Pedestrian Head Impact, Automated Post Simulation Results Aggregation, Visualization and Analysis Using d3view

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Abstract

Euro NCAP Pedestrian head impact protocol mandates the reduction of head injuries, measured using head injury criteria (HIC). Virtual tools driven design comprises of simulating the impact on the hood and post processing the results. Due to the high number of impact points, engineers spend a significant portion of their time in manual data management, processing, visualization and score calculation. Moreover, due to large volume of data transfer from these simulations, engineers face data bandwidth issues particularly when the data is in different geographical locations. This deters the focus of the engineer from engineering and also delays the product development process. This paper describes the development of an automated method using d3VIEW that significantly improves the efficiency and eliminates the data volume difficulties there by reducing the product development time while providing a higher level of simulation results visualization. This method reduces post-simulation analysis time through automation thereby eliminating the effort and time of manual data management and visualization. d3VIEW is tightly integrated with LS-DYNA® and as the raw LS-DYNA data is processed on HPC, the resulting output data stored in d3VIEW server is considerably small and eliminates the issue of data bandwidth throttling when the output is to be made available across different geographical regions. Besides score calculation, the capability of d3VIEW has been challenged to include the generation of automatic opportunity chart that can highlight potential locations which require a minimal design change to improve overall score. In summary, d3VIEW platform provides significant benefit in reducing product development process and provides an efficient guiding tool in pedestrian head Impact analysis that can also be extended to other regulatory requirements.

Introduction

Virtual tools play a big role in the development of a new vehicle. For Euro NCAP pedestrian head impact mode, prior to the tests, the vehicle manufacturer has to rely on virtual tools for the prediction of the head impact score. Figure 1 shows Euro NCAP pedestrian head impact mode. The shape and dimension of the vehicle front end determines the number of possible head impact points of the adult and child pedestrian on the hood, windshield. For a regular passenger car these head impact points range from 150 to 200 as shown in Figure 2. The vehicle manufacturer has to provide the HIC prediction for all the points to the Euro NCAP secretariat. Later the prediction level is verified by Euro NCAP [1].
Hence for every grid point it is required to run a simulation to predict the HIC. This results into a high number of simulations yielding huge data which consumes considerable amount of computer memory space. Engineers have to spend a significant portion of their time in managing the data. Processing and visualization of the data are the other challenges which are time consuming and delay the complete vehicle development process.

