APPENDIX I: EXAMPLE NOTES ON INVESTIGATION OF 3-D INPUT DEVICES

(Aclarus, notes on personal communications, 2003 and 2004)

3-D Optical Systems
Multiple cameras are set up with a sinusoidal (graph of sine function in Trigonometry) fringe pattern projected onto the object (Figure 1). The 3-D coordinates of every point on the pattern are captured by each camera. An algorithm then generates the 3-D geometric data. These systems are often large and require landmark targets. They seldom offer real-time stitching together of a 360 degree view. Not the best technique for sampling data since the cameras may be limited to specific focal lengths. Foot landmarks must be marked via target stickers or in some 3-D mode later (http://www.shoemaster.co.uk/orthopedie.htm; http://www.cyberfx.com/)

Figure 1: 3-D Optical Systems
✔ Sinusoidal (graph of sine Fx in Trig) fringe pattern projected on object
✔ 3-D coordinates of every point on pattern
✔ Algorithm generates 3-D geometric data
X Lower accuracy
X Limited to specific focal length

Computer Measuring Machines (CMM)
Axila Sigma. Rotation around the foot is a problem, because it is difficult to work around a vertical object. Moving the arm around to predefined points could solve this, so some form of mobile ring around the foot is still needed. These devices are really substitutes for micrometers, and the higher the resolution, the more expensive. Pros: Will get measurements quickly and accurately, communicates via Ethernet to other computers,
simple to interface. Cons: Expensive. The Sigma starts around $45,000 (http://www.axila.com/sigma.htm). An interesting possibility is to place a laser scanner on the arm - this could solve the problem of getting points plus surface data, and the arm can put the scanner close enough to build a picture. Axila's scanner is too expensive, around $40,000. Note: these are products made for the auto industry, not medicine.


FARO Gage. If the project could afford an arm, this would be the one - compact, simple to use (http://www.faro.com/Products/Gage.asp#). With the attachment of a laser scanner for point clouds (http://www.faro.com/Products/ScanArm.asp), could be the perfect combination. Pros: Great stuff. Cons: The Gage starts at $20,000, and no pricing on the scanner.

Browne & Sharpe have a similar CMM product set, but on a table – (http://www.brownandsharpe.com/home.asp?div=cmm_products&id=7290&pagetitle=Manual%20CMMs). Basically, this is set up like a plotter, but with a higher clearance. The problem here is the difficulty in moving the foot around to get both front and back. Pros: Complete system for $13,000. Browne & Sharpe have a medical application at http://www.brownandsharpe.com/applications/app_examples/mfg1art2.asp. Cons: Usability, and lack of collaboration on a project.

Immersion Microscribe G2: This is interesting - if one sacrifices size and resolution, the Microscribe G2 starts at around $3,500 – see http://www.immersion.com/digitizer/products/index.php. They have actually customized this for medical applications - see the bottom of the page at http://www.immersion.com/digitizer/case_study_gallery/scientific_1.php. Several medical manufacturers use their gear as part of microsurgery equipment. Their software is quite comprehensive too. Pros: Price, completeness. Cons: Discomfort and “tickle factor” of drawing the stylus across a live participant’s skin surface. See their kit at http://www.immersion.com/digitizer/products/microscribe_accessories.php.
Conclusion: Microscribe (Figure 2) may be the way to go, but needs further investigation.

Figure 2: Immersion Microscribe Digitizer

- Articulations = move in any direction
- Sensors register $x$, $y$, $z$ coordinates in space
- Micro-station processor builds mesh from co-ordinates

X Fixed base requires rotation of the object (foot and ankle)
X Unsuitable to run stylus across and along sensitive skin surface of foot

Laser Stripe Triangulation

*Polhemus FastScan Cobra.*

Laser triangulation is a commonly used technique of 3D data acquisition. It is an active stereoscopic technique in which the distance to the object is computed by means of a directional light source and a video camera. Figure 3 shows this triangulation principle.

A laser beam is deflected from a mirror onto a scanning object. The angle of the laser beam ‘$a$’ is known. The object scatters the light, which is then collected by a video camera. The
distance between the location of the camera and the laser is known and is called triangulation distance.

For facilitation purposes the camera is modelled as an ideal lens and the detector is modelled as flat. One can see that the angle and the pixel position of the scattered light are related. Since the focal length (f) of the camera lens is known, the analysis of the resulting video image can determine the angle (B) of the scattered light. The angle is also known since it is the projection angle of the laser beam. The laser beam makes it possible for the camera to see the object. When the camera only sees the layer that is highlighted by the laser, it records only this line, so the z-coordinate is known. Thus, using basic geometric rules, the 3-D (x,y,z) coordinates of a surface point can be determined.

In using a hand held laser, the only difference is that the system is not fixed within some sort of rack. A magnetic tracker is used to determine the position and orientation of the equipment, enabling the computer to reconstruct the full three-dimensional surface of the object.
By utilising an accessory called a stylus, landmark points can be recorded. These can be bony landmarks in foot anatomy, as well as end points needed for linear, circumferential and volumetric calculations (to be placed by a qualified podiatrist). Custom software could then calculate the distances (lengths and widths), the circumferential distances (the girths) and the volumetrics (e.g. across the heel entry depth) for export into a spreadsheet programme such as MS Excel.

The Cobra is a hand-held scanner, free-standing, that auto-stitches 3-D surfaces together as one rotates around an object. There is also a stylus marker that can be used to touch specific reference points. They have used this combination in medical studies for face swelling and for orthotics (see http://www.polhemus.com/Hanger.htm). Their site is at http://www.fastscan3d.com/, and the Cobra is at http://www.polhemus.com/fastscan.htm. Pros: Good combination of landmark data plus point cloud data. Portable. Costs about $19,300. Low cost solution that merits further investigation.


3D Scanners (UK). (http://www.3dscanners.com/) Has products at around $96,000. Not under consideration due to high cost.

Proximity Lasers (only if one builds the entire system oneself)
Acuity is a small R&D company, good products. Would require own design of a ring (Azimuth) and a rocker (elevation), plus distance from the laser to sample any point on the surface http://www.acuityresearch.com/products/ar4000/index.shtml. Pros: Definitely measures distance, and at a reasonable price of $3,500. No point cloud for later research. Cons: Not very accurate (error can be up to 9 mm), and all the hardware and control electronics would have to be built.

Custom systems such as used in CAESAR project (Figure 4) are out of the question with regard to cost and installation logistics, plus further work needed for good foot detailing.
Figure 4: Laser output as produced in the CAESAR Project
(Civilian American & European Surface Anthropometry Research Project)

X Not portable – 300kg installation that takes months to set up and calibrate.
X Poor definition in the foot area
X No data on curvature or topography of the plantar surface

Point processing software (ready-made)
Rhino is full-featured and reasonably priced (http://www.rhino3d.com/); others are Polyworks; Geomagic; Rapidform. Basically, the latter was the German company contacted by the project from South Africa that quoted 30,000 Euros for custom software.

Future direction of investigation
Firstly, assess what is there: a project, a research methodology, a clinical approach, about 500 participants, a little grant money, a software developer, two electromechanical engineering shops, a few different measurement technologies, and about 3 months to get ready.

Secondly, the strategy should be to closely follow a clinical approach and focus only on what is needed now. Perhaps additional data can be collected in parallel, but only if it is little extra effort. There is no question that landmark point data is needed first, point cloud data later. Best outcome will be to get both at the same time; if not, cloud data is part “next” of future projects. There is no doubt that the study will migrate to 3-D models, because that
is what is needed to show industry. With a database of landmark data and associated cloud data, anything that is needed can be generated later in software.

