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Integrated CAD/CAE/CAI Verification System for Web-based PDM

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ABSTRACT

The demand for technology to aid sharing product information between digital manufacturing and C3P (CAD, CAE, CAI, PDM) systems has increased along with the technological development of computers and networks. Although usage of these systems has risen, system integration is difficult in practice because of the heterogeneous characteristics of the systems. In order to resolve this problem, the design of a CAD/CAE/CAI verification system is required to develop a Web-based PDM system, which would allow for wider verification of engineering data within the Web environment. In this paper, a CAD/CAE/CAI verification system interfaced with a Web-based PDM is presented to examine CAD, CAE, and measurement data. For the integration of CAD/CAE/CAI systems and a PDM system, the CAD and CAE translators were interfaced and an integrated verification system was constructed on the basis of the verification kernels. By applying the integrated CAD/CAE/CAI verification system toward actual automobile design processes, the effectiveness of the CAD/CAE/CAI verification system has been successfully verified.

Keywords: CAD, CAE, CAI, PDM, verification kernel.
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1. INTRODUCTION

PDM (Product Data Management) systems are widely used to manage engineering data in the manufacturing industry. However, the data registered on the PDM systems are not utilized well. There are two main reasons for this underutilization. One is the high cost of engineering programs, which prevents distribution of programs that allow users to verify engineering data. The other reason is the complexity involved in using the engineering programs. A number of commercial viewing systems have been developed to resolve these problems, but the level of usage is poor except for the CAD (Computer Aided Design) industry. Also, there are a few studies being conducted regarding integration among the systems [1]. Programs available today include AutoVue from Cimmetry [2] in the CAD field, GLview from Ceetron [3] in the CAE (Computer Aided Engineering) field, and Rapidform from INUS [4] in the CAI (Computer Aided Inspection) field. These programs, however, are only capable of verifying data in their respective field and cannot compare or verify data associated with other areas. Furthermore, with the exception of the CAD industry, there are limited research efforts toward networking and integration with PDM systems.

In this paper, development of the framework for Web-based CAD/CAE/CAI/PDM integration and its implementation are proposed. Following previous works are implemented to design the proposed system. The lightweight CAD kernel [5] developed for Web-based 3D verification of measurements [6] and interferences [7] was expanded to verify CAE [8] and CAI data [9]. A converter compatible with the PDM system is designed to verify various forms of commercial CAD and CAE data. In addition, previously developed lightweight CAD files [10] are applied for efficient transmission of the converted data. Previously developed digitizing data interface algorithm [9] is implemented to verify the digitized CAI data, which is then integrated with the PDM system [11, 12]. To confirm the validity and performance of the developed system, CAD, CAE, and CAI data integration on the PDM system is examined through the verification of design, analysis and measurement data.

2. ARCHITECTURE OF THE SYSTEM

2.1 Structure of the Overall System

Fig. 1 shows the integrated CAD/CAE/CAI/PDM system structure composed of following units. The CAD adapter in Fig. 1(a) registers various CAD data in the PDM system to various CAD systems. Digitizing data sampled by a layout machine is registered to the PDM system through the UI system as shown in Fig. 1(b). Based on the analytical results obtained from various CAE systems, analyzed post-processing data are registered in the PDM system as shown in Fig. 1(c). Fig. 1(d) illustrates the PDM server composed of the file server for managing physical files, the Web server for implementing the Web interface, and the database server. To enable for visualization and verification of those data on the Web environment, CAD and CAE data registered in the PDM server are converted into lightweight data by the CAD and CAE converters shown in Fig. 1(e) and (f), respectively. Users are able to search and verify a diverse range of engineering data through the PDM client shown in Fig. 1(g). The engineering data are also verified by using the viewer system of Fig. 1(h) to analyze the CAD/CAE/CAI data on the Web-based PDM system.

