Developing the Next Generation of Metrology Software

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EXECUTIVE SUMMARY

Competition in the CMM (coordinate measuring machine) market, and the metrology industry as a whole, is fierce. Manufacturers continue to push software vendors to do more, faster. And it's not always just about doing more, but also keeping up with technology trends. How will CMMs connect to the cloud? How can CMM software further automate the inspection process? Should measurement technology be "connected" to the IoT (Internet of Things)?

Leveraging the right toolkits to build metrology software that is robust enough to meet today's current demands, but also flexible enough to adapt to these technology trends over time, is critical to the success of a CMM company. A variety of third-party tools exist to read CAD data, perform complicated mathematical analysis, visualize the results and produce informative reports. But is that enough? What good is an analysis of data if the data itself isn't accurate?

In this paper we explore what's driving manufacturers to make their product development processes as efficient as possible, including getting measurement and inspection as close as they possibly can to the actual manufacturing of the product, technology trends such as cloud and IoT and how to deal with them, and reliable technology solutions that are available today.

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Dependable. Dynamic. Durable.

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BACKGROUND

For decades, manufactures have sought ways to make their product development processes as efficient as possible, because efficiency means higher productivity, reduced costs and increased profits. In the CMM market specifically, research shows that manufacturers are looking to move measurement and inspection as close as possible to the actual manufacturing of the product to detect defects earlier. Facilities are automating inspections with the use of optical measurement devices to increase the frequency and accuracy of inspections.

Cambashi Limited, the leading market research firm for manufacturing software, sees the manufacturing industry buying better software, adding new (largely non-contact) sensors to their systems, implementing scanners on robots and moving toward using generic software across their businesses. This is accelerating the growth of metrology software to an estimated 7.1% annually.

Additionally, manufacturers are now required to manufacture and inspect from a multitude of CAD file types from a variety of CAD applications. These trends are requiring that a large variety of CAD formats be natively read, more inspection data be processed and that it be done in a real-time environment.

These developments are driving CMM companies to add more and more functionality into their products making them increasingly more powerful and complex. With new technology trends and new business models, barriers to both entry and exit have never been lower, and users expect to be able to get up and running with a product quickly.

And as new technologies and trends are emerging – such as connectivity (IoT) and data sharing over the cloud, interactive 3D PDFs and mobile computing – CMM companies must develop strategies around these technologies *now* if they want to remain competitive.

Companies are re-architecting or developing new software and are looking for best-in-class tools to do so rapidly. With limited resources, existing technology must be leveraged to avoid downtime or any loss of productivity. There are a number of software development toolkits (SDKs) available with varying degrees of performance, features and stability.

In this paper, we answer the question − What is needed to power the next generation of metrology software?

QUALITY DATA ACCESS IS CRITICAL

Metrology software must rapidly compare measured points from a multi-axis probe, vision system or laser scanner to the surfaces described in the original CAD file. Accurate measurement requires access to good data. This is impossible if the CAD data to which it is compared to is inaccurate. Good data is ground zero for good CMM.

CMM operators, and the software they use, process files authored in multiple CAD systems. CMM software needs to load more than the interoperable CAD standards of STEP, IGES and JT. It must quickly, accurately and natively support file formats from the large variety of CAD vendors in the market including CATIA, SOLIDWORKS®, Creo (Pro/E), NX™, Inventor™ and Solid Edge.

Not all SDKs are created equal, and a careful evaluation of each toolkit's strengths and weaknesses is necessary. Some toolkits support a subset of the available file formats. Some support a large range of formats, but each with different levels of quality.

Each CAD format is complex and contains assembly structure, BREP, product manufacturing information (PMI) and metadata. This information is read by the SDK from the original CAD file, placed in data structures and then accessed through the toolkit.

Boundary Representation (BREP)

A common way to mathematically define a solid as a collection of connected surfaces.

In most SDKs, analytic surface types like planes, cylinders, and tori (common to all CAD systems) are presented in the toolkit exactly as they are in the CAD file. However, some CAD systems have specific surfaces that the SDK may not be able to accurately represent within its data structures.

