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Pattern Data Format Standardization Between Apparel CAD and 3D Body Scan with Extensible Markup Language

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ABSTRACT

In the apparel industry, 3D body scan systems have been attractive to apparel CAD/CAM companies, apparel companies, and researchers in that the body scan systems can provide fast and accurate enabling the development of made-to-measure garments. Apparel CAD/CAM companies have partnered with body scanner manufacturers and linked the body scan system with their existing apparel CAD products for made-to-measure solutions. As more companies increase globalization and partnership with new technology suppliers, the CAD/CAM data compatibility and standard data formats have been critical issues. For this reason, XML (eXtensible Markup Language) has been considered for the standard exchange data format in that XML has extensibility, structure, mega data transport capabilities, and easy conversion. In fact, the XML has already been implemented in apparel companies who are dealing with e-business, globalization, and standardization. For example, the use of XML for standardization was found in the global standard organization for apparel business, and attempts at standardization of 2D and 3D body measurement representation with XML was found in e-T Cluster in U.K. In addition, the importance of XML for the future apparel pattern data exchange format has been in development the ASTM D13.66 sub committee: Apparel & Sewn Products Automation.

The purpose of this study was 1) to introduce XML format for pattern data exchange, 2) to provide an experimental design written in XML for bi-directional transmission of data from a 3D body scan system to an apparel CAD system, and 3) to investigate the potential use of XML for standardizing pattern data format between apparel CAD systems and 3D body scan systems by examination of the experimental design written in XML format. The experimental design in XML format was sent to an apparel CAD supplier (Gerber Technology Inc.) and a body scan supplier ([TC]²) to determine if it would be a viable standard format. In this study, current data file formats for data exchange and use of XML format were reviewed, and limitations of using the XML format were revealed in that the acceptance of the XML format was tightly related to timely agreements in the apparel industry.

Keywords: 3D Body Scanning, Data Integration, xml, Standards, Patterns, CAD

1. INTRODUCTION

In the apparel industry, 3D body scan systems have been used in the apparel CAD/CAM companies, apparel manufacturers and retailers (Levis and Brooks Brothers), and researchers (Size USA, e-T Cluster, and CAESAR) in the attempt to develop mass customization and fit solutions. As interest has increased, apparel CAD suppliers have partnered with 3D body scan suppliers. For example, two of the major CAD suppliers, Lectra Systems, Inc. and Gerber Technology, Inc., have partnered with 3D body scan suppliers and are linking the body scan system with their existing apparel CAD products for their made-to-measure solutions (Gerber Technology, Inc., 2003; Lectra Systems, Inc., 2003).

Apparel CAD/CAM data compatibility and standard formats are very important for companies who are dealing with globalization and/or partnerships with new technology suppliers such as 3D body scan suppliers. The nature of the global industry has caused us to be aware of the many issues related to data translation and a use between different systems. For instance, since pre-production and production procedures for any one product are being accomplished at a variety of location, product developers are very aware of issues related to the movement of design, grading, marking and cutting data being moved between systems. Pattern might be created using a Gerber system with grading and marking done with a Lectra system and cutting with Assist-Bullmer.

Apparel CAD users have encouraged the industry to establish standards for presenting CAD/CAM data in formats that would allow apparel and sewn product producers to utilize a choice of machinery and software from different vendors, and to exchange information with contractors or third parties that may not have the same machinery and software. The work is currently being done in an ASTM subcommittee to allow integration between CAD vendors and marker making, grading, and cuttings.

Currently, however, there is no approved standard format for transmissions of the 3D body scan data between body scanning companies and CAD companies. Each body scan supplier has its own method of data acquisition, extraction, and output. Even current CAD standards were poorly defined in some respect and lacked meaningful definitions for many pattern data processes, properties and attributes. Therefore, a standard data file format, XML (eXtensible Markup Language) might be a potential data file format for prototyping communication standards due to: extensibility, structure, mega data transport capabilities, and easy conversion. The effort relating to 3D body measurement data is a logical step to fit right into the other components of a full garment design process. The purpose of this study was 1) to introduce XML for the pattern data exchange format, 2) to provide an experimental design written in XML for bi-directional transmission of data from a 3D body scan system to a CAD system, and 3) to investigate the potential use of XML for standardizing pattern data exchange between apparel CAD systems and 3D body scan systems.

2. REVIEW OF CURRENT DATA FILE FORMATS AND XML

2.1 Current Standard Data File Formats for Pattern Data Exchange

In the apparel industry, CAD/CAM data compatibility and standard data file formats have been increasingly critical issues during the past decade. As apparel production has moved offshore, more and more product is being designed and produced in varying location around the world. Different CAD/CAM systems between contractors and product developers cause time consumption when the contractor might be forced to re-digitize pattern pieces, purchase compatible systems, or establish a customized interface to get the data into its systems. At the same time, producers currently are limited in their ability to switch contracting partners if their existing contractors with compatible systems are not performing well (Chang, 2000). For this reason, CAD/CAM standardization for pattern data exchange is being developed through the ASTM (American Society for Testing and Materials) D13.66 sub committee that has participants from CAD/CAM vendors and the end user communities.

