Modeling and Optimizing Ergonomic Activities in Automobile Product Development

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Abstract

We collect ergonomic rules and normative rules considerations for automobile business and modeled these activities with a special UML language created for automobile business, VDML (Vehicle Development Modeling Language). From these high level process vision integrated in the product development activity a wide variety of improvements can be achieved related with time reduction, activity process quality as well as use of past experience. Also we intend to define ergonomic associated templates, which reflect standard ergonomic job routines to be incorporated in CAD application and improve the ergonomics process reference points and also the process optimization reached thorough UML high level vision. In these process we define also a ontology for ergonomics (EOL – Ergonomics Ontology Language) based on the OWL (Ontology Web Language) standards.

Keywords: Ontology, Knowledge Retrieval, Collaboration, CAD, Ergonomic, Modeling.

1. INTRODUCTION

The creation of a new product (e.g. new vehicle, new airplane, etc) is a complex task, characterized by uncertainty and variability. It requires the cooperation of experts in different fields and the analysis of the several aspects involved - both general and specific ones - such as brand positioning, target market, customer requirements, costs, style and performance attributes, specific company target cascades and naturally homologation rules [1, 2, 3]. Research has shown that upwards of 70% of a product's manufacturing cost is dictated by decisions made during the product design phase [4]. Starting from the Kick Off gateway where basic program viability is established by means of, the requirements for the new vehicle, the early stages of the design take care both of the styling and the performance. While stylists attend to the aesthetics through drawings or virtual sketches, engineers prepare the basic vehicle organization through specific digital models. The key elements of the exterior and interior package dimensions and preliminary locations of major modules and components are selected to verify ergonomics and homologation rules. Then virtual simulations are performed to check if the conceived design would work under various intended usage situations, thus satisfying customers and feasibility constraints. This implies interactions among the different actors and design loops until the basic checks are satisfied before starting the detailed product design. Moreover, not only one proposal but some alternatives are created whose feasibility aspects have to be evaluated.

High and strong competition in the automotive sector forces companies to minimize changes, which implies producing new vehicle models based on the previous ones without major changes in order to reduce costs. Both styling and analyzing strongly rely on past experience: it often happens that a collection of past solutions, possibly coming from different projects is put together with newly conceived parts to have a first version of the new vehicle on which they refine the specifications to be considered in the detailed design. To speed up the evaluation process at this stage different kinds of data and digital representations (such as surfaces, simplified components volumes, 2D sections, and ergonomic rules) are simultaneously used.

This pre-design activity generally requires 3-6 weeks or even more due to the time required to retrieve and adapt existing data to the needs of the different software tools which are used independently. In fact, existing automotive feasibility analysis packages (mechanical, ergonomics, regulations, benchmark databases, and so on) are usually not defined in a unique environment and not fully integrated into CAD systems. In addition, the retrieval of the past experience currently relies on how the company product data are organised, while there is a lack of tools able to capture the knowledge which is implicitly embedded in past project data. Information preservation and retrieval would avoid the high costs of loop back in company.

2. UML AND ONTOLOGY LANGUAGES

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 [5]. 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, [6]) 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 [7,8], automating the execution of business processes [9,10] and facilitating coordinated business and system development by keeping the alignment between processes and their support systems [11]. 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 (e**X**tensible **M**arkup **L**anguage).

Ontology is a data model that represents a set of concepts within a domain (in this case, ergonomics rules and concepts in new product development) and the relationships between those concepts [12]. Semantic web architecture is a functional, non-fixed architecture [13]. Barnes-Lee defined three distinct levels that incrementally introduced expressive primitives: metadata layer, schema layer and logical layer [14]. XML and XML schema define syntax, but mean nothing about the data that it describes. That means that some standards must be built on top of XML that will describe semantics of data. This conduct to RDF and a general model in metadata layer RDF schema, which provides mechanisms for defining the relationships between properties declared and others resources. To enable services for the semantic web we have on top the logical layer. This layer introduces ontology languages, that are based on meta-modeling architecture defined in lower layer. This enables the use of tools with generic reasoning support, independent of the specific problem domain. Examples of these languages are OIL (Ontology Inference Layer), DAML (DARPA Agent Markup Language), OWL and VCO. OWL is a semantic markup language for publishing and sharing ontology's in the web. OWL is developed as a vocabulary extension of RDF and is derived from DAML and OIL [15].