Thirdly, there are really a few viable technology approaches - for point data only, use **CMM**, and the cheapest with the best support is **Immersion Microscribe 2**. CMM can be regarded as a free-form Brannock device, at about $3,500 plus PC plus extras, plus some programming from an outside contractor. A concern is still that, whereas touching the skin lightly with one “dot” of a stylus marker may be acceptable to most subjects, drawing the stylus marker across the surface of the skin in long lines is bound to elicit a “tickled” response with subsequent unwanted movement of the foot.

There are also some usability problems: Microscribe does point data only, and one can get data from this into any PC with little additional programming - a little scripting gets data right into an Excel spreadsheet. Operator error can be a problem, since it is similar to typing - lose the place and one has to start over. Also, not much of a migration path here: in order to obtain cloud data, one has to move to another technology. **FARO Gage** is CMM for a cost of $30,000 that will supply the point cloud data and landmarks with the user interface of a pointing device.

The only other viable technology apart from CMM is **Laser Stripe Triangulation**. This is similar to the systems from Germany and Japan already explored, and it supplies point cloud data only, but one system gets landmarks plus cloud data. **Polhemus FastScan** is the best option here. For $18,500 plus extras, one can record both landmarks and cloud data. The stylus works like a pen and the big advantage here is that the landmarks are in the cloud, and part of a single dataset. This is very important - one can get the measurements from the landmarks, plus the 3-D anthropometric data surrounding the points, which open up a whole raft of possibilities, such as being able to create a realistic computer model from "standardized" landmark points. In other words, given a set of landmarks which one chooses as being statistically representative of the samples, one can also create a 3-D representative model of a last, knowing that this is interpolated from real-world data. Without the 3-D data, one would have to create a "synthetic" model of a last. One thing to note - any scanner must have a completely clear view to be able to map crevices (like the bottom of the toes), so the 3-D model will not be perfect unless one can also scan under the foot or develop a mathematical model to generate the interstices.
One can also get cloud data from Optical systems, but these are too big, too expensive, and don't offer more than the laser scanners. Finally, the project cannot build the instrument from the ground up, mechanical and scanning, in 3 months - too many unknowns about performance and integration.

The choices come down to:

1. Landmarks vs. Cloud vs. Both
2. Touch (CMM) vs. Scanning

Landmark points only is Microscribe; Landmark plus Cloud points is Fastrack Cobra or FARO Gage with a Scanner. If money were no object, CMM with scanning gets both data types. On the Touch vs. Scanning, for CMM only Microscribe is one fifth the price of Gage, but no upgrades. Best for Scanning is FastTrack Cobra, for ease of use and software.

Finally, there is the question of usability. In considering CMM arms, there is no way to easily examine both sides of the foot without moving around a lot, and bending the arm around the leg for the occluded view, and using the left hand. So, either one moves the subject or one moves the arm - and so the design concept is back to the azimuth ring, sans hoop, on which the arm rotates. The arm location can be offset to its measurements, and so move freely.

The same problem exists with the Cobra scanner - somehow this must be moved between the ankles to get the inside ankle view.
APPENDIX II: BACKGROUND ON TECHNICAL COLLABORATORS

Aclarus Corporation

Aclarus Corporation is a systems integration consulting practice. The firm has three practices, which focus on: system integration (custom applications, third-party software and hardware); business intelligence (database architecture and design, decision tools and modeling); and project leadership through project management, software evaluation, risk analysis, performance tuning, mentoring and knowledge transfer (Aclarus promotional material, 2003).

On briefing, Aclarus wrote the technical specifications for the custom version of scanning software subsequently carried out by ARANZ (Applied Research Associates New Zealand).

Applied Research Associates New Zealand

Applied Research Associates New Zealand (ARANZ) develops 3-D scanning and modeling technology. ARANZ was formed in 1995 to commercialize a patented hardware and software technology in a successful hand-held laser scanner device. The scanner subsequently found wide application in prosthetics and orthotics, forensics, medicine, archaeology, bio-sciences, and reverse-engineering. Examples of anthropometry applications for the scanner include a fast, non-contact casting system for the largest prosthetics and orthotics provider in the USA.

Through work initially carried out in conjunction with the Department of Mathematics, University of Canterbury, ARANZ developed advanced software for processing various types of 3-D data-sets. For researchers working with sampled data, these functions smoothly interpolate scattered 2-D and 3-D data by a mathematical concept known as Radial Basis Functions. No other technique can model irregular, non-uniformly sampled data as effectively as RBF interpolation (ARANZ promotional material, 2003).

In the present study, a custom version of this software, with several additional modifications to join sole underside data, was used to process the data that is gathered by the laser system. The software is used to merge sweeps, join objects and smooth surfaces,
so that sole underside data is merged with foot upper surface data, and incorporating the use of a sole impression material. ARANZ agreed to work on a pro bono cost-only basis for this project, in return for the extensive beta testing and collaboration provided by the study to bring the software to the standards required for commercial application.

**Polhemus**

Polhemus of Colchester, Vermont in the United States of America designs and manufactures systems for motion tracking. The Polhemus tracking system computes the position and orientation of a small receiver as it moves through space. The system provides dynamic, real time six degrees of freedom measurement of position (x, y, and z coordinates) and orientation (azimuth, elevation, and roll), and it was the most accurate electromagnetic tracking system available (Polhemus promotional material, 2003). Polhemus products are used widely in the medical market, including such applications as image-guided surgery, EEG localization, ultrasound training and simulation, kinematics measurements, and gait and limb movement analysis.

Polhemus provided the basic scanning hardware, user training and the 3-D positioning hardware, as well as warranty support and engineering expertise.

**Walbac, Southern Air Repair and Elro J Braak**

Walbac and Southern Air Repair are precision engineering companies that design and manufacture subassemblies for industry. Southern Air Repair specializes in building custom aerospace stainless steel prototypes.

Walbac, Johannesburg and Southern Air Repair, Florida USA, collaborated to manufacture the pyramid measurement stand. Paradigm Plastics, Heriotdale South Africa, manufactured the wooden and Perspex™ step up measurement platforms. Elro Braak of Pretoria, South Africa supplied the pre-cut blocks of phenolic orthopaedic impression foam at academic discount prices.
APPENDIX III: REPLICATION TESTING OF MEASUREMENTS

Table 1: Confidence intervals for Minor Foot Length replicates

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<thead>
<tr>
<th>Descriptive Statistic</th>
<th>Mean</th>
<th>95% Confidence Interval for Mean</th>
<th>Standard Deviation</th>
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<td></td>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
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<tr>
<td>Minor Foot Length 1</td>
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<td>212.96</td>
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<td>198.33</td>
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<td>183.19</td>
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Figure 1: Means-on-spokes for confidence intervals in replication testing of Minor Foot length (95% confidence interval; x-axis represents means of replicate tests, y-axis indicates measurement in millimetres, replication accuracy was within 1 millimetre).
Table 2: Confidence intervals for Toe height replicates

<table>
<thead>
<tr>
<th>Descriptive Statistic</th>
<th>Mean</th>
<th>95% Confidence Interval for Mean</th>
<th>Standard Deviation</th>
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<td>Toe height 6</td>
<td>22.50</td>
<td>21.40</td>
<td>23.60</td>
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Figure 2: Means-on-spokes for confidence intervals in replication testing of Toe Height (95% confidence interval; x-axis represents means of replicate tests, y-axis indicates measurement in millimetres, replication accuracy was within 1 millimetre).
Table 3: Confidence intervals for Tread width replicates

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<th>Descriptive Statistic</th>
<th>95% Confidence Interval for Mean</th>
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<tr>
<td></td>
<td>Mean</td>
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<td>Tread Width 1</td>
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Figure 3: Means-on-spokes for confidence intervals in replication testing of Tread width. (95% confidence interval; x-axis represents means of replicate tests, y-axis indicates measurement in millimetres, replication accuracy was within 1 millimetre).
### Table 4: Confidence intervals on Navicular height replicates

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**Figure 4:** Means-on-spokes for results of replication testing of Navicular height. (95% confidence interval; x-axis represents means of replicate tests, y-axis indicates mean measurement in millimetres, replication accuracy was within 1 millimetre).
Table 5: Confidence intervals on Heel seat width replicates