According to Chang (2000), prior to the work of the ASTM D13.66 subcommittee, the ANSI/AAMA 292 pattern data interchange (or ANSI/AAMA 292 DXF) standard was available for CAD/CAM vendors. First approved by ANSI/AAMA in September, 1993, 292 DXF was a good first attempt to define a standard. The standard was based on Autodesk Inc.'s DXF file format, which is designed to exchange mechanical engineering drawings. DXF is a specially formatted ASCII file, which means it is created using standard characters on the computer keyboard and can be viewed in a word processing application like Microsoft Word (see Figure 1.)

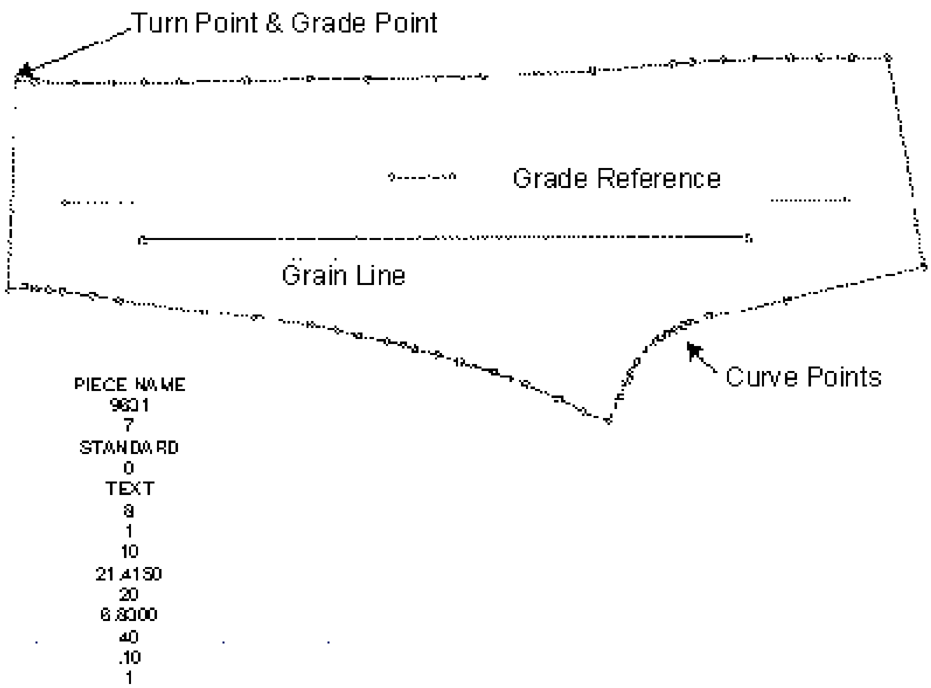


Figure 1. Example of an ANSI/AAMA 292 ASCII DXF file (Chang, 2000)

As shown in Figure 1, ANSI/AAMA 292 DXF includes a set of conventions that represent apparel piece geometry, or 2-D flat patterns, and associate meanings to pieces, base size names, lines, and points. The standard defines how the conventions should be organized in a file for exchange of information between CAD systems. For example, there are 14 layers for organizing the data that are divided into fourteen categories when written into the ASCII DXF file format. Thus, the DXF translation programs know where to go within the file to get the information needed to display and work with the pattern piece. The 292 DXF standard's development received good participation from industry CAD/CAM vendors, and it was relatively easy to implement (Chang, 2000).

However, ANSI/AAMA 292 DXF documentation is not very clear in its definitions and the standard does not include a grade rule growth specification or curve-smoothing algorithms leaving an opportunity for different CAD vendors to have different interpretations of the curve line control. For example, one system may require the curve line to pass through control points, whereas a different system may only require the same curve line to pass along the points. This difference in curve-smoothing algorithms can cause accuracy problems when pattern pieces are imported. In addition, the DXF structure limits the amount of information that can be included and is available for use (Chang, 2000). This results in confusion and inconsistent implementation by apparel CAD/CAM vendors. Currently, ASTM D13.66 has been developing a new standard for pattern data exchange, and XML is the core of that file format.

2.2 Current Data File Formats for Describing Body Measurements

Information on the format of body scan data is very important for determining compatibility between 2D CAD systems and 3D scan systems since many apparel CAD and virtual design suppliers are joining with body scan suppliers to support mass customization with accurate body measurement data. Body scan data includes both body measurements extracted from the scanned image and a body image with point cloud. Generally, VRML is a dominant file format for the body image data, and XYZ is a commonly used format for the raw scan data files. However, each body scan supplier has various detail body measurement data file formats for describing body measurements or transferring the data.

