RESEARCH SUMMARIES:

Deformational Characteristics of Plain Knitted Yarn Loops Under Shear Loading

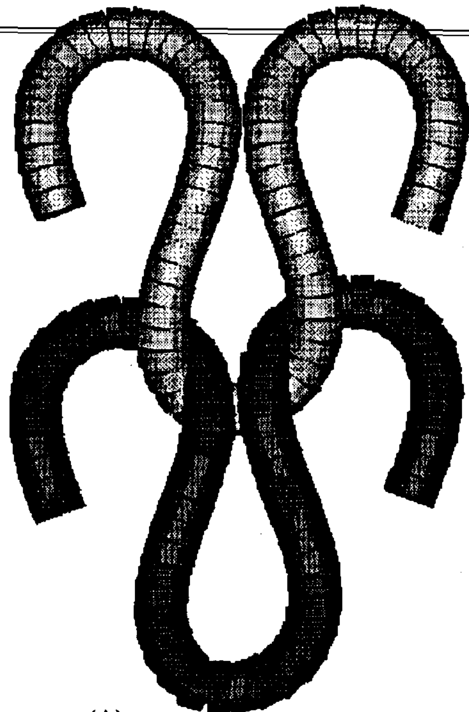
Developing an automatic feeding or sewing mechanism requires an understanding of the behavior of knitted fabrics under stress. A fabric which will be fed by an automatic feeding mechanism or will be sewn rarely experiences symmetrical loading. To date, however, most analyses made determine the structural behavior of knitted fabrics under no load or are symmetrically loaded. Therefore, for practical applications, it is important to examine the behavior of knitted fabrics under nonsymmetric loading conditions.

S. de Jong and R. Postle, authors of "A General Energy Analysis of Fabric Mechanics Using Optimal Control Theory", used an energy analysis based on Optimal Control Theory (OCT) to determine the key deformational characteristics of symmetrically loaded knitted loops. This approach assumes that yarns in a knitted loop will take a shape such that their internal energy is minimized while maintaining the force/couple equilibrium. By modifying this model it is possible to analyze how a knitted fabric deforms under an uniform shearing load.

The first step in this project was to reproduce de Jong's work. A computer program, written in C, was developed to determine the deformational behavior of a knitted quarter loop that is symmetrically loaded. Certain algorithms were developed to reduce run time and increase solution stability. This computer program will be the basis for any future research involving the nonsymmetric loading of knitted fabrics.

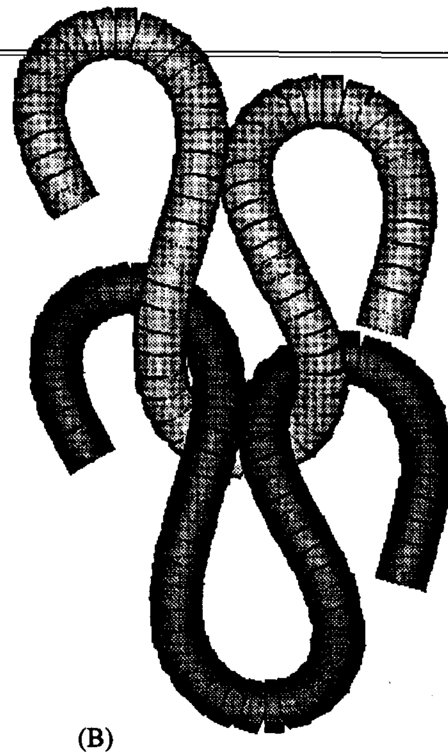
The second step was to modify the OCT algorithm to analyze the deformational behavior of knitted loops under nonsymmetrical loading. This involved the expansion of the analysis from a quarter loop to a half loop. In addition, two subroutines were developed to solve the two point boundary problem, which arises from the expansion of the analysis to a half loop.

A review of the modified OCT analysis of plain knitted fabrics under a shearing load confirms the anisotropic behavior of knitted fabrics. A loop subject to counter–clockwise uniform shear loading will skew in the counter–clockwise direction. To counteract this moment, the force exchange between interlocking yarns on the left side of the loop becomes higher than the force exchange between interlocking yarns on the right side of the loop. As the shearing load increases: 1) the loop becomes more skewed; 2) the tightness of the left side of the loop increases due to a decrease in yarn curvature; and 3) the tightness in the right side of the loop decreases as the yarn segment begins to straighten. Sewing or feeding mechanisms add this type of shearing load to a fabric and therefore require further study.



