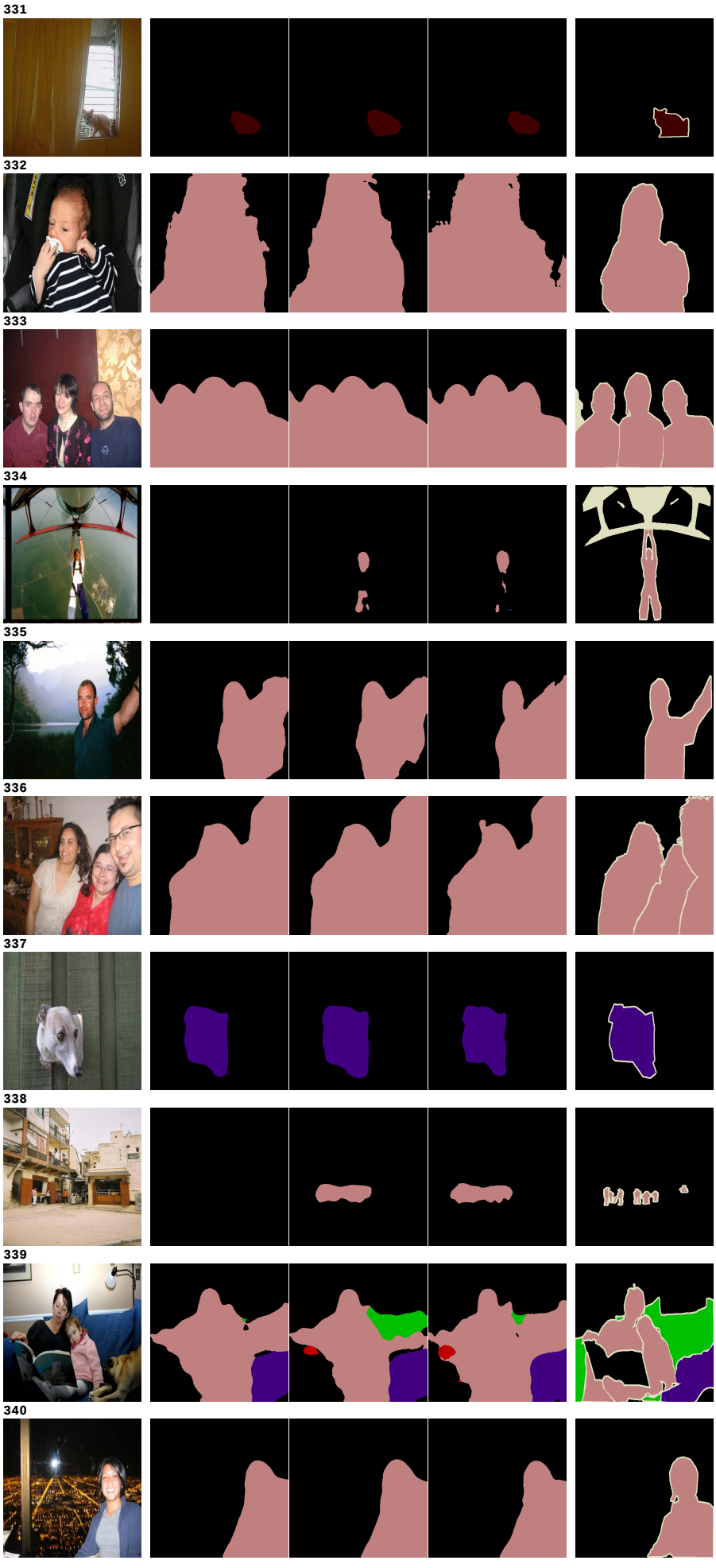
Input image
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(both stages)
Ground truth
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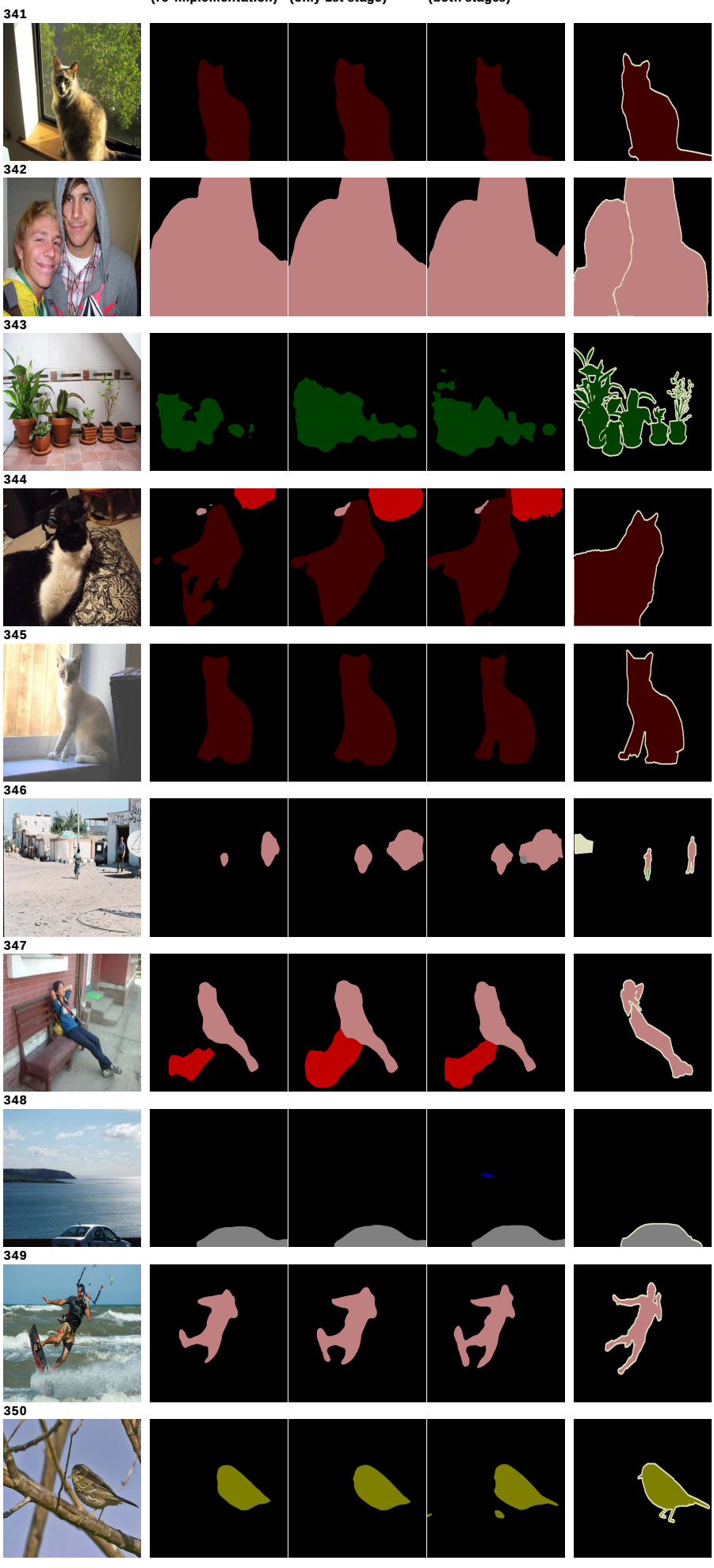
Input image
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(both stages)
Ground truth
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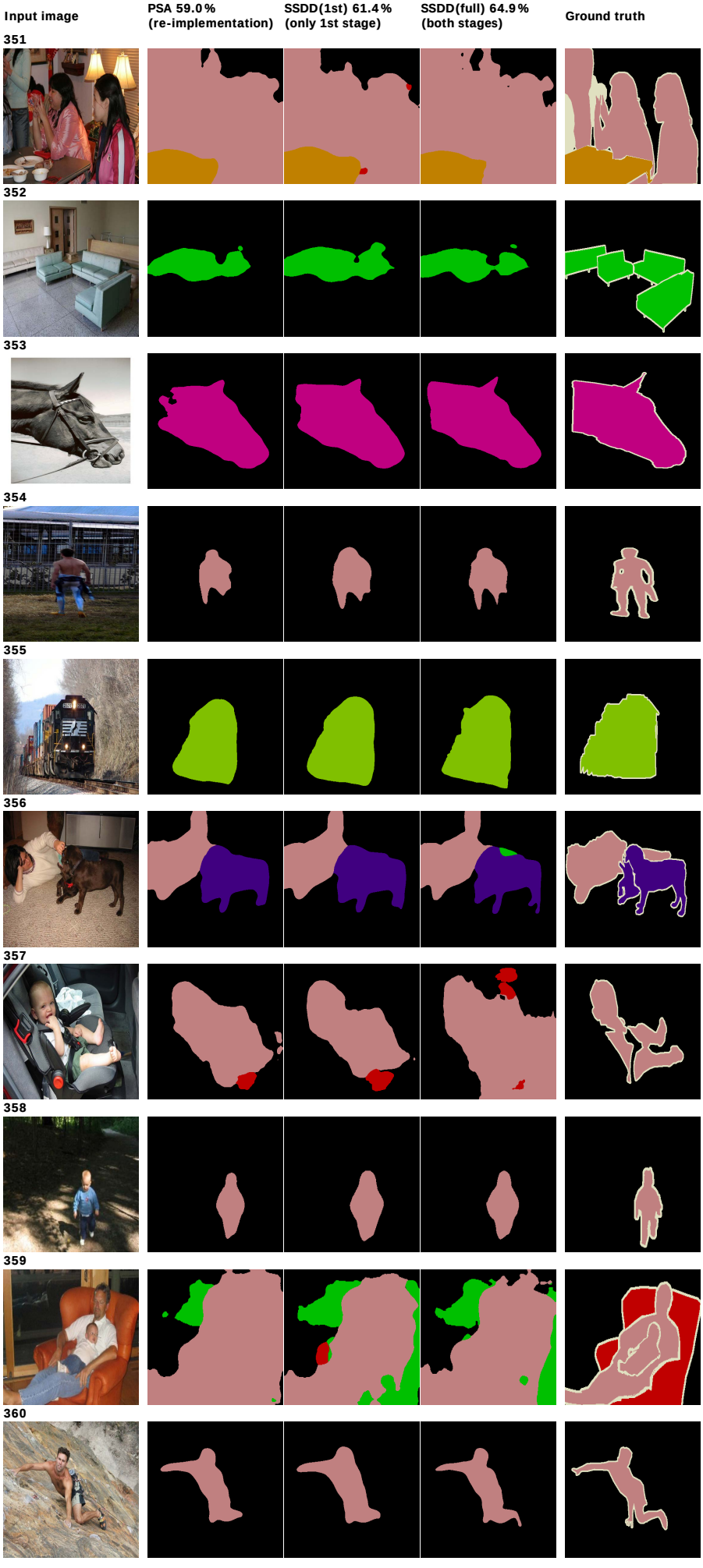