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<th>Heel Seat Width</th>
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Figure 5: Means-on-spokes for results of replication testing of Heel seat width. (95% confidence interval; x-axis represents means of replicate tests, y-axis indicates mean measurement in millimetres, replication accuracy was within 1 millimetre).
Table 6: Confidence intervals on Heel to ball 1 replicates

<table>
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<th>95% Confidence Interval for Mean</th>
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Figure 6: Means-on-spokes for results of replication testing of Heel to Ball 1. (95% confidence interval; x-axis represents means of replicate tests, y-axis indicates mean measurement in millimetres, replication accuracy was within 1 millimetre).
Table 7: Confidence intervals on Heel to Ball 5 replicates

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Figure 7: Means-on-spokes for results of replication testing of Heel to ball 5. (95% confidence interval; x-axis represents means of replicate tests, y-axis indicates mean measurement in millimetres, replication accuracy was within 1 millimetre).
Table 8: Confidence intervals on Tread girth replicates

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Figure 8: Means-on-spokes for results of replication testing of Tread girth. (95% confidence interval; x-axis represents means of replicate tests, y-axis indicates mean measurement in millimetres, replication accuracy was within 1 millimetre).
APPENDIX IV – a

FACULTY OF HEALTH SCIENCES

FACULTY RESEARCH AND ETHICS COMMITTEE
RESEARCH PROPOSAL REPORT

DETAILS OF REPORT:

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<thead>
<tr>
<th>NAME</th>
<th>THOMPSON A L T</th>
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</thead>
<tbody>
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<td>PROGRAMME</td>
<td>PODIATRY</td>
</tr>
<tr>
<td>SUPERVISORY PANEL</td>
<td>MRS S EAGLETON MR B ZIPFEL</td>
</tr>
<tr>
<td>PROJECT TITLE</td>
<td>DOES THE SHOE FIT THE FOOT? – A SOUTH AFRICAN PODOMETRIC STUDY</td>
</tr>
</tbody>
</table>

I am pleased to inform you that your proposal has been approved by the FREC.

PROF M F DUTTON
CHAIR: FREC

DATE: 20/9/2004

S. Eagleton
SUPERVISOR’S NAME

SIGNATURE

DATE: 12.10.2004
APPENDIX IV – b

TECHNIKON WITWATERSRAND, JOHANNESBURG
COMMITTEE FOR RESEARCH ON HUMAN SUBJECTS (MEDICAL)

CLEARANCE CERTIFICATE PROTOCOL NUMBER:  EC212004/009

PROJECT:  DOES THE SHOE FIT THE FOOT? – A SOUTH AFRICAN
          PODOMETRIC STUDY

INVESTIGATOR:  THOMPSON A L T

DEPARTMENT:  PODIATRY

DATE CONSIDERED:  03 DECEMBER 2003

DECISION OF THE COMMITTEE

Approved

CHAIRPERSON:  

(Prof M F Dutton)

DECLARATION OF INVESTIGATOR

To be completed in duplicated and ONE COPY returned to the Research Administrator
at Room 7228, Faculty of Health Sciences.

I fully understand the condition under which I am authorized to carry out this research
and I guarantee to ensure compliance with these conditions. Should any departure to be
contemplated from the research procedure as approved I undertake to resubmit the
protocol to the Committee.

DATE: 12-10-2004  SIGNATURE:  

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APPENDIX V: EXAMPLE OF CORRESPONDENCE FOR UNIVERSITY
PROTOCOL CLEARANCES

Hi Anette

I have followed up on our request and Prof Tyobeka has referred the matter back to me to handle. Could we please have a 30 minute meeting to clarify some of the aspects and also finalise the matter?

Regards
AS

Dr. André Swart
Head: School of Public Health
FACULTY OF HEALTH SCIENCES

Technikon Witwatersrand
PO Box 17011
Doomfontein 2028
Gauteng
South Africa

Tel: +27 11 406-2434
Fax: + 27 11 406-8456

From: Anette Thompson [mailto:anette_thompson@iafrica.com]
Sent: 14 November 2004 12:57 PM
To: andres@twr.ac.za
Cc: eagleton@twr.ac.za
Subject: Permission to recruit research participants from HEIs

Dear Dr Swart,

When last we spoke, this matter was in hand and the requests to HEIs were to be prepared.

If these are in the form of letters, when may I collect them?

If the requests are prepared in some other medium, may I have a list of whom to contact at the various HEIs, so that I can proceed with logistic and measurement timetable planning with them?

Many thanks, Anette Thompson.

(Podiatry Masters student, 9901926)

Ms T

You need to take this up with Prof Dutton in view of the ethics issues involved – he will be able to guide you on what steps and protocols to follow.

TADH

-------------------------------------------------------------------------------------------------
Professor Thomas Auf der Heyde
Dean: Research
Technikon Witwatersrand
PO Box 17011
Doomfontein 2028
Johannesburg
On 1 January 2005 the Technikon Witwatersrand and Rand Afrikaans University will merge to become the University of Johannesburg.

For more information please visit www.ujhb.ac.za

-----Original Message-----
From: Anette Thompson [mailto:anette_thompson@iafrica.com]
Sent: 27 August 2004 12:40
To: reetha@twr.ac.za; tadh@twr.ac.za
Subject: FW: Permission to measure feet of university personnel

F.Y.I. Best regards, Anette Thompson.

From: Anette Thompson [mailto:anette_thompson@iafrica.com]
Sent: 27 August 2004 12:38 PM
To: 'eagleton@twr.ac.za'
Subject: Permission to measure feet of university personnel

Dear Saramarie,

I phoned Reetha to ask her what procedure to follow.

I need to begin making arrangements with the 5 universities on the list we discussed, to visit and co-ordinate appropriate venues, and set dates, etc. for foot measurement of admin personnel, if possible.

She believes that the request must come from you to your head and from him to his head (academic)

In TWR's case, this means a letter from you to Andre Swart (I think) and from him to Prof Thobeka (?)

Here is a draft outline (to save you time) of what I imagine needs to be in a request:

Dear (insert name),

As HOD for Anatomy and Physiology, I consider that TWR (Technikon Witwatersrand) is proud to be associated in a collaboration between the Faculty of Health Sciences, Department of Podiatry and Department of Anatomy and Physiology; the Department of Trade and Industry, THRIP (Technology and Human Resources in Industry Programme) and SAFLIA (The South African Footwear and Leather Industries Association), as well as Michelle Footwear (Pty) Ltd., in a research project to investigate footwear fit among South African women.

As TWR prepares for merger with RAU (Rand Afrikaans University) and Vista University (?), collaboration between industry and Technikon research is particularly valuable to help ensure and strengthen the industrial focus of research in the new University of Johannesburg.

Footwear manufacture depends on accurate last manufacture. The footwear last industry in South Africa, in the absence of updated data, has continued to utilise Eurocentric quasi colonial information in the manufacturing process. Accurate and representative foot anthropometric data
across the full ethnic diversity of our female population is urgently needed on various levels to redress inaccuracies and errors in footwear manufacture, inaccuracies that have been positively linked to many painful foot pathologies.

To this end, we request your assistance.

We require official permission to approach TWR female personnel to volunteer for foot measurement, and for TWR permission to utilise a suitable space for data collection, preferably a 3 x 3 metre clear office or foyer area, to accommodate the custom portable measurement stand. The area should be in or close to admin block to minimise disruption of work. A mature post-graduate student under my supervision, Mrs. Anette Thompson, has been trained in the operation of the measurement instrument, a state of the art 3-D laser scanner that has been sourced from the United States. Measurement per person will be discreet and time per person will not exceed 10 minutes. She requires at least 40 female participants from each TWR campus, aged 21 to 69, of all ethnic backgrounds.

