FINAL REPORT

*VECVEV: VE*HICLE *C*RASH *V*IRTUAL *E*NVIRONMENT *V*ISUALIZER

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Executive Summary:

Crashworthiness of automotive vehicles and impact response of highway structures represent very active research areas. The ultimate goal is to design vehicles and highway structures to minimize risk to passengers while also controlling damage to vehicles and barriers. The main task of the current investigation is to develop *Virtual Reality Visualization* (VRV) as a tool for visualizing finite element (FEA) simulations of automobiles, trucks and barriers in crash scenarios. VRV *integrated with FEA* has great potential for drivers and personnel training. Finite Element Analysis has been in use for many years. Many codes are available for a variety of analyses such as static, dynamic, thermal and modal response.

VRV allows more effective assimilation of the voluminous output files. The analyst or trainee can ‘fly by’ and/or ‘fly through’ the impacted structures as though 'immersed' in them. The finite element models used are adapted from public models available from NHTSA (NHTSA, 2000), based on LS-DYNA. VR Libraries are built using the ASCII output files from the code. Those libraries are subsequently accessed by the user.

Details of the archived models, such as element types and constitutive relations, are enhanced to accommodate a broad range of crash scenarios, including vehicles crashing into each other and higher impact speeds. The output files are used to create Crashworthiness Effect Files in VRML format for visualization.

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1. **INTRODUCTION**

VRV represents a major technological advance over traditional graphics on 2D computer screens. It offers three positional and two rotational geometric degrees of freedom, as well as control over textures, lighting, shading, opacity and even sound. The system combines the versatility of virtual reality visualization with the powerful results of the finite element (FE) impact code LS-DYNA. Recently a prototype VRV system was presented (Moraes & Nicholson, 2000) for visualization of automotive crash. This work is a continuation of this reference, showing a broader range of its capabilities.

Using devices such as a head mounted display; the trainee or analyst becomes totally immersed in the 3-D environment being visualized. Furthermore, he/she has total control over the viewing process, flying by and flying through the visual field. The experience of VRV is very stimulating and informative. For example, the response of certain structural regions can be vividly displayed while the rest of the structure is displayed in a more muted color or texture. In the current system, the output files generated from analysis are converted through a developed windows based application (Dyn2VRML) to Crashworthiness Effects Files (CWEFS), which are capable of VRV. The user is then able to observe the crash analysis as if he/she were actually inside the automobile. Virtual reality visualizations of the responses of two Fiesta automobiles colliding and a light truck colliding with a fiesta automobile are presented.

The system has great potential in any environment where training is needed for large numbers of individuals, for example operators of military vehicles or helicopter pilots. It likewise has great potential in enhancing the performance of analysts requiring better visualization of crash and impact scenarios. With further development, the system can be available to the civilian aviation community and the automotive/highway safety communities.

1.1 Nomenclature

CWEFS	Crashworthiness Effects Files
DLL	Dynamic Link Library
dVISE	Software for VR
Dyn2VRML	Software for files conversion
FE	Finite Element
FEA	Finite Element Analysis
LS-DYNA	Finite Impact Element Code
PDL	Program Design Language
UCF	University of Central Florida
VR	Virtual Reality
VRV	Virtual reality Visualization
VRML	Virtual Reality Multi Language

2. LS-DYNA & VRV SYSTEM

LS-DYNA is used to model the crash scenarios for different contact angles. The output files generated from the analysis are converted to Crashworthiness Effects Files (CEFS) capable of VRV. The trainee is then able to observe the impact process simulation as if he/she were actually inside the automobile. Figure 1 shows the VRV system. More detailed information can be found in Moraes and Nicholson, 2000.

Figure 1 – VRV system ready for use.

Figure 2 below represents the communication between the finite element code, virtual reality and the user.