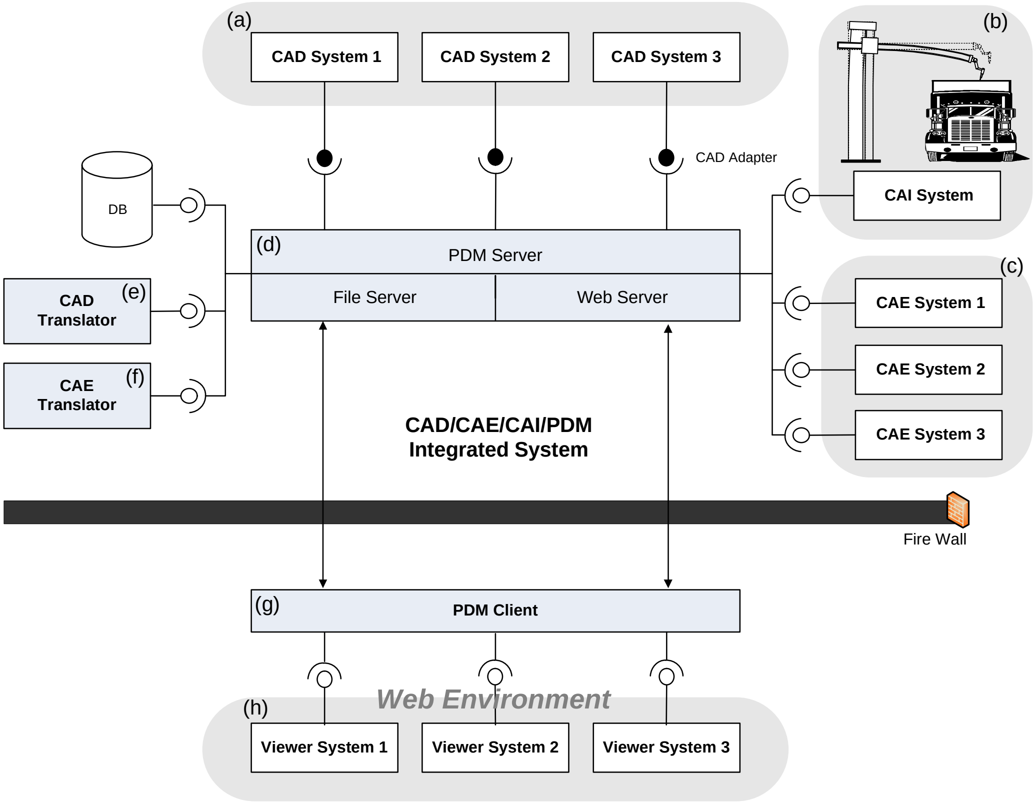


Fig. 1: Overall structure of the integrated CAD/CAE/CAI/PDM system.

2.2 Structure of the Client System

Fig. 2 shows the Web client module distributed from the Web-based CAD/CAE/CAI system servers. The client system uses the ActiveX server structure. Comparing with the conventional distributed computing system structure, the ActiveX server structure enables a user to access the system on the Web without installing additional software. Furthermore, only the server's ActiveX component in the program needs to be modified to update the program. HTML is used to install ActiveX on the Web and VBScript for the ActiveX plug-in interface. The ActiveX control is implemented with MFC programming using Microsoft's ActiveX technology. In order to visualize 3D data, Silicon Graphics' 3D graphic processing library OpenGL is applied for the ActiveX control. The actual function modules of the developed system are composed of the lightweight file read/write, IGES migration, 3D viewer equipped with lightweight configuration kernel, measurement verification and markup, and interference inspection modules. These functional modules are implemented with the ActiveX control using MFC.

