A Framework for Garment Shopping over the Internet

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In this chapter, we propose a framework for integrated design, advertisement and retailing of garments over the Internet. This on-line shopping framework would make use of the latest research in computer graphics, image processing, computer vision and artificial intelligence. We describe these technologies in more detail, and explain how they can be used to build a visually attractive and easy to use interface to an intelligent integrated system that fulfils most of the functions of the traditional production chain, while allowing for mass-customization.

(3D Body Modeling/Reconstruction, Advertisement, Case-Based Reasoning, Content-Based Image Retrieval, Garment Design, Knowledge-Based Design, On-line Shopping, Physics-Based Modeling, Virtual Agents, Virtual Reality)

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1. Introduction

The modern computer and telecommunication technologies have had an enormous effect on design, manufacturing and marketing in most of the existing industries. Computer aided design (CAD) systems have become indispensable tools for the designers of almost any type of products. The developed designs and the raw materials are the input to the next component in the chain, the highly automated manufacturing processes based on computer aided manufacturing (CAM) tools. The final products are delivered to distributors and retailers, but also advertized through attractively designed video commercials or images presented to the targeted group of users through different media.

Computers are also essential for administration, and in modern companies most of the relevant information, such as product and advertisement designs, market analysis results, raw material and final product orders, memos, e-mails, company presentations, etc. are processed, stored and communicated electronically. Therefore, it is not surprising that many industries have gone through a process of integration of the designers, suppliers,

manufacturers, marketing infrastructure, etc. into global networks that can develop and market products in a much faster and more inexpensive manner than before. Most of the companies acknowledge the importance of the interaction among different parts of the company and/or the external partners, and work on improving it.

On the other hand the communication with the target of the whole system, the customers, is not nearly at the same level of interactivity. The information given to the customers may be carefully presented through impressive advertisement, but it is still mainly pipelined through the classical media: television, radio, newspapers/magazines, catalogs, etc. While different media require different strategy and technology in advertisement design, one feature of the modern marketing on classical media remains the same. The only feedback about their needs the customer gives by making a choice among the available final prooducts. This information comes back to the manufacturers through the market statistics. Of course, there are other attempts to get the customer feedback, through complaint records, customer satisfaction polls, etc., but these require additional mechanisms for acquiring and processing such information, and still result in some statistical data as the feedback to the manufacturer. The situation is somewhat remedied by a natural increase in the number of manufacturers and products with the aim of satisfying all possible needs. The problem is then transferred to the problem of markets cluttered with products and indecisive customers.

Instead of spending a lot of time browsing through the abundance of the available products (and meeting with variable success), many people find it appealing to sometimes shop for an item by specifying the features they need and having the appropriate product made exclusively for them. However, for this luxury, the customer usually has to go back to the small custom fit shops (tailors, custom fit carpenters, etc.) and give up the speed of delivery and the low prices inherent to the mass production.

In this chapter, we intend to demonstrate how the modern technology is going to further affect all the components in the production chain and make the whole system more accessible to the customers through the more interactive medium, the Internet, bringing them faster access to the product information and possibility of shaping the products before ordering them. We concentrate on the garment industry and study a possible design, manufacturing, distribution and advertising scenario using the Internet and the latest research results in computer graphics, image processing, computer vision and artificial intelligence. Many, if not all of the major technological components used in this scenario, can be, or already are successfully applied in the traditional approaches to garment design and advertising, or have been developed and used for other purposes. Before outlying the on-line garment shopping scenario and the involved computer technologies, we give a brief survey of interesting existing examples of the application of modern computer technology in the garment industry.

1.1. **Existing Computer Technologies in Garment Design and Advertising**

Several software companies specialize in the CAD software for garment design. The most popular are the tools used in the design of sewn garments, knitted and woven fabrics, and textile-prints.

For the purposes of sewn garment design, the software usually allows the designer to create patterns from basic sloper shapes (A sloper is a basic garment shape, also known as a body glove or a body block). The designer can then modify the patterns, insert darts and create seam allowances. The garment (always consisting of several patterns) can be parameterized by several size parameters to allow for better size customization in the mass production. The patterns can be viewed in the fabric layouts in which the designer can align the patterns, make the measurements, create markers etc. The final design can be printed in the form of a technical drawing. Also, the designs on paper can typically be digitized and then edited in such software.

Another type of CAD tools in garment industry is the software for knitted-fabric design. For example, the designer can choose stitches from the library of stitch groups and arrange them on a grid. Such software often interfaces directly to the computer controlled knitting equipment.

The tools for coloring the woven fabrics also exist. The designer can construct different weaves and colorways, or choose from the existing designs in the database, and apply the woven fabric pattern on a surface.

In textile-print design, the CAD tools are used for creating and manipulating tonal or flat-color designs, or processing arbitrary digital images and creating corresponding spot or tonal manufacturable prints. This type of software usually includes some basic image processing tools, and stores the designs in a database, just like all other types of CAD software.

These databases are searched in a traditional manner: by a combination of textual queries and browsing through the list of hits. For example, the user can ask for all floral print-fabric designs in the database, or specify a specific type of slopers (skirts for example), and retrieve several hits. The databases are typically annotated by hand.

Most of the CAD software developers also offer the tools for visualization of the designs for catalogs. These tools are based on operator-assisted texture mapping. The user manually defines a 2-D or a 3-D mesh over the garment in a photograph of a mannequin. Usually, the mannequin wears a garment of uniform color, so that the light-dependent shading in the photograph can be extracted. The woven, knitted or print-fabric designs are than mapped on the mesh and the shading from the photograph is applied. This process, often referred to as re-imaging (Computer Design Inc.), allows the user to create several images of a mannequin wearing different designs, all from a single photograph. Further more, some of the methods that we will cover later in this chapter, also allow for building an advertisement by changing the layout of the photo, adding text, etc.