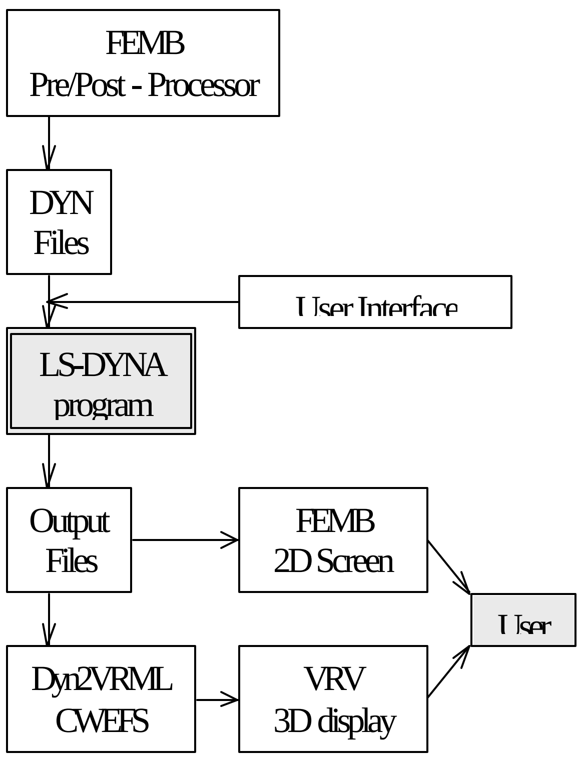

Figure 2 – Communication between finite element files and virtual reality visualization

Dyn2VRML is the prototype of a fully integrated, user-friendly windows based application. It translates the ASCII output files from LS-DYNA into VRML files. The application is written in FORTRAN90 using double precision dynamically allocatable arrays for memory optimization. All subroutines are compiled into DLL to be used by the windows–driven graphical interface.

3. VIRTUAL REALITY VISUALIZATION

3.1 Octant Concept

The main intent for this system is training of a large number of personnel. Since LS-DYNA simulation cannot be performed in real-time for purposes of visualization (due to the large elapsed time for the numerical solution), the notion of creating a library of possible zones of crash scenarios was adopted. Figure 3 shows the concept of an octant region for different impact angles. For the sake of ‘proof of principle’, the crash zones are described as octants in a two dimensional space. Figure 3 represents the octant concept used to build the library.

Once the user defines a zone, the closest damage result or scenario, previously solved and stored in the library, is shown according to the angle and velocity of impact between the two vehicles.

The octant concept considerably enhances the time response of the VRV system.

Figure 4 shows the concept on how the libraries are being built using the finite element analysis from LS-DYNA.

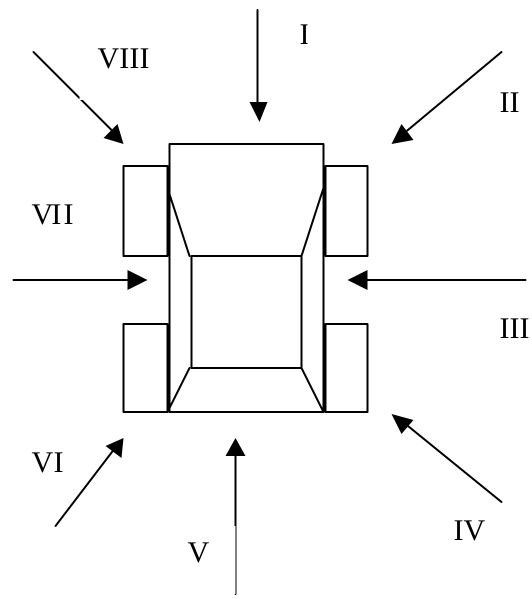

Figure 3 – Concept of octants used to build the library of crash impacts

As a starting point, small libraries already exist with five simulations for each octant retrieved, resulting in a total of forty simulations. The following libraries are currently available: a) Fiesta car impacting a fiesta car and b) Fiesta car impacting a light truck C2500. The construction of further libraries would involve different impact velocities, different car models and different initial conditions. The numerical results are compared with actual test data involving two cars and involving a light truck with a passenger car.

4. MODELS

The finite element models presented in this work were originally obtained as LS-DYNAv.942 files from the 'National Highway Traffic Safety Administration'. These models require that a large number of materials and parts be modified prior to simulation in order to enhance the material behavior. This will allow the numerical simulation to achieve better physical results, as at this velocity some parts must have an elastic-plastic response and not just elastic or rigid response. The models used for VRV of LS-DYNA crash simulations in this work are a Fiesta car and a light truck C2500.

