Tested on 2016 Model S 70 (Pre-Refresh), Software Version 2019.32.2.1 9b8d6cd

- Height and distance seem to impact probability of misclassification. Initially we thought brightness seemed to impact too, but after performing experiments we realized it did not have a huge impact.
- Traffic sign classification seems to occur at a maximum of 80 feet.
- Traffic sign classification is displayed on the HUD right as the vehicle passes the speed limit sign.

Notes specific to Traffic-Aware Cruise Control (TACC):

- Activating TACC while driving at a constant speed will set the max cruise speed to the current speed.
- **Activating TACC while accelerating/decelerating will set the max cruise speed to what the vehicle believes the speed limit is in that area. This is our attack vector.**
- TACC cannot be activated while the vehicle is under 18 MPH.
- Once TACC is activated, the max cruise speed can only be altered manually; it does not update based on recognition of a new speed limit, whether higher or lower.

- In the case of a conflict between GPS tagging and sign recognition, the vehicle errs on the side of sign recognition.
- Longer stickers seem to perform better than shorter stickers. A sticker of length 76mm causes misclassification far more frequently than one of length 67 mm.
- Plain black sticker (with purchased black paper) which resembles an '8' and a long sticker placed diagonally across the '3' cause misclassification consistently, as seen in our experiments below.
- Approach speed, distance between car and sign as the car passes it (perpendicular distance), and lighting conditions seem to impact probability of misclassification.

- Approach distance (parallel distance) seem to have little to no impact on probability of misclassification.
- Slower approach speed, keeping the sign in the shade, and shorter perpendicular distance seems to improve chance of misclassification.
- After switching to a sign mounted about 2.2m off the ground, misclassification has become more consistent, misclassifying even in direct sunlight, at faster approach speeds, and closer perpendicular distances.
- Putting a "gap" in the sticker, even only ~20mm in length, seems to prevent misclassification.
- Angling the sign towards the vehicle seems to prevent misclassification. Having the sign perpendicular to the road has provided the most consistent results thus far.
- An approach distance of ≥8m seems to cause the car to not recognize the speed limit sign at all.
- Colors/shades besides black seem to be ineffective at inducing misclassification.
- Covering up a significant portion of the sign doesn't seem to cause a misclassification. We covered up the bottom of the 2 (sticker type I) and the middle of the 3 (sticker type J) with reflective and IR reflective tape respectively, and it still read the signs as 25 and 35.
- We confirmed that the height of the sign off the ground impacts the likelihood of misclassification. The slightly shorter sticker (74mm x 42mm) misclassified somewhat consistently at a height of 2.2m, but not at all at a height of 1.29m.
- Misclassification is very sensitive to the length of the sticker. While our original sticker of length 76mm misclassifies fairly consistently, a sticker only 4mm shorter (72mm) didn't misclassify at all under the same conditions. From there, we moved on to a sticker of length 74mm (only 2mm shorter), which still misclassified, but less consistently - when the sign was placed at a lower height, it failed where the original sticker did not.
- Placing the original sticker (76mm x 42mm) at a shallow angle (~16.7°) seems to prevent misclassification under the same conditions where misclassification normally occurs.
- Minor variance in lighting conditions seems to have negligible impact on the rate of misclassification. In our tests, the Type A sticker was able to fool the Tesla's camera in illuminance levels ranging from 11,800 to 16,800 lux. Note that these tests were all conducted outdoors during the daytime.

Test Results (No Measurement Tools)

Traffic Sign	Speed	Parallel Distance	Perpendicular Distance	Lighting conditions	Result
Left	7 to 10 mph	shorter (unsure of exact measurement)	constant, not consciously measured	mid-morning, not in shade	85 mph
Left	18 to 20 mph	shorter (unsure of exact measurement)	constant, not consciously measured	mid-morning, not in shade	85 mph
Left	7 to 10 mph	longer (unsure of exact measurement)	constant, not consciously measured	mid-morning, not in shade	85 mph
Left	18 to 20 mph	longer (unsure of exact measurement)	constant, not consciously measured	mid-morning, not in shade	85 mph
Left	18 to 20 mph	longer (unsure of exact measurement)	constant, not consciously measured	mid-morning, shade	85 mph
Right	7 or 15 mph	shorter (unsure of exact measurement)	farther from sign	closer to 12 pm, not in shade	35 mph
Right	7 mph	shorter (unsure of exact measurement)	closer to sign	closer to 12 pm, not in shade	85 mph
Right	7 or 15 mph	shorter (unsure of exact measurement)	closer to sign	closer to 12 pm, in shade	85 mph