Most SDKs **translate** any surface that it can't represent into a form that it can. For instance, a CATIA radial blend surface may be approximated as a B-spline surface. Many times there are additional translation steps to convert the surfaces into a form that conforms to the SDK's internal requirements. These steps are invisible to the user and can further alter the data.

Translation of any kind can introduce several problems:

- **Loss of accuracy** – With each conversion, even though the resultant surface may be within a specified tolerance, any measurement done from it will not be exact. Precision is critical for CMM workflows.
- **Poor data integrity** – Translation can introduce complications to the workflow and possibly errors or even failures. The simpler the workflow, the higher rate of success in importing and working with the data.
- **Performance degradation** – Conversion takes time and can multiply with increased tolerance. Despite the fact that CAD files and assemblies are getting increasingly larger and more complex, users are demanding that data access be quicker than ever. File load performance is now even more critical to a positive user experience.

HOOPS Exchange gives you Read access to the following formats:

CAD Format	Tessellation	B-Rep	PMI
ACIS®	•	•	◦
Autodesk Inventor®	•	•	◦
CATIA® V4	•	•	•
CATIA V5	•	•	•
CATIA V6	•	•	•
Creo™ Parametric	•	•	•
I-deas	•	•	•
IGES	•	•	◦
Industry Foundation Classes (IFC)	•	◦	◦
JT	•	•	•
Parasolid®	•	•	◦
PDF	•	•	•
PRC	•	•	•
Pro/Engineer®	•	•	•
Rhino	•	•	◦
Siemens PLM Software's NX™	•	•	•
Solid Edge®	•	•	•
SolidWorks®	•	•	•
STEP	•	•	•
Stereo Lithography (STL)	•	◦	◦
VDA-FS	•	•	◦
Universal 3D	•	◦	◦
VRML	•	◦	◦

• = supported
◦ = this concept is not supported by this format
• = not currently supported

For metrology unaltered, native data is desirable. A powerful alternative to data translation is to use an SDK that provides data ***access*****.** This differs from data translation, in that whatever is in the original CAD file is presented in the SDK, both analytic surfaces as well as unique surface types. This is fast, efficient and accurate. You get access to the original data precisely as it was in the CAD file without altering the data.

HOOPS Exchange is a premium data access toolkit with broad format support (more than 20 file formats) providing direct access to all native surface types, topology and PMI. GOM, highly regarded in the automotive and aerospace industries, saw the benefit of using HOOPS Exchange. GOM is known for precision in their industries where there can be ***no compromise on quality***. With this reputation, GOM chose to use HOOPS Exchange as the CAD file reading technology for their next generation of inspection software. HOOPS Exchange delivers the quality solution required and provides a foundation for GOM to build upon for decades to come. This includes soon supporting CAD access natively on mobile devices. With mobile displays being imbedded or tightly coupled with scanners, error detection can be done remotely and instantaneously.

MODELER WORKFLOWS

Metrology workflows demand mathematically intensive operations. Points collected from the measuring instrument are aligned to the original CAD data. The points are then projected to the nearest surface or edge and the nearest distance is calculated. CMM software will frequently employ a solid modeler, also known as a geometric modeling engine, to accomplish these tasks and more.

Connecting to Commercial Solid Modelers

Frequently the Siemens Parasolid and Dassault Systems ACIS modeling kernels, and to a lesser degree IntegrityWare Solids++ and OPEN CASCADE kernels, are used within a CMM application to supply the needed mathematical tools. These geometric modelers are proven technologies with rich feature sets and years of sustained stability.

Getting data quickly and accurately into these modelers is critical. This is why data access toolkits, such as HOOPS Exchange, are preferable over data translation toolkits.

Parasolid is the world's leading 3D solid modeling component software and is the basis of some of the world's most popular CAD applications including SOLIDWORKS, NX, Solid Edge and Onshape. These applications store critical Parasolid data within their unique file formats. Additionally, analysis, rapid prototyping, reverse engineering, CAM and metrology companies use Parasolid as the mathematical core for their applications. This has added to the prevalence of Parasolid data throughout the engineering supply chain.

