

# DigTrace Pro

## *User Manual V1.1*

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[www.digtrace.co.uk](http://www.digtrace.co.uk)



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# 1.0 Introduction

**DigTrace** is an integrated software solution for the capture and analysis of 3D data whether in a forensic context (footwear evidence) or in the study of vertebrate tracks and footprints. It caters for everything from the study of dinosaur footprints to the analysis of footwear evidence at a crime scene.

Developed from a decade of research at Bournemouth University on fossil footprints, the freeware provides a bespoke solution to the analysis of such evidence. The project was funded by a Natural Environment Research Council (NERC) Innovation Grant (NE/M021459/1) with project partners from the UK's National Crime Agency, Home Office Centre for Applied Science and Technology and Liverpool John Moores University.

Three workbenches – create, measure and compare – allow you to *create* 3D models via photogrammetry, visualise those models and make a range of *measurements*, before computing mean tracks and/or *comparing* directly individual tracks or track populations (Fig. 1).

There are two versions of the freeware currently available an academic version (DigTrace Academic) that is aimed at the study of vertebrate tracks and a version designed specifically for forensic use (DigTrace Pro). Currently both versions have the same functionality and one manual serves both.

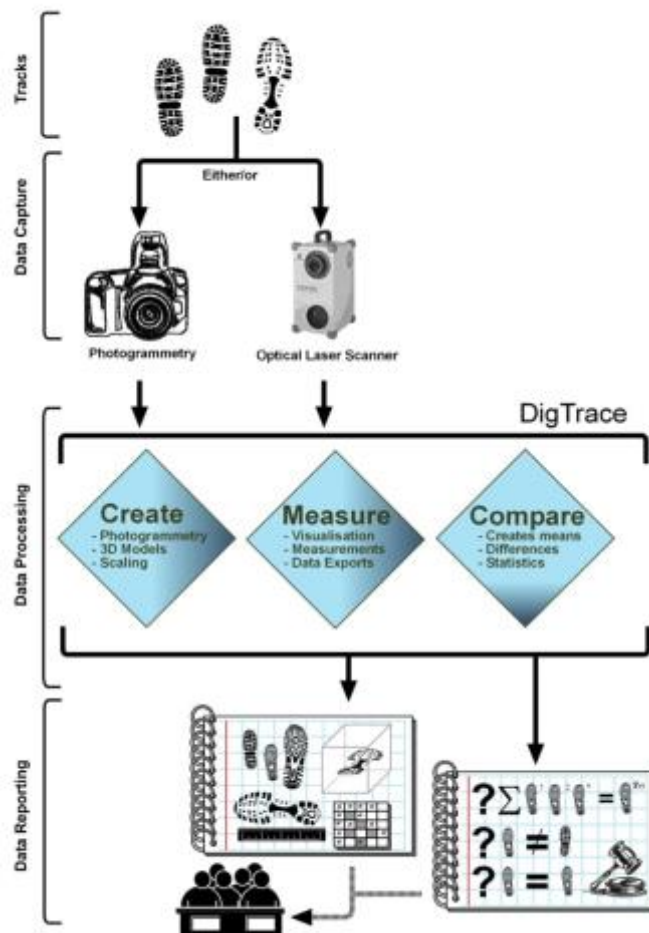


Figure 1: Generalised workflow for DigTrace showing the three workbenches and the relationship of one to the other

Term	Definition
Track	A single footprint or partial impression made by a foot, hand or other object of interest.
Trackway	A series of tracks made by the same individual.
Track-maker	The individual that made the track.
Tracked surface	The surface on which the track-maker(s) walked and moved. This may contain the traces of one or more individual and the temporal sequence maybe apparent from the cross-cutting pattern of tracks.
Track cast	A mould of a track formed by infilling of a track with plaster or some other material forming a negative replica.
Displacement rim	A marginal rim around a track formed by the displacement of sediment, sometimes referred to as a 'push-up' structure.
Track ejecta	Material ejected by the removal of the track-maker's foot from a track; material may be thrown either in a proximal (rear) or distal (forward) direction.
Track topology	The geometrical properties and spatial relations of a deformed surface, in this case deformed by the track-maker (i.e. the surface morphology of a track).
Orthogonal plane	The plane at right angles to the track or tracked surface (i.e., viewed vertically from above).
Point cloud	A mass of points each with a three dimensional coordinate (i.e., x, y and z values).
Colour ramp	The gradation of colours used to differentiate low from high areas.

Table 1: Common definitions used in this manual.

## 2.0 Applications to Forensic Footwear

Footwear impressions provide an important source of evidence within a range of criminal investigations. For example, they may place a suspect's footwear at a crime scene or link multiple crime scenes with the same footwear marks. As set out in the UK's police footwear guidance there is a role both as evidence and in the gathering of criminal intelligence (Fig. 1; Appendix I).

The distinction is made here between cases where footwear has tracked fluid of some description (e.g., mud, blood etc.) around a scene leaving two-dimensional traces and three-dimensional traces left in a soft compliant substrate (e.g. grass verge, flowerbed, footpath etc.). Despite rapid advances in other areas of forensic science the technology used to capture and analyse *three-dimensional* traces has not changed in recent years and they are usually cast in plaster, photographed and compared visually. Three-dimensional imaging now offers a superior approach and DigTrace is bespoke software for this task.

There are simply two requirements to the deployment of DigTrace: (1) that a crime scene officer takes an additional series of digital photographs of a footmark or target area of interest: and (2) that a police force or user has a PC able to run DigTrace (see Section 3.0). Figure 2 shows a modified guidance chart with the contributions of DigTrace identified at the appropriate stage. This is developed more fully in Appendix II.

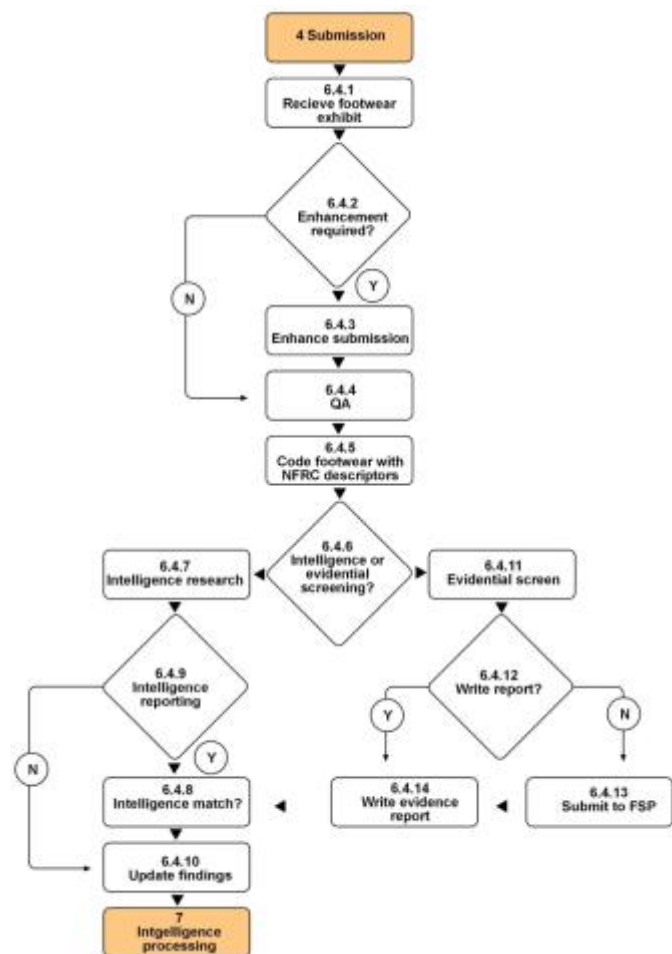


Figure 1: Process map for dealing with footwear evidence in the UK based on National Policing Improvement Agency guidelines 2007. See Appendix I for detailed description of each stage

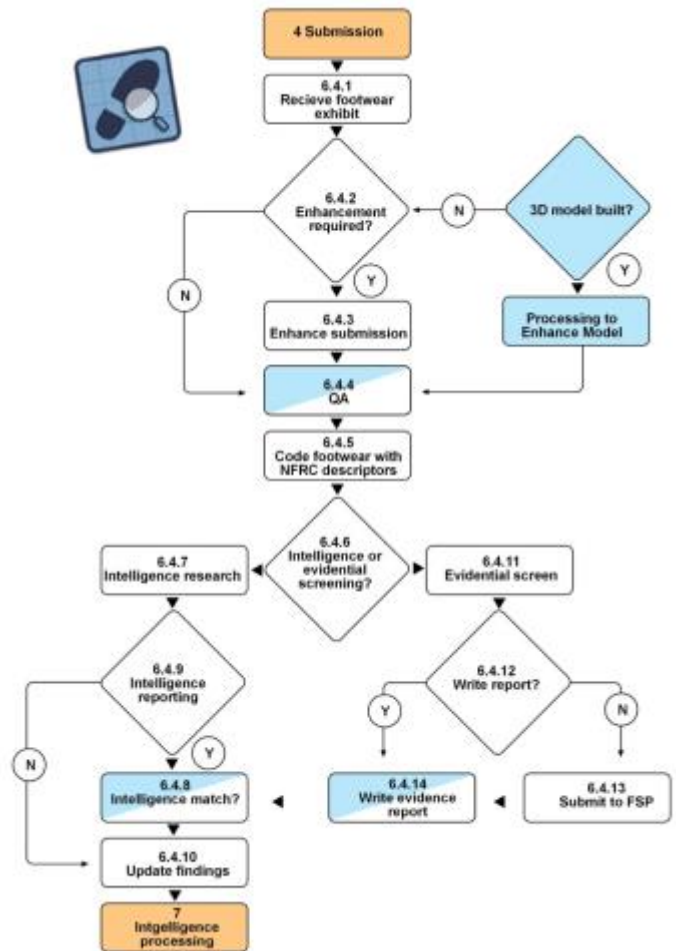


Figure 2: Process map for dealing with footwear evidence in the UK based on National Policing Improvement Agency guidelines 2007 modified to include the use of DigTrace. See Appendix II for detailed description of each stage.

DigTrace allows the forensic user to:

- Create a 3D model of a footwear mark from oblique digital photographs taken with a conventional digital camera.
- Models may be of specific exhibits of interest or of larger areas to help contextualise multiple traces.
- Models can also be made of the soles of a suspect's shoe for comparison purposes.

- It allows you to visualise a 3D model in different ways and to output views as image files for use in reports.
- It allows the investigating officer to study the cross-cutting relationship of one track to the next in order to support a reconstruction of events or actions.
- It allows the investigating officer to make accurate measurements from a 3D trace.
- It allows multiple traces to be registered with each other and compared so that difference can be noted.
- It allows a 3D model of a suspect's shoe to be compared to a trace.
- It allows an average trace to be created from multiple examples, for example from multiple tracks in a trackway along a path.
- It allows the investigating officer to return to the evidence (effectively the crime scene) repeatedly as a case evolves.

Not all footwear evidence demands or will benefit from taking a 3D approach. We have already identified the distinction between 2D and 3D traces. Figure 3 provides a simple decision tree to help a crime scene officer decide whether to adopt a 3D approach and to how to focus their recording strategy accordingly.

This evaluation starts with assessing the advantages and disadvantage of the approach. The first key issue is whether the traces have enough 3D relief to register in a model. It is worth noting however that sometimes a 2D trace can be draped over a 3D surface and therefore creating a model can still be of value in reporting the 2D trace. Typically, however, we are looking for relief greater than 0.25 mm.

The second question is whether the photogrammetry process will work effectively. Digital photogrammetry is based on pixel recognition across a range of pictures. If the surface tone/colour is very uniform the process can sometimes fail. Overhanging vegetation immediately above a track can cause problems in processing files by introducing floating points above the surface. It is best where possible to gently hold such vegetation out of the way. Pooled water in a track or lots of reflection from damp soil in bright sunlight can also pose a challenge. These are the types of factor that need to be considered (Fig. 3). It is also important to note that a 3D model can be made in the lab from a cast or of a suspect's shoe sole; simply upturn the shoe and mount it on a cobbler's last.

Figure 3 also reviews the different things that a 3D approach can be used for. For example, one can target a specific track in which the model is framed by this track or the fragment of particular interest. Alternatively the purpose of the model may be to capture the relationship of one or more tracks more generally. In this case the areas covered may be larger and the resolution of each

track less but the gain in terms of site context and in determining the relationship of one track to the next may be considerable.

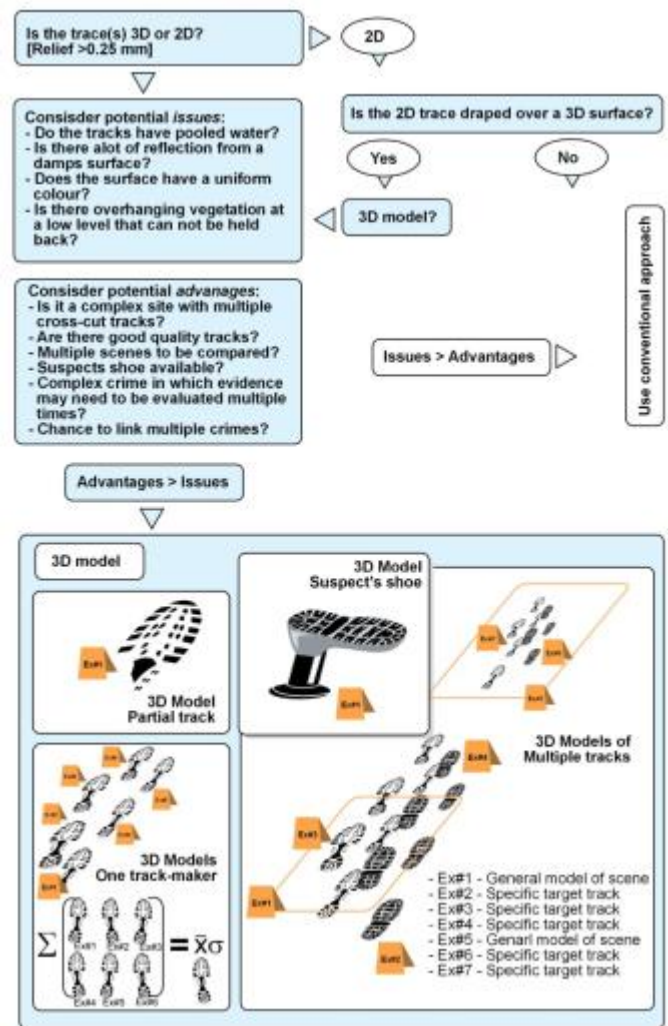


Figure 3: Decision tree for deciding whether a 3D model can be made and is worth the extra effort. The bottom panel shows four basic types of analysis from the large multiple track scenes on the right to the partial fragment on the right.

If in doubt it is worth collecting the additional images for 3D modelling. It can be done quickly (see Section 5.0) and if the data is not used nothing is actually lost. We always recommend that good quality vertical images are taken as per standard collecting procedures as well as the additional oblique images.

# 3.0 Installation and Licensing

DigTrace was developed in Python and has been packaged into a Windows executable file, together with required 3<sup>rd</sup> party libraries.

The current release requires the following to run smoothly:

- OS: Windows 7 64-bit or newer
- RAM: 8GB (minimum), 16GB (recommended)
- CPU: Dual-core (minimum), Quad-core (recommended)
- HDD: 1GB of free space to install the software + 1GB of free space per each 3D model

To install the software, follow these instructions:

Step One: Select the appropriate version and download to your computer or external hard drive.

Step Two: Decompress the zipped folder and look for the



DigTrace icon it should have an 'exe' file extension. Double click on this file and the programme should load.

Step Three: Pin the icon to your toolbar or create a desktop shortcut.

DigTrace should load irrespective of the operating system you are running. However it does require **Visual C Runtime Environment (VCRE)** and the default may vary with the operating system you have installed. If you experience problems running the software then make sure that the 64-bit version (vcredist\_x64.exe) of VCRE 2008 as well as 64-bit version (vcredist\_x64.exe) of VCRE 2015 are installed. You can download the files by following the links below:

VCRE 2008: <https://www.microsoft.com/en-gb/download/details.aspx?id=15336>

VCRE 2015: <https://www.microsoft.com/en-gb/download/details.aspx?id=48145>

If you have problems with installation please contact us directly. We are also keen to hear from users both with feedback and suggestions for future functionality and development.

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## *Licensing, credits and note to developers*

The software is distributed as freeware and the source code will be available at <https://github.com/> soon. We ask potential developers to contact us directly so that we can include additional functionality in future updates.

Please read the licensing details ([www.digtrace.co.uk](http://www.digtrace.co.uk)) available on the website and in Appendix III and the user is deemed to accept the terms and conditions of this licence by either downloading and/or using a copy of the software.