Right	7 or 15 mph	shorter (unsure of exact measurement)	farther from sign	closer to 12 pm, in shade	85 mph
Right	7 mph	longer (unsure of exact measurement)	farther from sign	closer to 12 pm, in shade	35 mph
Right	15 mph	longer or shorter (unsure of exact measurement)	closer or farther from sign	closer to 12 pm, not in shade	35 mph

Legend:

- Left - of the driver
- Right - of the driver
- Parallel distance - distance at which the sign is first in view of the vehicle
- Perpendicular distance - distance between the sign and the car as the car passes it.
- Mid-morning: between 10 AM to 11 AM
- All the above tests were done with a rectangular black sticker of size 76mm x 42mm, attached right at the end of the center of the '3'.

Sticker Types:

Type A:

SPEED
LIMIT
35

42mm

76mm

Type B:

SPEED LIMIT 35

Type C:

SPEED
LIMIT
35

42mm

66mm 19mm

Type D:

Type E:

Type F:

Type G:

SPEED LIMIT 35

42mm

72mm

Type H:

SPEED
LIMIT
35

42mm
74mm

Type I (Reflective Tape):

SPEED LIMIT 25

122mm
22mm
28mm
112mm

Type J (IR Reflective Material):

Type K:

Test Results as of Day 1: 09/20/19

#	Parallel Distance (±0.5m)	Perpendicular Distance (±0.05m)	Illuminance (±100lx)	Approach Speed (±1mph)	Sign Placement	Sign Facing	Sticker Type	Sign Height (±0.05m)	Classification
1	27	3.1	16,800	8	Right of Vehicle	Perpendicular	Type A	2.20	85
2	27	3.1	16,800	12	Right of Vehicle	Perpendicular	Type A	2.20	85
3	46	3.1	16,800	8	Right of Vehicle	Perpendicular	Type A	2.20	85
4	46	3.1	16,800	12	Right of Vehicle	Perpendicular	Type A	2.20	85
5	27	5.1	16,800	8	Right of Vehicle	Perpendicular	Type A	2.20	35
6	27	5.1	16,800	12	Right of Vehicle	Perpendicular	Type A	2.20	35
7	46	5.1	16,800	8	Right of Vehicle	Perpendicular	Type A	2.20	N/A

8	46	5.1	16,800	12	Right of Vehicle	Perpendicular	Type A	2.20	35
9	8	3.1	16,800	8	Right of Vehicle	Perpendicular	Type A	2.20	85
10	27	3.1	16,800	8	Right of Vehicle	Perpendicular	Type A	2.20	85
11	27	3.1	16,800	12	Right of Vehicle	Perpendicular	Type A	2.20	85
12	46	3.1	16,800	8	Right of Vehicle	Perpendicular	Type A	2.20	85
13	46	3.1	16,800	12	Right of Vehicle	Perpendicular	Type A	2.20	85
14	27	5.1	16,800	8	Right of Vehicle	Perpendicular	Type A	2.20	85
15	27	5.1	16,800	12	Right of Vehicle	Perpendicular	Type A	2.20	85
16	46	5.1	16,800	8	Right of Vehicle	Perpendicular	Type A	2.20	85

17	46	5.1	16,800	12	Right of Vehicle	Perpendicular	Type A	2.20	85
18	27	3.1	16,800	8	Right of Vehicle	45° Towards	Type A	2.20	35
19	27	3.1	16,800	12	Right of Vehicle	45° Towards	Type A	2.20	35
20	27	5.1	16,800	8	Right of Vehicle	45° Towards	Type A	2.20	35
21	27	5.1	16,800	12	Right of Vehicle	45° Towards	Type A	2.20	35
22	46	3.1	16,800	8	Right of Vehicle	45° Towards	Type A	2.20	35
23	46	3.1	16,800	12	Right of Vehicle	45° Towards	Type A	2.20	35
24	46	5.1	16,800	8	Right of Vehicle	45° Towards	Type A	2.20	35
25	46	5.1	16,800	12	Right of Vehicle	45° Towards	Type A	2.20	35

Findings:

- After switching to a sign mounted about 2.2m off the ground, misclassification has become more consistent, misclassifying even in direct sunlight, at faster approach speeds, and closer perpendicular distances.
- Angling the sign towards the vehicle seems to prevent misclassification. Having the sign perpendicular to the road has provided the most consistent results thus far.

