A PARAMETRIC MODEL FOR AUTOMOTIVE PACKAGING AND ERGONOMICS DESIGN

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Abstract - *This paper describes the capabilities of a parametric model developed to perform design and analysis tasks in the areas of advanced engineering activities during the development of a new automotive product. The model focuses on selection of vehicle parameters for exterior shape specification, positioning of occupants in the vehicle space, and interior ergonomics considerations related to reach, clearances and vision. The model has been built using OpenGL to develop the required graphics functionality, C++ to incorporate the back end computations, and FLTK to develop the Graphical User Interface. The model, when fully developed, has the potential to be an interactive, multi-user, multi-disciplinary and comprehensive tool that can be used by any major automotive OEMs and suppliers, as well as by various universities as an instructional and teaching aid, for vehicle design.*

Keywords: Vehicle Packaging, Ergonomics, Advanced Engineering

1.0 Introduction

Designing a new vehicle involves the design, development, and integration of a large number of systems and sub-systems within a vehicle. This is a demanding and multifaceted process that requires close coordination and inputs from a number of disciplines in order to ensure that these systems/sub-systems fit within the confined vehicle space, function, and provide the customers an acceptable combination of all relevant vehicle attributes such as appearance, performance, safety, ride, comfort etc. The design and development of a new vehicle usually begins with an activity known as "*advanced engineering*." During this phase, a design team consisting of designers, engineers, product planners, market researchers and other stake holders work together to create and evaluate an acceptable design concept. The design (styling department) develops alternate vehicle concepts that will be “attractive” to targeted customers and “feasible” from the engineering and manufacturing viewpoints. Currently, there is no comprehensive but simple tool available to reduce the time required to undertake the *advanced engineering* activity and to train future team members with the necessary background knowledge. Models developed by General Motors researchers focus on information about the material properties, interior and suspension components, masses added to the structure, and engine data and conduct analyses such as structural optimization, exterior aerodynamic, drag estimation, fuel economy calculation, interior roominess calculation, and business models with cost saving as their central theme [4,5]. Whereas the Parametric Model presented here places emphasis on the very early part of creating the basic vehicle exterior and interior package and working with the styling/design to provide a conceptual exterior shape by keeping the reduction in time as the central factor[1].

2.0 DESCRIPTION OF THE PARAMETRIC MODEL

2.1 Design Details

The Parametric Model has been designed by conforming to the Object Oriented design principles of encapsulation, polymorphism and inheritance. Each object hides its internal operations and exposes only those methods required to interface with it. The main menu allows a user to begin the vehicle design process by inputting parameters of a new vehicle or allows a user to continue his/her design work based on inputs saved during earlier sessions. The current model provides modules for *Parameter Selection, Ergonomic Analysis and Mechanical Analysis.*

When the user selects the *Parameter Selection*, the *vehicleIdentification* object is created (see Figure 1 below). The design of a vehicle begins by defining the key characteristics of a vehicle, such as the class it belongs to, the geographical location where the car will be sold, the shape category the vehicle will fit in, the manual to automatic ratio and the male to female ratio of the drivers of this design.

