

The Performance of Photo Based Vehicle Models using HVE’s DyMesh Algorithm

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Abstract

HVE’s DyMesh algorithm uses 3-dimensional vehicle models to simulate vehicle contact and the resulting collision forces and vehicle motion. The authors compare the performance of custom vehicles made using photographs and Photomodeler (a commercially available photogrammetry software) with vehicles available in the HVE database. The results show that the basic vehicle geometry obtained from this technique is sufficient to closely match the results obtained from HVE vehicles. Further improvement, especially in acceleration profiles, can be achieved through tessellation of the Photomodeler derived vehicles.

Introduction

HVE’s DyMesh algorithm, available in the SIMON solver, utilizes 3-dimensional meshed vehicles to determine contact between objects and the resulting forces between vehicles or between vehicles and the environment. Validation of the SIMON algorithm and DyMesh was published by Day (Day, 2004).

The DyMesh algorithm utilizes both the geometry of the vehicle and the corresponding mesh density to determine the contact location and corresponding forces. Custom vehicles for use with HVE’s DyMesh can be made in a number of ways. These include: modification of vehicles in the HVE database, using 3-dimensional CAD models developed by a third

party, models made from laser scanned data, or models made from photogrammetry software such as Photomodeler.

The authors utilized Photomodeler to build three vehicles that exist in the HVE database. These vehicles are as given in Table 1.

Vehicle	Model Year Used	Database Model Year
Toyota Corolla	1995	1993-1997
Ford Crown Victoria	1979	1979-1991
Chevrolet Impala	2001	2000-2005

Table 1: Vehicle models used

Numerous photographs were taken of each vehicle utilizing targets placed in the environment and on the vehicle. The final meshed models were orientated appropriately in AutoCad and eventually imported into HVE.

Each of the Photomodeler derived vehicles was compared to the HVE database equivalent in five impact configurations. These included a frontal impact, a front corner impact, a side impact, a rear quarterpanel impact, and a rear end impact. The impacting vehicle was a Mazda 6 2003-2008 model year. The results show that Photomodeler vehicles match the HVE database vehicles closely. The authors compared the change in velocity or delta-V, peak acceleration, average acceleration, and rest position. In certain impact configurations, tessellation of 10 inches on the Photomodeler

vehicle improved the match to the HVE vehicle's acceleration profile.

Photomodeler Vehicle Models

Photomodeler is a commercially available software program that can extract 3-dimensional data from photographs. The authors used a Nikon D300 with a Nikkor 20mm wide angle lens which is calibrated with the Photomodeler software. The calibration gives Photomodeler the parameters of the camera and lens such as focal length, image size, and lens distortion to provide more accurate results.

For each vehicle the authors used circular targets that are easily identified in the software. These targets were placed in the environment next to the vehicle and on the vehicle to easily define the exterior shape. Figure 1 shows the targets around the Chevrolet Impala.



Figure 1: Photomodeler targets on Chevrolet Impala

Photographs were taken around the entire vehicle. These photographs were imported into the Photomodeler software and used to determine the 3-dimensional location of each target on the vehicle body. It is possible to extract the vehicle geometry without targets, however, the targets make the task easier and more accurate.

The resulting vehicle geometry was converted to inches and separated into different layers to expedite the process of importing the file into HVE. The layers consisted of windows, trim, headlights, taillights, and body. The geometry file was exported as a 3-dimensional meshed model. The resulting model of the Chevrolet Impala directly from Photomodeler is shown in Figure 2 and Figure 3 in wireframe and shaded, respectively. The polygon count for each vehicle is given in Table 2.

