- optimize the layout of garment parts using computer algorithms to increase fabric utilization
- provide such computer programs to allow small apparel firms to improve their competitiveness and profitability.

Thus far, we have interviewed marker makers and production personnel on marker making techniques and the needs of the industry, begun work on shape generation code to create pattern pieces that will be used in automatic marker layouts and set up system to begin porting software to PC formats.
[Other Contributors: Graduate Student: D. Koza]
Industry Interactions: 12

Lisa A. Shanley, an Associate Professor at Auburn, has been on the faculty since 1971. She received a Ph.D. from Oklahoma State in clothing, textiles and merchandising with an emphasis on functional design of apparel, statistics and physiology. Lisa's research interests include protective clothing prototype design, physiological response to clothing and software development for the apparel industry.

Lenda Jo Anderson: See page 33

Victor Milenkovic, an Associate Professor in Mathematics and Computer Science at the University of Miami since 1994, received a Ph.D. in computer science from Carnegie Mellon in 1988. Then he became assistant professor of computer science in the Division of Applied Sciences at Harvard where he earned a BA in mathematics in 1981). In 1991, Victor was named an NSF Presidential Young Investigator. His research interests include computational geometry, numerical robustness, automated part layout and CAD/CAM.

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The On-Line Inspection of Sewn Seams

S94-4

Timothy G. Clapp, leader, Michael B. Gunner, (NC State); J. Lewis Dorrity, L. Howard Olson (Georgia Tech)

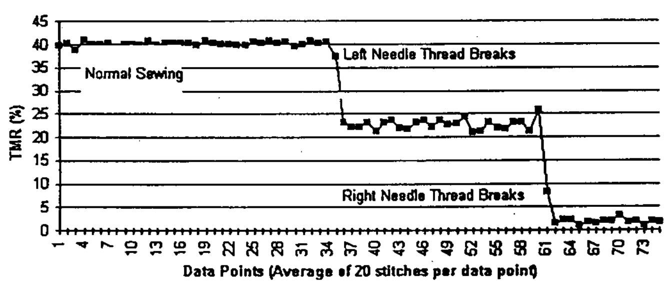
Because of extensive style and fabric variations, apparel manufacturing is traditionally very labor intensive. Most sewing machine manufacturers and some of the larger apparel companies have developed semi-automatic sewing stations to perform operations which are constant across a large style range. These normally require an operator to load a machine which then automatically sews and stacks the components. Although such stations improve production efficiency, they remove the almost unconscious operator inspection of the operation. As a result only major seam faults such as thread breaks are observed. Other faults, such as mis-stitches and non-included seams, may not be detected until the garment is completed or perhaps not until after it is laundered. By then, the manufacturer's cost is at a maximum. In order to reduce the number of defective garments produced, it is necessary to develop complete seam monitoring systems at intermediary steps in the construction process that meet the apparel manufacturer's requirements of flexibility, cost and reliability.

We are developing techniques to monitor and control sewing machine seam construction on-line.

Our immediate objective is to investigate new technology which could be used to automatically monitor all aspects of sewn seams including skip-stitches, incorrect tensions, seam allowance variations and the number of plies sewn. In an initial technology survey of the industry, we have identified major stitch types (lockstitch, double- and multiple-needle chainstitch and the overedge stitch). We will research seam inspection techniques which monitor the construction of seams as well as those which determine the quality of sewn seams. Longer term, we hope to produce a "black box" which, when attached to a sewing machine, would provide information so that the sewing machine settings could be automatically adjusted in real-time to optimize performance.

One method developed to monitor seam formation provides for an indirect measurement of thread usage to detect incorrectly sewn seams in a general sewing environment. Research indicates that stitch length is generally a good indicator of stitch quality and that the time during which the thread is in motion can be related to the stitch length at constant speed. This technique utilizes a piezoelectric transducer to provide information on the time of motion of the thread during the sewing process. For a given stitch type, the thread for which consumption is the greatest is monitored. Thus, experiments involve the top thread in a lockstitch and the lower looper thread in a chainstitch. The ratio of this time of motion to the total single sewing cycle time, called the thread motion ratio (TMR), is consistent with variation in sewing machine speed. For several stitch types the system yields a reliable indication of thread consumption related faults, such as broken top or bobbin threads, misfed fabric and thread tension imbalance. For example, for a double-needle chainstitch, the change in TMR with either thread break well exceeds four sigma limits and its magnitude reflects the change in stitch geometry (See Figure: 406 stitch at 4300 rpm). Other techniques which show potential to monitor sewn seam quality are

- a beta-particle transmission gauge utilizing a Sr^{90} source which can successfully distinguish between 1, 2, 3 and 4 layers of fabric
- optical sensor technologies



