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FUTURE TRENDS IN CAD – BY THE PERSPECTIVE OF AUTOMOTIVE INDUSTRY

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ABSTRACT
Computer-aided design (CAD) is the key in car development. 3D-CAD models not only deliver geometry data, but also form a foundation for configuration of modules and systems, as well as for various simulation and verification steps. Product assemblies within CAD-platforms include structure-related information, are used for digital mock-up (DMU) investigations and provide lots of data for production and manufacturing engineering. Since initial CAD systems were implemented in automotive sector during the 1980s, design software has evolved continuously, such that present-day CAD software is capable of offering far-reaching potential for integrated product development. The current work contains an analysis and review of current and prospective technologies for the implementation in the future CAD applications and presents alternative implementation scenarios into vehicle development. Vehicle architects, design engineers, project managers, IT-administrators for CAD, stylists as well as styling engineers have participated in a survey at automotive manufacturer and supplier. The findings of this survey are introduced into this paper to talk about the future role of CAD in new car development and to establish requirements for the next generation of CAD softwar.
Keyword : future CAD, visualization technology, adaptable models, generic programming, development processes.

1. INTRODUCTION:

Up to the mid 1980s, vehicle development processes were dominated by strong hardware and prototype-oriented optimization cycles. Then, full-vehicle development lasted for approximately 6 years and consisted of three prototype stages. The integration of virtual, computer-aided techniques into vehicle development resulted in substantially amended processes. Around the middle of the 1980s, computer-based design and simulation techniques started dominating engineering activities that had previously been performed through hardware based development. At the end of the twentieth century, integrated
CAD/CAE activities facilitated network-based design in automotive engineering. Virtual prototypes were created, replacing at least one physical prototype creation. The use of virtual engineering in full-vehicle development promoted global collaboration by pooling together partners and markets in various countries and regions. Today, full-vehicle development projects take 4 years (in case of derivate development less than 3 years) and the trend is moving towards an additional decrease . Figure 1 shows a typical automotive full-vehicle development process. Aside from the core process phases, various disciplines are presented in comparison to the respective phases.

The diagram emphasizes the strong integration of CAD into car development: all car development disciplines connect either to CAD data or processes. Most of the styling, design and simulation activities are carried out in CAD or on the basis of CAD data (e.g. In the event of computer-aided engineering, CAE). Even domains without CAD work exhibit a certain CAD data involvement: for purposes of evaluation, prototyping and data exchange with the supplier. In the years to come, the proportion of thought work in the field of electronics and communication technology will grow exponentially. During the past decade, the significance of these mechatronics technologies has been raised from comfort-related features to integrated modules with a strong impact on drivetrain, vehicle safety and automated driving functionalities .he high complexity of electronics networks challenges established development processes.

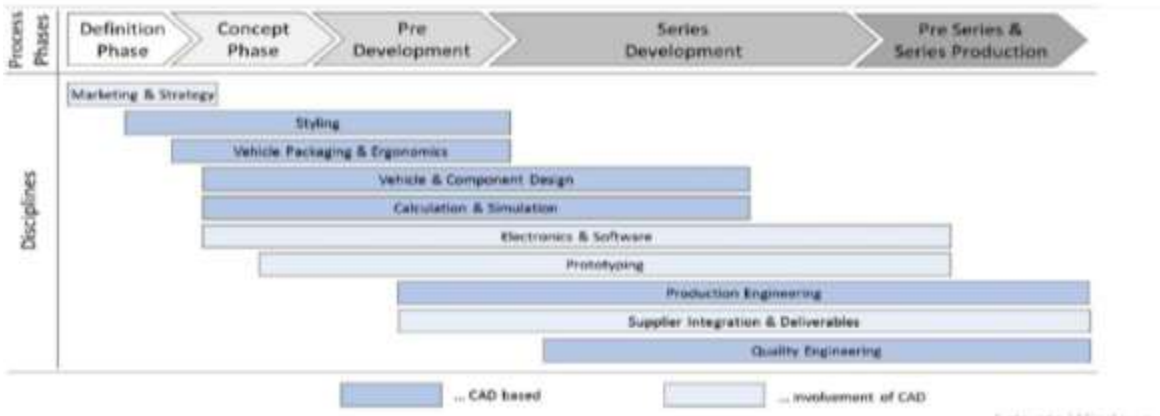

Fig. 1: Process phases and development disciplines in a typical state-of-the-art full-vehicle development process