The software should be acknowledged as follows:

Budka, M. Bakirov, R., Deng, S., Falkingham, P., Reynolds, S.C., Bennett, M.R. (2016). DigTrace Pro [Computer Software]. Bournemouth University. Version 1.0.

We also openly acknowledge use of the following open source libraries:

(1) OpenMVG (<http://openmvg.readthedocs.io/>); and (2) PMVS/CMVS for dense cloud generation (<http://www.di.ens.fr/cmvs/>).

Monasse, P., Marlet, R. (2012). Adaptive structure from motion with a contrario model estimation [Incremental SfM, Computer Software]. In ACCV, 2012.

Moulon, P., Monasse, P., Marlet, R. (2013). Global Fusion of Relative Motions for Robust, Accurate and Scalable Structure from Motion. [Global SfM, Computer Software]. In ICCV, 2013.

Furukawa, Y., Ponce, P. (2010). Accurate, dense, and robust multi-view stereopsis. IEEE Trans. on Pattern Analysis and Machine Intelligence, 32(8):1362-1376, 2010

## 4.0 Create Workbench

In the Create Workbench you can produce 3D models from a series of oblique digital photographs using photogrammetry. The generic workflow is shown in Figure 3. This process involves the recognition of pixels in different photographs and the computation of their location in three dimensional space. A minimum relief of between 0.5 and 1 mm is typically required. The software can cope with data over various length-scales from submillimetre to several metres. The process creates a point cloud in which each point has x and y coordinates with a z value equivalent to elevation relative to an arbitrary datum. The model created is unscaled and must be scaled before any measurements or comparisons can be made, therefore the inclusion of a scale alongside the subject is essential.

This part of the software is based on the open source code called openMVG one of the leading photogrammetry solutions. More details if required can be found at: <http://openmvg.readthedocs.io/en/latest>. The user interface here is however specific to DigTrace.

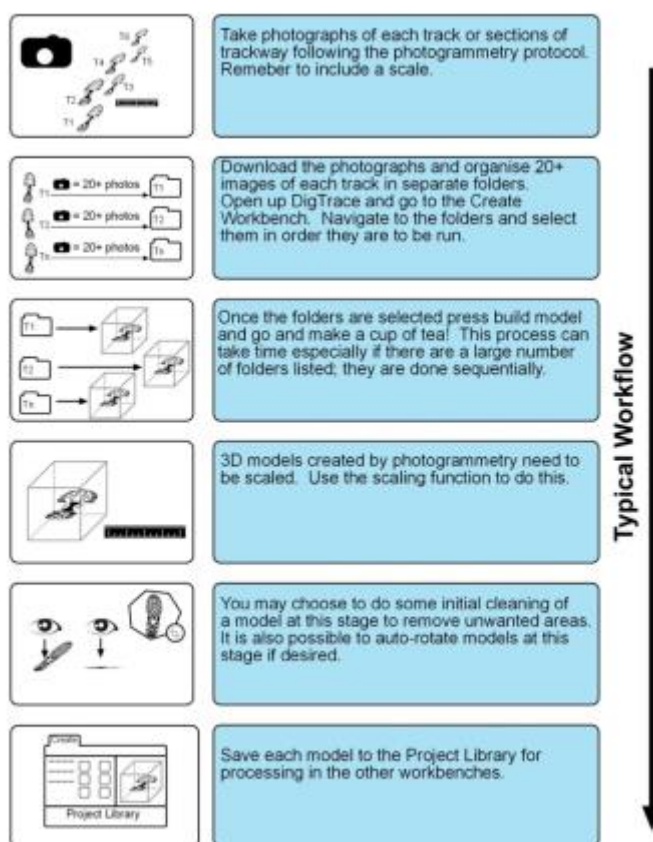


Figure 3: Generic workflow within the Create Workbench

We recommend that the user needs to pay particular attention to file naming and the systematic collection of data (Fig. 4; see Section 7.0). Typical field steps are as follows.

**Step One: Evaluation and planning.** Review the data present and decide on which tracks (or marks) need to be recorded. Ensure the overall scene is well documented via notes and photographs. You can make 3D models at various scales. For example, you might decide to create a single model (or series of models) of a section(s) of trampled ground capturing several individual tracks and trackways. This could be an area of up to several metres in length and width (Fig. 4). The model created, however, will show the relationship of one track to the next, but will not necessarily have sufficient resolution to explore the detail in each track. You may wish therefore to make additional detailed models of specific tracks. The order in which you take the photographs may often be determined by your ability to record it without destroying the evidence, for example by your own feet. Recording a large area first and then focusing in on individual tracks is the normal sequence of events and some initial planning can really help get the sequence correct.

**Step Two: Taking the photographs.** Your aim is to take approximately 20 photographs of the area of interest from different angles. Start by mentally defining the extent of the required model; the area of interest should ideally be at the centre of this model. You may wish to restrain over hanging leaves or branches. Place a scale of on the ground close to the focal object. This scale should ideally be flat and have the measurements to the absolute edge, however any form of ruler will work. Now take four to five overview photographs of the area of interest. Each of these should be from a distance such that the whole area of interest is within the frame, but taken from different angles. Ideally, this will be one top-down image and one from each side at  $\sim 45^\circ$  as shown in Figure 5A. Having taken the overview pictures you now need to take some closer photographs ( $\sim 15$  to 20) to capture the detail. If there are no significant overhanging areas in the footprint, these photos can be taken perpendicular to the ground, in an overlapping series forming a grid. Start at one corner, with the footprint barely in frame, and work sequentially along the length of the footprint. At least three rows will be required, such that photographs in the centre row have the footprint's width fill the image. Side rows overlap with the central

row. Each image needs to overlap with the image before and after by  $\sim 2/3$  as shown in Figure 5B. In this way you will end up with a total of between 20 and 30 photographs for each model. Less will work, but could reduce quality of final data. More will work, and potentially capture more detail in the model, but will significantly increase processing time. Each photograph needs to overlap by about  $2/3$  with 2 other photos (see above). As a rule of thumb, the aim is to take photographs with enough overlap that a human can quickly and easily identify how they relate to each other without seeing the object themselves. Include additional area around the area of interest, as quality will be reduced at the edges of the modelled area. Footprints with water pooling in the base may prove problematic as reflections may change with point of view and cause failure when generating a model.

Overhanging areas may need photographs taken from low angles. Take photos according to the above instructions, and then supplement these with additional photographs taken at a low angle. Repeat the exercise for each model you wish to build.

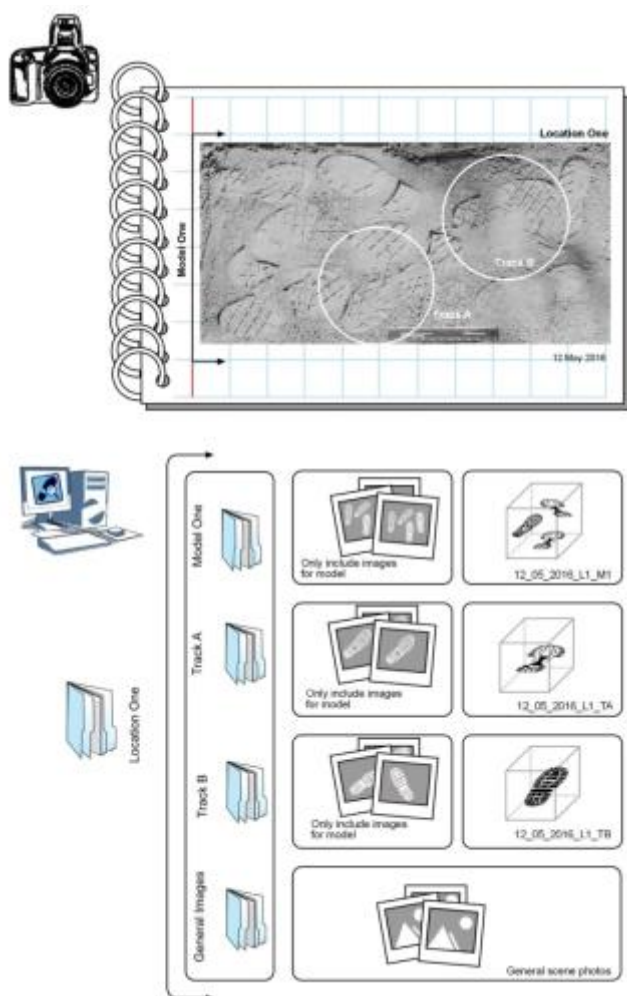


Figure 4: The importance of organising your notes and photographs ready for use within DigTrace.

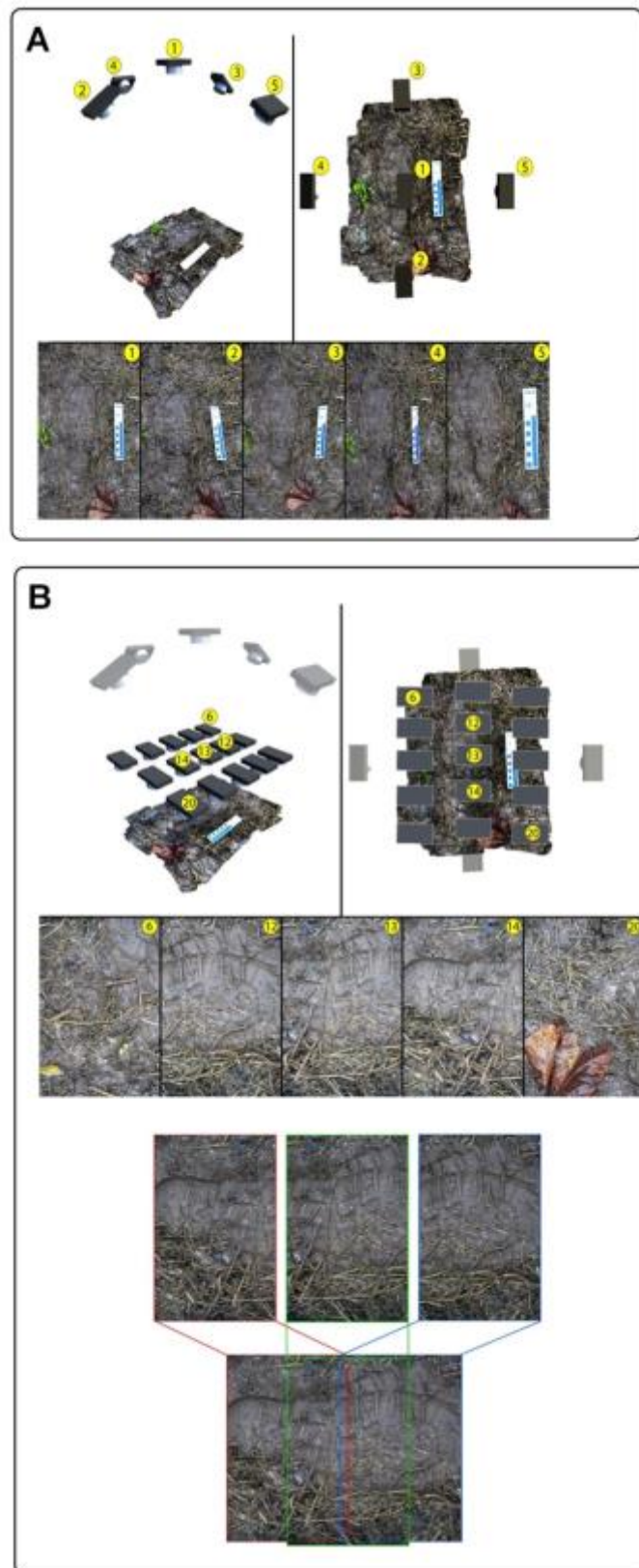



Figure 5: Sequence of oblique photographs required to produce a three dimensional model. [Images courtesy of Peter Falkingham].

**Step Three: Organise the photographs.** When you return from the field you need to download the photographs and organise them carefully. Place the photographs for each model in a separate directory and use logical and consistent file names for the directories. It is good practice to include the date and location details in the directory name. There is no need to re-name the photographs themselves. Don't place or leave any additional photographs in these folders, for example general shots of the scene; only include those needed to build the model. Remove any other non-photograph files and store them separately at this stage. Figure 4 tries to illustrate the directory set up and this subject is discussed further in Section 7.0.

**Step Four: Create models.** Now open DigTrace and select the Create Workbench. Toggling the Open

Folder icon  brings up a directory window. Use this to navigate to the directory with the photographs for the first model you wish to build. Select the directory and it will appear in the table on the left hand side of the Create Window.

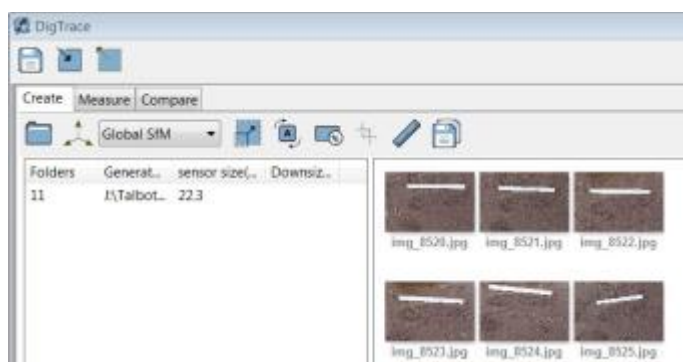

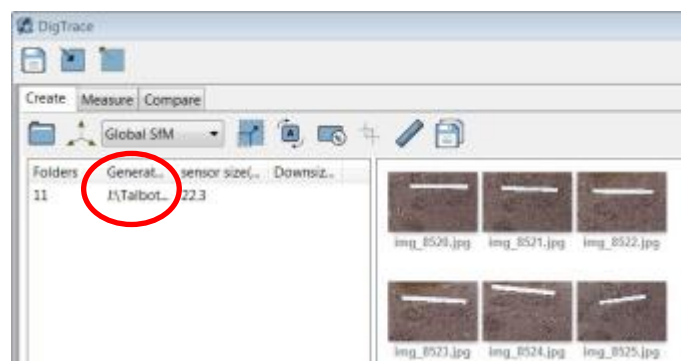


Figure 6: Table embedded in the Create Workbench.

If you select the wrong folder or wish to remove it, hover the mouse about it and right click and it will be removed. If you click the folder name in the first column of the table thumbnails of the images in this folder will appear in the middle panel. If you double-click on the chosen photo in the middle panel, the photo will appear in the third panel. At this stage it is worth checking again that only the photographs relevant to the model you are building appear. If there are unwanted photographs then they need to be removed – do this in the file management software on your PC and then reload the folder into DigTrace. The software looks at every photograph in the folder and tries to match the pixels and the model will fail if there is an irrelevant photograph. Care at this stage can save time later. The software requires information on the camera sensor size and contains a database with information for most modern cameras. If there is no information recorded the Sensor Size column will be blank. If this is so the user can click the third column

and enter the data manually this will be stored for future retrieval. Information on camera sensor sizes can be found in your camera manual or on line in one of the camera databases (e.g., [www.digicamdb.com/](http://www.digicamdb.com/)). You are now ready to create your first model, do so by

clicking on the create model button . The generation of model will start. After 10 steps are completed, the location of the created model will appear in the second column of the table. To view the model, you have to click on the folder location in the generated column. The model will appear in the right panel.



If a model fails to build, then there are a number of possible explanations. The most likely is that there is a rogue photograph in the directory so that is the best place to start. If this is not the case then it is probably a reflection of the number of photographs or the size on the individual images. You may like to remove a few of the images, if for example you have more than 25. In our tests the software was able to process a batch of ~20 photographs, 20Mpix each on a machine with 8GB of RAM. Alternatively you can press the final column of the table which downsizes the photographs automatically reducing their resolution. When downsize is applied "Yes" will appear in the last column of the table. This does not have an appreciable impact on the quality of the model produced for most purposes but may be an issue when producing very high resolution models of a small section of a track for example. It is now possible to edit and scale this model. Note that a sub-directory and a text log file have now been added to directory with your photographs. The sub-directory is called 'Outputs' and you will find a file with the name output and ply file extension. The text file is simply a processing log which can help an experienced developer work out why a model fails should it do so.

You will notice that there is a dropdown menu from which you can choose Sequential or Global SfM. We recommend that as default you use Global unless a model repeatedly fails in which case you may wish to try Sequential SfM. Sequential SfM is also called Incremental SfM in some documentation and is a

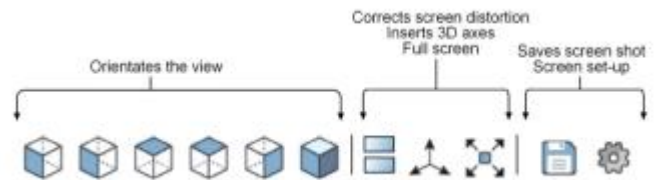
growing reconstruction process. It starts from an initial two-view reconstruction (the seed) that is iteratively extended by adding new views and 3D points, using pose estimation and triangulation. Due to the incremental nature of the process, successive steps of non-linear refinement, like Bundle Adjustment (BA) and Levenberg-Marquardt steps, are performed to minimize the accumulated error (drift). The Global SfM uses a global calibration approach based on the fusion of relative motions between image pairs. It distributes residual errors evenly, instead of treating the views incrementally that the external calibration can be subject to drift. Further details if required can be found at:

<http://openmvg.readthedocs.io/en/latest/software/SfM/GlobalSfM/>.

