VIRTUAL REALITY APPLICATION IN DESIGN, PROTOTYPEAND TEST DRIVE PROCESSES IN AUTOMOTIVE INDUSTRY

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ABSTRACT

Currently, most researchers find out that Virtual Reality (VR)systemsare now a highly implemented inautomotiveindustry especially in design and development process. The automotive industry was amongst applied this technology since VR was developed. In the real manufacturing practice, they need to cater the demand in shortening the production time. Therefore, the VR systems becomea crucial stage in car manufacturing. The use of VR technologies allows a large amount of variants can be shown, modified and assessed at a very early phase of the process hence cost and time saving. This paper reviews current applications of Virtual Reality for Design, Prototype and Test drive in automotive industry.

Keywords:Automotive, Design, Prototype, Test drive, Virtual Reality.

I. INTRODUCTION

Currently, the increase demand in automotive industry is accompanied with growing complexity within product development, manufacturing, supply chain and logistics processes that are the lifeblood of the modern automotive company [6]. The automotive industry has become one of the world largest economic contributors and therefore it is important for car makers to sustain good momentum in supplying demand for the customers with the help of technology advancement. Gusikhin et al. [5] have stated that since the introduction of moving assembly line, the automotive industry has become one of the big leaders of developing new advanced technologies.

To stress the importance of the technology in automotive industry, in 2006, National Automotive Policy (NAP) was introduced by the Malaysian government to transform the domestic automotive industry and integrating NAP into the highly competitive global industry network and in 2009 NAP was reviewed with one of the objective is fostering the development of the latest, more sophisticated technology in the domestic automotive industry [7]. This is to encourage Malaysian automotive industry to compete with international car makers in producing top notch product in the shortest time possible. Therefore the adopting of VR systems in this automotive industry is very effective to meet the objective itself.

The technology of Virtual Reality (VR) systems is seen as a powerful tool in developing and implementing more natural and intuitive interface, minimize the use of expensive physical mock-ups, allows users to predict and prevent problems early in the product-development process, to meet critical time-to-market objectives and enabling vehicle design department to maximize their profit margins. Also by adopting VR with fully human

interaction in the real time could help generate saving through enabling better project coordination, quicker testing, engineering change reduction and process optimization in the stage of conceptual design of the product.

Virtual Reality (VR) is commonly known as "reality simulated by the computer" or as an "artificial world". There are a few definitions of VR as reviewed in literatures as follows. For instance H. Fuchs, G. Bishop et al define VR as Real-time interactive graphics with three-dimensional models, combined with a display technology that gives the user the immersion in the model world and direct manipulation [1]. M. Gigante defines VR as the illusion of participation in a synthetic environment rather than external observation of such an environment. VR is obtained at no additional time expense because everything needed to perform motion simulation has been defined in CAD assembly model [17].

VR relies on a three-dimensional, stereoscopic head-tracker displays, hand/body tracking and binaural sound [2]. In a study conducted by Mujber et al., [3] VR is categorized in three types; (i) Non-immersive VR, (ii) Semi-immersive VR, (iii) Fully-immersive VR.VR can be traced back starting in 1860s with 360° art "Baldarsare Pesuizzi" to the revolution of "Oculus Rift HMD" in 2012.The vast change in VR technology has been applied in various fields such as medicine, architecture, games and also automotive industry.

Presently hardware technologies such as Head Mounted Display (HMD), Binocular Omni Orientation Monitor (BOOM), Cave Automatic Virtual Environment (CAVE), Data glove, Control devices and software technologies such as Multiverse, Virtual Reality Studio, Sense8 World Tool Kit and Autodesk Cyberspace Development Kit are widely used with VR systems [4].VP is a natural development of VR and CAD systems. The competitive nature of the industry dictates a rapid prototyping turnaround and traditional physical prototyping methods are no longer fast enough thus the use of VR in design and prototyping process.

