

Investigating new ways to nest leather

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Leather is one of the most versatile materials available to man. It has been used to produce footwear for at least 30,000 years and, with the absence of an equivalent synthetic alternative, will continue to be used for many years to come. However, leather is a natural material and all hides are different in shape, quality, substance and stretch. Most leather is a by-product of the meat and milk industry and, despite efforts to the contrary, still lacks many of the qualities shoemakers would prefer. Most animals live in the open, scratch themselves against trees or wire, are subject to parasites and are often branded for identification purposes.

Consequently, leather is full of flaws. Scar tissue, parasite activity and stretch marks from multiple calvings all conflict with our need to cut efficiently. To complicate matters further, shoe patterns are complex shapes, come in different sizes and, in most instances, need to be cut in a specific area and direction. On top of all this, an exact number of lefts and rights must be cut. Lasting machines can also exert 300 psi at the toe and, if it bursts, not only is there more waste leather but the added value in a complete upper is also lost.

This explains why most shoe uppers are still cut by highly skilled and experienced craftsmen. It also explains why a great deal of expensive leather ends up in the waste bin. The potential for savings through improved cutting is therefore staggering. Even for a small factory, leather waste can amount to a loss of over \$700,000 per annum. Typical figures indicate that for a factory employing only 120 staff, every 1% improvement in cutting efficiency represents a saving of \$45,000 per annum. The maths for this part of the problem is easy and has a clear answer: make every effort to improve cutting efficiency.

The place of technology

However skilled manual cutters may be, they are up against a huge disadvantage. Patterns are cut and nested one at a time. Whilst experience and training helps efficient local nesting there is no going back and, once cut, the hide effectively develops an additional flaw. In addition, the manual cutter is not afforded the luxury of laying out the full hide and experimenting with different approaches.

When nesting leather, the final result is influenced by the position of every pattern. Technology-based systems allow the whole hide and, indeed, an entire order to be nested prior to any cutting. Pick and place systems allow a trained cutter to nest a complete hide before passing the marker on to an



automatic cutting table. The nest can be manipulated to give far better material usage well before the decision is made to cut. This is where the enormous potential for savings lies.

Developments in automatic nesting are at an advanced stage, but the problems associated with cutting shoe patterns are still immense. At the end of the day, if an automatic cutting and nesting system cannot beat a highly trained cutter, it will potentially cost more. This is the driving force behind developing the systems and technology required for good automatic nesting.

SATRA has worked on this problem from all angles over many years and, in fact, a nest can be created fairly quickly. However, to produce nests that are consistently as good as those produced by well trained and experienced cutters on difficult hides can take a very long time. This is a complex waste minimisation problem and to achieve even a small percentage improvement requires significant increases in computing time. Improving a good plan by only 1% can involve an enormous computational overhead though, as already explained, even 1% can lead to very significant savings indeed.

Applying mathematics

The mathematical methods to create a nest are well understood but to reach the levels of cutting efficiency that we know to be achievable, demands a computational burden that is an obstacle to implementation. In key areas such as cutting

Figure 1: An example of a shape-hide no-fit polygon (NFP) and window region centred on point labelled A.

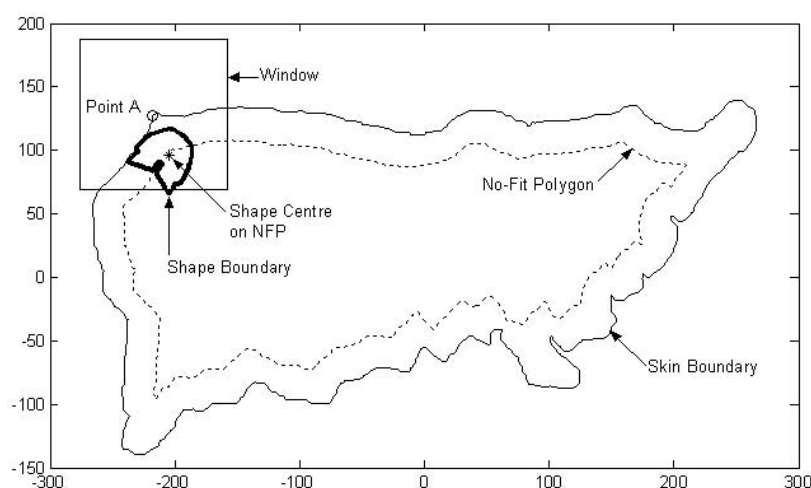
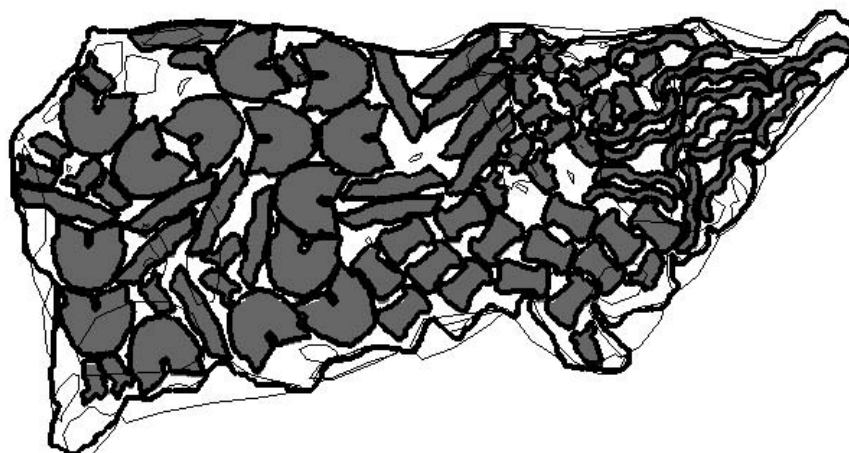


Figure 2: Lay plan of 14 shoes giving 61.6% coverage. Note that this nest is produced to evaluate the algorithm and is not intended as a cutting guide!



upper sections for footwear from complex hide shapes, it is important that fundamental research work is continued in order to increase opportunities for automation in future years.