For example, [TC]^2 provides data file formats for point clouds, body surface models, and extracted measurements that may be found in data flow from 3D scan to 2D pattern. The extracted body measurement data, one subset of the body scan data, is very important for pattern alteration, outputting pattern outlines, and draping garments for visualization. At this point, measurement definitions and standards are demanded by body scan users, and the definitions in [TC]^2 are fully customizable within the measurement definition data file (*.mep) format. According to David Bruner (2002), sample definition sets have been developed for many ISO measurements and for the draft eT-Cluster (European Standard) with an *.mep data file format. In addition, [TC]^2 has developed a generic *.dxf format for direct pattern output from body scans.

Hamamatsu Photonics also provides a variety of data file formats including point clouds, body surface models, and measurement data, but each body scan data file format is different from those of other body scan suppliers. One type of output data file format, VRML, is commonly used to display the body surface, but point cloud data and others are unique in their data file format. The measurement data file format is an ASCII file or *.txt file, and the file format is compatible with [TC]^2's measurement data file format.

Cyberware, Inc. has a body scan data file format to display the body surface. Body scanners from Cyberware, Inc. were used in the Civilian American and European Surface Anthropometry Resource (CAESAR) project, and the PLY file format was used to deliver body measurement data in the CAESAR project. However, the body measurement data file format is different according to each organization or researcher. For example, the LPD file format (Hutton et al., 2002) was used for the UK sizing survey, and later the XML format was used in aEuropean commission standardization project (eT-Cluster) for the integration of 3D body measurement, advanced CAD, and personalized avatars in the European fashion industry.

2.3 XML (eXtensible Markup Language) for Standardization

XML is a potential data file format for the modeling, developing and prototyping of communication standards. Any document written in XML must follow the rule of XML formatting (as XML schema), which is called an XSD (XML Schema Definition Language). The XSD gives the XML rules of format, structure, and definitions. Therefore, the validation of XML is related to the XSD.

There are few studies on implementation of XML in apparel industry, and the use of XML was found in standards development. The World Wide Web Consortium (W3C), the international standards organization that developed HTML, reviewed XML as a meta-grammar that allows for web automation and data interchange across multiple platforms and applications (Matsumura, 1998). According to Matsumura (1998), XML must be a universal data grammar and syntax language because the XML is structured, self describing, extensible, and viewer adaptive. XML is a very structured language specification, and XML documents utilize a DTD or XSD for defining the syntax, grammar and data structure of XML documents (Matsumura, 1998). With these characteristics, XML naturally became a standard language.

Attempts at standardization of 2D and 3D body measurement representation with XML were found in the e-T Cluster (IST-2000-26084) project that researched the development of a common standard for the representation of human bodies. The XML data format, called BodyXML (Kartsounis, G. et al., 2002), was expected to open up the possibilities of a Sizing Survey in UK. The standardization development of the e-T Cluster was on two levels: the definition of a common set of body measurements for apparel, and definition of formats for the exchange of this information with BodyXML (Kartsounis, G. et al., 2002).

The advantages of XML are being touted by many branches of the sewn products industry and beyond for use in software development, web development, collaborative communications and supply chain management. With its almost infinite flexibility and user-friendly attributes, XML also is attractive from a standards development viewpoint (Chang, 2000). Standards based upon XML will be developed for communication interfaces in a supply chain consisting of links that receive products from many suppliers in the chain and create products for many customers in the chain. As a result, linear relationships of suppliers, manufacturers and customers (supply chains) will be represented (Peck, 2000). According to Baker (2002), when companies expand globally, through acquisition or business relationships, a sudden merge of two sets of unrelated electronic communications means huge financial and time losses. Through XML, an emerging B2B commerce computer language, EAN and UCC, two non-profit global standards organizations, have been enabling companies to define standards, and resolve specific business issues.

Since XML has a potential for standardization in most areas of the industry, the opportunities for use of XML were discussed at the July, 2000 meeting of ASTM D13.66 sub committee, which is the CAD/CAM pattern data exchange standards task force group of ASTM. According to Chang, XML is an exciting emerging technology with great potential, is a universal format for exchanging information between software components, and is legible to both computers and human beings (Chang, 2000).

3. METHODOLOGY

3.1 Research Method

In this study, an experimental design was developed for bi-directional transmission of data (measurements) from a 3D scan system to a CAD system. The experimental design written in XML format was sent to an apparel CAD supplier (Gerber Technology, Inc.) and a body scan supplier ([TC]²) to determine if it would be a viable standard format. An experimental design was written in XML, including XSD (XML Schema Definition Language) for validating the XML document (See Figure 2).

