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ENABLING DISTRIBUTED DATA PROCESSING FOR INTERNET ANALYSIS WITH GENX

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ABSTRACT

This paper describes how an XML mapping of a product neutral standard, GenCAM[sm], has been used in combination with a JavaScript XML parser to enable product-data driven analysis from a web interface. This client side processing of detailed design data results in greater accuracy of analysis inputs, lower Internet bandwidth requirements, and greater intellectual property security. The web interface lowers the barriers to use of sophisticated CAE analysis software, enabling tool use by product and process experts throughout the supply chain. An example illustration based on a Plated Through Hole thermomechanical analysis is presented. Application to an Internet-based Engineering Service Bureau is discussed.

INTRODUCTION

Complex engineering systems are produced by a network of companies, typically a primary systems integration provider (the Prime) purchasing or contracting out to a supply chain of manufacturing corporations. Many of the companies involved in the supply chain are small to medium enterprises (SMEs) who are niche experts at producing a single component or families of components. The Internet-based, self-serve Engineering Service Bureau (ESB) paradigm [Scholand et. al., 1997, Peak et. al., 1997, Fulton et. al, 1997] presents the opportunity to dramatically improve the quality of complex engineering systems by cost effectively providing analysis capabilities to these manufacturing SMEs. SMEs can bring to analysis:

- Detailed product knowledge, such as the orientation of laminates in a Printed Circuit Board (PCB)
- Detailed process setting information (which often is needed as boundary conditions or other parts of an analysis)
- Knowledge of what possible alternatives exist to address issues with the product or process and
- Detailed knowledge of the costs associated with these different options

Thus, there are two benefits realized when SMEs perform analysis. First, the accuracy of the results is improved. The greater level of detail known about the product and process means that SME-run analyses often are more precise than those which can be performed by the Prime. Second, there is the employment of the results in a meaningful way. Analysis results can help the SME determine optimal process settings and avoid manufacturing problems. If product design changes appear warranted due to cost or performance considerations, the analyses allow the SME to quantify the benefit associated with different product configurations so that the Prime can make informed decisions on cost/benefit tradeoffs.

The Engineering Service Bureau is an important part of the equation, however, because although there are significant benefits to SME-run analyses, there are substantial barriers also. The most prominent barrier is the simple cost of access to analysis capability. Most general purpose engineering analysis tools, such as Finite Element computer codes, cost thousands of dollars a year to license, and require expensive computer resources to run. Specially trained personnel are generally needed to run the tools as well, since many have highly complex interfaces and require a good understanding of the fundamental principles involved. Finally, the development of models of products or processes within the analysis tools is typically a laborious and time consuming process, even before model validation by correlation to experimental data is considered.

The Internet-based Engineering Service Bureau reduces these barriers in several ways. First, because an ESB specializes in providing analysis services to multiple customers, the utilization of the computer aided analysis tools is much higher than is likely in a single SME focused on manufacturing. Since software and hardware investments are averaged across the user base of an ESB, the per-use cost for any given analysis run by the SME is much less than the cost of maintaining an in-house capability. The ESB also offers the opportunity to utilize pre-developed, validated analysis modules parameterized to adjust to product specifics. These predefined analysis modules are wrapped in graphical user interfaces (GUIs) which hide analysis-specific details (such as finite element mesh density) and request analysis parameters in product-specific terms. This encourages frequent 'self-serve' use by SME personnel, for example by members of the engineering sales department when responding to requests for quotes.

This paper describes how XML enables deploying the Engineering Service Bureau paradigm on the Internet's most popular interface, the Web, without sacrificing access to the product data needed for analysis.

Web Interfaces

A web-based interface to analysis tools presents several advantages important from an Engineering Service Bureau point of view. The web interface and its associated navigational conventions are increasingly ubiquitous. Future 'information appliance' trends, such as web surfing through television and portable phone devices, will probably further expand the exposure of this data presentation metaphor. The familiarity of this method of presenting information increases the prospective audience for using the tools behind the web interface. Web interfaces can be rendered by a wide variety of Web browsers, available on virtually all computer operating systems. Some of these web browsers, such as Opera, have been optimized for execution on computationally lightweight clients. Both the familiarities of the web interface and its widespread availability provide an opportunity for ESBs to market their services to the widest possible customer base.

Web interfaces are much less bandwidth intensive than other technologies for presenting graphical interfaces remotely (such as X Windows). This maximizes the perceived performance of ESB tools over slower dial-up Internet connections. These slower connection methods predominate in the small business market that ESBs serve.

Web browsers are relatively mature client applications, and employing them to render and support user interfaces represent a good reuse of software components. An example of a web-based interface for an analysis of PCB plated through holes is illustrated in Figure 1.