The re-imaging method obviously does not take into account the topology of the garment, as specified by the patterns and sewing lines in the sewn garment design, for example. The correctness of the final image depends on the user's knowledge of the garment topology, their perception of depth in the given photograph and their ability to transform this perception into a good mesh for texture mapping. An alternative, a physics-based simulation of the complex garment's drape over the given three-

dimensional geometry of a mannequin, often produces computer graphics-like images, i.e., it lacks realism.

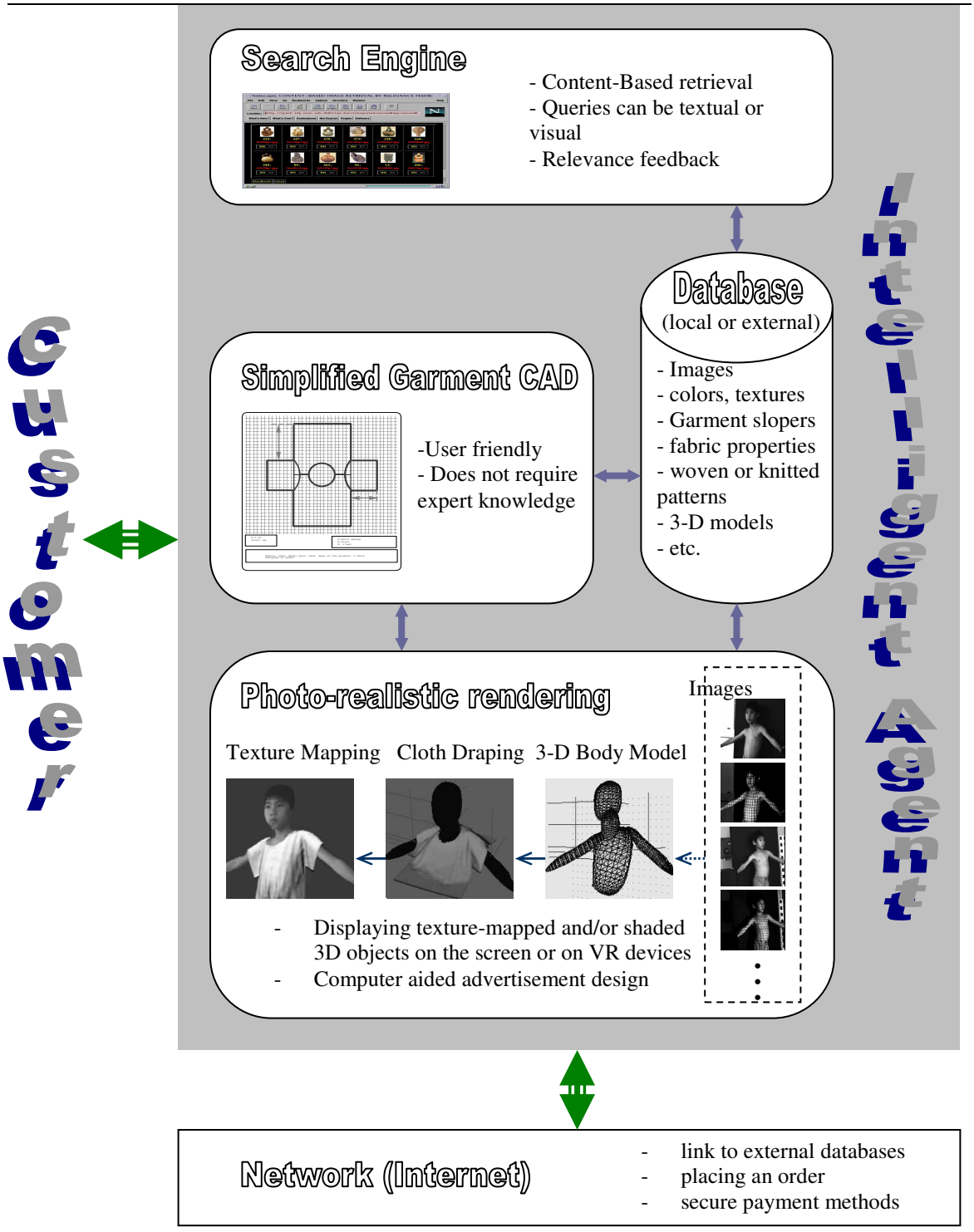


Figure 1. The framework for garment shopping over the Internet

With the growing popularity of the Internet, the CAD software in garment industry is slowly becoming “Internet friendly”, but the network oriented capabilities usually offer a little more than an easy access to e-mail.

Another important technological development for textile industry is body scanning systems, usually based on laser scanners, photometric stereo or structured light assisted stereo systems. These systems can be used for automatic body measurements, and custom-fit shops based on these systems already exist. The customer chooses one of the offered garment styles, and then their body measurements are acquired automatically by the scanning system. These measurements are used to determine several size parameters of the garment, and the order is placed. The garment can still be manufactured on a regular manufacturing line.

1.2 The New Computer Technologies and a Scenario for Shopping over the Internet

There are several advancements in computer technology that have not yet been fully used in the garment industry. Here we propose a scenario for shopping over the Internet that is based on an integration of the existing and novel computer technologies (Figure 1).

In this scenario, the customer visits the virtual shop on the Internet. There, customer browses through different designs, and even uses a simplified CAD tool to change them. The customer can search the database for desired colorways, knitted or woven designs, print designs and/or different types of fabrics for sewn garments. In the case of the print designs, the customer could even submit the digital image that they want printed on their garment. Also, the customer should be able to specify images and shapes as the database query instead of simple text. The modern image processing techniques allow for image retrieval based on content. The computer can return images similar to the query image in color, texture or shape. This method can be applied to retrieval of print designs, woven design textures, or pattern shapes in sewn garment.