Input image
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Ground truth
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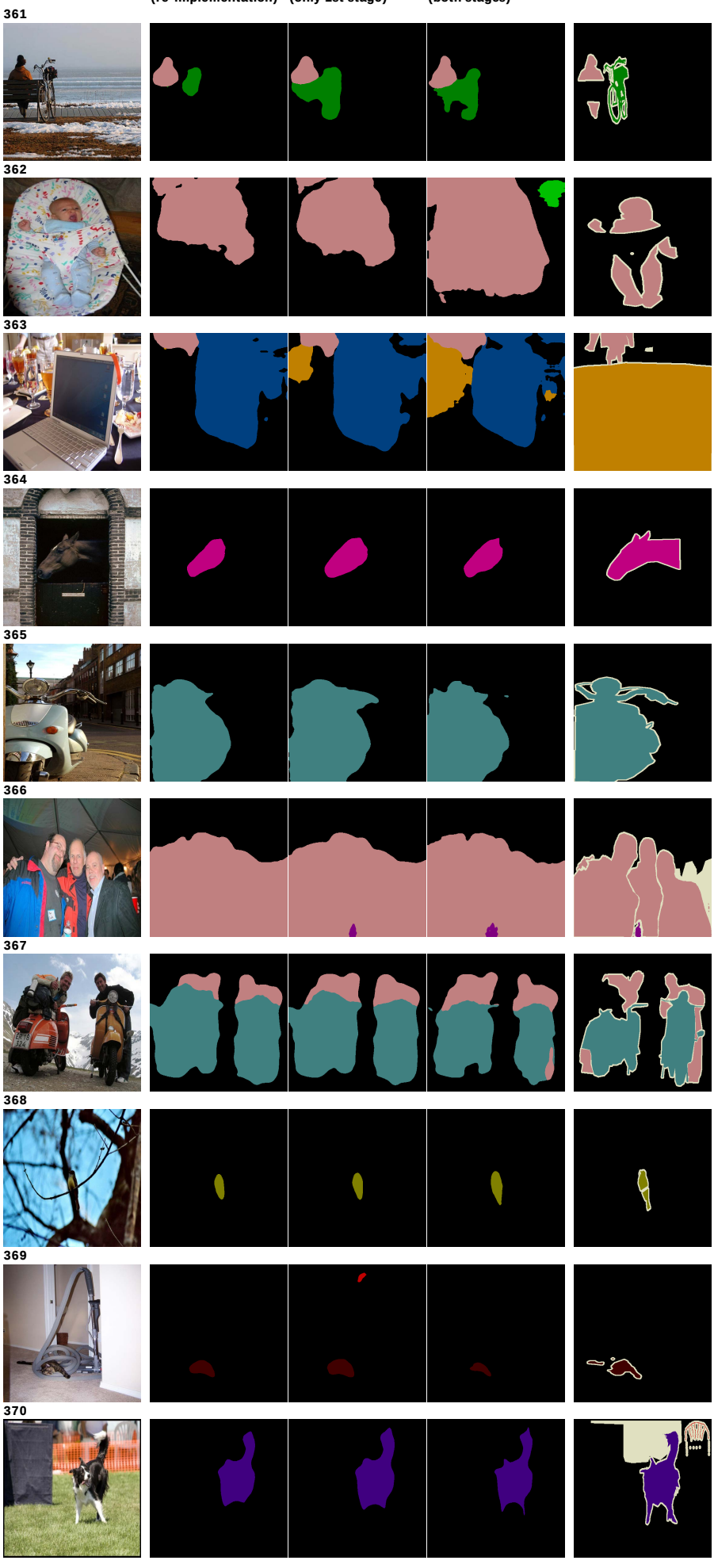
Input image
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SSDD(1st) 61.4%
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Ground truth
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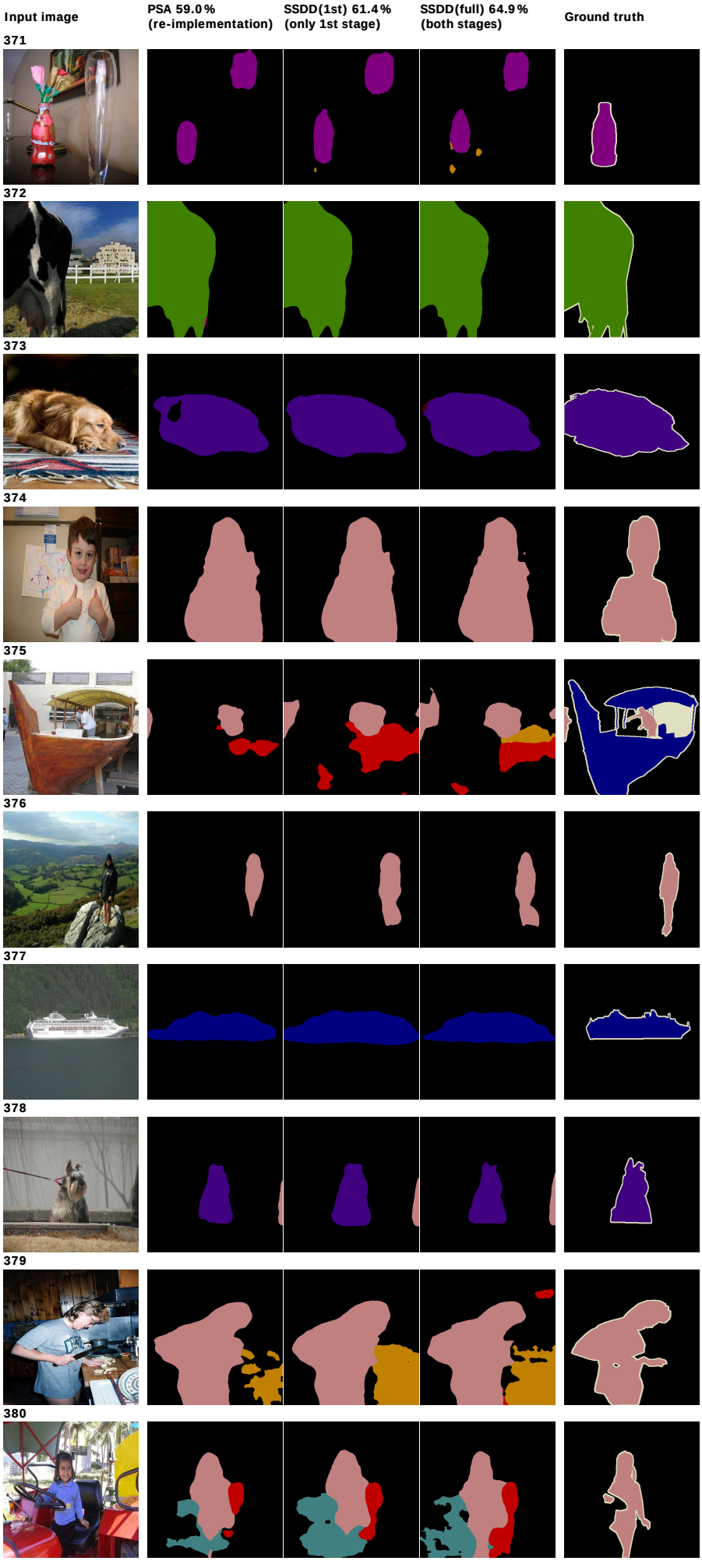
