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Viewing Technologies for CAD Models

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Abstract

This report describes Computer-Aided Design (CAD) model-viewing technologies[1] used to support CAD-model review and analysis. CAD model viewers are tools that allow engineers and other users to view CAD models from distributed locations, often using lightweight viewing applications, often supporting multiple CAD formats. These tools are typically less expensive, faster, and simpler to use than native CAD systems for model review. These features are especially important for small and medium-sized enterprises that can not typically support multiple native CAD systems. Additionally, considerations when choosing a viewing technology are described, as well as, popular CAD-model file formats that viewing technologies can import.

Introduction

Visualization solutions offer the possibility of expanding engineering data review and collaboration to the extended enterprise. These tools allow engineers and others involved in product development and review to view 3-dimensional (3D) models from distributed locations, often using lightweight viewing applications or a standard Web browser. Visualization solutions are also useful when multiple CAD systems are used throughout an organization, because many viewers support multiple CAD formats. Viewers allow every authorized member in the organization to deal with heterogeneity and visualizing designs from a variety of formats without running full-function CAD systems. Some viewers can enable design review meetings over the Internet by allowing project members to view and analyze a model concurrently while shifting control between members. Common functionality other than visualization over the network includes: markup, geometric measurement, extraction of inertial properties, and generation of cut views.

Visualization solutions are distinct from manipulation solutions in that manipulation solutions are typically native CAD systems that support changing the CAD model, as opposed to reviewing a model or a representation of the model. Visualization solutions are typically much less costly, faster, and simpler to use than native CAD systems, and are used to support model review and analysis.

Acknowledgement and purpose of this report

This report was funded by Pennsylvania's Technology Insertion Demonstration and Evaluation (TIDE) program. The TIDE program was established to accelerate the diffusion and adoption of advanced manufacturing technologies to help US manufacturers. The mission of the program is to identify barriers to adoption of technology within the community of smaller defense manufacturers and help that community overcome those barriers. One such barrier to adoption of tools supporting distributed, CAD-model review is an understanding of the characteristics of these tools, what formats they support, and other important considerations for a requirements review and product evaluation. CAD-model review tools are attractive because they offer the possibility of expanding engineering data review and collaboration to the extended enterprise. However, there is a broad range of CAD-model viewing tools on the market today with widely varying capabilities. Choosing an appropriate tool for a given situation requires an understanding of the functionalities these tools provide and deployment-specific requirements. This report addresses the identified barrier to adoption of distributed, CAD-model review tools by documenting tool characteristics with brief explanations of the functionality they provide, the various types of CAD-model formats, popular systems and specifications, as well as, issues to consider when performing a needs analysis and comparative product evaluation with the intent of acquiring a CAD-model viewing solution.

Background

There is a plethora of viewing technologies for CAD on the market today. These tools provide a broad range of functionality ranging from simple viewing of printer-formatted representations of CAD models to advanced operations such as data-management-systems queries, simulation, animation, fly-through, collision detection, assembly analysis, and so on. Viewer tools often allow users to rotate, zoom, section-view, measure, and markup 3D models or assemblies. CAD-system vendors generally offer viewers that are restricted to their CAD model format(s). These viewers are useful if there is only one CAD system being used in the extended enterprise. Independent viewers cover a variety of *file formats*[2] for 2D and 3D CAD and

[1] Any commercial product identified in this document is for the purpose of describing a software environment only. This identification does not imply any recommendation or endorsement by NIST; nor imply it is necessarily the best product available.

[2] A format for encoding information in a file. Each different type of file has a different file format. The file format specifies first whether the file is a binary or ASCII file, and second, how the information contained in the file is organized.

other documentation. Some independent viewers support more than 200 file formats.

Viewer tools typically provide good support for project review and verification activities, but may not support active, co-design activities adequately. Collaborative design activities, as opposed to product review, often require capabilities such as interaction with the CAD software to change the model (rather than merely view it), version control with associated design rationale at different levels of abstraction, and coordination provided a work flow management system using a product realization process manager. These capabilities are more extensive than most viewing technologies provide.

Viewing technology capabilities

This section provides a brief overview of the various capabilities that a viewing technology may provide.