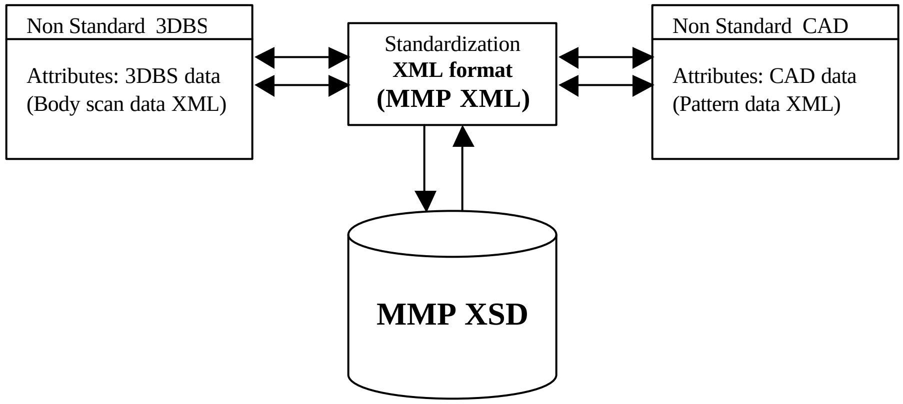


Figure 2. An experimental design with XML/ XSD format

The experimental design included three groups of data written in XML:

- Body scan data XML: this group describes body measurement data that might be necessary for the made-to-measure garments.
- Pattern data XML: this group describes pattern data.
- MMP XML: this group describes identification codes (that tell how measures were obtained) for each body measurement data set.

In the experimental design, the MMP XSD is a schema for XML formation and validation. The schema, MMP XSD, was centered as a main ruler for validation of the three groups of data in XML (Body scan XML, and pattern data XML, and MMP XML). The MMP XSD was based on the previous study of an MMP model (Hwang-Shin & Istook, 2002). In this study, transmission of the measurement data from a body scanning system to an apparel CAD system was a main focus since apparel CAD suppliers were attempting to link the body scan system with their existing apparel CAD products for the made-to-measure solutions.

3.2 Instruments and Resources

Body scan data sample was received from [TC]². Patterns in the previous study of enabling mass customization: computer-driven alteration methods (Istook, 2002) were used for an experimental design in this study. A sample pattern XML format was received from Gerber Technology, Inc. and modified for this study purpose. Formations of the scan data set and patterns were created with XML notepad and XMLSPY5 software, and the validation of the XML format was evaluated with the XMLSPY5.

4. RESULTS AND DISCUSSIONS

In the results, the apparel pattern data in XML format was successfully exchanged in bi-directional interpretation and communication between the CAD system and the body scan system. In the experiemental design, the XML format was useful for bi-directional interpretation and communication between a body measurement provider and an apparel CAD pattern data provider for the following reasons: potential data format for the future,simple custom markup language for standardization, compatibility of data file formats, and small file size for fast transmission.

4.1 Apparel CAD Pattern Data Exchange with XML Format

Sample pattern pieces were chosen from previous research on enabling mass customization with computer driven alteration methods (Istook, 2002). In this study, the sample pattern pieces shown in Figure 3 and 4 were written in XML format.

The sample garment pieces had unique point numbers. The unique point numbers were associated with alteration rules in Figure 4. For example, marked point numbers used to alter the pattern pieces, 2130 at the side waist and 2140 at the armpit, are also shown in Figure 4. These pattern data could be written in XML format.

Figure 5 shows the sample pattern piece data in XML format that follows the rules and restrictions in the pattern data XML schema. The <Pattern xsi:noNamespaceSchemLocation> indicates schema that were referenced for this pattern data XML. This sample pattern data XML included pattern style name, vendor information, and detail piece information (See Figure 5).

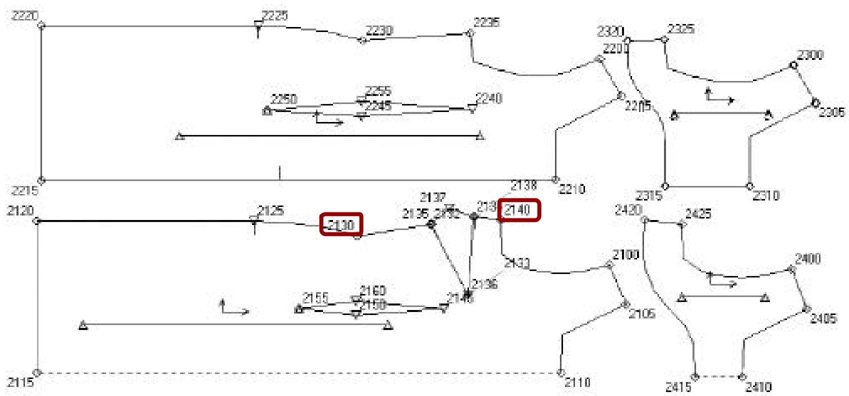
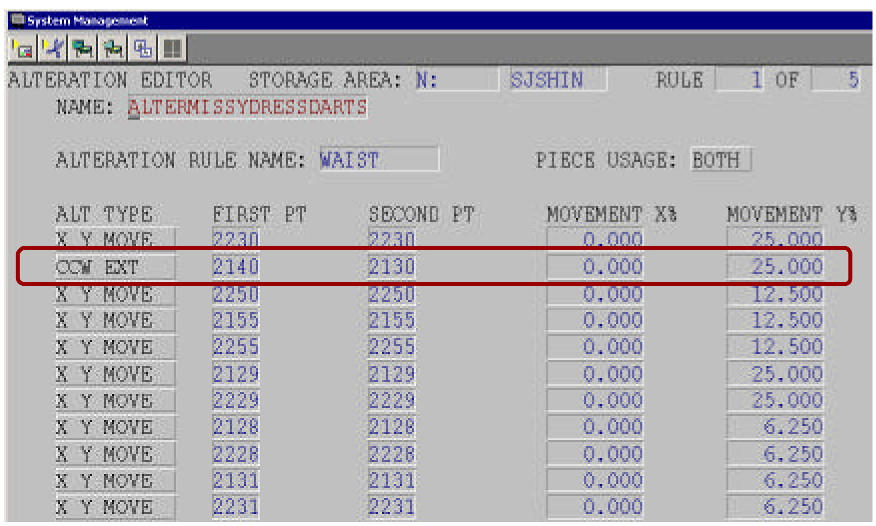


