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BodyXML: A XML-based High-Level Representation Framework of Human Bodies for the Development of Body Modelling Applications.

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Abstract: This paper describes the outcome of the e-T Cluster (IST-2000-26084) project, in particular the activities concerned with the development of common standards for the representation of human bodies for the purpose of facilitating easy development of human body modelling applications and the interoperability between them. XML is proposed to form the infrastructure of a generic, inclusive, high level data wrapper that allows a diverse collection of formats to be combined with the meta-information that is necessary for the development of complete, non-trivial applications. A tentative high-level data structure is presented, along with a demonstration of how its use has contributed to the success of a real-world interoperability experiment involving data from various 3D scanners, pattern alteration manufacturing software and pattern cutting software as well as animated dressed avatars. In addition, the use of BodyXML is expected to open up the possibilities of a Sizing Survey at a pan-European level.

Keywords: human body modelling, XML, body landmarks, measurements, textiles, patterns, sizing, made-to-measure.

1. Introduction

The work presented here is an attempt to resolve the problem of lack of *standard* representations for 3D and 2D body data in various fields of research and development (and, more specifically, in the area of garment design, manufacturing and retailing). Section 1 contains a description of the problem. Section 2 describes previous work that has motivated the proposal of BodyXML. The sections that follow present a description of the design issues that had to be dealt with, as well as an overview of the standard itself. Interoperability issues are discussed in section 5, followed by conclusions and a description of future work.

1.1. Description of the Problem – Background

BodyXML is being proposed as an open representation standard aiming to assist application developers by providing a set of common placeholders for information, which can subsequently be parsed and processed using straightforward, standardised methods. Since many years, the need of a Pan-European Measurement Survey has been discussed by the European Sizing Co-operation, a CEN workgroup comprising the largest European apparel manufacturers and retailers as a prerequisite for development of a *European* Size-Indication System and Coding. One of the biggest issues, which arose in many discussions, is that of comparability of the measurement methodologies and thus combinability of results form different countries in a unique data pool. Whereas 3D Body Scanning technology, thanks to the E-Tailor Project (IST-1999-10549), has been accepted now as the method for body data acquisition by the relevant industries, there exist still no common standards with regard to body measurement extraction from 3D scan information, despite the known ISO and ASTM standards for manual body measurement (which are inconsistent and by far not sufficient for standardizing scan-based measurement methods). Major steps in this direction have been reached now by the outcomes of the Standardization preparations of e-T Cluster on both levels: the definition of a common set of body measurements for the apparel area and definition of formats for the exchange of this information (BodyXML).

1.2. Objectives of the e-T Cluster Project

The main objective of e-T Cluster was to bring together the main key players in Europe and cluster European and National projects to propose a framework of standards, enabling the seamless integration of 3D scanner,

CAD and Avatar technologies, thus homogenising innovative infrastructures for Virtual retailing services of customised clothing and possibly other related services.

Three main Technical workpackages included:

- The development of CAD Interoperability Standards,
- The development of Standard 3D Body and measurements' representations,
- The testing Standards in Common Testbeds

The project completed successfully in December 2002. The main technical deliverables included: A proposed standard for definitions of human body measurements, adapted to the needs of 3D scanning technologies; a proposed standard (BodyXML) for the representation of body information and related data; a proposed data flow model for interoperability between systems using the other two standards; and a report on the tests carried out in a number of testbeds to evaluate the feasibility and performance of all the aforementioned standards.

2. Previous work

This work is not the first attempt to standardisation of 2D/3D human body representation. During the second half of the nineties, which saw the emergence of a number of 3D scanner manufacturers, the development of both hardware and software has evolved independently from various points. The need for appropriate standards had been identified back then, especially since their main application for the new hardware technology had already been identified as the automation of garment sizing, manufacturing and retailing. In the related areas of pattern making and alteration, there had already been established standards such as the DXF/AAMA for pattern description. However, with various hardware systems being developed independently at the times, there had been as many body representation standards and formats as scanning hardware products. The study by Carrere et al. [CILHP01] back in 2001 summarises the state of the market at the time and illustrates the diversity of representation formats. Another one of the early attempts was the 3DCentre Project, which attempted to bring together a consortium of UK clothing retailers and establish common sizing standards. At the early stages of that project, a report was compiled [Dour99] that also illustrate both the wealth of standards and activities for human body representation, and the lack of a reasonable ‘lowest common denominator’ for information interchange between different systems. The outcome of standardisation work from the 3D Centre project has been eventually utilised by e-T Cluster as described later in this paper.

