NATIONAL TEXTILE CENTER
ANNUAL REPORT

TITLE: Part Layout and Optimization of Part Shape for Layout in Apparel Manufacturing

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GOAL: To determine if layout of garment parts can be optimized through computer algorithms such that fabric utilization can be increased. To determine how to provide such computer programs to small apparel firms to improve their competitiveness and profitability.

ABSTRACT:

Our initial goal is to create a prototype system SchemaCAAM (ComputerAided Apparel Manufacturing) for apparel design and· layout. This system will act as a prototype for demonstration to industry and other researchers. We will also use the system as a testbed for new algorithms in design and layout. We have chosen to implement SchemaCAAM on the PC architecture under the DOS/Windows operating system. This choice will permit interested companies to test the system on low-cost hardware, and it will permit us to demonstrate the system on portable notebook computers. Our plan is to integrate SchemaCAAD, a computer-aided apparel design program developed by Shanley, with the automatic marker generation program developed by Milenkovic to provide the most complete and efficient low-cost garment development software on the market.

RELEVANCE TO NTC GOALS:

Layout of parts (marker generation) on cutting stock is an important step in apparel manufacturing. Expert humans spend large amounts of time finding the tightest non-overlapping packing of a set of polygonal parts. Totally automated layout is still a distant goal, but any amount of automation would reduce costs, decrease manufacturing time, improve quality, and increase variety of product. Reduced costs follow from reduced labor and improved cloth utilization. A computer could lay out a marker faster than a human, more consistently follow cutting rules, and optimize the layout for cuttability, hence decreasing time and improving quality. Computers would also have a steeper learning curve on new types of products, learning to lay them out effectively faster than humans, and hence easing the introduction of new products. Decreased cost is of course, very important for competitiveness, yet it it not enough to offset lower labor costs abroad. Decreased manufacturing time enables "quick response" to consumers' preferences and retailers' demands, which in turn can offer

a competitive edge over foreign manufacturers with longer shipping distances. Improved quality is essential for the export market, particularly meeting European ISO 9000 quality standards. Finally, the introduction of new products is essential for maintaining profitability. Automated layout is a difficult task, requiring a combination of techniques from computer science, operations research, and manufacturing research.

OBJECTIVES:

1. Investigate the basic CAD/CAM tools used by small companies, and design a common format for description of patterns, design rules, and layout tasks.
2. Set up a central computer system and support staff for storing data, developing and testing new layout algorithms.
3. Gather examples of pattern designs and layouts.
4. Interview designers and expert marker makers to learn techniques and needs.
5. Adapt current algorithms to satisfy as many needs as possible, and provide these over a network. This can first be done directly by Auburn and then, once established, by a third party such as Microdynamics.
6. Select two or three domains for the focused development of layout tools.
7. Develop tools specific to these domains for optimal layout and optimizing shapes for layout.
8. Use database of layouts to develop algorithms that "learn" new domains automatically or semi-automatically.
9. Provide algorithms to industry as developed over the network.
10. Determine other industries that would benefit from new techniques.

TECHNICAL APPROACH:

Marker layout is a very difficult task because the parts have three degrees of freedom (two in translation and one in orientation) and they are irregular: non-rectangular and non-convex. Even humans must learn one domain (such as pants) at a time, and expertise on one domain does not transfer to another. It is therefore reasonable to focus on one domain at a time, but develop as many domain independent techniques as possible.

In our (TC)^2 project, we focused on the domain of pant markers. Our general approach was to apply techniques of computational geometry to reduce the layout problem to a simpler non-geometric optimization problem, such as linear programming. Some of our algorithms are specific to pants, but many can be applied to any marker making task.

An example of the latter is COMPACTION: finding a small simultaneous motion of the pieces that "improves" the marker: reduces length, opens up a region for another piece, or eliminates overlap among pieces. Elimination of overlaps can be used in substitution based marker making: 1) start with a database of quality markers; 2) given a new layout task, find a marker in the database with a similar set

of pieces; 3) substitute pieces and eliminate overlaps using compaction.