[Other Contributors: Faculty: *R. Gardner, K. Verghese (Nuclear Eng, NC State);* Research Associate: *Kim Gossett-Titus (Physics/Textiles, NC State);* Graduate Students: *Z. Zhu, Carla Barrett (Nuclear Eng, NC State); R. Schoenborn, M. Wetherington (Textile & Fiber Science, Georgia Tech)]*
Industry Interactions: 5 (Levi Strauss, Russell Corp.)
For Further Information, see page 42

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Analysis/Modeling of Actions and Interactions of Fiber-Textile-Apparel-Retail (FTAR) Firms

S92-4

Gordon Berkstresser, leader, N. Alan Hunter (NC State, Textiles); Russell E. King, Henry Nuttle, James R. Wilson, Shu-Cherng Fang (NC State, Eng) in collaboration with Barbara Mazziotti, Peter Butenhoff (Textile/Clothing Technology Corp.)

We have been specifying and developing models of the firms in the U.S. fiber-textile-apparel-retail pipeline (See Figure). Two basic goals of the modeling project are
- to understand the operation of each firm and then
- to understand how information and material must flow in response to consumer demand, and how manufacturing segments react to this demand as it percolates back through the pipeline.

With this understanding, we will be able to specify the trade-offs necessary to make quick response attractive to all parties.

The project has three primary thrusts: research, education, and industry support. The models provide a vehicle for:
- analyzing and developing operational practices within individual firms and across subsets of firms
- understanding the interactions of one firm's decisions with another firm's decisions
- developing CEO-type information systems
- training personnel in making operational decisions.

The advantage of the modeling approach in understanding and exploring the modification of the pipeline operation, as well as for education and training, is the ability to observe the results of operational changes quickly, inexpensively, and without risk to the actual production system.

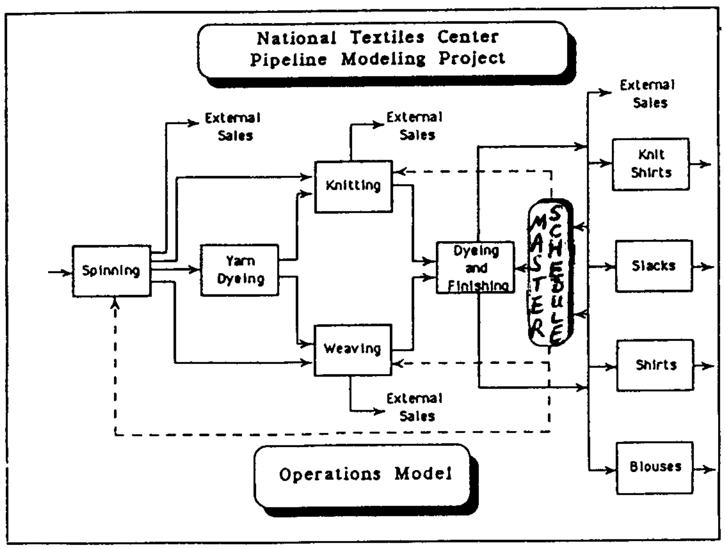
Input - Output

The plant models are fairly high level, not detailed shop-floor models. They are data-driven (i.e., they require numerous inputs such as customer order streams, machine capacities and production rates), and they produce outputs including the sample mean and an empirical frequency distribution of order lead times and inventories. Each model includes flow of material from raw or semifinished material inventory, through the key production processes, through inspection, into final inventory and "out the door". These models simulate plant activity for a user-specified time horizon (e.g., 52 weeks). The daily activity is directed by routines which generate weekly (or daily) schedules for key processes, but the activity is also influenced by randomness in factors such as cycle times and yields.

The objective of decision surface modeling is to develop an interactive information system that captures the essential features of each plant model (or integrated collection thereof) in mathematical relationships between plant performance (inventory, order lead times, etc.) and key decision parameters (product mix, number of machines, etc.). These "metamodels" are intended to provide CEOs with rapid, easy-to-use capability to predict impact on system performance under various "what-if" scenarios such as:

We are developing simulation and neural network models to understand the actions and interactions of FTAR firms.

- What are the consequences of broadening the product mix?
- What are the cost/benefits of reducing order lead times or of introducing new equipment?



Model Status

At this point we have operational standalone simulation models of dyeing and finishing, weaving, knitting and spinning plants plus the master schedule generator. We are developing apparel plant models and are testing a prototype integration of the spinning and knitting models.

We are conducting experiments using the plant models to study the impact of input parameters performance measures. We are developing neural-network CEO models, trained with performance data from the simulation experiments, for the spinning plant and for a retail model originally developed under the CRAFTM project. For both plants the prediction errors are quite small. We have used the spinning plant model to compare the performance of alternative frame scheduling strategies and as the basis for exploring the use of object-oriented modeling to permit easy tailoring of models to match