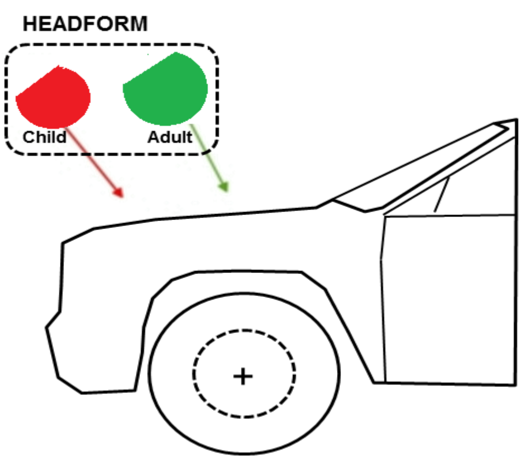

Figure 1. Euro NCAP pedestrian head impact

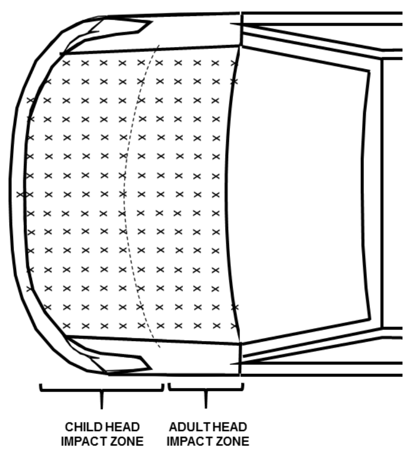

Figure 2. Pedestrian head Impact grid points

Traditional Method

The current traditional method flow chart is shown in Figure 3. And the solver used is LS-DYNA.
The process starts when pedestrian head impact target is decided for a particular vehicle development program. This target score is further categorized in terms of color code for each individual head impact grid point. These target color codes are based on past expertise and current design packaging space. Engineer study the packaging at every grid point to decide the target color achievable at different grid points. Figure 4 shows an example of target color code matrix defined by an engineer. The number of head impact grid points and their position data is available from the vehicle front end marking process which is done as per the Euro NCAP protocol [2]. The complete process from running simulations to analyzing and deciding the next design change or iteration to meet the target score can be categorized into four main operations.

1. Data Management
2. Data Processing
3. Data Visualization
4. Identification of Impact Points with highest opportunity for improvement

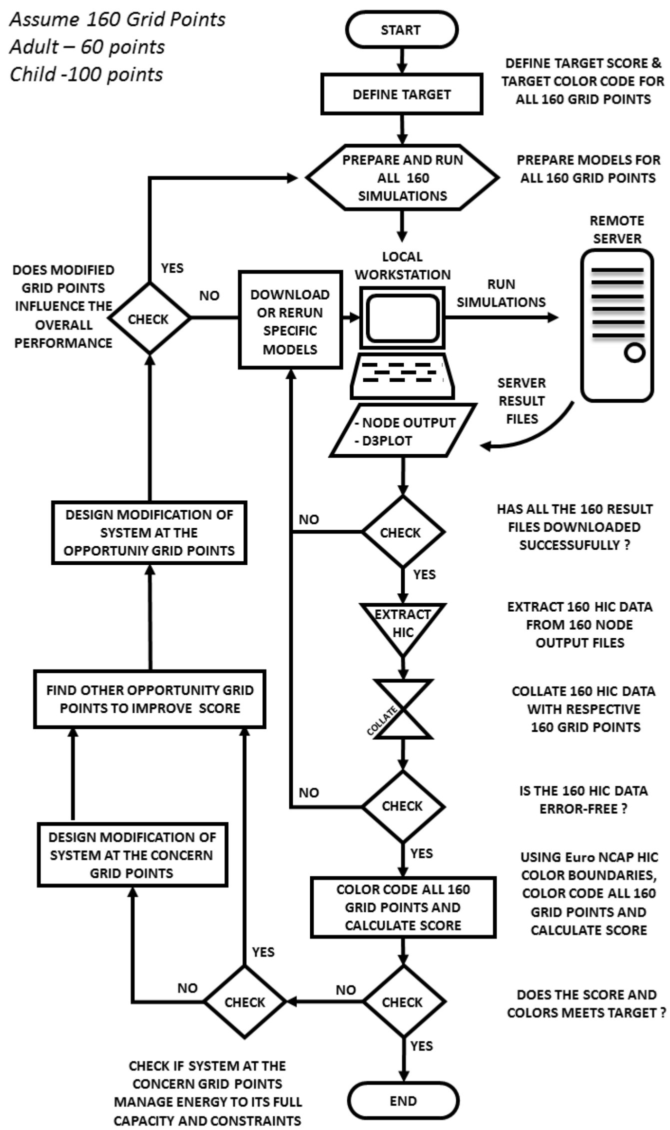

Figure 3. Pedestrian Head Impact Post Processing Flow Chart

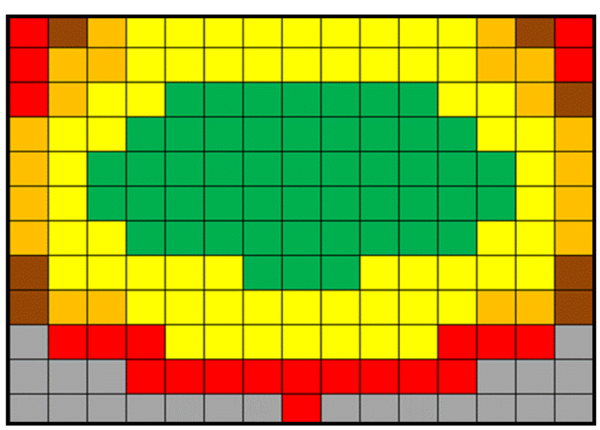

Figure 4. An example of target color matrix decided by an engineer.