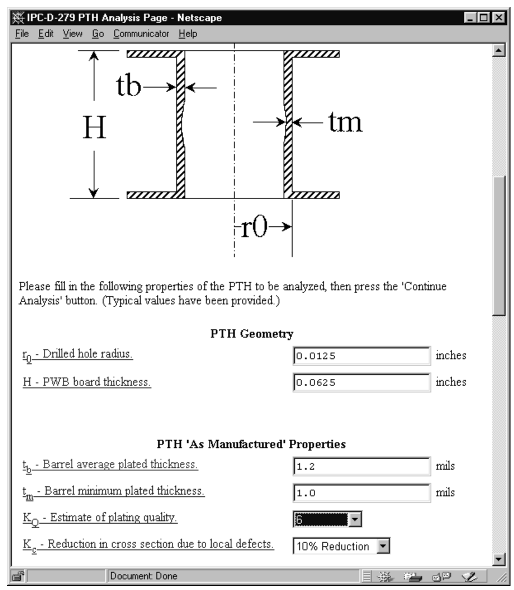

Figure 1: Example Web Interface for PCB PTH Analysis

From a computer-aided analysis viewpoint, however, there are a few disadvantages to using a Web Interface for direct data gathering as illustrated in Figure 1. The main issue is a reliance on human data processing. Particularly in the case of process data this is appropriate, as the information is readily known to experts in the field. For example, in the specific case of plated through hole analysis, the loads which are applied to the structure are determined from the temperatures of various manufacturing processes on the factory floor, such as the temperature of the solder in a Hot Air Solder Leveling (HASL) machine. Operators are familiar with this temperature, since it is a controlled process variable presented to them by instruments on this machine. In contrast, however, the product data required by the analyses may not be so readily known. For example, the plated through holes which are most at risk of thermo-mechanical failure are the smallest holes. When manually populating fields in a web interface, the operator must determine the minimum hole diameter among the thousands of holes in the PCB. Even in cases where the operator doesn't have to manually determine a maximum or minimum among a large data set, simple re-entering of data is inconvenient. Re-entry of data is also a prime opportunity for the introduction of errors.

So, while a traditional web-based form interface is easy to use, it lacks automated integration with product and potentially process data. The emerging standard eXtensible Markup Language (XML) presents an opportunity to represent product data in a web-enabled format, and thereby address the data integration issues mentioned above.

GenX- A Specific XML Language for PWA/B Data Transfer

XML (eXtensible Markup Language) is a web-enabled data interchange language derived from the Standard Generalized Markup Language (SGML). The World Wide Web Consortium (W3C) approved XML as a W3C recommendation in February 1998. As a platform and vendor independent technology, XML has been publicly endorsed by almost all of the leaders in the computer industry, including Microsoft.

XML is not itself a set of ready-to-use tags the way another SGML subset, HyperText Markup Language (HTML), is. Rather, XML is used to define application-specific markup languages (such as GenX) to represent structured data. XML defines the rules for these markup languages to ensure that they are easy to parse and validate by machine. XML-defined markup languages enable the separation of semantics from the way the data are used by an application or rendered for presentation. This is analogous to the practice of model and view separation in good object-oriented design.

Validation in XML-defined grammars allows an application to ensure that a given instance of data is complete, correctly hierarchical, and with acceptable content values. Comparing a data instance to a Document Type Declaration (DTD) enforces validity. A DTD is a computer processable description specifying which tags and attributes, and in what order, are allowed in the data instance file. A DTD can be included in line with a data file, or the instance file can point to a DTD using the Universal Resource Identifier (URI) mechanism.

GenX[1] is a specific XML markup language initiated by the first author mapped from the Institute for Interconnecting and Packaging Electronic Circuits (IPC) standard, IPC-2510, GenCAM^{sm}. The GenCAM^{sm} standard has been developed to facilitate the communication of PCA/B manufacturing data from the designer to the fabricator. It integrates functional descriptions, test data, and administrative information into a single file format. It is sufficiently detailed for tooling, manufacturing, assembly, inspection and testing requirements. The GenX DTD is identical to the contents of the IPC-251x series of documents; both describe what is legally allowable in the file.

The next major release of GenCAM, version 2.0, is slated to be in an XML format [McLay, 1999]. A draft DTD based on the GenCAM 1.1 object model will be made public in early August 1999 [Scholand, 1999a]. Some of the design decisions in creating this DTD are described in [Scholand et. al., 1999].

Integrating ESB Web interfaces with XML Data

The inherent structure of XML files makes them easy to parse. This, in turn, means that XML parsers can be relatively small and compact. XML parsers have been written in less than 26K of Java [Microstar, 1999] and less than 5K of JavaScript [Miller, 1999]. These low footprints mean that a GenX parser can easily be embedded in a web page (or pages) that acts as the interface to sophisticated product analysis capabilities. The combination of web interfaces and standard-driven product analysis yields several unique benefits.

