



Seeking a good fit (Part 2)

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In the May/June 2019 issue of *World Footwear*, I gave a general outline on why it is difficult to manufacture shoes that can fit all customers. With this problem in mind, the team at ATOMLAB-Bristol has started multiple lines of research to assist shoe manufacturers by seeking knowledge to improve the fit of footwear. In contrast with previous shoe related research, the primary goal has been to gain an understanding into the shapes of feet. This is the most fundamental metric that dictates the fit of a shoe to an individual and must be understood before considering the shapes of lasts and shoes. After all, if you do not understand the shape of your customers' feet, how can you make shoes for them?

Restating some points made in the previous article, recent studies have shown that more than 40% of men in the UK are buying shoes that are one or even two sizes too big in order to achieve sufficient width. This results in shoes that are technically incorrect in other aspects, such as the shoe flexing in the wrong position. Typically, Internet shoppers purchase up to three pairs of shoes in different sizes, as they lack confidence in the sizing systems currently used. This involves the return of at least two or, possibly, all three pairs. In any business model, this must be viewed as inefficient and costly. It is also common knowledge that consumers tend to migrate to

manufacturers that provide the shape of shoes that better fit their feet, so there does appear to be a need to improve the way that shoe fit is understood.

UNDERSTANDING FOOT SHAPE

The rapid improvement of scanning technology now means that there are numerous readily available devices that can be used to capture the 3D shapes of feet. There are even mobile phone apps, capable of scanning feet, that can be used at home. This gives us a real advantage over past researchers who had to rely on taking measurements manually and would typically only have one physical opportunity to do so. It is certainly true that you can take measurements with these new foot scanners, but more importantly they create a 3D geometrical copy of the complete foot's shape and it is the availability of these foot models that allows us the opportunity to evaluate shape.

Now that we can gather 3D foot scans from many people, how best can we use this information to help make better footwear? Our first thought was to try to find the average shape of feet and the spread of different shapes away from that average. Assuming foot-shapes follow a typical normal distribution, we predicted that more feet would be within a given tolerance of the average. The average foot-shape could therefore be a good starting

point for engineering shoes. A methodology was proposed to calculate a geometrically average foot-shape from a group of scans. The result produced looked like the average shape but, the question we asked was "How do we know it is correct?" Our solution was to develop an entirely different mathematical method and cross-compare the efficacy of the two. In this comparison we observed identical results and are now confident that we can produce a geometrically average foot of a given population that is correct.

The other innovative nature of our work is that we can find the geometrical average of feet regardless of length. It is the shape of a foot that we are interested in, not whether it is large or small. Additional benefits of calculating an average foot shape are that we can do it for different demographics. For example, is the average foot shape of people in their twenties the same as the ageing population or the typical shape for a size 4 the same as that of a size 9?

HOW AVERAGE IS A FOOT?

If we can calculate an average foot-shape, can we determine if the feet of an individual are similar or far away from this average? This investigation was the first real deliverable of the research. Effectively, we have devised a way to produce a ranked list of foot scans with the most average shape at

the top of the list and least average at the bottom.

This now allows us to automatically process many scans and be able to identify how close they are to the average of a group. Our first test group of individuals showed some interesting results (*Figure 1*). Our ranking list clearly identifies the two people that are the least average. Observing cross-sections of their feet, it is clear why. They are both far from the average, but for different reasons. On a small scale this process has quickly identified non-average feet. This style of analysis is invaluable when studying small subgroups of scans but becomes increasingly harder to interpret in larger populations. When dealing with these, the methods employed here result in tens of thousands of comparisons between all pairs of feet, the analysis of which will be discussed later.

Initial research looked at the total foot. However, it was clear that feet are not uniformly the same. *Figure 2* shows results from the same test group and we can see that although some people are average in certain zones, they can be far from average in others. For current research, we are therefore now analysing feet in different zones as in *Figure 3*.

HUMAN FITTING MODELS

A closer understanding of foot-shapes led to us to consider the shapes of a very important group of people, those used by shoe companies for their practical fit and wear tests. The question to be asked here is “Are these people, used as human fitting models, a suitable representation of the customers you are trying to sell shoes to?”