We intend to explore domain ontology with a domain UML profile to establish: (1) common notation and standards; (2) improve and reduce time of development process; (3) integrate automatic or semi-automatic new ergonomics considerations in CAD programs. We are proposing applying known techniques and approaches of software engineer in the new product design and try to integrate ergonomics and normative rules usually performed manual in a late phase of design, automatic or semi-automatic in the CAD working environment in an initial phase.

3. VDML AND EOL

VDML - UML Profile for new Vehicle Design (VDML): The aim of this new profile created specifically for new vehicle process development is to capture the specific concepts involved in this activity process and provide an appropriate notation. Based on UML we will propose a meta-model for automobile industry, based on a specific stereotype, illustrated in Figure 1. New vehicle design main stereotypes are: (1) «Activities», which are performed by actors and operated over resources and information; (2) «Actors», that are someone (a human actor) or something (an automated actor, such as an information system or a production machine) that can perform the actions required by an activity; Actors belong to organization units (departments) (3) «Resource» is the input and output of an activity representing things such as materials, information system operated by human actors; (4) «Information» is also input/output of activity; (5) «Goal» represents a measurable state that the organization intends to achieve; (6) «Measure» and; (7) «Alert». For a detailed description see [1]. There is a big diversity of applications and data bases. These databases are often created from the point of view of a particular application and not from a broader company-wide point of view, which makes difficult the reuse across different applications. Owing to those difficulties, developers tend to create new data sources that have some semantic overlap with existing sources. For a particular application this might be an efficient solution – from a company-wide perspective, however, it is the worst solution.

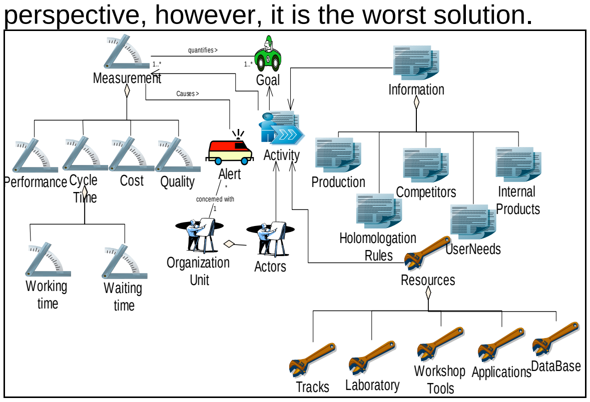

Figure 1: VDML Profile.

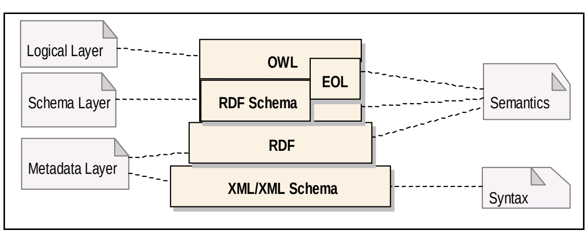

Figure 2: OWL and EOL in the semantic Web Architecture.

EOL (Ergonomics Ontology Language): Our aim in the EOL is to create a knowledge space by combining existing ergonomics data sources and is based on OWL standards, Figure 2. We applied Semantic Information Integration to solve the problem of integrating heterogeneous ergonomics approach in CAD parametric applications. EOL has created information architecture to support locating and accessing ergonomics information available. In order to realize this approach we had to integrate the heterogeneous data sources and present the user a unified view of the disparate data schemas for browsing and querying. The meaning of the data is captured in a central ontology and the data in the sources is given meaning by creating mappings between the sources and the ontology Figure 3, illustrates the mapping operations through three operations: (1) transformation the ontology in XMI. In our case we use Enterprise Architecture (EA); (2) format change to XSL, EOL oriented; (3) transformation is performed based on predefined templates based on EOL and VDML language. All these sources had to be integrated in the information architecture. A small example how EOL is organized and build is described on Figure 4, with a division of major ergonomics studies in occupant based or components based. Under this level we define major ergonomics process checks and their components on a pre-defined structure. More information about this process can be found at [16], where we explore vehicle corporate domain ontology (VCO) and EOL can be derivate.

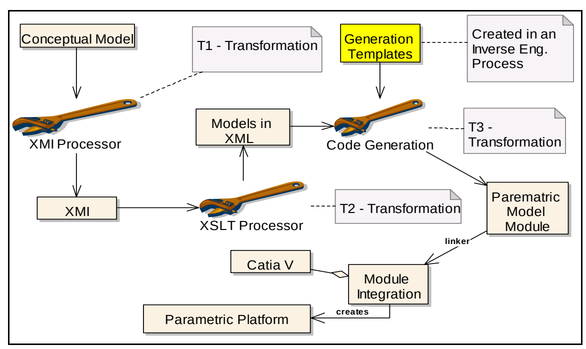

Figure 3: Code generation from models with appropriated templates.