The consists of a collection of features of the forthcoming car to be designed. This has market analysis of forthcoming trends, customer requirements and legislative border conditions. Besides, manufacturer-related strategic considerations are made, e.g. Integration of the intended model in existing platforms. At the close of the, the specification list is established, which offers requirements definition for future vehicle development. During this first stage, CAD - data of available car models and platforms is used for technical and economic potential-appraisal of the new car to be planned.

The process of development itself begins with the, which includes the entire vehicle layout, including styling, vehicle packaging and ergonomics, as well as body and component development. Starting from preliminary styling works, the car architecture is built up and all components are integrated. Drivetrain modules are inherited from current platforms or newly developed, together with new technologies, i.e. Electric or hybrid drivetrains. The whole idea phase is closely connected with CAD.

There are computer-aided styling (CAS) for modeling works, computer-aided design (CAD) as engineering science, and associated computer-aided engineering (CAE). CAE comprises digital mock-up (DMU) and different types of simulation, e.g. Multi-body simulation for kinematics (MBS), finite-elements simulation (FEM) for stress, durability and crash simulation, as well as computational fluid dynamics simulation (CFD) for aerodynamics and heat management investigations. All these CAE operations are provided with geometrical and functional information from a central CAD model. Results of simulations are fed back to the CAD model and utilized for design verification or modification work on specific components and modules. Thus, the CAD model takes a central position in the concept phase of a new vehicle.

The encompasses a continuation of concept development with regard to careful technological and economic considerations. This includes finalization of styling activities, 3D-CAD engineering of all components and modules, and far reaching validation. Along with virtual development, prototypes of modules and even vehicles are tested and examined on test beds and on road. During this stage, the new vehicle model is fully designed in 3D-CAD with a detailed model in DMU as the foundation of production engineering activities. Thus, supplier are more and more integrated into the development. From the perspective of CAD, this stage opposes data exchange between the central CAD model and simulation processes and vice versa, as well as between automobile manufacturer, external engineering partner and module supplier. By the end of the, the new automobile model is designed with all modules and technologies, free from E/E components. Owing to the various development cycles of electric/electronic components and software, these components are still being developed, even after the hardware models are completed so far.

The has a close link to production development and supplier integration including logistics, assembling processes and quality engineering. During this phase, the virtual car model, in a sophisticated CAD form, acts as the foundation for extensive research into production-related processes. This involves highly data exchange between vehicle design and production design, in which the end product is shaped by production requirements. At the end of this phase, both the new car model and its production are completely developed and all interactions with manufacturing facilities and supplier are defined.

The development status of the central CAD vehicle model is frozen for production. The final phase of car development includes. Last adjustments of the assembly line and in the logistics management are carried out in the production of first pre series models. Final adjustment of machines and robots and quality-related investigations, e.g. In the paint shop or in consideration of tolerancing, are part of these. As throughout the whole production development, the core CAD vehicle model serves data for manufacturing and assembling adjusting, series production phase begins following new car homologation in target markets. In series production, the core CAD model is updated in the event of model-related or production-related optimizing.

2. FUTURE IN CAD TECHNOLOGY:

First commercial CAD-software emerged during the 1970s and included features for 2D-drawings as well as data storage. The evolution from 2D-generation of drawings to 3D-representation of models began in the early 80s, but commercially established 3D-CAD-software was first introduced around 5 years later. 3D-CAD design changed the applied design methods significantly. The introduction of 3D surface and solid models resulted in an evolution of design methods from static, two-dimensional drawings in several views and sections to dynamic, three-dimensional virtual geometric product models.