A process devised by our research team creates a map representing the differences in shape between different feet. A further analysis lets us determine for each fitting model those foot scans that are close in shape to this model. This gives us two important pieces of information. First, we can tell if people in a population are represented by a fitting model and, possibly more importantly, we can tell if there are foot shapes in a population that are not represented by a fitting model. The conclusion to this is that even if a new shoe passes fit tests it may not have been tested for all foot shape groups in the customer base. An

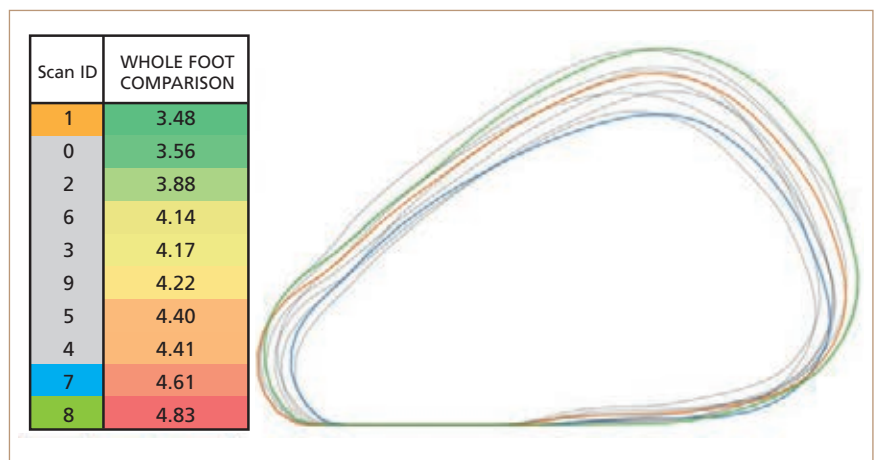


Figure 1: Ranking lists and cross-sections showing why two people have the least average shape in a group. ALL CREDITS: ATOMLAB BRISTOL

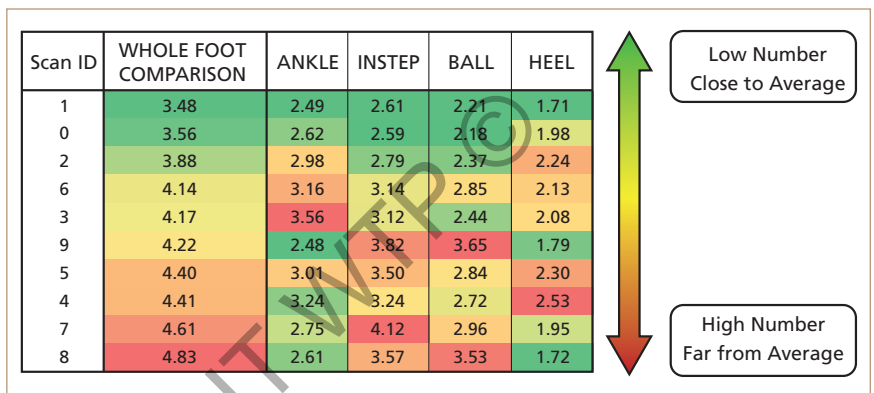


Figure 2: Average shape ranking lists for different zones of feet for a group of people.

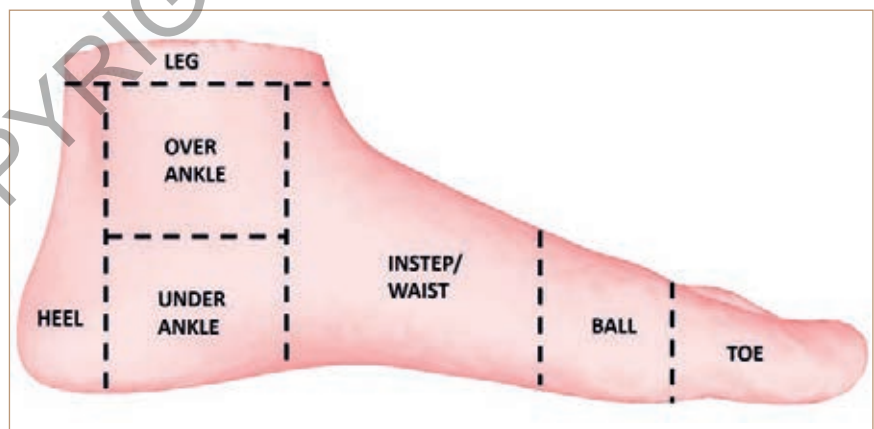


Figure 3: Zones of the foot.

extra advantage is being able to report back on how suitable a current fitting model is and whether individual fitting models are each representative of a sufficient portion of the population.