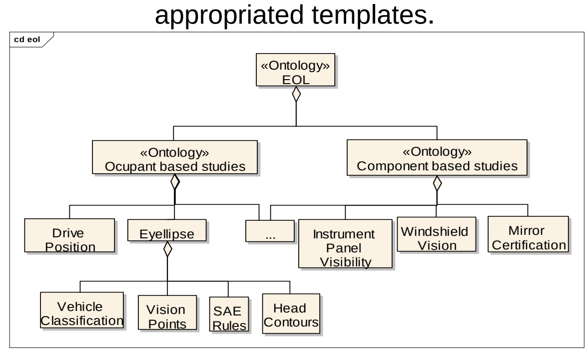

Figure 4: Example of EOL ontology class and attributes.

4. MODELING ERGONOMICS PROCESS

We already describe the advanced design of new vehicle by using a UML language derivate (VDML-Vehicle Design Modeling Language) [17]. 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 [18] and we propose a general feasibility plan study that will include the following ergonomics and normative activities, usually performed in a late stage of new product development. Based on VDML, new product development activities are described and improved. For a detailed analysis of these activities see [17, 18]. In this paper we will concentrate on ergonomics modeling activities and integrate then automatic in CAD activity:

2D Manikin function, illustrated on Figure 5, 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;

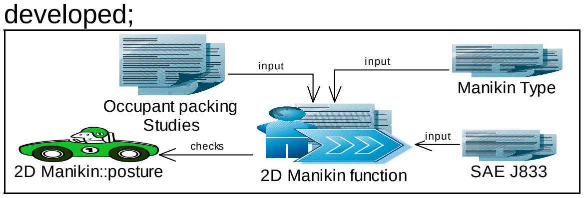

Figure 5: 2D manikin function.

Eyellipse, described on Figure 6, 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;

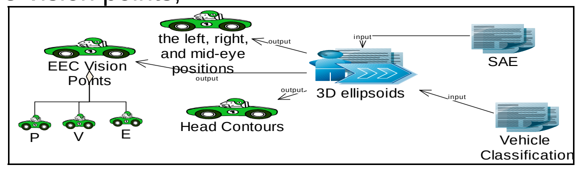

Figure 6: Eye Ellipse activity.

Mirror Certification, illustrated on Figure 7, macro will certify and analyze the performance of the inside and outside rearview mirrors; The Mirror Certification wizard lets you perform analysis, 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 comply with National Standards for inside and outside rearview mirrors for the several countries and regions;

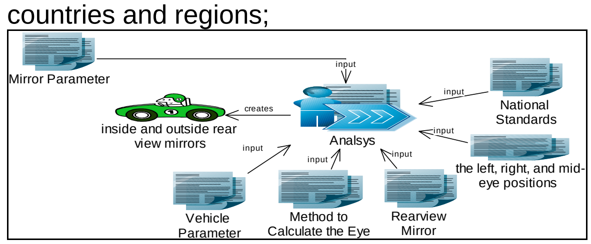

Figure 7: Mirror Certification activity.

Windshield Vision Zones, described on Figure 8, 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 then calculate and validate the percentage of the wiped area based on either SAE standards or ECE regulations;

Direct Field of View, illustrated on Figure 9, 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;

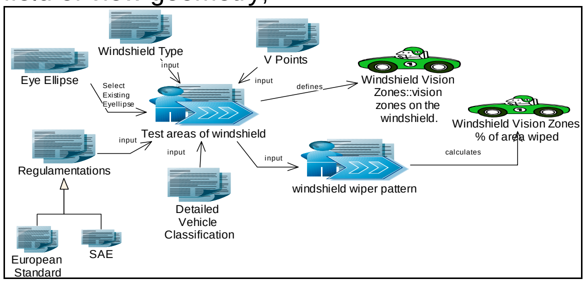

Figure 8: Windshield Vision Zones activity.