SATRA has always been willing to work with high quality academic staff from universities in order to advance knowledge in such important areas in the footwear industry. It is working jointly on research with universities in the UK through the collaborative Engineering and Physical Sciences Research Council (EPSRC) projects, the latest being to investigate ways to minimise waste when cutting leather for footwear. The EPSRC receives more than £500 million (\$875 million) each year from the UK government in grants for research into fundamental problems.

Algorithms

This particular project was primarily concerned with looking at novel ways to reach an optimum solution in a shorter time. Whilst not generating full nests, it focused on optimising placement algorithms in order to reduce computational overhead. The very nature of genetic algorithms (GAs) had

instant appeal. Five cutters will all cut differently and produce completely different nests, all at acceptable efficiency levels. In this instance, GAs offer the same flexibility of finding differing solutions to the same problem, all acceptable and all optimal. More traditional methods attempt to calculate exact answers to exact criteria and it is not until the final pattern is cut that we understand the question or what the answer will be.

No fit polygons

In this application, potential positions for nested patterns are calculated in relation to the surrounding flaws, grade areas, previously placed patterns and their own individual requirements. Placement options are calculated by generating what is known as a 'no fit' polygon (NFP). This is a shape that represents the limits of where the new pattern can be placed (Figure 1), which clearly shows that this is a collection of points that represent potential placement options for that particular pattern at that particular orientation. Different orientations will produce different NFPs.

It is then the job of the GA to decide on the best placement solution based on fitness criteria suited to that particular pattern. It must be said that the fitness criteria will vary according to the pattern being placed in that particular instance. Vamp patterns will have strict criteria in terms of orientation and grade area, so placement options are in fact far more limited than say a back strap. However, sufficient vamps still have to be cut.

In this scenario the GA would consider the need to cut a particular pattern and weight this need accordingly. The decision of whether to place a particular pattern in a particular position is not simply 'yes' or 'no', but is based on the required outcome at that particular stage in the nesting. The GA then decides which is the optimal placement position and so drastically reduces computer time.

Several different nesting strategies were investigated in this project. All the variants demonstrated that this approach gave good results. In particular a local packing strategy (comparable to the approach that a cutter would use), gave a simpler coding solution and better nest results. This method also allowed the implementation of grading and directionality constraints more readily and gave nests that were competitive with human cutters (Figure 2). **Note: This nest was produced to test the method and is not a cutter guide.*

Improving cutter efficiency

Finally, the technology involved—given the investment—has the potential to produce very efficient automated cutting of ➤

What is a Genetic Algorithm?

A GA is simply another way of finding a solution to a problem. For most mathematical problems there is an established method that gives an exact answer. Some problems, however, are so complex that even if there is a method to find an exact answer, it may take years to calculate, plus there may be several optimum solutions that are very different. When faced with this situation we need a method for finding an optimum solution in a short time that will satisfy our need for accuracy. GAs offer a very effective way of finding an optimum solution and we don't even have to know how to calculate the right answer. All we need is a test to tell us if one answer is better than another, which simplifies the calculation enormously.

A GA works by creating, at relative random, a set of possible answers to a problem. Each one is then tested against the others. Weak answers are removed (killed) and the survivors kept. These survivors are then mated mathematically to provide offspring that are a combination of better answers. The survivors and their 'children' are then tested against each other and the cycle begins again. Very quickly, clusters of similar answers are created that improve with each generation. To prevent the algorithm chasing up any blind alleys, a small proportion of answers from each generation are mutated to generate other avenues.

Key steps in a simple genetic algorithm:

- Starts with an initial random population of potential solutions
- Population is ranked in terms of fitness as a solution
- Fittest members randomly selected and re-combined to produce an offspring
- Small proportion of offspring mutates to extend the search
- Fitness values for the offspring are calculated
- Offspring and their corresponding fitness values replace poorly performing members of original population.

Iteration is used to generate more and more offspring solutions to yield better approximations to the final optimal solution.

leather. This was a small project investigating new ways of approaching the nesting problem and funding is currently being sought to continue this work, even possibly incorporating the algorithms in a full nesting system. The technology can also be employed to assist cutters. Currently we are looking at further projects to create systems based on these techniques to improve the training of cutters. Such systems do not replace cutters but, instead, assist them by suggesting better alternatives and predicting the outcome. This can help both experienced and even the most inexperienced cutters to improve their efficiency up to very high standards indeed. 🌐

Footnote: Co-authors of this project were Alan Crispin, Paul Clay and Gaynor Taylor of Leeds Metropolitan University and David Reedman of R&T Mechatronics.



**ALTA QUALITA'
DALLA TESTA
ALLA PUNTA.**

- Semenze per montaboette (calzera)
- Microsemenze
- Punte rullate ed elicoidali
- Semenze fissasolette
- Semenze a mano
- Gamma completa di chiodi per calzatura
- Punti metallici a borchie

**HIGH QUALITY FROM
THE HEAD TO THE TIP
OF THE POINT.**

- Heel seat lasting tacks
- Micro tacks
- Buttress and helical heel nails
- Insole tacks
- Wire hand tacks
- Full range of shoe tacks
- Staples and decorative tacks

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