The customer's body has already been scanned, in one of the available scanning centers nearby, and they “brought” the electronic form of their body geometry with them to the Internet site. The selected garment can be shown to the customer draped directly over their body model, using the physics-based simulation and image-based rendering to increase the realism. In the future, with the increase of the computational power of personal computers, it will be possible for the customers to use one or more cameras and the computer screen as a virtual mirror in which they can see themselves just as in the real mirror, except that on the screen they are dressed into a virtual garment that they want to try on.

An intelligent virtual agent can assist the customer. This virtual salesman acts similarly to the real sales personnel. It uses its experience and the observations of the customer's actions to help in making the choices or to guide the database search. The agent may even suggest other types of garment that match the garment the customer has already chosen.

The sale can be finalized and payment made using a secure protocol directly on the Internet site, and the order is automatically placed. Within several days the garments have been manufactured and delivered.

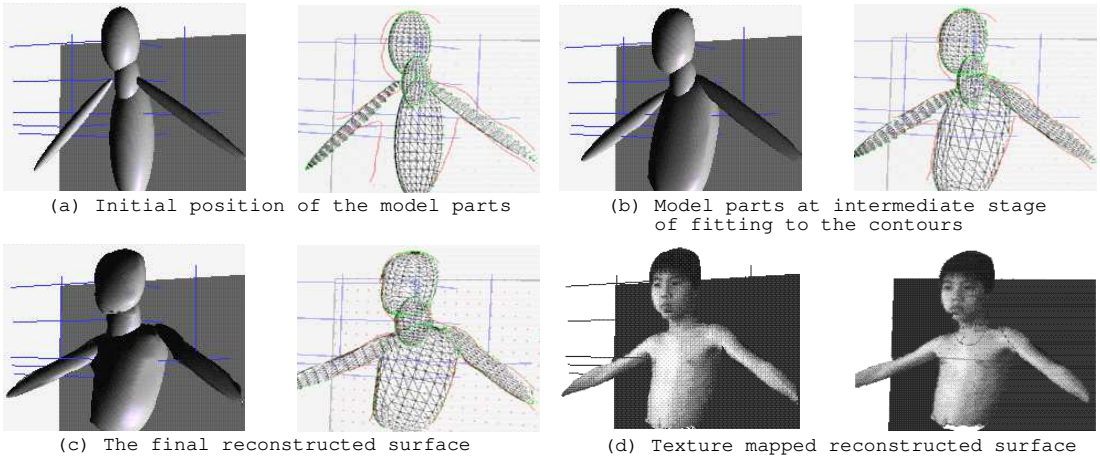


Figure 2. Several stages of 3-D reconstruction of a human body

This scenario requires several important computer technologies:

- A body scanning system that efficiently reconstructs the body of the user, acquires the texture for photo-realistic rendering, and extracts the body measurements.
- A cloth draping algorithm based on physics-based simulation.
- Visualization tools and devices (from the computer screen to the immersive virtual reality devices).
- Databases with image-based retrieval capability.
- Artificial intelligence of the whole system simplifies the access to the system capabilities and also makes the interface more natural to the human, as it consists of an intelligent communication with a virtual agent.
- Simplified and easy-to-use CAD tools for increased customization.
- The Internet as the medium for integrated design, marketing and retailing.

In the rest of the chapter we will present the research performed by the authors and others, mainly in the first five computer technologies on this list.

2. 3-D Body Modeling Using Images of a Real Person

While the traditional garment CAD systems work almost exclusively with two-dimensional data, as described in the introduction, some recent additions to the rich family of CAD software in textile industry are meant to allow the designer to work directly on a 3D model of a human body, making measurements, defining the darts, seam lines, etc directly on the model, and then visualizing the final design draped over it.

Apart from a potentially much easier way of designing garment using a user-friendly 3D interface, and perhaps 3D displays such as the stereoscopic devices, the advantage of

modeling the human models, garment design and draping effect in three dimensions is in the possibility of photorealistic rendering of real people wearing the garment that is still in a design stage. This could replace the re-imaging procedures described in the previous section, that are very demanding in terms of human assistance.

There are several devices for capturing the 3D geometry of a human body, mostly based on relatively expensive laser scanning technology. However, several algorithms for reconstruction of 3D bodies using cheaper equipment (such as regular cameras and possibly overhead projectors) have recently been developed (Kakadiaris and Metaxas, 1995; Jojic et al., 1998a; Jojic et al., 1999).

There are several important issues in the problem of building 3-D models using visual information. One is the camera calibration and accuracy of triangulation techniques in stereo reconstruction. This problem has been extensively studied and several calibration techniques were developed (Tsai, 1987). Another problem is that a human body, being a complex multi-part object exhibits serious self-occlusions in images taken from almost any angle of view. Finally, there is a trade-off between stereo reconstruction accuracy that increases with the stereo pair baseline (distance between two cameras) and the ambiguity problems in stereo matching that become more serious when the baseline is increased.

Recently, there have been several approaches to 3-D reconstruction using occluding contours of objects in the images (Wang and Aggarwal, 1989; Kakadiaris and Metaxas, 1995; Jojic et al., 1998a; Jojic et al., 1999). The occluding contours from several views provide information about spatial extent of the imaged objects. When the properties of the class of objects that are being reconstructed are known, it is possible to incorporate these properties in a prior model of the reconstructed object, and then use occluding contours to build a rather good reconstruction. For example, if we know that the imaged objects are polyhedral, the occluding contours may even be sufficient for correct reconstruction. In the case of the human bodies, we can use a model consisting of smooth parts, such as deformable superquadrics, to build an imperfect, but still quite realistic reconstruction (Kakadiaris and Metaxas, 1995; Jojic et al., 1998a; Jojic et al., 1999).