We intend to provide known general techniques, such as COMPACTION and substitution-based marker making immediately. At the same time, we will gather examples of new domains, such as jackets, and develop domain-specific algorithms for this domain as we have for the pants domain. Once we have solved enough specific domains, we can begin the task of programming the computer to learn new domains on its own by analyzing sets of example markers for that domain. We will have the example markers available because they will already be in use for substitution based marker making. In this manner, the technology transfer will feed the development of new technology.

Once we are familiar with the layout task, we can examine how the shapes of the pieces affect the efficiency of the layout. Particular "trouble spots" such as sharp corners can be detected. Once we gain an understanding of the design process, we can parameterize the shapes in the design in a way that will allow us the alter the shapes without changing the finished product. Using linear programming, integer programming, or other optimization techniques, we can choose values for these parameters that optimize the efficiency with which we can layout the marker.

BACKGROUND ON AMGT:

In 1990, the Sloan Foundation funded the Harvard Center for Textile and Apparel Research (HCTAR) through a subcontract of the Textile Clothing Technology Corporation ((TC) ^ 2). Professor Frederick Abernathy of the Harvard University Division of Applied Sciences heads HCTAR. Part of the Center's research is a project to automatically lay out pants markers. Professor Victor Milenkovic heads this project and has worked with two graduate students, Karen Daniels and Zhenyu Li. Zhenyu Li finished his dissertation and graduated in June, 1994. In July, Professor Milenkovic joined the Math and Computer Science department at University of Miami. Karen Daniels remains at Harvard to finish her dissertation under the direction of Milenkovic and Abernathy.

The project generated a system called AMGT (Automatic Marker Generation Testbed). The primary purpose of AMGT is the automatic layout of pants markers, and it currently generates expert-quality pants layouts (89 to 91 percent efficiency). However, a number of domain (garment type) independent tools were also developed as a result of this project, particularly compaction and containment. Compaction improves a layout in some fashion: increase efficiency, remove overlaps, or open up space for new pieces. Containment places new pieces into gaps of unused material.

Microdynamics, Inc. has licensed the compaction software. Compaction makes heavy use of the commercial optimization software CPLEX. Large companies using compaction might save 0.25 million to two million dollars per year as a result of efficiency gains in their current markers. Microdynamics is also using compaction to alter markers: substitute different pieces or change the width. These functions use

the ability of compaction to eliminate overlaps. Unfortunately, the combination of software, hardware, and optimization code costs each customer over $60,000, and thus it is available only to large companies. We also hope to license the pants layout software to Microdynamics, but again this will be limited to large companies.

BACKGROUND ON SCHEMACAAD (Computer Aided Apparel Design)

Dr. Shanley has been working for the past two years on SchemaCAAD. This program has been designed to generate patterns based on customized measurements. SchemaCAAD will also incorporate the automatic grading function, as well as illustration and specification generation, pattern alteration and style component development, and style library to provide a complete computer-aided apparel design package. This program runs under the Windows platform and will be completely compatible with new 32-bit architecture operating systems such as Windows 4.0 (Chicago). Developing this program for 32-bit architecture at this point in time, insures that it will not become obsolete in the near future. Our plan is to integrate SchemaCAAD with the automatic marker generation programs developed by Milenkovic to provide the most complete, low-cost garment development program on the market.

PROGRESS TO DATE:

Our initial goal is to create a prototype system SchemaCAAM (ComputerAided Apparel Manufacturing) for apparel design and layout. This system will act as a prototype for demonstration to industry and other researchers. We will also use the system as a testbed for new algorithms in design and layout. The creation of an initial version of SchemaCAAM corresponds to Tasks 1 and 3 on the management schedule. We expect to accomplish this within three to six months. We have chosen to implement SchemaCAAM on the PC architecture under the DOS/Windows operating system. This choice will permit interested companies to test the system on low-cost hardware, and it will permit us to demonstrate the system on portable notebook computers. Furthermore, it is important to determine how much geometric/optimization computation a 486 or Pentium CPU can handle.This information will indicate which tasks we must delegate to a more powerful server on a network. We will also develop and maintain a version of SchemaCAAM on a UNIX-based workstation which will act as this server. In addition, this UNIX version of SchemaCAAM will permit us to test algorithms which would require too much computational power to run on a PC.