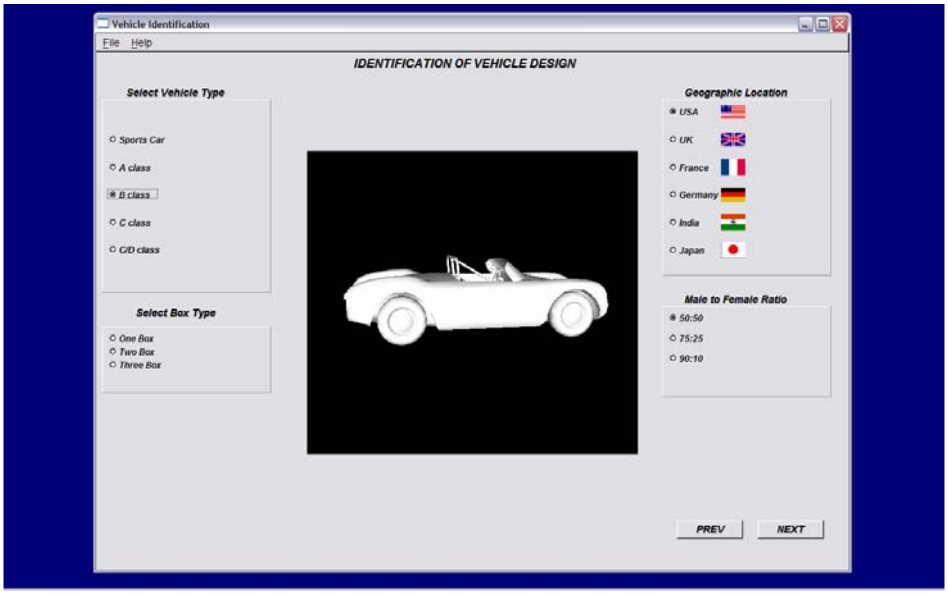

Figure 1. Vehicle Identification Screen

The first pane of the *vehicle dimension specification* screen allows the user to modify the X, Y and Z locations of the vehicle coordinate system (i.e. the body "zero"). It also allows the user to modify the overall length, width and height of the vehicle envelope. See Figure 2 below.

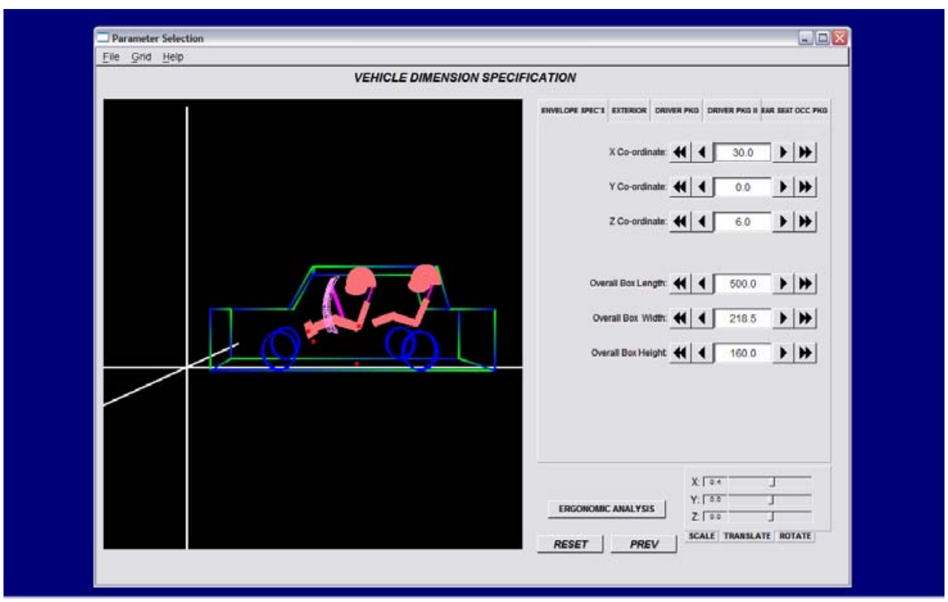

Figure 2. Screen shot of the envelope specification tab of the parameter selection module.

Any modifications to the parameters of the vehicle results in their corresponding callback functions modifying the corresponding value of the *parameterselectionGL* object's variable and calling the draw function.

2.2 Exterior and Interior Package

The second tab (“Exterior” on top right side) displays key exterior dimensions such as wheelbase, overhangs, tire size, cowl height, windshield and backlite slopes, etc. The tab provides counters that allow the user to modify these exterior dimensions using the SAE J1100 dimensioning nomenclature [2] (see Figure 3 below). It also provides output boxes to display values that have been modified due to changes generated by the user input function.