Moreover, the reconstruction based on occluding contours has been shown to help guide the stereo matching process in wide baseline stereo. In other words, the parts of the body surface that were not estimated completely correctly using occluding contour constraints, are still sufficiently well estimated to give a stereo matching algorithm an idea where the 3D point resulting from triangulation should be. Stereo helps refine the surface further, and the combination of occluding contours and stereo has been shown to be more complete than pure stereo reconstruction, and more precise than occluding contours based reconstruction (Wang and Aggarwal, 1989; Jojic et al., 1998a; Jojic et al., 1999).

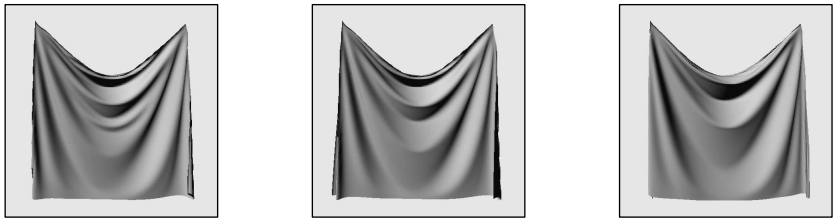
From the reconstructed body, the measurements necessary for garment design can be extracted automatically (Jojic et al., 1998a). Furthermore, the 3D reconstruction can be observed from arbitrary angle and the garment can be visualized draped over it.

For realistic rendering, the image information could also be used for texture mapping, i.e., pixel intensities from available images could be mapped onto the reconstructed surface in 3D (Jojic et al., 1999). As an example of 3-D reconstruction of a human body,

in Figure 2 we show several steps in deforming the initial crude model to fit the image information.

3 Physics-based cloth modeling

A number of physics-based cloth modeling techniques have been developed over the last decade or so. These techniques are based on simplified models of flexible materials that can drape under the influence of simulated gravity. These models typically have several stretching, bending and shear parameters that define the behavior of the cloth. For example, in Figure 3, the effect of bending constants is demonstrated in the case of the particle-based cloth model in (Jojic et al., 1998b).



$k_{bh} = k_{bv} = 0$ $k_{bh} = k_{bv} = 0.01$ $k_{bh} = k_{bv} = 0.02$

Figure 3. 100x100 particle systems with different bending constants

Most of the research in cloth modeling has been done by two groups of researchers - computer scientists and textile engineers. While the research in computer graphics was until recently mainly concerned with the qualitative visual effect, textile engineers studied low-level mechanical properties of cloth such as Young's modulus, bending modulus and Poisson ratio (Chu et al., 1950; Skelton, 1976; Shanahan et al., 1978), and relationships between these properties and the parameters of the models they were constructing (Collier et al., 1991).

A good survey of cloth modeling techniques is available in a recent special issue on cloth modeling of IEEE Computer Graphics and Applications (Ng and Grimsdale, 1996). While the first cloth models were geometrical, today most attention is focused on physics-based models, and to a certain extent on hybrid techniques. The two main approaches in physics-based modeling of cloth are either to treat the cloth as a continuum, utilizing finite-element or finite-difference techniques (Terzopoulos et al., 1987; Carignan et al., 1992; Collier et al., 1991), or to represent the cloth object as a large set of particles with prescribed interactions between them (Breen et al., 1994; Eberhardt et al., 1993; Ng et al., 1995).

Using the mechanical measurements of cloth properties, the cloth models can be tuned to represent real cloths. Another approach to tuning the physics-based cloth models to represent real cloths is based on a vision technique (Jojic et al., 1998b). The 3-D geometry of a real cloth drape is studied to recover optimal modeling parameters. The

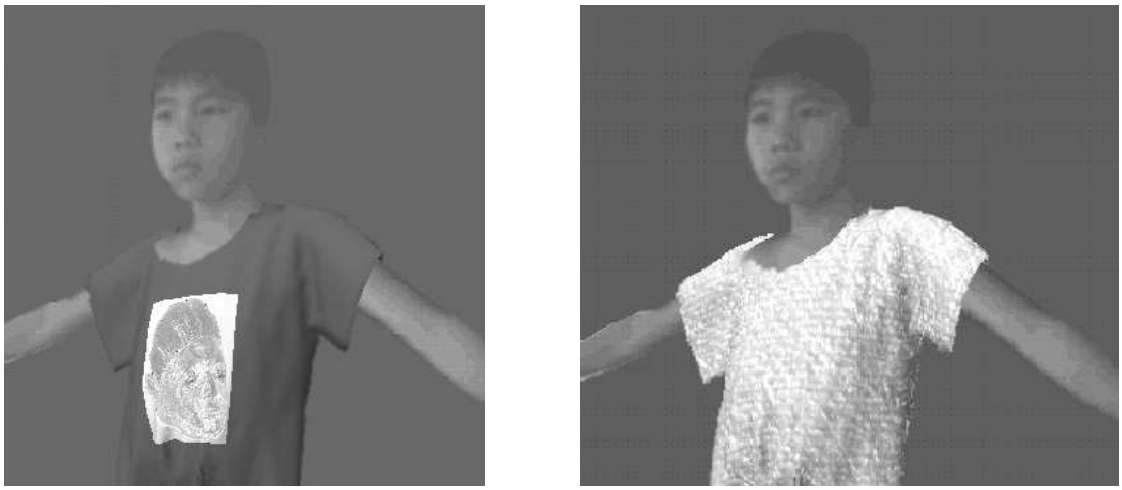


Figure 4. Examples of dressing a human into virtual garment

optimization algorithm is also capable of finding the contact points between the cloth and the object over which it was draped, by studying the given 3-D drape geometry. This has a potential to be used in analysis of the 3-D scans of dressed humans. In fact, by fitting garment models to the 3-D data acquired from images and estimating the contact points between the garment and the body, the detailed dressed human model can be built from images. This 3-D model can then be used in the re-imaging procedures described in the introduction, and not only for texture mapping of the new garment patterns, but also for creating new views at the model, and even for animating it.

