FrameWork for Advanced Design Vehicle Process Development

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ABSTRACT

The goal of this project is to reduce development time of such a complex product as a car design by using an iterative model that can perform many key analyses mainly related with homologation, occupant, mechanical packaging and ergonomic considerations. All these activities will be modeled and optimized with UML. This proposal describes a project for the development of a set of tools that automates many of the tasks associated with the feasibility process of an automobile in a CAD (Computer Aided Design) or CAS (Computer Aided Style) systems. This software tool will provide assistance to certify the vehicle for compliance with all governmental regulations and standards. It allows the users to access the ergonomic performance of the vehicle. All these tools will be written in the style of macro SCRIPT (Visual basic or c++), wizards and buttons will be created as well as the instructions to complete these, often very complex, tasks. Parameterization of the output geometry allows easily the update of the different vehicle parts. The developed software will be fully used in a parameterized CAD\CAS environment.

KEY WORDS

UML, Modeling, Vehicle Design, CAD and Neural Networks.

1. Introduction

Designing a vehicle is a complex task as it requires close coordination and inputs from a number of disciplines in order to develop the different systems and sub-systems in the vehicle. Further more, the numerous systems in a vehicle must fit within the confined vehicle space, function and provide the customers an acceptable combination of all relevant elements of the vehicle. The objective of this research is to model the process business using UML (Unified Modeling Language) [1] and develop a design tool that can be used in early stages of the design of a new product. UML will play two major rules: (1) describing process business activity; (2) MDA (Model Driven Approach) [2] oriented for the automatic software development. The model is intended to substantially reduce time (from several weeks to a few hours) required to evaluate alternate design concepts and themes generated by designers (styling) and design engineers. Thus, the research focuses on development of a conceptual framework and a software development to perform design and analyse tasks in the following areas: (1) Plan of vehicle's roominess (study of Occupant and Mechanical Packaging, Ergonomics, Human Factor); (2) Packaging definition containing technical, ergonomic and legal bonds; (3) Check of the model parameters and the possibility to compare it with competitors' vehicles by using an Excel program and benchmarking & teardown databases integrations on CAD; (4) Comparison with competitors' vehicles by using CAD maths and by loading several vehicles profiles from existing databases, like "Autograph". The first requirement in automobile design is to make sure occupants are placed safely and comfortably. This process of "Ergonomic vehicle packaging" consists of several competing activities. In the preliminary stage, most attention is focused on the manikin in its seated position. A basic package is achieved by establishing front and rear seat geometry, front and rear seat entry and egress as well as seat environment (visibility, reach). The automotive occupant packaging process relies on a "human factors" database that defines spatial locations for the driver's eye and head, hand reach, preferred seat positions and other related dimensions. Many of the studies involved hundreds of human subjects and have resulted in standardized drafting templates and CAD procedures that are used to develop seating packages for combined populations of male and female vehicle users. The necessity for speed in the preparation of these renderings prohibits a full package study (all components). Even with the help of a CAD system, producing a full package requires days and even weeks of intensive work and has to be repeated many times during the development of a vehicle. At each stage of this process, each component must be carefully checked. If a given component provoques necessitates changes in the vehicle interior dimensions, all other components have to be checked. A typical component study consists of 10 to 20 variables and about 10 relationships. Certain variables are common to all studies, creating complex dependencies among activities. Each change to a basic dimension needs to be propagated to all the other components. The traditional CAD approach does not support iteration very well. When a change to a package occurs late in the process, the costs of repackaging are very high considering that each individual study has to be verified. In practice, such an alternative is not even considered. Shortcuts are often taken in order to expedite the process. The need to improve this process is the key for producing vehicle packages quickly and accurately. Any improvement in this process has to provide a way of capturing each activity's goals, variables and relationships in an active way. The model, developed as software integration (Visual Basic or C++) on a parametric CAD system, has the potential to be an interactive, multi-user, multi-disciplinary and comprehensive tool that can be used by any major automotive OEM and suppliers, as well as by various universities as an instructional and teaching aid, for vehicle design. The model requires key input parameters to define the kind of a new vehicle to be designed - in terms of details such as its intended driver/user population, vehicle type and some key exterior and interior dimensions related to its size and proportions. The model computes and graphically displays interior package, ergonomic zones for driver controls and displays, and fields of view through the windows openings. It also allows importing or inputting and superimposing and manipulating exterior surfaces created by a designer to access compatibility between the interior occupant package and the vehicle exterior. The model users will also 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, selecting different materials for body structural components). The interactive nature of the model will allow continual dialogs between various design and engineering disciplines as the design team members iterate the model and make changes to perform various trade-off and feasibility related decisions.