- viewing – presentation of a computer-generated, graphical image
- mark-up – drawing and annotation feature (sometimes called “redlining,” however redlining is being subsumed by mark-up capabilities)
- rotate – changes the perspective of the view of an object
- scale – changes the size of an object while maintaining its shape
- mirror – produces a mirror image of the object
- pan – changes the viewed area while maintaining a fixed perspective for the viewer
- zoom – enlarges the view of an object enabling the user to see more detail
- section-view – creates sections of an assembly to view separately
- edit – typically provides the ability to change appearance features of a drawing, such as line color
- print – creates text or illustrations on paper via a printer
- plot – produces an image by drawing lines, either on a display screen or on paper
- publish – exports formats of views in web and other publishing formats
- geometric measurement – measurement capabilities between geometric entities in the model
- model comparison – compares revisions between two models and highlights the differences
- extraction of inertial properties – e.g., mass properties
- cut view or cross-section – produces a cross-section view of an object
- data-management-system queries - users can access and view product data, typically in context with the visual model
- access control – mechanisms to restrict or grant access to specified model elements or files
- document management – mechanisms to organize various documents and files related to a product or other entity
- simulation – the process of imitating a real phenomenon with a set of mathematical formulas
- animation – a simulation of movement created by displaying a series of pictures or frames
- fly-through – real-time changes to the viewed area by creating the impression of moving through the object space
- collision detection – Computer-Aided Engineering (CAE) function used to detect interference issues
- assembly analysis – CAE functions used to provide assessment of the behavior of the design
- conversion or translation – export to a different file format (some data loss may occur depending on the type of conversion)

Needs analysis and product evaluation

Choosing the best fit

When choosing a viewing/visualization technology, an enterprise needs to determine its needs first, and then the ability of each candidate application to meet those needs. The most important issues are what CAD formats need to be supported and who will use the technology. Relative to this latter issue, engineers need specific capabilities that are often found in more advanced features of visualization tools, whereas others may need an easy-to-use, viewing tool. Requirements gathering efforts should also include a list of database and process applications that must be accessed from the viewing/visualization technology. Questions that should be addressed during a requirements-gathering effort include:

- What CAD formats need to be viewed?
- Who needs to view the CAD models?
- What capabilities are required? (See list in previous section)

- What types of computers will the software run on?
- What is the file size of a typical CAD model to be viewed?
- Does sufficient communication capacity to move the CAD data exist?
- As the viewing technology becomes more valuable to the organization, can it be (easily) integrated with other IT systems? Do the relevant technologies have open application protocol interfaces (APIs)?
- What are the viewing management requirements, such as confidentiality and access control during design review?
- Are customizable interfaces required or anticipated?

Integration issues

As mentioned in the previous section, when choosing a viewing technology, it is important to realize that the functionality the viewing technology affords may become embedded in and change various business processes. Therefore, attention should be given to these candidate business processes and viewing technologies with future integration issues in mind. For instance, do all the existing and candidate technologies involved have open APIs? Changing business processes calls for the review of the ability of legacy and candidate systems to meet new needs.

Future

Currently there are many existing and evolving technologies that meet niche market needs. However, while new capabilities and technologies evolve and new commercial arrangements emerge, a fluid state of product offerings is likely to be the norm. In this changing market place, users of these technologies should identify their current and future needs and strive to find solutions that meet those needs, with the expectation that comparative product evaluations are unlikely to be valid for more than a year.

The following sections of the report describe popular CAD model formats.

Model Formats

CAD models are stored in many different formats. The main reason is that different CAD systems have their own, often proprietary, model formats. These formats are typically rich in information beyond the model's geometry data, including such information as design intent, design history, constraint information, and so on. Examples of "native" CAD formats include CATIA, Pro-Engineer, and I-DEAS.

Additionally, some formats have evolved, have been developed, or have been co-opted as exchange formats between various CAD systems and other applications. These formats do not contain all the information that native formats contain, however, they have the desirable property of conveying a representation of the CAD data to other applications. Examples include:

- Three-dimensional, solid-shape, data exchange with a kernel-based data format is often supported and used between CAD products that utilize the same modeling kernel
- Neutral (non-proprietary) specifications for shape and product data exchange such as IGES[3] and STEP[4]
- Computer graphics technology that is used to view three-dimensional images, including 3D representations of CAD data, such as 3D Studio.