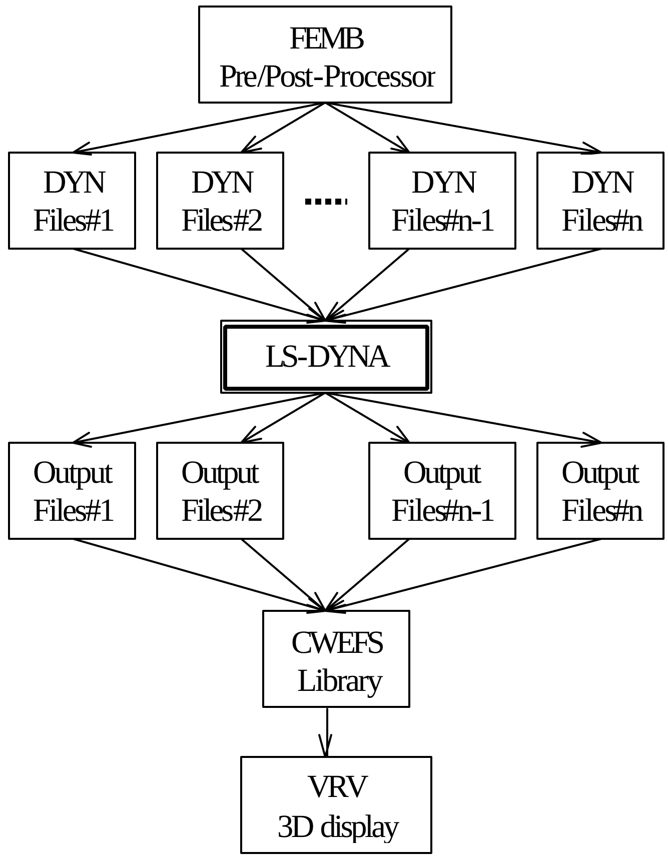

Figure 4 – Library building procedure for CWEFS

4.1 Fiesta Car colliding with a Fiesta Car

Figure 5 represents the first scenario with two Fiestas colliding. This model has close to 10,000 elements including beam, shell and solid elements. The impact velocity is 55mph (left car only) and the angle between the cars symmetry axes is 130 degrees.

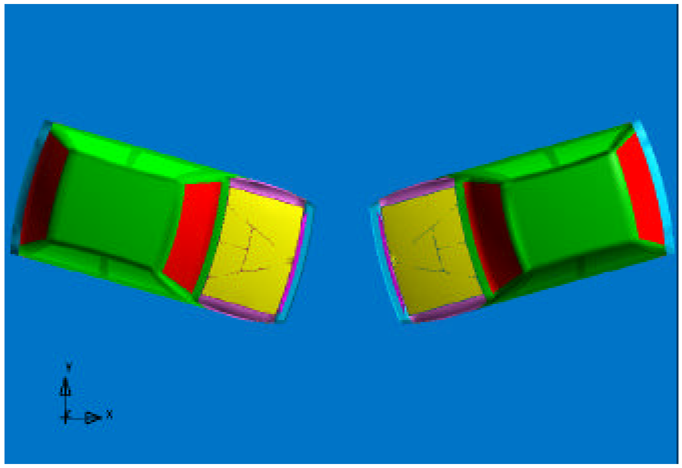

Figure 5 – Fiesta models just before collision

4.2 Fiesta Car colliding with Light Truck C2500

Figure 6 next represents one scenario with a fiesta automobile colliding against a light truck. This model has over 70,000 elements including beam, shell and solid elements. The impact velocity is 75mph (light truck only) and the angle between the vehicles symmetry axes is 90 degrees. The obtained results show reasonable agreement with experimental results obtained from George Washington Library.