Input image
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Ground truth
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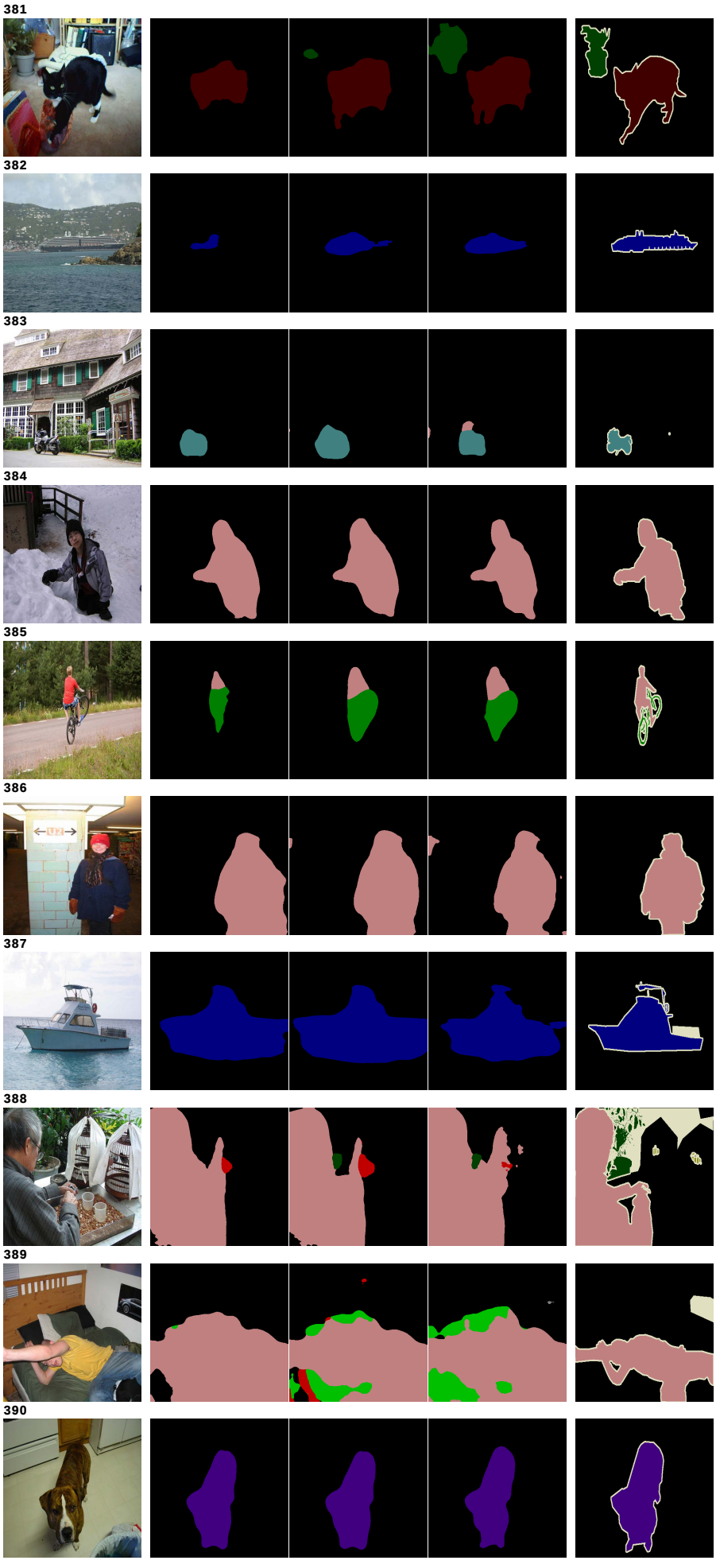
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Ground truth
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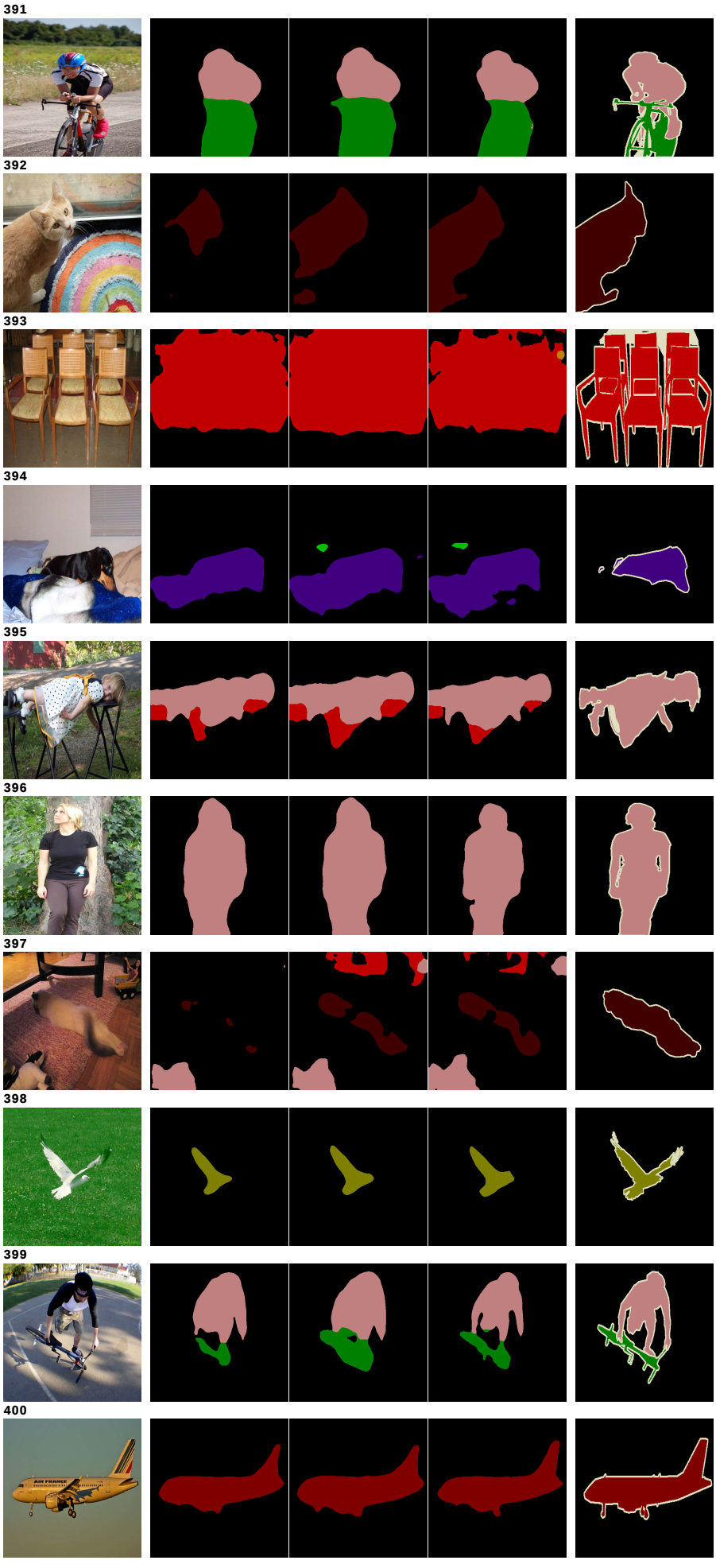