In Figure 4, we show an example of dressing a reconstructed and texture-mapped body from Figure 2 into virtual garment. This garment exists only in the computer, as a set of definitions - topological (CAD design), physical (fabric properties for cloth draping simulation), textural (textile print design, or a woven pattern), and yet it can be realistically rendered on the computer screen or in the virtual reality, so that the customer in the virtual garment shop can decide if they want to order it. After the order is made, the garment can be manufactured and delivered.

4. Image Databases with Content-Based Retrieval Abilities

The usage of databases can be traced back to 1961, the year the first generalized Database Management System (DBMS) - GE's Integrated Data Store (IDDS) - was released. In the 1990's, the spread of the Internet and progress of multimedia processing techniques brought databases to all the fields of our society. Banks use databases to manage the accounts; universities uses databases to keep track of each student's performance; even an elementary school kid uses ``Databank'' to maintain his or her friends' phone numbers. Databases are becoming a part of our everyday life in an ever increase rate.

Most of the existing databases use text as the searching mechanism directly or indirectly. That is, even in image databases, most of the existing databases search images by their titles and key words. As we will discuss in Subsection 4.1, this mechanism encounters many difficulties in today's databases.

Searching images over multimedia databases has great impact on today's garment industry. First, the design process involves the selection of colorways, knitted or woven patterns, and print graphics. In addition, a visual browsing and retrieval tool will be greatly appreciated by a garment customer as well.

The remainder of this section is dedicated to the content-based image retrieval techniques required by modern garment industry. In Subsection 4.1, we give a brief review of the history of image databases and the motivation of content-based retrieval for images. Subsection 4.2 describes what are the tractable visual contents of an image and how they can be extracted. The retrieval process and possible applications in garment industry are explained in Subsection 4.3.

4.1 Brief History of Image Retrieval

How can we search for an image in an image database? Research on this topic can be traced back to the late 1970's. A very popular paradigm for image retrieval then was to first annotate the images by text and then use text-based DBMS to perform image retrieval. Representatives of this approach are (Chang and Fu, 1980; Chang, 1981; Chang, 1988). Many advances, such as data modeling, multi-dimensional indexing, query evaluation, etc., have been made. However, there exist two major difficulties with this text-annotation approach. One is the vast amount of labor required in manual image annotation. The other difficulty, which is more essential, results from the rich content in the images and the difficulty of describing the content. This is particularly acute in the garment industry. For example, for a particular knitted pattern or a print design, two people, more often than not, may come up with two different sets of textual descriptions. This makes the future retrieval of this pattern almost impossible.

In the early 90's, because of the emergence of large-scale image collections from various fields including geographical information systems (GIS), museum archiving, garment design, etc, the two difficulties faced by the manual annotation approach became even more acute. To overcome these difficulties, content-based image retrieval was proposed as an alternative. That is, instead of being manually annotated by text-based keywords, images would be indexed by their own visual content, such as color, texture, shape, etc. Since then, many techniques in this research direction have been developed and many retrieval systems built, including QBIC (Niblack et al., 1994), Virage (Jeffrey et al., 1996), VisualSEEk (Smith and Chang, 1996a), MARS (Ortega et al. 1998).

The key techniques such as how to extract the visual content from images and how to search images efficiently will be discussed in the next two subsections.

4.2 Extracting Visual Contents

Color, texture, and shape are the most widely used image content features in the content-based image retrieval. These are also well suited for representing the ``raw information'' (such as colorways, knitted or woven designs, print designs, etc.) used in the

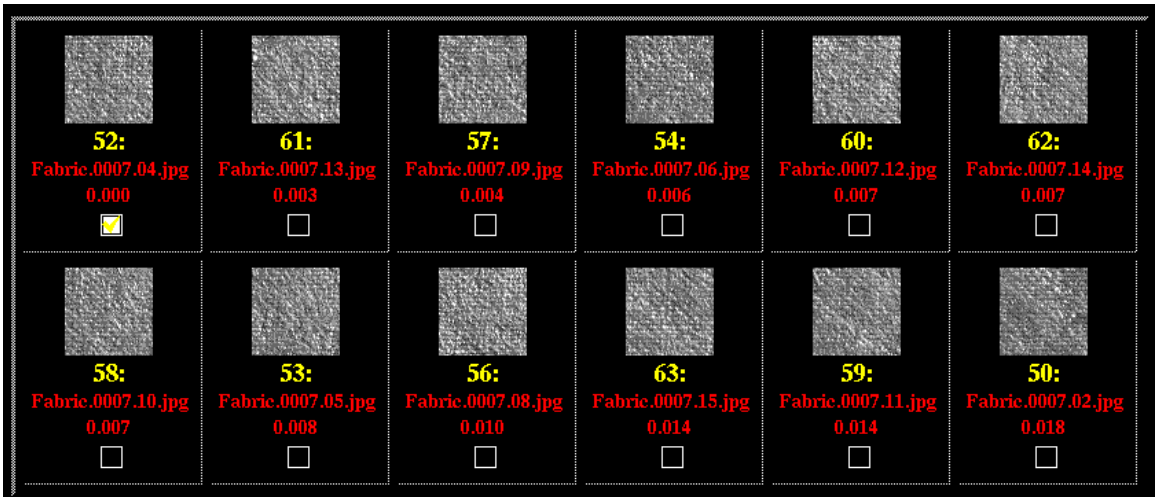


Figure 5. Texture-based image retrieval results after relevance feedback

garment industry. For example, colorways can be captured by the color feature; woven patterns can be captured by texture feature; and prints can be captured by the combination of color, texture and shape features.