Before creating a model you may wish to load other photo directories into the table in the Create Window. In this way you can stack and organise a programme of work. By holding down “CONTROL” on the keyboard you can highlight each folder before clicking OK. The software is designed to run up to four models simultaneously one on each core of your PC, assuming you have four cores. If you have less than four cores then correspondingly fewer models will run simultaneously. You have to complete the required details (e.g. sensor size) in each folder you have loaded. Then highlight all of them to generate models. A single model can take anything from 5 to 10 minutes to run depending on the number of photographs, their quality and the speed of your PC. You will notice that steps 2nd and 10th take the longest during model generation. The idea of stacking multiple models is that you can set the computer running and then work on something else or take a tea break while it works. The disadvantage is of course that if a model fails or something goes awry with your PC you can return later to find that no models have been completed. We advise you to gain confidence in running one model at a time before stacking multiple builds and not to do so if your PC has limited memory.

When loading folders to the list, it will load previously generated ply file paths at the second column. By default, the ‘Generate’ button will trigger generation process for the folders that don’t have ply files listed. However, the user can select folders that need to be generated by clicking with “CONTROL” key pressed or box selection by mouse click and drag.

**Step Five: Edit and save models in Create.** With a model open in the Create Window you can now edit it. The first task is to learn how to navigate within this window. The toolbar looks like this:



*Figure 7: Toolbar associated with 3D model view in the Create Workbench. The icon with the two parallel boxes toggles parallel projection on/off. Parallel projection has lines of projection that are parallel both in reality and in the projection plane. Parallel projection corresponds to a perspective projection with an infinite focal length.*

By holding the left mouse button down and dragging over the model window you will rotate the view point in the direction moved. Holding down “SHIFT” when doing this will pan the scene; you can also do this by depressing the middle button – wheel – of your mouse if you have one. You can move the model sideways by the same action. Holding down “CONTROL” will rotate around the camera’s axis (roll). Holding down “SHIFT” and “CONTROL” and dragging up will zoom in and dragging down will zoom out. You can do this also with the right button of the mouse. You can also zoom in by using the = or + keys and zoom out by using the – key. Using the left, right, up arrows lets you rotate the viewpoint in the specified direction. When “SHIFT” modifier is also held down the camera is panned. This window is based on the Mayavi library and further details can be found at: <http://docs.entthought.com/mayavi/mayavi/application.html>

The first stage is to scale the model so that it has real dimensions. To do this toggle the scale button on




. Move the cursor to a known point on your scale which should be visible in the model; a left click will place point. Move the cursor to the other end of your scale and click and again a dialogue box will now appear into which you should enter the true distance between the two points in millimetres. The model will now scale, disappearing and reappearing. You can check the accuracy of this scaling by using the ruler



to measure the distance between two placed points. Placement of scaling points can be enhanced by learning to enlarge and navigate the model window.

Having scaled your model, it is a good idea to do some basic clean up before saving it to the Project

Library. You can use the Auto-rotate  function to correct the orthogonal plane; that is the surface is viewed vertically from above rather than obliquely.

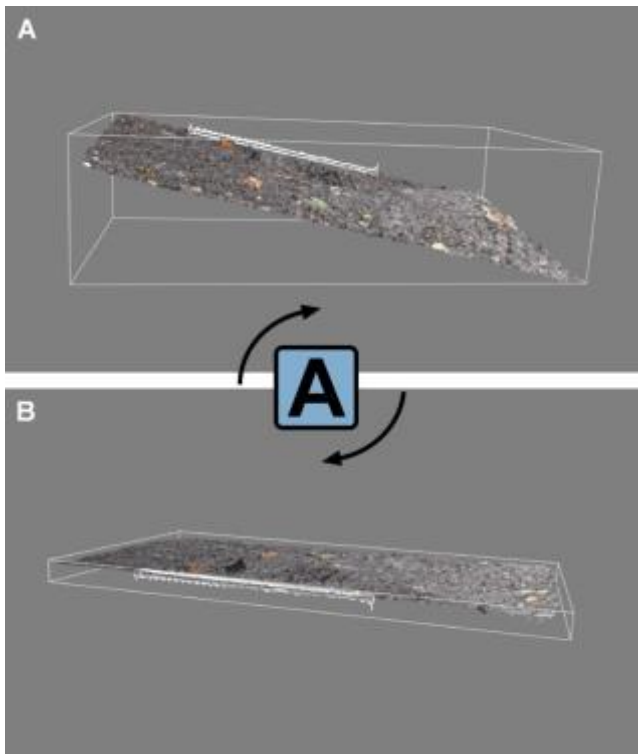




Figure 8: Auto-rotate function correcting the orthogonal plane.

It does this by calculating the principle plane through the point cloud and rotating all points to that plane. Next it is a good idea to reduce the file size by deleting unwanted areas. For example, you will note that the edges of the model are often ragged and the point cloud because discontinuous. You can neaten this up by cropping the model. You might also wish to remove unwanted areas and focus the model on the key area or track of interest. You can always return to the original model and it is good practice to export a screen shot of the uncropped model. To crop toggle

this  button on and then place the cursor at one corner of a square around the area of interest. Click to place a point before moving to the next corner working in a clockwise or anticlockwise direction. When you place the fourth point the polygon will automatically close and crop the model. After placing the four points, the green lines showing the area of interest will appear.

It is possible to crop a 3D model in the vertical plane

as well using button . For example, image a situation in which a model of a suspect's shoe has been made. The sole of the shoe is photographed on a cobbler last or improvised stand. The surface of interest in the sole of the shoe but the model will pick up lots of unwanted background such as the surface on which the last is placed. We need to be able to remove this. The 3D crop button allows you to do

this. A dialogue box appears with various sliders when the 3D crop button is toggled as shown below.

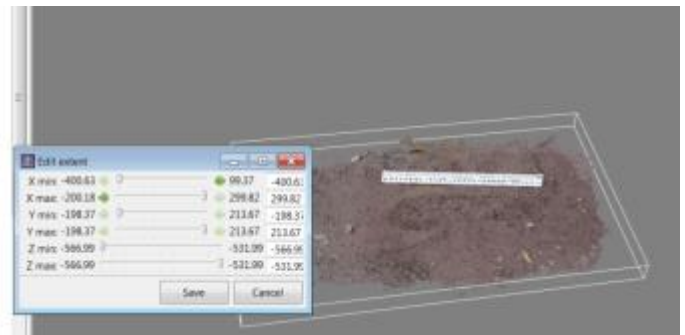



Figure 9: 3D crop function within the Create Workbench.

By moving the sliders you effectively move the dimensions of the bounding box and by pressing save you can crop the file in 3D. Another scenario in which this might be helpful is if a model captures some points associated with over hanging vegetation. This may appear as a few random/floating points above a surface of interest. Again these can be removed by using this tool.

If you wish to return or undo an action then you can double click on the original model in the table on the left and this will restore the model.

It is worth at this stage accessing the accuracy of your model. A poor model will have lots of 'holes' without any points; a good model will have a good density of points around the target area. It is good practice to take screen shot for the record to show this.

When you have completed your edits you are ready to


save the model to the Project Library . The Project Library is the horizontal panel at the bottom of the screen. The saving process interpolates a surface through all the data points and stores the data as an ASCII file. Interpolation will occur irrespective of the quality of the model – that is the holes will be filled! It is important therefore to always keep mind the quality of the original model prior to interpolation. Once a model has been saved to the Project Library it can be examined in the Measure and Compare workbenches.


**Step Six: Project Save Functions.** As you work on a project creating and saving files to the Project Library you may wish to periodically save the project as a whole.




Figure 10: Project save functions.

You can do this at any stage and are advised to do so at regular intervals. Immediately below the DigTrace icon in the top left of the window are two buttons. The

save button  creates a .ftproj file which you should save to a directory of your choice; a good idea is to create a project folder in the in the directory with the

photographs. The import button  can be used to reload a previously saved project.

If you wish to send the files to a third party for examination this can be done via the export function

. This saves all the files involved in a project and creates a zip file that can be sent via a file transfer service or uploaded to data management system.

A worked case study can be found in section 8.0 Case Studies. The data for the case study together with premade models can be downloaded from our website.

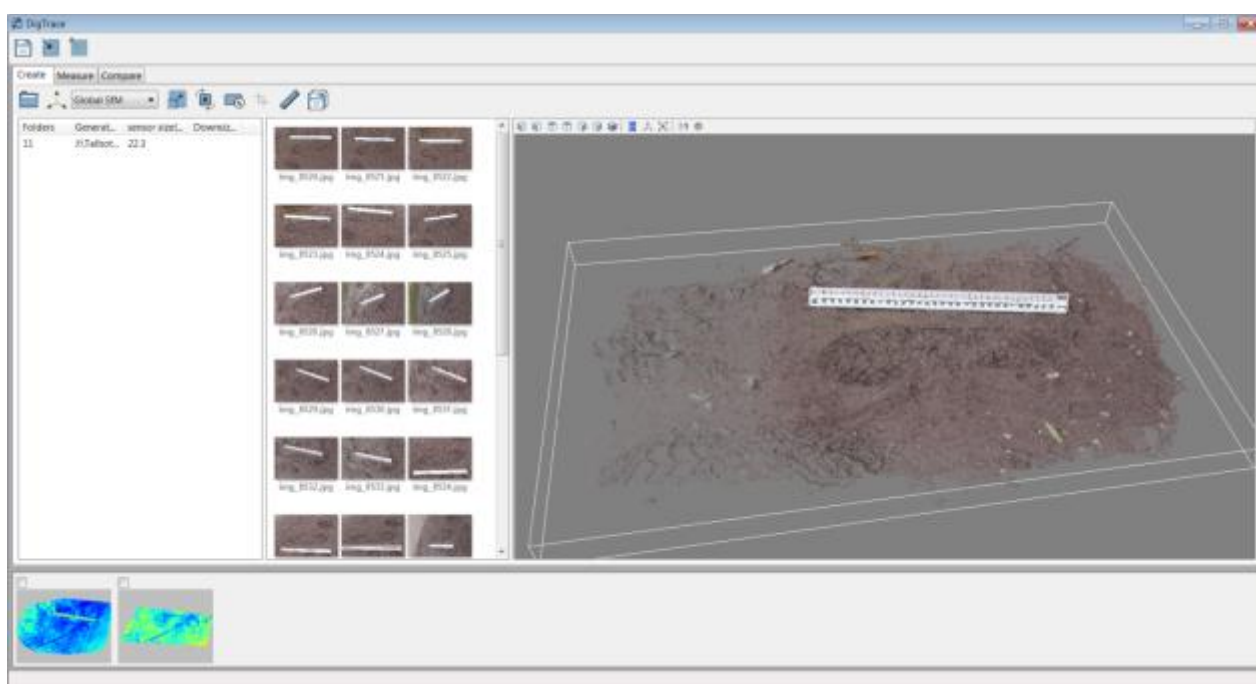


Figure 11: Create Workbench with a model loaded. Note the basic layout with a table on the left, a series of thumbnails in the centre and the model on the right. The model is a good quality model; note the lack of 'holes' around the area of interest. The model has a feathered edge with an increased number of holes but this is well away from the area of interest and can be cropped and clean easily. Note the ruler for scale. The model has yet to be saved to the Project Library.










Lookup Table for Create Tools	
	<b>Open Files:</b> Allows the user to connect and select folders that contains photographs from which 3D models are to be created. The photographs for each 3D model to be created should in separate folders; other images should be removed. Once selected the folder will appear in the table on the left hand side of the Create-Window. Multiple folders can be selected with the sequential processing order being determined by the order of listing.
	<b>Generate:</b> This will set in motion the creation of one or more 3D models depending on the number folders loaded to the table. There are ten steps to create each model. Models are run in parallel up to the number of cores in the PC.
	<b>SfM Method:</b> Allows the user to chose between different methods of photogrammetry processing. See the following link for details: <a href="http://openmvg.readthedocs.io/en/latest/software/SfM/GlobalSfM/">http://openmvg.readthedocs.io/en/latest/software/SfM/GlobalSfM/</a> .
	<b>Scaling:</b> Allows the user to accurately scale a model using the scale placed alongside the original track and included within some of the photographs. Select two points and type in the correct distance between them using the dialogue box.
	<b>Auto-Rotate:</b> This function calculates the principle plane through the point cloud and rotates all points so that they lie parallel to it. The effect is to ensure that you view a model vertically rather than from an oblique angle.
	<b>Polygon Cropping:</b> Allows the user to place a series of landmarks (placed-points) around an area of interest within a 3D model and crop to that area. It is useful and advisable to remove unwanted area around a point of interest (e.g., track) in order to reduce file sizes.
	<b>3D Crop:</b> Allows the user to crop a model in 3D and remove unwanted areas either below or above the surface of interest.
	<b>Quick Measure:</b> Allows the user to measure the straight line distance between two points, a useful tool to check the accuracy of scaling.
	<b>Save:</b> Allows the user to save the created model to the Project Library and project folder.

Table 2: Lookup table for create tools.

## 5.0 Measure Workbench

In the Measure Workbench you can visualise and analysis 3D models either build in the Create Workbench or imported directly into programme. For example, if you have data from another source or derived from a 3D optical scanner you can import it here. The programme recognises the following file formats: ply, asc, and csv. A pop-up box appears asking you to confirm the length-scale of the data and the precision with which you wish to express it.

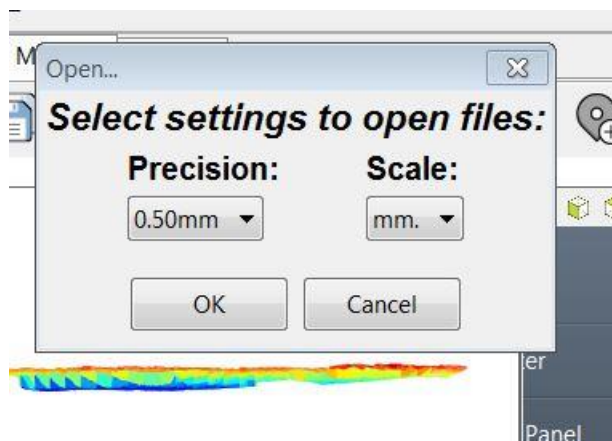


Figure 12: Scaling dialogue box which appears when you first load a file into Measure or Compare workbenches.

The software makes a suggestion which is usually correct. There are a couple of reasons why you might need to alter this, but it is best to accept the default and only change it if your data does not display correctly. Typical reasons for incorrect display may be if the model has not been correctly scaled, or is particularly large for example when dealing with dinosaur track several metres in diameter.

You can remove files from the Project Library by right clicking on the relevant thumbnail. As you hover over a thumbnail the file name and location will appear in the bottom window border. Once you have imported a series of files you can use the Project Save function to create a project as described in the last section. A generic or typical workflow is shown in Figure 14.

To start working on a three-dimensional model drag one of the pre-loaded thumbnails from the Project Library into the main window on the right. It will first appear in the Normal View (Fig. 16) in which most of the tools in the toolbar are active. Typically tools need to be toggled on and off after each action. Navigation tools for this view are to be found in the window specific tool bar:



Figure 13: Navigation tools within the Normal view in the Measure Workbench.

The home icon returns the user to the full extent, while the arrows allow you to browse between successive views. The pan key allows you to move the view point, while the magnifying glass allows one to zoom. Finally the save icon capture a screen shot. There is the option to export this screen shot not just as a raster image but as a vector file for use within Adobe Illustrator for example. This is particularly valuable for the export of contour maps.