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Ground truth
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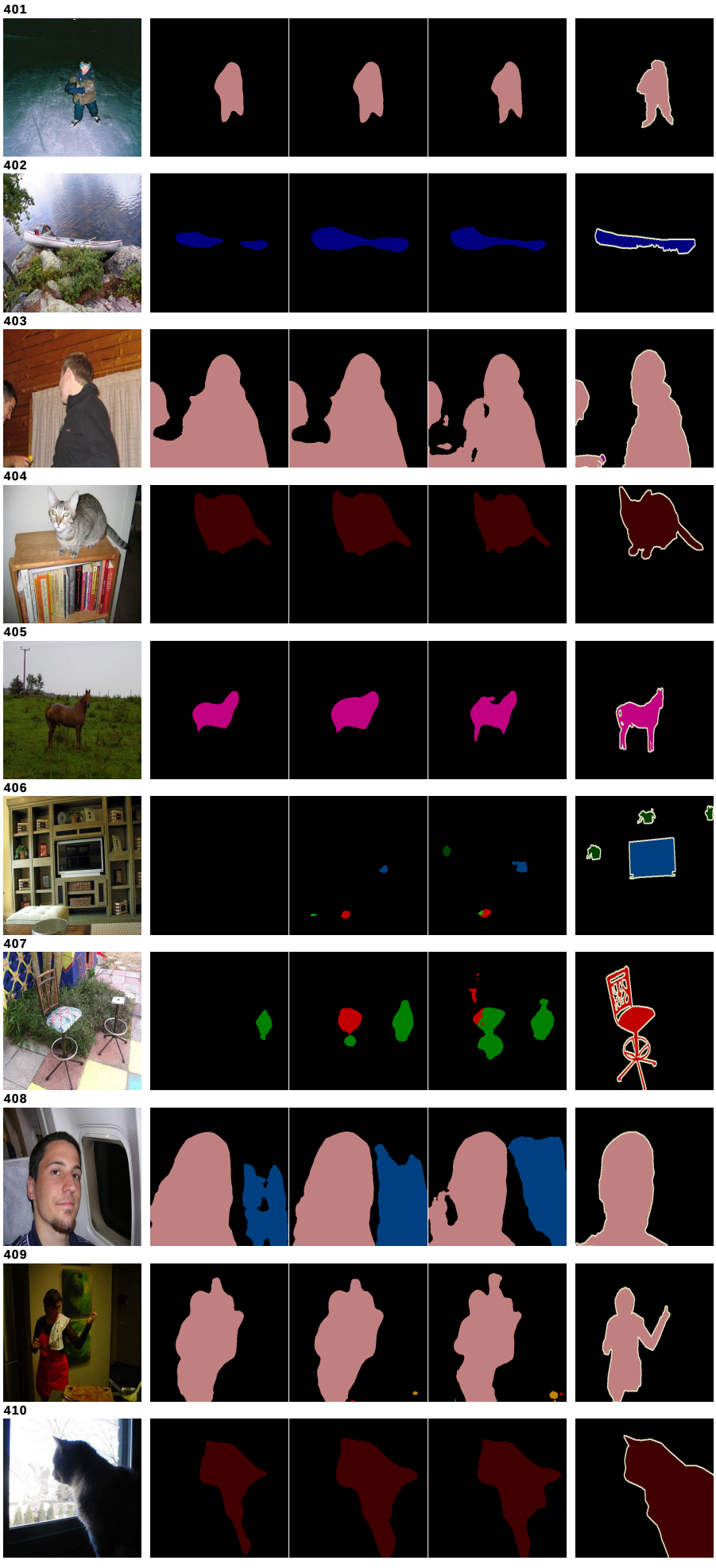
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Ground truth
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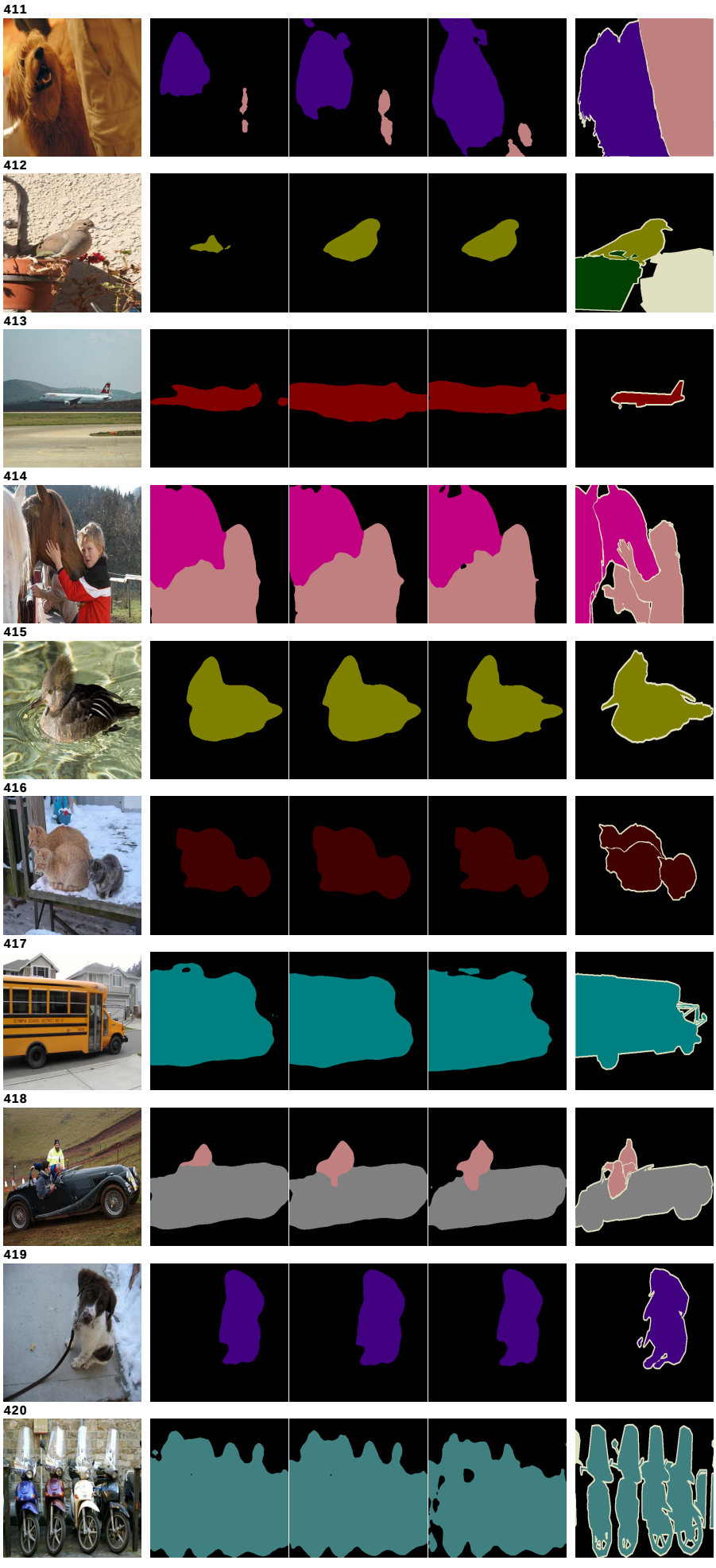
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(both stages)
Ground truth