This paper deals with the nature of the problem, previous works, purposes, and new contributions.

2. State of art

2.1 New vehicle design process

The Automotive industry is changing drastically. Many companies are re-organizing, reengineering, downsizing, and above all changing their approach to vehicles engineering. The reasons for these changes are numerous; increased competition, new market/legal requirements, greater customer focus, vastly improved information technology, outdated business practices, etc. To be successful in the coming century the company must challenge and beat the intensifying competition; understand, exceed and drive the new markets; surpass heightened customer expectations; install and fully utilize the most advanced information technology; replace the old business practices by new aggressive global strategies; and, finally, do all this profitably. Automotive companies are focusing on the processes of delivering a new or updated high quality vehicle to the market faster and cheaper. The creation of a new vehicle is a complex task, which deals with product assumptions, sketches, CAD drawings, mock-ups, virtual reality simulations. On top of this, a number of engineering analyses must be performed to check if a newly created design would work under various intended vehicle usage situations, and thus satisfy its customers. The sketches, the mock-ups and virtual reality are also shown to selected groups of prospective customers in market research centers to determine customer reactions and acceptance to the product concept. During the early stages of development of a new vehicle, its design team (generally consisting of individuals from disciplines such as marketing, product planning, target setting, styling, design engineering and manufacturing) or develops alternative vehicle concepts that will be attractive to targeted customers and feasible from the engineering and manufacturing viewpoints. Currently the design of a new vehicle in most automotive design organizations begins with the designers creating a sketch/drawing/ rendering or a virtual reality representation. At the same time, the engineers develop the basic vehicle drawing showing key elements of the exterior and interior package dimensions and preliminary locations of major modules and components (e.g. powertrain, wheels, fuel tank, steering column, seats, occupants, climate control unit, etc). As the exterior design and the vehicle package drawings are developed, key engineering activities (such as aerodynamics, vehicle dynamics, body structures analysis, crash and safety analyses, manufacturing capabilities, etc.) perform approximate feasibility analyses with low to medium levels of confidence (e.g. 40-60% confidence that such a design can be achieved using the available technologies and production capabilities). Assuming availability of technical manpower and technical sophistication of various engineering organizations, these crude analyses generally take about 3-6 weeks or more time to be completed and determine if the design is technically feasible. Insipite of all these issues and needs, we still have the traditional development process with good niche software but not fully integrated in an unique environment interfaced to a main CAD system. Existing Automotive feasibility software packages (mechanical, ergonomics, regulations, benchmark databases…) are not defined in an unique environment adapts to be manipulated in a multidisciplinary form.