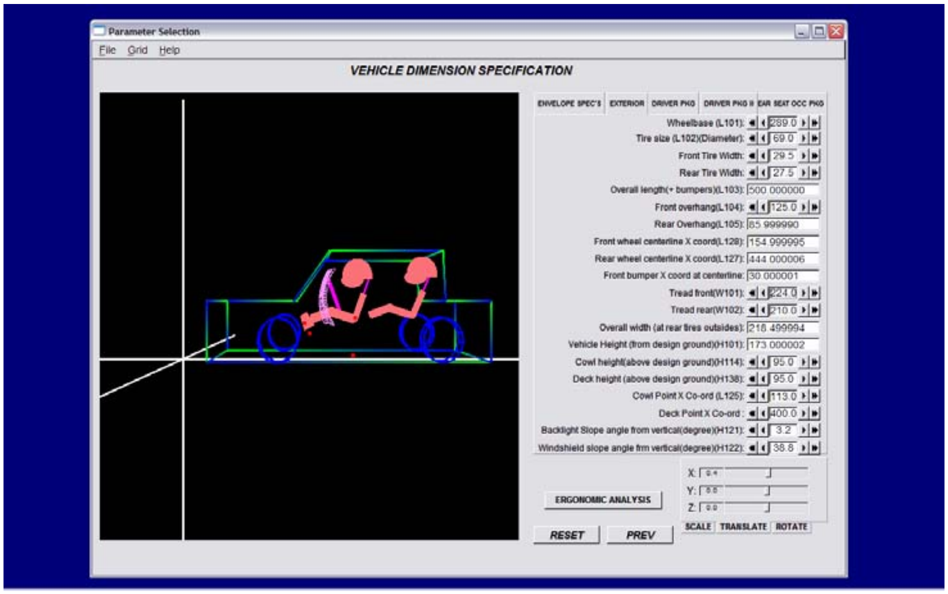

Figure 3. Screen shot of the Exterior Vehicle Parameters of the Parameter Selection module.

The third and fourth tabs display key *driver package* reference points such as accelerator heel point, seating reference point computed according to the SAE J1516 and J1517 [2], and steering wheel location. The driver eye locations (i.e. eyellipse) and head clearance envelope are placed according to the SAE J941 and J1052 procedures [2]. These tabs provide counters that allow the user to modify these interior dimensions (see Figure 4 and 5 below). It also provides output boxes to display values that have been modified due to changes generated by the user input.

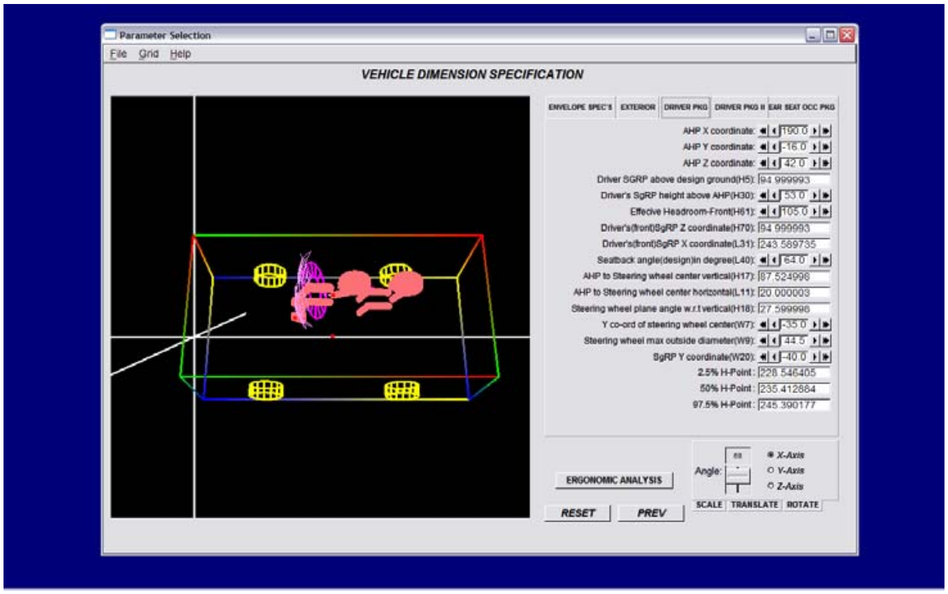

Figure 4. Screen shot of the Interior Vehicle Driver Package Parameters of the Parameter Selection module.