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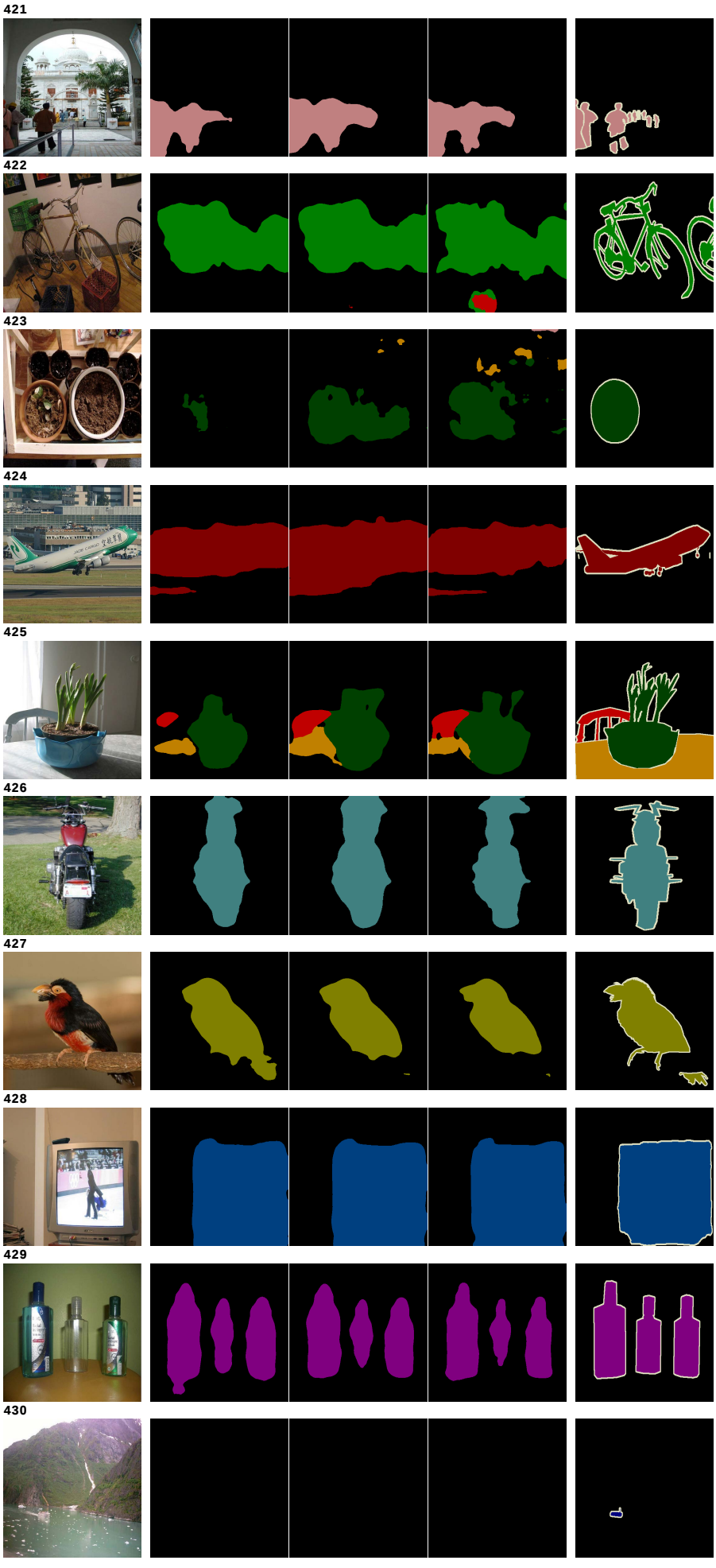
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(both stages)
Ground truth
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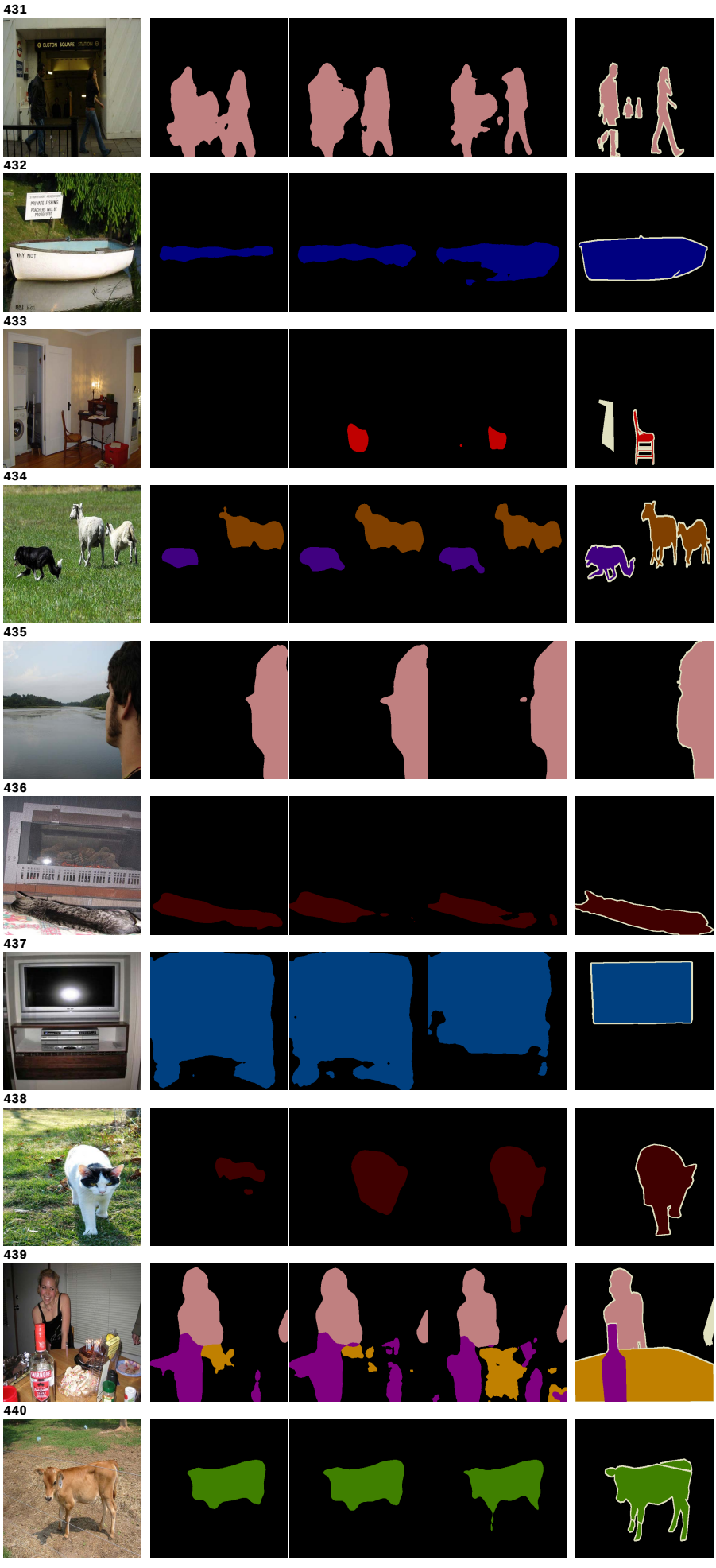
Input image
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SSDD(1st) 61.4 %
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(both stages)