A key benefit is the improved accuracy of the data input to analysis. Since the same data source used to drive manufacturing also drives the analysis, there is no potential for errors arising from manual duplication. Automation of data extraction also enables tasks that are not feasible when humans provide analysis inputs. For example, exhaustive searches over numerous input combinations are typically simple programming exercises, but are infeasible for a human operator.

Depending on how the parsing is carried out, it is also possible to increase the intellectual property protection available to the ESB customer.[2] The

[1] GenX is an abbreviation of "GenCAM^{sm} in XML".

[2] We use the term "greater intellectual property protection" here to refer to greater protection from outside malicious parties. We assume the ESB to be a trustworthy partner.

processing of the GenX file in preparation for computer aided analysis can be performed on either the remote machine (server) or on the local machine (client), depending on where the parser is located. If the parser is loaded onto the local machine, the parser operates on the GenX file in local memory. Only those abstract parameters needed for analysis (what we describe as the *idealized* attributes of the product) are entrusted to the remote machine. Since it is typically almost impossible to reconstitute a detailed description of the product from the idealized attributes, the ESB customers enjoy relative immunity from intellectual property theft in the event the ESB server is compromised.

Finally, there is a natural data compression benefit which can be realized if the parser is located on the local (client) machine. The idealization process (abstracting the detailed manufacturable description into a simpler form more amenable to analysis) typically reduces the amount of pertinent data by two orders of magnitude. Thus, under typical usage situations[3], it is much less expensive to send the parser to the client than to send the data file to the host. This is a particularly important benefit to the target market for ESB usage, since most SMEs will access the Internet through dial up links with limited bandwidth.

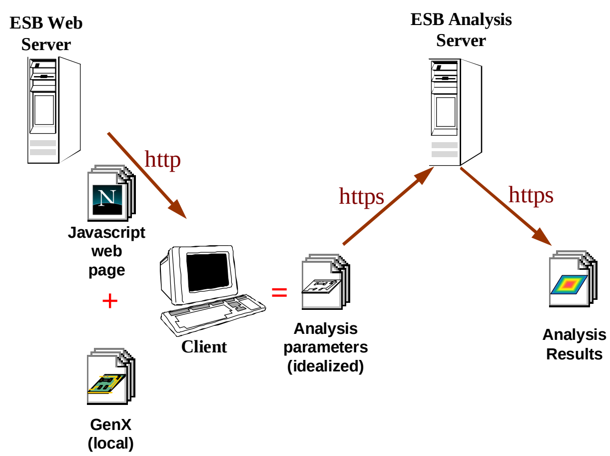

Figure 2: XML and Web-enabled Analysis

Thus, the scenario in which an XML-enabled web analysis interface is accessed is illustrated in Figure 2.

1. The end user accesses a GenX-capable web page from an Internet-based Engineering Service Bureau using a standard web browser.
2. The GenX parser downloads to the local machine along with an HTML form or Java applet interface.
3. Using this interface, the end user loads the GenX file into the browser, and the parser operates on the file on the local machine.
4. The idealized attributes are now ready to be sent to the Engineering Service Bureau for sophisticated CAE processing.

The example below illustrates this scenario, using an HTTP form and Common Gateway Interface (CGI) script to send the data to the ESB server, where it is handed off to an analysis server on the back end.

Example ESB Application- PTH Analysis

Plated through holes (PTHs) are metallic structures in Printed Circuit Boards that electrically connect the various layers of the PCB. Repetitive heating and cooling cycles in both manufacture and field use of the PCBs creates a thermo-mechanical loading of these structures, which can result in product failures if the loads are high enough or the manufacturing process is marginal. One formula-based model for predicting how a given PTH will respond to a given load is documented in the IPC Standard IPC-D-279 [Engelmaier, 1996]. In the ProAM project [Scholand, 1999b] we have implemented these equations in *Mathematica*, a commercially available software package, and provided a web based front end to this analysis model. (See Figure 1 above for an illustration of this interface.)

Illustrated in Figure 3 is the GenX-enabled version of the same analysis model. The frame on the left hand side contains the GenX file. The 'Process' button in that frame runs a JavaScript parser (*Xparse*, [Miller, 1999]) and additional domain-specific routines for processing the GenX file. The output from the local parsing is put into the fields of the IPC-D-279 analysis form, which is displayed on the right hand side frame. Currently, the GenX parsing engine determines the maximum permissible board thickness and the minimum plated through hole diameter, since these are the 'worst case' parameters for this type of analysis. The analysis form can then be edited as usual, in case the operator wants to override any of the automatically generated values. Pressing the 'Continue Analysis' button (not visible in Figure 3) submits the form for CGI processing on the web server in the manner described above. The total combined downloadable size of this web interface is 29K and is thus very suitable for Internet-based usage.