2.2 UML

UML has emerged as the software industry’s dominant language and is already an Object Management Group (OMG) standard. It represents a collection of best engineering practices that have been proved successful in the modeling of large and complex systems. OMG is proposing the UML specification for international standardization for information technology [1]. Wide recognition and acceptance, which typically enlarges the market for products based on it, will be the major benefits. Therefore specific subjects (e.g. vehicle design process) require making UML models more specific and thus more precise. This can be done by using stereotypes (since they are an extension mechanism inherent in second version of UML) as a means of adding necessary information to existing model elements. Stereotypes have been given a special attention together with the idea of the Model Driven Architecture (MDA, [2]) and generative programming approaches, which are gaining popularity. UML is proposed to be used in two senses: (1) business process modeling; and (2) software process modeling. Modeling the design process of one vehicle development specializes on describing how activities interact and relate with other design processes’ activities while supporting the operation of the business. Can also be used for multiple purposes, such as general overview of complete activities and processes, facilitating human understanding and communication (lots of external actors participate on these tasks: dealers, insurance companies, country regulation, etc), supporting process improvement and re-engineering through business process analysis and simulation [3, 4], automating the execution of business processes [5,6] and facilitating coordinated business and system development by keeping the alignment between processes and their support systems [7].Also the UML is used to detail high level software specifications that will be interpolated for XMI and XIS (XML Information Systems) as interchange formats based on XML(eXtensible Markup Language).

3. Methodology Proposed

We intent to describe the advanced design of new vehicle by using a UML language derivate (VDML-Vehicle Design Modeling Language) [8] . Standard design has already been modulated at [9]. Now we intent to improve the business process activity by using VDML (permits high level vision) and creating a parametric unified software tool that integrates in a single environment, several programs in a early phase of Advanced design Vehicle Process. The main activities already described at [9] are illustrated in Figure 1.

Additional to the usual activities we propose a general feasibility plan study that will include the following activities: **(1)** 2D Manikin function creates a 2D (side view) manikin that you can use to check posture. The size and posture are dependent on the selected manikin population percentile and manikin type (that is, driver or passenger). You can use the 2D manikin for an occupant packaging study early in the vehicle development process (according to SAE J833 (SAE - Society of Automotive Engineers)). A 3D manikin in a further phase of work will be developed. Activity is illustrated on Figure 2; **(2)** Eyellipse allows certifying automotive vehicles as compliant with various government and regulatory standards. You can create an eyellipse feature that represents the location of the driver’s eyes as defined by a statistical sample of the population. You can also create features that represent head contours and EEC vision points. Eyellipse is a contraction of the words "eye" and "ellipse," and describes a statistically-derived elliptical model representing driver eye locations in road vehicles. There are several other vehicle design activities that require an eyellipse feature as input. These include Windshield Vision Zones, Direct Field of View, Instrument Panel Visibility, and Mirror Certification. The output of this activity is: 1-3D ellipsoids that represent the left, right, and mid-eye positions for a statistical sample of the population; 2-head contours, and 3-vision points. Activity is illustrated on Figure 3; **(3)** Mirror Certification macro will certify and analyze the performance of the inside and outside rear view mirrors; The Mirror Certification wizard lets you perform analyses on automotive driver and passenger side outside and inside rearview mirrors before certification, or to certify the performance of an existing mirror design. You can generate vision rays and lines describing the geometric field of vision of rearview mirrors. These vision rays and lines that comply with National Standards for inside and outside rearview mirrors for the several countries and regions. Activity is illustrated on Figure 4; **(4)** Windshield Vision Zones activity lets you verify the conformance of a windshield and wiper system design to established vehicle standards. You can generate test areas on a windshield based on SAE and ECE (European) standards. The program creates the actual windshield wiped area and calculates the percentile of the actual wiped area and checks it against the standard. It will be possible to generate the test areas and the wiped area on a windshield and calculate and validate the percentage of the wiped area based on either SAE standards or ECE regulations. Activity is illustrated on Figure 5; **(5)** Direct Field of View calculates the binocular vision regions of an individual driver. You can use this option early in the development process of a vehicle to calculate the ambinocular vision regions of an individual driver or a group of drivers. This lets you check if the vision angles are within an acceptable range. You can limit the vision region by either defining the eye/head rotation or by specifying an aperture. The regions are dependent on the eye points or an eyellipse (the eyellipse takes into account the vehicle type and the driver population percentile).Output is a Direct_Field_Of_View feature, which allows you to specify what display options you want for the field of view geometry. Activity is illustrated on Figure 6; **(6)** Driver Selected Seat Position Lines describe where certain percentages of drivers position their adjustable seats. You can use the seat lines as a design tool to estimate the location and length of seat travel for a target driver population. You can also use the lines as a check in predicting the level of accommodation provided by a given seat travel (SAE J1516 and J1517). Activity is illustrated on Figure 7; **(7)** Instrument Panel Visibility macro will calculate the visible and non-visible regions of homologation the instrument panel has obscured by the steering wheel and smart switches lever. This determines whether the vehicle design meets the recommendations of the SAE J1050 standard, which describes the minimum mandatory driver's view of the instrument panel. As output of these activity we have: output results as: 1-Instrument Panel Obscuring Curves; 2-Steering Wheel Vision Faces; 3-Smart Switch Vision Faces; 4-Smart Switch Obscuring Curves. Activity is illustrated on Figure 8; **(8)** Mechanic Package Development the program allows the user to allocate space for various interior systems and components such as Climate Control Unit Envelope (box), suspension, engine, etc. The user will be able to select pre-developed box and spaces for various components and place those at required locations in the vehicle space A complete list of mechanical parameters, their values selected and a parametric CAD definition is developed for the mechanical package design: this means allocation of functional space for all mechanical systems (e.g. powertrain, wheels, suspension, spare tire, battery, etc.).