Figure 3. Sample garment pieces with point numbers (Istook, 2002)



System Management

ALTERATION EDITOR STORAGE AREA: N: SJSHIN RULE 1 OF 5

NAME: ALTERMISSYDRESSDARTS

ALTERATION RULE NAME: WAIST PIECE USAGE: BOTH

ALT TYPE	FIRST PT	SECOND PT	MOVEMENT X%	MOVEMENT Y%
X Y MOVE	2230	2230	0.000	25.000
CCW EXT	2140	2130	0.000	25.000
X Y MOVE	2250	2250	0.000	12.500
X Y MOVE	2155	2155	0.000	12.500
X Y MOVE	2255	2255	0.000	12.500
X Y MOVE	2129	2129	0.000	25.000
X Y MOVE	2229	2229	0.000	25.000
X Y MOVE	2128	2128	0.000	6.250
X Y MOVE	2228	2228	0.000	6.250
X Y MOVE	2131	2131	0.000	6.250
X Y MOVE	2231	2231	0.000	6.250

Figure 4. Sample alteration tables in Gerber Accumark System management

```
<?xml version="1.0" encoding="UTF-8"?>
<Pattern xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="C:\Dissertation (SU XML)\MMP_XML\MMPDB_XML\10 Pattern
data.xsd">
    <PatternData>
        <StyleName>DRESS</StyleName>
        <PatternDataDetails>
            <VendorName>Gerber Technology Inc.</VendorName>
            <Application>AccuMark</Application>
            <ApplicationReleaseVer>7.6.3</ApplicationReleaseVer>
            <Units>English</Units>
        </PatternDataDetails>
        <Pieces NumberOfPieces="4">
            <Piece PieceId="101">
                <PieceName>SQSHIFTBK</PieceName>
                <PieceQuantity>
                    <Lefts>1</Lefts>
                    <Rights>2</Rights>
                        …
        </Piece>
        </Pieces>
        <SampleSize>8</SampleSize>
        <GradeRuleTable>MISSY</GradeRuleTable>
    </PatternData>
```

Figure 5. Pattern data XML example

Each tagged data describes each value with a capability not found in other data formats such as DXF. For example, as shown in Figure 5, 'SQSHIFTBK' can be easily understood that it means a piece name and not a style name, looking at the tagged data descriptions such as <PieceName>SQSHIFTBK</PieceName>. In addition, detail piece information can be seen in the XML format. For example, the number of graded nest sizes is 12, and the master boundary is based on a sew line. The sample size was chosen to be size 8 in MISSY grade rule table. This tagged data format is a simple and easy method to describe ambiguous data values. Figure 6 shows waist alterations in pattern data XML format, and Figure 7 shows reproduced image alteration pattern figures from the pattern data XML format (See Figures 6 and 7).


```
    <Alterations>
        <Alt_Table>ALTERMISSYDRESDARTS</Alt_Table>
        <Unit>%</Unit>
        <Alt_Rule_Name>WAIST</Alt_Rule_Name>
        <MMP_ID>WSpsx1_WSpbx0_WSpsx2_(WSpfx0)cu_WSpsx1</MMP_ID>
        <Alt_Type>CCW EXT</Alt_Type>
        <First_Point>2140</First_Point>
        <Second_Point>2130</Second_Point>
        <X_move>0</X_move>
        <Y_move>25</Y_move>
    </Alterations>
```