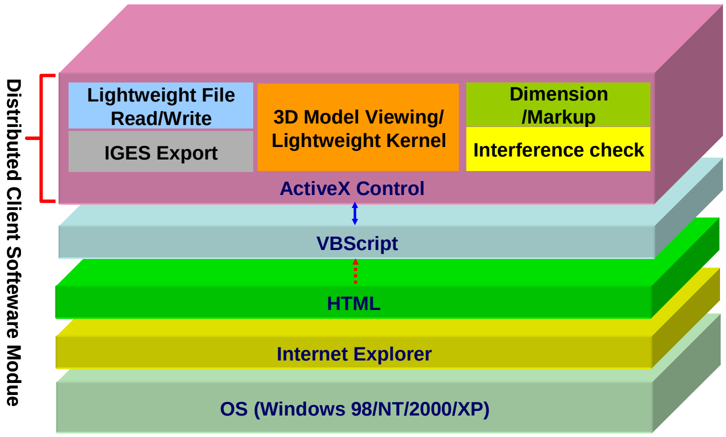
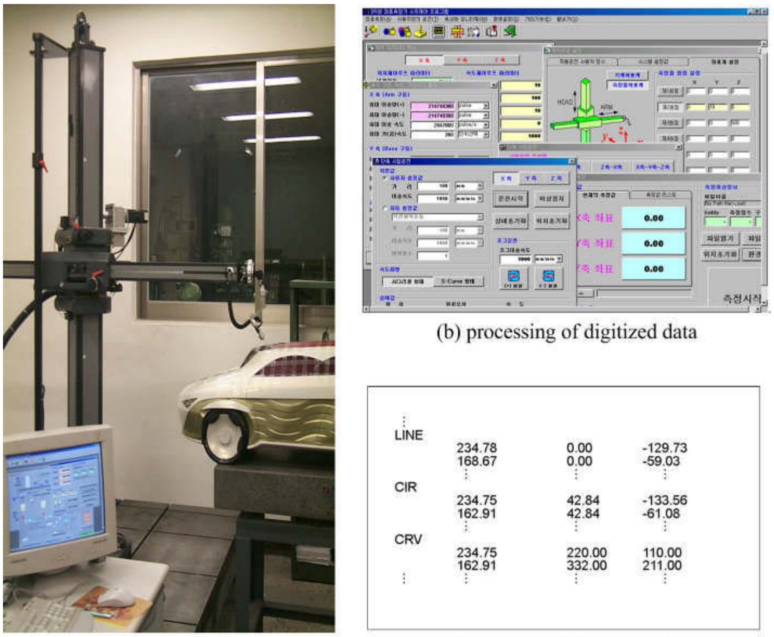


Fig. 2: Structure of the client system.

2.3 Interface Methodology of Digitized Data

Most measuring machines have their own data formats which may not be used in other machines. The new file format recognizes all format types. This includes a format composed of geometric forms and three-dimensional coordinate values, as well as a format composed of just three-dimensional coordinate information. In general, operators of measuring machines in the styling room know the shape of objects when they digitize clay models of cars (Fig. 3(a)) [9]. In order to sort digitizing data, they put tick marks between three-dimensional coordinate values during the digitizing processes (Fig. 3(b)). They also intentionally place tick marks to distinguish geometric features during the digitizing process. Fig. 3(c) shows a sample of the digitized file. By using the above digitizing procedures, the designer's intention is included in the digitized data. Users inspect measurement values on a monitor by clicking a displayed geometric feature composed of digitized point data. Then, the users confirm the geometric feature and verify dimensions according to the designer's intention.



(b) processing of digitized data

(a) digitization of an object (c) format of digitized data

Fig. 3: Digitization processes in a styling room.

2.4 Structure of the CAD Translators

A lightweight file converted from CAD data produced from a commercial CAD system should be prepared to verify the interference of a mold on a CAD viewer [7]. In this paper, a file translation system generating the native file is constructed by using the InterOp and API of ACIS kernels to produce them from the commercial CAD systems. Fig. 4 shows a schematic diagram of the file translator. Fig. 4(a) shows neutral and commercial CAD files supported by this system. Interpretation and translation of the CAD files are done by InterOp. Fig. 4(b) shows that the files are translated into the ACIS data structure. Fig. 4(c) is the module generating the lightweight CAD file from the ACIS kernel data. In this ACIS kernel, information extraction required for the proposed files is classified into two processes. First, MESH_MANAGER, a mesh-generating function of the ACIS kernel, generates meshes by using the function according to the specific mesh tolerance, and extracts information of the meshes. Secondly, edge information required for dimensional verification is extracted from commands of the ACIS kernel. Entity characteristics of the ACIS kernel are considered in this procedure. Using B-rep models and mesh data extracted from the native files, the lightweight CAD files with topological information are constructed as binary files. As the lightweight CAD files retain topological and geometric information, they are applicable to dimensional verification, digital mock-ups, and visualization of CAD files through CAD viewers [6],[10],[12],[13].