The developed parameterized mechanical database will be used in the initial phases of the design of a new vehicle, for the first packaging and ergonomic evaluations. A parametric CAD database will be developed. Activity is illustrated on Figure 9; These activities performed during the early design phase can reduce development time and significantly reduce cost. We want to introduce these activities usually done by isolated processes at a late phase, in integrated parametric software applied in an early phase mainly assisting CAS and CAD activities. Since we describe this activities with a common language MDA oriented, it is possible to generate almost automatically the software through one approach. The abstract models development from Figure 2 to 10, will be detailed using VDML.in EA (Enterprise Architect). EA can convert models in XMI (T1 in Figure 11), from XMI we can generate an appropriate XML file (T2) and from appropriate templates created in an engineering inverse process we can generate code in different languages. All this modules can be integrated in one specific CAS or CAD platform. Details of this process can be found at [10]. With these functionalities we can change CAD and CAS activities and integrate in an unified way, several sub activities performed later by different actors in the usual software resources (e.g Catia, Alias, ICEM Surf,). Activity descriptions are on Figures 12 and 13.

4. Conclusion

Thanks to the described technology it is possible to redefine the basic design process in a parametric-associative way using a common language UML derivate. The most relevant results of this project are:

- Time reduction in the setting phase of the project;
- Ergonomic studies and vehicle setting phases are unified in one parametric product;
- Standardization of the vehicle process setting and establishing a common language and notation;

The main advantage of the tool is to unify and integrate in a single environment, integrated in a major CAD\CAS platform, the typical functionalities of several programs. Both the parameters relating to ergonomics and the ones concerning vehicle settings are linked together. It will be developed an "open parametric environment" that will be able to integrate all automotive knowledge packages when developed. This work will provide: (1) time reduction in product development, because homologation and safety relevant issues are taken in to account at a earlier phase of the project; (2) The system will provide a central data base of country homologation and safety issues, that could facilitate harmonization among different countries; (3) We propose a site with this information, which facilitates the access to it; (4) Cost reduction, because process is optimized; (5) Better knowledge of competitors. Also this work is part of a project that will join several experts from important design and manufacturing companies.

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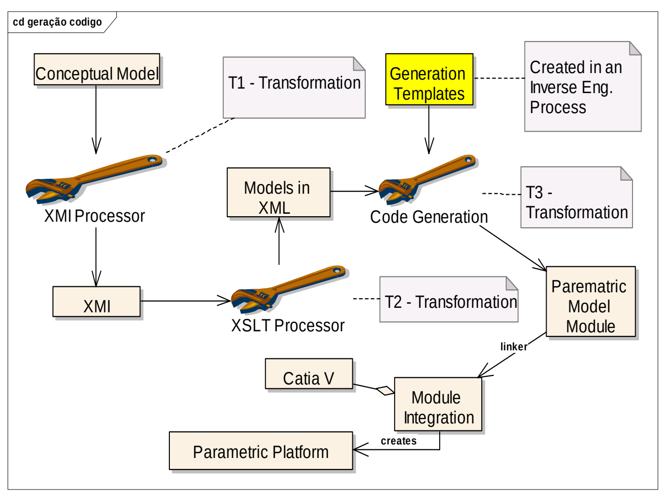

Figure 11: Code generation from models with appropriated templates.