In addition to a realistic and close-to-life description of product geometry, these models had a range of other information and features. With the assistance of 3D design, it was feasible to incorporate production-relevant knowledge and assembly-relevant information into the models . Direct data exchange between design and simulation began during the 90s via the application of standardized neutral data exchange formats. It was thus possible to employ geometry data defined in design software packages in the description of product geometries in simulation processes. Imported geometry was utilized to create meshes for finite element simulations, the modeling of dimensions and inertia properties to perform multibody simulation, or other calculation purposes.

The parameterization of the geometry data was an evolutionary milestone in 3D-CAD procedures. Parametric-associative 3D-CAD software divided the management of the geometry and its managing parameters. A clear and well-defined connection of parameters and geometry in the creation of geometry generated completely parameterized models of geometry.

Geometrical model properties controlled by parameters opened up a broad area of problem-oriented design tasks. Parameterized CAD programs offered additional functionalities, such as data interfaces, integration of catalogue and knowledge ware functions, and the possibility of macro-based procedures. All of these functionalities characterize state of-the-art CAD packages, which come into use in automotive development.

2.1. FUTURE IN THE CAD SYSTEMS:

One trend in software industry is going into the direction of integrated packages, which combine parametric design programs (CAD) and simulation software (CAE) in the same environment. Although this strategy reduces data interface losses, it has been criticized for resulting functional reduction in directly compatible program platforms. However, Next-Generation intelligent geometry data exchange formats, which can support both geometry data and richer product information, are capable of accelerating the efficiency of virtual product development processes substantially. Virtual development will be carried out on the whole spectrum of product creation, beginning at concept stage, proceeding through various steps of development (including manufacturing and production engineering), facilitating sales and after-sales, and culminating in the coordination of disposal procedures. This calls for an additional incorporation of product properties into 3D models, such that they can act as in real life.

This time, there are a number of integrated development platforms, but they are plagued by high complexity, resulting in drawbacks in operation efficiency and user management. Overloaded with interconnected software modules for design, digital mock-up, simulation and data management, these platforms have developed into huge software giants, which provide more functionalities than ever before. Platforms for future developments must offer a smarter integration of various disciplines so that they become more efficient and easier to handle. Apart from that, the licensing models have to shift from inflexible, module-based systems towards adaptive accounting, which can take into account single software use. Options to conventional CAD software will emerge with a growing proportion of open-source CAD systems.

Open source CAD of today, such as BRL-CAD , are not yet as prevalent, but there is strong demand for basic, versatile CAD software particularly in small- and mid-range supplier enterprises. Just like Linux , openoffice or Firebird , such kind of programs will be open-source-based on platforms such as the Open CASCADE engine , and have the capacity to offer adequate functionalities for product and systems design . One of the main challenges for the development of such software packages is the potential incorporation of generated data into already installed data management frameworks of large (car) producers. Overall, cooperating CAD systems and environments come to hold a more central position within the global acting automotive sector. In order to face this challenge, next-generation CAD systems will offer capabilities of cloud-based development that allow all engineers on a design team to work together at the same time with a web browser, phone or tablet, as some programs already do.

Thus, interoperability between various CAD platforms and data management systems becomes a pre-condition for achieving a high level of interoperability . Due to high complexity, automotive development process data management is done by Product Data Management Systems (PDM), which represent a subset of Product Life Cycle Management Systems (PLM). These platforms are much more than simply data management software: Wide-ranging functionalities are made available to facilitate the whole development, production and use phases. In this manner, PLM tools are embedded in data transfer, visualization and assessment procedures . Development trends in data management are treated in several literature Target is an increased integration of design, engineering and data management for the global acting industry.

2.2. VISUALISATION BY USER INTERFACES:

State-of-the-art CAD systems are operated by the keyboard in combination with operators such as mouse, space mouse or pads. With the advent of virtual and augmented reality technologies, new functionalities of virtual model visualization and handling emerged over the last decade. This time, there are new technologies coming, which offer an integration of 3D models, virtual and real world, e.g. the Microsoft HoloLens . The majority of these applications have their roots in gaming industry, but now they are on a higher level of technology so that they may be utilized in industrial development processes, as well. Holographic animation of virtual models will be used for styling, design and DMU applications including manipulation and kinematics simulation. Especially the integration of DMU and real scenarios enables real-time development and evaluation in a collaborative way, independently from the actual geographic location of involved engineers.