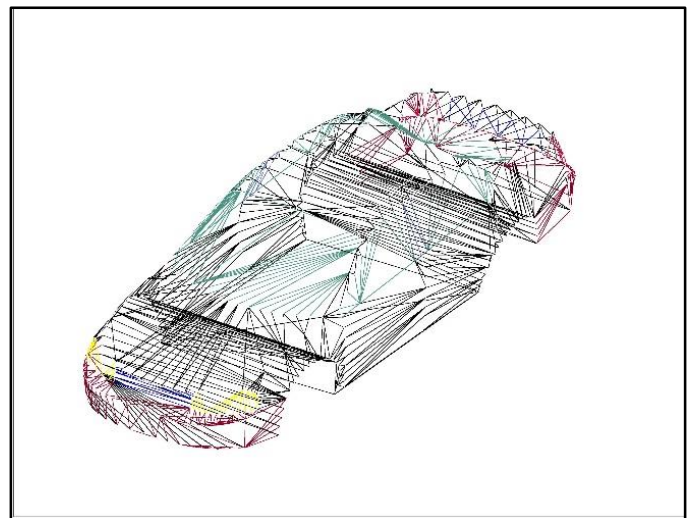


Figure 2: Chevrolet Impala wireframe model

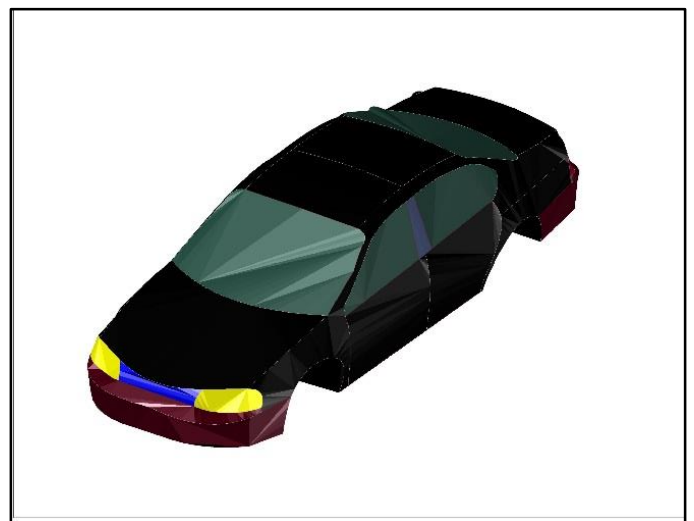


Figure 3: Chevrolet Impala shaded model

Vehicle	Mesh Size
Toyota Corolla	772
Ford Crown Victoria	804
Chevrolet Impala	969

Table 2: Mesh size of Photomodeler models

Importing Models to HVE

The resulting models from Photomodeler were opened in AutoCad in order to move vehicles so that the origin was at the center of gravity location with coordinate orientation consistent with HVE (x-axis forward, y-axis to the right, z-axis down). The center of gravity location was obtained from the HVE database model of each vehicle.

Once this transformation was complete, the importation process followed the protocol by Anderson and Garvey (Anderson, 2005)(Garvey, 2000). The vehicle geometry was saved as a release 12 dxf file from AutoCad. This file was imported as an environment in HVE. Once the import was completed the temp.iv file was modified to incorporate the desired material properties for each of the layer components. The extension of this file was then changed to h3d and the vehicle model was ready for use in HVE. Figure 4 shows the final HVE model of the Chevrolet Impala.