In response to the urgent need of solving parametric CAD data interchange problems, many services and translators have sprung up providing exchange of product data including feature, history and constraint information, with proprietary technologies. Although translation solutions are an important option for exchanging product data between CAD and other engineering and business systems, they are only pertinent to this discussion of viewing technologies when a viewer is not available for a particular CAD format. Fortunately, this is not the typical case, as viewing technology vendors have embraced a plethora of model formats. Furthermore, as noted above, some viewing solutions support more than 200 formats.[5] Additionally,

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[3] Initial Graphics Exchange Specification (IGES) – see the section on Exchange Specifications for further information.
[4] STandard for the Exchange of Product model data (STEP) – see the section on Exchange Specifications for further information.
[5] Although some products claim to support a large number of formats, often these supported formats are not CAD model formats, but are other document formats, e.g., CompuServe Graphics Exchange Format (GIF), Encapsulated PostScript (EPS), MacPaint (MACPNT), Microsoft Windows 3.1 Icon (ICO), Microsoft Windows Bitmap (BMP), and so on. Care should be exercised to identify requirements and application capabilities.

most CAD system vendors provide a free viewing solution for their model formats.

Native CAD formats

This section lists popular, native CAD systems. The company name is given parenthetically after the product name. Some of these systems support additional capabilities, such Computer-Aided Manufacturing (CAM) and CAE. These capabilities are identified in the *system type* item for each product, however, it should be noted that some systems have additional modules that can perform these functions and that system packaging is subject to change. Additionally, it is often helpful to know what type of modeling kernel is used by a CAD system, as this characteristic often has implications for the format in which the native model is stored, and hence, can be viewed. This information is given in the *kernel* item for each product. A proprietary kernel typically writes a proprietary CAD model file format. Each system has one or more file formats – designated in the *file extension* item for each product. It should be noted that while most CAD systems can export model representations in other formats, the native format file extensions are listed in this document. Other file formats are given in the following sections.

- AutoCAD Inventor (Autodesk)
  System type: CAD
  Brief description: A suite of components to do 2D and 3D design for the manufacturing industry. The suite includes Autodesk® Mechanical Desktop® for 2D design and Autodesk Inventor™ for 3D design.
  Kernel: proprietary
  File extension: .ipt, .iam, .idw, .dwf

- AutoCAD Mechanical (Autodesk)
  System type: CAD
  Brief description: The AutoCAD solution for 2D mechanical design and engineering.
  Kernel: proprietary
  File extension: .dwg, .dwf

- CADDS 5 (PTC)
  System type: CAD/Computer-Aided Manufacturing (CAM)
  Brief description: CADDS 5 is a CAD/CAM suite that is based on a hybrid, concurrent engineering architecture, allowing large groups of engineers to simultaneously design, validate, and machine the same product assembly.
  Kernel: PTC hybrid kernel (proprietary)
  File extension:

- CATIA (Dassault Systemes)
  System type: CAD/CAM/Computer-Aided Engineering (CAE)
  Brief description: CATIA is a family of CAD/CAM/CAE software solutions for product lifecycle management developed by Dassault Systemes and marketed, distributed and supported by IBM. There are many compatible modules in the CATIA family to meet various computer-aided design, manufacturing, and engineering goals including data management for digital product definition and simulation.
  Kernel: proprietary
  File extension: model, export

- ICEM DDN (PTC)
  System type: CAD/CAM
  Brief description: ICEM DDN is a 3D CAD/CAM system for a large range of applications, from 2D design and drafting to complex surface and solid modeling. DDN stands for Design Drafting Numerical Control.
  Kernel: proprietary, based on ACIS[6]
  File extension:

- I-DEAS (EDS)
  System type: CAD/CAM/CAE
  Main use: Applications using master product models to enhance innovation.

[6] A geometric-modeling kernel – see the next section for additional information.

Brief description: I-deas, part of the Unigraphics suite, is a CAD/CAM/CAE solution. This product purports to support the facilities to develop digital master product models, with the assumption that this concept will better support understanding products from a "manufacturability" standpoint during the early design stage.
Kernel: proprietary
File extension: .mca, .idi, .idz

- IronCAD (Ironcad)
  System type: CAD
  Brief description: Solid modeling software for mechanical designers and engineers. IronCAD provides an alternative to history-based, parametric systems, utilizing a drag and drop 3D environment with Direct Face Modeling that provides design flexibility with the ability to generate fully associative manufacturing drawings.
  Kernel: proprietary
  File extension: .ics, .icd, .icc

- MicroStation (Bentley)
  System type: CAD
  Brief description: MicroStation is the foundation of Bentley's CAD solutions. Discipline-specific applications are available for civil engineering, transportation, process plants, discrete manufacturing facilities, utilities, and telecommunication networks.
  Kernel: proprietary
  File extension: .dgn, .cel, .svf