An integration between the market-leading HOOPS Exchange technology and Siemens Parasolid software helps developers enhance data reuse within Parasolid by providing easy access to a broad range of CAD formats. Tech Soft 3D worked closely with Siemens PLM Software to deliver an integrated product that helps developers leverage the full breadth of Parasolid functionality, even when working with imported data.

The integration accomplishes this in a few key ways:

- Models of any supported format are loaded into Parasolid through a single API.
- All CAD applications based on Parasolid, including applications such as NX, Solid Edge and SOLIDWORKS have geometry natively imported without any kind of translation, so data remains pristine. This ensures the best possible success rate.
- For file formats not based on Parasolid, the integration uses advanced functionality within Parasolid to map the CAD data format to a valid Parasolid model. This phase resolves issues such as inconsistent tolerances, sliver faces and geometric discontinuities, and enables a set of surfaces to be sewn into a single, watertight solid.

Additionally, HOOPS Exchange precisely imports other important data including advanced assembly and configuration information, PMI, views and other metadata, giving users access to clean and complete data they can preserve for downstream use.

Data access through HOOPS Exchange can be used with any solid modeler. SAT and STEP file export facilitate easy transfer through stand-alone files. The HOOPS Exchange application interface (API) also allows developers to programmatically access data and transfer it into any modelling kernel.

Connecting to Internally Developed Solid Modelers

However, many times CMM software developers find that an entire solid modeling kernel may not be needed within their application. Commercial solid modelers contain a broad range of features and are the basis for entire mechanical CAD applications. A CMM developer may instead choose to build their own metrology specific modeling routines.

Importing data accurately and efficiently into an internally developed modeling engine is a high priority for these applications. Many times the format of the data must be adapted into a form that the internal modeling engine can accept. This massaging of the BREP can be complicated, slow and prone to error.

HOOPS Exchange has a rich set of tools that efficiently adapts BREP to the needs of the internal modeling kernel. This includes a set of tools to convert curves and surfaces between parametric and 3D space, split periodic surfaces and convert curves and surfaces to B-splines.

Users of metrology applications are pushing developers to improve the performance and accuracy of their file import as well as support a larger number of CAD formats. Using HOOPS Exchange to supplement or replace the existing file reading routines within an application is an easy, low risk way to improve the overall performance and functionality of an application.

CMM without a Solid Modeler

Many applications do not require the full functionality of a solid modeler and the modeling capabilities of HOOPS Exchange may be sufficient for what that application needs to do. Several metrology companies are choosing to do this in their next generation of software. HOOPS Exchange provides direct access to the native BREP surfaces without conversion. It contains native evaluators for each format and does not require translation into an intermediate form. This gives fast, true access to the surface data.

The growing use of non-contact sensors, capable of acquiring over a hundred thousand points per second, is rapidly generating more and more inspection data. Software containing powerful point projection is vital to keep up with the mass of data being generated. HOOPS Exchange contains a high performance multi-threaded point projection engine capable of keeping up with the immense amount of data being acquired. Additionally, HOOPS Exchange covers critical metrology modeling needs including calculating cross sections, moving trimming curves between 3D and parameter space, and tessellating surfaces for visualization.

Using HOOPS Exchange has benefits beyond providing superior data quality. Time is saved when limiting the number of steps data must go through when loaded into a modeler. Similarly, performance is even faster when no modeling kernel is used and the native HOOPS Exchange evaluators and point projection functions are used instead. One major metrology company who stopped using a modeling kernel in favor of HOOPS Exchange was amazed by the reduced memory and improved speed when loading and processing files.