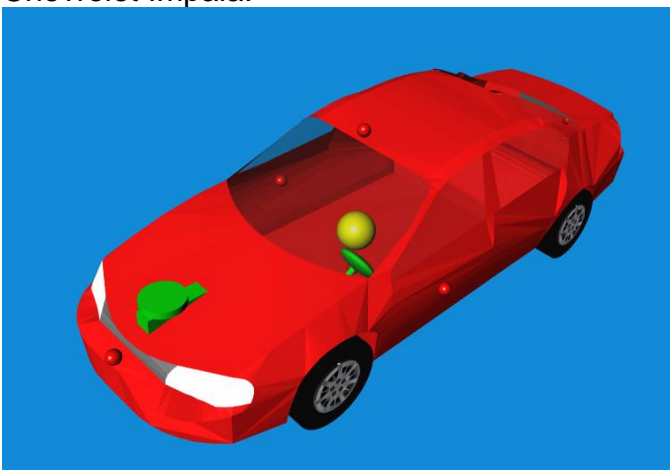


Figure 4: Chevrolet Impala final HVE model

Impact Simulations

In order to compare the performance of the Photomodeler vehicles to the HVE database vehicles a Mazda 6 model year 2003-2008 was used as the bullet vehicle with the target vehicle being either the HVE vehicle or the Photomodeler vehicle. In order to compare the Photomodeler model with the HVE model the authors wanted to test multiple areas of the vehicle. Therefore, the authors set up the front of the bullet vehicle to impact the stationary target vehicle at 5 locations: the front, the front corner, the side, the rear corner, and the rear. The bullet vehicle was given an initial speed of 25 mph. The target vehicle was stationary with the brakes applied to prevent excessive motion after impact. Figure 5 shows the five configurations used in HVE. The bullet Mazda 6 is shown in green and the target vehicle is shown in blue.

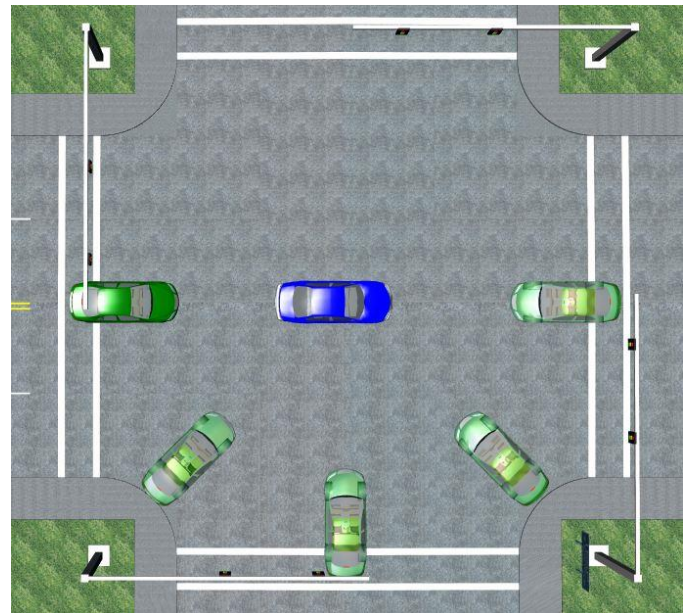


Figure 5: Impact configurations

The simulations were run with a DyMesh time interval of 1 millisecond. Data was also output at a time interval of 5 millisecond. For each configuration the authors recorded the following outputs for the target vehicle: velocity, acceleration, impact force, vehicle position, and rotation angle. The configuration shown in Figure 5 results in 5 impacts for the HVE target

vehicle and 5 impacts for the Photomodeler target vehicle, or 10 impacts per target vehicle model. This setup was repeated for each of the vehicle models in Table 1.

In order to evaluate the effect of mesh size on the model, the default Photomodeler vehicle was also tessellated to 10 inches and 5 inches. These tessellated results were also compared with the standard untessellated HVE vehicles.

Results

For each run the velocity, acceleration, impact force, and position of the target vehicle were