These could be the largest advantages of holographic technologies: styling analysis, packaging and assembly studies. From engineering point of view, holographic technologies are regarded even more important. Component and module design and engineering are accompanied by a more challenging integration of descriptive technical data into visualization technologies. In this way, future CAD systems will work within virtual environment to gather boundary conditions for subsequent technological development of components and systems. CAD models will be integrated in holographic DMUs to be investigated, and information will be fed back into design processes. One of the largest future challenges in developing fully comprehensive virtual environment for product design is incorporating the above-discussed working steps into a single effective workflow.

2.3. 3D PRINTING USE:

3D printing has proven to be an able method of creating hardware models from virtual 3D-CAD geometry data. In the recent years, new technologies offered the opportunity to apply new materials with particular properties, e.g. Various kinds of plastics, metal and even textile and ceramics. This makes possible on-time creation of hardware models throughout product development, with properties close to serial production output. Thanks to improved manufacturing capabilities, 3D printing actually has the capability to even feed mass production processes.

Cost lowering makes 3D printing appealing for a profound integration into upcoming product development, with a certain portion of virtual modelling and hardware-based innovation discovery. To integrate hardware and virtual modeling into one development cycle, novel "intelligent" materials are being researched. Outstanding, Dynamic Physical Rendering (DPR) is an interdisciplinary research initiative between Carnegie Mellon University in Pittsburgh and Intel .

Target is the creation of flexible material on nanotechnology that may be controlled in two modes: geometrical information from virtual 3D-CAD models and manual manipulation. After being changed by hand, the geometrical changes are passed back into the CAD system automatically.

The technology is based on millions of so-called catoms that represent tiny particles within a type of plasticine. A 3D printing process forms a hardware model out of these catoms, and afterwards the model can be reshaped with fingers. All geometrical modifications are handed over to the CAD system and modify the behind lying virtual model. Because of high computational effort to manage shaping of millions of catoms into dynamic 3D forms, new approaches for reliable and robust software programs are required. The DPR idea, or "Claytronics", presents a broad range of applications for product design in the future.

Once implemented for industrial production, this technology will directly facilitate styling and shaping activities due to the ability to incorporate artwork that is intuitive-oriented and engineering that is technological-oriented. Furthermore, resource-intensive cycles of clay modelling, 3D scanning and optimization of shape for virtual models will be minimized, and work on creative and productive products will be supported. Incorporating DPR in technology-based engineering procedures is a more significant challenge. 3D-CAD component and module modelling involves bringing together many technological, functional and production-related factors into product development. Only time will show whether and how this new technology is incorporated into technical product design and assessment processes.

2.4. CAD PROGRAM OVERALL:

Modern CAD systems have features for knowledge-based engineering to facilitate the incorporation of template models, automated routines for computation and even programs into CAD models. All these features serve as a reasonable foundation for reducing development time and product improvement simultaneously [19]. Despite chances of personalization offered in contemporary CAD systems up to this point,both functionality and management have shortcomings when compared with commercial available scientific software, such as MATLAB [13]. The programming languages employed, e.g. VBScript [14] are not current for effective programming in CAD environment, as they reflect shortcomings in deployment and portability along with in sophisticated programming, e.g. ontological and generic functionalities, development with classes. Moreover, they provide only limited support of extended operations and cooperation with other packages of software.

Upcoming CAD platforms will offer improved object-oriented programming with built-in functions and operations for effective problem-specific solution creation [9]. Design activities will continuously shift from exclusive geometry generation towards combined development cycles involving effective layout and simulation. This will be facilitated not only by utilization of integrated standard simulation tools, but also by CAD automatisms, which assist design engineers and facilitate their work without burdening them with management of perplexing software packages. Additionally, coming CAD systems shall be capable to learn from earlier development in order to assist the engineers with optimisation processes behind the scenes. Thus, the engineers will be provided with propositions for their genuine design problem that are based upon knowledge transmitted through automated algorithms and databases.