3. Design Issues – The Choice of XML Technology.

The major high-level requirements of the proposed BodyXML standard are the following:

- To interpret the world of ‘bodies’, ‘persons’, ‘garments’ and ‘products’, and provide a high level representation thereof.
- To provide application developers with a set of both high-level and low-level placeholders that can accommodate diverse levels of information into a structure that can be easily and intelligently parsed.
- To enable a smooth transition from existing formats by integrating them into the high-level structure by means of external reference.

The Extensible Mark-Up Language (XML) is ideally suited to the above requirements, as it is an open standard that allows the definition of structures, as well as the external referencing of low-level files. In addition, there is a wealth of development tools that speed-up application development by handling the parsing of structures. XML is also ideal for separating the information content from the method that it is displayed, thus allowing maximum flexibility. For a full reference and further information on XML and its data representation mechanisms, please refer to the World Wide Web Consortium website [w3c].

4. Overview of BodyXML

As part of the European Commission standards project e-T Cluster we are attempting to create a ‘body’ XML. BodyXML specifies a European ‘XML wrapper’ standard principally for clothing applications, such as virtual shopping and custom clothing/MTM, that integrate ‘body’ representations and ‘product’ representations. However, in the future we wish to see BodyXML extended to other environments such as ergonomics, fitness/diet, and health etc.

In BodyXML, a ‘person’ is a unique individual. The person has two attributes: ‘details’ - unique information such as their name and contract information, colour of hair, eyes and skin, shopping and colour preferences etc; and multiple ‘representation’(s) - each of which could be a picture of a body part, a point cloud from a scan, a set of body measurements etc.

In BodyXML, a ‘product’ – currently scoped to clothing - is a unique garment range. The product again has two attributes: ‘details’ - unique information such as the product, retailer and manufacturer names, textiles, care instructions etc; and multiple ‘representation’(s) - each of which might be a picture of a specific garment, such as a size 8 red garment, and its measurements etc.

These are the basic attributes of BodyXML. Everything else forms part of the application that combines a ‘person’ and a ‘product’. For instance, a virtual shopping application might take as input a 3D colour picture (multiple JPEGs) of a person and the pattern pieces for a specific size/colour instance of a product from a CAD/CAM system, realistically drape the product on the person, and place the resulting 3D image in a virtual dressing room. In this example the person and product specification are part of BodyXML. The draping and dressing room are part of the *application* - not part of BodyXML.

The current latest version of BodyXML is described in detail in e-T Cluster Deliverable D6 [eTCD6]. The document is divided into five parts:

- **Part I -** provides a top-level specification of BodyXML.
- **Part II -** covers 3D body shape representation.
- **Part III -** describes the body measurements standard which is part of BodyXML
- **Part IV -** covers interoperability and compliance in particular with CAD/CAM systems.
- **Part V -** presents the basic BodyXML specification.

In this paper we present an overview of the first four parts (the last one is too long and detailed, and beyond the scope of this paper – however, the draft is available upon request in case the reader is interested).

4.1. BodyXML Top-Level Specification

As discussed above, the concepts embodied in BodyXML centre on an individual person and an identifiable product (range). The key concepts are:

Person	A uniquely identifiable human being (e.g. “Joe Bloggs, born 29/11/1973 in London”).
Details	A set of meta-information about a person (i.e. anything about the representation of the physical body: contact details, socio-economic information, identity profile, shopping preferences etc.)
Representation	A representation of a person (2D, 3D, in that sense a ‘person’ can have many ‘representations’, e.g. “bloggs.tfm”, “jblg002.wrl”, “jb98347.bls”)
Product	A collection of garments to be marketed as one entity (e.g. “Otto Shirt”)
Details	A set of information that accompanies the physical description of the garment (e.g. target market information, manufacturer, retail outlets, stock information)
Representation	A representation of a specific garment (size 8, red, image JPEG)

The top-level specification provides a discussion of the semantics of BodyXML. More specifically, it covers the semantics of: *bodies*, *products* and the *applications* linking them. Currently we are focusing on scanning whole bodies and clothing whole bodies. Clearly the semantics needs to be extended to the head (for hair and makeup) and accessories (leather goods, jewellery etc.). More importantly systems processing BodyXML will need to operate with incomplete and possibly asymmetric representations (2D/3D, whole body/head) and sizing data (key measurements, point cloud), and map correctly between them.