Figure 6. An alteration in the pattern data XML example

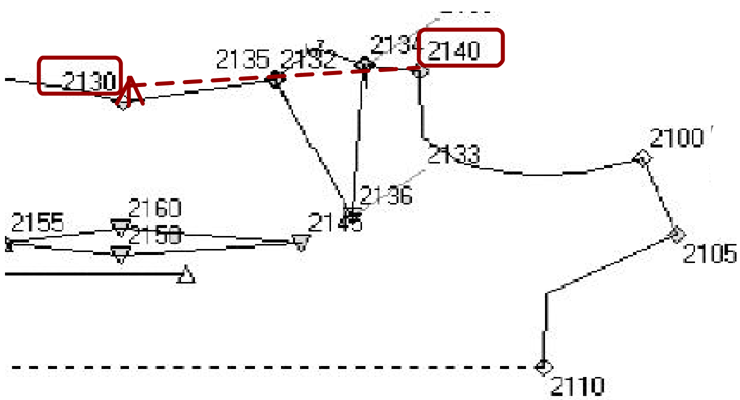


Figure 7. Understanding of alterations from the sample pattern data XML format

As shown in Figure 6, the alteration rule name (WAIST) in an alteration table (ALTERMISSYDRESDARTS) has percentage units, and the value of 'MMP_ID' element (WSpsx1_WSpbx0_WSpsx2_(WSpfx0)cu_WSpsx1) indicates waist girth. This 'MMP_ID' was useful for the description of the waist since the Gerber Accumark system limits the length of characters for alteration rule names. As shown in Figure 7, according to the pattern data XML for an alteration, the first alteration point (2140) is held stationary. Every point is going counter-clockwise from the first point (2140) until the second move alteration point (2130) moves vertically 25 % that is difference between the person's measurements and the base amount.

Figure 8 shows the size code table, and Figure 9 shows an example of a size code table in pattern data XML format (See Figures 8 and 9).

SIZE CODE EDITOR STORAGE AREA: C: PROTOTYP NOTATION:

NAME: MISSY DRESS

ACTUAL SIZE	ORDERED SIZE	ACTUAL SIZE	ORDERED SIZE	ACTUAL SIZE	ORDERED SIZE
4	4 STD	6	6 STD	8	8 STD
ALT RULE NAME	**AMOUNT**	**ALT RULE NAME**	**AMOUNT**	**ALT RULE NAME**	**AMOUNT**
WAIST	25.930	WAIST	26.930	WAIST	27.930
HIPS	35.500	HIPS	36.500	HIPS	37.500
KNEEHEIGHT	17.110	KNEEHEIGHT	17.485	KNEEHEIGHT	17.860
BUST	34.500	BUST	35.500	BUST	36.500
BACKWAIST	16.000	BACKWAIST	16.250	BACKWAIST	16.500

Figure 8. Basic size code table (Istook, 2002)

```
<Size_Tables>
        <SizeName>MISSY_DRESS</SizeName>
        <SizeId>4</SizeId>
        <Unit>inch</Unit>
        <Alt_Rule_Name>WAIST</Alt_Rule_Name>
        <MMP_ID>WSpsx1_WSpbx0_WSpsx2_(WSpfx0)cu_WSpsx1</MMP_ID>
        <Measure>25.93</Measure>
   </Size_Tables>
```

Figure 9. A size table in the pattern data XML example

Figure 9 shows a size table example in the sample pattern data XML. This represents a part of the basic size 4 for ‘MISSY_DRESS’ in Figure 8. The alteration rule name in Gerber had a limited number of characters. This might cause miscommunication of measurements. In this case, the ‘MMP_ID’ element clarifies and interprets the specified measurement. According to the sample pattern data XML, ‘WAIST’ is interpreted as 25.93 inches in waist girth with ‘MMP_ID’ that is also used in body scan data descriptions. Formation and validation of the pattern data XML were tested with the XMLSpy software program. The test results showed that the XML formats were well formed and validated.