II. APPLICATION OF VR IN AUTOMOTIVE INDUSTRY

VR is essential to the automotive industries as now designers and engineers works on one and same digital model, fully utilizing the model rather than building several prototypes. The elevation of VR since the last decade not only provide an environment for virtual visualization but also hold great potential in solving problems before being manufactured [5].Since the introduction of moving assembly line, the automotive industry has become one of the big leaders of developing new advanced technology [8].

VR mostly appliedin the fields of design, collaborative design and engineering, ergonomics or human factor, maintenance analysis, training and education, styling, simulation, digital prototyping, marketing and sales in the automotive world. It represents a user interface technology that enables the interaction of the engineer with the virtual models of the car, thanks also to the immersion feature. VR allows, in fact, intuitive analysis and simple presentation of complex three-dimensional systems.

In real practice, car manufacturers even established VR Center, so that designer can chooses the car style model, development team can executes design reviews, analyses alternative solutions and deliberates product and process validation all in one place. In 2007, PROTON, Malaysia'snational car maker established its own Virtual Reality Center to fully use VR technologies in their research and development process as shown in Figure 1[9]. Furthermore with immersive virtual environment, ergonomist can study the "man-car-environment" interaction and evaluate the comfort of a new car [10].

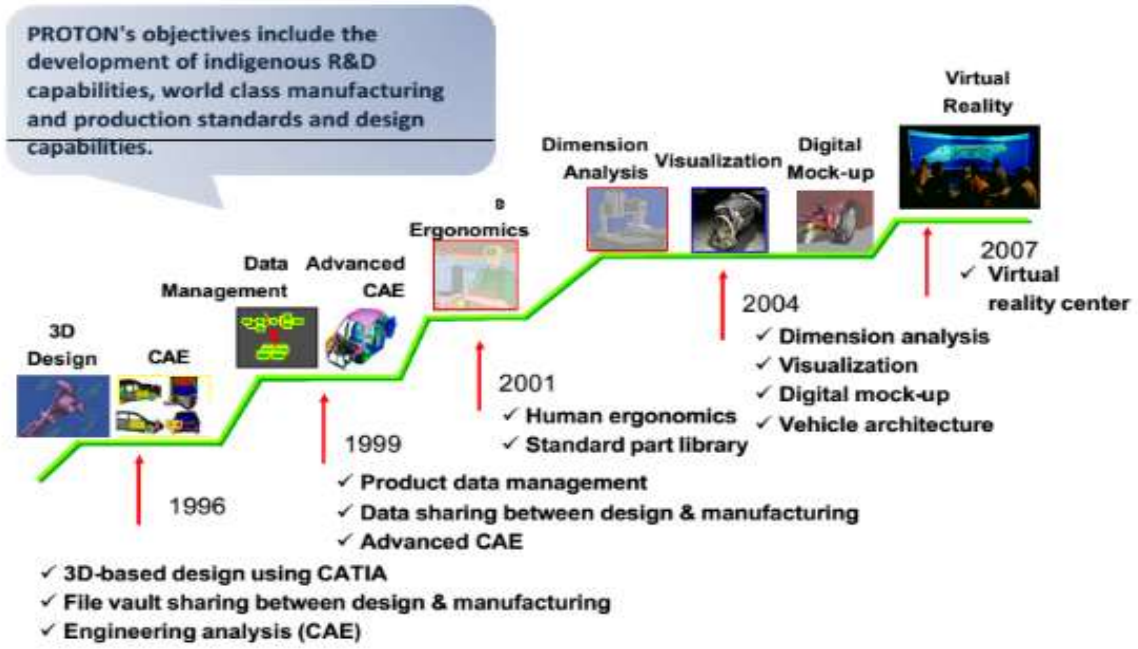

Fig.1: PROTON Vehicle Engineering Milestone

III.VIRTUAL DESIGN

The very first data set representing a new design concept can be shown in VR offering foundation for virtual tests. Even though it is possible to create VR model using VR package, the transfer of geometrical data between CAD and VR is desirable to avoid repetitive work[11].Computer Aided Design (CAD) is used to create a geometrical product representation within a virtual environment. In automotive development, the product is composed of three-dimensional models in so-called 3D CAD programs.