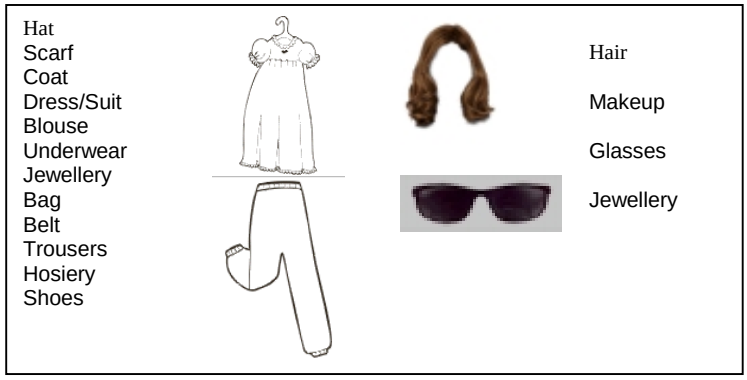
Persons

On the right we illustrate the principal parts of the body representations to be captured by BodyXML. In practical terms we are likely to have images and sizing data of *whole body*, *head*, *upper torso* and *lower torso*. However, we could theoretically have images and measurement representations of the eyes (for glasses), hands (for gloves), feet (for shoes) or even individual fingers (for rings). We may have multiple images and measurements, or none.

In addition, when we come to services there will be mapping information that associates a specific product with a particular body representation. For instance, eyeglasses can be image fitted to the eyes, but may also be placed on the head. Likewise a scarf might be worn on the head, around the neck or even draped over the shoulders.

Products

The diagram on the right attempts to capture the range of product representations that need to be encapsulated in BodyXML. For the 'whole body' representations this comprises clothes, accessories and shoes etc., and for the 'head' hair, makeup, eyeglasses and jewellery. Again, we may have multiple images and measurement representations, as well as the requirement of a mapping between incomplete and asymmetric information. For instance, having to reconcile 3D and 2D images.



Applications

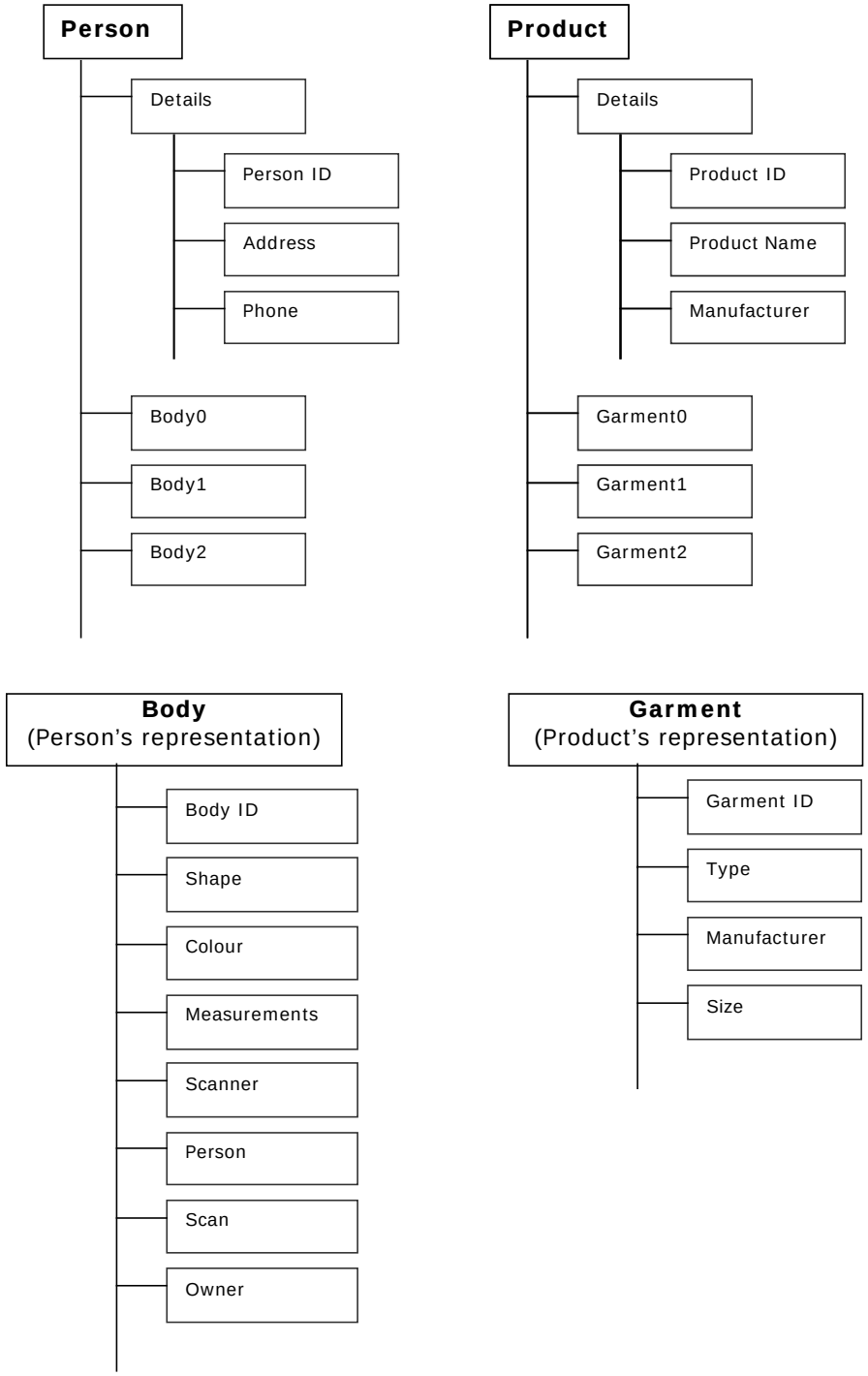
Applications are not part of BodyXML, but it is useful to consider them with regard to mapping between persons and products. For instance, any virtual shopping or MtM service is attempting to replicate the traditional shopping experience electronically. Onscreen *virtual dressing rooms* where you can try on clothes from web and TV catalogues and magazines, *virtual mirrors* where you can see yourself, *virtual tape measures* for selecting ready-to-wear clothing or clothes' made-to-measure just for you, *virtual makeovers* of hair and makeup, *virtual wardrobes* to store your clothes, and *virtual shop assistants* for advice. However, these concepts are NOT part of BodyXML. The collection of diagrams on the next page illustrates the information included under each one of the top-level types.