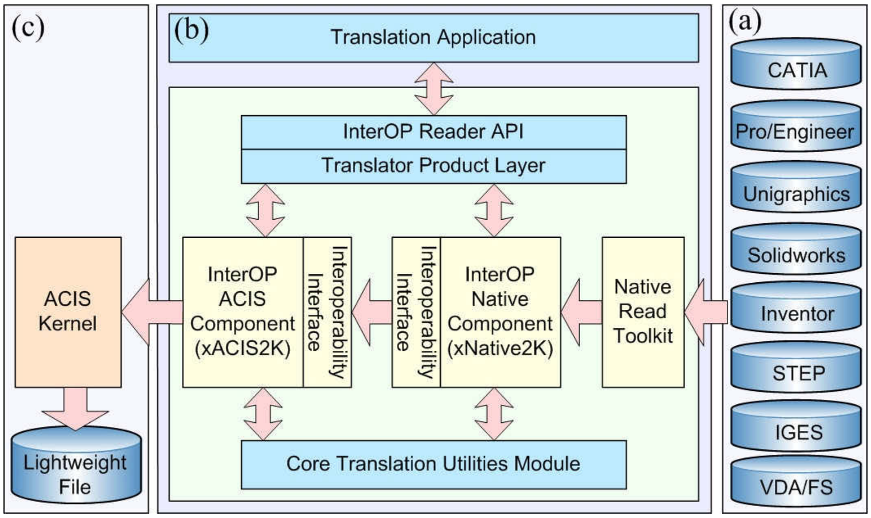


Fig. 4: Structure of the CAD data translator.

2.5 Structure of the Lightweight File

The lightweight file structure for accommodating the CAD/CAE/CAI data is indicated in Fig. 5. It is in binary format and the first part is the file header shown in Fig 5(a), which describes the file version, compression, and the number of entities. When a file is read, a file converter is selected according to the file version. Various entities will be explained in Section 3 are constructed into blocks prior to storing the data in the lightweight file. Storing data in blocks has an advantage in terms of future data expansion. When a new entity needs to be added, the system only needs to add a type for distinguishing the block and describing its data. The block structure includes the header section shown in Fig. 5(b) designed to identify each block and store its type. Next to the header is the data section of Fig. 5(b), which contains the actual data of the entity. As indicated in Fig. 5(c), the layer structure of the lightweight file allows the data section to describe another block, which is created and saved as a child block. A block without a child block is shown in Fig. 5(b).

2.6 Structure of the CAE Translators

CAE data is constructed with various geometric configurations which must be divided into triangular data for visualization. Accordingly, a conversion process is necessary to transform CAE data into triangular data. For this, CAE system's geometric configurations must be defined first. Typically, eight geometric configurations are used in a CAE system: point, beam, triangle, quadrilateral, tetrahedron consisting of four vertices, hexahedron consisting of eight vertices, pyramid consisting of five vertices, and pentahedron consisting of six vertices. The type of geometric configuration is determined based on the number of points used in its construction. Among the eight configurations used in the CAE system, quadrilaterals and tetrahedrons cannot be distinguished because they have the same number of vertices. Accordingly, they are categorized using identifiers. If an identifier is not provided, a calculation is performed to check if the four vertices are on a single plane. A configuration is categorized as a quadrilateral if the four vertices can be positioned on a plane. Otherwise, it is determined as a tetrahedron.

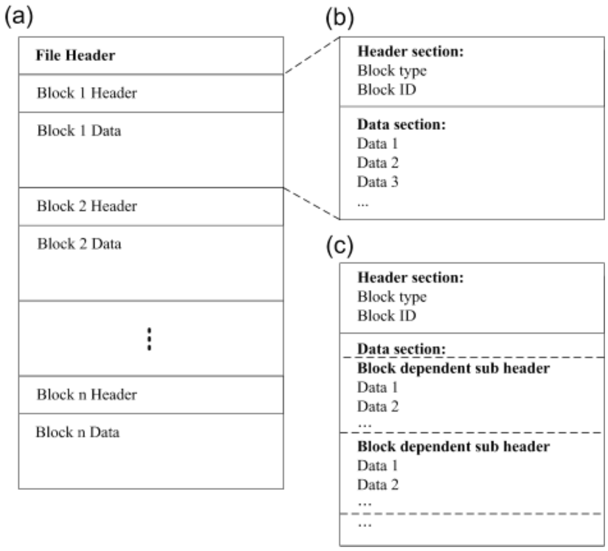


Fig. 5: Structure of the lightweight file.

The analytical results obtained from the CAE system consist of one-dimensional scalars and three-dimensional vectors as classified and specified in Tab. 1. The results are attributed to each coordinate value or element of a geometric configuration. If the number of analytical results coincides with the number of coordinates, an analytical result is assigned to a coordinate value by referencing the index value for which the coordinate value is used. If the number of analytical results is identical to the number of elements, the results are assigned to elements. The CAE data results consist of static and dynamic values. Dynamic result values are constructed in multiple stages and a time interval is given for each stage whereas static results have only a single stage.