Test Results as of Day 2: 09/24/19

#	Parallel Distance (±0.5m)	Perpendicular Distance (±0.05m)	Illuminance (±100lx)	Approach Speed (±1mph)	Sign Placement	Sign Facing	Sticker Type	Sign Height (±0.05m)	Classification
1	27	3.1	14,800	5	Right of Vehicle	Perpendicular	Type B	2.20	35
2	27	3.1	14,800	10	Right of Vehicle	Perpendicular	Type B	2.20	35
3	27	3.1	14,800	15	Right of Vehicle	Perpendicular	Type B	2.20	35
4	27	5.1	14,800	5	Right of Vehicle	Perpendicular	Type B	2.20	35

5	27	5.1	14,800	10	Right of Vehicle	Perpendicular	Type B	2.20	35
6	27	5.1	14,800	15	Right of Vehicle	Perpendicular	Type B	2.20	35
7	46	3.1	14,800	5	Right of Vehicle	Perpendicular	Type B	2.20	35
8	46	3.1	14,800	10	Right of Vehicle	Perpendicular	Type B	2.20	35
9	46	3.1	14,800	15	Right of Vehicle	Perpendicular	Type B	2.20	35
10	46	5.1	14,800	5	Right of Vehicle	Perpendicular	Type B	2.20	35
11	46	5.1	14,800	10	Right of Vehicle	Perpendicular	Type B	2.20	35
12	46	5.1	14,800	15	Right of Vehicle	Perpendicular	Type B	2.20	35
13	27	3.1	14,800	5	Right of Vehicle	Perpendicular	Type C	2.20	35

14	27	3.1	14,800	10	Right of Vehicle	Perpendicular	Type C	2.20	35
15	27	3.1	14,800	15	Right of Vehicle	Perpendicular	Type C	2.20	35
16	27	5.1	14,800	5	Right of Vehicle	Perpendicular	Type C	2.20	35
17	27	5.1	14,800	10	Right of Vehicle	Perpendicular	Type C	2.20	35
18	27	5.1	14,800	15	Right of Vehicle	Perpendicular	Type C	2.20	35
19	46	3.1	14,800	5	Right of Vehicle	Perpendicular	Type D	2.20	35
20	46	3.1	14,800	10	Right of Vehicle	Perpendicular	Type D	2.20	35
21	46	3.1	14,800	15	Right of Vehicle	Perpendicular	Type D	2.20	35
22	46	5.1	14,800	5	Right of Vehicle	Perpendicular	Type D	2.20	35

23	46	5.1	14,800	10	Right of Vehicle	Perpendicular	Type D	2.20	35
24	46	5.1	14,800	15	Right of Vehicle	Perpendicular	Type D	2.20	35
25	27	3.1	14,800	10	Right of Vehicle	Perpendicular	Type A	2.20	85
26	27	5.1	14,800	10	Right of Vehicle	Perpendicular	Type A	2.20	85
27	46	3.1	14,800	10	Right of Vehicle	Perpendicular	Type A	2.20	85
28	46	5.1	14,800	10	Right of Vehicle	Perpendicular	Type A	2.20	85

Findings:

- Putting a "gap" in the sticker, even only ~20mm in length, seems to prevent misclassification.

