# Web-based Precision Dimensional Verification System for Rapid Design and Manufacture

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**Abstract:** This paper describes an web-based precision dimensional verification system for rapid design and manufacture. Collaborators related to the development of a new product can confirm geometrical form from the STEP and the inspection data. They can also check dimensional errors, human factors, form errors, as well as mark up the important parts and make a statement of their views over the Internet. Developed system directly uses an inspection file format composed of 3 dimensional point data without any modification of the file format. And for CAD files, STEP is used as a neutral file format. In order to share information between users, this system store dimensional verification and markup results using XML. The usefulness of the developed system is confirmed through a case study.

**Key Words**: ActiveX, Dimensional Error, Form Error, Human Factor, STEP, Web-based Verification, XML

## 1. Introduction

In the 21st century, the concept of remote design and manufacture is strongly required in manufacturing processes to reduce cost and time-to-market.

Previously, all the collaborating designers were at the same geographical location within an enterprise. With the evolution of electronic verification tools and wide spread availability of the Internet as a medium for sharing and distributing CAD models and inspection data, the constraint that collaborators should be located geographical proximity has been relieved. The most important activity during the collaborative verification is the resolution of design conflict in the early design stage. This reduces the product development lead-time and manufacturing cost to a large extent.

In the research, Ahn, et al [1] have proposed Internet-based CAD/CAM system. Kan, et al [2] have discuss real time collaborative system for product design in Internet environment using VRML form and Java applet. Huang, et al [3] have begun work in creating a standard Internet based Design for X (DFX) shell that provides a framework in which many types of DFX tools can operate. Commercialized viewing tool that can generate information of product through ST-WebPublisher was developed by Step-Tool Company [4]. However, each of them has insufficient dimensional verification function. They do not support inspection of design and fabrication data.

The objective of this paper is the development of an Internet-based high-precision dimensional verification system for rapid design and manufacture. An inspection client registers inspection data at the developed web server. Collaborators related to the development of a new product confirm the geometrical forms of inspection data, verify dimensional information and mark up the important parts, and leave messages on their views through the Internet. Functions of the dimensional verification module are constructed as ActiveX by using the visual C++ and OpenGL. This system can check inspection data as well as CAD data to inspect dimensional errors, form errors, human factors over the Internet environment. As we use the inspection data and the STEP file directly, robust verification results are obtained. Dimensional errors of a clay model for a prototype car door are demonstrated to verify the potential effectiveness of the developed dimensional verification system in the distributed business environment.

## 2. System Architecture

Fig. 1 shows architecture of the verification system. ActiveX-Server accommodates multiple users at the same time. In the architecture, the application server contains dimensional verification module with different functionalities while the client software has the ability to access the server via the Internet [5]. Integration server consists of the database server, the STEP translator and the application server. ActiveX takes charge visualization of inspection data and STEP files as well as dimensional verification results and markup functions. User authentification in the dimensional verification system, file upload and search of the inspection results and STEP files are embodied using Microsoft company's ASP (Active Server Page) and SQL (Structured Query Language).