Type	*Resultant values*
vector	acceleration, displacement, magnetic potential velocity, reaction force, external force, temperature gradient, heat flux
scalar	current, creep strain, density, kinetic energy, magnetic potential, plastic strain, pressure, strain energy, stress tensor component, strain tensor component, temperature, turbulent kinetic energy, turbulent dissipation, viscosity, voltage, volume

Tab. 1: Classification of CAE results.

3. DESIGN OF THE CAD/CAE/CAI KERNEL

In this paper, a CAD/CAE/CAI kernel is devised by using the data structure of the previously developed lightweight CAD kernel [5]. The integrated kernel structure shown in Figure 6 is used to propose the CAE kernel structure and the structure of the lightweight CAD kernel. The lightweight CAD/CAE/CAI kernel structure discussed in this paper is designed in three parts depending on the application as shown in Fig. 6. One is the triangle mesh data part (Fig. 6(a)) and the other is the edge data part (Fig. 6(b)). The detailed structure of the proposed file is as follows. “Group” is the top entity for managing the combined structure of several solids and sub groups. “TRANSFORM” is the matrix for translation and rotation of each “Group”. “Solid” is applicable to the solid of the CAD entity which consists of faces.

“Face” is located under the “Solid.” “Face” consists of tessellated triangle data for visualization of the CAD model (Fig. 6(a)) and edge information for the dimensional verification (Fig. 6(b)). “Edge” is saved with a separator to be classified into “Line”, “Conic”, and “Curve”. “Line”, “Conic”, and “Curve” consist of linear lines, conic curves, and spline curves, respectively. “Time” is the time step for dynamic CAE analysis results. “Time” consists of “vector” data and “scalar” data of the CAE analysis results (Fig. 6(c)). A loop-edge-(line, conic, curve) layer structure shown in Fig. 6(b) is used for the CAI data. The digitizing data are verified by categorizing the data as line to line, circle to conic, and curve to curve. Using this data structure, group, solids, faces, and triangle meshes are able to be successively CAD/CAE/CAI verified.

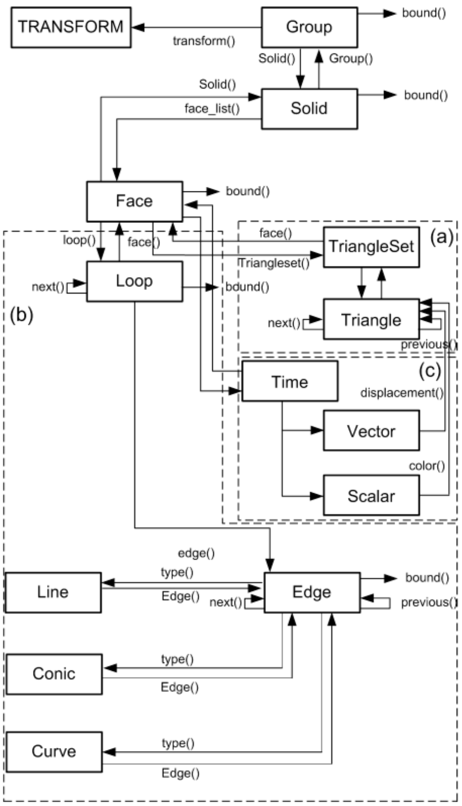


Fig. 6: Structure of the integrated kernel.

4. CASE STUDY

In order to evaluate the Web-based CAD/CAE/CAI/PDM integrated system, data verification is conducted for styling, design, CAE analysis, and CAE system's post-processing data of an automobile dashboard. Collaborative verification using the developed integrated system involves the following processes. First, the automobile designer sketches the dashboard according to the concept of the automobile. Next, a clay model is prepared with respect to the designer's sketch. The clay model is then digitized using a layout machine. Once the digitized data is registered in the PDM system, design and measurement verifications are performed by searching the digitized database in the PDM system as shown in Fig. 7.

After the verification is completed, the data is converted into an IGES file [14] using the conversion module of the developed system and is registered to the PDM system. The registered IGES files are migrated to CATIA V5, a commercial CAD system, and curvature is provided to the IGES data to generate the design data for mass production as shown in Fig. 8. Then, the CAD data is registered to the PDM system as shown in Fig. 9, and converted into the lightweight CAD data. If a user searches for data associated with the automobile dashboard in the PDM system and requests to verify the design and measurements of the CAD data, the developed system is executed with the lightweight CAD data to perform verification (Fig. 10).