- Pro-Engineer (PTC)
  System type: CAD/CAM
  Brief description: A 3D product development solution, spanning the product development process, from creative concept through detailed product definition to serviceability.
  Kernel: Pro-Engineer (proprietary)
  File extension: .prt, .asm, .frm, .drw

- Solid Edge (EDS)
  System type: CAD
  Brief description: Solid Edge is a 3D CAD system for mechanical design. Associated tools are focused on supporting machinery design and sheet metal industries.
  Kernel: Parasolid[7]
  File extension: .dft, .par, .asm

- SolidWorks (subsidiary of Dassault Systemes)
  System type: CAD/CAE
  Brief description: SolidWorks offers solid modeling and 2D drawing capabilities, as well as, web publishing, animation tools, and photorealistic image generation features.
  Kernel: Parasolid[7]
  File extension: .sldprt, .sldasm

- Unigraphics (EDS)
  System type: CAD/CAM/CAE
  Brief description: Manufacturers can use Unigraphics to perform conceptual, industrial, and detailed mechanical design, along with engineering simulation and digital manufacturing.
  Kernel: Parasolid[7]
  File extension: .prt

Geometric-modeling kernel formats

A geometric modeling kernel lies at the heart of every commercially available, 3D-modeling application. A kernel is the library of core mathematical functions that the CAD system uses to define and store 3D shapes in response to users' commands. The kernel processes the commands, stores the results, and submits the output for display. There are basically three types of licensing arrangements for geometric modeling kernels: licensed, proprietary, and open source. Licensed, geometric-modeling kernels are developed and maintained by one company and then licensed to other companies for use in their CAD applications. Proprietary, geometric-modeling kernels are developed and maintained by a CAD application developer for use solely within its application. Open-source, geometric-modeling kernels are similar to licensed kernels. They are developed and maintained by one company and then licensed to other companies for use in CAD applications.

- ACIS (Spatial, a subsidiary of Dassault Systemes)
  System type: Licensed geometric-modeling kernel
  Brief description: ACIS®, is the de facto 3D solid modeling foundation for a variety of 3D products[7], including CAD/CAM/CAE, animation, and shipbuilding. ACIS was the initial offering in 3D-modeling component technology. Newer versions of ACIS bundle components to give software developers various types of functionality from which to build applications, such as blending, local operations, precise hidden line, shelling, space warping, advanced surfacing, cellular topology, and a visualization manager.
  File extension: .sat, .sab

- Open CASCADE (Matra Datavision)
  System type: Open source geometric-modeling kernel
  Brief description: Open CASCADE is a set of reusable C++ libraries and development tools for the development of 3D modeling applications. The majority of Open Cascade is available as open source. This means that the source code is publicly available for software developers to use and modify. Some specialty components are available for purchase.
  File extension: .brep

- Parasolid (EDS)
  System type: Licensed geometric-modeling kernel
  Brief description: Originally designed for high-end, mechanical CAD applications, Parasolid is now used in a wide diversity of mid-range systems. Parasolid is currently the fastest growing modeler available for license by MCAD developers, according to its developer, UGS (now EDS). Parasolid provides technology for solid modeling, generalized cellular modeling, and integrated free-form surface and sheet modeling.
  File extension: .x_t, .x_b

- SMLib (Solid Modeling Solutions)
  System type: Open source geometric-modeling kernel
  Brief description: SMLib from Solid Modeling Solutions is a set of Non-Uniform Rational B-Splines (NURBS) -based geometry and topology libraries that have been on the market for seven years and are used by more than 200 companies and universities. With integrated, nonmanifold-topology capability, SMLib includes a set of NURBS curve and surface modeling functions as well as code for object-to-object distance measurements and ray firing.
  File extension: .iwp, .iwb, .pbp

- Thinkdesign (think3, Inc.)
  System type: Proprietary geometric-modeling kernel
  Brief description: A shape-based, single-environment kernel. The architecture gives designers parametric solids, advanced surfacing, wire frame, and 2D drafting in a single CAD system. The nonmanifold topology of the thinkdesign kernel provides the ability to mix surfaces and solids, import and use imperfect 3D geometry, integrate 2D drawings into the 3D database, and provide diagnostic information in the event a solid modeling operation cannot be completed. The kernel can also assign variable tolerances to different geometric entities.
  File extension: .e3, .e2