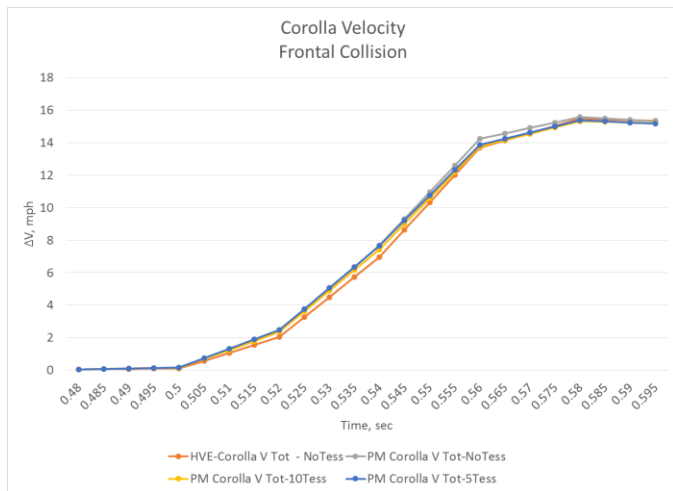


Figure 6: Velocity of Toyota Corolla target vehicle

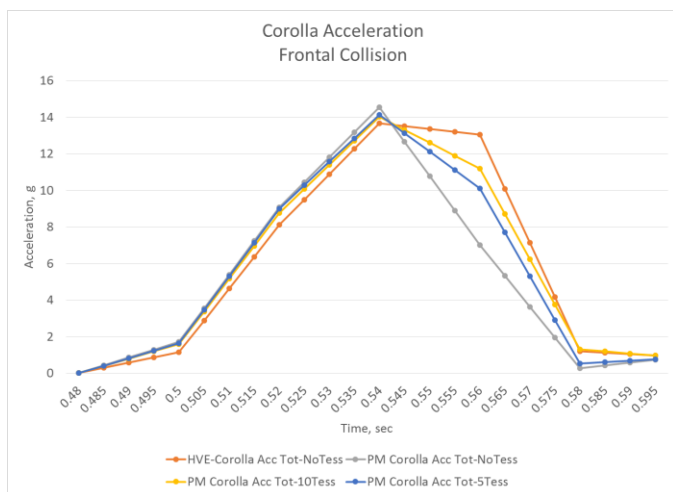


Figure 7: Acceleration of Toyota Corolla target vehicle

output. The velocity and acceleration plots for the Toyota Corolla frontal collision are shown in Figure 6 and Figure 7, respectively. Each graph compares the results of the HVE Corolla (dark orange), to the Photomodeler Corolla (gray), the Photomodeler Corolla tessellated to 10 inches (yellow), and the Photomodeler Corolla tessellated to 5 inches (blue). This data was used to calculate the target vehicle's change in velocity or delta-V, peak acceleration, and average acceleration. This process was repeated for each target vehicle and each configuration, including the tessellated Photomodeler vehicles.

The results for the Toyota Corolla are given in Table 3. The Table gives the delta-V in mph, the peak acceleration in g's, the average acceleration in g's, the contact time in seconds, and the final position and yaw angle for each target Corolla. The percent error is also calculated for the delta-V, the peak acceleration, and the average acceleration.

Figure 8 through Figure 12 plot the percent error between the Photomodeler Corolla and the HVE Corolla for the delta-V, peak acceleration, and average acceleration. The percent error between the untessellated Photomodeler Corolla and the HVE Corolla are shown in gray, the percent error between the Photomodeler Corolla tessellated to 10 inches and the HVE Corolla are shown in yellow, and the percent error between the Photomodeler Corolla tessellated to 5 inches and the HVE Corolla are shown in blue. The figures show the results for the frontal collision, front 45 degree collision, side collision, rear 45 degree collision, and rear collision.

The results for the other vehicles are tabulated in the Appendix in table 4 and table 5.