From previous study, the use of CAD programs such as Autodesk can be link into VR system such used by Ford Motor to examine the entire exterior and interior of a car design, as well as to focus on how certain elements looks such as dashboards and upholstery during the design stage. The engineers at Ford's immersive Virtual Evaluation Lab (iVE) collaborated with United Space Alliance's imaginary lab to evaluate early vehicle designs against backdrop of virtual conditions to help create a car that provides perfect environment for the customers. Details such as light positioning, size or brightness can be observed and improved by using CAD integrated with VR systems [12].

Analysis for Virtual design also can been done using Computer Aided Engineering (CAE). CAEincludes a wide range of product calculation, simulation, optimization and planning processes in several disciplineswhich are performed parallel to the geometry creation. Of course, throughout the virtual development cycle, design always goes hand in hand with computational engineering processes. In some literature, virtual development in general is denoted as CAx (computer aided technologies)[12]. However, even with the predictive capability of CAE tools, physical testing is still used as a final confirmation for subsystem since there is limitation for variables such as metal stretch and thinning cannot be predicted using CAE.

CAE based software's was developed by MSC.Software for PROTON to create reliable engineering environment that develops and test virtual prototypes, VP of component and subsystems, saving time and resources compared to conventional build and test process. Siemens PLM Software introduces NX CAE for automotive companies to create better designs by leveraging design data directly through integrated modeling

and meshing tools, analysis data can be obtain earlier in the design stage, integrate multiple solutions in a single environment. The data then can be used as input data in VR Tools to further improve the design without having unnecessary data to be analyzed twice.

Modern VR studio or commonly called as Cave Automated Virtual Environment (CAVE) is also widely used throughout design stage. The CAVE is a room where stereo computer images are projected on three walls and the floor. Multiple users can be in the CAVE at the same time, however, only one person controls the view with the position tracker. The users wear stereo shutter glasses that convert the images on the walls and floor into stereo images [13]. In the CAVE all perspectives are calculated from the point of view of the user. A head tracker provides information about the user's position. Offset images are calculated for each eye. To experience the stereo effect, the user wears active stereo glasses which alternately block the left and right eye.

This application enables user to move around a virtual environment in which the user is surrounded by up to six walls presenting pictures projected in real time [14]. French automotive manufacturer Renault has implemented a new CAVE, a 5 rear projected wall virtual reality room with a combined 3D resolution of 100Megapixels distributed over sixteen 4k projectors and two 2k projector as well as an additional 3D HD collaborative powerwall. Renault's CAVE™ aims at answering needs of the various vehicle conception steps [15]. Initially CAVE was used for interior ergonomic design, it has been broaden into other departments in Renault.

Fig.2: Renault Vr Cave

IV.VIRTUAL PROTOTYPING

Car development is a complex process but it's in sequence of decisions and fine tuning until it is produced. Beside, in production, decision making process is very crucial thus VR helps to take part in decision making procedure by providing virtual prototype, VP of new vehicles before the physical component are made [16]. Prototype development can affect the final stages, prices and the product itself. Physical prototype is not cost-saving as it takes longer time to finish therefore most automotive industry players uses Virtual Prototyping (VP) as a way to reduce prototype construction time without the physical prototype construction. Therefore, by using VP techniques also can be minimized therisk, which periodically confirmed that design was headed on right directions. VP is about presentation, testing and analysis of three-dimensional CAD models prior to creating any physical prototypes. The technology for using virtual prototypes was pioneered and adopted initially by large automotive and aerospace industries [19].