Since human perception of image content is subjective (different people may perceive the same image content differently), for a given feature, various representations have been developed to model the feature from different perspectives. For example, we can use both color histogram and color moments to represent the color feature, but with different emphasis. We next briefly describe various representations for the color, texture and shape features.

Color feature. This is one of the most widely used visual features in image retrieval. It is relatively robust to background complication and independent of image size and orientation. It is useful in garment industry in characterizing the colorways of garment. Many color representations exist, out of which the Color Histogram is the most commonly used. Statistically, it denotes the joint probability of the intensities of the three color channels. Besides Color Histogram, several other color feature representations have been applied in image retrieval, including Color Moments (Stricker and Orengo, 1995) and Color Sets (Smith and Chang, 1995). The mathematical foundation of Color Moments approach is that any color distribution can be characterized by its moments. A Color Set is defined as a selection of the colors from the quantized color space. Color Set feature vectors are binary, which allows the use of binary search trees for fast search.

Texture feature. Texture refers to the visual patterns that have properties of homogeneity that do not result from the presence of only a single color or intensity. It is an innate property of virtually all surfaces, including clouds, trees, bricks, hair, fabric, etc. It contains important information about the structural arrangement of surfaces and their relationship to the surrounding environment (Haralick et al., 1973). This is an important visual feature for characterizing garment's knitted and woven patterns. The

Figure 6. Image retrieval based on shape similarity

most widely used texture representations are the co-occurrence matrix representation of texture (Haralick et al., 1973), Tamura texture representation (Tamura et al., 1978), and Wavelet transform based texture representation (Smith and Chang, 1996b). The co-occurrence matrix approach explores the gray level spatial dependence of texture. The motivation for the Tamura texture representation is based on psychological studies in human visual perception of texture. These studies helped the development of computational approximations to the essential visual texture properties. The six visual texture properties were *coarseness, contrast, directionality, linelikeness, regularity*, and *roughness*. Finally, the Wavelet transform based approach makes use of this transform's compact support of signal at both spatial and frequency domains. Experimental results show that Wavelet transform is very effective in capturing the texture feature (Smith and Chang, 1996b).

Shape feature. The shape of the objects in an image is a very important feature in various applications including garment industry. For example, the slopers can be characterized by their shape feature. In general, an important criterion for shape feature representation is its invariance to translation, rotation, and scaling, since human beings tend to ignore such variations for recognition and retrieval purpose. The shape representations can be divided into two categories: boundary-based and region-based. The former uses only the outer boundary of the shape while the latter uses the entire shape region (Rui et al. 1996). The most successful representatives for these two categories are Fourier Descriptor (Persoon and Fu, 1977; Rui et al. 1996) and Moment Invariants (Jain, 1995).

4.3 Retrieval Process and Applications to Garment Industry

After the features have been extracted from the images, they are stored and indexed into the database. With these features, the retrieval system can then support content-based queries. A typical retrieval process can be summarized as follows:

- The user browses through the database. Once he finds an image of interest, he can submit this image as the query image. Alternatively, a query image can be generated outside the database, or even sketched by the user using a simple drawing interface.
- Based on the set of visual features supported by the database, the image retrieval system finds the best matches to the query image.

In advanced image retrieval systems (Rui et al., 1998), there is a third step called *Relevance Feedback*. By having this additional step, the retrieval system can interact with the user and refine user's query intention. This relevance feedback process can be considered as controlled by an intelligent agent as illustrated in Figure 1. In plain words, the intelligent agent uses the fed-back information from the user to dynamically refine user's query intention and intelligently provide the answers (Rui et al., 1998).

The described retrieval system is well suited for garment CAD applications. Two examples are given below for texture-based woven/knitted pattern retrieval and textile prints retrieval.

Imagine that a designer, or even a customer, is looking for a particular woven/knitted pattern. It is normally difficult to express such an image pattern in words, especially for a non-expert customer. The content-based image retrieval system offers a natural alternative. Figure 5 demonstrates the performance of the content-based retrieval for a knitted pattern. The top left image is the sample (query image) that the user submits to the retrieval system and the rest are the best 11 returns. The selected texture pattern can then be forwarded to the photorealistic rendering module and used as the pattern on the garment, as shown in Figure 4 (b).

In the design of textile prints (for example for T-shirts), all visual features can be important to the user. In Figure 6, an example of the retrieval for a print design is demonstrated. The top left images is the sample (query image) and the rest are the best 11 returns. This time the retrieval is based on all the color, texture, and shape features. The retrieved image 3 is what a user is looking for and then used as the print of a T-shirt, as shown in Figure 4 (a). Of course, the best result can be enhanced by using relevance feedback during which the system learns what the user preferences are, for example if the user is more likely to prefer similarity in texture, or color, or shape.

5. Artificial intelligence in garment and advertisement design

In the garment industry, several Artificial Intelligence (AI) techniques (Russell and Norving, 1995) have been used in applications such as the knowledge-based technology in the complex mechatronic systems (Czarnecki, 1995), intelligent textile machines and systems (Acar, 1994), and the "smart" garment that heats or cools in response to temperature changes (Davis and Botkin, 1994). In comparison, AI has been much less used in garment or advertisement design. The primary reason for this is that garment design is a very flexible and creative process, and it is often regarded as something that possesses too few rules that can be traced. But with the development of AI, design

methodology, as well as other related areas, the application of AI techniques is becoming much wider.