Toyota Corolla										
	ΔV		Acceleration				Time	Rest Position		
Frontal	ΔV, mph	ΔV-%Error	Acc Peak, g	Acc Peak-%Error	Acc Avg, g	Acc Avg-%Error	Contact Time, sec	X, ft	Y, ft	Yaw, deg
HVE - Corolla - NT	15.44		13.66		7.00	0.00%	0.100	12.51	29.96	0.32
PM - Corolla - NT	15.53	0.58%	14.54	6.44%	6.19	-11.48%	0.100	12.48	29.93	1.77
PM - Corolla - 10T	15.28	-1.04%	14.03	2.71%	6.93	-0.95%	0.100	13.31	29.94	1.28
PM - Corolla - 5T	15.33	-0.71%	14.14	3.51%	6.70	-4.21%	0.100	13.07	29.93	0.85
Front45										
HVE - Corolla - NT	13.10		9.6		4.28		0.140	17.34	16.62	-69.05
PM - Corolla - NT	14.16	8.09%	11.49	19.69%	4.73	10.64%	0.140	17.49	16.84	-55.97
PM - Corolla - 10T	14.07	7.40%	10.48	9.17%	4.52	5.78%	0.140	17.83	17.70	-68.63
PM - Corolla - 5T	13.89	6.03%	9.92	3.33%	4.39	2.74%	0.140	17.77	17.66	-69.13
Side										
HVE - Corolla - NT	14.84		13.73		6.64		0.100	30.00	12.61	-0.58
PM - Corolla - NT	15.15	2.09%	15.8	15.08%	7.09	6.70%	0.100	30.06	12.23	0.35
PM - Corolla - 10T	15.00	1.08%	15.47	12.67%	7.32	10.22%	0.100	30.02	12.73	-0.38
PM - Corolla - 5T	15.22	2.56%	15.37	11.94%	7.28	9.70%	0.100	30.01	12.99	-0.13
Rear45										
HVE - Corolla - NT	12.70		8.17		4.24		0.140	42.63	16.08	64.39
PM - Corolla - NT	12.50	-1.57%	9.63	17.87%	4.09	-3.51%	0.140	42.47	16.36	61.90
PM - Corolla - 10T	13.64	7.40%	9.21	12.73%	4.18	-1.26%	0.140	42.18	16.60	51.73
PM - Corolla - 5T	13.88	9.29%	9.69	18.60%	4.32	1.94%	0.140	42.22	16.78	47.97
Rear										
HVE - Corolla - NT	15.27		15.8		5.90		0.115	48.76	30.00	-0.25
PM - Corolla - NT	14.93	-2.23%	13.53	-14.37%	5.41	-8.34%	0.115	48.55	30.04	-0.21
PM - Corolla - 10T	15.47	1.31%	15.07	-4.62%	5.47	-7.34%	0.115	48.63	30.01	-0.32
PM - Corolla - 5T	15.50	1.51%	15.25	-3.48%	5.52	-6.51%	0.115	48.77	30.07	0.78