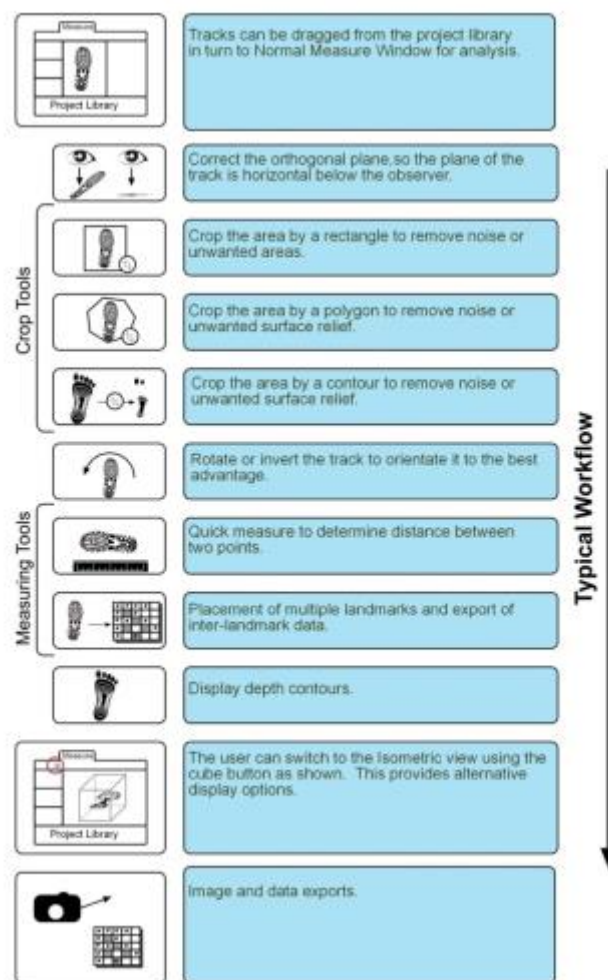



Figure 14: Generic or typical workflow within the Measure Workbench.

The user is advised to check that a model is orthogonal to the vertical plane; that is it is viewed directly from


above. Reference to the three panels on the left should provide some guidance on this and the user can use the


Auto-Rotate tool  at any time. As the user crops or removes areas from a model it is often worth repeating auto-rotate to ensure the model remains perfectly orthogonal.

The editing and visualisation tools fall into the following broad groups:

1. Cropping tools. These allow the user to remove unwanted areas or focus on the core feature within a model. Crop by square, polygon and by contour (elevation) are possible.
2. Measurement tools. These allow the user to place landmarks on an image and extract coordinates for them or make inter-landmark measurements. A landmark is simply a point from which a measurement is taken from or to. It is possible to export data from multiple measurements as a csv file for use within spreadsheet programmes such as Microsoft Excel.
3. Visualisation tools. It is possible to change the colour ramp, view the model as a contour map and export all of this data as both raster and vector based images. The best visualisation is often obtained by switching to the Isometric View which is described below.

Details on each of these tools are provided at the end of this section. It is worth noting that you need to save changes to a model after editing it by using the Save As

button . This saves a new version of the model to the Project Library. If you want to return to an earlier version of the model then simply switch the older version into the main screen from the Project Library.

By toggling this icon  you activate the Isometric View (Fig. 17). Most tools are deactivated in this view, but it does provide a superior visualisation tool. The view uses the Mayavi library like that the model window in the Create Workbench. Note that in isometric view it is not possible to change the colour ramp. The toolbar is the same as that in Create (Fig. 7).

By holding the left mouse button down and dragging over the model window you will rotate the view point in the direction moved. Holding down “SHIFT” when doing this will pan the scene; you can also do this by depressing the middle button – wheel – of your mouse if you have one. You can move the model sideways by the same action. Holding down “CONTROL” will rotate around the camera’s axis (roll). Holding down “SHIFT” and “CONTROL” and dragging up will zoom in and dragging down will zoom out. You can do this also with the right button of the mouse. You can also zoom in by using the = or + keys and zoom out by using the – key. Using the left, right, up arrows lets you rotate the viewpoint in the specified direction. When “SHIFT” modifier is also held down the camera is panned. This window is based on the Mayavi library and further details can be found at: <http://docs.enthought.com/mayavi/mayavi/application.html>

A worked case study can be found in 8.0 Case Studies section which illustrates much of the functionality in the Measure Workbench.

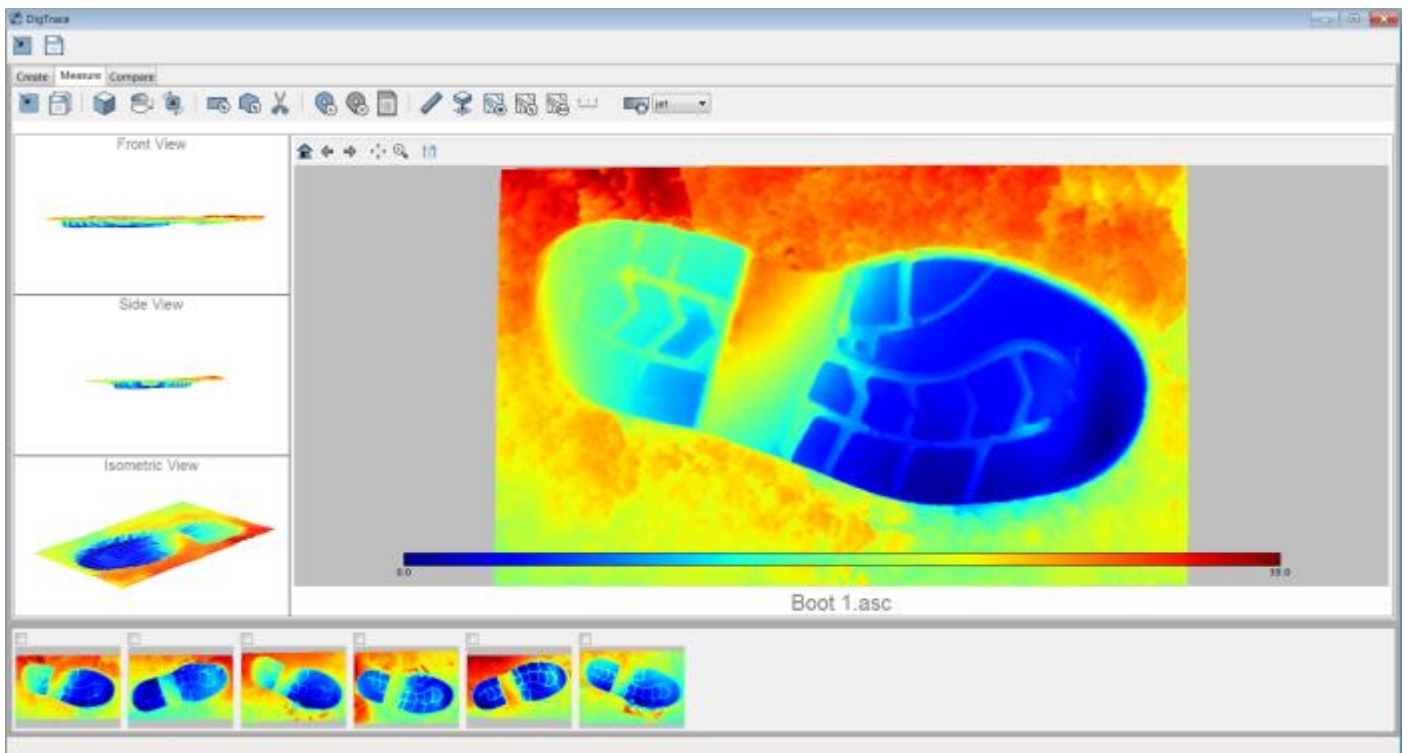


Figure 16: Screen shot of the Measure Workbench showing a 3D model loaded into the normal view where most of the editing tools are active (i.e. not greyed out). Note the library of models loaded to the Project Library.

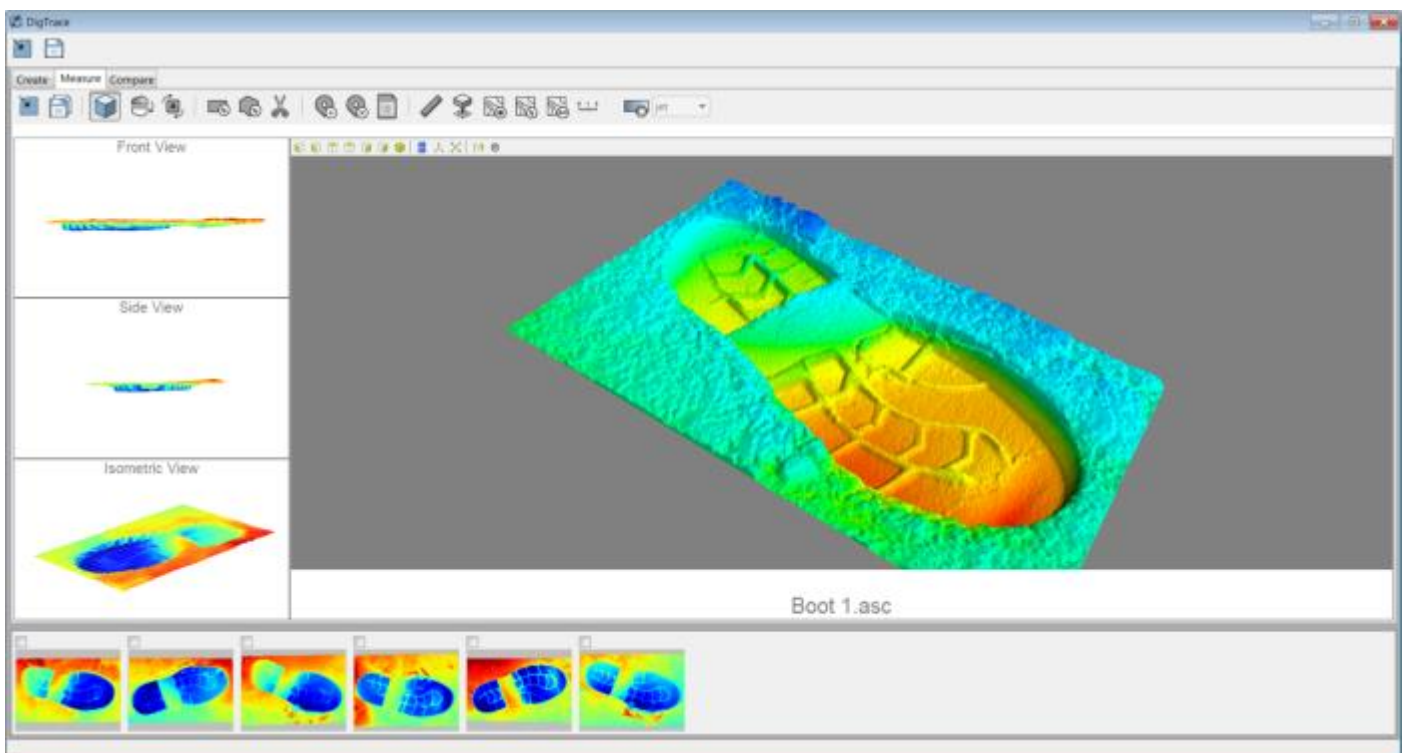
























Figure 17: Screen shot of the Measure Workbench showing a 3D model loaded into the Isometric View. Note the colour ramp cannot be changed in this view.

Lookup Table for Measure Tools	
Import and Save Tools	
	<b>Import Files:</b> Allows the user to import asc, csv or ply files directly to the project library.
	<b>Save As:</b> Allows the user to save a copy of the modified model outside the <b>Project Library</b> .
Navigation Tools – Normal View	
	<b>View Home:</b> This returns the image to its maximum extent after using the pan or zoom functions.
	<b>Back:</b> This returns the image to the previous one.
	<b>Forward:</b> This moves the image forward if the user has moved it back.
	<b>Pan:</b> Allows the user to move the image within the window. Place the cursor over the part of the image to be moved and left click and hold while moving.
	<b>Zoom:</b> Allows the user to zoom into the image. Use the <b>Back Arrow</b> or the <b>Home</b> toggles to zoom out or return to an earlier view.
	<b>Image Output:</b> Exports the image displayed in the window as an image file. Possible outputs include: tiff, jpeg, png, svg and eps.
Optimisation Tools – Normal View	
	<b>Auto-Rotate:</b> Rotates the principal plane of the image so that it is orthogonal to the vertical. It does this by looking for the principle plane in the point cloud and automatically rotating it to this plane. Press <b>Save</b> to store the change into the file in the <b>Project Library</b> . Put another way this tool ensures that the track is viewed vertically from above.
	<b>Rectangular Crop:</b> Allows the user to define a box by holding-down the left mouse button in one corner of the desired area and releasing it in the opposite corner. Once defined press <b>Crop</b> to implement followed by <b>Save</b> to store the change in the <b>Project Library</b> file.
	<b>Polygon Crop:</b> Allows the user to place a series of landmarks (placed-points) around an area of interest on the track to define a polygonal cropping area. Once defined press <b>Crop</b> to implement followed by <b>Save</b> to store the change in the <b>Project Library</b> file.
	<b>Contour Crop:</b> Allows the user to select areas vertically by contour and remove higher elevation areas. Use the slider at the bottom of the window to define the elevation. Once defined press <b>Crop</b> to implement followed by <b>Save</b> to store the change in the <b>Project Library</b> file.
	<b>Crop:</b> Allows the user to implement one of the above crop functions.
Visualisation Tools – Normal View	
	<b>Colour Ramp:</b> Allows the user to change the colour ramp (isopleth colour) with which the elevation (z values) are rendered.
	<b>Inversion:</b> This tool inverts the elevation (z values) such that high areas become low and vice versa. Press <b>Save</b> to store the change in the <b>Project Library</b> file.
	<b>Rotate:</b> This tool rotates the image through 90 degrees. Press <b>Save</b> to store the change in the <b>Project Library</b> file.
	<b>Scale Bar:</b> Inserts a scale bar into the image.
	<b>3D to 2D:</b> This tool allow the user to convert a 3D model into a 2D black and white imprint such as would be obtained if the sole of a shoe was inked and rolled over a piece of white paper. The user must define by trial and error the elevation range turned black. Place the cursor to the left of the toggle on the slider at the bottom of the window and click to define the lower elevation. Now move the cursor to the right of the toggle on the slider and click to define the higher elevation. The range is now set and the user can move the toggle backwards and forwards. As they do so a black and white 2D image of the track will show to varying extents. If the elevation range is too large/small then redefine the range by clicking to the left and right of the toggle.
	<b>Display Contours:</b> This tool creates a display of contours with a grey background. By right clicking on a particular point sets that point as the zero contour.
	<b>Number of Contours:</b> The default contour interval is a 1 mm but this can be changed using the slider or the forward or back arrows at the bottom of the window. This slider is shown by this icon.
	<b>Sets Zero Contour:</b> By toggling this on the user can set a point on a track as the zero contour. All contours are then measured in equal increments from the zero point. Activate the icon and place the cursor on the correct point and then depress the left mouse button.
	<b>Export Contours:</b> This tool allows the user to export the contours as a vector file.
Visualisation Tools – Isometric View	
















	<b>Isometric View:</b> This opens the isometric view window, allowing the user to rotate, pan and zoom via mouse movements. Place the cursor over the track and press and hold the left mouse button. If you have mouse with a wheel then this can be used to zoom in or out. Notice that the main toolbar is grey and inactive in this mode.
	<b>End-Left View:</b> In <b>Isometric View</b> this automatically rotates the image to show the surface specified by the icon.
	<b>End-Right View:</b> In <b>Isometric View</b> this automatically rotates the image to show the surface specified by the icon.
	<b>Side-Left View:</b> In <b>Isometric View</b> this automatically rotates the image to show the surface specified by the icon.
	<b>Side-Right View:</b> In <b>Isometric View</b> this automatically rotates the image to show the surface specified by the icon.
	<b>Bottom View:</b> In <b>Isometric View</b> this automatically rotates the image to show the surface specified by the icon.
	<b>Top View:</b> In <b>Isometric View</b> this automatically rotates the image to show the surface specified by the icon.
	<b>Insert Axes:</b> This icon inserts axis into the image.
	<b>Full Screen Mode:</b> In <b>Isometric View</b> this expands the window to fill the whole screen and is ideal for demonstrating a track during a presentation or using screen-recording software to create a video. Press <b>Esc</b> to return to the normal window.
	<b>Screen Shot:</b> In <b>Isometric View</b> this saves a screen shot as a tiff or jpeg.
	<b>Configure Screen:</b> Does not currently do anything.
<b>Measuring Tools</b>	
	<b>Measure:</b> this tool provides a quick distance measure between two points (direct line of sight). Toggle on place click the cursor at the first point and move to the second and click. The distance appears in the bottom left corner of the main window.
	<b>Place Landmark:</b> When toggled on it allows the user to place multiple landmarks over the surface of a track. A right mouse click removes the last landmark. Landmarks are labelled sequentially L1, L2, L3 and so on. In placing multiple landmarks on successive tracks, for example to take the same measurements the user needs to be careful to ensure that they place the landmarks in the same order on each track. This will ensure that landmark identifiers are consistent; for example if the user defines a landmark at the heel of a track first on every track measured then the heel landmark will always be L1. However if the place landmarks in a different order this may not always be the case.
	<b>Export Landmarks:</b> If the user has placed a series of landmarks data on them is exported by pressing this icon. A window will appear with two matrices, one showing the inter-landmark distance and another the x, y, z coordinates for each landmark.
	<b>Delete All Landmarks:</b> When pressed all the placed landmarks are removed allowing the user to start again if required.


Table 3: Lookup table for create tools.