(A)

A) Symmetrically Loaded Knitted Loop.



(B)

B) Nonsymmetrically Loaded Knitted Loop

On-line Fabric Identification and Adaptive Control of the Sewing System for Improved Apparel Assembly

Analysis of current sewing techniques indicated that higher quality apparel assembly required research into the fundamental aspects of sewing control. From this analysis, the two courses of research to be followed were 1) the determination of methods for characterizing the dynamics of high speed sewing machine and fabric interactions, and 2) the determination of methods of adaptively controlling the sewing system based on the on-line evaluation of the fabric/machine interactions.

Needle bar forces occurring during high speed sewing can be used to identify fabrics on-line. A neural network classifier for on-line identification of fabrics has been created. The neural network acquires its data from a sewing machine equipped with force transducers. These transducers measure the forces occurring at the needle during the sewing process. The neural network is trained to identify fabrics based on their force "fingerprint" (See Figs. 1 and 2). By implementing the neural network on a microprocessor, a practical way exist to identify not only the fabric type but also the number of plies sewn. Utilizing this type of classifier, the automated apparel assembly station can adapt itself to changing sewing conditions and provide quality checks such as making sure all plies were sewn.

The second course of research pursued was the determination of methods of adaptively controlling the sewing system based on the on-line evaluation of the fabric/machine interactions. The fundamental knowledge gained from these investigations has led to a full report on a presser foot force actuator and patent disclosure to the University. This control method stabilizes the forces applied to a fabric during feeding. By maintaining an optimal applied force, fabric may be less likely to pucker during sewing. A prototype to demonstrate the fundamental operation of this device is currently being designed and built. The digital controller design method uses an ellipsoid algorithm to optimize controller parameters. Time domain specifications are implemented as linear inequality constraints within the ellipsoid algorithm (See Figs. 3 and 4). The ellipsoid algorithm then searches for controller parameters that optimize some (usually non-linear) objective function subject to the constraints. In this manner, the controlled presser foot behaves with certain specified time responses.