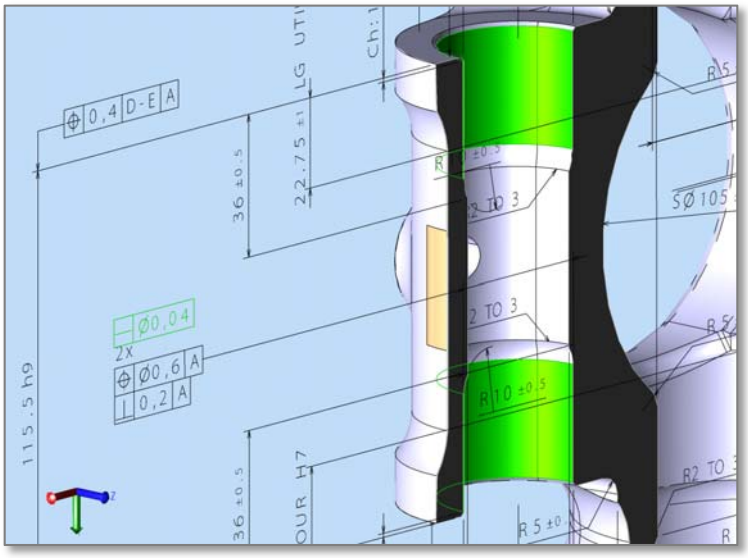
HOOPS Exchange is the most powerful and versatile tool on the market for data access and reuse. It allows you to quickly and easily get data into a commercial or internally developed modeler. It can even take the place of a solid modeler with built-in metrology focused functionality.

RICH PMI SUPPORT

In response to the growing popularity of model based design (MBD), most major CAD applications contain tools to fully annotate a 3D model with product manufacturing information (PMI), including geometric dimensions and tolerances (GD&T). This important information ensures products are manufactured to specification. PMI attached to the 3D model contains the geometric dimensions and tolerances used to verify that key features have been correctly manufactured. PMI can also be used to automatically generate an inspection program for the CMM to execute.

Semantic PMI is presented as a set of data structures that can be programmatically interpreted. Semantic PMI is displayed to the user, included in reports, and is used to create automatic measurement plans. Implementing accurate semantic PMI across all file formats is becoming standard in the next-generation of metrology software to facilitate automated inspection plan creation. Semantic PMI must be 100% accurate, as it is a critical basis for this workflow.

PMI is also a visual language, meaning that it is meant to be viewed, interpreted and acted upon by a human operator. **Visual PMI** must look exactly the way it does in the original CAD application. This gives the end user confidence in the accuracy of the solution. Complicated parts can have a tremendous amount of PMI which can be difficult to navigate. As a result, **PMI Views** are created to organize the PMI into feature related categories and only show a subset at a time, making it easier to interpret the PMI.



Different SDKs support semantic PMI, visual PMI and PMI views to varying degrees and qualities. One type of PMI may be better supported than the other, and quality will frequently be different from format to format. Many SDKs have a particularly hard time supporting PMI views correctly.

HOOPS Exchange accurately supports both semantic and visual PMI, as well as PMI views for all major CAD formats. Using HOOPS Exchange allows for the development of powerful PMI driven inspection with the most accurate visual representation available.

HIGH PERFORMANCE VISUALIZATION

A key component to any metrology software is its ability to visualize and navigate the original CAD data, scanned data and processed results. SDKs are commonly used for CAD data access and solid modeling, and many companies also benefit from relying on component technology to supply their visualization needs as well. This allows developers to focus on their core competency – developing high impact metrology-specific functionality.

The visualization toolkit should be able to do more than just organize and display geometry. It should be a rich framework with tools and functionality that can be employed to quickly create interactive applications. The framework should support general purpose tools for visualization like panning, zooming, rotating, touch support and object selection. Additionally, it should have more specific functionality for supporting metrology workflows including efficient point cloud loading, advanced call-outs and labels to show inspection results and notes, animation to show path planning or CMM state, color interpolation to show inspection results visually and quality 2D export for report generation.