Ground truth
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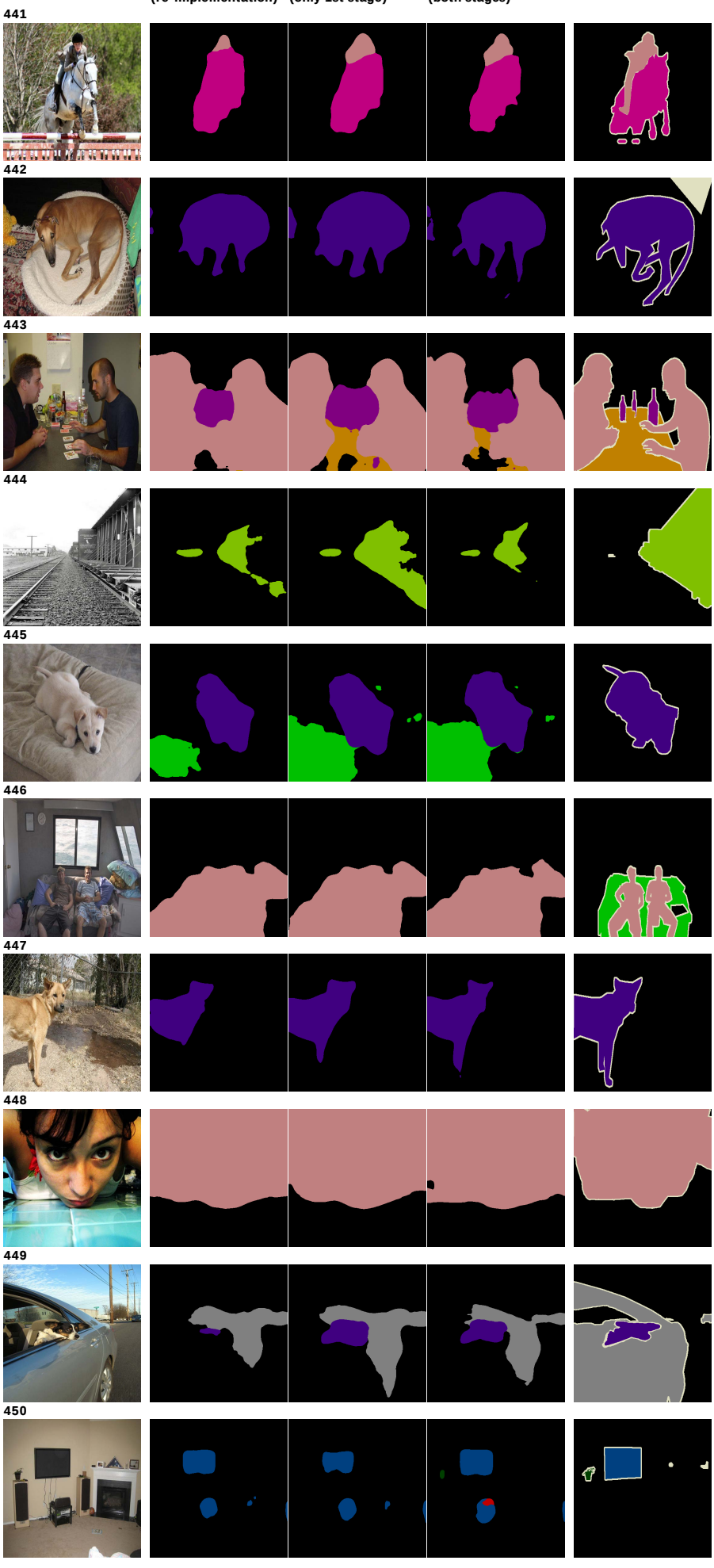
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Ground truth
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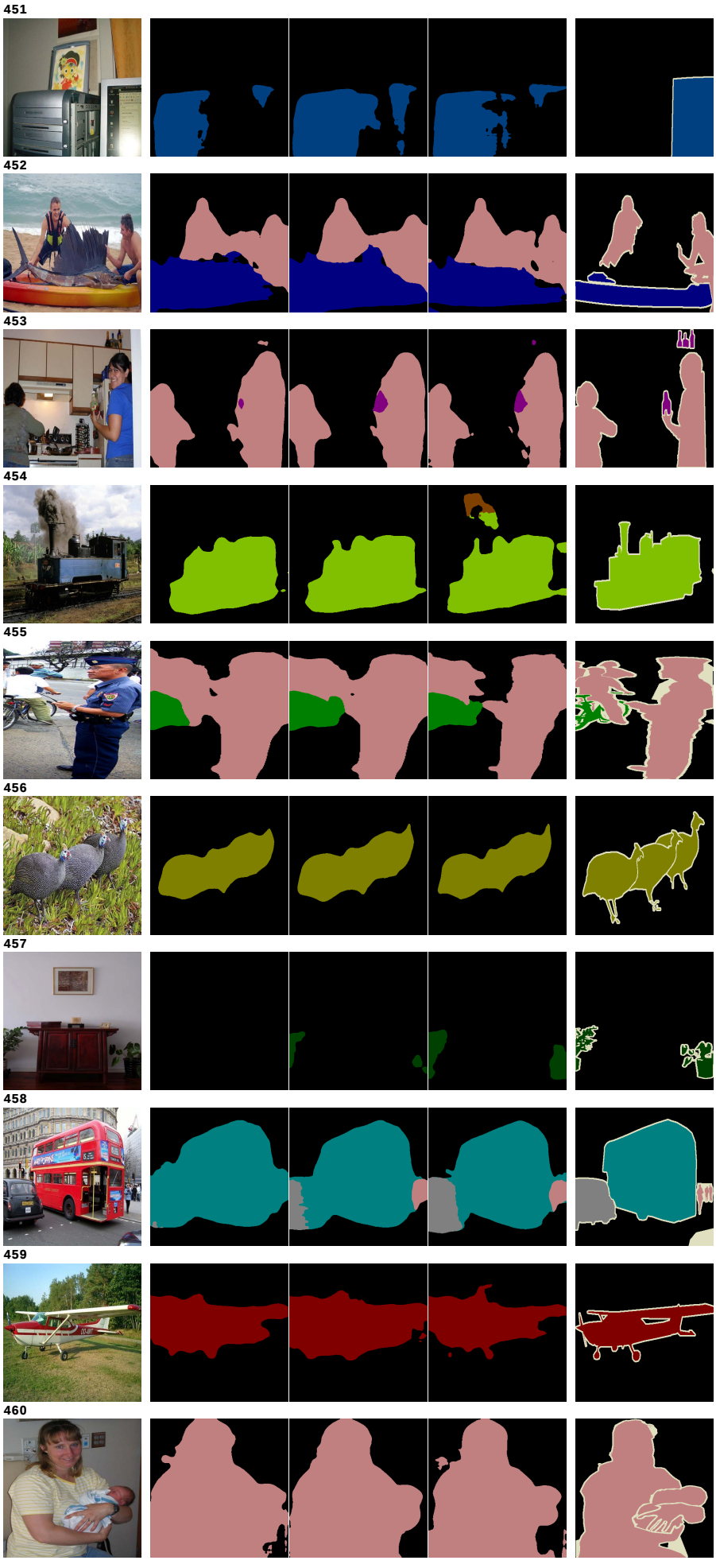
Input image
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SSDD(1st) 61.4% (only 1st stage)