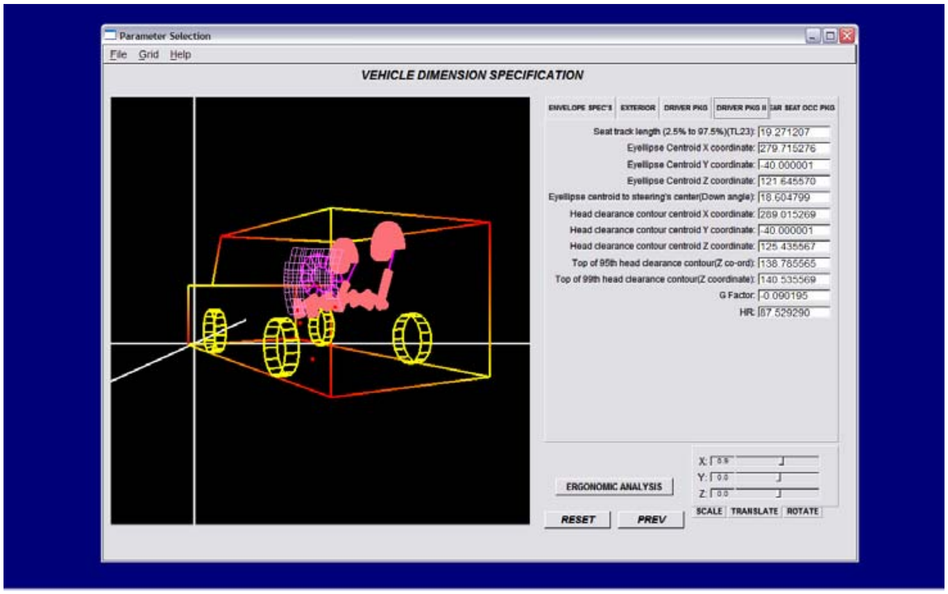

Figure 5. Screen shot of the Interior Vehicle Driver Package Parameters of the Parameter Selection module.

The last tab display shown in Figure 6 shows the key parameters required for the *rear seat occupant* packaging such as H-point couple distance, back angle of rear seat, head clearance envelope centroid X, Y and Z co-ordinates, etc. The functions called to display the changes in the rear occupants packaging are the same as those called for the driver package positioning.

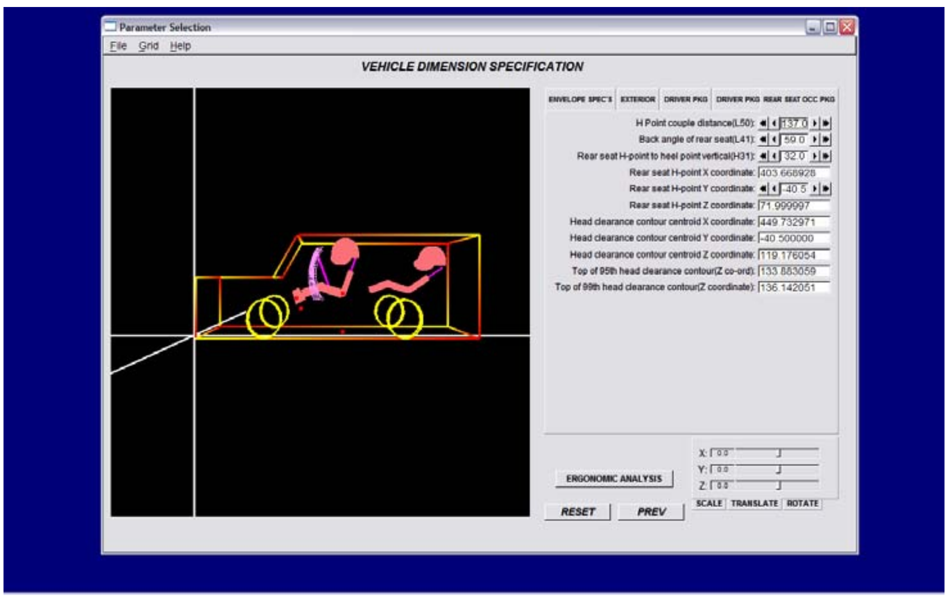

Figure 6. Screen shot of the Rear Occupant Package Parameters of the Parameter Selection module.