In this way, future CAD programs will be able to provide an enhancement of state-of-the-art knowledge based engineering. The development of complex components, modules and systems, as they occur in automotive industry, often includes an optimization of numerous, partially conflicting aspects. Improved design engineering quality contributes to reduced number of modification cycles, more effective development processes and improved product quality. Quality of the results relies on the experience.

the design engineers involved, but the assistance of applied software also has a significant influence. With this challenge in mind, future CAD systems will more and more offer optimization capabilities, which can support engineers during beginning from initial product development stages. One research area involves the application of genetic programming within CAD environment which employs evolutionary algorithms to optimize sets of designs based on specific criteria. Based on the evolution of computer programs, genetic programming provides novel methods for the design of multifaceted products with many components.

2.5. REQUIRED NEW DEVELOPMENT PROCESS:

Growing integration of electrics and electronics (E/E) systems into vehicles is driven by comfort and communication aspects as much as by increasingly reinforced legislative frame conditions for exhaust emissions and car safety. In a new midsize vehicle, the proportion of value creation by E/E through averaging is over 30 %, and this value will rise further in the course of future years. New vehicles are fitted with up to 80 electronic control units (ECU), which exchange information through an inter-network of communication systems [8]. Today, E/E is concentrating on two key groups: efficient drive train technologies such as hybridization and electric drives as well as comfort and automated driving technologies.

The second category consists of camera and radar systems for road obstacle detection, car to car and car to infrastructure communication and the design of new user interfaces for car control. Nevertheless, research and development have surpassed conventional mechanical-oriented development activities and it will remain progressively significant for the next years. While car makers are researching the merging of mechanical, electrical and electronics design (e.g. [28]), the respective development processes have not yet followed the new, comprehensive requirements, and used development software is missing in this regard, as well.

Future CAD systems have to face these new product characteristics by provision of enhanced development methods for mechatronics systems, which support simultaneous development of mechanical, electrical and electronics systems including software. Particularly software development is governed by other principles than hardware development, due to different behavior from the perspective of complexity management, errors and failure happening, sustainability and lifespan. This way, new CAD systems will not only offer functionalities to integrate an electric motor or a camera system into a DMU, but also functionalities to take into account functional aspects of implemented modules for the used CAD platforms

3.UNDERSTANDING THE V-MODEL PROCESS:

Requirements Engineering:

It is the initial step in the V-model process and involves setting and documenting requirements. It involves specifying in detail and recording the task/s to be done by the automotive function/feature and how. The success in the design and development stage relies heavily on this stage being done properly. But often, the implementation details may not be included in the requirement document. As the development process comes next, it is advisable to have the development team involved during the preparation of the requirements document so that it will be clear.

System Design and Development:

The subsequent step is the actual design and development of the function/feature for which the requirement was collected in the initial phase. During the development phase, the functionalities are created and tested through the model-based development environment. The function/functionality must be tested when it is being developed in such a way that bugs and errors are corrected early on.In the model-based development platform, simulation software like MATLAB/Simulink is capable of simulating real-life situations. The possible bugs and errors are identified and fixed at this stage. Such tests are referred to as Model in the Loop (MIL) because the testing is carried out within an environment that is controlled by using models. After the development process and testing are finished and the result is satisfactory, the model – a block diagram – is passed on to the software development team.

Developing Software:

The software component is developed based on the model. There could be various versions of the software based on the use case. Model-based design tools can produce automatic code; most of the hand (written) codes are in C language, and most of the ECUs are developed in C too. The software development input may be in the form of the model or a requirement document, both providing a detailed description of the function/feature.

