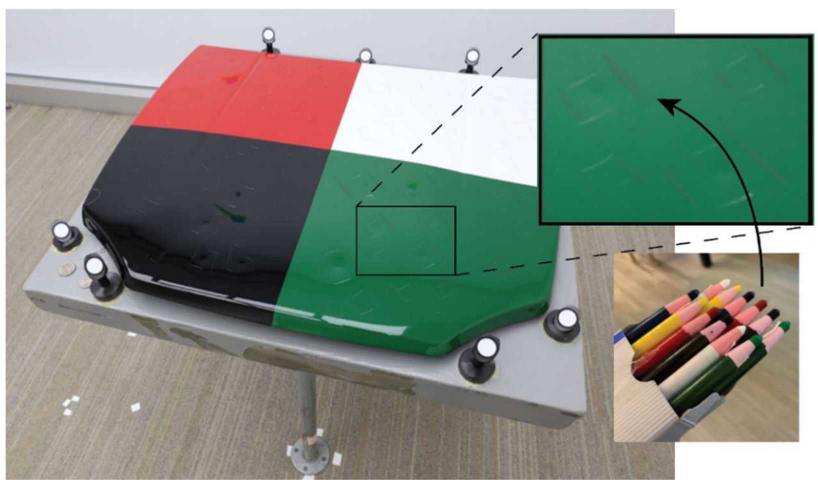
Sizing Hail Dents using Machine Learning

Overview

Using our dented "mini-hood" and our Hail Damage Recorder (HDR) 4200 prototype, we previously demonstrated the ability to create 3D dent profiles from a single image that measured within 28-micron RMSE in comparison to a highly accurate Zeiss Comet structured light system[1]. We also provided a method for using this measured profile to determine a reference size (S_R) suggested to be 6 times the standard deviation of the profile, hence six-sigma. We now discuss how we used machine learning (ML) to train our 4200 to automatically measure dent size patterned after industry experts. Our first step was to invite two hail dent assessment experts to our lab at Quidient's Technology Center to visually measure dent size (S_V) for all 57 dents on our mini-hood, multiple times from different orientations. Their S_V measurements where then processed along with the 4200's S_R measurements using ML to determine a learning coefficient "k." We then show that by multiplying our automatically determined reference size S_R by the learning coefficient k, our HDR 4200 is able to repeatably measure dent size S_A that is on average nearly identical to an expert's visual measurements S_V. And finally, we showed that our resulting automatically determined dent size S_A is convertible a "coin size" following accepted industry practices.

Procedure

Our mini-hood comprises 57 total dents of various sizes distributed over the four colored quadrants. We conducted independent measurement sessions with each of two industry experts. In each session we first asked the expert to mark the size of each dent with a grease pencil defining what in their opinion was the boundary width of the "claimable dent." Our team then measured each of the expert's boundaries associated with the respective dent to obtain the visual dent size S_V.