4.2. BodyXML 3D Body Shape Representation

This section is concerned with the representation of body shape and geometry irrespective of the application domain. The content is based on e-T Cluster Deliverable D3 (Requirements Specification for 3D Body Data Standard). Please refer to that document [eTCD3] for further details on requirements' specification.

Structure of the Application Domain

The 3D body data is split into six content modules. The raw scanner 3D data is likely to be a point cloud with connectivity and links to textures. The textures (images of the person) are likely to be in a standard format such as the JPEG format. The meta-data is of two types: personal and body. The body meta-data includes measurements that are being defined in Deliverable D7 [eTCD7]. 'The Seamless Generic Measurement Avatar' is a watertight high-level definition of the surface geometry of the person, aimed at measurement applications. The 'Seamless Generic Animation Avatar' is for visualisation applications in which the avatar is animated e.g. walking or waving.



Deliverable D3 also includes requirements for data storage and communication of the 3D body data. The data storage requirements vary from smart cards to anthropometric databases and animatable avatar servers. Communication requirements include those of the Internet such as compression and streaming. In addition to the two main clothing industry applications (virtual try-on and made to measure), other emerging applications have been analysed. These other applications are included in an attempt to throw up issues that may broaden the usefulness of the e-T Cluster 3D body data standard, without compromising its usefulness or usability. However, the consortium is primarily focused on Fashion and Garment applications.

Content Requirements

The proposed standard must cater for the following types of information:

- **Stance**: The posing stance is the position that a person holds whilst being scanned in a 3D scanning booth. In practice, several posing stances are used and more information can be obtained. There is a common requirement for a scanner: to capture as much of the body surface as possible. Different anthropometric surveys also define different posing stances; each survey usually defining several stances.
- **Person's details (Meta-Data)**: Data containing biometric information (body meta-data) should in all cases be included in the 3D body data file whenever available. This is because many applications will require this data. It can be argued from a data security point of view, that the 3D body data and body meta-data should be stored separately from personal meta-data. This could be done with an identification number in the 3D body data that associates the 3D body data with personal meta-data in a database. It is recommended that meta-data is split into the meta-data in the 3D body data file (Body meta-data) and the meta-data in the database or XML wrapper (Personal meta-data). Body meta-data might include: Weight; Sex; Age; Scanning data (scanner location, scanner operator, scanner make, model etc). Personal meta-data might include: ID code; Contact data (name, address, e-mail, phone); Medical data; Privacy/security (level of consent for use of data etc).
- **'Raw' 3D Scanner Data**: The raw manufacturer's scanner data should be kept in the 3D body data file. The main reason is that usually when 3D data is processed, information is lost. By keeping the raw data, no information is lost.
- **Measurements and Shape**: The list of required measurements is specified in Deliverable D7 [eTCD7].
- **Colour and Texture**: These are required for visualisation applications. Conformance with existing commonly used methods of texture mapping 3D models is advisable. The standard method is to index vertices on the 3D model with U,V texture map coordinates in the image file, although it is possible to store them on an external file (e.g. JPG, GIF) that is referenced from the 3D body file./
- **Animation**: The requirements for body and facial animation are fully covered in the existing h-anim 1.1 specification.
- **Structural Information**: The following types of structural information should be allowed to be included (in order of dimension):