Second, once we have obtained the numerical differences between each pair of feet in the population, we are able to convert this into a visual aid, spreading the different groups of similar shape across a 2D map—where physical distance between points is representative of similarity and the positions of fitting models and outliers

are easier to interpret in a meaningful way. *Figure 4* is an example created to illustrate how this can be used. There are three regions of different colour which are represented by a ‘star’ fitting model approximately near the region centre. However, not all people fall within a fitting limit of the three models (see the group to the top-right). Knowing this, we can investigate further and in this specific example the people not served are quite clearly seen to have feet that are wider and of greater depth than the

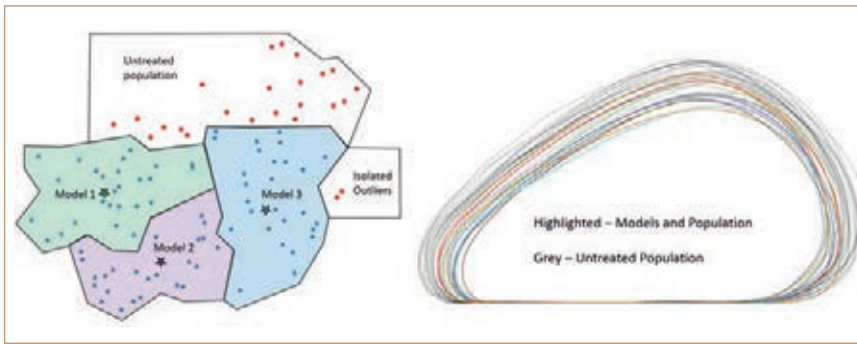


Figure 4: Distance map of a population with fitting model zones of influence and cross-sections of fitting models against the unfitted outlier group.

current fitting models.

From this information, we are able to select a person from the population who can be used to represent that group. This is a simplified example, but we have seen this method work on real data, allowing us to quickly identify and recommend a group of people of model size that could be added to a company's fit test trials.

Analyses of the shapes of different demographics in a population are also of interest and the first we tackled was analysing the change in foot shape as feet become longer. The paradigm we considered was, "Do people with short feet have the same shape as people with average length feet and with long feet?" Initial research has shown that there could indeed be a general gradual change in the shape of feet as they become longer. At this stage, however, results are not conclusive and further research is planned on larger sets of data. We need to determine if this is a genuine effect and if the change is significant enough to consider modifications to the way that the shapes of shoe lasts are graded in order to reflect the natural grading in feet.

ONGOING RESEARCH

The research is ongoing and with our deeper understanding of foot shapes we will be assisting shoe companies to improve their shoe fit procedures and provide them with information that can let them more fully understand their fit test results. We are also providing shape reports for the human fitting models used by shoe companies. This includes a much higher level of analysis, including indications of which fitting models are close to average shape and which are at the extremes of shape when compared to the customer population.

Further research has been started to evaluate differences in shape between left and right feet as this can be in shape and/or dimensions. Continuing research will determine when this difference becomes significant and if some action is needed to ensure a pair of shoes will still fit. Methods are also being evaluated to auto-extract features from foot scans allowing us to identify sub-populations of different foot types so that we can analyse how this affects the fit of shoes. Demographic analysis of foot shape related to age is another obvious area to research. We are interested to see how foot shape changes with age and different generations. If shoes are aimed at a specific age group, are adjustments to last shapes required?

COMMENTS

At the beginning of this research, we were motivated to focus on the benefit of using 3D scanners to capture not just dimensions but also shape. It seems obvious that to create good fitting shoes you need to match shoe

shape to the shapes of feet so that they can function correctly while being worn and provide protection, structure and comfort. It is also true that people and their feet come in many different shapes and sizes. How can you create shoes that can cope with this variation and still provide good fit to individual customers? We are not providing exact answers or formulas, but we are providing new knowledge that can be used to improve the way that shoes can satisfy the fitting requirements of customers.

Although we are still at the very beginning of our foot shape research, we are nevertheless making significant progress. It has now become clear that to analyse shape thoroughly, we need to visualise foot shapes and the relationships between them in several different ways. This, in conjunction with size information and some traditional measurements, is giving us greater insight into the nature of feet and, most importantly, how we can use this information to improve the way that shoes are made. 🧠

**Ian Paris is CTO of ATOMLAB-Bristol which is itself a subsidiary of ATOM s.p.a, a leading supplier of cutting systems and automated shoemaking equipment. The Bristol-based team has its origins within Clarks Shoes and Shoemaster International, developers of the Shoemaster 3D CAD system from which it has inherited a wealth of knowledge concerning shoemaking and shoe related technology.*



Feet of different sizes are not always the same shape.

CREDIT: KOSMOS111 / SHUTTERSTOCK