Data Management in Traditional Method

High number of head impact grid points adds challenge to the process when it comes to data management. First step is to model a detailed front end of the vehicle and then run the simulations for all the grid points. The simulations run on a remote server. And once the simulation terminates, results are downloaded to the local workstation. The results consist of node output file and d3plot files. It is required for the engineer to check if all the data is correctly downloaded to their workstation or not. And if any data is missing the engineer has to rerun that particular grid point and acquire the data for further analysis.

Limitation of traditional data management

The memory space occupied by the data of one grid point is around 3 gigabytes (GB). For all the grid points the total size is around 500 GB. This is the size of just one study or iteration. If the engineer intends to compare two iterations in detail the memory space required is around 1 Terabytes. Since large amount of data is generated at each development cycle and due to limited storage availability of local workstations, engineers have to delete data very frequently. Hence during enabler development process, the baseline runs are required to be resubmitted to compare with the enabler. This process is redundant and can be avoided if the old baseline results were available on the local workstation.

Another issue is that, sometimes results are not transferred completely to the local workstation due to server issues. In such cases, the results have to be downloaded manually which is again a very tedious and time-consuming process. This delays the vehicle development process.

Global companies are now experiencing a new issue called the bandwidth issue. If the remote servers are located far away from the local workstations, for example in a different country, the huge amount of data transfer chokes the bandwidth and the overall network speed is hampered. This delays the data transfer from the server to the local workstation and hence hampers the post processing.

Data Processing in Traditional Method

Once it is confirmed that the output for all the grid points is transferred to the local workstation from the server then it is time to start processing the data. The first processing step is to extract the HIC information from the node output file for all the grid points. This is done using any of the available post processors like Hypergraph, Metapost or Oasys Primer etc. The post processors come with automation tools to expedite this process of opening the node out file, plotting the head acceleration and calculating the HIC for all the grid points. The next step is to collate the HIC data with its respective grid point. It is also done using the automation tools provided by the pre-processors. The output is a file having the grid point identification, its position and the HIC number associated to it. At this stage since the HIC numbers are available it is necessary to check for errors in the HIC numbers. These errors occur due to error termination of the simulation at a particular grid point. An easy way to identify such grid points are to look for HIC with very low numbers or with a drastic difference in their value compared to its neighboring grid points.

At the end of this process, the grid and its respective HIC information is used to plot the color-coded chart showing the performance of all the grid points as shown in Figure 5.

Pedestrian head impact score is finally calculated using the HIC information [1]. The calculation can be carried out using Microsoft Excel.

Limitation of traditional data processing

Data extraction is a time-consuming process. Even though the Pre-processors are equipped with automation tools, the time required to extract the HIC information for all the grid points is around 2 to 3 hours.
The automation tools also lack robustness in their extraction process. This may be due to different formats of node out file generated by different solver versions. The extraction process suddenly stops and the engineer has to redo the process again.

Data Visualization in Traditional Method
This is the stage when the engineer has to confirm the iteration for its performance. The first check is to compare the obtained score with the target. If the target is not met, then the engineer looks forward to review all grid points. The performance of all the grid points can be visualized using the color matrix shown in Figure 5. It is compared with the target color code matrix shown in Figure 4.