SSDD(full) 64.9% (both stages)
Ground truth
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Input image
PSA 59.0 %
(re-implementation)
SSDD(1st) 61.4 %
(only 1st stage)
SSDD(full) 64.9 %
(both stages)
Ground truth
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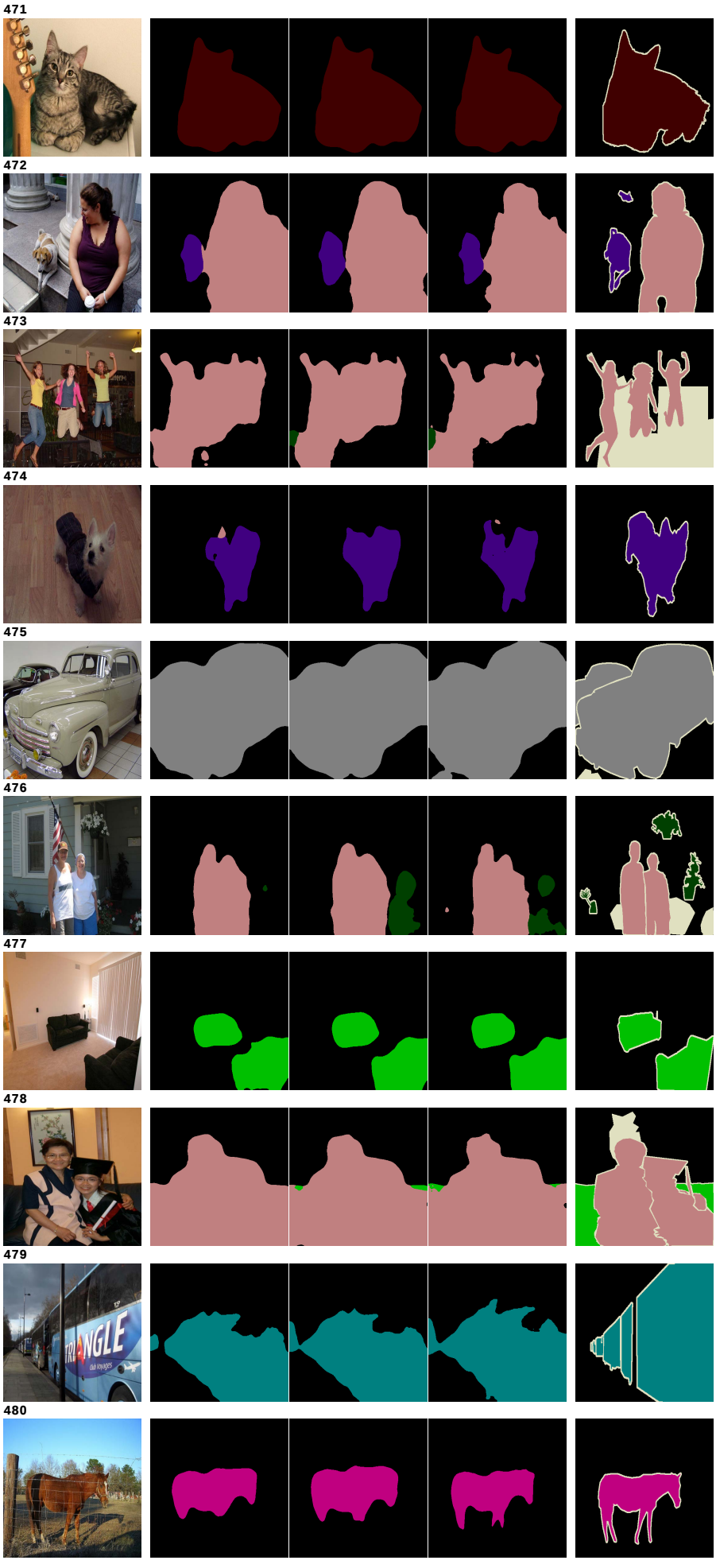
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Ground truth