This research project embodies certain aspects, both in technology and approach that are bound to attract local and international attention in future publications. As such, we consider that it would add reciprocal status to both the TWR as well as local universities, if they were similarly approached to provide access for participant recruitment from admin personnel.

The universities we should like to target are:
University of the Witwatersrand
University of the Witwatersrand Medical School
Rand Afrikaans University
University of Pretoria
Vista University, Soweto
University of Kwazulu Natal

Please formulate an official request on our behalf or advise accordingly.
Baie dankie from Anette and Happy Birthday for tomorrow! 😊

As from the 1st of January 2005 Technikon Witwatersrand and Rand Afrikaans University will merge to become University of Johannesburg.

For more information please visit www.ujhb.ac.za

This message has been scanned for viruses and logged.

Electronic mail disclaimer:
http://www.twr.ac.za/email.htm
APPENDIX VI: INFORMATION POSTER FOR DOORNFONTEIN CAMPUS

WOMEN of SOUTH AFRICA!
It’s time to say NO to uncomfortable shoes!

Have you ever wished shoes for women fitted better?
If your answer is YES, then here’s your chance to make it happen.

WE NEED YOU TO VOLUNTEER!
Technikon Witwatersrand (University of Johannesburg) and our Footwear Industry is
sponsoring the 2004/5 South African Foot Project for Women to measure all kinds of women’s
feet, of all ages from 21 to 69, from all ethnic backgrounds. This project will provide much
needed information to improve the comfort and fit of women’s shoes made in South Africa. If
you volunteer, you may be the lucky person who wins the draw for a free shopping voucher for
a pair of Froggie shoes worth R400.

WHAT MUST I DO?
The 2004/5 South African Foot Project for Women will be at the Doornfontein campus in
January, in G03 conference room. Once we contact you, all you need to do is turn up and put
your best foot forward!

Qualified podiatrists (foot health specialists) will take an impression of the bottom of your
foot. At the same time, they will scan your foot with a laser camera, similar to those used at
supermarket cash registers. The procedure is quick, simple and safe.
Your confidentiality is assured. When you volunteer, you’ll be allocated a participant number -
and only that number will be used in all research results.

Questions? Call 082 570 3384 for more details.

Step forward for progress!
Be a part of future shoe design for South African Women!

SA PODIATRY
ASSOCIATION

Froggie

PROUDLY
SOUTH AFRICAN

SA FOOTWEAR
& LEATHER
INDUSTRIES ASSOC
APPENDIX VI:
EXAMPLE OF CORRESPONDENCE TO PLACE POSTER ON A CAMPUS INTRANET

From: Anette Thompson [mailto:anette_thompson@iafrica.com]
Sent: 09 February 2005 07:53 PM
To: 'mbom@rau.ac.za'
Subject: Memo 2005/045 for all users on intranet

Dear Mary,
Earlier today, Miss Dreyer would have faxed to you the 3 pages containing my intranet message (from Prof Exner) as it should go out on the intranet, with his signature authorising this. Attached is the text for the intranet message. Please let me know by calling 082 570 3384 when it has gone out into the intranet for rau.ac.za

Many thanks, Anette Thompson
Dear colleagues,

Once again, our campus is making history. One of our mature students, Anette Thompson, is conducting her masters research in Podiatry by compiling the first ever three dimensional database of women’s foot morphology in South Africa.

The purpose of the study is to supply information to the SA footwear industry to positively influence women’s shoe fit.

Her equipment is currently set up in D Lab block 337. Scanning of a volunteer’s foot takes 10 – 15 minutes. Women of all ethnic groups, ages 21 to 79 are needed as participants.

Scanning of almost two hundred staff at the Doornfontein campus is already complete and all necessary clearance has been given for her task now on the main Kingsway campus.

To minimise time away from your desk in order to participate, Anette will be visiting your office during the coming weeks to book your 15 minute appointment with history. Please support her.

Sincerely,

Professor H.V. Exner  
Executive Dean: Faculty of Health Sciences

Below is the recruitment poster for the project:
APPENDIX IX: MODIFIED POSTER FOR KINGSWAY CAMPUS

WOMEN of SOUTH AFRICA!
It's time to say NO to uncomfortable shoes!

Have you ever wished shoes for women fitted better?
If your answer is YES, then here’s your chance to make it happen.

WE NEED YOU TO VOLUNTEER!

The University of Johannesburg, National Research Foundation (THRIP), Department of Trade and Industry and our Footwear Industry is sponsoring the 2005 South African Foot Project for Women to measure women’s feet, of all ages from 21 to 69, from all ethnic backgrounds. This project will provide much needed information to improve the comfort and fit of women’s shoes made in South Africa. If you volunteer, you may be the lucky person who wins a free shopping voucher for a pair of Froggie shoes worth R400.

WHAT MUST I DO?
The 2004/5 South African Foot Project for Women will be on the Kingsway campus during February and March, 2005. Anette will call on you to make 15 minute appointments. All you need to do is turn up and put your best foot forward!

Qualified podiatrists (foot health specialists) will take an impression of the bottom of your foot, using dry foam. At the same time, they will scan the upper surface of your foot with a laser camera, similar to those used at supermarket cash registers. The procedure is quick, simple and safe. Your confidentiality is assured. When you volunteer, you'll be allocated a participant number - and only that number will be used in all research results.

Step forward for progress!
Be a part of future shoe design for South African Women!

South African Podiatry Association (SAPA)  
Froggie  
Southern African Footwear and Leather Industries Association (SAFLIA)
APPENDIX X PARTICIPANT INFORMATION SHEET

My name is Anette Thompson. I am a medically qualified podiatrist carrying out independent research on footwear for women in South Africa by measuring the feet of at least five hundred women. I need to measure your feet to find out whether our shoe manufacturers are making correctly fitting shoes for our South African population.

You are free to participate. Your name will not be disclosed nor identified with any measurements. Instead, your data will be allocated a number. You may stop taking part or drop out at any time. If you choose not to participate, there will be no penalty nor loss of benefits to which you are otherwise entitled.

To measure your body mass index, my assistant will weigh you and measure your height. To measure your feet, I will ask you to remove your shoes and stockings. You will be given a pair of disposable booties to protect your feet. You will stand barefoot on a measuring platform, with your bare right foot on a disposable block of foam. I will scan your right foot with a 3-D laser scanner (made in America) and lightly touch various bony prominences on your foot with a stylus. A measuring tape will be used to measure across the front circumference of your foot.

I assure you that the examination is safe and cannot cause any pain or discomfort. Although the laser beam used is low intensity and no more dangerous than the bar code scanners used in supermarkets, we will ask you to use the protective eyewear supplied to absolutely prevent any possibility of over exposure. The small magnetic field generated by my equipment is affected by precious metal, aluminium, nickel and iron within a two metre radius. Please, therefore, remove all jewellery and metal such as money purses before being scanned. Recipients of pace-makers, metallic implants or metal prostheses may not participate.

Please ask me should you have any questions. If you are willing to spend 15 minutes to help me make history for South African women by participating, please sign the consent form.

Thank you.

Anette Thompson
B. Tech Podiatry (S.A.)
APPENDIX XI: INFORMED CONSENT FORM

I, ______________________________________________ (researcher) have fully explained the purpose of the study, and the type of examination that will be used. I have assured the subject of safety and confidentiality. I have asked whether questions have arisen regarding the examination and have answered them to the best of my ability.

Researcher’s signature ____________________________ Date ____________________________

I, _______________________________________________ (participant) __________ agree that the proceedings of the study were explained to me. I understand the aim of the study. I also understand that I am free to withdraw my consent and to discontinue participation in the study at any time. I understand that if I have questions at any time, they will be answered. In signing this consent form, I agree to participate voluntarily in the study.