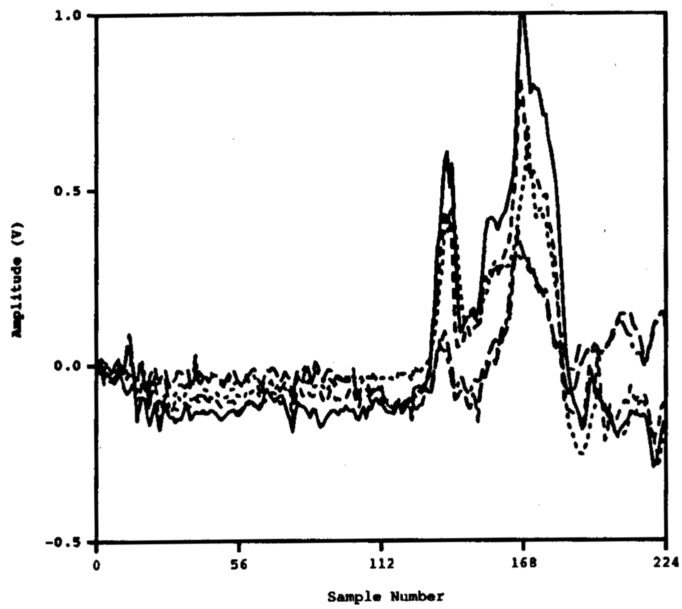


Figure 1. Typical needle force waveforms for one stitch for five fabrics

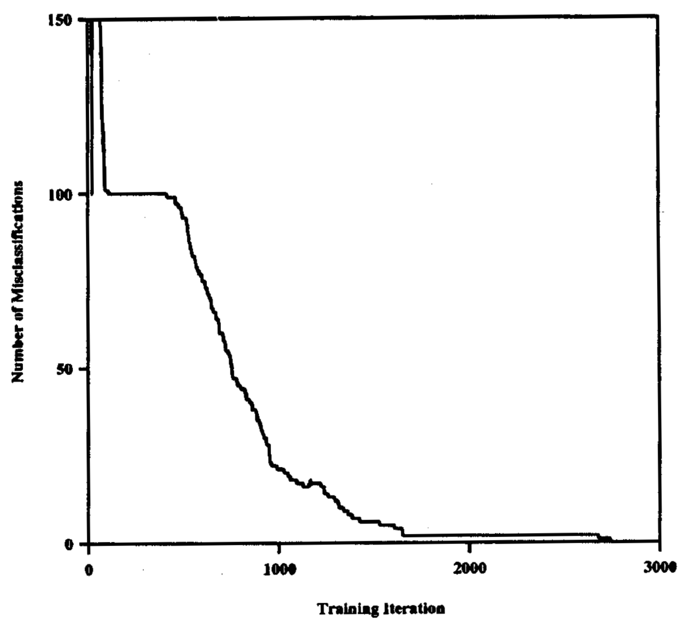


Figure 2. Neural network misclassifications of fabric type as a function of training time

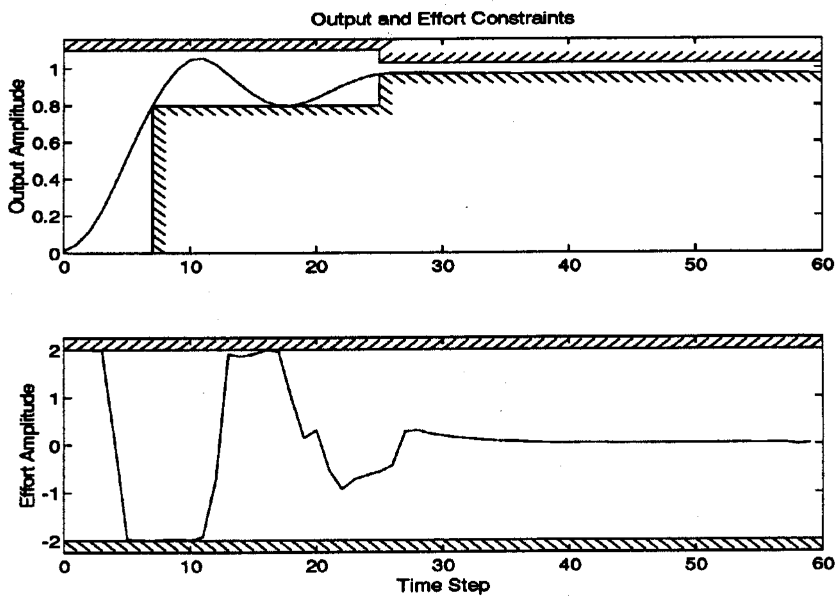


Figure 3. A unit step response of presser foot force that satisfies the time domain constraints

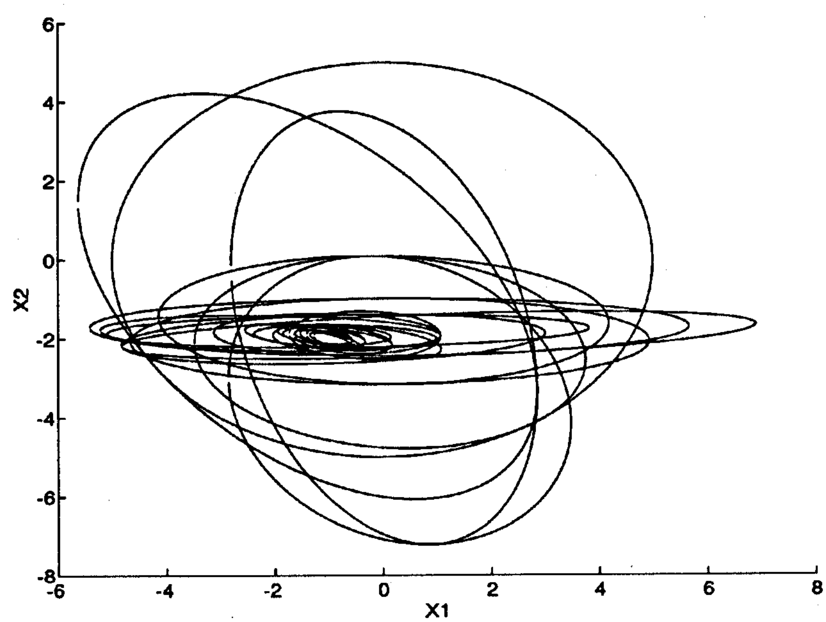


Figure 10. Convergence of a two dimensional parameter search to an optimal feasible point using the ellipsoid algorithm