A lot of capabilities of using VP, for example Zorriassatine [19]identified that VP can be used for several process such as checking and analyzing parts in visualization, examine part for considering fit and interference of mechanical assemblies, testing and verification of functions and performance, evaluation of manufacturing and assembly operation, and capable of human factor analysis. Besides, it's capable to perform motion

simulation. The VP technique using motion simulation also checks for interferences, and this is a very different process from interference checking available with CAD assembly animation. Motion simulation conducts interference checks in real time, and provides the exact spatial and time positions of all mechanism components as well as the exact interfering volumes. This process not only solves analytical problems but also can be extended to generate the new parts in the assemblies using trajectories of motion into CAD geometry [20].

Different prototypes were prepared and verified to formulate the final car carrier design [18]. In VP basic models are transferred to motion simulation program. These processes not only avoid using physical prototyping techniques, but also validate products in all stages of designs. Thus in today's sustainable environment use of virtual prototyping is becoming popular with virtual enterprising designs in automotive industries [19]. Product marketability is increased with use of VP techniques allied with concurrent engineering. VP brings several advantages: reducethe time and cost of new product development; reducethe product cycles; reduce the number of expansivephysical prototypes and experiment with more designalternatives; automotive engineers can quickly exploring multiple design variations, testing and refining until optimizing suspension behavior, long before building the first physical prototype. Virtual prototyping platform includes CAD (ex.EUCLID, CATIA, PROENGINEER), MBS (example ADAMS, DYMES, SDS) and FEM (ex. NASTRAN,NISA, COSMOS) software as in Figure 3[21].

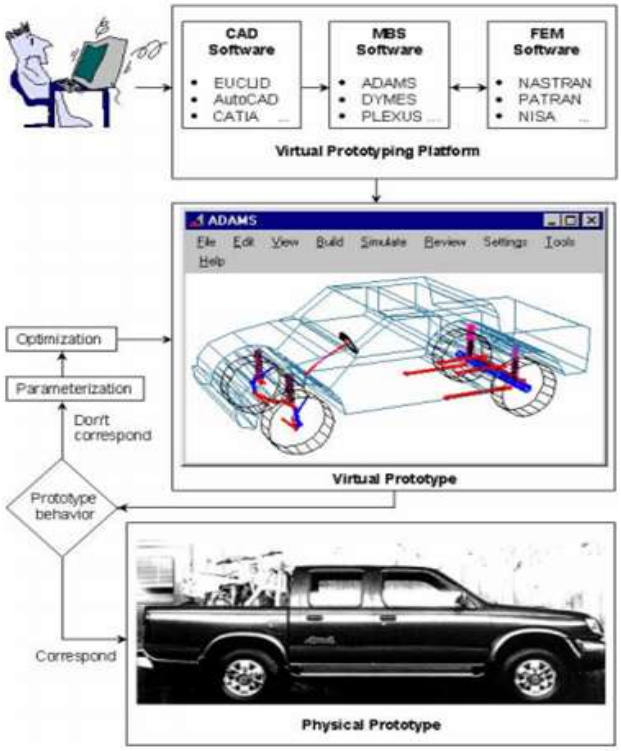

Fig.3:Virtual Prototyping Platform

In previous study, VPsystem provides tools for simulation and visualization to analyze and improve product design and its fabrication process. Hence the key factor such as product shape and manufacturability that can affect the product maturity and profitability can be optimized quickly [22]. CoMET-METeor applied VP for the solution of embedded software development environment develop by Synopsys,Inc for Mazda to conduct testing for ECU verification which is taking a longer time during design stage. This software helps Mazda to save time and cost by decreasing the number of tests on real vehicles and Hardware in the Loop (HIL) test equipment. It's designed to improve developer productivity with ease of integration, non-intrusive multicore