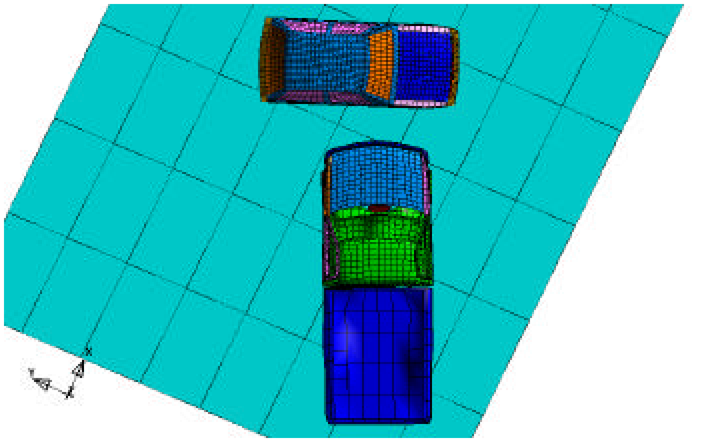

Figure 6 – Light truck and fiesta car ready for analysis

5. NUMERICAL SIMULATIONS

5.1 Fiesta models colliding at frontal impact – Region I

The numerical simulation performed on the Fiesta model in this particular case is based on Figure 5. Figure 7 shows the numerical result at an intermediate step.

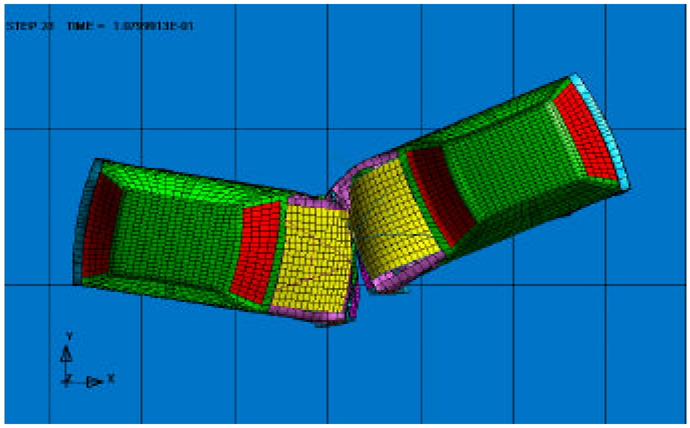

Figure 7 – Fiesta crash – Intermediate step.

It is important to emphasize that the visualization procedure proposed in this work is not a 2-D screen seen on a regular monitor screen or the picture in this paper. *The 3-D environment is achieved with the head mounted display*. Once in use, the analysis can be easily done from outside the car (as a witness that sees the crash) or from inside the car (as the driver or as a passenger).

Figure 8 shows the final step of the simulation with some internal details. This feature is obtained by removing some of the components from the post-processor (visually only). Figure 9 depicts a zoom image from Figure 8. The different views permit a better understanding base on the internal behavior of the different parts inside the hood.

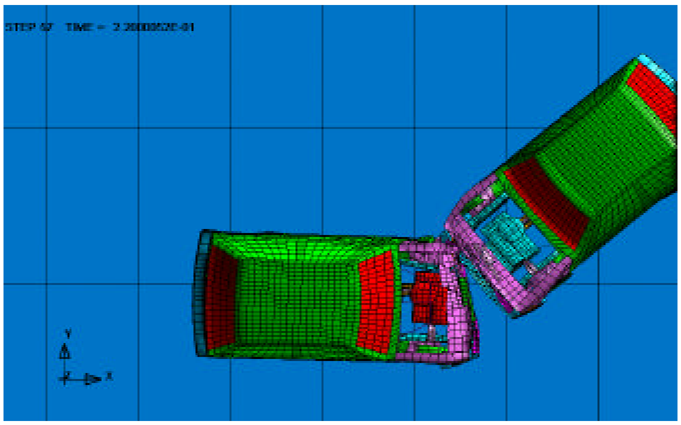

Figure 8 Fiesta crash – Final step with internal details.