[3] Assuming that the typical GenX file will be ~700K and that only a limited family of related analyses will be repetitively performed on a given board.

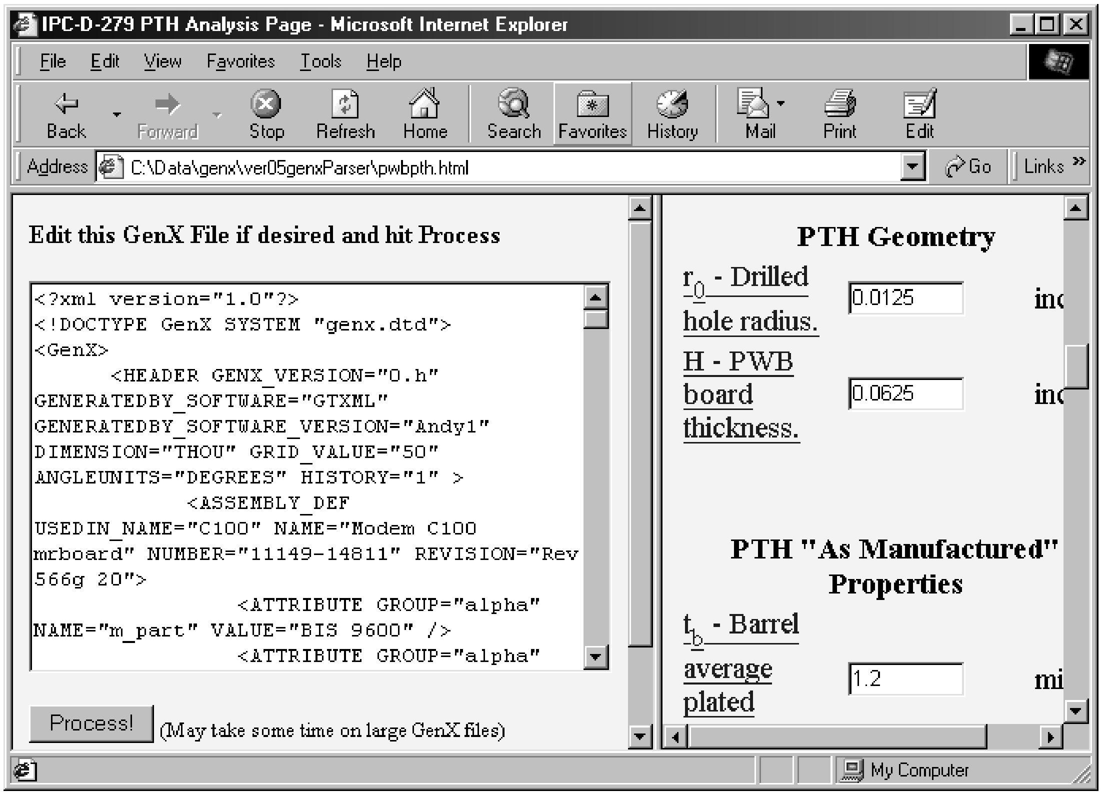

Figure 3: GenX Enabled PTH Analysis

Conclusion and Further Work

To maximize their target customer base, this paper presents how Engineering Service Bureaus can employ web-based “front ends” to the sophisticated engineering tools they provide cost-effective access to. XML-compliant product standards enable the benefits of the web interface (ubiquity, portability, and comprehensibility) to be realized without sacrificing data integrity or automated data processing. We illustrated how an XML form of one such neutral standard, GenCAM^{sm}, can be used to drive analyses such as thermo-mechanical reliability checks on plated through holes. When analyses such as these are performed throughout a supply chain by the organizations with the most knowledge of the product and process in question, we hold that a significant improvement in product quality can be achieved.

The use of XML allows product data to remain distributed across the web, rather than requiring it to be concentrated on ESB servers. Uploading only idealized product parameters offers a significant reduction in bandwidth requirements and improves the intellectual property protection for ESB customers.

We are working on a more sophisticated CORBA-based version of the same application, where by the analysis parameters are sent to a "middleware" object residing on the web server. This object generates a query to talk to an analysis integration software tool (XaiTools [Peak et. al, 1998, Peak et. al., 1999, Wilson et. al., 1999]) residing on another server, which in turn submits the parameters for processing on various distributed Computer Aided Engineering (CAE) tools. The results eventually get formatted and sent back as Web pages accessible to the client.

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