Participant’s signature: ____________________________ Date ____________________________

Subject Number* allocated to participant for data collection purposes __________
(*to be used on Data Recording Form)
APPENDIX XII: DATA RECORDING FORM

Urban Region: Gauteng / Kwazulu Natal  Participant Number ____________

Participant age ____________ years

Home Language:

Afrikaans □  English □  IsiNdebele □  IsiXhosa □  IsiZulu □  Sesotho □

Setswana □  Sepedi □  Siswati □  Tshivenda □  Xitsonga □

Other ________________________________

Ethnic and cultural self-identification
(as per Statistics South Africa census definitions, to measure progress towards equality):

Black African □  White African □  Coloured □  Asian/Indian □  Other ____________

ITEM | MEASUREMENT | NOTES
--- | --- | ---
1. Height | metres | |
2. Weight | kilograms | |
3. Forefoot girth (1st MPJ to 5th MPJ) | Tape - mm | |

DATE ____________  RESEARCHER SIGNATURE ____________________

____________________  ASSISTANT  SIGNATURE  ____________________
Regional Radio Spot (female voice)

Calling all South African women!

*After 10 years of democracy, we're finally “finding our feet”!* 

Have you ever wished shoes for women fitted better?

If your answer is yes, then here’s your chance to make it come true.

A team of research podiatrists from Johannesburg is conducting the first national measurement study of women’s feet in South Africa. The results will influence shoe fit of the future!

They need to measure all kinds of women’s feet, of all ages, from all ethnic backgrounds. Participants will receive free foot care advice and foot care samples! One lucky lady could win a voucher for a pair of Froggie shoes worth R400!

__________________________

If you’re age 21 to 69, call (telephone number) to find out details of dates and venues for your area

Put your best foot forward and call today at (telephone number)
APPENDIX XIV: EXTRACTS FROM ANNUAL REPORTS & PROGRESS TIMELINES

October 2003 to March 2004
Unaided search conducted for systems of 2-D and 3-D data input for foot measurements. Search for information and commitment from industry. Preparation of budget in order to solicit funding. Commenced 6 month pre-registration period on receipt of TRC (Technikon Research Committee) Ethical approval. National Research Foundation THRIP (Technology and Human Resources in Industry Program) funding application for 2004 is submitted.

Telephonic contact with industry. Ongoing literature review and search for South African information (within the industry and abroad) which may not have been published in scientific literature form. Writing of literature review commenced. First contact with Aclarus. Working plans are drawn up for manual data collection instrumentation and methodology, in absence of funding for three-dimensional data input. No outside work possible due to waiting period for the result of THRIP 2004 funding application.

March 2004
First field trip is undertaken to Industry Partners in Durban and Last makers in Pinetown.

Need for three dimensional data definitively established in interactive work group meetings.
Prior two-dimensional measurement instrument is replaced with three-dimensional instrument but project is unchanged.

Ordering and payment to manufacturer of manual measurement (two dimensional) instrumentation is cancelled due to replacement by three dimensional (3-D) instrument.
THRIP and TWR (Technikon Witwatersrand, now University of Johannesburg) are advised of reasons for project expansion.

April to June 2004
Four month investigation is undertaken, in collaboration with one of the Industry Partners, Michelle Footwear, into locating a suitable and affordable 3-D input device to collect the required 3-D data. South African sources for laser technology indicate unacceptable time delays for design of instrumentation and custom software.
Japanese and German scanners are ultimately found to be unaffordable and/or unsuitable. Industry Partners indicate North American contacts and student conducts internet and telephonic communication with technical collaborators in the United States of America (USA) and New Zealand.

Student writes a third article based on prior Bachelors of Technology thesis for submission to an internationally accredited journal published by Elsevier, “The Foot”. This article is subsequently accepted and published in 2005. On-going meetings with Industry Partners are conducted at regular intervals.

**June 2004**

Investigation concluded with location of FastScan scanner technology from Polhemus USA and software customisation from Aclarus USA in conjunction with ARANZ in New Zealand. Successful financing is concluded by Industry Partner to cover cost of 3-D equipment and training, while awaiting response from THRIP. Investigation commenced into operator training dates in USA. Meetings conducted with Industry Partners in Johannesburg.

**July/August 2004**

Research student travels to USA, undergoes operator training on laser scanning equipment. Student acts as import agent and carries scanner back to SA as hand luggage, clearing customs formalities on behalf of Industry Partner. Mock-up and design of measurement stand (pyramid) is completed and specifications drawn up for costing and manufacture. Investigation into a number of impression materials for plantar weight bearing contour capture is conducted and concludes with defining of phenolic foam as best medium. Investigation is conducted into cost and supply of phenolic foam in South Africa. Negotiations conducted by student with Elro Braak Nelspruit/Pretoria for price and supply of phenolic foam at cost in consideration of non commercial research educational use.

**August/September 2004**

Student prepares and delivers PowerPoint presentation of expanded Research Project at TWR Research Day. Meetings conducted in Johannesburg with Industry Partner, Michelle Footwear. Student conducts ongoing testing of beta software versions 4.0.0.12 through 16
in Johannesburg in preparation for preliminary participant measurement in Durban at premises of one of the Industry Partners, Michelle Footwear.

Design is completed of custom step up platforms and local manufacture is undertaken. Student travels to various footwear industry contacts in Johannesburg and Pretoria to locate copies of out of print footwear related literature on manufacture and standards.

**October 2004**

Travel to Kwazulu-Natal. Successful single factor ANOVA intra-observer validity test conducted on 6 volunteers. Eight day field test of measurement method is conducted on 30 participants in Durban. Post processing of data from Durban testing is completed while testing a new version of software from ARANZ New Zealand.

Research student conducts recruitment of suitable data collection assistants (one is a qualified podiatrist and the other is qualified as a personal assistant, with experience in footwear fitting) Student prepares design and layout of posters for project; presents for approval. Software for post processing and importation into Microsoft Excel and macro calculations is completed. Official permission request process commenced at TWR in order to enable research student to recruit participants at other Higher Education Institutions and Nursing Colleges. Measurement step up platform (containing magnetic field transmitter) is smashed within its protective padded bag, clearly marked Fragile, while returning from Durban test trip on Kulula Airlines. Replacement step up platform ordered from manufacturer (Paradigm, Johannesburg).

**November 2004**

Three week delay awaiting replacement platform manufacture.

In the fourth week, student is required by Industry Partner to present project material to retail trade in Johannesburg and Cape Town over a period of four days. Student prepares Retail Day presentation on PowerPoint and coordinates purchase by Industry Partner of projector equipment for future presentations rather than paying hire fees charged by conference venues. Purchase is co-ordinated with TWR purchasing department contacts.

Dissertation writing continues.
December 2004
Data collection at TWR 7th floor (top floor) admin offices is set up but discontinued after three days of testing due to flaws and then looking for reasons for the scanning flaws. Reason is discovered to be excessive reflective metal in the vicinity, embedded in the building structure and roof.
Alternative data collection venue is located and moved to G03 Ground floor, Conference Centre, TWR and tested for suitability. Data collection at TWR continued until December 10th, while other institutions were canvassed for ground floor venue locations and permission to measure their personnel and students. Annual shut down on December 15th. Data collection at TWR G03 was booked for January 3rd to 12th, 2005.

January to March 2005
Technikon Witwatersrand merges with other universities and becomes University of Johannesburg over 6 campuses. Data collection continued at venues throughout University of Johannesburg campuses in Gauteng region.
Contact established with statistician on Kingsway campus to co-ordinate beginning of analysis of post processed data. Reporting process is to be completed for THRIP/NRF. Student relinquishes all part-time obligations to private practice in order to commence technology transfer for industry partners in terms of National Research Foundation requirements.