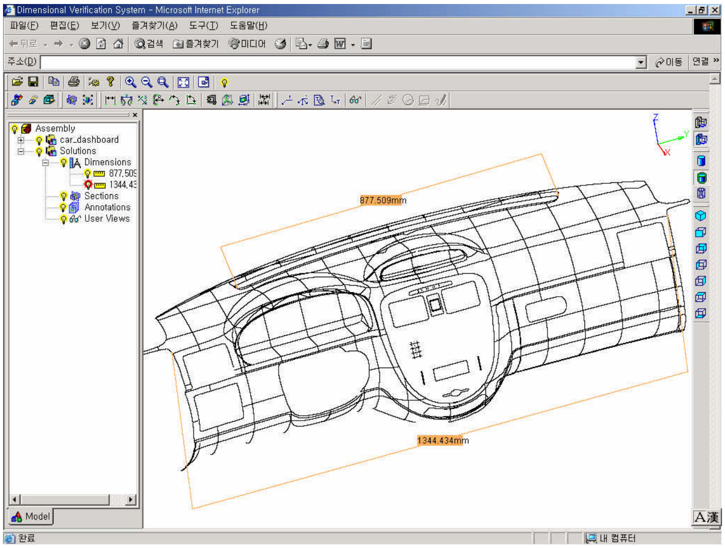


Fig. 7: Design and dimension verification of the digitized data on the developed system.

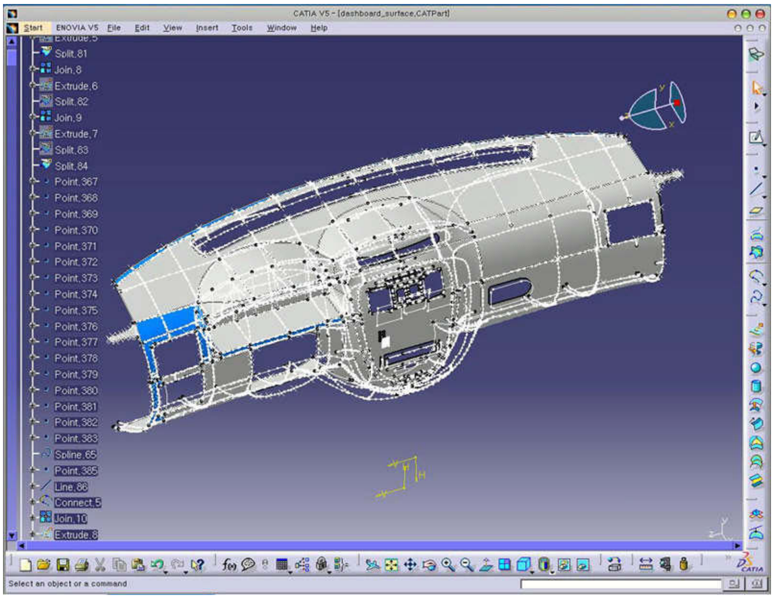


Fig. 8: Designed dashboard through the CATIA V5.

After the verification process, analysis is performed using the CAD data and the analytical system. Since a dashboard is a large injection-molded plastic product, the design of the gate, through which molten resin enters the cavity, is important [15]. Fig. 11 displays the analytical result of the fill time according to the gate location using Moldflow, a software product for analyzing injection properties. The analytical result is then saved as an ASCII file from Moldflow and registered in the PDM system. When a user searches for the data of the analytical result registered in the PDM system, the developed system visualizes and verifies the result as shown in Fig. 12. Based on the integration with the

PDM system, the developed system allows users to verify various engineering data over Internet Explorer without installing additional software.