0	Landmarks	Point
1	**Reference contours**	Line
2	**Surface segments**	Area
4	**Volume Segments**	Volume

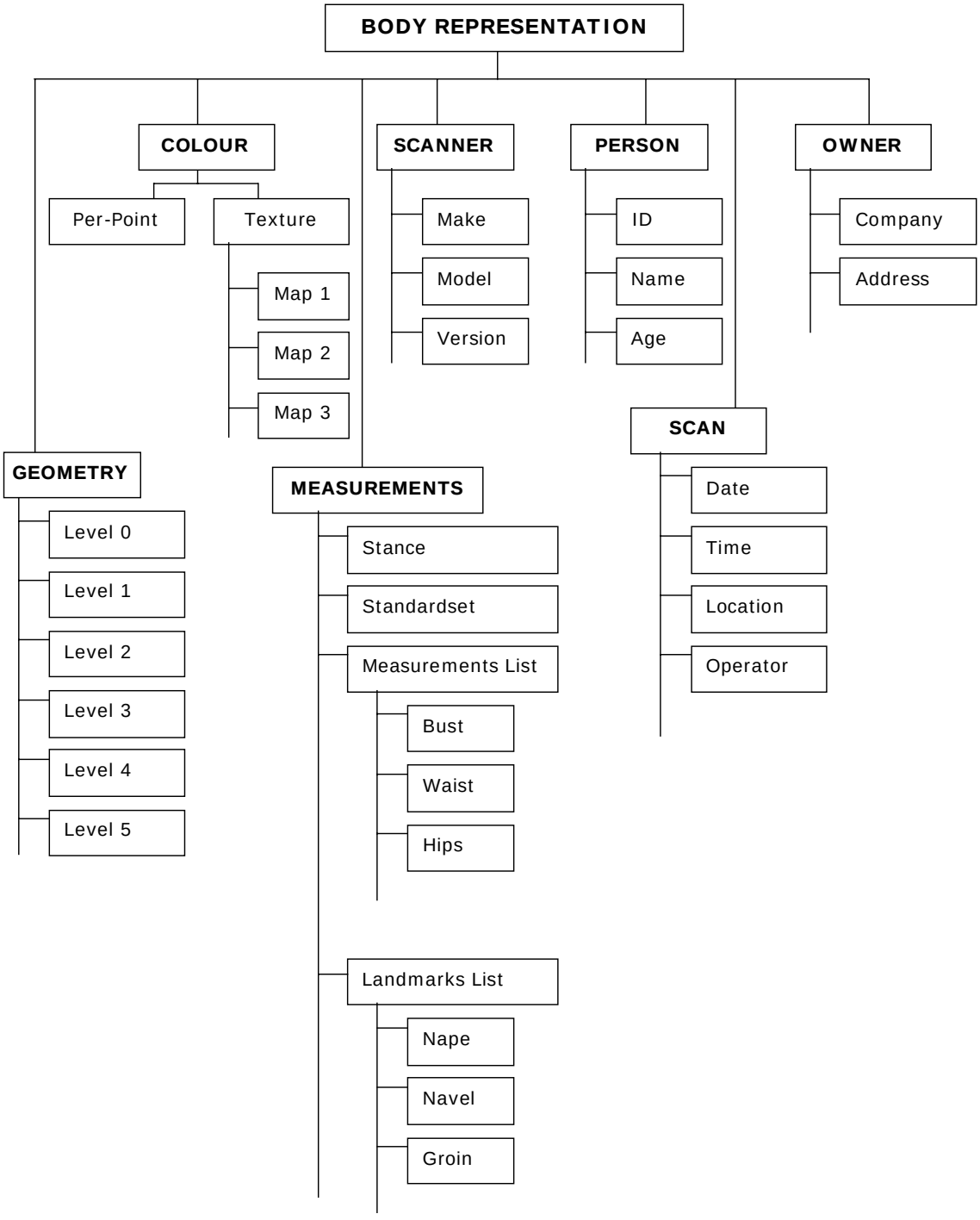
The diagram on the next page shows the structure of that information. This particular level of the standard does not try to enforce a particular file format for the representation of body shape and geometry. Instead, it is used as a placeholder to allow external references to 3D files of any format (more about that on the next section).

Levels of 3D files for body representation

This classification is necessary in order to enable application designers to design their applications correctly and efficiently by giving them a correct and precise idea of the kind of 3D information they have available. Also, this arrangement allows each 'body' to be represented by different versions of the same file at different stages of processing, thus making it suitable for a wider range of applications.