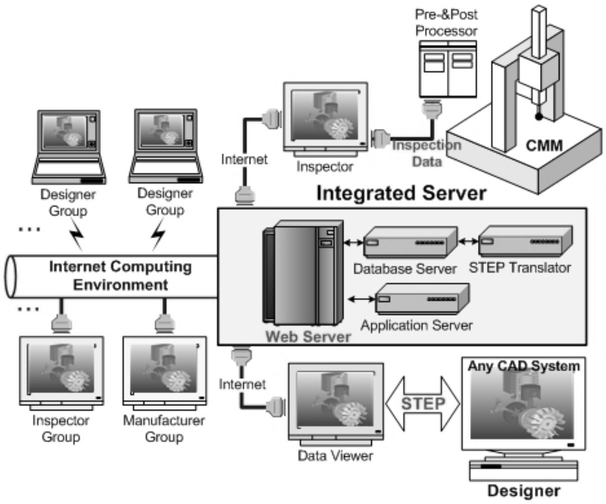


**Fig. 1** Architecture of web-based precision dimensional verification system.

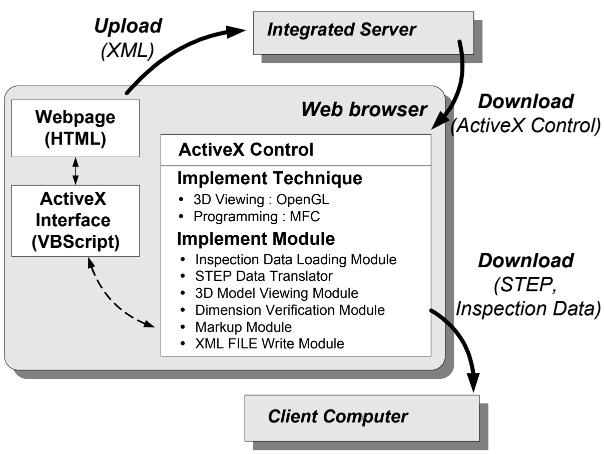


**Fig. 2** Configuration of client ActiveX for product verification system.

Developed client ActiveX of the verification system consists of five modules: (1) The inspection data loading module which loads inspection data files. (2) The CAD data translation module extracts features from the CAD/CAM system through the neutral data format of STEP. (3) The 3 dimensional viewing module using 3 dimensional viewing techniques developed by graphics library of Silicon Graphics. (4) The dimensional verification module classifies verification functions according to CAD objects by characterizing geometric entities for high precision dimensional verification. This module has an extensible architecture, so that measurement functions can be easily added to the system. (5) The XML file saving module contains markup and saving functions. Fig. 2 shows the configuration of the client ActiveX.

## 3. Creation Method of Inspection Data

Most measuring machines have their own data formats. However, a format of inspection data applied to this study is designed to recognize all kinds of formats including not only a format composed of geometric forms and 3 dimensional coordinate values, but also a format just composed of 3 dimensional coordinate information. In general, operators of measuring machines in the styling room know the shape of objects when they digitize clay models of a car. In order to sort digitizing data, they put tick marks between 3 dimensional coordinate values during digitizing processes. They also put tick marks to distinguish geometric features during the digitizing process. By using the above digitizing procedures designers' intention is included in the digitized data. If we inspect the measurement values through clicks of the displayed feature on a monitor, we can confirm the geometric features and verify the dimensions based on the digitized data. In order to be available to verify the dimensions, we put tick marks intentionally when the digitized 3 dimensional values have no tick marks.

## 4. Geometric Data Extraction through STEP

STEP Standard includes the product data covering the entire product life cycle and has a neutral format that is independent from any software packages and particular hardware platforms. The basic concept to extract geometric features and dimensional information depends upon the STEP physical file containing data instances according to the model schema.

For this purpose, a hierarchical approach is proposed to extract STEP data. Based on this structure, the extraction procedure analyses the STEP file from the highest level of CLOSE_SHELL to the lower level of CARTESIAN_POINT. To ensure the proper connectivity of different functional elements, all the associated pointers are traced in the same manner. Once the necessary data has been extracted from the STEP file, a set of equations representing the feature boundary is obtained. These equations are called boundary equation in [6].

## 5. Design Method of Dimensional Verification and Markup Module

Coordinate measurement function verifies 3 dimensional coordinate values of a point on the two-dimensional display by selecting a simple mouse click. Measurement of a line length means extraction of the length of line composed of points. The length between two points is measured by the distance difference of two points. Distance between lines is computed from the minimum distance between two lines obtained from least square fitting of point data. Radius of a circle is computed from a least square fitting of points making a circle. An angle and a curvature composed of 3 points are calculated from the 3-point angle and the radius of curvature. A distance between two circles is computed from the difference of two circle centers.