- VX Overdrive (Varimetrix Corp.)
  System type: Proprietary geometric-modeling kernel format
  Brief description: VX Overdrive is an engine that provides 3D, hybrid-modeling capabilities and enterprise-level tools. VX Overdrive is a hybrid system that combines features of solid and free-form surface modeling. The system supports functions such as concurrent engineering, object versioning, history control, filleting/blending, undo/redo, and in-context modeling of assemblies.
  File extension: .vx

[7] http://www.wave-report.com/1999%20Wave%20issues/wave9070.html

Exchange specifications for CAD data

Exchange specifications are neutral (non-proprietary) specifications for shape and product data exchange. Relevant specifications for CAD-model exchange include the following:

- IGES – American National Standards Institute (ANSI) Y14.26M
  System type: exchange specification
  Brief description: Initial Graphics Exchange Specification (IGES) is a specification enabling the transfer of two- and three-dimensional drawing data, in a fixed-file format, in an electronic form. Although IGES serves its purpose of exchanging CAD data between different CAD systems, limitations of the standard include: lack of upward compatibility due to the fixed file format and, most importantly, the restriction of information exchange to shape data only rather than covering complete product data. Implementation problems include handling large file sizes and long processing times. Despite these limitations, IGES is supported by most CAD products and is widely used for CAD data exchange [1].
  File extension: .iges, .igs

- SET – Standard d'Echange et de Transfert
  System type: exchange specification
  Brief description: SET was designed to address the difficulties in using IGES. The initial drivers for the effort were the automotive and aerospace industries. SET version 1.1 was contributed toward the STEP standardization activity [2] (see below).
  File extension: .set

- STEP AP203 – International Standards Organization (ISO) 10303-203
  System type: exchange specification
  Brief description: STEP (STandard for the Exchange of Product model data) is a set of standards for complete product data definition and exchange under the international standard ISO 10303. STEP specifications are realized as application protocols (APs). STEP AP203 - Configuration Controlled Design - supports the transfer of 3D CAD models, specifically advanced boundary-representation (b-rep) solids, basic wireframe, assembly information, and configuration management data--such as product I.D., version and description. STEP uses an ASCII-based file serialization format (STEP part 21) that is human readable. STEP AP203 is widely implemented. Almost all major CAD systems will accept this format [3].
  File extension: .stp, .step

- STEP AP214 – ISO 10303-214
  System type: exchange specification
  Brief description: STEP (STandard for the Exchange of Product model data) is a set of standards for complete product data definition and exchange under the international standard ISO 10303. STEP specifications are realized as application protocols (APs). STEP AP214 - Core Data for Automotive Mechanical Design Processes - supports the transfer of geometry data as well as design features, tolerances, 2d drawings and the STEP product data management schema. AP203 and AP214 geometry are essentially identical.
  File extension: .stp, .step

- VDAFS – Flachenschnittstelle des Verbands der deutschen Automobilindustre
  System type: exchange specification
  Brief description: VDAFS is used by the German Motor Manufacturers Association (VDA) to exchange 3D CAD model data, specifically free form surfaces and free form curves needed by the automobile industry [2]. VDAFS was published as a German national standard in 1986. A number of automotive manufacturers and suppliers throughout Europe use the standard to exchange surface data used in the design of automotive tooling and components such as body parts, injection molded parts, seats, panels, and so on.
  File extension: .vda

Other file formats relevant to the exchange of graphics data

- BMP (Bit Map)
  System type: graphics file format

Main use: bit-mapped or raster graphics file format for the Windows environment
Brief description: The standard, bit-mapped, graphics format used in the Windows environment. Bit maps are representations of graphics images, consisting of rows and columns of dots, of a graphics image in computer memory. The value of each dot (whether it is filled in or not) is stored in one or more bits of data. For simple, monochrome images, one bit is sufficient to represent each dot; but, for colors and shades of gray, each dot requires more than one bit of data. The more bits used to represent a dot, the more colors and shades of gray that can be represented. Bit-mapped graphics are also referred to as raster graphics.
File extension: .bmp

- CGM (Computer Graphics Metafile)
  System type: graphics file format
  Main use: vector graphics file format
  Brief description: CGM is a graphics data interchange standard that defines a neutral computer-interpretable representation of 2D graphical (pictorial) information in a manner that is independent from any particular application or system. The purpose of the standard is to facilitate the storage and retrieval of graphical information between applications, software systems, and/or devices.
  File extension: .cgm

- GIF (Graphics Interchange Format)
  System type: graphics file format
  Main use: scanned photos, World Wide Web graphics
  Brief description: a bit-mapped graphics file format used by the World Wide Web, CompuServe and many Bulletin Board Systems. GIF supports color and various resolutions. It also includes data compression, making it especially effective for scanned photos.
  File extension: .gif