The proposed arrangement in this section follows an earlier proposal by TecMath for multiple-level representation. TecMath's proposal can be found on the relevant e-Tailor specifications document T3.2, titled 'Uniform Body Representations'

The reason for proposing this arrangement is to enable applications and systems developers to use whichever file format and technology they see fit for their application, without been forced into using a specific format, but also without compromising interoperability between systems. Therefore, this standard defines a hierarchy of placeholders for 3D representations, in a manner that allows developers to have a common language for understanding the nature and extent of the representation used.



The levels of representation are defined as follows:
Level 0: Raw binary uncleaned (usually proprietary) point cloud with holes (e.g. BLS – not for general use, and may be encrypted)
Level 1: Raw uncleaned unconnected point cloud with holes, in a generic, text based, human-readable form (e.g. VRML, XYZ, TXT)
Level 2: Cleaned unconnected point cloud with holes, in a generic, text based, human-readable form (e.g. VRML, XYZ, TXT)
Level 3: Cleaned connected point cloud with holes, in a generic, text based, human-readable form (e.g. VRML, XYZ, TXT)
Level 4: Complete watertight SGMA-compliant surface (triangulated or parametric, e.g. h-anim)
Level 5: Complete watertight animatable SGAA-compliant surface (e.g. h-anim 2.0, MPEG-4).

For more information on H-ANIM, please refer to the Humanoid Animation Specification [hanim01].

4.3. Body Measurements

Most of the e-T Cluster work on defining sets of measurements has been done as part of Deliverables D4 and D7. Please refer to the latest available version of D7 for further information. The goal of that task was to initiate the attempt for standardisation of the definitions of body measurements used for clothing design in Europe. The list of measurements and their definition has been built by gathering input and feedback from the e-T Cluster partners, and work is currently focused on achieving agreement upon the structure and content of this list.

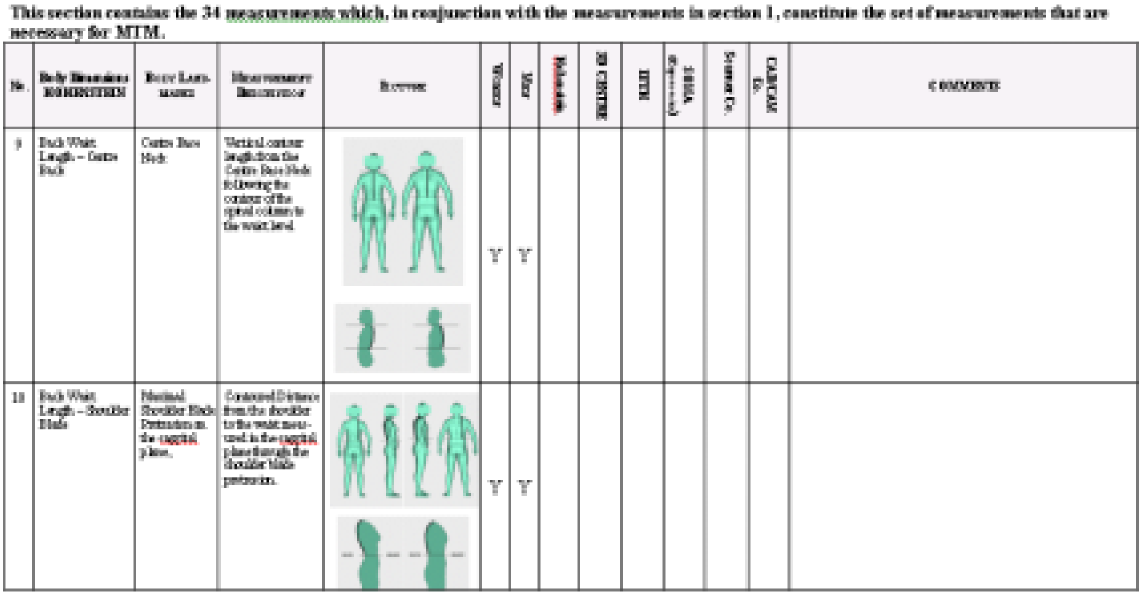
The measurements are divided in the following 3 categories:

- Primary Measurements – used for Sizing
- Secondary Measurements – used for MTM
- Additional Measurements – for general use, pattern making and shape analysis

The purpose of endeavouring to achieve a set of clear, precise and undisputable measurement definitions is to define ultimately a standard that covers the needs of the European clothing industry. It was desirable, through the e-T cluster project, to promote the use of 3D scanning technologies for clothing design and manufacturing. However, the attempt has mainly been focused on adapting and improving these technologies in order to meet current needs, rather than re-adjusting the perceived needs of the industry in order to match the capabilities of 3D scanning technologies in general, and the capabilities of the product of a specific scanner manufacturer in particular. Each measurement has been included or excluded from the list not according to how easy or possible it is to extract it using current scanning technology, but according to how important it is for the production of garments. This is in order to enable hardware and software developers to steer their development towards technologies that may meet the specifications proposed here. It is desirable, as a follow-up of this work, to proceed to standardising the software used for automatically locating landmarks and extracting measurements described in this specification. However, it is still too early to address the issue of standardising the software, and such an issue is outside the scope of this document.
It is therefore important to note that:

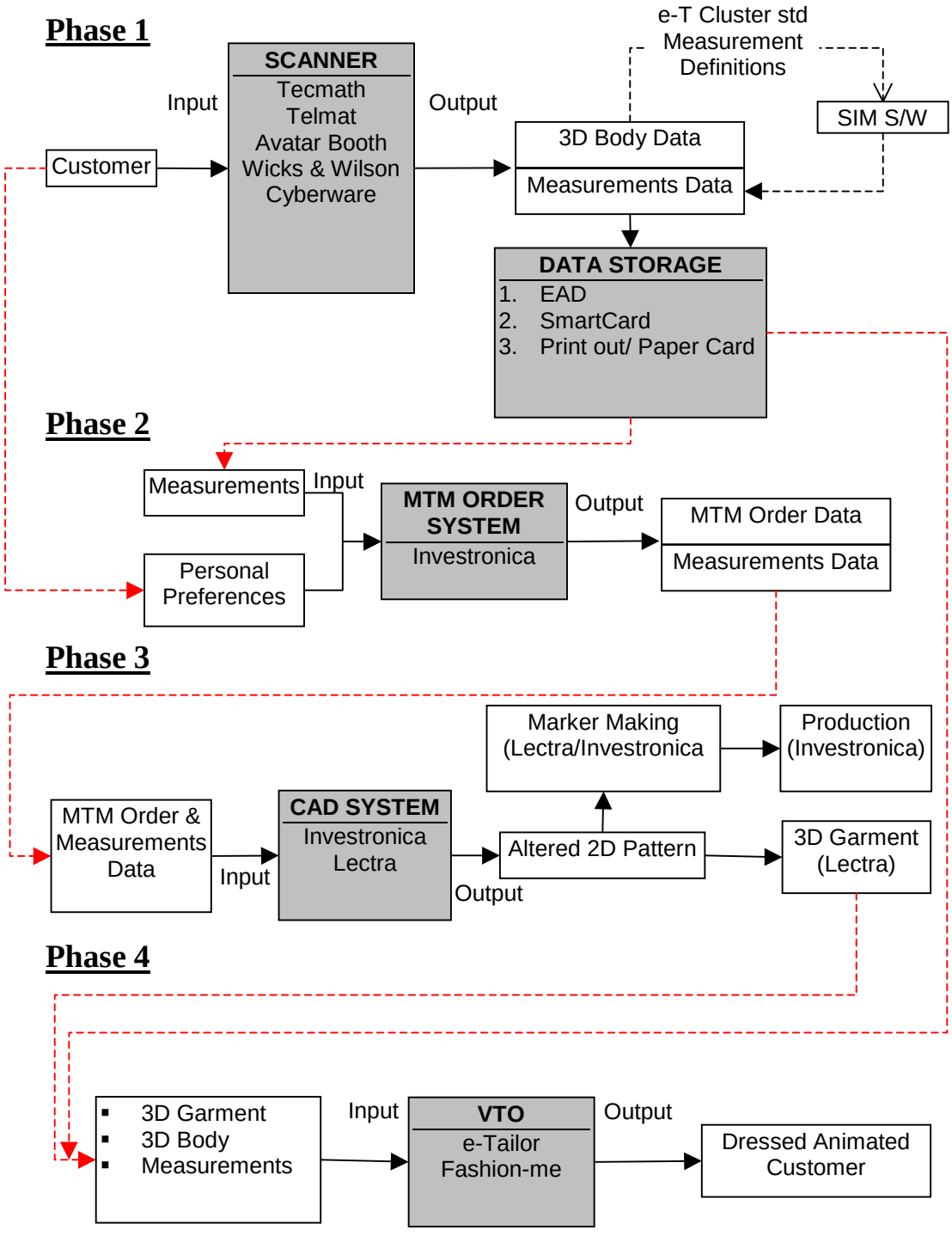
1. Body measurements were identified that are important for clothing design
2. An unambiguous description is given of these scan derived body measurements
3. The detectability of the 3D-scanning technique is incorporated in the description
4. The measurements are as close as possible to ISO 8559 and ISO 7250.

Some of the measurements in the ISO standards require palpation of bony points before the measurements. 3D scanning offers the advantage of untouched size determination and therefore palpation is not desired. Deviations of the ISO standards therefore occur for these measurements. The figure below illustrates the structure used for measurement definitions:


This section contains the 34 measurements which, in conjunction with the measurements in section 1, constitute the set of measurements that are necessary for MTM.