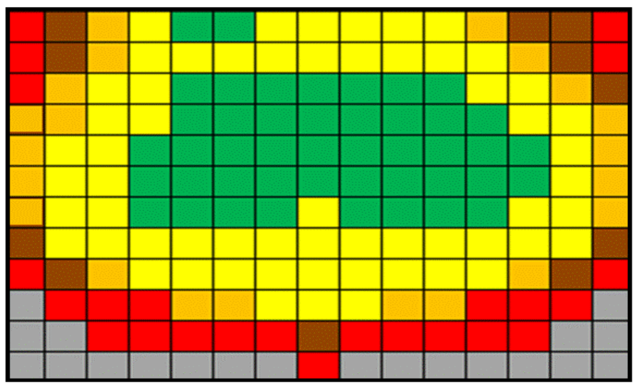

Figure 5. HIC Performance Color Matrix of all grid points

For every grid point where the performance color is not matching the target, the engineer performs a detailed investigation to check if the system at the concerned grid points is managing energy to its full capacity or yet there is scope to improve in the existing design. The engineer has to study the head acceleration time history data as shown in Figure 6. This data shows the acceleration that head experiences in the complete event of the impact.

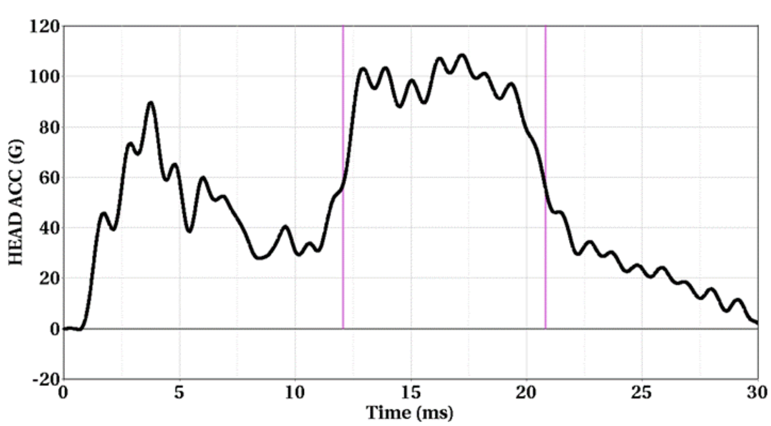

Figure 6. Head acceleration Vs Time

To understand every peak, it is necessary to know which component of the vehicle is taking part in the event and at what time it is loading the head. Hence it is necessary to observe the kinematics of the impact in detail. Figure 7 shows an example of the kinematics of head impact with the hood. The kinematics files like d3plot animations occupy maximum memory compared to other results files.

Limitation of traditional data visualization

Since the total number of grid points is huge, it is impossible to review all the points for visualization and the engineers have to choose wisely what points need to be checked for complete visualization. It is very likely that some potential points are missed where there is an opportunity to improve the energy management in that region which would improve the overall score.

For each grid points chosen, the section view animation needs to be exported along with the HIC plot. Since the output file size is huge, it takes at least 15 minutes to view and generate a section image for each grid point. The total time taken to export all the necessary points would exceed more than 2 hours.