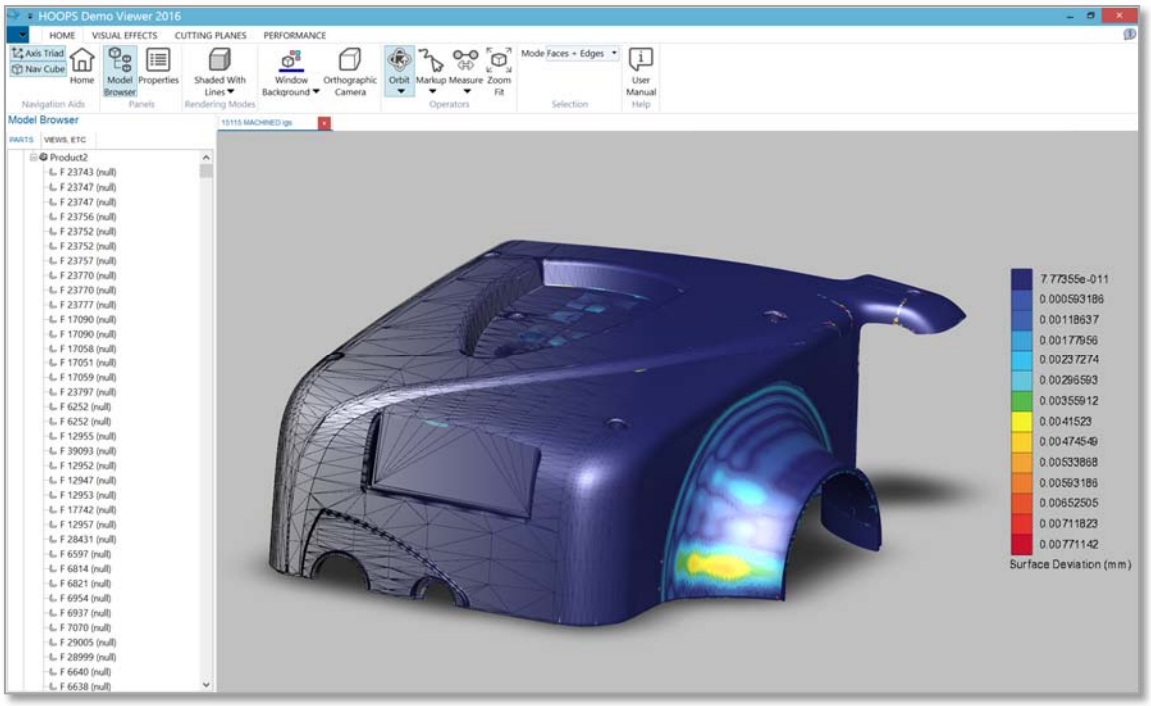
With CAD assemblies getting larger and more complex and more data being generated from optical scanners, attention must be given to performance to ensure interactivity doesn't suffer. The visualization toolkit should take advantage of performance enhancements including:

- Creating accelerated draw lists for optimized display
- Backface, extent and frustrum culling to remove invisible faces and objects from the rendering pipeline
- Optimizing transparency for speed and visual accuracy
- Taking advantage of graphics card specific features

CMM users are used to a high quality visualization from other 3D applications and demand the same from their metrology software. This includes rendered objects with smooth surface shading, anti-aliasing, texture support, high quality text display and a variety of rending modes, lighting conditions and other rendering effects. With the improved visual quality comes a performance cost and a good graphics toolkit will optimize for both performance and visual fidelity.

Engineering software is being created for mobile devices to supplement what already exists on the desktop. This growing trend is demanding the same from metrology software. A mobile app allows measurement to be truly decoupled from a desktop computer and get it as close to the manufacturing process as possible. Touch-enabled mobile displays are commonly imbedded within hardware solutions themselves. Choosing a graphics toolkit that supports the iOS and Android platforms is a must to remain competitive in the changing technological environment.

HOOPS Visualize is the gold standard graphics engine for developing high-performance for desktop and mobile applications. It is a robust, engineering-focused graphics toolkit with unparalleled performance and quality, a rich set of features for CMM software and the ability to run on all major desktop and mobile architectures. HOOPS Visualize is the framework upon which hundreds of engineering applications are built to satisfy the needs of the industry. It also provides a solid foundation to build upon in the future no matter where the industry goes, be it augmented reality or supporting new graphics sub-systems such as Vulcan, Metal or new versions of DirectX.