# 6.0 Compare Workbench

The Compare Workbench allows you to do one of two main functions, either: (1) compute measures of central tendency from a sequence of tracks made by the same track-maker; or (2) compare two or more tracks, these may be mean tracks created previously or individual tracks. A typical workflow is shown in Figure 18.

Tracks or 3D models are imported to the Project Library as described previously or a series tracks edited in Measure are left in the Library and the user simply switches to the Compare Workbench. The process of comparison proceeds as follows. First the user identifies a track or model as the Master, usually the most complete track. This model is dragged from the Project Library to the left hand window in the Compare Workbench where it will appear. Now take any other track from the Project Library and move it to the right window; this track will be registered to the Master. Navigation within each of these windows is similar to the Normal View in the Measure Workbench (Fig. 13).

To start the registration process activate the Place

Landmark tool  and move the cursor over a prominent point on the left hand (Master) track then left click with the mouse to place the landmark. Now move the cursor to the right hand panel and locate the identical point on the other track; left click on the mouse to place the matching landmark. The colours of the two landmarks should match. Proceed in this way matching points of reference working from the left track to the right track in each instance. If you make a mistake simple right click of the mouse to remove the last point and the whole set of landmarks can be removed by pressing the

Delete Landmark button . Zooming the window may help with landmark placement. You can also change the location of a landmark by hovering over it before holding down the left mouse button and dragging the landmark to its new location.

After you have placed three landmarks a contour map of the two tracks being registered will appear in the central panel; the black contours correspond to the Master and the red to the registered track. You can adjust the number of contours to suit your needs by using the relevant buttons on the toolbar. You can also link the depth and colour scales if required.

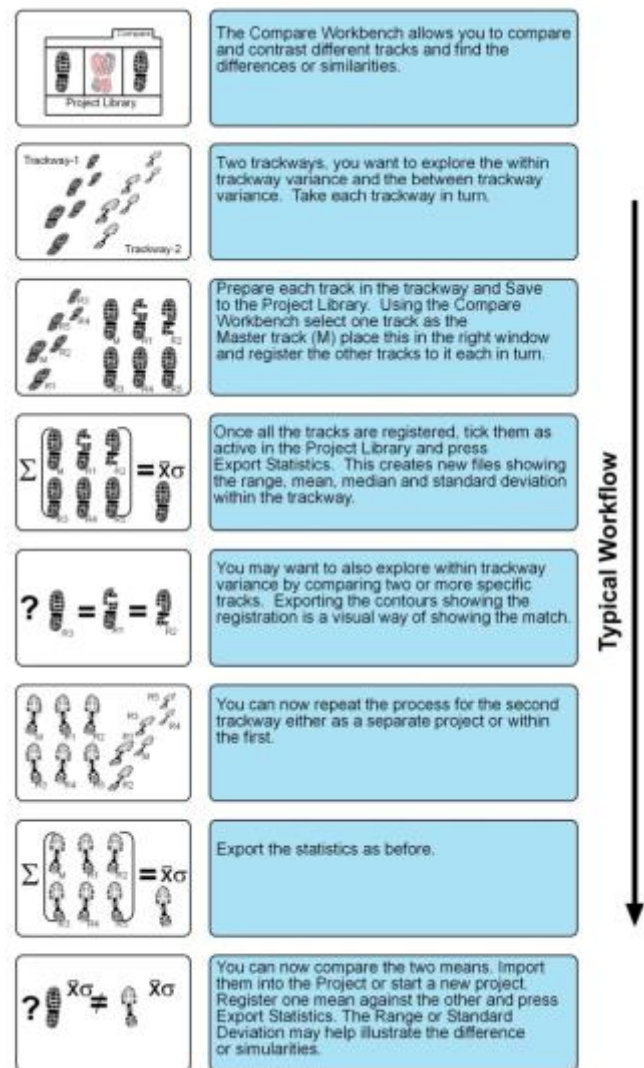




Figure 18: Typical workflow in the Compare Workbench.


Using the dropdown menu you can select either a rigid or affine transformation depending on what is most appropriate. If you are registering 'within-subject' tracks (i.e. made by the same individual), or are interested in both the properties of size and shape then select a rigid transformation. Alternatively if you are registering 'between-subject' tracks (i.e. different people) and are interested only in the properties of shape then an affine transformation may be more appropriate.

Once you are happy with the overlap between the two tracks, for example you have minimised the error score which is based on the least square difference between


the landmarks, the user selects the register button . The letter 'M' will appear on the Master track in the Project Library and the letter 'R' against the registered track (Fig. 19). You can also add geometrical landmarks if you wish. These are landmarks placed in various ways


between the one you have located, for example at the mid-point between two landmarks. You can export the comparison contours as an eps or svg file by clicking on

the export contour button in the central panel .

Now clear all the landmarks using the delete landmarks button .

Now drag a new track into the right hand window to replace the first and repeat the registration of the new track to the master. Note that the central contour panel does not reset until three landmarks have been placed. Once you have registered all the tracks you wish to with respect to the Master you are ready to compute measure of central tendency. Any track that shows a tick in the Project Library will be included in these calculations;

either select all  if you have registered all the tracks or make a bespoke selection.

Now press the Export Statistics button  and wait for the process to complete. New csv files are created as follows: mean, median, standard deviation, maximum difference, minimum difference, and range. The mean is automatically added to the Project Library and you can import the other measures of central tendency if you wish using the import button on the main toolbar.

You can run the Export Statistics function with as many or as few (minimum two) tracks or models as you wish. If you subsequently wanted to compare two means then you would open a new Project Library and import and register the tracks as if they were individual examples. In this case the range and standard deviation are the most likely to be of interest

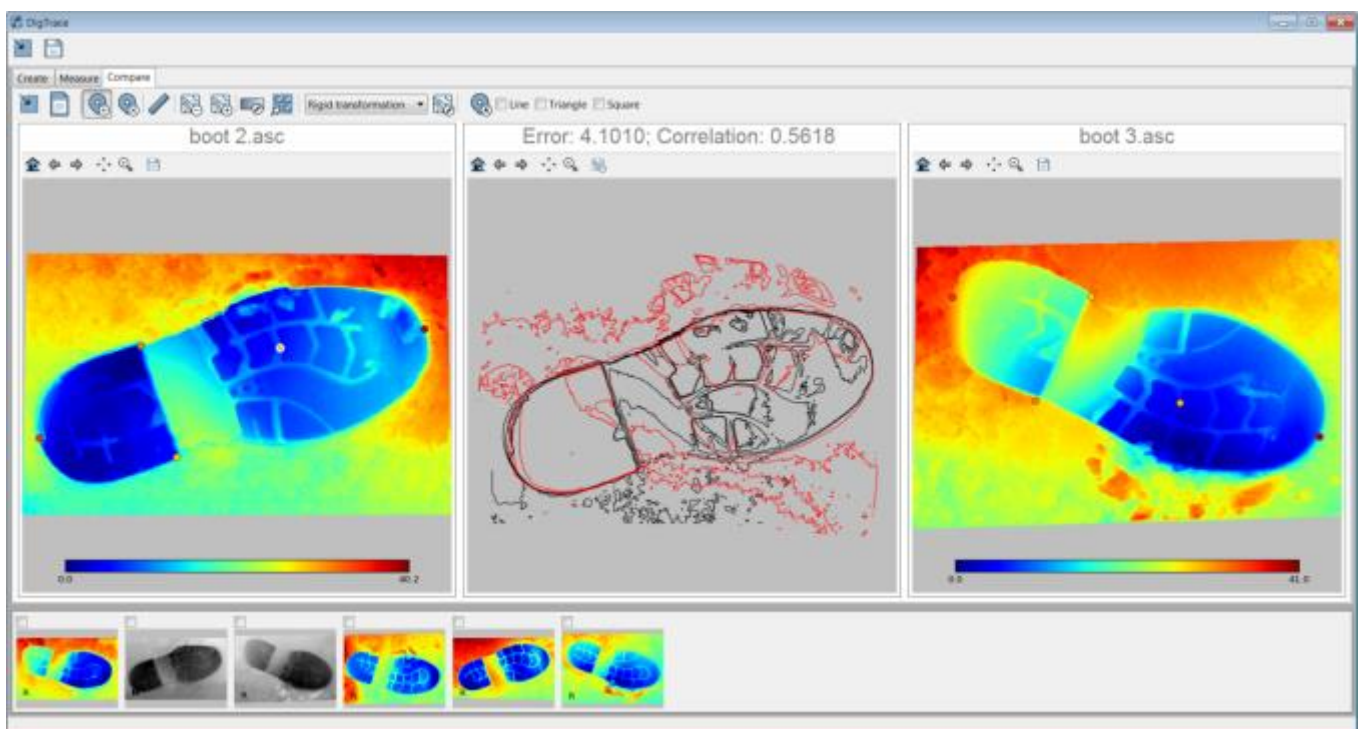


Figure 19: Compare Workbench. The track/model on the left is the Master to which all other tracks are being compared in this project. Note that they have been all been registered as indicated by the letter 'R'.



















Tools	
	<b>Import Files:</b> Allows the user to import asc, csv or ply files directly to the project library.
Individual Panels	
	<b>View Home:</b> This returns the image to its maximum extent after using the pan or zoom functions.
	<b>Back:</b> This returns the image to the previous one.
	<b>Forward:</b> This moves the image forward if the user has moved it back.
	<b>Pan:</b> Allows the user to move the image within the window. Place the cursor over the part of the image to be moved and left click and hold while moving.
	<b>Zoom:</b> Allows the user to zoom into the image. Use the <b>Back Arrow</b> or the <b>Home</b> toggles to zoom out or return to an earlier view.
	<b>Image Output:</b> Exports the image displayed in the window as an image file. Possible outputs include: tiff, jpeg, png, svg and eps.
	<b>Export Comparison Contours:</b> Exports the comparison contours (central panel). Possible outputs include svg and eps.
Registration Tools	
	<b>Measure:</b> this tool provides a quick distance measure between two points (direct of sight line). Toggle on place click the cursor at the first point and move to the second and click. The distance appears in the bottom left corner of the main window.
	<b>Place Landmark:</b> When toggled on it allows the user to place multiple landmarks over the surface of a track. A right mouse click removes the last landmark. The order of landmark placement is always left panel first, then right panel to ensure that the same points are identified for registration on both images. The colour of the landmarks should match between the two panels.
	<b>Delete All Landmarks:</b> When pressed all the placed landmarks are removed allowing the user to start again if required.
	<b>Geometric Landmarks:</b> To the right of this icon are a series of tick boxes, select as required. These functions place a series of additional landmarks automatically between the ones placed manually.
	<b>More Contours:</b> Toggle this button to increase the number of comparison contours.
	<b>Less Contours:</b> Toggle this button to decrease the number of comparison contours.
	<b>Link Colour Ramps:</b> Toggle this button in order to link the two colour ramps on the Master and Registered images.
	<b>Register Image:</b> Once the user has placed registration landmarks to their satisfaction and minimised the registration error (least square error between landmarks) toggle this button to register the image. A small letter 'R' will appear on the relevant track in the <b>Project Library</b> .
	<b>Select All:</b> When the user has finished registering images to the Master and just before they toggle <b>Calculate Statistics</b> you can use this button to select all the images in the <b>Project Library</b> . Alternatively you can do it manually. All checked images will be used in the calculations.
	<b>Calculate Statistics:</b> When the user is ready to calculate measure of central tendency for a series of registered images they should toggle this button. Processing may take some time depending on the number of images involved. A series of new files are written to the Project Directory and the Mean is automatically uploaded to the <b>Project Library</b>

Table 4: Lookup table for create tools.

# 7.0 QA, Best Practice and Accuracy

If the software is to be used as part of forensic practice there are some clear guidelines that need to be followed.

Appendix I contains the current National Policing Improvement Agency guidelines for the analysis of footwear evidence in the UK. In Appendix II contains the author's modified schema which accommodates digital 3D data capture by DigTrace.

We suggest that there are five essential principles to follow in establishing a foundation for using 3D models in an investigation whether in an intelligence or evidential context:

- *A third party should be able to reproduce all stages of an analysis independently from the raw data.*
- *A detailed file history with processing notes should be available.*
- *In creating and processing a three-dimensional model digital files should be saved at all significant steps, allowing a third party to evaluate the impact of each step.*
- *That there should be complete transparency at all times in terms of data limitations and risks to accuracy.*
- *All data files should be collated and made available if required including the raw data.*

The key to enacting these principles is knowledge of best practice, file organisation and good record keeping. We deal with these issues as follows: (1) record keeping and the effective digital custody chain; (2) file archiving; and (3) best practice in terms of accuracy assurance.

## **Record keeping and digital custody chains**

In Appendix IV we provide generic examples of three record sheets, which can be downloaded as a word template from [www.digtrace.co.uk](http://www.digtrace.co.uk) and customised as required.

When you create a 3D model in DigTrace a series of sub-folders (i.e., directories) are added automatically. Some of these contain temporary files used in generating the model, while others actually contain the model itself. You are advised to keep all files and to create some additional sub-folders in which to save your output. Table 5 contains a list of the automatically generated sub-folders and those we recommend the user creates.

Create generates a 3D model file in a ply format. By default the file name is the folder name containing the photographs. This file format is commonly used by other 3D software. If you need to examine the data in another programme for example, you should locate and extract

this file. For information ply file formats are also known as Stanford Triangle Format and further detail can be found at:

<http://paulbourke.net/dataformats/ply/>  
[https://en.wikipedia.org/wiki/PLY\\_\(file\\_format\)](https://en.wikipedia.org/wiki/PLY_(file_format))

DigTrace however uses a simple csv/asc format for its data. When you first save a 3D model in Create a CSV file of the same name is created. This file is used in all subsequent stages and we recommend that you save each significant version of this file throughout the processing journey. You should also record the processing steps undertaken between each saved version using the processing log form or something similar (Appendix IV; Fig. 20). A good file naming protocol will help. For example:

2016\_06\_07\_Xhibit1\_v1.csv

This file was created on the 7 June 2016 and refers to Exhibit 1 and is version 1 of that file. If you now process that file, for example by cropping unwanted areas and re-save it the file name should become:

2016\_06\_07\_Xhibit1\_v2.csv

If you now take a screen shot of that version 2 then the file name should read:

2016\_06\_07\_Xhibit1\_v2\_Im1.jpeg

The 'Im1' signifying that it is the first screenshot of this version of the file; subsequently versions would be Im2 and so on.

All the files are saved and or moved to a new directory from 'model'. We suggest you call this something like Xhibit1\_3Doutput. The reason for doing so is that the 'output' folder in which the 'model' sub-folder lies can be overwritten by re-running the model generation command.

If you follow a different file naming convention that is fine, but it is important to keep track of file versions carefully and to record processing steps faithfully.





Project/Scene Identifier Test Site Talbot Woods, BH12 5BB

File Name	Date/Time	Action
Xhibit1.ply	06/07/2016 10:43	Ply file generated in Create, scaled, verified, auto-rotated and cropped. Note the file name is the same as the sub-folder with the photographs.
2016_06_07_Xhibit1_img1.jpg	06/07/2016 10:45	Screenshot of the model showing the density of points is the closed. Note the good coverage of points across the target area. File name adapted to include the date.
Xhibit1.csv	06/07/2016 10:47	File saved to the Project Library.
2016_06_07_Xhibit1.csv	06/07/2016 10:47	Using file manager the file was copied and the name was adjusted to contain the date.
2016_06_07_Xhibit1_v1.csv	06/07/2016 10:48	Model loaded into Measure; cropped using rectangular crop and inverted.
2016_06_07_Xhibit1_v1_img1.jpg	06/07/2016 10:48	Screenshot of version 1 showing the file post processing.
2016_06_07_Xhibit1_v1_img2.jpg	06/07/2016 10:49	Screenshot of version 1 as a contour map with contour interval set at 1 mm.

Figure 20: Example of a completed processing log completed

You can interrupt a processing session at any point. We recommend that before doing so that you save your work as Project. This will allow you to pick-up from where you left off with all the files in play being uploaded automatically to the Project Library. To re-cap on project saving (Fig. 10); immediately below the DigTrace icon in the top left of the window are two buttons. The save

button  creates a .ftproj file which you should save to a directory of your choice; a good idea is to create a project folder in the in the directory with the photographs.

The import button  can be used to reload a previously saved project. You may wish to save a project on top of one another, or alternatively to use sequential file names.

Systematic use of projects can also be used to organise your workflow. Typically a single project would be all the processing associated with a single exhibit (Fig. 21). If you keep each of the file versions in the Project Library all will be re-loaded on importing a project and the user can step easily between the different versions by dragging each in turn into the Measure window. For this reason it is best to build up a piece of work as a series of projects as set out in Figure 21. Each exhibit, track or shoe forms a single project, which can then be compared in another project.