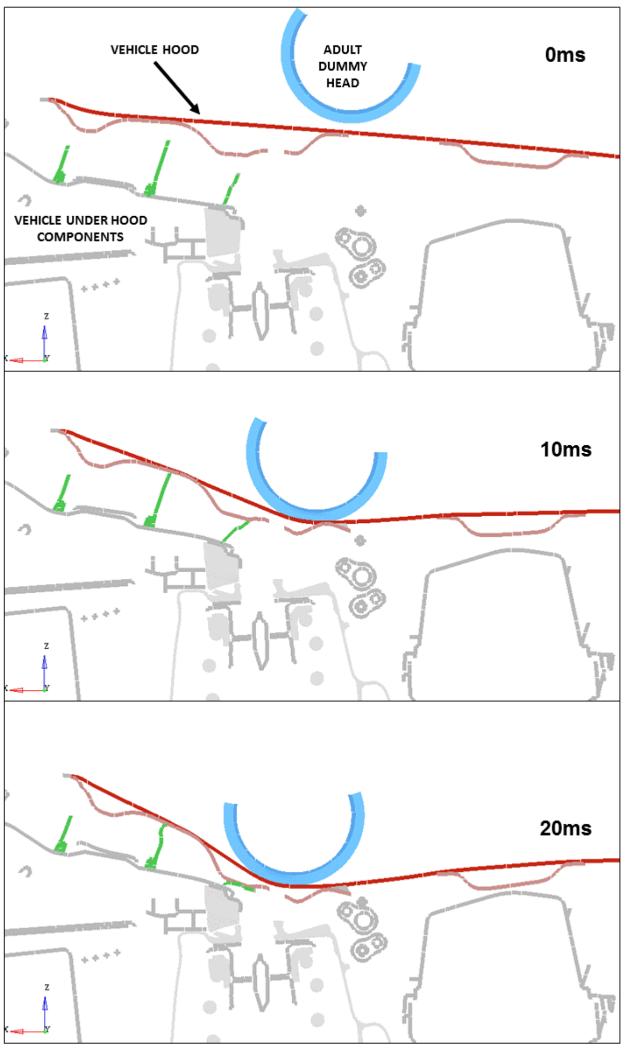

Figure 7. Kinematics of head impact with the hood.

Identification of Impact Points with highest opportunity for improvement in Traditional Method

The next step is to identify potential enablers. The potential enablers are required at the grid points where small change in HIC can impact the overall score. These are the opportunity grid points which require around 50 to 100 HIC reductions to change color and achieve a better score as shown in Figure 8. This operation of finding the potential grid is done using Excel spreadsheet. Once the grid points are identified the next step is to map those points to vehicle to identify the potential enabler components as shown in Figure 9. Later the components are reviewed for their efficiency in energy management by monitoring their kinematics in d3plots. All potential enablers are reviewed for their effectiveness like ease in manufacturing, cost and feasibility. Generally, the enablers in pedestrian consist of modifying the stiffness or changing the displacement gap of the system for energy absorption. Once the design changes are decided it is necessary to modify the Vehicle CAE Model and to understand if it influences the overall performance or if it only has a local effect. The engineer takes a decision based on judgement and accordingly runs the second complete iteration or just a few grid points simulations and attain an updated score. This process is repeated until the Target is met.

Limitations in traditional method

It is very challenging to identify potential points which can undergo easy color change without a proper digital visualization method. Each point needs to be meticulously checked to see if there is a possibility of color change and its feasibility. Due to very limited time between each product cycles, engineers cannot focus on all the potential grid points and instead work only on some of the points based on their expertise to improve score

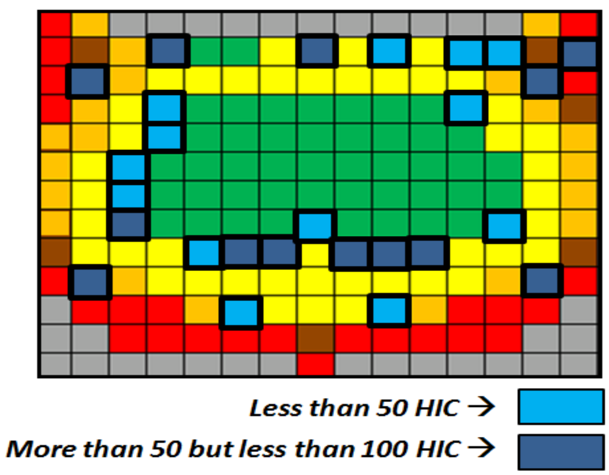

Figure 8. Opportunity Grid Points which require around 50 to 100 HIC reductions to change the color.

Automated Post Simulation Results Aggregation, Visualization and Analysis using d3VIEW

d3VIEW

d3VIEW Inc., founded in 2003, is headquartered in Rochester Hills, Michigan with worldwide customers using its platform for on premise and cloud infrastructure. The flagship product is d3VIEW with several supplemental applications that works within it to form a platform for enabling data driven decisions.

d3VIEW is tightly integrated with LS-DYNA making it easier to define the data that are to be extracted and visualized. As the raw LS-DYNA data is processed on HPC, the resulting output data is reduced to a small footprint and is stored in d3VIEW server. Figure 10 shows the architecture and data flow of d3VIEW platform.