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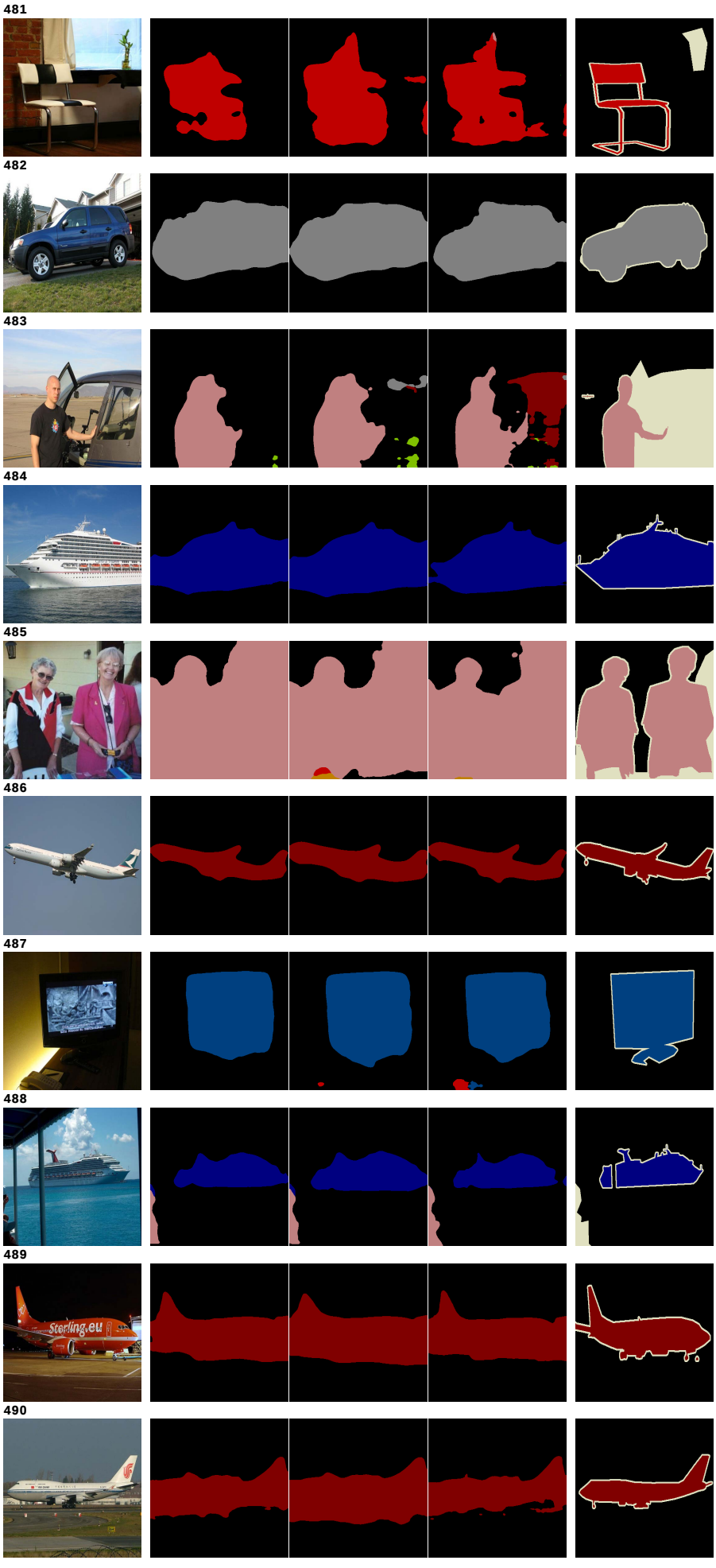
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(both stages)
Ground truth
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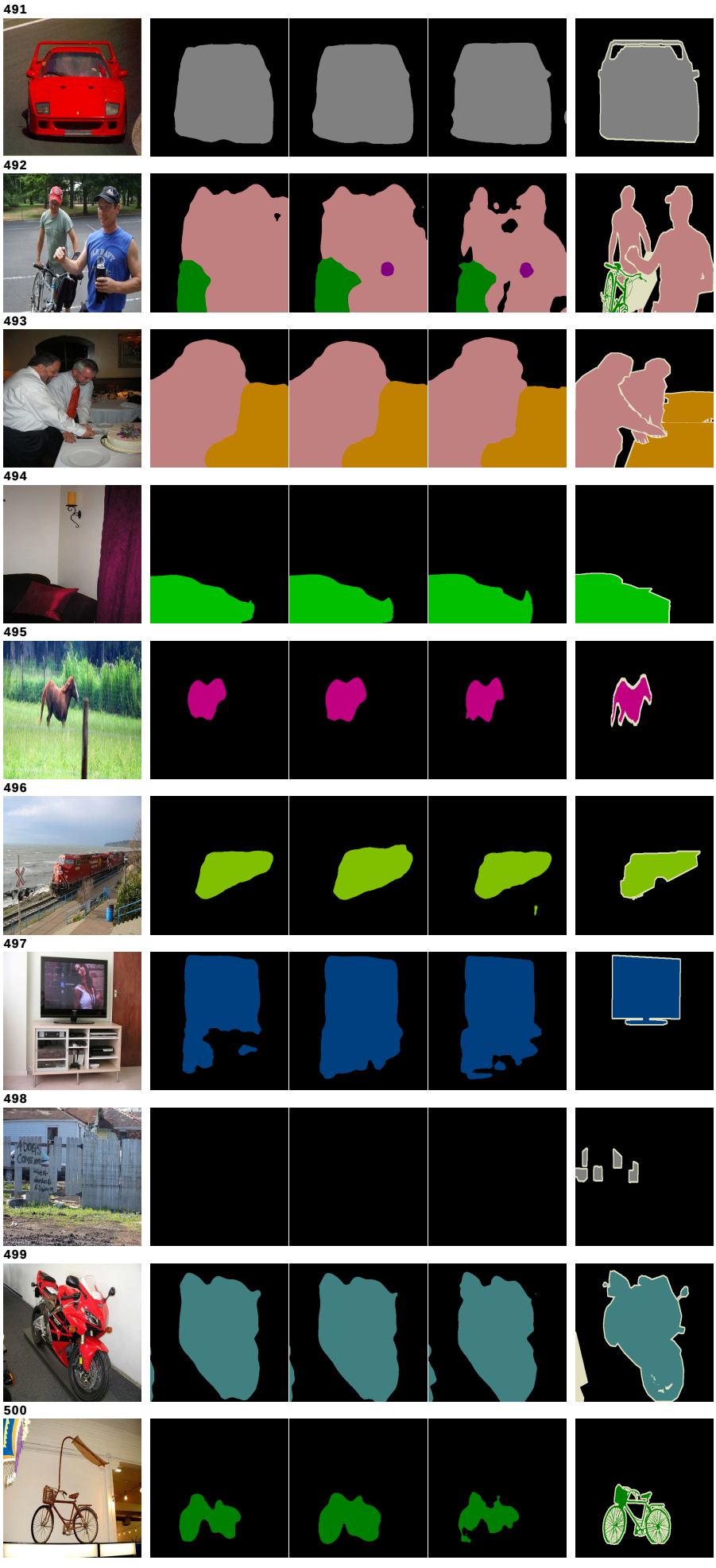
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SSDD(full) 64.9%
(both stages)
Ground truth
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