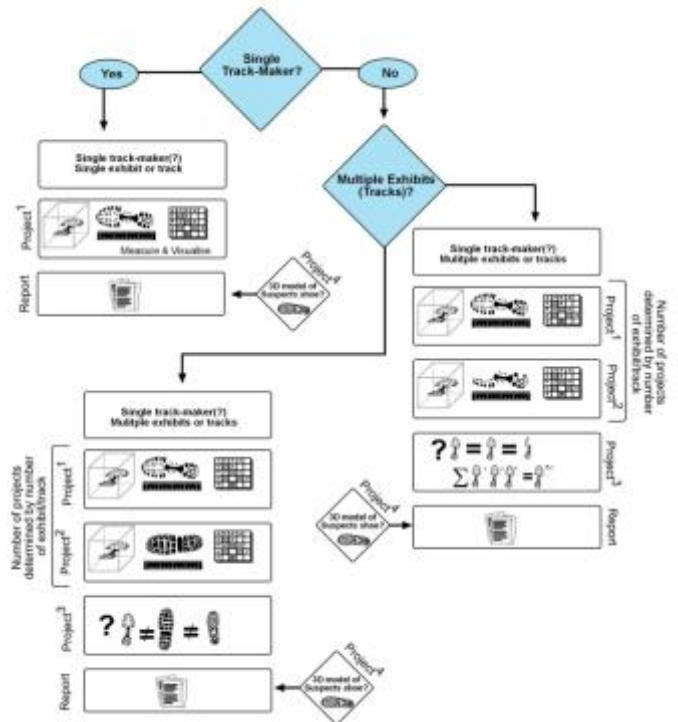


Figure 21: Organisation of projects. The four scenarios set-out are common tasks for which DigTrace is built.

## File archiving

Once an analysis is complete we recommend that you archive the data carefully along with your records. In Table 6 we provide a checklist of the key files that should form part of this archive for a simple piece of work. We have assumed that two exhibits (tracks) are recovered from a scene and then compared. Three projects – one per exhibit and one comparing the two tracks. The more processing steps and file version you create the more that the archive should contain. It is important to note that it is not enough simply to save the project files (.ftproj) since these files simple store the relative path information not the actual data itself. If you move the data from one computer to the next or to another location the project files will not work. You can use the export function however to zip all relevant files














Folder	Sub-folders				
 Scene#	Group all photographs and files created therefrom in one primary directory relating to a single scene or location at a multi-site scene. Ideally keep these separate from other images you may have from that scene				
	 Xhibit1	Create and name a folder for the exhibit. Place the relevant photographs to create a 3D model of that exhibit. Other images and files need to be stored separately.			
		 Outputs	When you generate a 3D model in Create this folder is generated. It contains the model and also various temporary files created during the process. A text file called 'log' is also created – this contains information about the speed and running of the software and its main use is for troubleshooting software problems. For example, if you contact us with a problem we may ask you to forward this file; it contains no sensitive information.		
			 matches	Keep but ignore; files created by the Generate model process	
			 reconstruction_global	Keep but ignore; files created by the Generate model process	
			 PMVS	 models	This contains the ply files (i.e. the 3D model). They are labelled the folder name initially; in this case Xhibit1.
				 txt	Keep but ignore; files created by the Generate model process
				 visualize	Keep but ignore; files created by the Generate model process
		 Xhibit1_3Doutput	We recommend that you create a folder in which to save your 3D model and all subsequent versions of the model. Move the ply and associated csv file from 'models' to this folder using your file manager. We recommend that each subsequent version of the model file a sequential number. You may also wish to save any project files you generate to this folder as well.		
	 Comp_Xhibits	Depending on the nature of your analysis you may need to generate output based on the comparison of one or more exhibits. We recommend that you create a 'Comparison' folder and save such output here.			

Table 5: file structure generated both by the user and automatically by DigTrace.  = Auto-generated;  = User-generated. The cells identified in green are the ones with key data in them, the others contains temporary files generated during the process

### Best practice and quality assurance

Transparency with respect to accuracy is essential and starts with the model itself. It is worth reviewing first the potential sources of error in a 3D model:

1. Failure to take sufficient photographs at the site leading to a poor model. Equally trying to build a model with too many images can cause it to be slow and even fail. The First Goldilocks principle applies – getting the right number of images. User experimentation will build confidence in getting this right.
2. Surfaces with little pixel contrast – uniform colour for example – can cause a problem and lead to large holes in the model.
3. Reflection from wet surfaces or water filled tracks/depressions can cause a problem for the model.
4. A model may fail to build because the images are too large (i.e. in resolution); it does not follow that the better the camera resolution, the better the model. While low resolution images can lead to a poor model. The Second Goldilocks principle applies – getting the resolution just right. User experimentation different

camera settings will build confidence in getting this right.

5. Undercut edges and overhangs. If a track or exhibit has strongly over cut edges then it is essential to take additional photographs from oblique angles. Depending on the density of the shadow in these areas will determine whether the model faithfully records these undercut areas. However it is important for the user to be aware how such areas are displayed in the Measure and Compare workbenches. The software is designed to look vertically from above and undercut areas may not therefore display correctly. If this is an issue then the user is advised to explore the model within Create and some of the additional functionality of the other workbenches may not be available. Awareness of this is important especially if the undercut areas are subtle or not very evident.

Ideally one is looking for a model that has an even coverage of data points with few gaps. If you examine a model in Create you will see by zooming in that it is created from a series of points. Compare the models in Figure 22 for example. It is good practice for the user to export an image, with a vertical view point, of the model

showing the gaps and holes. This should be done in Create on the raw point cloud.

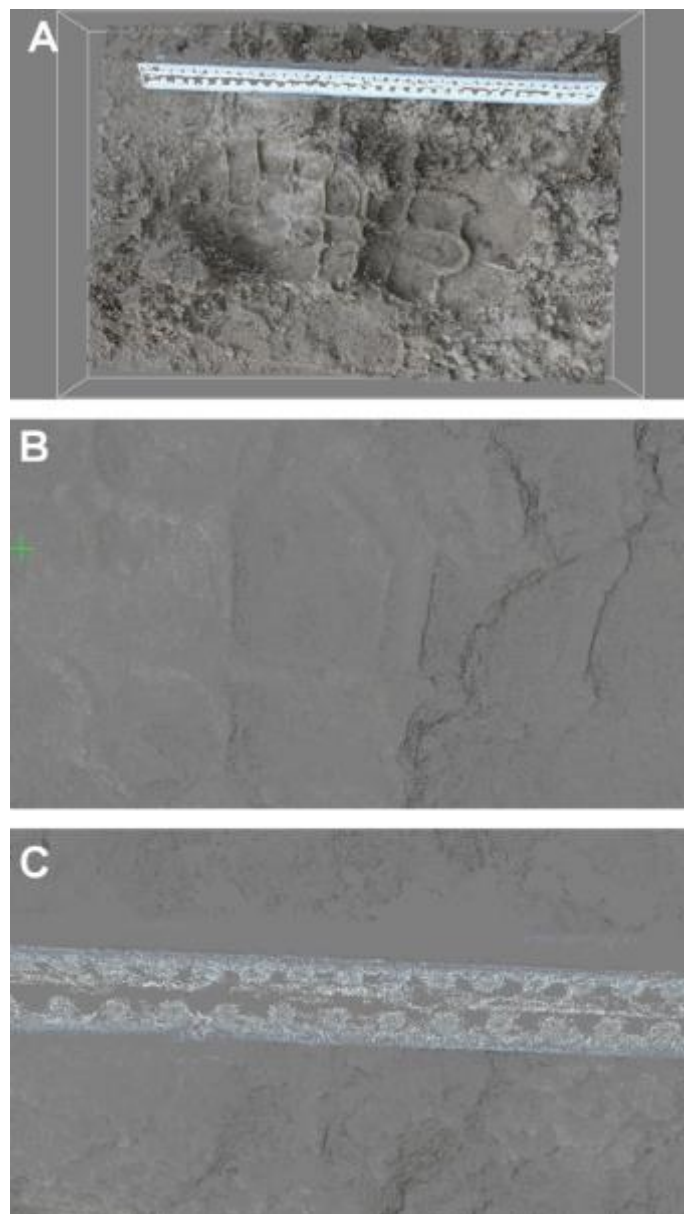
xhibit1 Directory	Raw photographs
Xhibit1_3Doutputs	Xhibit1.ply model
	Xhibit1.csv
	Xhibit1
	2016_06_07_Xhibit1_v1.csv
	2016_06_07_Xhibit1_v2.csv
	2016_06_07_Xhibit1_v2_lm1.j peg
	And so on
Xhibit2 Directory	Raw photographs
Xhibit2_3Doutputs	Xhibit1.ply model
	Xhibit1.csv
	Xhibit1
	2016_06_07_Xhibit1_v1.csv
	2016_06_07_Xhibit1_v2.csv
	2016_06_07_Xhibit1_v2_lm1.j peg
	And so on
Comparison_xhibits1an d2 Directory	2016_06_07_Xhibit1_v2_lm1.j peg

*Table 6: Example of files that should be saved and archived for a simple project.*

The other significant source of error is in scaling a model. When a 3D model is first generated the point cloud is unscaled, that is the points are correctly placed with respect to one another but not in terms of 'real' or absolute distances. We have discussed how to scale a model in Section 4.0.


The choice of scale can be critical to the precision with which accurate scaling can be obtained. Figure 23 shows a range of scales that can be used. As Figures 22 and 24 show the graticules on a scale do not always display well in the point cloud. Scaling is often done therefore by the overall length of a scale bar. Having a scale that is graduated right to the end helps in this respect especially if a third party user for example does not know the true length of the scale. Having a flat scale can also be an advantage. While the scale in Figure 24 is in some respects ideal – it has a very prominent red stripe which is precisely 300 mm long – its 3D nature causes a problem with later visualisation. Contour maps or colour height renders include the depth of the scale

bar which can swamp the detail in a shallow track. In this case the scale has to be cropped out of the image to enhance visualisation (see Section 8.0).



*Figure 22: Shows a point cloud of a track at various levels of magnification. A. General view of the track. This is a good model with good coverage of data point across the target, note the ragged edge and holes towards the margins where the data accuracy declines. The user would crop this image around the target and could then assume an even accuracy across its area. B. A zoomed view of the target area showing a good even coverage of data points in the cloud. C. A zoomed view around the ruler, note the gaps in the point cloud around the centre line of the ruler and to one side of it. This is not a problem since it is not in the target area.*

Once scaling has been achieved one needs to verify this

using the measure tool . Place the cursor at one end of a known length and hold and drag until you reach the other. A pop-up window will appear with the distance.

The first obvious check is to re-measure the scaled distance; it should be exactly the distance you entered. Now choose some other distances; for example if you have included a second scale or used a right angled scale then use this to check a distance. The inclusion of a second scale bar is one of the best measures of accuracy. If you repeat the test measurement a dozen or so times noting the distance in each case you can calculate simple error bands for your model. We recommend that this is done in all cases. If you are unhappy with the accuracy you are achieving then we suggest that you re-scale the model.

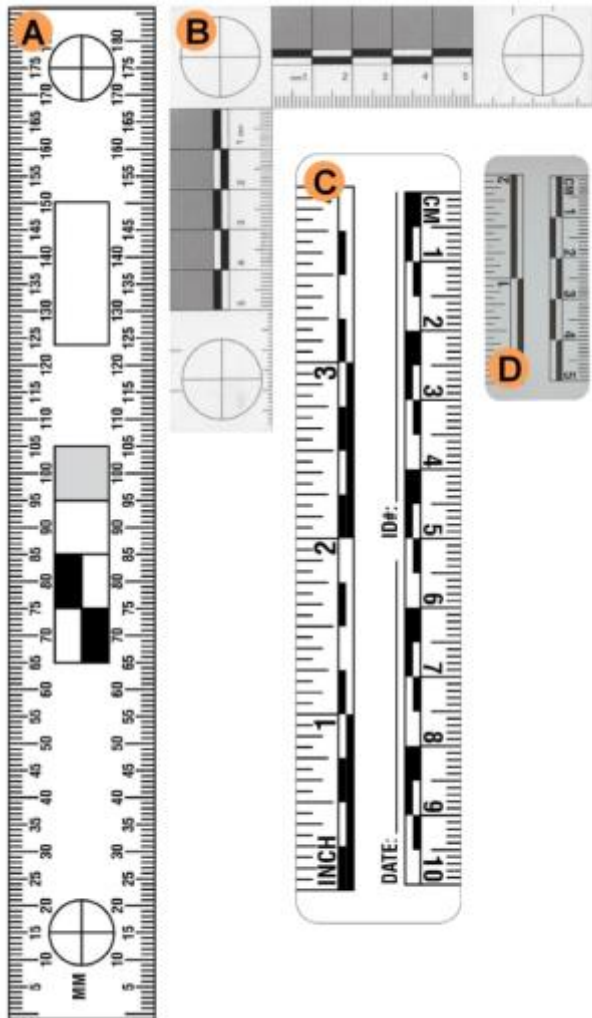


Figure 23: Four different types of ruler. One of the issues is that the ruler does not always accurately display on the model. The model is a point cloud each with a vertex colour taken from the matched and triangulated pixel. The user often needs to scale on the basis of the overall extent of the scale bar rather than specific gratitudes on it. Therefore have a scale bar with numbers to the absolute edge, or alternatively knowing the true dimension of the scale bar is important. Sharp corners also help. Reviewing above scales A and B are best.

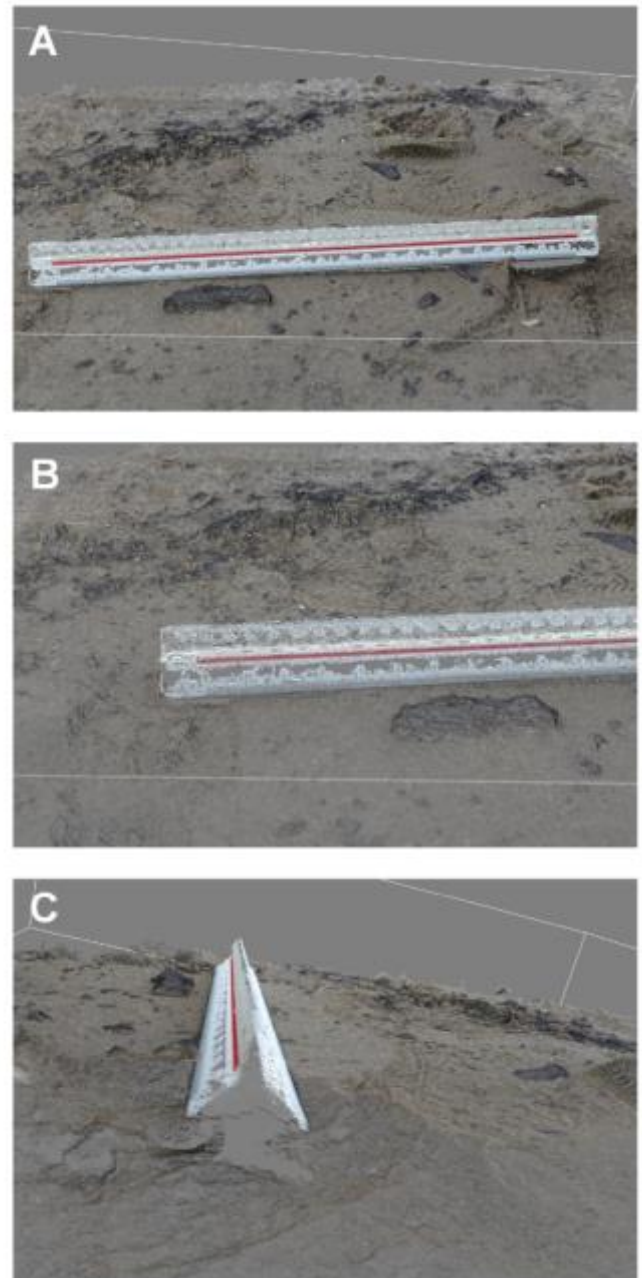


Figure 24: Issues with scaling of a 3D model. A and B, note the holes in the point cloud around the gratitudes on the ruler. The red bar is very useful however since it shows up well and is a precise 300 mm long. C. The 3D nature of the scale bar which can cause problems with visualisation of subtle relief in a model.

## 8.0 Case Studies

In this section we provide a few examples to illustrate the potential of DigTrace in a forensic context.

### Example One

Figure 25 shows a simple 3D model of track and the source photographs used to create it within DigTrace. Things to note in the model is the even distribution of points within the cloud around the target track. Note how the point cloud becomes 'ragged' towards the edges. These areas would normally be cropped out and neatened up (Fig. 26). The model may not be as reliable in this area. For example note the partial track in the top right corner of the model adjacent to the dog track. Should this track become of interest in an investigation one might need to proceed with caution or alternatively seek another model that shows it more clearly. The point density in the cloud visibly decreases across part of this track. It is always important to focus a model on a core area and to build multiple models to ensure that everything of importance is captured.