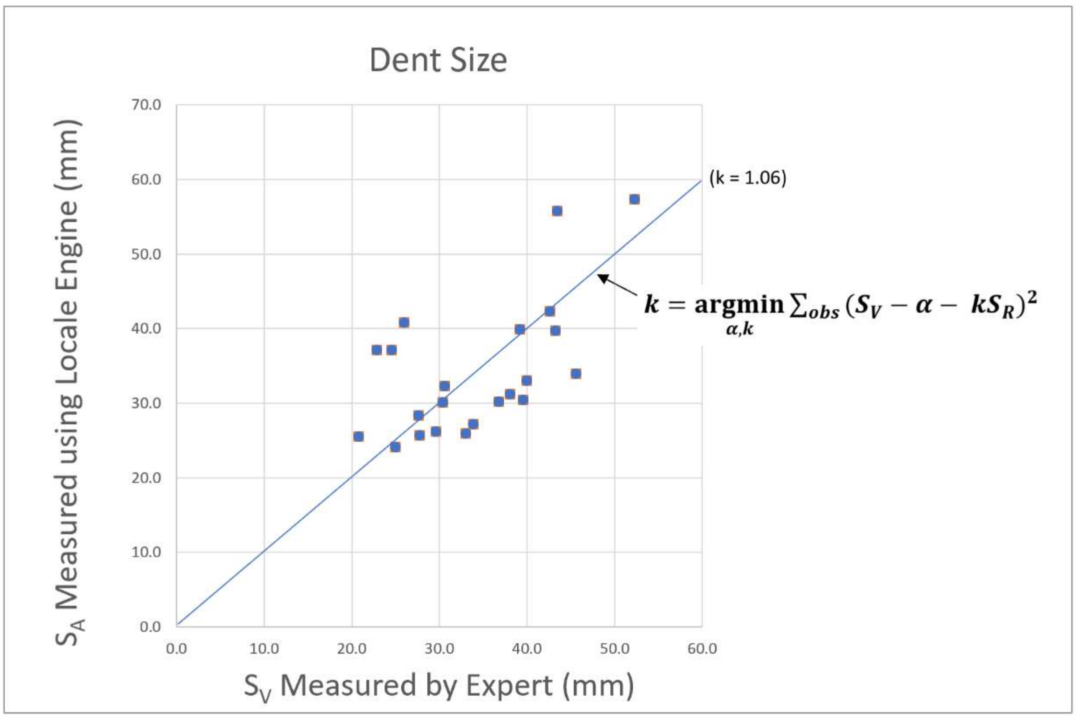


[1] See Tech Note, Quantifying Hail Dent Accuracy, Working

Dent ID	S_V 1.1 Expert 1 - Rotation 1	S_V 1.2 Expert 1 - Rotation 2	S_V 2.1 Expert 2 - Rotation 1	S_V 2.2 Expert 2 - Rotation 2	Combined Average	Max Deviation	Std. Deviation
K1	24.5	34.5	29.5	30.0	29.6	5.1	4.1
K2	25.0	23.5	31.0	31.0	27.6	4.1	3.9
...							
R6	28.0	33.0	35.5	35.5	33.0	5.0	3.5
R7	47.0	45.5	39.0	39.0	42.6	4.4	4.2
...							
W1	40.5	40.0	51.0	51.0	45.6	5.6	6.2
W4	43.0	42.0	44.0	44.0	43.3	1.3	1.0
...							
G3	23.0	24.0	22.0	22.5	22.9	1.1	0.9
G5	39.0	39.0	37.0	37.5	38.1	1.1	1.0
...							

After cleaning off the mini-hood we asked each expert to repeat the process this time from a 90-degree rotated perspective. We repeated these steps to create second sets of measurements at each rotation and compiled the expert measurements for each of the various mini-hood dents as shown in the table on the left.

We then used ML to determine a best fit between the expert's visual measurements S_V and our 4200's reference measurements S_R. Although several ML algorithms could be used, we chose the linear least squares method to arrive at the learning coefficient "k," where in our case k = 1.06. Next, we calculated an automatically determined size $S_A = k \times S_R$. As shown in the Dent Size table below, after scaling S_R by k, the resulting S_A on average is identical to the industry expert's S_V.



(We note that our reference size S_R was automatically determined by first sampling deviations along our measured 3D profile (the dent) as compared to a Normalized (undented) panel surface, mapping these deviations into a 2D bell curve diametric distribution. Using the resulting distribution, we set S_R = six-sigma, thereby statistically representing 97.7% of the profile deviations from the Normal.)

The table on the right compares the expert's average visual dent size's S_V with our automatically determined sizes S_A. Across the entire 57 dents, our average $S_A = k \times S_R$ result substantially equaled the expert's S_V, where our largest deviation was roughly 30%.

Dent ID	Expert S_V	HDR 4200 $S_A = k^*S_R$	S_V / S_R Ratio
K1	29.6	26.2	1.1
K2	27.6	28.3	1.0
…			
R6	33.0	25.9	1.3
R7	42.6	42.3	1.0
…			
W1	45.6	33.9	1.3
W4	43.3	39.7	1.1
…			
G3	22.9	37.1	0.6
G5	38.1	31.1	1.2
…			
Mean	34.2	32.7	1.0
Max	52.3	43.4	1.2

Dent Size Chart

Classes	Minimum Diameter (mm)	Maximum Diameter (mm)
Dime	Smallest Detectable	17.91
Nickel	> 17.91	21.21
Quarter	> 21.21	24.26
Half Dollar	> 24.26	30.61
Oversize	> 30.61	100.00
XXL	> 100.00	Largest Detectable

And finally, we asked our experts to classify each of the mini-hood dents according to the industry's traditional "coin system" where dents are sized as "dimes, nickels, quarters or half-dollars." We then used the industry standard Dent Size Chart shown above threshold our dent sizes S_A measured in millimeters into the conventional coin system. Our resulting coin sizes matched those of the experts.

Conclusions

We have demonstrated a useful method for calibrating our HDR 4200 to measure hail dent sizes "trained" like an industry expert. Our results have shown that our 4200 will allow any conscientious person such as the vehicle owner to measure dent sizes on par with industry practices. We further anticipate that the P&C industry will eventually establish a process to determine an industry-wide learning coefficient k, where our HDR 4200 is then trained across all insurers to provide standardized dent size S_A measurements. Our vision includes a Hail Dent Assessment Gateway connecting our HDR Platform with all industry stakeholders opening up an era of owner-initiated and first-assessed claims processing. We believe that in the near future a vehicle owner using our Local Engine embedded in their cell phone will measure their own vehicle damage including hail dents and other non-structural damage.