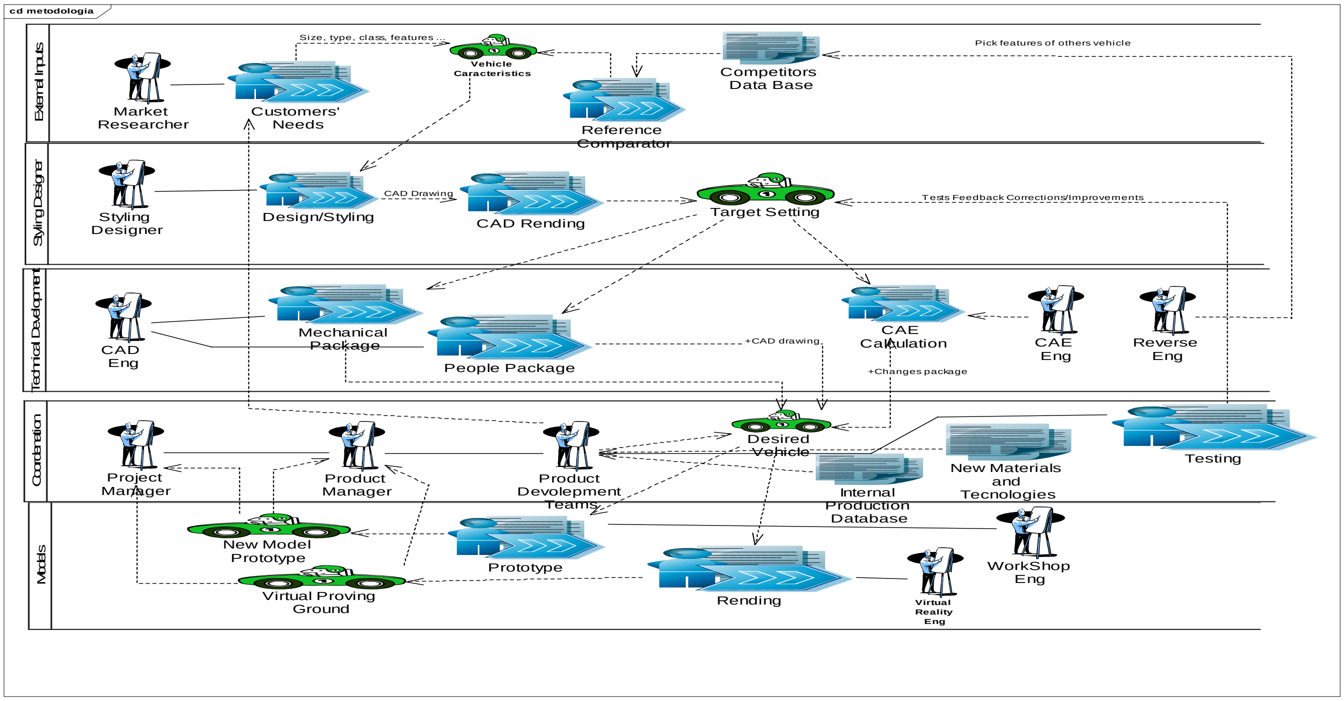

Figure 1: Activity view of Advanced Design Vehicle Program.