5. Interoperability and Compliance

BodyXML (developed as part of the e-T Cluster project) and the CAD Interoperability standard (developed as part of the e-Tailor project) were be tested in a configuration combining systems developed at both projects. The tests were aiming to verify that the info is generated correctly (by scanners and CAD systems) and read correctly (by CAD systems and fashion visualisation software). The resulting deliverable document [eTD9] details a test plan that tests every aspect of every feature in the standards and provides the design of a number of complete test cases involving the use of different software entities (booth, CAD system, web fashion show, etc), in various configurations simulating real service scenarios. The test beds were not situated physically in one place. The Internet was used to send data generated in one location to be read in another location. The following systems were used for generating data: Telmat scanner; TecMath scanner; AvatarMe booth; Lectra CAD system; Investronica MtM ordering and CAD systems. The following systems read the data: Lectra CAD system; Investronica CAD system; AvatarMe fashion show system. The diagram below illustrates the data flow:



6. Results - Conclusions

BodyXML was used extensively throughout the interoperability testing. Given the individual reports provided by the partners involved in this task, and presented in sections 1-5 of this report, it is reasonable to claim that on the whole the task has been successfully completed. The chain of interoperability transactions from Scan-to-Pattern-to-Garment-to-Animated-Dressed-Avatar has been implemented, in effect proving the principle of the possibility to use diverse sources of 3D and 2D human body representations (i.e. scans from various types of scanners) and from them produce not only animated 3D avatars dressed with a specific garment, but also manufacture the garment itself, properly sized up so that it may fit the customer scanned. Both the animated avatars generated from this exercise (by AvatarMe), and an example shirt manufactured (by Investronica) as the physical result of the interoperability chain, were presented during the final e-T Cluster Review meeting, in December 2002.

This achievement bridges a gap that has been making its presence intensely known in the scanning and clothing industries during the last few years. Namely, the problem of compatibility in the 3D body representations generated by various makes and models of scanners, and therefore the (up until recently) unworkable difficulties of building generic 3D body modelling software. This software should be capable of processing virtually any 3D human body scan, and therefore provide suitable export to any sizing, pattern making and garment manufacturing system. The work carried out has shown that now there is sufficient infrastructure and expertise to allow the development of such software. Adoption of the technologies and standards developed in the framework of this e-T Cluster workpackage should ignite further progress in the development of modular, interoperable custom clothing and virtual shopping systems in the European industry.

Finally, this workpackage has demonstrated the suitability of Extensible MarkUp Language (XML) as a generic, tolerant, flexible and customisable mechanism for exchange of information within this collection of diverse hardware and software and software systems. In particular, the ability of XML to act both as a syntax for information content, and as a placeholder/wrapper of information held in files of other formats, makes it the ideal interoperability infrastructure for integrated application of the type that concerned the e-T Cluster Interoperability workpackage.

7. Future Work

The main results of the work presented in this paper are initial proposals on standards, targeting two communities: the 3D whole body scanner developers' community and the apparel CAD community, and the garment manufacturers and fashion retail industry.

Future dissemination / standardization follow-up activities will evolve around the following axes:

7.1. Activities in Europe

- Submission of e-T Cluster results (Body XML and CAD Interoperability) to the TEX SPIN CEN/ISSS workshop (http://www.cenorm.be/isss/Workshop/Workshops.htm) to be considered as a special case of the Textile-Clothing XML framework to be developed in the above CEN initiative, relating to Made-to-Measure services (from order to production). The Workshop “Textile Supply Chain Integrated Network (Tex-Spin)” aims to provide the Textile/Clothing sector with an open pre-normative platform for electronic data interchange based on XML documents. The TEX SPIN workshop started on July 1, 2002 and will end by September 2003 (http://www.cenorm.be/isss/Workshop/Workshops.htm).
- Submission of eT-Cluster final list of Measurement definitions to the CEN Committee TC 248/WG10 (textiles and clothing), working group 10 “Size designation system of clothing”, which.is involved in the definition of 4 European standards on Sizing, of which the most relevant is the recent standard on the definition of primary and secondary body measurements. Close links to TC 248 have already been established and will be maintained.
- Promotion of the common objective of a European Sizing Survey making use of the homogenized framework developed in eT-Cluster and the supported IST project E-Tailor (IST-1999-10549).

7.2. International activities:

Our plans for international dissemination of BodyXML worldwide include:

- Further presence to the ASTM D13.66 - 3D Body Scanning Task Group.
- Submission of results to h-anim (Humanoid Animation Working Group of the WEB3D Consortium)

8. Acknowledgements

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