3D Display using HOOPS Visualize

ENRICHING PDF REPORTING

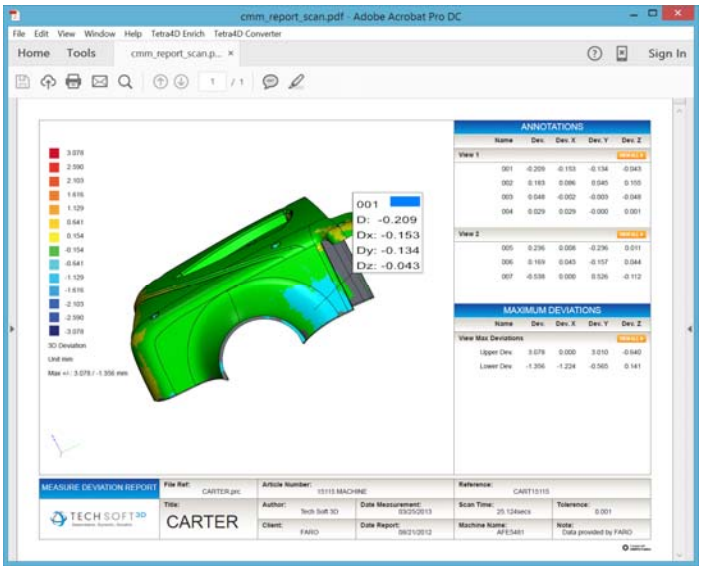
A key capability of any CMM software application is report generation. Adobe® Acrobat's Portable Document Format (PDF) is used worldwide for measurement reports. PDFs are an extremely desirable document format because it is nearly ubiquitous in terms of its use by anyone with a computer, there are many free PDF viewers, it is easily integrated into a company's existing document management system, the files are compact and there is the ability to add security to the document.

PDFs contain a variety of content that is well suited for CMM software reports including tables, text, forms and images. There are additional features of PDFs that can bring value to CMM reports:

3D data – 3D models can be contained within a PDF since Adobe Acrobat 7 in 2005. Since that time the 3D definition within the PDF format has gone through several improvements and has become an ISO standard. When a PDF containing 3D data is loaded into Adobe Acrobat Reader, one or more regions devoted to 3D can be easily interacted with, including 3D data that allows better communication of design intent and the measurement results.

Interactive 3D models – CMM reports can be further enhanced with data-rich, interactive 3D content. The advanced 3D data model supported within PDF allows for defining camera views for easy navigation to specific areas of interest. Call-outs and notes can be added into the 3D scene. JavaScript can connect 2D elements within the PDF to the 3D model to:

- Enable buttons to hide/show objects, change rendering modes, show/hide specific notes and activate a specific view.
- Create intelligent tables that change the camera location and note when a specific cell is selected.
- Alter each 3D PMI view to display relevant inspection data and pass/fail results.
- Automatically populate tables with measurement results, acceptable tolerances and highlight gaps.



Interactive 3D PDF Report

Interactive 3D PDFs support advanced workflows and blur the line between document and application. What once would have taken tens or hundreds of pages can now be captured in one or two pages.

Attachments – In addition to the 3D data viewable inside the 3D PDF, the native CAD file can be included as an attachment. It may also be converted to a neutral file format, such as STEP, and included for future interoperability or long term archival, further increasing the value of the report.

Using HOOPS Publish you can easily create intelligent PDF reports and be on the cutting edge in the way 3D data is used and shared. HOOPS Publish, the only toolkit based on native Adobe technology, enables applications to export rich 3D PDF reports with advanced layouts, interactive tables and 3D objects, 3D views and critical PMI.