4.2 Body Scan Data XML

A sample body scan data from [TC]^2 was written with XML format. The body scan data XML format was based on MMP XSD schema that includes ‘Body scan data XSD’. The following Figure 10 shows a part of the body scan data XML format.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<Body_Scan_Data xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
xsi:noNamespaceSchemaLocation="C:\Dissertation (SU XML)\MMP_XML\MMPDB_XML\02 MMP.xsd">
    <Scan_Company>
        <Company_Name>[TC]²</Company_Name>
        <Scanner>2T4</Scanner>
        <Website>http://tc2.com</Website>
    </Scan_Company>
    <Scan_List>
        <Scan_ID>Female_001</Scan_ID>
        <Measure_File>Female_001_mmpsetup.ord</Measure_File>
        <Scan_Date>2001-11-29</Scan_Date>
        <Scan_Time>14:31:00</Scan_Time>
        <Scan_By>Staff in [TC]²</Scan_By>
        <Scanner>2T4</Scanner>
    </Scan_List>
    <Measurements>
        <Scan_ID>Female_001</Scan_ID>
        <MMP_ID>(Bugxxxp -xin)pa</MMP_ID>
        <Terms>Under bust girth</Terms>
        <Measure>33.8188</Measure>
        <Unit>inch</Unit>
    </Measurements>
```


Figure 10. Body scan data XML example

As shown in Figure 10, MMP XSD schema was assigned for body scan data XML format. The schema location appears in the second line of the body scan data XML. Formation and validation of the body scan data XML were tested with the XMLSpy software program. The test results showed that the XML formats were well formed and validated.

4.3 MMP XSD Formation and Validation Test Results

MMP XSD includes all necessary XML schemas for formatting body scan data XML and pattern data XML. Figure 11 shows the validation process of all experimental XML and XSD (XML Schema). The validation process was divided into an upper and lower level. The upper level is easily recognized by XML users such as [TC]^2 and Gerber Technology, Inc.

The lower level is a hidden process for validating XML documentations that have appeared in the upper level (See Figure 11).

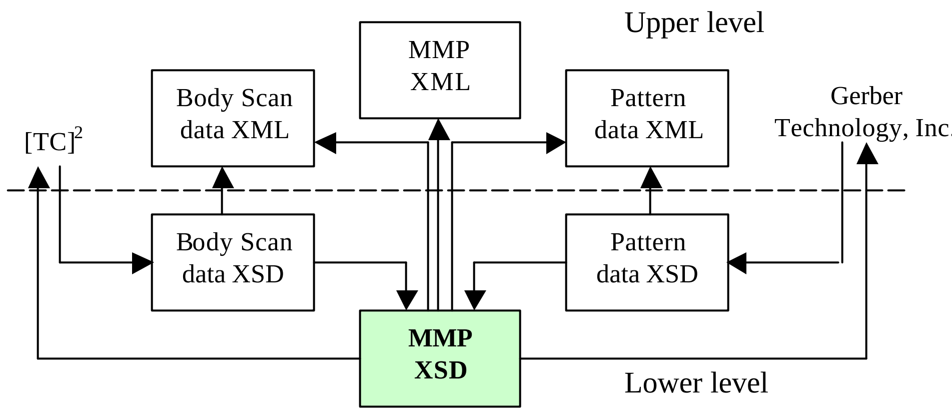


Figure 11. Validation process of XML and schemas between [TC]² and Gerber Technology, Inc.

As shown in Figure 11, in the upper level, a sample pattern data XML and a Body scan data XML are validated with MMP XSD. In the lower level, MMP XSD was understood by only software programmers at [TC]² and Gerber Technology, Inc., and body scan data XSD and pattern data XSD were imported from each company's system into MMP XSD. The validation of MMP XSD including body scan data XSD and pattern data XSD was examined with a XMLSPY software program tool. The result is shown in Figure 12.

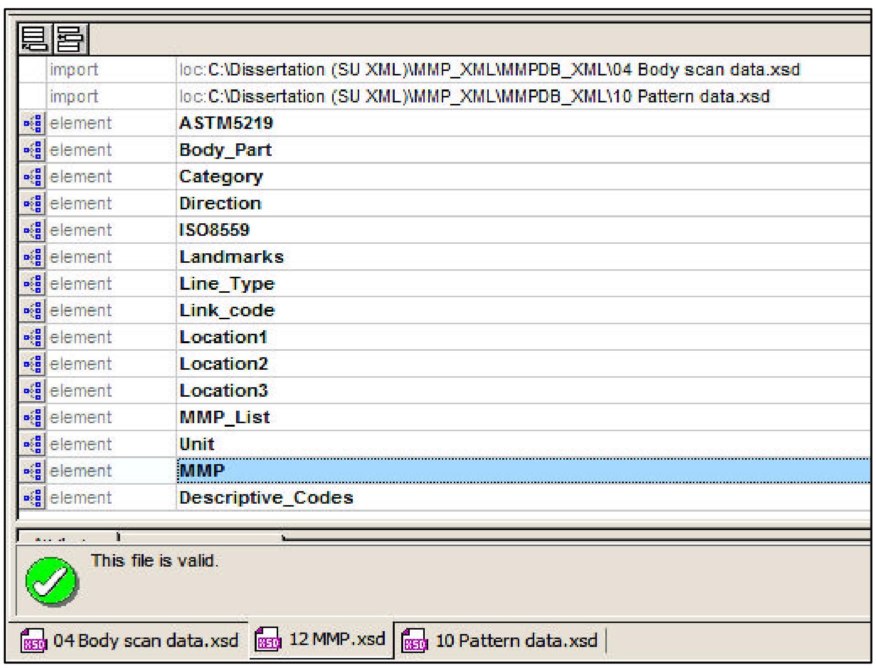


Figure 12. MMP XSD formation and validation test result

As shown in Figure 12, the XMLSPY test validated the MMP XSD. This proves that both XML in the upper level and XSD in the lower level are applicable. However, practical acceptance of the XML schema is still dependent on users or companies.

4.4 Advantages of Using XML (eXtensible Markup Language)

In this experimental design of body measurement data standardization, the XML format was used for bi-directional interpretation and communication between 3D body scan systems and 2D apparel CAD systems for the following reasons:

- Potential data format for the future,
- Simple custom markup language for standardization,
- Compatibility of data file format,
- And small file size for fast transmission.

4.4.1 Potential data format for the future

XML is a potential data format for the future since it has been generally implemented in most businesses. From the review of XML, the XML format was determined to be a significantly useful tool for emerging B-to-B commerce computer language in many industries, including the apparel industry and in standard organizations (Baker, 2002; Chang, 2002; Eshelman, 2000). The ASTM D13.66 subcommittee has discussed implementing the XML data format for developing future standard pattern data exchange formats.

4.4.2 Simple custom markup language for standardization

An advantage of the use of XML is that it is an easily readable data description. For example, XYZ coordinates or color values with other file formats, such as DXF, RGB and VRML, had limited ability to describe the data. However, XML could include definitions of the values with tagged data formats since XML (eXtensible Markup Language) is a meta-language that is used to create other markup language.

XML is a custom markup language with tags that are unique to a certain type of data with flexibility in solving data structuring problems. This result supports previous studies of XML format (Matsumura, 1998; Morrison, 2001) that XML format provides a basic structure and set of rules to which any markup language must adhere (Morrison, 2001). According to Matsumura (1998), key characteristics of XML are structured, self-describing (metadata= data about data), and extensible. XML is an extremely structured language specification. Good XML can be both well-formed and valid (Matsumura, 1998). Unlike most people's misunderstanding of the XML flexibility, XML included certain rules and structure in this study. This means that well formed and valid XML is important for standardization.

4.4.3 Compatible data file

XML was used to represent all information and on any computer platform. Table I shows the XML data file format compatibility with the following sample data file formats used in this study: XML, database file, [TC]^{2}'s body measurement file, and Gerber pattern data file.