2.3 Ergonomics Analyses

Once the user has completed the parameter selection process he/she can proceed to perform ergonomic analyses (e.g. reach, visibility) on their vehicle model. This can be done in two ways. In the first method the user can click on the *ergonomic analysis* button under the vehicle specification screen. This will load the vehicle package modified by the user into the ergonomic analysis screen. The other way is to load the ergonomic analysis from the main menu. This will result in loading the default one box package on which the user can perform ergonomic evaluation.

The ergonomic analysis module computes and graphically displays ergonomics zones for locating driver controls and displays. It also allows importing and superimposing vehicle packages that fall in the same category to perform a comparison analysis. That is the users will be able to compare their design with a number of benchmarked vehicles and conduct a number of "what if" analyses (e.g. changing driver's seating reference point, H-point couple distance, etc).

The ergonomic analysis module is displayed by creating an instance of the *ergonomicAnalysis* object. Depending from where the call to create this instance is placed (i.e. from the *main* object or the *parameterSelection* object) either a default vehicle package is loaded or the package created by the user is loaded (see Figure 7 and 8 below).

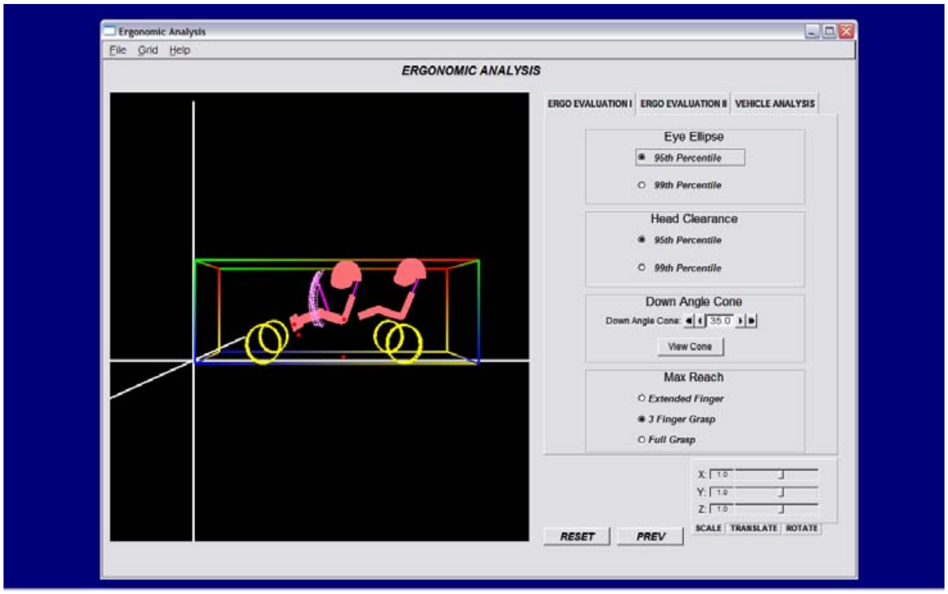

Figure 7. Screen shot of the default model loaded for ergonomic analysis.