Mark up function makes sharing information possible between distributed verifiers. Using the mark up function someone on the Internet uploads his or her review messages to the displayed verification feature. Anyone who wants to review others' message about the verification views the mark ups by simple mouse clicks. Fig. 3 shows several mark up functions. Through the mark up functions design and manufacturing collaborations between designers, manufacturers and buyers are available in the distributed environment. They could not only share their opinions about the design but also verify dimension and geometry of the product. Fig. 3 shows available mark up functions. Using the mark up function someone defines his or her viewport and viewing vector on the reviews as well. In order to diversify the sharing of verification results XML file type is incorporated for the developed system. Separators are applied to distinguish dimensional verification results and mark up messages. New dimensional verification result or mark up message is included in the mark up file followed by a separator. In order to allow a lot of consultation from the clients, hyperlink function is also used in the mark up function. It is easy to expand the mark up file by using the separators and hyperlinks [8].

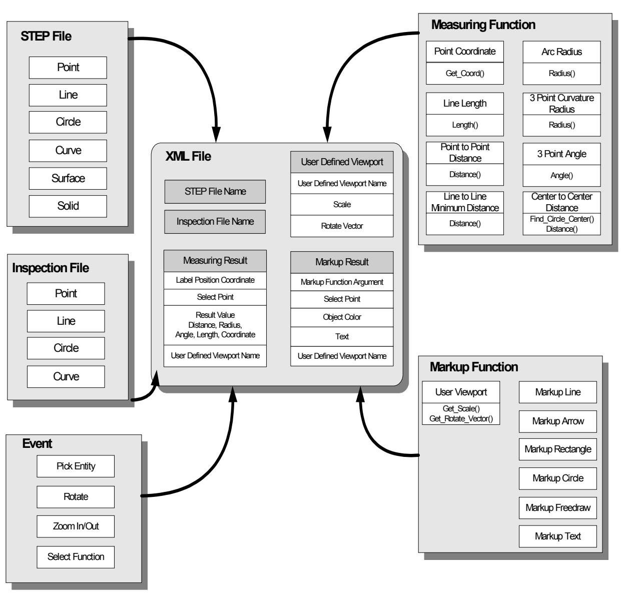


**Fig. 3** Architecture of web-based precision dimensional verification system.

## 6. Case Study

Fig. 4 shows a design and dimensional verification result. After measuring a clay model of a car door with a coordinate measuring machine and inputting a design data through the STEP translator, we can upload the results over the Internet as shown in Fig.4. Clients verify the intermediate design and fabrication result for a reverse engineering over the Internet.

After receiving authentication through the web page, clients such as designers, dimensional inspectors and buyers can get the permission to use the system. In order to start the system, they should input their names, affiliations and date on the starting window. If they select the search file mode, they can look at other clients review files. If they select a specific file, they can review the verification results through the execution of ActiveX.

Fig. 4 shows the dimensional verification according to the design result. From the STEP data the distance between points [A] and [B] of the car door panel is given by 449.002mm as [C]. If we select start point [A] and end point [B] after selecting icon to compute length between points, dimensional verification data of the door panel is given by length 449.150 mm as [D]. By comparing results [C] and [D], user can confirm the design and manufacturing errors. If the client does not satisfy the inspection result, he or she might leave verification message by using the mark up function.

Radius of curvature of a car door is an important human factor. By using the curvature measurement function, user can verify the design and manufacture results. After selecting curvature radius measurement icon, if user clicks points [E], [F] and [G] successively, radius of curvatures are obtained and calculated as 343.006mm of the STEP design result and 344.920mm of the fabrication result as shown in Fig. 4. User can verify the radius of curvatures of the design and fabricated ones.