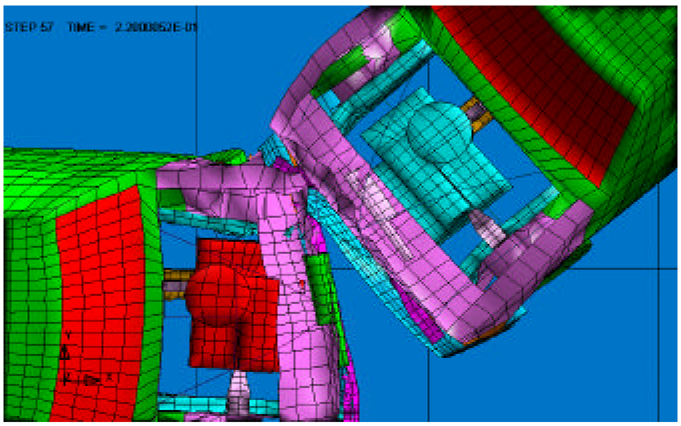

Figure 9 – Fiesta crash – Final step with internal details and zoom

Similar procedures are performed for all the others impact regions, i.e., other octants (II, VIII).

5.2 Fiesta model colliding with light truck – Region III

Figure 10 shows the numerical result at an intermediate step between the light truck and the fiesta automobile. The region of impact is region III for the car and region I for the truck.

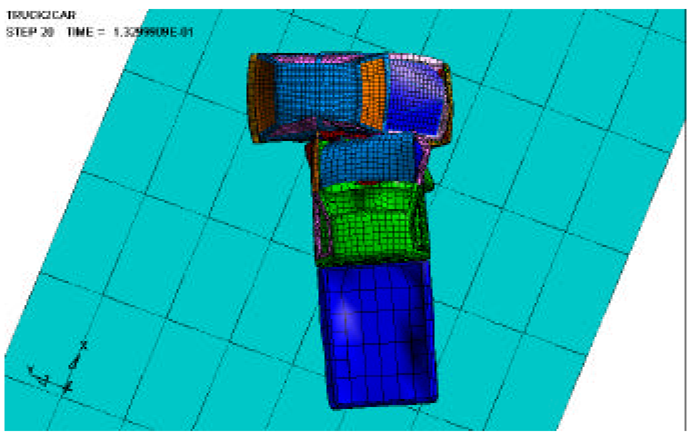

Figure 10 – Collision of light truck and Fiesta automobile

5.3 **Completed Simulations and Visualizations**

The models in the NHTSA archive generally involve collisions of highway vehicles with highway structures such as guardrails. We were successful is extending the vehicle models to use in vehicle-vehicle collisions.

? car–car collisions:

Three to five simulations were performed for all eight octants surrounding the ‘target’ vehicle, for a total of 30 scenarios

? *car–truck collisions:*

Two simulations were performed for a truck impacting a car (frontal and lateral).

? *car–guardrail collisions*:

Simulations were performed for a car impacting a guardrail at 3 different angles (Guardrail is G4 - made of sheets of metal type W)

? *truck– guardrail collision*

Simulations were performed for a truck-impacting guardrail at different velocities (guard rail is made of concrete for this case)

The VEC files from the Octant scenario were organized into a database for quick retrieval.

VEC files generated by LS-DYNA in 3.1 were successfully visualized using the MMAE scientific visualization facility. That is, Ricardo Moraes (the graduate student supported by the project) used the head mounted display, the motion trackers, and the mouse to 'fly through' the crash scenario captured by the VEC file. The fly-through capability is currently restricted to static ‘worlds’. The capacity to fly through dynamically changing worlds is not currently available through VRML.

6. FINAL REMARKS AND CONCLUSION

A low-cost prototype system for visualization of automobile crash, previously introduced, is being developed for visualizing numerical crashworthiness simulations. All analysis made use of finite element techniques and VRV.

All FEA is performed using LS-DYNA. Dyn2VRML is the software used to integrate the two tools. This fully integrated; user-friendly, Windows-based application is under continued development. However, the initial results obtained up to this point, show that the program has great potential for driving training and for supporting analysts and designers.

The LS-DYNA analysis are converted into CWEFS and then stored in libraries, which are later used for the training of a large number of personnel.

Future work, with appropriate funding, should include further development of the visualization system, additional crash scenarios, use of crash dummies to visualize occupant protection, and embedding the visualizer in a driving and/or traffic simulator.

7. REFERENCES

HALLQUIST, J.O., *LS-DYNA User Manuals*, Livermore Software Tech. Co., 1993

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NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION HOME page (http://www.nhtsa.dot.gov/)

8. ACKNOWLEDGEMENT

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