CONNECTING TO THE CLOUD

Metrology software has traditionally resided on the desktop in close proximity to the measuring device, but that is rapidly changing. Much like the way CMMs moved from climate-controlled rooms to the shop floor and inline, CMM workflows will change in the smart manufacturing facility due to automation, internet of things (IoT), reliance on mobile devices and access to the cloud.

Robotic arms are loading and unloading work pieces making it possible to automate their measurement. Instead of measuring every *X* machined parts, it is possible to measure every piece being manufactured. This allows for an unprecedented increase in quality control. Once a problem is detected, a notification is sent to other networked devices so the entire process can be automatically adjusted. The result is reduced downtime, less waste and lower costs.

By sharing 3D inspection results, manufacturers can create virtual part-mating simulations, so a model of inspected parts produced halfway around the world can be virtually assembled with models from another supplier.

No longer is inspection data being displayed only on a connected desktop computer but it is flowing to control rooms, mobile devices and cloud portals. As jobs are run wirelessly, real-time access to the data is desirable and a key differentiator for the metrology software market.

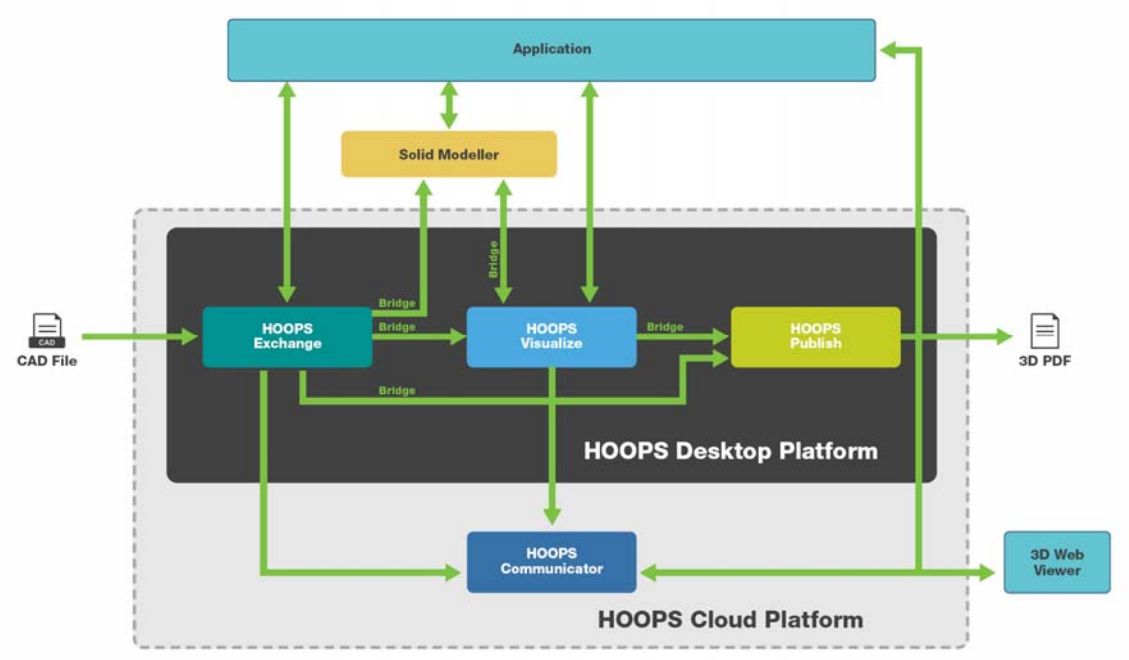
HOOPS Communicator and the HOOPS Cloud Platform enable users to virtually share 3D engineering data and inspection results anywhere, anytime and on any device. Additionally, Tech Soft 3D has an entire set of toolkits that are purpose-built to power applications living in this kind of world: From data exchange on the server or on a mobile device to advanced 3D visualization for any platform, whether it's a connected desktop, a mobile device or a browser.