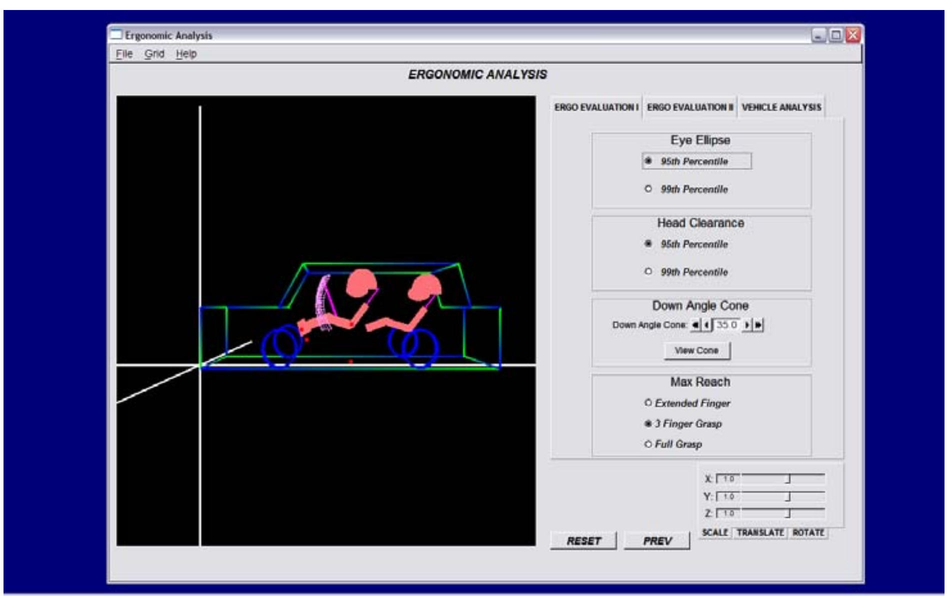

Figure 8. Screen shot of the user created model loaded for ergonomic analysis.

The *ergonomicAnalysis* object provides three tabbed panes in addition to a separate slider group created to handle calls for transformations on the vehicle envelope. This group supports the translation, scaling, and rotation of the model around the XYZ axes.

In the first tabbed pane the user can choose from 95th percentile and 99th percentile eyellipse and head clearance envelopes which have been defined in the SAE J941 and J1052 Recommended Practices. The down angle vision cone constructs a cone with its vertex at the mid point of the two eyellipse centroids. The cone is drawn to illustrate the drivers down vision sight lines for peripheral viewing the road scene while looking at a control or a display located on the instrument panel at the boundary of the conical surface. The max reach defines the space that the 95 % of drivers can reach comfortably (SAE J287 Recommended Practice), and the minimum reach zone is defined by the short driver's closest upper hand reach when her elbows are constrained by the seat back in a "chicken-winging" posture.

By default the eye ellipse and head clearance are selected for 95th percentile of the population. When the user selects the 99th percentile option for the eye ellipse a call is made to the *drawEllipsoidFront* and *drawEllipsoidRear* functions of *parameterSelectionGL* object which in turn re-computes the head clearance for the 99th percentile and updates the graphics accordingly (See Figure 9 below).