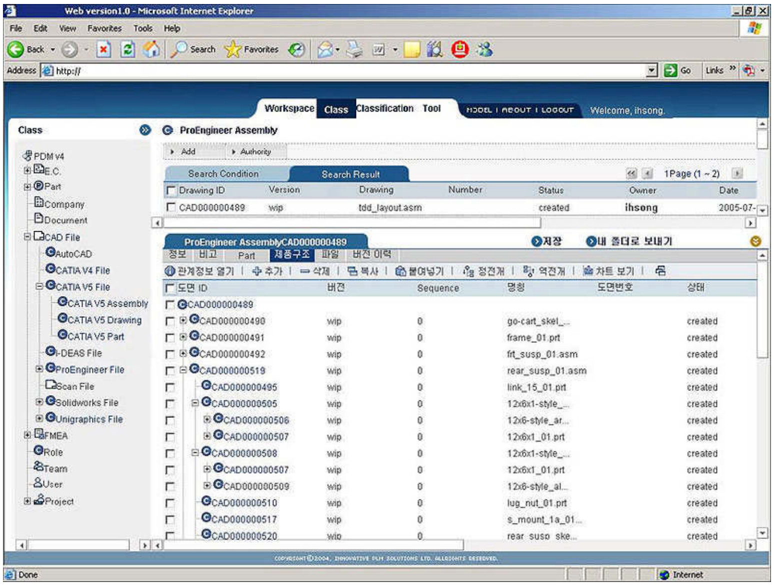


Fig. 9: Check-in of the dashboard data on the PDM system.

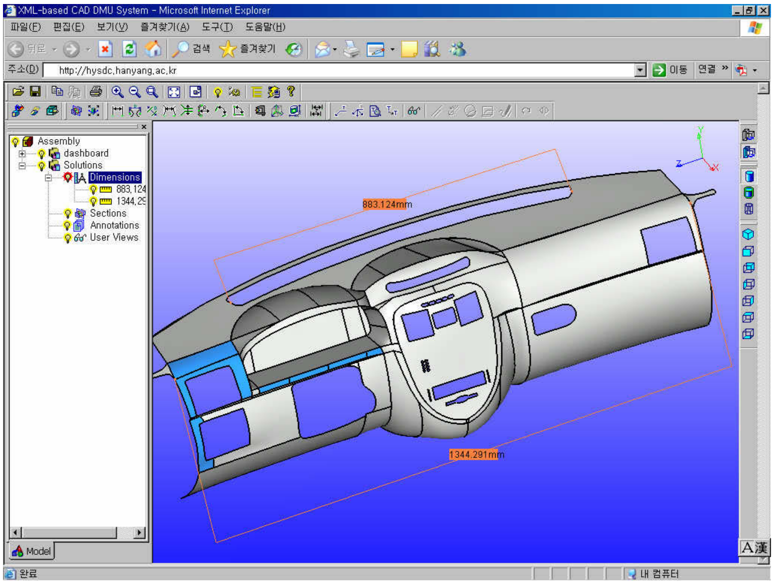


Fig. 10: Design and dimension verification of CAD data on the developed system.

5. CONCLUSIONS

This fundamental study for implementing a Web-based CAD/CAE/CAI/PDM integrated framework provides the following conclusions. Previously developed CAD lightweight configuration kernels for the Web environment is redesigned and expanded to be compatible with CAE and CAI data. A methodology for integrated inspection systems of various engineering data based on the CAD converter, CAE converter, and digitizing data interface is devised to integrate the CAD/CAE/CAI verification system and the PDM system. In order to verify the effectiveness of the developed integrated system, an automobile dashboard has been digitized, and the digitized CAI data has been inspected on the Web. After designing the dashboard on a CAD system, its CAD data has been verified on the developed system. CAE analysis result is then verified on the system as well. Effectiveness of the CAD/CAE/CAI/PDM integrated framework is confirmed through the case study.

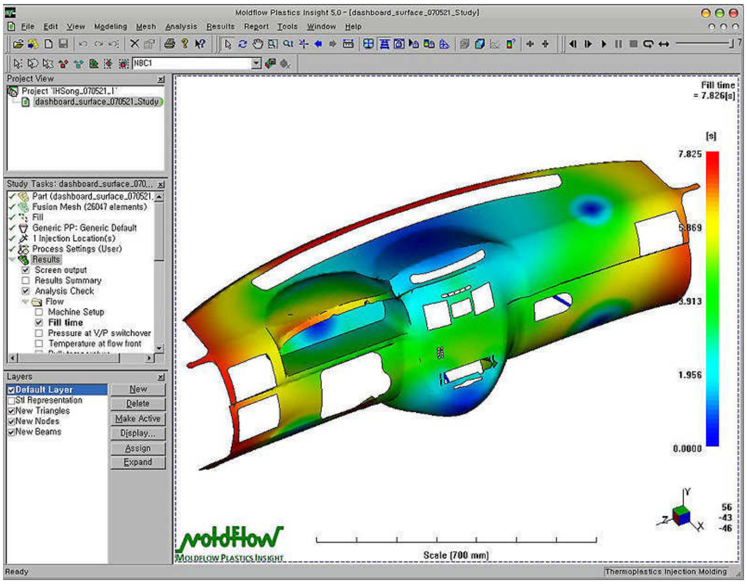


Fig. 11: CAE analysis result using Moldflow.