From \ To		XML	MDB	HTML	TXT	DOC	XLS	ORD	DXF
Experiment format	XML	v	v	v	v	v			
Pattern data in Gerber Technology,Inc.	DXF								v
Body measurement data in [TC]²	ORD	v			v		v	v	
Database	MDB	v	v				v		

Table I. Data file format compatibility

As shown in Table I, the *.DXF file format pattern data from Gerber has the least compatibility with other documentation files. On the other hand, XML had the most compatibility with the other compared documentation files. [TC]²'s *.ORD file generated from the MEP file that provided customizable body measurement definitions can be read in XML format. The MEP file provided the *.ORD file through the body measurement data batching process after a body scan was processed. Even though the MEP file with the *.ORD file provided flexibility in defining different body measurements, the *.ORD file still had the limitation of transferring data to database.

In addition, the *.ORD data file format could not show data structure in a database. The database could display data structure but it did not have compatibility with *.ORD data file format. XML was created to show data structure with tags and can be transferred to any database as well as to HTML. Compared to a traditional database, XML data is pure text, which means it can be processed and manipulated very easily. The XML document can be opened in a text editor such as Windows Notepad to view or edit the XML code. XML makes it easy to transfer data between one application and another, and across networks since XML is pure text. XML essentially establishes a platform-neutral means of structuring data, which is ideal for networked applications, including Web-based applications.

4.4.4 Small file size for fast transmission

The XML file size used in this study was very small. Because of the small file size, it was easy and fast to transfer the data through the Internet. In addition, the XML file is small enough so that it can be stored on a smart card. Table II shows examples of XML format file size for body measurements and ASTM pattern data schema.

Table II. XML file format size of body measurements and pattern data

List of File format	File Size
MMP XSD	14 kb
MMP XML	35 kb
Body scan data XSD	10 kb
Body scan data XML	24 kb
Pattern data XSD	6 kb
Pattern data XML	5 kb
ASTM Pattern data schema XSD (From Gerber Technology, Inc.)	90kb

As shown in Table II, the range of file sizes used in this study was from 5 kb to 90 kb. Body scan data XSD and Body scan data XML had file sizes from 10 to 24 kb to describe data two body measurements from the [TC]^2's scan system. MMP XSD and MMP XML had file sizes from 14 to 35 kb. These files included full descriptions of landmarks and body measurements. The ASTM pattern data schema from Gerber Technology Inc. had the biggest file size of 90 kb but, this is still considered to be a small file size since the file contains all of the information about garment pattern pieces.

5. CONCLUSIONS AND SUGGESTIONS

XML format was found to be important for standardizing apparel CAD pattern data exchange formats providing several advantages. First, XML format provides easily readable data descriptions with a simple custom markup language. For instance, pattern data in XML format was useful to organize any necessary pattern piece information in that XML could include definitions of each pattern data value with tagged formats. Second, XML format is a compatible data file to convert into other data formats such as ORD, MDB, TXT, and XLS. The data conversion with compatibility made possible bi-directional interpretation of data between a body scan system and an apparel CAD system. Third, data in XML format was efficiently transferred via the Internet with the small file size.

Regardless of the advantages of XML format, the following limitations of using the XML format were found in the current application. First, few people had began writing the XML format in both body scan companies and apparel CAD companies. Even though developers and researchers realize the importance of using the XML format for standardization, currently, it was difficult to find programmers who could actually write in XML format. Second, existing systems had limitations in character number and types for describing XML format data. For instance, body measurements in the [TC]^2 system and size tables in the Gerber management system had a character number limit for describing body measurements. Body measurement data in the XML format could not be directly represented in existing systems. Third, the acceptance of XML schema by any other companies was not guaranteed because the schema was a suggestion, not an obligation. These findings indicate that acceptance of the XML format is tightly related to timely agreements in the apparel industry.

Therefore, a standard should be fixed and practically adopted in the apparel industry by providing the validated schema through a standard organization. In addition, the approach with XML data format should be replicated in apparel manufacturing. Since XML allows us to build interfaces that remove the communication barriers, it can be applied to implement quick response by designing a system of efficient information interchange with emphasis on data flow in apparel manufacturing.

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