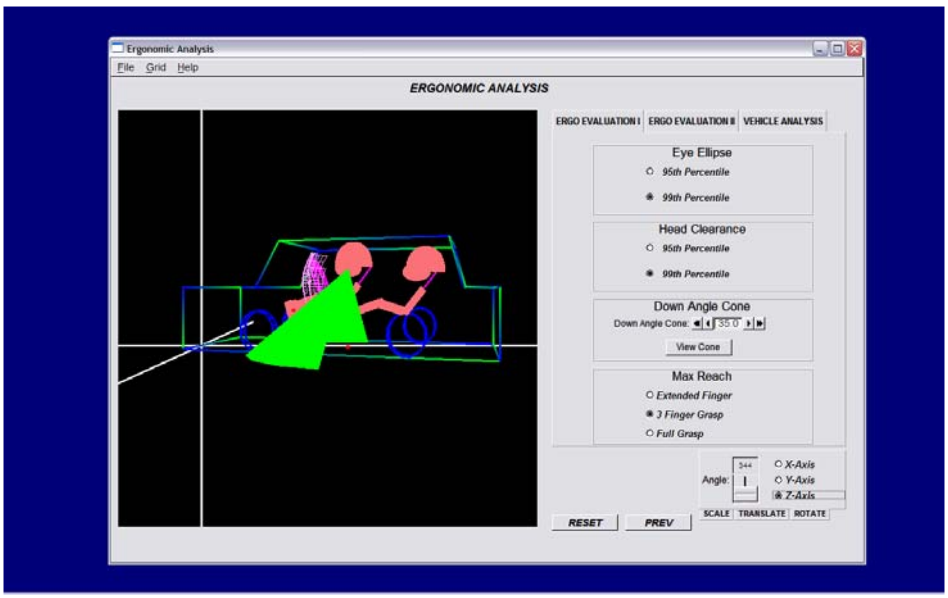

Figure 9. Screen shot of Ergonomic Analysis for eye ellipse, head clearance, reach and down angle cone.

A change in the head clearance results in a call to function *CreateUnitSphere* which recalculates the head clearance and updates the graphics package.

The down angle cone by default has a value of 35 degrees. When the user clicks on view cone a call is made to obtain the value of the down angle and is passed to the *DrawCone* function of *parameterSelectionGL* object. The *DrawCone* function generates a conical envelope.

2.4 Software and Hardware Requirements

The current version of the Parametric Model is designed to run on any windows operating system with at least a 256 RAM and 64 MB graphics card to support the processing needs of the models graphical capabilities.

The model has been developed using: a) OpenGL to develop the models graphical capabilities, b) FLTK to develop the graphical user interface, and c) C++ to perform computations in accordance with the SAE standards and to tie up the user inputs with the displayed graphics.

OpenGL is the premier environment for developing portable, interactive 2D and 3D graphics applications. Since its introduction in 1992, OpenGL has become the industry's most widely used and supported 2D and 3D graphics application programming interface (API), bringing thousands of applications to a wide variety of computer platforms. OpenGL fosters innovation and speeds application development by incorporating a broad set of rendering, texture mapping, special effects, and other powerful visualization functions. Developers can leverage the power of OpenGL across all popular desktop and workstation platforms, ensuring wide application deployment.

FLTK is a cross-platform C++ Graphical User Interface toolkit for UNIX®/Linux® (X11), Microsoft® Windows®, and MacOS® X. FLTK provides modern GUI functionality and supports 3D graphics via OpenGL® and its built-in GLUT emulation. FLTK is designed to be small and modular enough to be statically linked, but also works as a shared library [6]. C++ is a high-level programming language developed to add object-oriented features to its predecessor, C.

3.0 Future Work

In its current version the Parametric Model reflects only a part of the abilities of a full scale model. Modules for People Package Analysis, Mechanical Package Analysis and Impact Analysis need to be further developed to facilitate the Parametric Model to be useful in the *Advanced Engineering* process. In its current version the Mechanical Analysis module is somewhat limited in its abilities, as it only loads the beam models from ABAQUS and does not allow any further manipulations. In the next version this module should allow the beam module to be transformed along its key node points and along its beams to fit it within the vehicle being designed by the user. The beams should also reflect changes in depth, material, orientation and wall thickness depending on the users input. The module should also allow the ergonomic and design analysis performed by the user to be superimposed onto the beam model to visually aid in the transformations being applied to the beam model. An interface should be developed that will link the beam model to finite element analysis software's such as ABAQUS to analyze the torsional stiffness, bending stiffness, and modal frequencies of the body structure. In addition, the beam models will also be used to assess the crashworthiness of the structure roof strength /crush, front impact, angle impact, side impact, etc., and determine its approximate weight.

SQL databases need to be developed that will hold key information on characteristics of various existing benchmarked vehicles. This database can be connected to the Vehicle Analysis package of the Ergonomic Analysis module benchmarking to allow the vehicle to be compared against the model being developed by the user. A SQL database of the properties of different materials should also be developed. This database will include such information as Poisson's ratio, modulus of elasticity, density, strength coefficient, strain hardening exponent, and any other required material parameters. This can then be connected to the Mechanical Analysis module to enable the user to find materials best suited for his design taking design and cost trade offs into consideration.

4.0 References

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