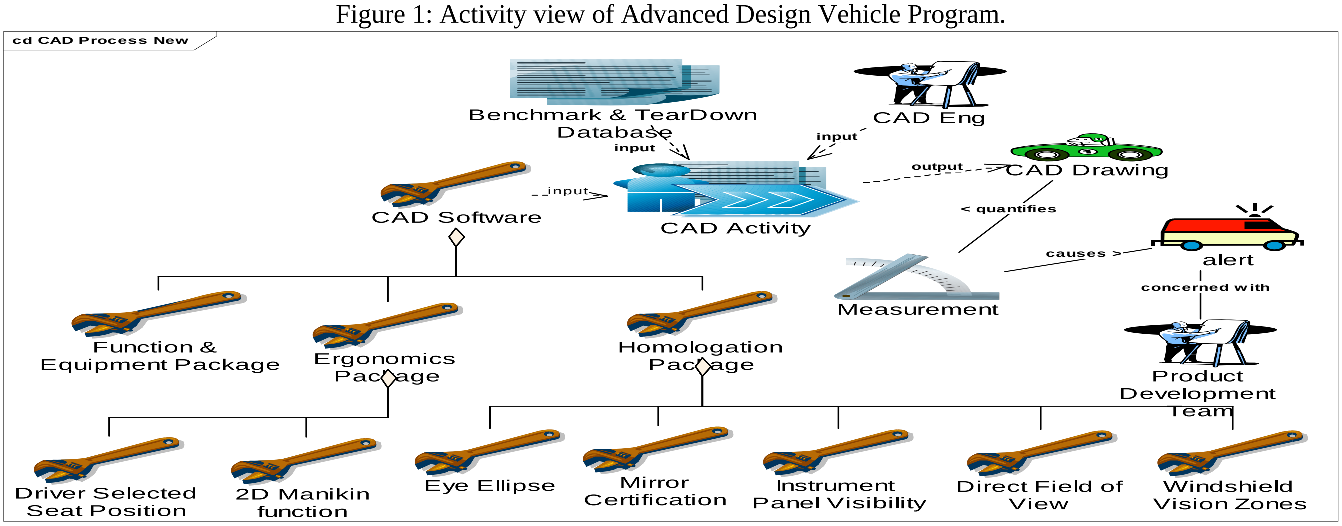

Figure 12: New CAD proposed activities.

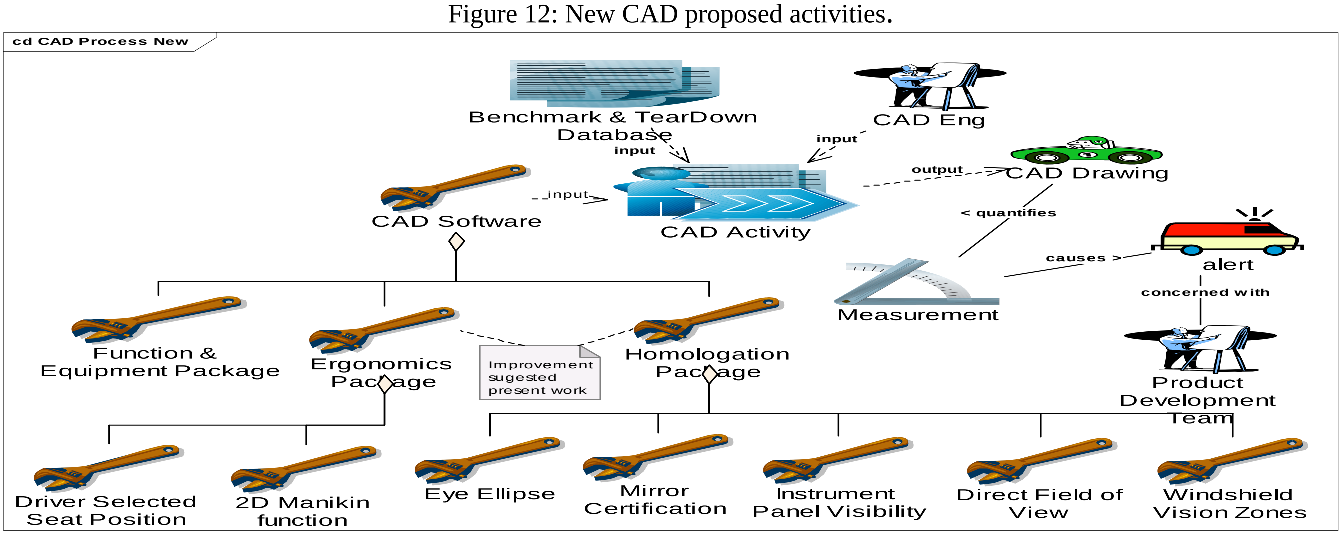

Figure 13: New styling proposed activities.