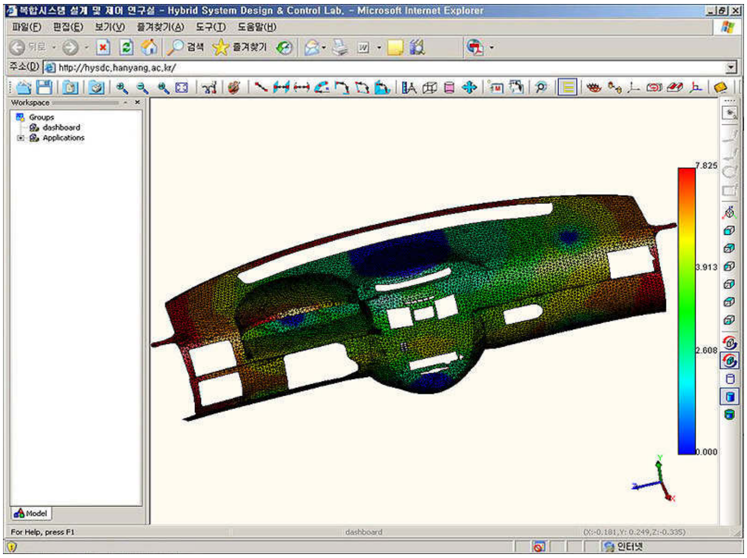


Fig. 12: Verification of CAE result on the developed system.

6. REFERENCES

[1] Balakrishna, A; Babu, R.–S.; Rao, D.-N.; Raju, D.-R.; Kalli, S.: Integration of CAD/CAM/CAE in Product Development System Using STEP/XML, Concurrent Eng. Research and Applications, 14(2), 2006, 121-128.

[2] Cimmetry Inc.: http://www.cimmetry.com.

[3] Ceetron Inc.: http://www.ceetron.com.

[4] INUS Technology Inc.: http://www.inustech.com.

[5] Song, I.-H.; Chung, S.-C.: Geometric Kernel Design of the Web-Viewer for the PDM Based Assembly DMU, Transactions of the KSME(A), 31(2), 2007, 260-268.

[6] Song, I.-H.; Chung, S.-C.: Web-Based CAD Viewer with Dimensional Verification Capability through the STEP Translation Server, Journal of Mechanical Science and Technology, 21, 2007, 1235-1243.

[7] Song, I.-H.; Chung, S.-C.: Synthesis of the Web-based CAD Viewer for Interference Verification of Injection Moulds, International Journal of Production Research, In Printing.

[8] Song, I.-H.; Kim, H.–G.; Chung S.-C.: Sharing of CAE Data to Fabricate Precision Parts in Injection Molding and Die Casting Processes, Proceedings of the ASPE 2007 Annual Meeting, 2007, 449-452.

[9] Song, I.-H.; Kim, K.–D.; Chung, S.-C.: Synthesis of a Web-based Dimensional Verification System for Styling Processes, International Journal of Production Research, In Printing.

[10] Song, I.-H.; Chung, S.-C.: Design of Lightweight CAD Files for Web-based Collaboration, Transactions of the KSME(A), 30(5), 2006, 488-495.

[11] Song, I.-H.; Chung, S.-C.: Synthesis of the Digital Mock-Up System for Heterogeneous CAD Assembly, Transactions of NAMRI/SME, 35(1) 2007, 553-561.

[12] Song, I.-H.; Chung, S.-C.: Design of Improved PDM and Real-time Collaborative Viewing System, Computer-Aided Design & Application, 2(6), 2005, 777-784.

[13] Song, I.-H.; Chung, S.-C.: A Collaborative Design and Dimension Verification System on the Internet, Transactions of NAMRI/SME, 33(1), 2005, 493-500.

[14] U. S. Department of Commerce: The Initial Graphics Exchange Specification (IGES) Version 5.3, NISTIR 44412, 1993.

[15] Deng, Y.-M.; Britten, G.-A.; Lam Y.-C.: Towards Automatic Shape Modification in Injection-Moulded-Pastic-Part Design, International Journal of Advanced Manufacturing Technology, 28(5-6), 2006, 495-503.