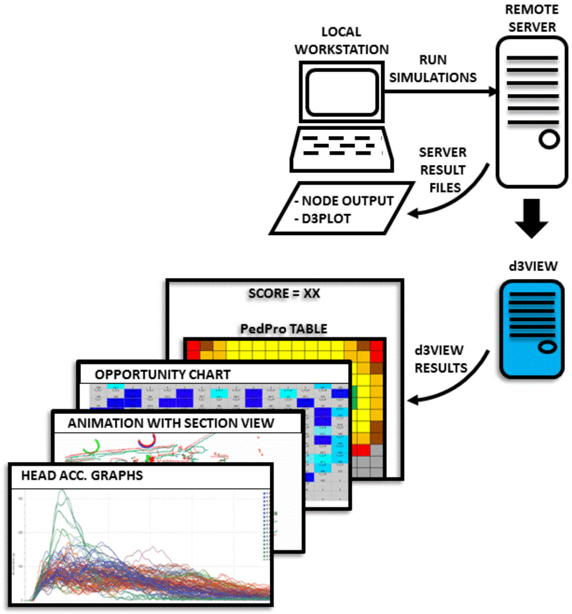

Figure 10. Architecture and data flow of d3VIEW platform

Data Management using d3VIEW Method

Each pedestrian protection (Ped Pro) simulation consists of several files generated by the solver whose total file size could be around 500Gb. Using smart templates in d3VIEW, computer programs self-extract the necessary data for assessing the pedestrian protection and stores them in the d3VIEW server with no human intervention. This means and if a simulation completes at mid-night, the data is still extracted and is made available to the engineer with no human involvement. As the extracted data is much smaller, in the order of MB as opposed to TB, they become ideal to be sent across different geographical locations with minimal bandwidth.

Minimum HIC	Maximum HIC	Multiplier Points	Color Group
	650	1.00	
650	1000	0.75	
1000	1350	0.50	
1350	1700	0.25	
1700		0.00	

Table 1. Pedestrian Protection HIC Multiplier Classification. [1]

Data Processing using d3VIEW Method

d3VIEW is focused to minimize or completely eliminate time and effort related to data extraction, transformation, storage and visualization (ETSV). As a platform, d3VIEW provides data extractors for a variety of solvers and requires no scripting or addition coding from the engineer. In addition to raw data extraction, d3VIEW can help transform the extracted data from a rich library of transformations which again requires no additional scripting. The extracted data is then stored in relational databases facilitating queries to find all simulations belong to a single sweep that can be used to visualize the overall assessment for a single design and sweep.

The scorecard is generated with the help of identifiers associated with each HIC value for every bin shown in Table 1 [1]. Each of the grid points can be awarded up to one point, resulting in a maximum total amount of points equal to the number of grid points. Each grid point is binned based on its location on the vehicle hood. The score for each bin is estimated based on the number of points in a bin multiplied by the Color factor for each group. Color groups are based on the HIC values and a total score is generated against the predicted score.

Data Visualization using d3VIEW Method

d3VIEW utilizes the Ped pro Table generator from its suite of visualizers in the Simlytiks application. The Ped pro Table provides a comprehensive view of the HIC values achieved across the hood position created for the design sweep. In addition, the total score is also calculated for the full sweep and displayed as a part of the visualization as shown in Figure 11.