Test Results as of Day 3: 09/25/19

#	Parallel Distance (±0.5m)	Perpendicular Distance (±0.05m)	Illuminance (±100lx)	Approach Speed (±1mph)	Sign Placement	Sign Facing	Sticker Type	Sign Height (±0.05m)	Classification
1	27	3.1	12,200	10	Right of Vehicle	Perpendicular	Type F	2.20	35
2	27	3.1	12,200	15	Right of Vehicle	Perpendicular	Type F	2.20	35
3	27	5.1	12,200	10	Right of Vehicle	Perpendicular	Type F	2.20	35
4	27	5.1	12,200	15	Right of Vehicle	Perpendicular	Type F	2.20	35
5	46	3.1	12,200	10	Right of Vehicle	Perpendicular	Type F	2.20	35
6	46	3.1	12,200	20	Right of Vehicle	Perpendicular	Type F	2.20	35
7	46	5.1	12,200	10	Right of Vehicle	Perpendicular	Type F	2.20	35

8	46	5.1	12,200	15	Right of Vehicle	20° Towards	Type F	2.20	35
9	27	3.1	12,200	10	Right of Vehicle	Perpendicular	Type A	2.20	35
10	27	3.1	12,200	15	Right of Vehicle	Perpendicular	Type A	2.20	85
11	27	5.1	12,200	10	Right of Vehicle	Perpendicular	Type A	2.20	35
12	27	5.1	12,200	15	Right of Vehicle	Perpendicular	Type A	2.20	85
13	46	3.1	12,200	10	Right of Vehicle	Perpendicular	Type A	2.20	85
14	46	3.1	12,200	15	Right of Vehicle	Perpendicular	Type A	2.20	85
15	46	5.1	12,200	10	Right of Vehicle	Perpendicular	Type A	2.20	85
16	46	5.1	12,200	15	Right of Vehicle	Perpendicular	Type A	2.20	35

17	27	3.1	12,200	10	Right of Vehicle	Perpendicular	Type E	2.20	35
18	27	3.1	12,200	15	Right of Vehicle	Perpendicular	Type E	2.20	35
19	27	5.1	12,200	10	Right of Vehicle	Perpendicular	Type E	2.20	35
20	27	5.1	12,200	15	Right of Vehicle	Perpendicular	Type E	2.20	35
21	46	3.1	12,200	10	Right of Vehicle	Perpendicular	Type E	2.20	35
22	46	3.1	12,200	15	Right of Vehicle	Perpendicular	Type E	2.20	35
23	46	5.1	12,200	10	Right of Vehicle	Perpendicular	Type E	2.20	35
24	46	5.1	12,200	15	Right of Vehicle	Perpendicular	Type E	2.20	35

Findings:

- Stickers of colors/shades besides black seem to prevent misclassification.

#	Parallel Distance (±0.5m)	Perpendicular Distance (±0.05m)	Illuminance (±100lx)	Approach Speed (±1mph)	Sign Placement	Sign Facing	Sticker Type	Sign Height (±0.05m)	Classification
1	26	3.1	11,800	10	Right of Vehicle	Perpendicular	Type I	2.20	25
2	26	3.1	11,800	15	Right of Vehicle	Perpendicular	Type I	2.20	25
3	26	5.1	11,800	10	Right of Vehicle	Perpendicular	Type I	2.20	25
4	26	5.1	11,800	15	Right of Vehicle	Perpendicular	Type I	2.20	25
5	47	3.1	11,800	10	Right of Vehicle	Perpendicular	Type I	2.20	25
6	47	5.1	11,800	10	Right of Vehicle	Perpendicular	Type I	2.20	25

7	26	3.1	11,800	10	Right of Vehicle	Perpendicular	Type J	2.20	35
8	26	3.1	11,800	15	Right of Vehicle	Perpendicular	Type J	2.20	35
9	26	5.1	11,800	10	Right of Vehicle	Perpendicular	Type J	2.20	35
10	26	5.1	11,800	15	Right of Vehicle	Perpendicular	Type J	2.20	35
11	47	3.1	11,800	10	Right of Vehicle	Perpendicular	Type J	2.20	35
12	47	5.1	11,800	10	Right of Vehicle	Perpendicular	Type J	2.20	35
13	26	3.1	11,800	10	Right of Vehicle	Perpendicular	Type H	2.20	85
14	26	3.1	11,800	15	Right of Vehicle	Perpendicular	Type H	2.20	35
15	26	5.1	11,800	10	Right of Vehicle	Perpendicular	Type H	2.20	85