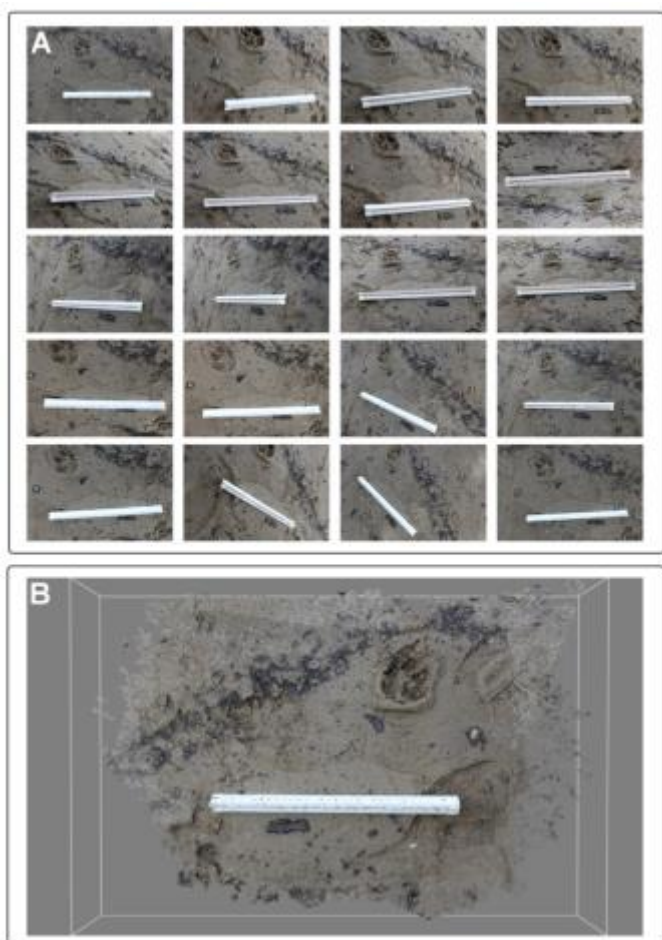


Figure 25: 3D model created from 18 oblique images. The images and the model are shown together.

Figure 26 shows model in later stages of examination. Note the multiple files saved to the project library. The first thumbnail is the original model; the second is an auto-rotated and cropped version; while the third is a close up of a small area showing the relationship between the track and a later dog track. Note the ruler has been cropped out of the later images because it swamped the relief. The image is scaled and the user can insert a scale bar if required. The cross-cutting relationships in this model are particularly striking. The track cross-cut the prominent dog track and partial track in the top right corner while the impressions of the second dog track, close to toe of the main track, came later obscuring some of the detail.

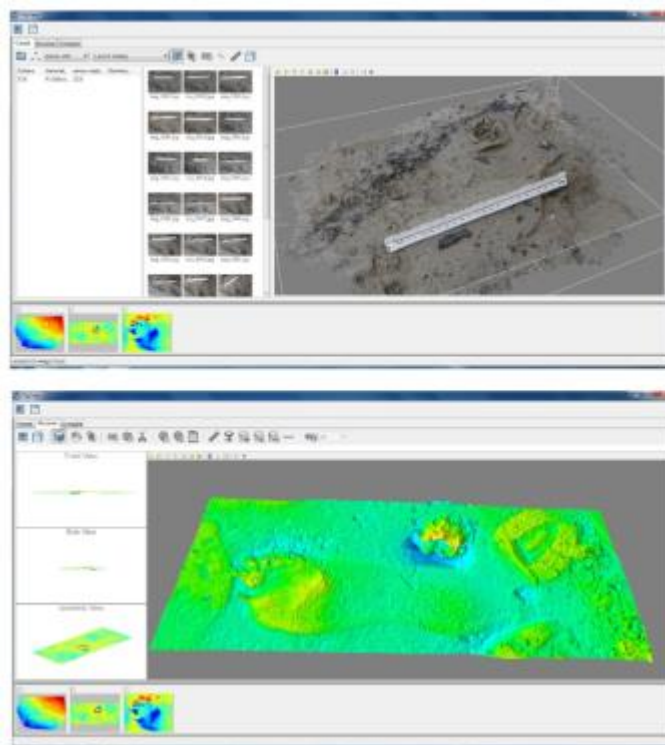


Figure 26: Views of the 3D model in Figure 25 in the Measure Workbench. Note how the ruler has been cropped out of the frame in the lower panel.

## Example Two

Figure 27 shows a typical DigTrace model of a footwear track taken from a muddy path through a set of woods regularly used by dog walkers. Note the model has been scaled and saved to the Project Library. The point cloud visibly becomes sparse towards the left hand side of the image. A partial track is visible in this area and falls outside the reasonable area of accuracy for this model. Figure 28 and 29 show different visualisation and measurement strategies available to the user.

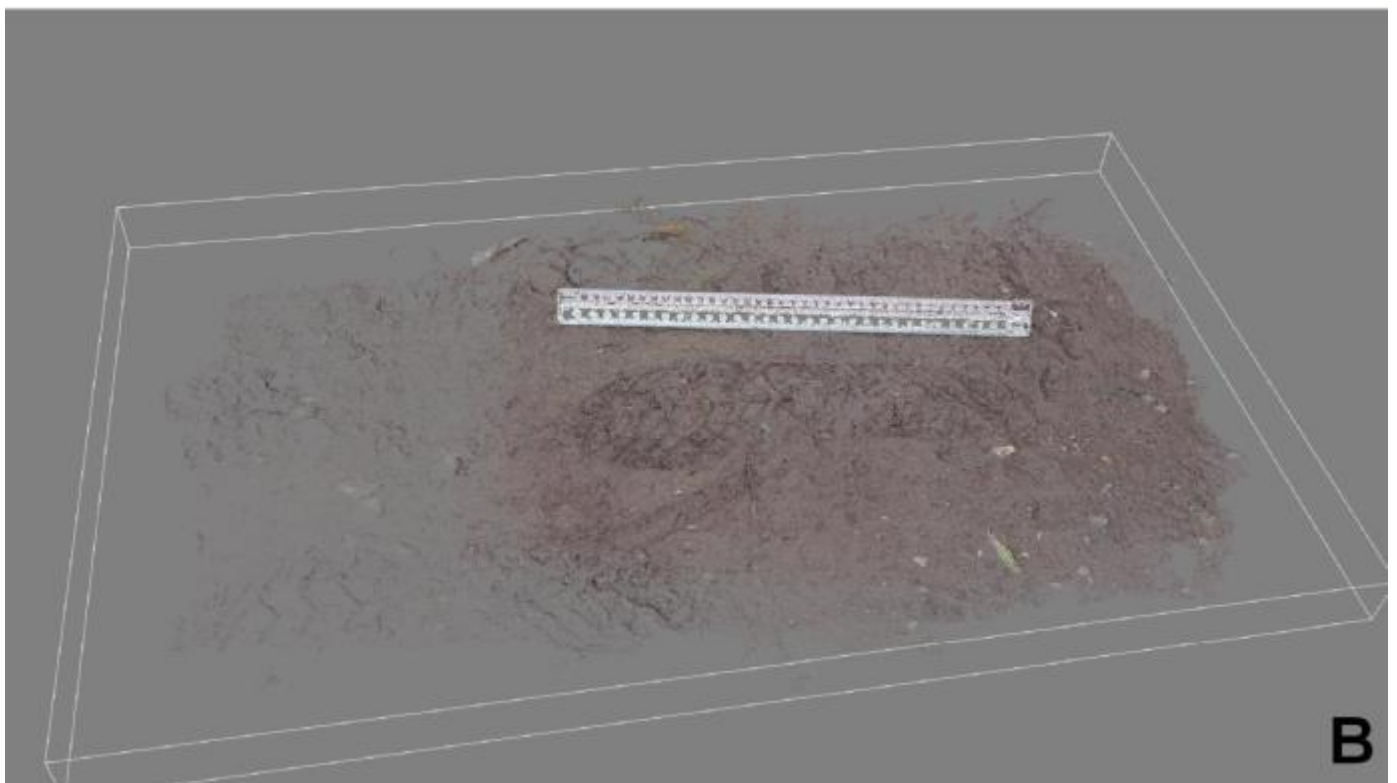
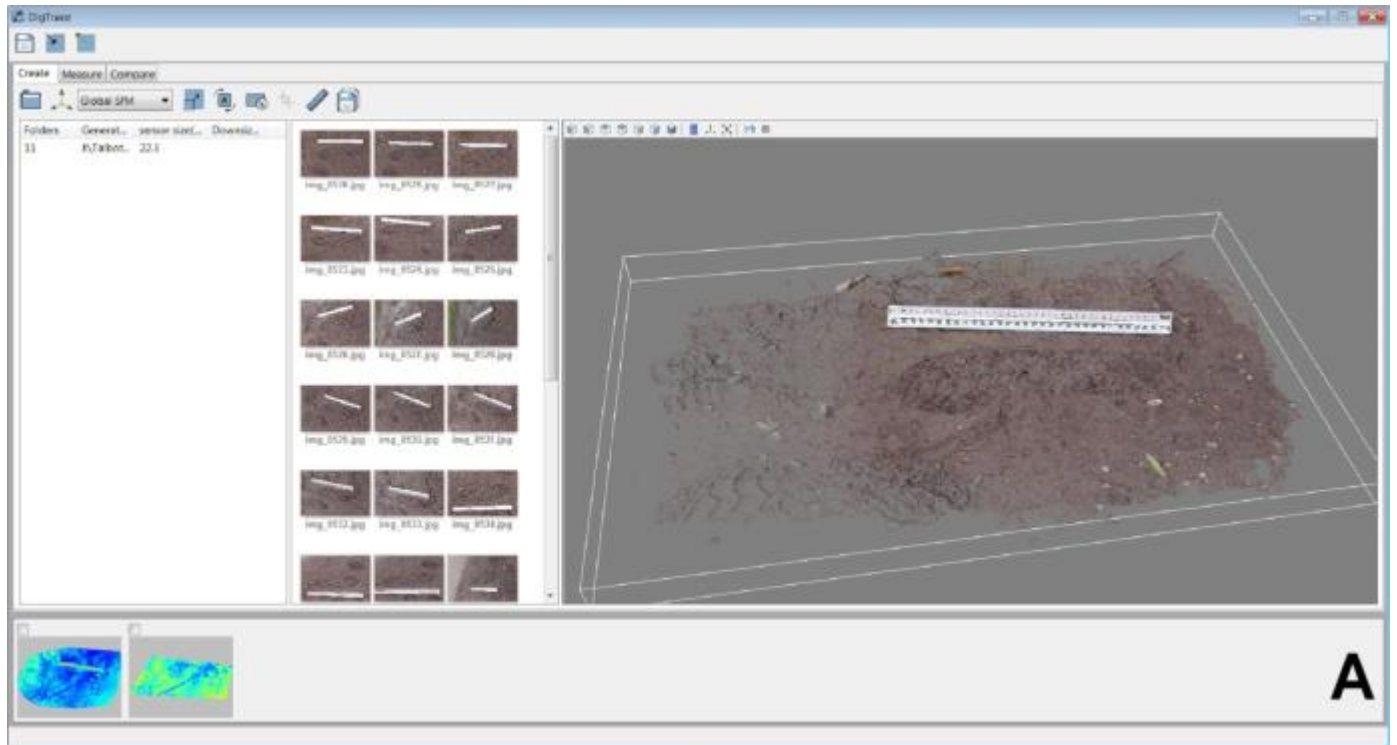


Figure 27: DigTrace model of a single track taken from a muddy path path through a set of woods. The lower panel shows a screen view of the model.

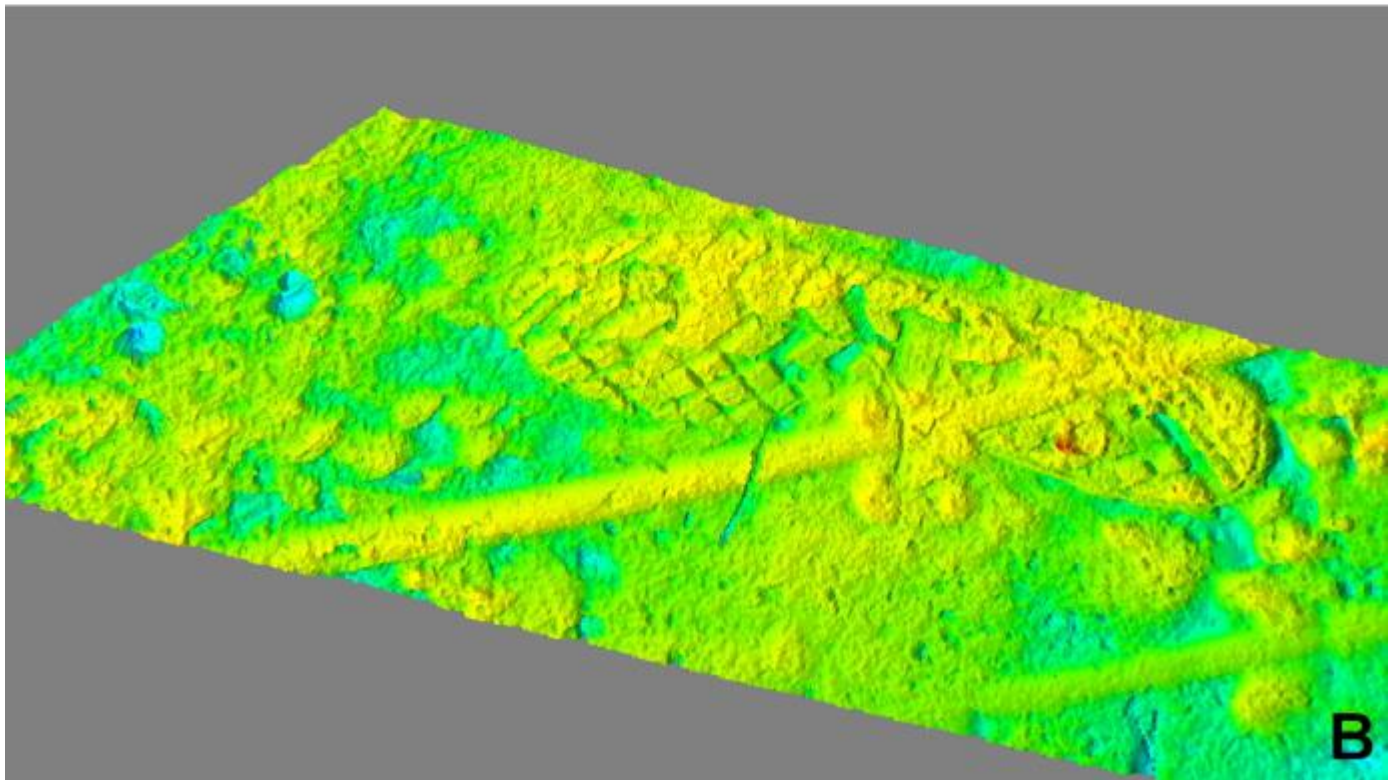
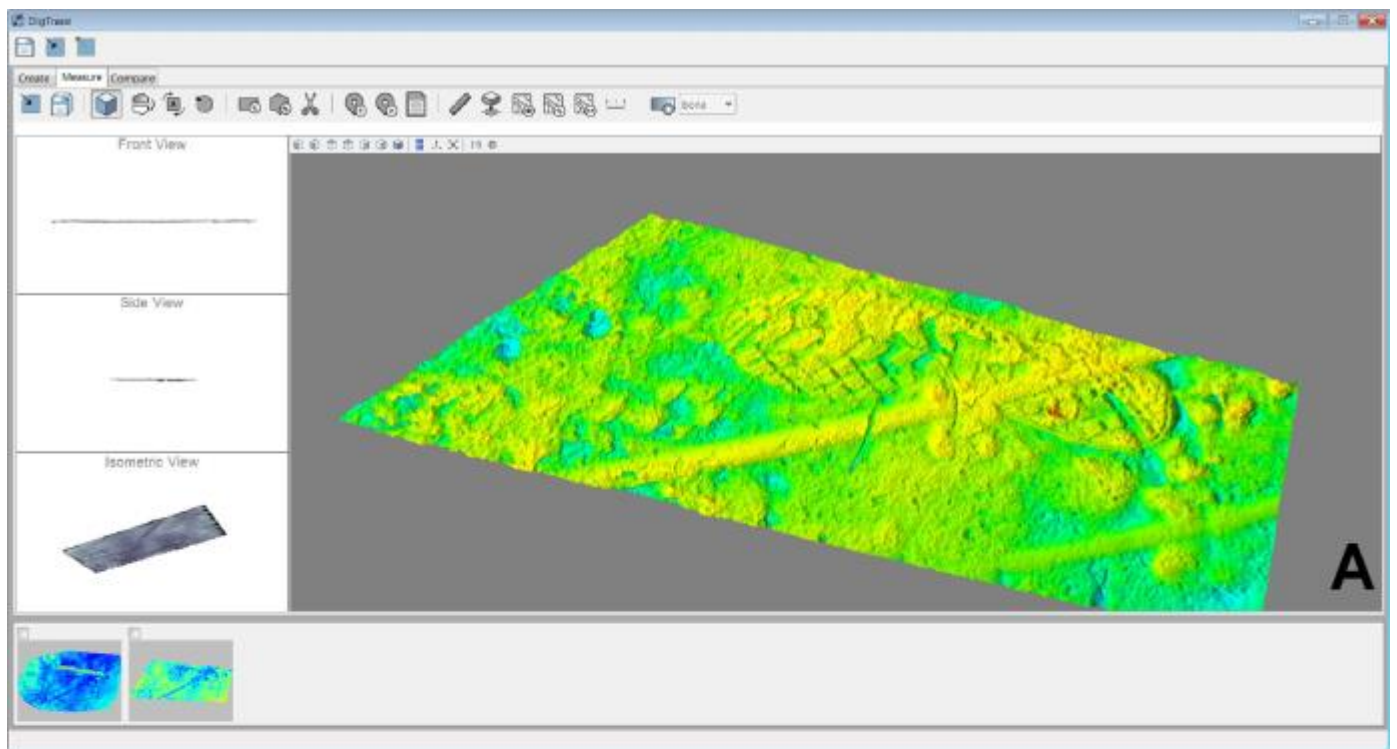


Figure 28: DigTrace model of a single track taken from a muddy path path through a set of woods. The model has now been auto-rotated, cropped and saved. The lower panel is the full scree view.