Table 3: Results for Toyota Corolla

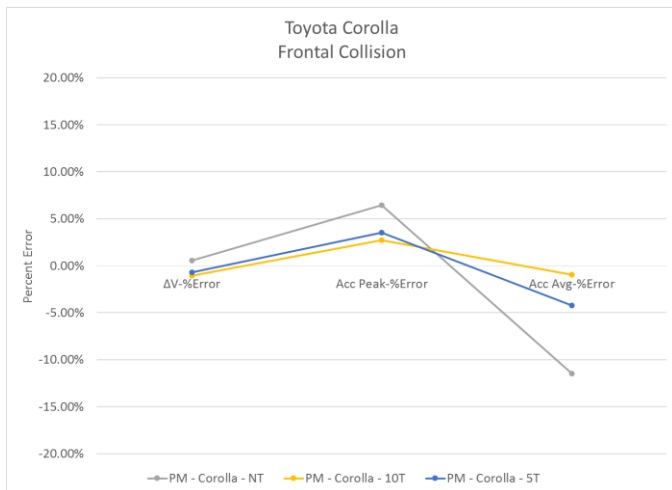


Figure 8: Toyota Corolla frontal collision % errors

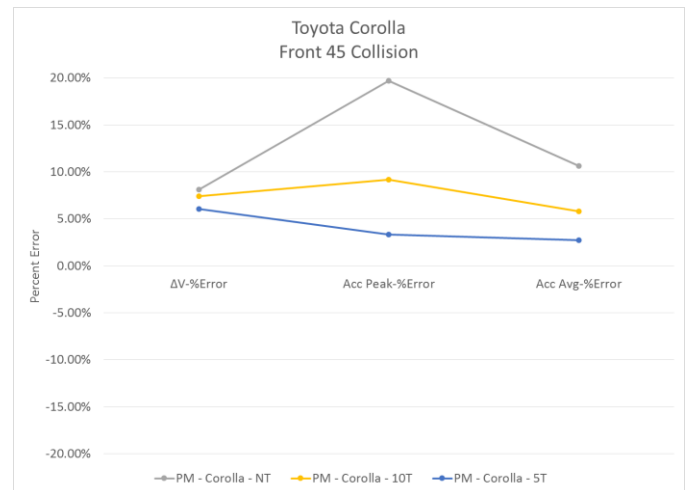


Figure 9: Toyota Corolla front 45 collision % errors

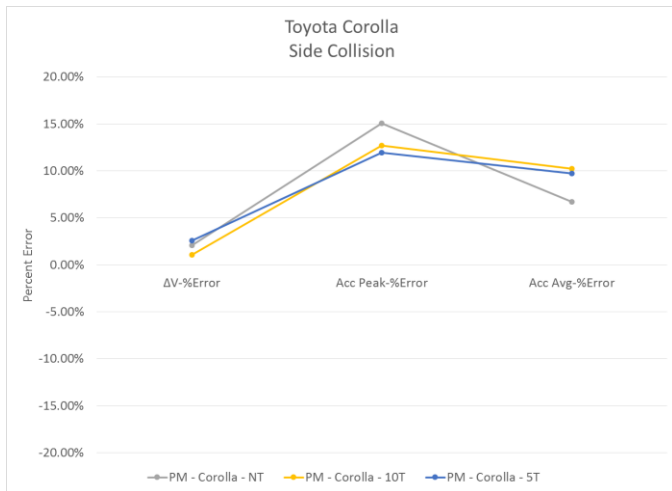


Figure 10: Toyota Corolla side collision % errors

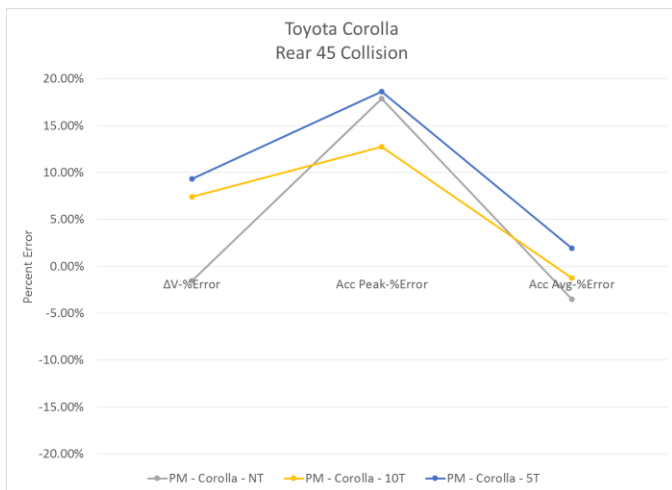


Figure 11: Toyota Corolla rear 45 collision % errors

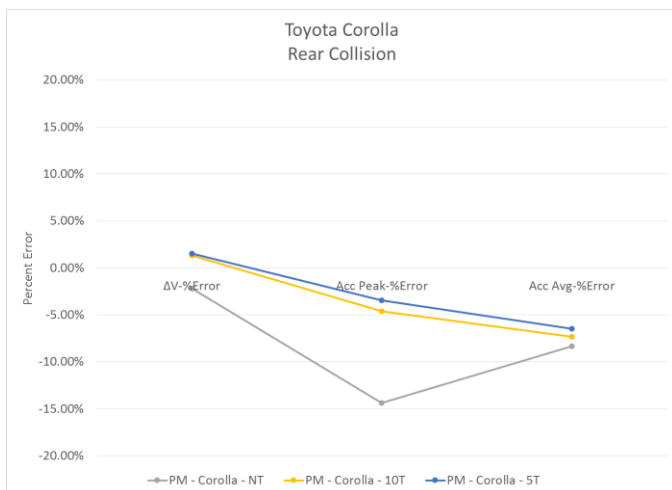


Figure 12: Toyota Corolla rear collision % errors

Discussion

The results for the Toyota Corolla given in Table 3 clearly show that the Photomodeler Corolla closely matches the results from the HVE Corolla. Although the untessellated Photomodeler Corolla matches the HVE Corolla well, tessellation of the vehicle does improve the results for certain impact configurations. For example, the front and rear collisions show some improvement with the tessellation. The front 45 degree impact shows more significant improvement with the tessellation. Even in cases where the tessellation did not significantly improve the results, it did not worsen the results either.

The velocity profile of the HVE Corolla is matched very closely by both the untessellated and tessellated Photomodeler Corolla (Figure 6). In general the error is less than 10%, and in most cases below 5%.