March 2005
Student relocates to Durban and finds accommodation. Student packs partial home contents and furniture for relocation to Natal, as well as packing books and practice contents for relocation to Industry Partner’s premises in Natal. Relocation brought about in terms of THRIP agreement on TIPTOP student placement for transfer of knowledge and technology process, pending a successful THRIP application for 2005 funding. TIPTOP placement commenced in July, 2005.
Preliminary meeting conducted with SABC Auckland Park regarding data collection potential but unable to test equipment for venue suitability as unit is still in repair.
April to June 2005
Student relocates to Natal for three year technology transfer period with Industry Partners. Once relocated, student returns for home visits to husband in Johannesburg during one week of each month in 2005. During the Johannesburg visits, statisticians at Statkon (Kingsway campus) consulted. Student prepares paper for presentation at SA Podiatry Association biennial conference in Cape Town, June 2005. Student is invited by international anthropometric community to attend WEAR (International Anthropometric Conference) in Pretoria, April 2005. Student collaborates with patent attorneys on Intellectual Property rights of method invention. Student presents paper on method invention at SA Foot Surgeons Congress in Johannesburg. Second round of meetings with SABC Auckland Park to arrange data collection and test scanner now repaired. Student begins employment process of technology transfer (podiatric input) at Industry Partner.

July to October 2005
Student represents UJ and Podiatry at Wellness Week at SABC TV Auckland Park. Final batches of data collection are conducted in Gauteng and Kwazulu Natal. Data analysis is ongoing, in collaboration with statistician. Commenced writing of results in dissertation. Continued technology transfer at Industry Partners on location in Natal.

November 2005
Data undergoes first analysis. Results and conclusions sections were commenced in dissertation. Preliminary conclusions drawn and presented to industry partner. Notification to be given that dissertation will be completed by November, 2006. Continue technology transfer at Industry Partners in Natal.

December 2005 to November 2006
Multiple visits to Johannesburg to UJHB to consult supervisors and Statkon. Full time application to employment, in-house training and continuation of transfer of technology at Industry Partner. Completion of dissertation work. Finalisation, proof reading and revisions of Masters dissertation. Submission of Masters dissertation to relevant University of Johannesburg authorities.
APPENDIX XV: VISUAL SEQUENCE FROM SCANS TO 3-D OBJECT

1. Dorsal surface
2. Plantar surface
3. “Clip” procedure for removing the overlap of dorsal and plantar surfaces

4 to 7. Rotation of 3-D objects to check for extraneous overlap

8 to 9. Positive scan “halves” fused into one 3-D object surface
APPENDIX XVI: RESEARCH POTENTIAL OF 3-D DATA

Figure 1: Example of 3-D foot data loaded into Rhino modelling program

Figure 2: Example of a shape and measurement that can be mined from 3-D data
APPENDIX XVII: EXAMPLE PREVIOUS AND NEW LAST BOTTOM PATTERNS

A: Previous size 4 pattern (right foot), with 8 degree in-flare geometry, pattern tread 78mm and heel seat width 54mm for former “average” foot.

B: New size 4 pattern (right foot), with 3 degree flare geometry, pattern tread 80mm and heel seat width 51mm for re-categorised “slender” foot group.

C. New size 4 pattern (right foot), with 3 degree flare geometry, pattern tread 84mm and pattern heel seat width 54mm for new “average” (wider) foot.

N.B. Pattern widths are not the same as last “stick” widths. The “stick” width of a last incorporates the additional 6mm to 12 mm of the “bulge” from seat to heel counter side wall, depending on style and construction.
APPENDIX XVIII: 3-D DATA RAPID PROTOTYPED BY 3-D RESIN PRINT

Figure 1: 3-D Foot Data Set

Figure 2: A “same size” 3-D print in resin of a 3-D data set
APPENDIX XIX: EXAMPLES OF 2-D VISUALS FOR INDUSTRY USE

<table>
<thead>
<tr>
<th>Grouping</th>
<th>Foot length</th>
<th>Overall length</th>
<th>Tread width</th>
<th>Tread Girth</th>
<th>Minor length</th>
<th>Need to ball length</th>
<th>Navicular height</th>
<th>Arch height</th>
</tr>
</thead>
<tbody>
<tr>
<td>PatsyF</td>
<td>250-255 mm</td>
<td>251 101 249 79 212 184 24 40 22</td>
<td>A  D  E  F  B  I  C  F  G</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DeniseF</td>
<td>254 104 244 72 215 186 24 46 27</td>
<td>250-255 mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JudalM</td>
<td>255 103 243 69 209 180 23 33 29</td>
<td>foot length</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dorsal view of a low arched foot

Dorsal view of a high arched foot

Medial view of a large instep girth

Medial view of a regular instep girth
APPENDIX XX:

DEVELOPMENT AND PRODUCTION OF NEW FOOT BED DESIGN

Figure 1: *Soul of Africa* sandal incorporating transfer of technology features such as heel cupping and plantar contours
APPENDIX XXI: DEVELOPMENT OF NEW VARIABLE FIT SHOE

Froggie Freedom Fit...

*because we understand that not all feet are equal.*

The size and shape of your foot can change as you age, lose or gain weight, exercise, become pregnant or enter menopause.

The secret to Froggie Freedom Fit is choice – you can now choose from a standard fit footbed for regular to narrow feet, or the optional wider fit footbed.

The inner footbeds are easily removable and interchangeable, to respond to your individual needs.

Froggie Freedom Fit footbeds have been designed and contoured according to research on South African women’s feet to provide mid foot support and gentle massage as you walk. The footbed material is a South African technological breakthrough, designed to pamper and cushion your every step.

Froggie Freedom Fit…

*one shoe, twice the comfort and twice the fit.*

(See advertising mock up on page 212)
The shoe that always fits...

Finally - a shoe that can be adapted to the changing needs of your feet.

The size and shape of your foot can change as you age, lose or gain weight, exercise, become pregnant or enter menopause.

The secret to Froggie FreedomFit is choice - you can now choose from a standard footbed for a regular to narrow foot or a wider footbed for broader feet.

Froggie FreedomFit footbeds have been designed and contoured according to research on South African women's feet to provide mid foot support and gentle massage as you walk.

The inner footbeds are easily removable and interchangeable to respond to your individual needs.

The footbed material is a South African technological breakthrough, designed to pamper and cushion your step.

Because at Froggie we understand that not all feet are created equal!

Made by South Africans for South Africans

Gauteng: (011) 887-1713, 8226; (031) 490-0260
Cape: (021) 685-1707

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APPENDIX XXII: PATENT 2006/04167

REPUBLIC OF SOUTH AFRICA
PATENTS ACT, 1978

APPLICATION FOR A PATENT AND ACKNOWLEDGEMENT OF RECEIPT
(Section 30(1) – Regulation 22)
The grant of a patent is hereby requested by the undersigned applicant
On the basis of the present application filed in duplicate.

OFFICIAL APPLICATION NO
21 01 2006/04167

FULL NAME(S) OF APPLICANT(S)

71 UNIVERSITY OF JOHANNESBURG

ADDRESS(ES) OF APPLICANT(S)

Cnr. Kingsway and University Roads, Auckland Park, Johannesburg, 2006, South Africa

TITLE OF INVENTION

54 ANTHROPOMETRY APPARATUS METHOD AND SYSTEM

x THE APPLICANT CLAIMS PRIORITY AS SET OUT ON THE ACCOMPANYING FORM P2
The earliest priority claimed is 2005/03624 dated 12 May 2005 in South Africa

x THIS APPLICATION IS FOR A PATENT OF ADDITION TO PATENT APPLICATION NO.
21 01

x THIS APPLICATION IS FRESH APPLICATION IN TERMS OF SECTION 37 AND BASED ON APPLICATION NO.
21 01

x THIS APPLICATION IS ACCOMPANIED BY:
1a A single copy of a provisional specification of pages.
1b Two copies of a complete specification of 11 pages.
1c P2 – Register Page
2x Informal drawings of sheets.
2b Formal drawings of 4 sheets.
3 Publication particulars and abstract (form P8 in duplicate).
4 A copy of figure 1 of the drawings for the abstract.
5 Assignment of Invention (from the inventors) or other evidence of title.
8 Certified priority document(s).
7 Translation of priority document(s).
8 Assignment of priority rights.
9 A copy of form P2 and a specification of S.A. Patent Application
21 01 2006/03624
10 A declaration and power of attorney on form P3.
11 Request for anti-dating on form P4.
12 Request for classification on form P6.
13a Request for delay of acceptance on form P4
12b Form P4

DATED: 24 May 2006

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Cnr. Kingsway and University Roads, Auckland Park, Johannesburg, 2006, South Africa
APPLICANT FOR A PATENT AND ACKNOWLEDGEMENT OF RECEIPT
(Section 30(1) – Regulation 22)
The grant of a patent is hereby requested by the undersigned applicant
On the basis of the present application filed in duplicate.