RAPID APPLICATION DEVELOPMENT USING HOOPS PLATFORMS

A well-integrated platform of multiple toolkits allows a developer to quickly create unique workflows with confidence. Just as not all SDKs are created equal, not all integrations are created equal. There are efficient and inefficient ways to connect these technologies. The bridges need to be built with a deep understanding of the toolkits being used. Within the bridges, special attention must be given to memory allocation and management, performance, data navigation and deployment.

The benefits of using a well-designed, deeply integrated platform far outweigh the sum of its parts. HOOPS Desktop and HOOPS Cloud Platforms are powerful toolkits for desktop and cloud application development.

The HOOPS Desktop Platform includes HOOPS Exchange for fast and accurate data access; HOOPS Visualize for powerful visualization on desktop and mobile; and HOOPS Publish for native 3D PDF creation. The HOOPS Cloud Platform adds HOOPS Communicator for advanced 3D web visualization. Both platforms can be coupled with Siemens Parasolid on the desktop or in the cloud to add advanced solid modeling capabilities.



CONCLUSION

CMM systems are often judged by the quality, power, speed and automation of the software that drives them. Choosing the right software toolkits to build upon is critical in a changing manufacturing environment where big data, connected machines and automation are becoming more prevalent. Powerful toolkits and software platforms exist to accelerate CMM software development and meet these demands.

HOOPS Exchange provides accurate CAD data access to read data with no or minimal translation. It has rich support for semantic PMI for automated inspection path planning and full support for visual PMI and PMI views. HOOPS Exchange also contains built-in modeling capabilities that in many cases can remove the reliance on solid modeling engines.

HOOPS Visualize is the workhorse 3D rendering engine in hundreds of successful applications delivering performance and stability across all major platforms, devices and graphics cards. In order to satisfy the market's ever-escalating expectations, you'll need powerful 3D visualization that will allow your developers to rapidly deliver eye-popping applications across both mobile and desktop platforms.

HOOPS Publish can be used to fuel the demand for creating rich 3D PDF reports. This native Adobe technology, the same found in Acrobat and Acrobat Reader, is the only solution for creating the next generation of interactive reports.

HOOPS Communicator is being used to create the next generation of 3D solutions by allowing users to view and interact with 3D data within all major internet browsers on desktop and mobile devices and connect 3D data to vital business intelligence in real-time. HOOPS Communicator is being used to cloud-enable applications and provide a stable framework for future development and growth in the rapidly changing technology landscape.

HOOPS Desktop Platform & **HOOPS Cloud Platform** allow you to build on a strong, integrated foundation, harnessing the combined power of our market-leading HOOPS technologies — the same technologies that already power advanced 3D on millions of machines every day.

Visit www.techsoft3d.com to learn more and to request a hands-on evaluation.

ADDITIONAL RESOURCES

HOOPS Exchange

http://www.techsoft3d.com/products/hoops-toolkits/hoops-exchange/

HOOPS Visualize

http://www.techsoft3d.com/products/hoops-toolkits/hoops-visualize/

HOOPS Publish

http://www.techsoft3d.com/products/hoops-toolkits/hoops-publish/

HOOPS Communicator

http://www.techsoft3d.com/products/hoops-toolkits/hoops-communicator/

HOOPS Desktop Platform

http://www.techsoft3d.com/products/hoops-desktop-platform/

HOOPS Cloud Platform

http://www.techsoft3d.com/products/hoops-cloud-platform/

Siemens Parasolid

http://www.techsoft3d.com/products/modeling-engines/parasolid/

An Introduction to 3D Measurement Technology

http://www2.faro.com/site/resources/details/1852

COMPANY INFORMATION

Tech Soft 3D is the leading global provider of development tools that help software teams deliver successful applications, as well as the creator of the 3D format that is part of the PDF standard. Established in 1996 and headquartered in Bend, Oregon, Tech Soft 3D also has offices in California, France, Germany, England and Japan. The company's toolkit products power nearly 500 unique applications running on hundreds of millions of computers worldwide, while the Tetra4D brand of end-user products is used by many of the top manufacturing and construction firms for converting CAD data into 3D PDF.

For more information, visit http://www.techsoft3d.com.