16	26	5.1	11,800	15	Right of Vehicle	Perpendicular	Type H	2.20	35
17	47	3.1	11,800	10	Right of Vehicle	Perpendicular	Type H	2.20	85
18	47	5.1	11,800	10	Right of Vehicle	Perpendicular	Type H	2.20	35
19	26	3.1	11,800	10	Right of Vehicle	Perpendicular	Type G	2.20	35
20	26	3.1	11,800	15	Right of Vehicle	Perpendicular	Type G	2.20	35
21	26	5.1	11,800	10	Right of Vehicle	Perpendicular	Type G	2.20	35
22	26	5.1	11,800	15	Right of Vehicle	Perpendicular	Type G	2.20	35
23	47	3.1	11,800	10	Right of Vehicle	Perpendicular	Type G	2.20	35
24	47	5.1	11,800	10	Right of Vehicle	Perpendicular	Type G	2.20	35

25	26	3.1	11,800	10	Right of Vehicle	Perpendicular	Type H	2.20	85
26	26	3.1	11,800	15	Right of Vehicle	Perpendicular	Type H	2.20	85
27	26	5.1	11,800	10	Right of Vehicle	Perpendicular	Type H	2.20	35
28	26	5.1	11,800	15	Right of Vehicle	Perpendicular	Type H	2.20	85
29	47	3.1	11,800	10	Right of Vehicle	Perpendicular	Type H	2.20	85
30	47	5.1	11,800	10	Right of Vehicle	Perpendicular	Type H	2.20	35
31	26	3.1	11,800	10	Right of Vehicle	Perpendicular	Type H	1.29	35
32	26	3.1	11,800	15	Right of Vehicle	Perpendicular	Type H	1.29	35
33	26	5.1	11,800	10	Right of Vehicle	Perpendicular	Type H	1.29	35

34	26	5.1	11,800	15	Right of Vehicle	Perpendicular	Type H	1.29	35
35	47	3.1	11,800	10	Right of Vehicle	Perpendicular	Type H	1.29	35
36	47	5.1	11,800	10	Right of Vehicle	Perpendicular	Type H	1.29	35
37	26	3.1	11,800	10	Right of Vehicle	Perpendicular	Type A	1.29	85
38	26	3.1	11,800	15	Right of Vehicle	Perpendicular	Type A	1.29	35
39	26	5.1	11,800	10	Right of Vehicle	Perpendicular	Type A	1.29	85
40	26	5.1	11,800	15	Right of Vehicle	Perpendicular	Type A	1.29	35
41	47	3.1	11,800	10	Right of Vehicle	Perpendicular	Type A	1.29	85
42	47	5.1	11,800	10	Right of Vehicle	Perpendicular	Type A	1.29	35

43	26	3.1	11,800	10	Right of Vehicle	Perpendicular	Type K	2.20	35
44	26	3.1	11,800	15	Right of Vehicle	Perpendicular	Type K	2.20	35
45	26	5.1	11,800	10	Right of Vehicle	Perpendicular	Type K	2.20	35
46	26	5.1	11,800	15	Right of Vehicle	Perpendicular	Type K	2.20	35
47	47	3.1	11,800	10	Right of Vehicle	Perpendicular	Type K	2.20	35
48	47	5.1	11,800	10	Right of Vehicle	Perpendicular	Type K	2.20	35

Findings:

- Covering up a significant portion of the sign doesn't seem to cause a misclassification. We covered up the bottom of the 2 (Figure) and the middle of the 3 (Figure) with reflective and IR reflective tape respectively, and it still read the signs as 25 and 35.
- We confirmed that the height of the sign off the ground impacts the likelihood of misclassification. The slightly shorter sticker (74mm x 42mm) misclassified somewhat consistently at a height of 2.2m, but not at all at a height of 1.29m.
- Misclassification is very sensitive to the length of the sticker. While our original sticker of length 76mm misclassifies fairly consistently, a sticker only 4mm shorter (72mm) didn't misclassify at all under the same conditions. From there, we moved on to a sticker of length 74mm (only 2mm shorter), which still misclassified, but less consistently - when the sign was placed at a lower height, it failed where the original sticker did not.
- Placing the original sticker (76mm x 42mm) at a shallow angle (~16.7°) seems to prevent misclassification under the same conditions where misclassification normally occurs.

- Minor variance in lighting conditions seems to have negligible impact on the rate of misclassification. In our tests, the Type A sticker was able to fool the Tesla's camera in illuminance levels ranging from 11,800 to 16,800 lux. Note that these tests were all conducted outdoors during the daytime.