OFFICIAL APPLICATION NO
21 01

AGENT'S REFERENCE
P310642ACO

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TITLE OF INVENTION
54 ANTHROPOMETRY APPARATUS METHOD AND SYSTEM

THE APPLICANT CLAIMS PRIORITY AS SET OUT ON THE ACCOMPANYING FORM P2
The earliest priority claimed is 2005/03624 dated 12 May 2005 in South Africa

THIS APPLICATION IS FOR A PATENT OF
ADDITION TO PATENT APPLICATION NO.
21 01

THIS APPLICATION IS FRESH APPLICATION IN TERMS OF SECTION 37 AND BASED ON APPLICATION NO.
21 01

Dated: 24 May 2006

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ASSIGNMENT OF INVENTION

WHEREAS I/we THOMPSON, Anette Leonor Telmo

am/are the inventor(s) of an invention entitled

ANTHROPOMETRY APPARATUS METHOD AND SYSTEM

AND WHEREAS UNIVERSITY OF JOHANNESBURG

of

UNIVERSITY OF JOHANNESBURG
Cnr. Kingsway and University Roads, Auckland Park, Johannesburg
2006
South Africa

has/have acquired the said invention from me/us for all countries.

NOW THEREFORE this Deed witnesses that I/we have assigned the said invention to

UNIVERSITY OF JOHANNESBURG

its successors, assigns or legal representatives, for all countries, together with the right to apply for Letters Patent in respect thereof in his/their own name, the assignment taking effect on or before 12 May 2005

I/we agree that when requested, I/we will without charge to the assignee, but at its expense sign all papers, take all rightful oaths, and do all acts which may be necessary, desirable or convenient for securing and maintaining patents for said invention in any and all countries and for vesting title thereto in said assignee, its successor, assigns, or legal representative.

DATE

18 April 2006

THOMPSON, Anette Leonor Telmo

SIGNATURE

No legalisation necessary
# Republic of South Africa

## Patents Act, 1978

### Complete Specification

*Section 30(1) – Regulation 28*

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**International Classification**

61

**Full Name(s) of Applicant(s)**

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**Title of Invention**

54 ANTHROPOMETRY APPARATUS METHOD AND SYSTEM
ANTHROPOMETRY APPARATUS, METHOD AND SYSTEM

FIELD OF THE INVENTION

This invention relates to an anthropometry apparatus, system and method, and more particularly to a foot anthropometry apparatus, system and method.

BACKGROUND TO THE INVENTION

Footwear is manufactured from lasts. Lasts are foot forms or moulds based on certain measurements of the feet for which footwear is intended.

It is important that footwear fits properly to ensure physical comfort or performance as well as psychological well-being. Ill-fitting footwear can cause poor foot function particularly of the forefoot and digits and can cause digital deformities, dermatopathologies, hallux valgus and bunions.

High heels of women's shoes exacerbate the problem of obtaining proper foot function and makes it even more important to properly measure the feet, especially in load bearing state and at different heel heights.

Foot measurement studies have been conducted for men in the armed forces and the mining industry. There are very little, or no, comprehensive foot measurement studies for women.

Foot morphology differs between ethnic groups. In many countries or regions where shoes are imported, the shoes are not suited for the local population. Women's lasts in South Africa are based on outdated colonial measurements, which are not applicable to the majority of the South African population.

It was reported at the South African P... A...[Note: Anette, please provide full name] (SAPA) congress, in 2003, that 80% of South African women suffer foot pathology due to ill-fitting footwear.

It is clear that it is important to properly model the feet of different ethnic groups and, if possible, make shoes specific to ethnic group average morphology. It would of
course be ideal but maybe too costly and time consuming, to make shoes accordingly to each individual's foot morphology.

It is important to properly model the plantar surface of the foot to implement findings of pressure studies. This may show what metatarsal cushioning is needed to dissipate impact shock.

Traditional anthropometric methods include advantages and disadvantages. [Note: Anette, what are the names of the instruments shown in the presentation. There are 4 instruments. The one instrument seems to be a vernier]. They are portable and provide linear dimensions but do not measure curvature or volume.

For footwear to correspond to the foot one would need to have a model representing the volume, curvature and linear dimensions of the foot. Not only of a non-elevated foot, but also of a foot at heel heights between 35mm and 60mm above the horizontal.

“Shape tape” have been used to obtain a three dimensional (3-D) image of a foot. Shape tape includes paired loops of optical fibres that dissipate light proportional to bending. The output signals from a array is used to construct real-time 3-D image on a computer screen. The problem with a shape tape image is that it is of insufficient definition and accuracy.

Manual digitisers have also been used. Manual digitiser includes a mechanical arm with a sensor at the free end of the arm. The arm includes hingable sections so that it can be moved in any direction in a 3-D space. The sensor is used to record 3-D co-ordinates. Thus, by moving the sensor over an object and recording co-ordinates, a 3-D representation of the object can be obtained. This type of measurement may work well to obtain a 3-D representation of a foot but it would not be convenient to obtain a representation of the foot under load. The movement of the sensor over sensitive skin is also undesirable.

Optical digitizers that uses the silhouette of an object to construct a 3-D representation of the object are also not accurate enough and are limited to a specific focal length.
Laser scanners deflect a laser beam from a mirror onto scanning object. The object scatters the light which is then collected by a camera. Triangulation techniques are used to construct a representation of the object. It may be difficult to scan an object under load without scanning the load-bearing surface.

The Civilian American & European Surface Anthropometry Resource [Note: Anette, who runs and/or funds this project?] (Ceaser), project uses a non-portable laser scanner to scan the whole body of a human being. The definition of the 3-D image generated by this scanner is not sufficient to use it in the manufacture of footwear. The use of this scanner also does not provide data on the curvature or topology of the plantar surface of the foot, under load, or otherwise.

Laser scanning with a person's foot over glass may provide a 3-D representation of the foot including the plantar surface of the foot under load. The load bearing surface is however flat and hard and may not provide an accurate representation of the deformation of the foot, on softer surfaces, to indicate morphology such as when cushioning is used in a shoe.

OBJECT OF THE INVENTION

It is an object of this invention to provide an anthropometry apparatus, method and system that, at least partially, alleviates some of the abovementioned difficulties.

SUMMARY OF THE INVENTION

An anthropometry apparatus comprising

- a deformable substance for, in use, receiving at least part of the plantar surface of the foot of the human body to cause an impression of the at least part of the foot in the substance;
- a support for supporting at least part of the leg of the human body to make the impression in the deformable substance.

The deformable substance is located in a tray.

The tray is supported on a spacing column so that, in use, the leg of the foot of a person being used to make the impression, is bent.
A further feature of the invention provides for the support to be attached to a support frame.

A still further feature of the invention provides for the deformable substance to be permanently deformable.

There is provided for the deformable substance to be a permanently deformable foam.

The foam may be phenolic foam.

A yet further feature of the invention provides for the apparatus to include a laser scanner for scanning an exposed surface of the foot whilst the plantar surface of the foot is pressed into the deformable substance.

The laser scanner is also used to scan the impression of the foot in the deformable substance, once the foot has been removed from the deformable substance.