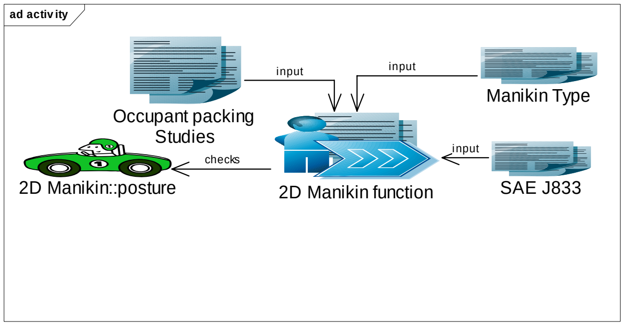

Figure 2: 2D manikin function.

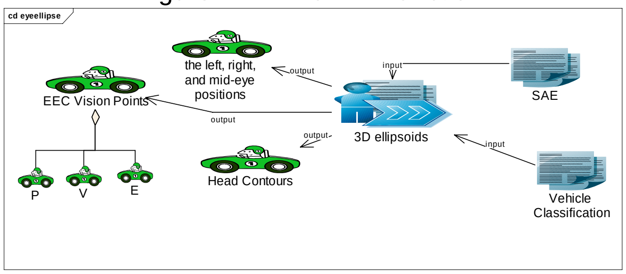

Figure 3: Eye Ellipse activity.

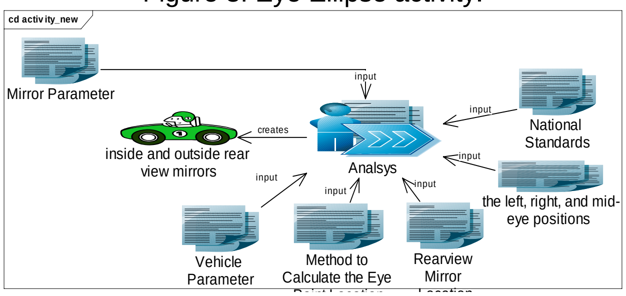

Figure 4: Mirror Certification activity.

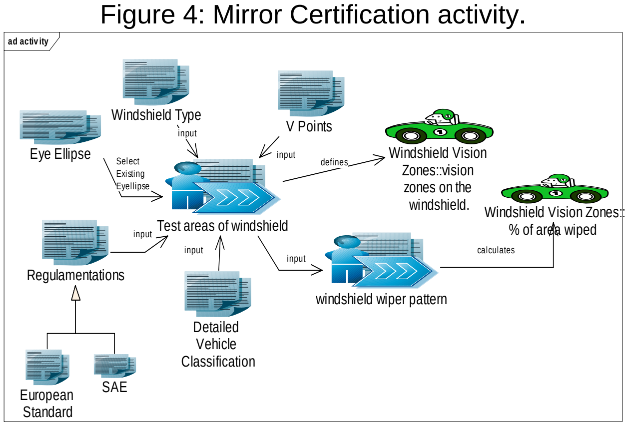

Figure 5: Windshield Vision Zones activity.