In this section, we will focus on these new AI applications in garment design and advertisement. We first introduce knowledge-based and case-based design approaches in the first two subsections. We then describe knowledge embedded interactive garment design system. Finally, we discuss the intelligent agent and how it can be used in consultation for garment selection and design.

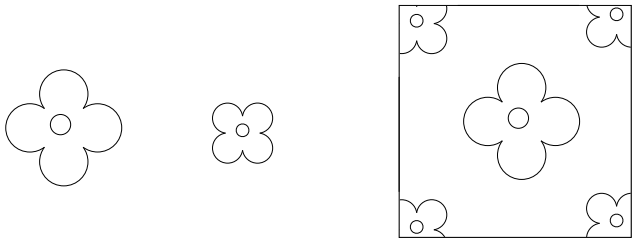
5.1 Knowledge-Based Pattern (Textile Print) Design

Here, *pattern* denotes any figure that is printed on cloth, T-shirt or other garment. Knowledge-based approach was introduced into the pattern design (Pan and He, 1986) to relieve designer from tedious work by automatically creating new patterns.

A *pattern* is defined as the combination of primitive elements, which can be flowers (e.g. rose), animals (e.g. cat, dog), or other patterns. Thus a pattern is regarded as the root of a tree. Each node of the tree represents one of its components, and each leaf node represents the primitive element.

The designer's knowledge is extracted to form the design knowledge base, which can be categorized into three types:

- *Pattern layout knowledge* defines how the components (either primitive elements or generated patterns) are arranged in the drawing space through a set of the basic layout rules. For example, one piece of the knowledge *is Four Corner Continuity (FCC)* which has been widely used in carpet pattern design. The following simple example shows how *FCC* is applied so that whenerver the element (a) is displayed in the middle, the pattern (b) is applied at the corners, so that the continuity is preserved.



(a) (b) (c)

- *Element grouping knowledge* defines the grouping of elements, for example, the element *A (e.g. fish)* usually comes along with element *B (e.g. water).* This type of knowledge ensures the selection and importantly, the harmonization of selected elements.
- *Element transformation knowledge* defines the possible element transformations such as translation, rotation, scaling, shearing, or concatenation of the above transformation sequences.

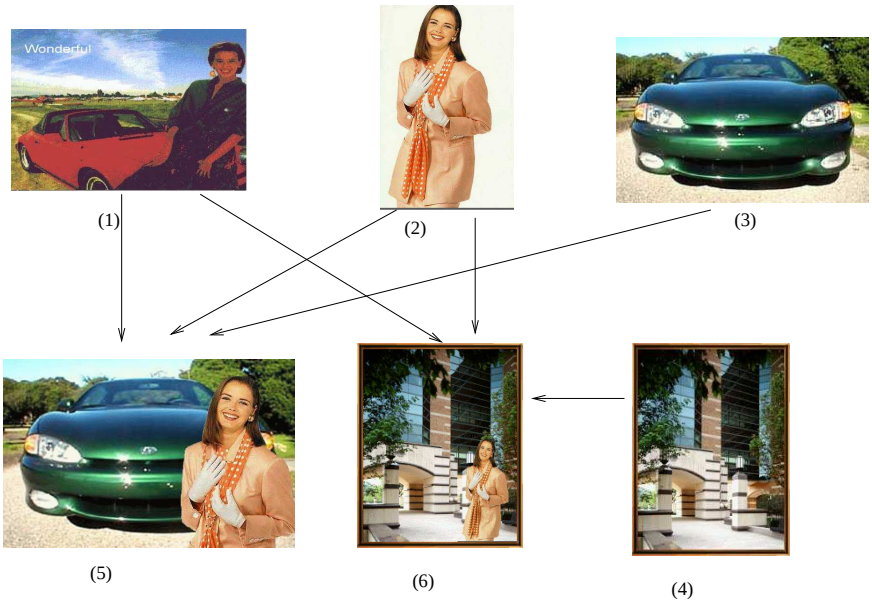


Figure 7. An example of case-based advertisement design

It has been estimated that if 30 pieces of knowledge and 30 elements are provided, the system has the capacity of designing more than $6.561*10^{18}$ different patterns simply through the combinatorial explosion.

5.2 Case-based Garment/Advertisement Design

An experienced garment or advertisement designer usually refers to some former design cases while creating a new design. When this is mimicked in AI, it is called case-based reasoning (CBR) (Mott, 1993). Compared with other design approaches, case-based reasoning provides a much more natural way to follow. No matter how difficult the current design problem is, the designer will always find some idea in a large collection of cases. In this way, a novice designer can utilize the knowledge of others. Figure 7 shows one example where (1) is an advertisement case, (2) is the fashion needed to be advertised, (3) and (4) are images taken from the image database, (5) and (6) are the design results by adapting (1)'a layout.

Garment advertisement is aimed at promoting the garment sale by attracting the customer's visual attention. In the past, advertisement was made fully by a human designer without any help from computer. But with the development of computer graphics and image processing techniques, computer-aided advertisement design systems came into being and had quickly started to dominate the design domain (Adobe, 1991; Corel, 1993). Furthermore, the case-based reasoning technique can be combined with the existing CAD systems to design advertisement automatically (Zhuang and Pan, 1995). The kernel of case-based reasoning consists of:

- *Case representation*. A case in CBR has two parts:

- *idea path,* which embodies the mapping of synthesis process from multiple design sources to the current design. The idea path is represented by a semantic network.
- *configuration* of the picture, represented as a list of 4-tuples (picture-element, position, content, composite-mode).