debugging and analysis, real-time execution speeds, and the ability to apply real-world user interfaces. This enables concurrent development of hardware and software, which shortens embedded system suppliers' hardware/software integration and test cycle time, resulting in accelerated time to market. For PROTON, Autodesk Digital Prototyping was used for sketching, illustration, image editing and integrated 3D environments that allow PROTON to reduce the use of expensive, physical models along with time consuming linear processes. Autodesk software enables Virtual Reality prototyping being combined to save time.Physical still are necessary at some downstream step (for example, car industry uses sculpture clay models for designers to check the physical form of a car). But, when applicable, the use of virtual prototypes provides many advantages. VP also plays an important part in analyzing the ergonomics features of an automobile. Zsolt et al [23] stated that by dynamic simulation it can verify kinematic assembly in real conditions of function and load, respectively design validation and making the testing process more efficient and also the study of car ergonomics can be determine.Car test crash are also able to be simulated using VR without having the physical prototype. At BWM, test crash is conducted using VP within 2-4 days in Virtual Environment. The computer simulate a head-on collision against a wall, operating day and night in the process and subdividingthe tenth of a second in actual the impact into increments each lasting just a thousandth of a second.This procedure saves a lot of time, since a "real" prototype car costs up to three-quarters of a million Euro. By comparison, a computer "crash" of the type described costs only about Euro 400, despite the long computer time required.

V.VIRTUAL TEST DRIVE

Another addition to VR is the use of Virtual Test Drive whereby potential car buyers doesn't need to go to showrooms to test drive a car. However there is lack of literature on this topic as this is fairly new in the automotive industry. VR Test drive system compromises a control means with an associated memory where the control means is being programmed with distant server computer. The server computer is control through a network particularly the Internet [24]. VR is adopted into Virtual Test Drive where it's designed to give users a sensation of being in certain surroundings, given adequate hardware. Potential buyers can compare car models of different brands without having to leave home. VR systems are coupled with the internet and also with headgear to complete the VR Test Drive. Virtual Test drive is more convenient for car retailers as they don't need to set up store with the physical car displayed, flagship store or digital store will replace the physical store. Dealerships are changing in format, size and concept emphasizing on going fully digital thus incorporating VR into the sales of the cars. Major market players in the automotive industries have begun to introduce Virtual Test Drive in order to get potential customers. In Nov 2014, Volvo introduces Volvo XC90 Virtual Test-Drive Uses Google Cardboard which combines a Volvo application with Google Cardboard [25]. Google Cardboard is developed by a group of VR enthusiast at Google that uses smartphone to create VR experience. By using a cardboard accompanied with open software toolkit makes VR software coding as easy as building a website.The VR Toolkit enables developers familiar with OpenGL to create VR applications.The toolkit simplifies VR development tasks, including head tracking, 3D calibration, side-by-side rendering,stereo geometry configuration and user input event handling [26]. Figure 4 shows the simple build-up of google cardboard than can create immersive experience for users. To name a few there are Nissan "Detour",Kia "Venga MPV Virtual Test Drive" and BMW "i3 Virtual Test Drive"

Fig.4: Google Cardboard Head Gear

In VR testdrive, another important data that need to be incorporated is Global Positioning System (GPS). Thomaidis et al [27] stated that by using VR, it is able to produce virtual trajectories of a vehicle along a given route and produce GPS log files in various protocols. The benefit that stems from this application is that many driving styles and road conditions can be applied while creating as many logs as the user wishes. The specific application was developed for stimulating and testing a navigation system extension that automatically detects deviations between car movement and digital map hence making the VR Test drive data more accurate.

VI. CONCLUSION

In conclusion, application of Virtual Reality is limitless inside the automotive industry. In design development stage, VR helps designers to simplify design processand identify parts problems earlier and reducing production cycle time. Computer aided design, CAD/CAE helps to integrated data into VR and enabling intuitive data to be analyze. Virtual Prototype has rapidly transform the automotive industry where it reduce the product cycles, reduce the number of expansive physical prototypes and can be use countless time within the process. Another new application for VR is VR Test Drive where potential customers can test drive without having to go to showrooms and provide better insight view of the car. It's more convenient and also helps to introduce VR to the public. It is certain that VR is very important part of the automotive industry that helps the industry fast growth to cater the market demand.

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