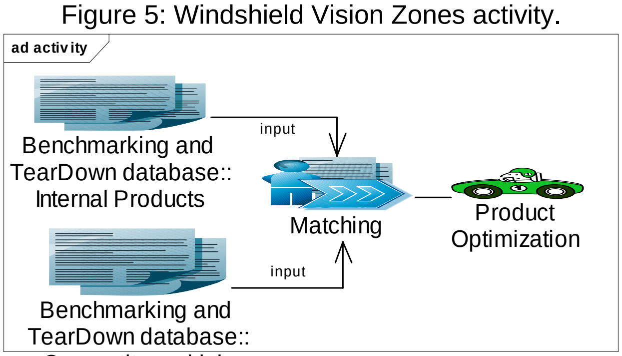

Figure 10: Teardown database for product optimization.

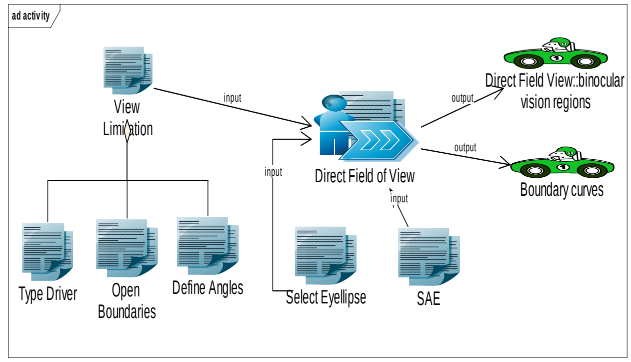

Figure 6: Direct Field of View activity.

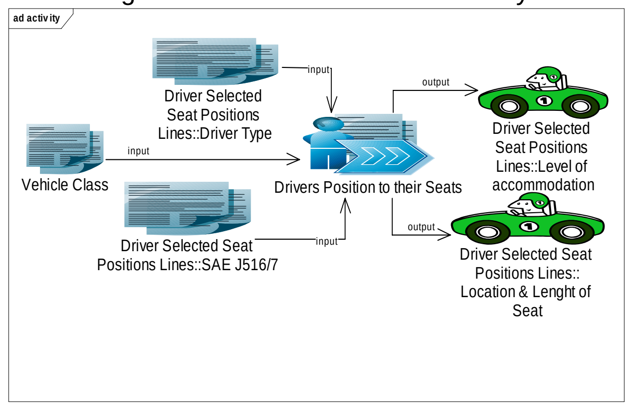

Figure 7: Driver Selected Seat Position activity.

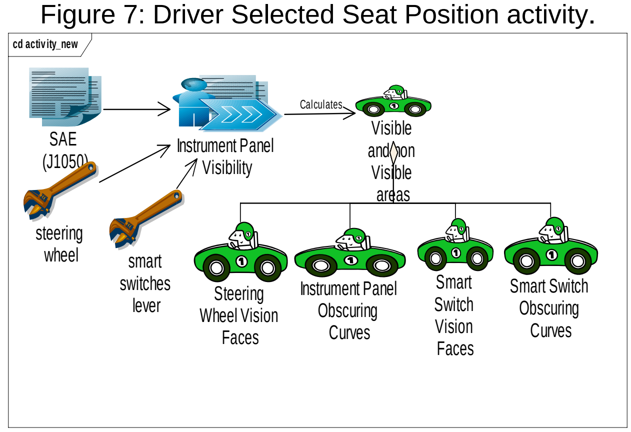

Figure 8: Instrument Panel Visibility activity.

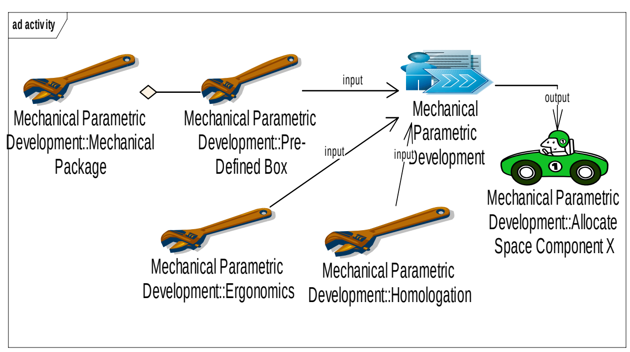

Figure 9: Mechanic Package Development activity.