Software Integration and Function/Feature Integration: Because there are various ECUs, the majority will probably have their own control software. The engineer integrates all these software modules in the software integration phase and verifies the interaction between them. The effect on the legacy code and other software modules is also monitored. Once again, the testing of this phase is carried out using simulations under Hardware in a Loop environments. Then the engineer must determine whether this new added function impacts any other module's operation. In this case, testing is conducted in a real-world setting (in-vehicle test). The most critical element of testing, in this case, is to verify that the implementation is proper, with no defects or undesired effects. Thus, a test environment should be established and set up to test the function in a vehicle. Then, the ECU is interfaced with a computer containing the stipulated tools through various communication methods. This verification process assists in ensuring that the product is able to perform as needed.

Fig. 2: Different domains and computer-aided applications in an automotive development process according to the V-model

Besics v model domain:

In the case of very complex products, e.g. Automobiles, the development process is executed multiple times, particularly on module and component level. Duration as well as complexity of these development cycles also vary considerably across the three areas, which results in different maturities in mechanic, hardware as well as software development. Figure 2 also indicates various domains which appear during mechatronics system development: mechanics (blue) and electrics/electronics (E/E) (orange). The E/E domain is split into hardware (dark orange) and software development (light orange). Bars on either side of the left and right branch represent the use of various computer-aided tools throughout the development process. The bar colors match the development domains mechanics, hardware and software. "Traditional" development professions in the mechanical field are ruled by CAD-based applications, i.e. CAS, DMU, CAP and various forms of CAE, i.e. Finite-elements simulation (FEM), multi-body simulation (MBS) and computational fluid dynamics simulation (CFD).

As a result of the integral position of CAD-based product models, which hold geometrical, functional, structural and manufacture-related information, a number of disciplines within the proper right branch of the V-model are further connected with CAD, i.e. CAP, CAM, RP and numerous facets of CAQ. In current development processes, E/E development is rather decoupled from mechanics development. There is some interaction in the fields of ECAD and ECAM, but not in software development, integration and testing.

In general, the V-model represents itself as a well-established approach for the development of mechatronics systems, but with rising complexity and increasing share of E/E, it shows disadvantages in terms of efficient cross-domain integration. For a solution to encounter these challenges, future development process will offer functionalities for effective structural and geometric design integration as well as functional design, not just limited to mechanics, but extend to hard- and software too.

An essential success factor is the introduction of flexible, interdisciplinary workflows, which can take into account various domain-specific methodological, functional, and development-cycle-time oriented characteristics. Furthermore, data exchange and communication will be enhanced by introduction of global data models, which are capable of providing all participating disciplines. To cope with these challenges, next generation CAD systems must offer much more than the aforementioned "conventional" functionalities and data models.

As core data model as it has been over previous years, next-generation CAD models will further feature full data structures, encompassing all product and process related information for successful cross-domain development of mechatronics systems. In addition to geometrical, product structure, function, and production information of mechanics and hardware.

4.CONCLUSIONS:

The future of automotive CAD is being rewritten with explosive technological innovation and changing industry requirements. While cars are becoming smarter, lighter, greener, and connected, the CAD systems that drive them have to keep pace with this change.Artificial intelligence and machine learning are bringing a new level of intelligence and automation to design processes.

allowing engineers to design more innovative and efficient designs at reduced times. Generative design and topology optimization are transforming how components are designed, emphasizing weight reduction and material efficiency particularly critical for the development of electric vehicles and sustainability objectives.Cloud-based CAD platforms are making design collaboration seamless and global, breaking down barriers between geographically dispersed teams.

At the same time, virtual reality (VR) and augmented reality (AR) are enhancing design visualization, improving decision-making in the early stages of development. Additionally, the incorporation of CAD with simulation software, iot data, and digital twins is generating a closed-loop feedback system through which actual performance data can impact design optimizations. This not only decreases the dependency on physical prototypes but also speeds up innovation cycles. As sustainability is prioritized, CAD software is likely to enable sustainable design practices such as material traceability, recyclability, and life cycle analysis.

Simultaneously, additive manufacturing compatibility and security features are emerging as must-have requirements in future-ready CAD systems.Essentially, CAD is transforming from a conventional design tool to a holistic, smart platform that links all stages of the automotive product life cycle—ranging from conceptualization to production. The automotive CAD of the future will be digital, smart, and collaborative, and it will remain a force driver for the next wave of mobility solutions.

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