Fig. 5 shows a design verification example. In this case, user defined viewport is managed by a viewport name specified by the tree structure as [A]. If user selects a viewport name in the treeview, a particular viewport with a specific viewing direction and zoom in/out window is appeared. User can look into the dimensional verification result and markup content as shown in [B] of Fig. 5. Circle and arrow existing in the mark up function as [C] deliver another verifier's message about the current design. Since this mark up function can be added on the verification file as a hyperlink function, clients deliver their opinion in detail and attach related documents and pictures as well.

After reviewing the mark up files written in XML files, the supervisor of the design and manufacture can modify the current design files or improve the current manufacturing processes through the reverse engineering procedure. He can also upload the improved new design and fabrication results on the Internet for the further reviews.

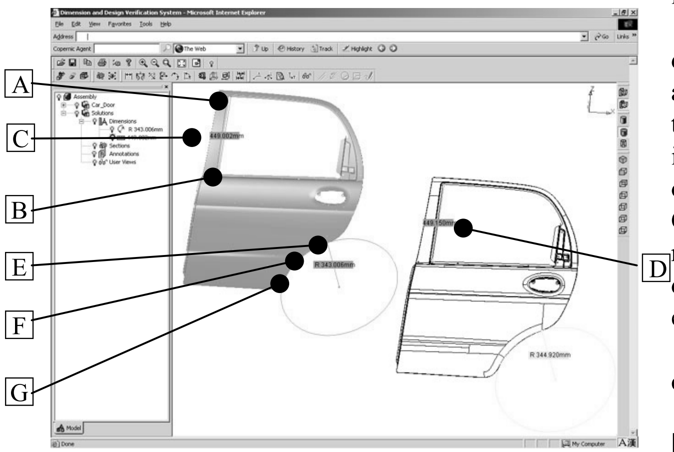


**Fig. 4** Case study of STEP and inspection data.

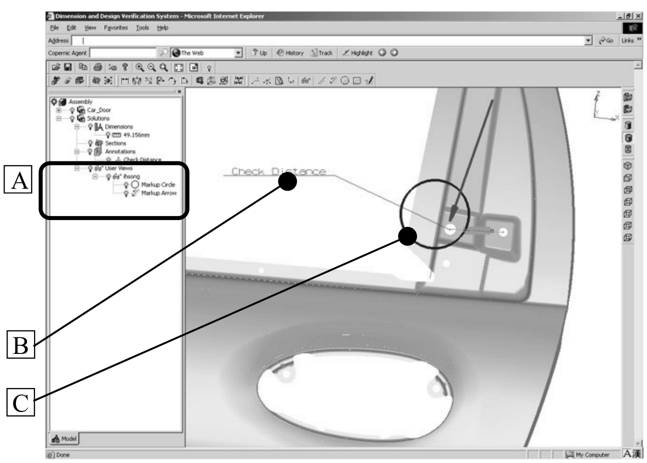


**Fig. 5** Case study of design verification.

## 7. Conclusions

A web-based precision dimensional verification system for rapid design and manufacture is proposed for the collaborative design and manufacture system.

In this system, inspection data and the STEP file are directly used for the verification without modification. It is possible to eliminate file conversion errors and confirm the robustness of the dimensional verification system. This also provides an effective evaluation mechanism to verify dimensions and geometries of the features displayed on the monitor.

By incorporating the mark up function to the system, dimensional verification results and mark up messages can be easily transferred between verifiers over the Internet. Using the developed hyperlink function and separators in the mark up function, clients can communicate a lot of documents and messages about the verification results each other. In order to expand the information sharing capability, XML file type is introduced to the mark up files.

As the system type is an open-architecture, additional dimensional and design verification functions could be added to the system. This system is an integrated tool that facilitates not only visualization of STEP and inspection data, but also other activities like verification of dimensions. Without the requirement of expensive CAD/CAM hardwares or softwares, users can enjoy a real-time shaded and animated view of their design and digitized models in the remote and distributed environment.

The usefulness of the developed systems has been confirmed through a car door case study.

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