In certain configurations, the tessellation of the Photomodeler vehicles better matched the acceleration profile of the HVE vehicle. In Figure 7 the acceleration profile of the HVE Corolla is matched fairly well by all the Photomodeler Corollas. However, closer examination shows that the untessellated Photomodeler Corolla's acceleration profile is a triangle shape without the flattening at the top of the curve. The tessellated versions begin to capture this flattening. In this case the 10 inch tessellation does the best job of matching the HVE Corolla. This may result because the tessellation of 10 inches most closely matches the default mesh sizes of the HVE Corolla model. Again, all the acceleration results from the Photomodeler Corolla are within 2 g's of the HVE Corolla model.

If acceleration is important for the user's analysis, these results suggest that tessellation of 10 inches gives overall the best match to the HVE Corolla. Continued tessellation to 5 inches does not significantly improve the match

with the HVE Corolla. This is probably due to the default mesh size of the HVE Corolla.

The rest positions of the HVE Corolla center of gravity are closely matched by the Photomodeler Corolla, usually within one foot. There is little improvement if any in the tessellated models. This is to be expected because the overall velocity is matched very well by all the Photomodeler vehicles.

The results for the Ford Crown Victoria and Chevrolet Impala (Table 4 and Table 5) follow similar trends to the Toyota Corolla. The data shows that the Photomodeler Crown Victoria and Impala matched the delta-V generally within one mph and the peak accelerations and average accelerations within 2 g's. As with the Toyota, tessellation for some impact configurations improved the match to the HVE vehicles' acceleration profiles. Similar to the Toyota Corolla, these Photomodeler vehicles closely matched the HVE vehicles' rest positions.

Conclusions

Photomodeler produced vehicles closely matched the HVE vehicles' velocity,

acceleration, contact time, and position. In some configurations tessellation of the Photomodeler vehicle to 10 inches more closely matched the HVE vehicle's accelerations. The results clearly show that Photomodeler derived HVE vehicles can be used to obtain results consistent with those expected from HVE database vehicles.

Bibliography

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Appendix

Ford Crown Victoria										
	ΔV		Acceleration				Time	Rest Position		
Frontal	ΔV, mph	ΔV-%Error	Acc Peak, g	Acc Peak-%Error	Acc Avg, g	Acc Avg-%Error	Contact Time, sec	X, ft	Y, ft	Yaw, deg
HVE - Crown Victoria - NT	11.82		10.36		4.02	0.00%	0.120	14.87	30.00	-0.28
PM - Crown Victoria - NT	11.89	0.59%	9.7	-6.37%	3.99	-0.82%	0.120	15.05	29.97	0.04
PM - Crown Victoria - 10T	11.98	1.35%	9.87	-4.73%	4.28	6.41%	0.120	15.05	30.01	-0.89
PM - Crown Victoria - 5T	11.89	0.59%	10.32	-0.39%	4.14	2.93%	0.120	14.86	29.97	-0.67
Front45										
HVE - Crown Victoria - NT	11.02		5.82		3.00		0.180	19.89	20.91	-86.34
PM - Crown Victoria - NT	10.84	-1.63%	6.49	11.51%	2.73	-8.87%	0.180	20.07	21.71	-106.39
PM - Crown Victoria - 10T	11.10	0.73%	5.89	1.20%	2.78	-7.39%	0.180	20.28	22.63	-76.97
PM - Crown Victoria - 5T	10.97	-0.45%	5.54	-4.81%	2.79	-7.11%	0.180	20.14	22.51	-74.88
Side										
HVE - Crown Victoria - NT	10.00		12.23		5.62		0.075	29.80	18.34	-2.14
PM - Crown Victoria - NT	11.58	15.80%	14.01	14.55%	7.23	28.56%	0.075	29.76	17.06	-3.69
PM - Crown Victoria - 10T	11.05	10.50%	12.56	2.70%	6.44	14.60%	0.075	29.86	17.18	-2.27
PM - Crown Victoria - 5T	11.10	11.00%	12.5	2.21%	6.44	14.51%	0.075	29.87	17.19	-1.71
Rear45										
HVE - Crown Victoria - NT	10.59		6.99		2.81		0.185	38.35	19.35	33.20
PM - Crown Victoria - NT	10.55	-0.38%	5.39	-22.89%	2.68	-4.54%	0.185	37.95	20.28	45.70
PM - Crown Victoria - 10T	11.14	5.19%	6.51	-6.87%	2.89	3.09%	0.185	37.87	21.42	10.16
PM - Crown Victoria - 5T	11.11	4.91%	6.19	-11.44%	2.83	0.92%	0.185	38.08	21.07	9.86
Rear										
HVE - Crown Victoria - NT	11.07		10.7		5.36		0.080	43.55	30.02	0.13
PM - Crown Victoria - NT	10.08	-8.94%	12.3	14.95%	5.98	11.67%	0.080	44.89	29.94	-0.48
PM - Crown Victoria - 10T	10.36	-6.41%	11.85	10.75%	5.86	9.33%	0.080	44.98	29.86	-0.83
PM - Crown Victoria - 5T	10.19	-7.95%	11.93	11.50%	5.75	7.30%	0.080	45.02	29.83	-1.02