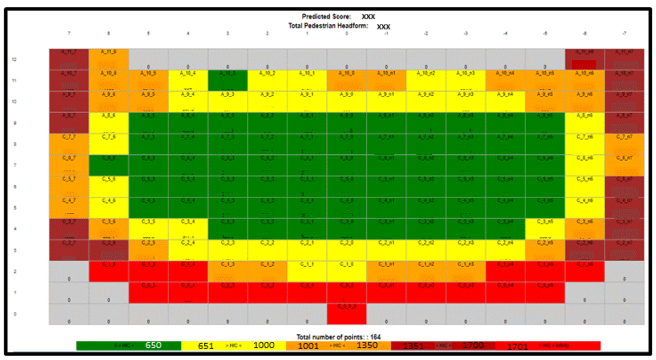

Figure 11. Ped Pro Table from d3VIEW

An additional feature that is supported includes the animations and a kinematic model as part of the Ped Pro Table it is called Ped Pro Visualization. This allows the engineer to select any grid point and visualize a section view animation as shown in Figure 12. In addition, a compact 3d model can also be visualized in place of the animation.

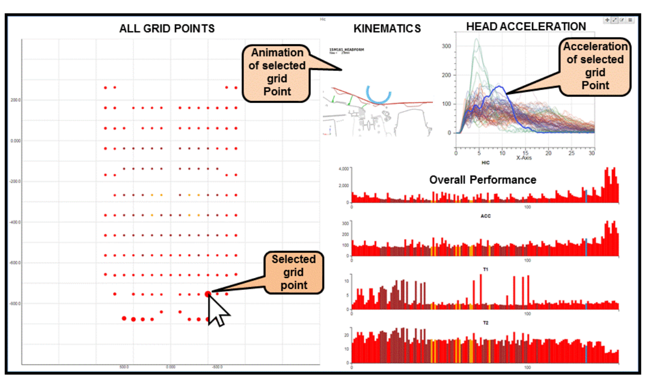

Figure 12. Ped Pro Visualization from d3VIEW

The template used to extract the HIC values also allows for the automated extraction of the animations and 3d model as shown in Figure 13.

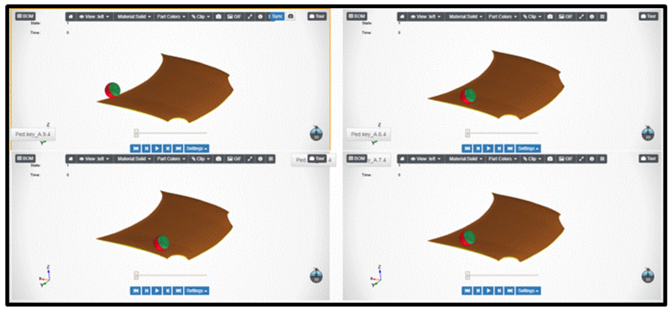

Figure 13. 3d Models extracted by d3VIEW template.

The animations include traditional views as well as section views cut across the Centre of gravity of the Headform to accurately reflect the deformations experienced by the Headform and parts in contact with the hood as shown in Figure 14.

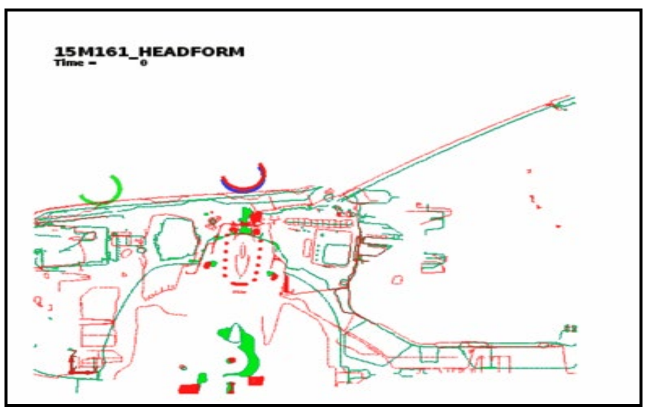

Figure 14. Animations Extracted by d3VIEW

Identification of Impact Points with highest opportunity for improvement using d3VIEW

To identify enabler development and facilitate improvements in the overall Ped Pro score observed, an Opportunity Chart is generated on d3VIEW. The Opportunity Chart identifies key regions across the grid points that have the potential to cause improvements in the overall score.
Points that lie in specific thresholds are identified and highlighted for quick viewing in Simlytiks. The Opportunity Chart supports all features available with the Ped Pro Table and provides an updated Score achievable.