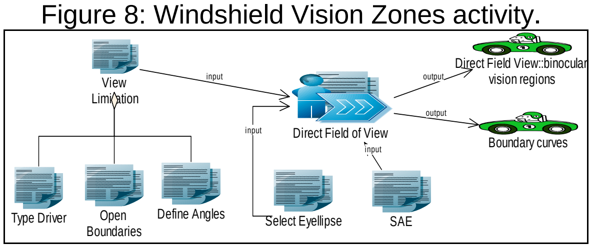

Figure 9: Direct Field of View activity.

Driver Selected Seat Position Lines, illustrated on Figure 10, 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);

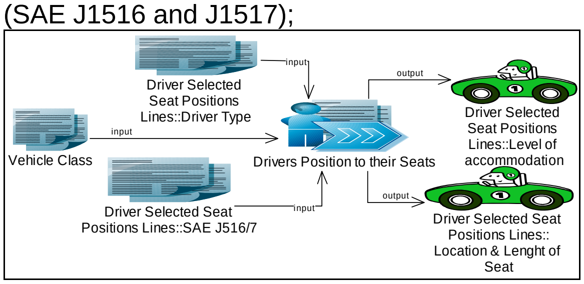

Figure 10: Driver Selected Seat Position activity.

Instrument Panel Visibility illustrated on Figure 11, 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 this activity we have output results as: 1-Instrument Panel Obscuring Curve; 2-Steering Wheel Vision Faces; 3-Smart Switch Vision Faces; 4-Smart Switch Obscuring Curves;

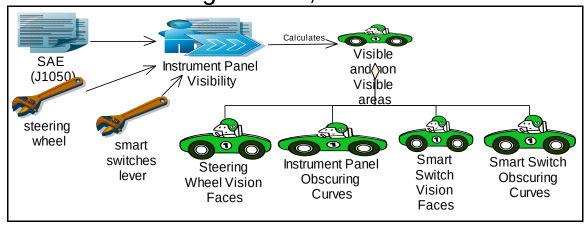

Figure 11: Instrument Panel Visibility activity.

5. CAD ENGINEER ACTIVITY

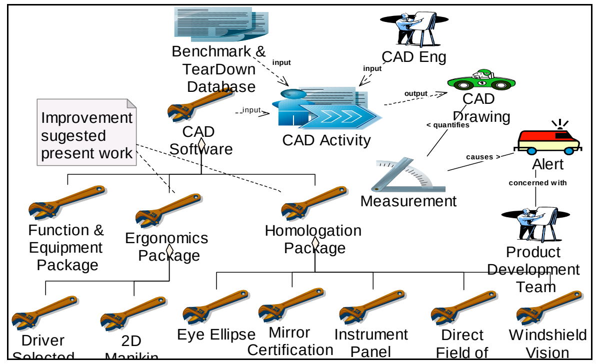

Figure 12: New CAD activity proposed.

CAD Engineer Activity, illustrated in Figure 12, defines the design of the vehicle paying special attention to ergonomic, functional and homologation requirements. Demonstrates the ability to interpret and develop a model from a 2D picture or instructions, such as design. As inputs this main activity has: (1) Guidelines: that is a specification list of the main characteristics given by Product Evaluation activity; (2) Benchmark & Teardown Database: database that contains information about benchmark products, which can be used as models; (3) Other Activities: This input makes part of the iteration development process and it may appear several times, as entry. Represents information given by other activities like the CAE activity, about reinforcements to approach and perform security rules in order to achieve a better protection to the passengers; (4) CAS Eng Activity: gives a general overview of final product shape and guidelines. The CAD activity is assisted by CAD software (e.g. Catia, Unigraphics, etc) as shown in [5], ergonomics and homologation issues are automatically embedded in this software. The goal of this activity is the car drawing part; (5) Measurement: this process will check CAD activity output based on pre-defined targets such as time spent by the activity, gaps on surface, failed compliances, general integration, ergonomics and homologation issues, center of gravity, weight and stability. Failures on these measurements can generate two types of alarms: (1) minor, small impact issues highlighted to Product Development Team and CAD Eng; (2) major, critical issues that can put the project in risk, highlighted to Product Development Teams and Product Manager.

6. CONCLUSIONS

The described approach has the bid advantage of being dynamical, and the new ergonomic process described in VDML (e.g. UML) can be easily and almost automatically integrated in a CAD parametric design tool. The ergonomic process should be improved through high level analysis using VDML and EOL allows data integration from different schemas ergonomics database.From models, program scripts (Visual Basic or C++) will be developed and integrated in parametric CAD design tools using appropriate API. These scripts are functions of the specific CAD application, but transformation scripts from one CAD parametric system to another can be developed. This approach 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, 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.

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