Table 4: Results for Ford Crown Victoria

Chevrolet Impala										
	ΔV		Acceleration				Time	Rest Position		
Frontal	ΔV, mph	ΔV-%Error	Acc Peak, g	Acc Peak-%Error	Acc Avg, g	Acc Avg-%Error	Contact Time, sec	X, ft	Y, ft	Yaw, deg
HVE - Impala - NT	12.66		11.38		5.62	0.00%	0.100	15.14	29.97	-0.12
PM - Impala - NT	12.72	0.47%	11.76	3.34%	5.12	-8.88%	0.100	15.01	29.94	0.21
PM - Impala - 10T	12.71	0.39%	11.84	4.04%	5.14	-8.50%	0.100	15.31	29.90	0.62
PM - Impala - 5T	12.84	1.42%	10.61	-6.77%	6.02	7.24%	0.100	15.29	29.96	-0.15
Front45										
HVE - Impala - NT	10.47		7.12		3.83		0.120	21.18	22.63	-74.24
PM - Impala - NT	11.43	9.17%	9.02	26.69%	3.95	3.08%	0.120	20.90	22.31	-72.87
PM - Impala - 10T	10.88	3.92%	7.98	12.08%	4.11	7.14%	0.120	21.41	23.25	-70.54
PM - Impala - 5T	10.64	1.62%	7.34	3.09%	3.92	2.16%	0.120	21.33	23.06	-70.57
Side										
HVE - Impala - NT	12.95		13.75		5.55		0.095	29.99	18.19	0.55
PM - Impala - NT	13.16	1.62%	15.79	14.84%	6.64	19.69%	0.095	30.02	16.63	-0.78
PM - Impala - 10T	12.98	0.23%	14.34	4.29%	6.01	8.29%	0.095	29.97	19.71	-0.31
PM - Impala - 5T	13.02	0.54%	12.99	-5.53%	5.65	1.85%	0.095	30.02	18.13	-0.58
Rear45										
HVE - Impala - NT	11.61		8.74		4.36		0.120	38.77	21.47	51.12
PM - Impala - NT	11.14	-4.05%	10.91	24.83%	3.94	-9.74%	0.120	38.26	21.01	45.94
PM - Impala - 10T	11.90	2.50%	9.27	6.06%	4.57	4.82%	0.120	38.75	21.92	44.73
PM - Impala - 5T	11.77	1.38%	8.77	0.34%	4.46	2.16%	0.120	38.81	21.74	42.90
Rear										
HVE - Impala - NT	11.23		9.92		4.96		0.100	42.88	29.98	0.02
PM - Impala - NT	11.54	2.76%	8.64	-12.90%	4.96	-0.12%	0.100	42.52	29.91	-0.34
PM - Impala - 10T	12.57	11.93%	10.54	6.25%	5.73	15.36%	0.100	42.92	29.95	-0.18
PM - Impala - 5T	12.84	14.34%	10.61	6.96%	6.02	21.31%	0.100	42.97	29.96	-0.15

Table 5: Results for Chevrolet Impala