- HPGL (Hewlett-Packard Graphics Language)
  System type: page description language
  Main use: printers and plotters
  Brief description: a set of commands for controlling plotters and printers. HPGL is part of Hewlett-Packard's PCL Level 5 page description language. PCL stands for Printer Control Language, the page description language (PDL) developed by Hewlett Packard and used in many of their laser and ink-jet printers.
  File extension: .hgl, .hpg, .plt, .prn

- JPEG (Joint Photographic Experts Group)
  System type: graphics file format, color photos
  Main use: color photos, World Wide Web graphics
  Brief description: JPEG is a lossy compression technique and file format for color images. Although the technique can reduce files sizes to about 5% of their normal size, some detail is lost in the compression. Lossy compression is a data compression technique in which some amount of data is lost. This type of compression technology attempts to eliminate redundant or unnecessary information.
  File extension: .jpg, .jpeg

- STL (Stereolithography)
  System type: file format
  Main use: 3D printers and rapid prototyping machines
  Brief description: The STL (stereolithography) file format is commonly used on most 3D printers and rapid prototyping machines. It can be exported from many CAD packages.
  File extension: .stl

- TIFF (Tagged Image File Format)
  System type: graphics file format
  Main use: high resolution graphics
  Brief description: TIFF is a file format for storing bit-mapped images. TIFF graphics can be any resolution, and they can be black and white, gray-scaled, or color.

File extension: .tif, .tiff

- VRML (Virtual Reality Modeling Language)
  System type: modeling language
  Main use: create "virtual worlds" accessible via the World Wide Web
  Brief description: VRML allows creation of "virtual worlds" networked via the Internet and hyperlinked with the World Wide Web. Aspects of virtual-world display, interaction and internetworking can be specified using VRML without being dependent on special gear, like head-mounted devices (HMD). It is the intention of its designers to develop VRML as the standard language for interactive simulation within the World Wide Web. Additional information can be found at http://www.w3.org/MarkUp/VRML/.
  File extension: .wrl

Visualization middleware

Computer-graphics tool sets have been developed for assisting computer programmers in displaying images in end-user applications. This type of tool set is categorized as "middleware" in the computer industry. Some of these tool sets have been used for developing applications for displaying CAD models. Examples of these technologies include:

- EON Studio (EON Reality), is a graphical-user interface (GUI) based tool for developing real-time 3D multimedia applications focused on E-commerce/marketing, E-learning/training and Architecture. The development process includes importing different 3D objects, usually originating from different modeling tools like 3D Studio, Lightscape etc., or from different CAD systems such as ArchiCAD, ProE, or CATIA. Once imported, behaviors can be associated with the models through EON's graphical programming interface, scripting or compiled C++ code. Simulations can also be integrated in other tools like Powerpoint, Word, Macromedia Authorware, Director, Shockwave, Visual Basic, etc.

- Immersive Design's IPA (Interactive Product Animator) - IPA is the communication tool for Pro/ENGINEER, Unigraphics, I-DEAS, SolidWorks, and Solid Edge, that provides product information across the enterprise in the form of highly visual full motion animations. The animations are compatible with Microsoft applications, and can be embedded in documents, presentations, and Hyper-Text Mark-up Language (HTML) pages.

- Autodesk VIZ (Autodesk) - Formerly 3D Studio VIZ. With its technological roots in 3ds max™[8], Autodesk VIZ provides tools for digital creation and output. Combined with the latest global illumination rendering capabilities, these tools provide a rendering for rich images that help predict what a design will look like under various lighting conditions.

Concluding statements

Visualization solutions offer the possibility of expanding engineering data review and collaboration to the extended enterprise. These tools allow engineers and others involved in product development and review to view 3D models from distributed locations, often using lightweight viewing applications or a standard Web browser. Visualization solutions are also useful when multiple CAD systems are used throughout an organization, because many viewers support multiple CAD formats.

Currently, there are many existing and evolving technologies that meet niche market needs. This situation is very fluid as new firms, new commercial arrangements, and new technologies and capabilities continue to emerge. In this changing market place, users of these technologies should identify their current and future needs and strive to find solutions that meet those needs, with the expectation of that comparative product evaluations are unlikely to be valid for more than a year. To facilitate that evaluation, this paper provides guidelines that can be used by the community of smaller manufacturers facing such an evaluation task.

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