This invention extends to a method of anthropometry comprising the steps of:
- pushing a foot of the human body into a permanently deformable substance thus causing an impression of the plantar surface of the foot in the substance;
- scanning, in three dimensions, the exposed surface of the foot not in the deformable substance, with the laser scanner;
- removing the foot from the deformable substance and scanning, in three dimensions, the impression of the plantar surface of the foot in the deformable substance with the laser scanner;
- creating an image of the foot from the scanned data by inverting the scanned data of the impression to merge it with the scanned data of the exposed surface of the foot.

The method includes pushing the foot into the deformable substance such that sides of the foot form a right angle with the substance at the line where the foot exists the substance.
The method further includes maintaining the leg of the foot used to make the impression, bent, such that the lower leg is substantially normal to an upper surface of the deformable substance.

This invention further extends to an anthropometry system comprising:

- a support for supporting a leg of a human body when a corresponding foot is pressed into a deformable substance;
- a laser for scanning, in three dimension, part of the foot exposed from the substance and for scanning the impression made in the substance by the foot after the foot has been removed from the substance;
- a computer for receiving data of scanning from the scanner; and
- computing means for generating a three dimensional image from the scanned data by merging the data received from the scanner of the exposed part of the foot with inverted data of the scanning of the impression made by the foot in the deformable substance.

BRIEF DESCRIPTION OF THE DRAWINGS

One embodiment of the invention is described below, by way of example only, and with reference to the accompanying drawings in which:

Figure 1 shows a front perspective view of an anthropometry apparatus

Figure 2 shows a close-up rear perspective view of the anthropometry apparatus of figure 1;

Figure 3 shows a perspective view of a deformable material in a tray located on a spacing column of the anthropometry apparatus; and

Figure 4 show an impression of a plantar surface of a foot made in the deformable material of the anthropometry apparatus.

DETAILED DESCRIPTION OF THE DRAWINGS

With reference to the drawings, in which like numerals indicate like features, an anthropometry apparatus is generally indicated by the reference number 1.
The apparatus consists of a pyramidal frame 2 made of three support pipes and a triangular base structure 9, made of three more pipes. The pipes that make up the base structure 9 lie flat on the floor and are secured end to end to form a triangle for supporting the pipes of the pyramidal structure of the frame 2, at its corners.

A support arm 8 extends from one of the pipes of the frame 2 and terminates in close proximity to a center of the pyramidal structure. The pipes of the frame 2 are secured together at an apex 7 of the pyramidal structure.

A spacer 4 and a spacing column 5 is supporting on a base platform 3. A tray having a deformable material 13 therein is supported on top of the spacing column 5. The tray is supported on the spacing column 5 such that the deformable material 13 in the tray is at a higher level than an upper surface of the spacer 4.

A laser scanner 12 is connected to a computer (not shown), as is known in the art.

The support arm 8 includes straps for receiving a lower leg of a human body therein, to support the leg.

In use, a person (patient) 6 places his one foot on the spacer platform 4 and its foot to be scanned on the deformable substance 13. The foot to be scanned is pressed into the deformable substance by the person 6 or on by an operator 11 applying downward pressure to the leg or the foot, or by placing a weight on the knee or leg of the patient 6. Pressure should be applied such that the sides of the foot protruding from the deformable material form right angle with the upper surface of the deformable material. The patient can also hold on to the poles of the frame for support.

The operator now ensures that the lower leg of the patient is properly secured with the straps with the support arm 8, so that no movement of the foot occurs during scanning.

The operator now scans the exposed part of the foot using the laser scanner, as is known in the art. The foot is removed from the deformable substance, in this case a slab of phenolic foam, and the impression made by the plantar surface of the foot is scanned using the laser scanner.
The data of the scanned exposed surface of the foot is now merged with the scanned impression of the plantar surface of the foot in the phenolic foam by first inverting the scanned data of the impression relative to the scanned data of the exposed surface of the foot, and merging the data to generate a 3-D image of the foot.

In the manner described above, a 3-D image of the foot under load is obtained. The impression shows and impression of the foot under load, not on a flat hard surface but in a deformable surface, such that proper cushioning of the foot under load can be derived therefrom [Note: Annette, can you please expand on this?]. The impression of the foot can now be used to make a last for making footwear.

It is envisaged that the apparatus, system and method described above will be convenient and relatively inexpensive to use. The apparatus is also portable in that the support frame is collapsible and made of hollow lightweight pipes.

The invention is not limited to the precise details as described above. For example, any shape or form of support structure may be used to support the leg of a person when the foot is pressed into the deformable material. The deformable material may be any other permanently deformable material instead of phenolic foam. The deformable material may be a re-useable deformable material.
1. An anthropometry apparatus comprising
   - a deformable substance for, in use, receiving at least part of the
     plantar surface of the foot of the human body to cause an impression
     of the at least part of the foot in the substance;
   - a support for supporting at least part of the leg of the human body to
     make the impression in the deformable substance.

2. An anthropometry apparatus as claimed in claim 1 in which the deformable
   substance is located in a tray.

3. An anthropometry apparatus as claimed in claim 2 in which the tray is
   supported on a spacing column so that, in use, the leg of the foot of a person
   being used to make the impression, is bent.

4. An anthropometry apparatus as claimed in any one of the preceding claims in
   which the support is attached to a support frame.

5. An anthropometry apparatus as claimed in any one of the preceding claims in
   which the deformable substance to be permanently deformable.

6. An anthropometry apparatus as claimed in claim 5 in which the deformable
   substance is a permanently deformable foam.

7. An anthropometry apparatus as claimed in claim 6 in which the foam is
   phenolic foam.

8. An anthropometry apparatus as claimed in any one of the preceding claims in
   which the apparatus includes a laser scanner for scanning an exposed
   surface of the foot whilst the plantar surface of the foot is pressed into the
   deformable substance.

9. An anthropometry apparatus as claimed in claim 8 in which the laser scanner
   is used to scan the impression of the foot in the deformable substance, once
   the foot has been removed from the deformable substance.
10. A method of anthropometry comprising the steps of:
   - pushing a foot of the human body into a permanently deformable
     substance thus causing an impression of the plantar surface of the
     foot in the substance;
   - scanning, in three dimensions, the exposed surface of the foot not in
     the deformable substance, with the laser scanner;
   - removing the foot from the deformable substance and scanning, in
     three dimensions, the impression of the plantar surface of the foot in
     the deformable substance with the laser scanner;
   - creating an image of the foot from the scanned data by inverting the
     scanned data of the impression to merge it with the scanned data of
     the exposed surface of the foot.

11. The method as claimed in claim 10 further including the step of pushing the
    foot into the deformable substance such that sides of the foot form a right
    angle with the substance at the line where the foot exits the substance.

12. The method of any of claims 10 and 11 further including the step of
    maintaining the leg of the foot used to make the impression, bent, such that
    the lower leg is substantially normal to an upper surface of the deformable
    substance.

13. An anthropometry system comprising:

    - a support for supporting a leg of a human body when a corresponding
      foot is pressed into a deformable substance;
    - a laser for scanning, in three dimension, part of the foot exposed from
      the substance and for scanning the impression made in the
      substance by the foot after the foot has been removed from the
      substance;
    - a computer for receiving data of scanning from the scanner; and
    - computing means for generating a three dimensional image from the
      scanned data by merging the data received from the scanner of the
      exposed part of the foot with inverted data of the scanning of the
      impression made by the foot in the deformable substance.
14. An anthropometry apparatus substantially as herein described with reference to and as illustrated in the accompanying drawings.

15. A method of anthropometry substantially as herein described with reference to and as illustrated in the accompanying drawings.

16. An anthropometry system substantially as herein described with reference to and as illustrated in the accompanying drawings.

Dated this 24th day of May 2006.

MARIUS LE ROUX

Patent Attorney / Agent for the Applicant