- *Case selection*. Cases in the case base are indexed and retrieved by a combination of keywords and content features. An ads case is more than a plain image. The design process starts with the user requirements, which are in return transformed into design constraints. Using the design constrains to look into the case bases, a set of candidate cases are retrieved.
- *Case adaptation and new design*. Case adaptation requires expertise, acquired from the design expert beforehand and stored into a knowledge base in the *if-then* form. After a candidate case has been chosen, rule based reasoning is applied to do the case adaptation.
- *User's final decision*. The right to make the final decision is always left to the user. If the new design scheme is not satisfying, the user can modify it directly or have the system run again. The user can also insert the appropriate knowledge into the system in order to make the system smarter.

5.3 Knowledge Embedded Interactive Garment Design Systems

In some garment design systems, the design knowledge and the design reasoning are directly embedded in the system. These systems usually provide a friendly user interface that guides the user through the design steps. For example, by providing the garment category and selection menus, it energizes the outfit design experience. Example categories are undergarments, shirts, pants, skirts, dresses, jump suits, jackets, socks, shoes, sunglasses, and backgrounds. Each category provides a list of selections and so on. These kinds of garment design software are easy to use either for professional designers or general customers. For example, Flash'N Fashion (Media Motion Publications) is a commercial product designed to bring the world of sewing to children. In (Tukaptrn), the TUKAdesign system makes it faster and more accurate to create various types of notches, darts, pleats, seams, drills holes, and internal contours.

Another example of knowledge embedding can be found in the systems capable of fulfilling a certain task using AI techniques. For example, some systems include features for intelligent trapping of adjacent colors, automatic join lines with protective masking, batch separations, and output file format support to connect with the leading production machinery (CAD Cut).

5.4 Intelligent Agent: Consultation for Garment Selection and/or Design

To make the whole system in Figure 1 attractive to a wide range of customers, intelligence and simplification in the design process and the user interface may not be sufficient. For example, the great advantage of physical garment shops is its human personnel that assists the customers, while the advantage of a human tailor is an easy access to his expertise.

For making the Internet-based virtual custom-fit garment shop closer to this, an intelligent agent that integrates all the intelligent functions discussed in this section is

necessary. In addition, this intelligent virtual agent (that may even has its graphical representation, for example an animated human-like figure, or a talking head (Capin, 1997)), should also be capable of learning the customer's preferences and giving the suggestions based on its expertise and the learned customer's profile.

For example, the system should be able to suggest garments based on the customer's characteristics, such as the weight, height, skin and hair color, and even 3D model as a pre-stored record, and his/her preferences. The agent could also help the customer make the alternation on the basic design (using a knowledge-embedded interactive CAD utility, for example), or help him choose the color or the textile print design using the relevance feedback technique in the content based image retrieval. After a customer has selected one piece of garment, say a shirt, the intelligent agent may act as a virtual salesman and suggest a matching tie, or assist the customer in creating a whole outfit.

In the on-line shopping system, this consultation service can be realized either as an expert system or an intelligent agent that works between the clients and the server. The knowledge base is divided into two types: general (or user independent) knowledge and user-specific knowledge. General knowledge is generally applicable to a wide range of customers or to a category of customers and includes, for example, some general aesthetics standards, such as color harmonization. User specific knowledge describes learned individual aesthetics standards, for example the user's subjective preferences about garment matching.

6. Conclusions

In this chapter we described the computer technologies that can be used in the Internet-based garment-shopping network. With the increase of its bandwidth, the Internet will become a perfect medium for on-line shopping. It will give the potential customers fast access to the remote resources, such as the databases and computational resources. Furthermore, it already provides easy and relatively secure payment possibilities. This will allow making the computer technologies described in this chapter available to everyone, directly from their homes.

Most of the described systems are up and running in our lab, though some of them were not strictly applied to the garment industry applications. To build the whole Internet-based garment shopping system of the kind described here, the major effort would be invested in the integration of the described components and the refinement of the virtual intelligent agent, but the preliminary systems are fairly easy to construct. It is our belief that the commercial CAD Garment systems will evolve in the direction that we have described.

The major technologies descirbed in this chapter but which are not yet used in the existing computer systems in the garment industry are:

- the texture-mapped 3-D models of real humans, which can be combined with physics-based cloth draping simulations
- the image databases with content-based retrieval capability and relevance-feedback mechanism that learns the user's visual associations
- the automatic advertisement design using case-based knowledge

We have shown how these contributions can be used together, for example to allow the customer to search for the garment design, and the woven or print design on the selected garment, and finally see their selection on their own body, whose geometry and texture were acquired using a cheap computer vision technique Figure 4. This is an example of integration of the several separate components of the garment industry today: design, advertisement and retailing of customized garment are all done at one place. By allowing the customers to see themselves (instead of a model) wearing the selected designs and in different settings using animation and/or the described case-based advertisement design, the power of advertisement becomes considerably greater than in the case of the catalogs, for example.

In conclusion, we expect that the development of such integrated Internet-based systems will significantly reduce costs of advertisement and retailing, while still allowing mass-customization.

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Index Terms

3D body modeling/reconstruction
Advertisement design
Artificial Intelligence (AI)
Bending modulus
CAD/CAM
Case-based reasoning (CBR)
Color feature
Cloth modeling/draping
Garment design
Garment shopping
Expert System
Image content
Image databases
Image retrieval
Intelligent agent
Knowledge-based design
Knowledge embedding
Relevance feedback
Photo-realistic rendering
Physics-based modeling
Shape feature
Texture feature
Virtual agent
Virtual reality