In our NTC project, we are hoping to find new applications of compaction and containment, particularly in the layout of garment types other than pants. Our initial SchemaCAAL system will use containment to lay groups of pieces from left to right and then apply compaction. As we gather more data on other domains, we will be able to develop more sophisticated algorithms in layout and design. Our second goal is to provide this "high technology" to small firms. We will port this software to inexpensive PCs and provide services over a network. Their are many technical and

scientific issues to be resolved, but if we are successful, out hope is that a company like Microdynamics will use our research to be able to market advanced garment manufacturing techniques to small firms.

Initially, SchemaCAAM will consist of four pieces of software: automatic piece shape generation software (SchemaCAAD), automatic piece layout software (SchemaCAAL), a multi-platform user interface, a commercial optimization library (CPLEX).

CURRENT STATUS:

Porting systems to the PC is often very technically challenging. However, we believe that we have all the parts necessary, and the work is proceeding rapidly. In July, we hired Irina Kaliman. Kaliman is an experienced system developer. The Department of Math and CS at University of Miami will pay half her salary, and she will spend half time on departmental system maintenance and half time on the development of SchemaCAAM. Initially, we had planned to hire undergraduate programmers, but they would have required training time. Kaliman has the experience needed, and she will be able to develop the system much faster. She and Milenkovic are currently developing SchemaCAAM.

About a year ago, Karen Daniels, a graduate student at Harvard, ported a version of the user interface and other parts of AMGT (now SchemaCAAL) to the PC platform. She ported the software in order to work on her dissertation research at home. Her husband, Murray Daniels, designed the user interface as part of his masters thesis to run under both PC/DOS/Windows and UNIX/X-Windows. Daniels used the Borland C++ compiler.

The technical staff at CPLEX Optimization Inc. informed us that we must use the WATCOM C++ compiler and the most recent version of Windows in order to link with their optimization libraries. We anticipate some technical difficulties with the different compiler and newer window system but nothing unsurmountable. Dr. Shanley has developed SchemaCAAD at Auburn University. SchemaCAAD is written in BASIC and uses a different data format than SchemaCAAL. Kaliman will translate the BASIC to C++. Shanley and Milenkovic will develop the common data format. We will base the new format on experience Shanley and Anderson have in the area of design and the experience Milenkovic has in the area of layout information gathered from companies. Finally, Kaliman and Milenkovic will implement the new format and integrate SchemaCAAD with the other three parts of the SchemaCAAM system. Once we have chosen a format, we can begin creating the database of patterns and markers (Task 4).

We expect only minor technical difficulties in transferring the entire SchemaCAAM system back to the UNIX platform. This version of SchemaCAAM will run on Sun workstations at Miami and Auburn. In advance of this, we will investigate the issues involved in providing the system over a network (Task 5). Once the

system is in place, we can implement the network protocols. Finally, as we are developing SchemaCAAM, we will continue work on new algorithm development in the area of design and layout.

Shanley, Anderson, and Koza have identified twelve companies who conduct marker making functions as part of their routine manufacturing process. We have categorized these companies into small, medium, and large firms. To date, interviews with marker personnel at five of the firms have been completed (Task 2). All other interviews will be completed by September 30th, 1994. Information generated has been extremely useful in identifying and clarifying the marker making process.

Shanley and Koza have begun work on development of pattern pieces for the pattern data bases (Task 5). A digitizer has been purchased and set up for the purpose of input pattern pieces. Dr. Shanley has started work on the user interface for both SchemaCAAD and SchemaCAAL (Task 13). Dianne Koza will be constructing multi-media computer-based tutorials for both programs as part of her dissertation (Task 14).