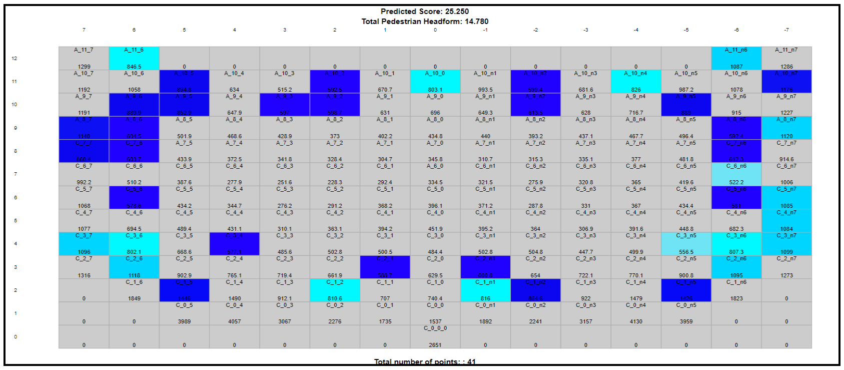

Figure 15. Opportunity Chart from d3VIEW

Traditional Method	d3VIEW Method
DATA MANAGEMENT - 1. Data stored in local work station. Manual downloading of results is required if the results are not transferred properly due to server issues. 2. Memory size for one complete study is greater than 500GB. Data cannot be archived for long duration due to memory space limitations of the local workstation. 3. Global companies face bandwidth choking issues as large amounts of data is being transferred between different countries.	1. Data stored in d3VIEW server without any human intervention. 2. Memory size is less than 1GB and data is preserved for more than 1 year on the d3VIEW server. 3. No bandwidth choking issues as compressed d3VIEW data is ideal way to transfer data.
DATA PROCESSING - 1. HIC extraction, score calculation and all grid color table processing takes around 2 to 3 hours after the results are downloaded on the local workstation. 2. Different formats of node output file generated due to difference in the solver versions create issues for the automation tools (used for extraction process).	1. Since the d3VIEW server is connected to the solver it extracts and processes the HIC, score and all grid color tables instantaneously. 2. Data extraction is done directly from the server hence no dependency on the solver output files.
DATA VISUALIZATION - 1. It is very likely that some potential grid points are missed as it is difficult to review animations and head acceleration time history data of all the grid points.	1. Ped Pro Visualization feature of d3VIEW gives the engineer control of all analyzing data (animation, graphs, HIC) at a click of a button.

Discussion

The d3VIEW template for pedestrian head impact is a smart simulation tool with built-in functionalities to auto-generate the necessary outputs for visualization and decision making. This aids the engineer to post process with minimal time and effort and facilitates to identify the potential enablers quickly to achieve the target score. A key area of focus in future research and development would involve identifying enablers and recommending parameter updates across the model for stiffness and displacement updates. This is planned to be performed in two phases. In phase 1 for every grid point highlighted in the Ped pro table, affected parts along with their stiffness and distance between parts will be reflected as a part of the PedPro Table. This will help the engineer identify key parts without having to review the animations.

For phase 2, the model is to be parameterized to allow d3VIEW to identify key variables form phase 1 and update these parameters for an improved model sweep. This will involve minimal user intervention for enabler development and provide comprehensive coverage across all grid points. This process will allow for standardization and reducing any human errors involved with enabler identification.

Conclusion

In conclusion, d3VIEW as a platform improves productivity and facilitates seamless collaboration for dispersed teams in different geographical regions and helps to build safer automobiles for pedestrian protection. As seen in this paper, d3VIEW platform reduces the processing time of a single sweep from 5 days to 2 days. This greatly allows more designs to be studies and compress the overall virtual product development time for Pedestrian Protection. d3VIEW template and process also brings standardization and eliminates human error increasing the confidence in reporting and assessment.

References

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3. LSTC (2007). LS-DYNA User’s manual, version 971