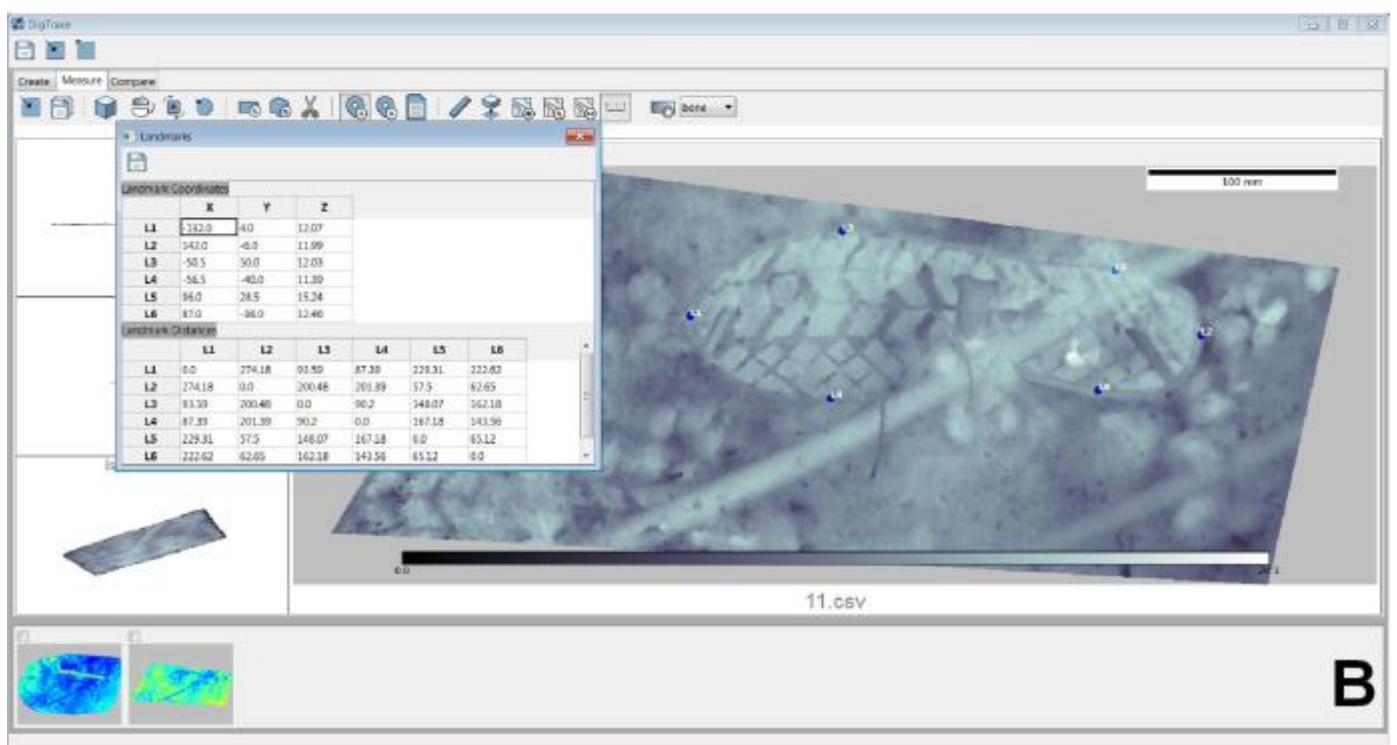
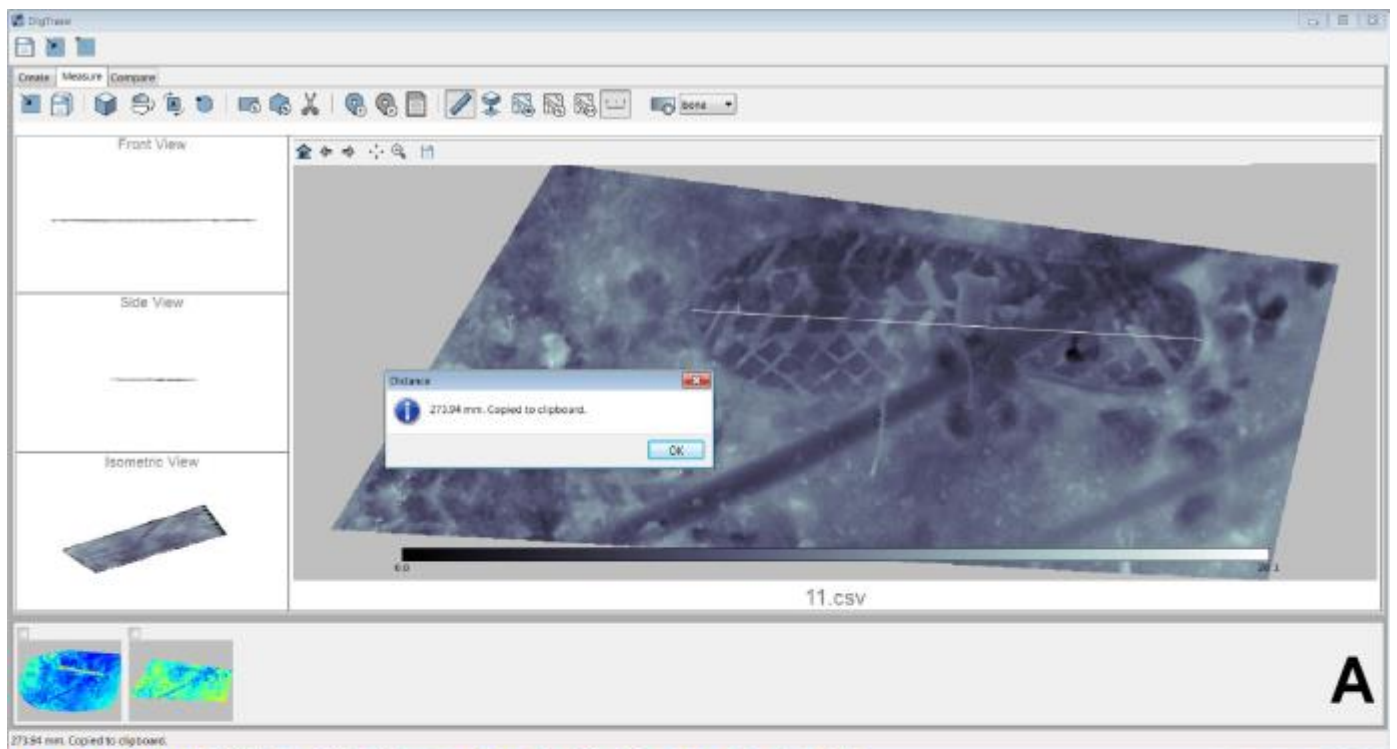


Figure 29: DigTrace model of a single track taken from a muddy path through a set of woods. The two panels shows different visualisation and measurement strategies. In the upper panel (A) the model is the same as in Figure 28, but a different colour ramp has been selected – grey. This brings out the geometry of the tread very nicely. A simple two point measurement, in this case track length, is shown with the pop-up box with the length shown. In the lower panel (B) The same colour ramp has been used but the print has been inverted so that low lying areas become raised and vica-versa. Six landmarks have been placed and the table shows the exported inter-landmark distances. This data can be saved as a csv file and is ideal when taking multiple measurements from a track.

# Appendix I: Footwear Procedures (UK)

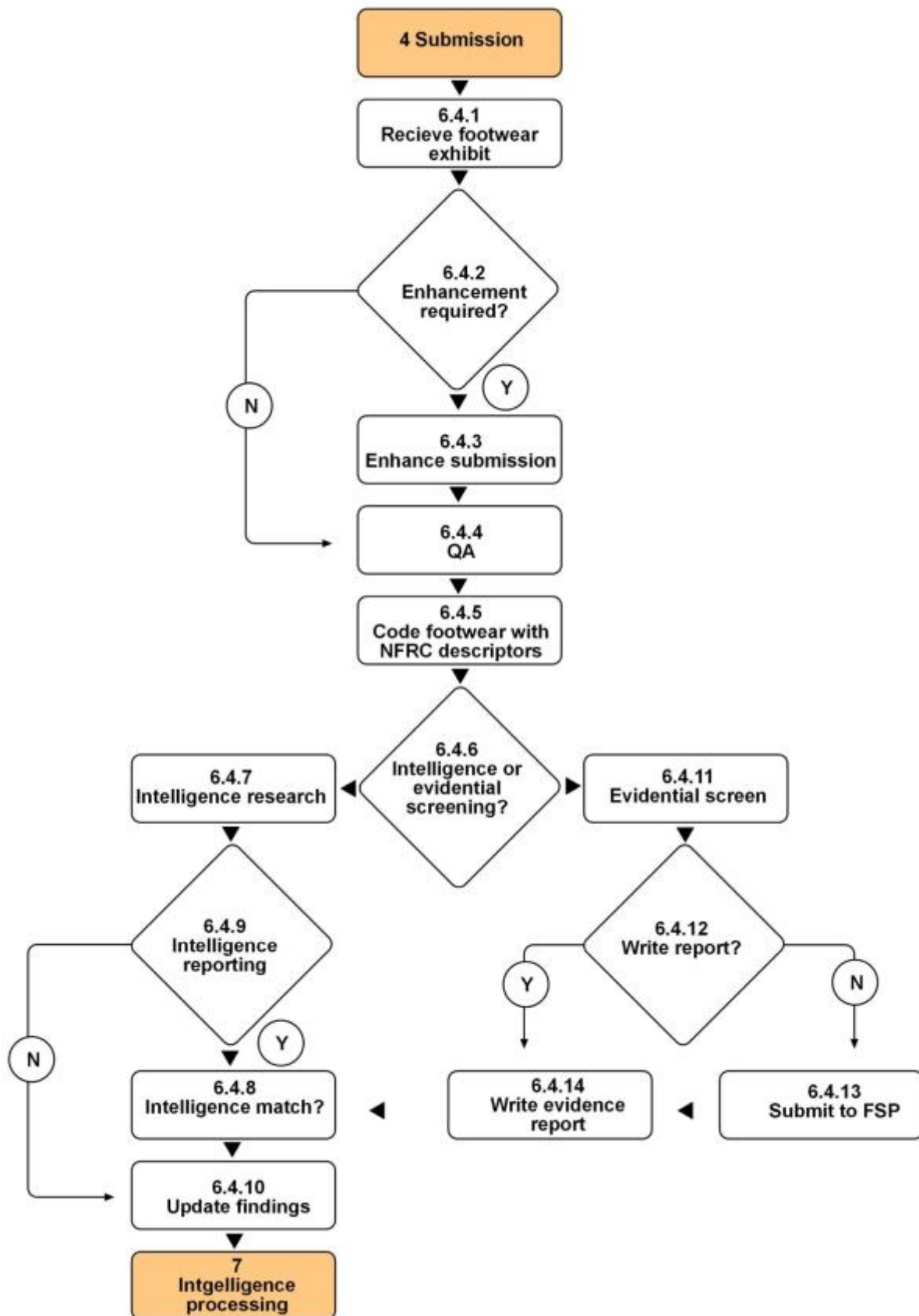


Figure A1: Process map for dealing with footwear evidence in the UK based on National Policing Improvement Agency guidelines 2007. See Table A1 or detailed description of each stage

Stage	Process/Decision
<b>6.4.1</b>	<b>Receipt</b>
6.4.1.1	Footwear staff should follow health and safety procedures at all times, particularly in respect of any contaminated item
6.4.1.2	ISO procedures should be in place and followed.
6.4.1.3	Received item, should be dated to evidence continuity.
6.4.1.4	Every item received should be correctly packaged and labelled in accordance with Force, ISO, HOSDB and NPIA guidelines to ensure continuity and integrity.
6.4.1.5	Items should be checked against all relevant documentation to ensure correct number of items is received in any particular case.
6.4.1.6	Force case management system should be updated.
6.4.1.7	Items, case managed system and documentation should be checked for any other forensic opportunities or forensic examination requests.
6.4.18	All received items must be handled and stored in accordance with current Force, ISO, HOSDB and NPIA guidelines.
<b>6.4.2</b>	<b>Enhancement Required?</b>
6.4.2.1	All marks and items should be considered for enhancement.
6.4.2.2	Crime scene marks examined and enhancement techniques considered.
6.4.2.3	If no enhancement is required proceed to Quality Assurance 6.4.4
6.4.2.4	If enhancement is required proceed to Enhancement 6.4.3
6.4.2.5	Marks and footwear items submitted for evidential screening should be enhanced to ensure that the best possible result can be achieved.
<b>6.4.3</b>	<b>Enhancement</b>
6.4.3.1	Enhancement procedures should be carried out in accordance with HOSDB guidelines.
6.4.3.2	Impressions should be taken of footwear items for intelligence or comparison purposes.
6.4.3.3	All enhancements should be documented and case management systems updated.
<b>6.4.4</b>	<b>Quality Assurance</b>
6.4.4.1	Examine and assess the suitability of all submitted items for required processes.
6.4.4.2	Items of insufficient detail for any meaningful intelligence coding or screening comparison should be filed and stored.
6.4.4.3	Documentation and case management system updated.
<b>6.4.5</b>	<b>Code Footwear</b>
6.4.5.1	All items must be coded using national (NFRC) descriptors.
6.4.5.2	Marks identified to specific footwear types must be given national (UK, National Footwear Reference Collection) code.
<b>6.4.6</b>	<b>Intelligence or Evidential Screening</b>
6.4.6.1	Submission for intelligence research continue to 6.4.7
6.4.6.2	Screening submissions proceed to 6.4.11
6.4.6.3	Items for screening should also be considered for intelligence research.
<b>6.4.7</b>	<b>Intelligence Research</b>
6.4.7.1	All marks and impressions should be searched to a user defined search criteria, for example consistent with Force policy, Crime trends and National Policy.
6.4.7.2	Crime scene marks searched, using user defined search criteria, against: <ul style="list-style-type: none"> <li>Outstanding similarly identified crime scene marks.</li> <li>Outstanding crime scene marks similarly coded.</li> <li>Other outstanding crime scene marks.</li> <li>Identified nominal impressions.</li> <li>Nominal impressions similarly coded.</li> </ul>
6.4.7.3	Crime marks case checked for: <ul style="list-style-type: none"> <li>Other forensic outcomes, in particular fingerprint and DNA.</li> <li>Forensic 'hits', i.e. fingerprint identification and DNA hits.</li> <li>Previous footwear and forensic links.</li> <li>Modus Operandi and intelligence links.</li> </ul>
6.4.7.4	Nominal impressions searched, using user defined search criteria, against: <ul style="list-style-type: none"> <li>Outstanding similarly identified crime scene marks.</li> <li>Outstanding crime scene marks similarly coded.</li> <li>Other outstanding crime scene marks.</li> </ul>
6.4.7.5	Nominal checked for:

	<ul style="list-style-type: none"> <li>Forensic hits that nominal, outstanding and previous.</li> <li>Current or previous footwear and forensic links.</li> </ul>
6.4.7.6	Forensic hits/identifications (fingerprint and DNA): <ul style="list-style-type: none"> <li>Case checked for footwear recovery.</li> <li>Identified nominal checked for footwear impressions.</li> <li>Available footwear impressions for named nominal searched against crime and outstanding marks.</li> <li>Case checked for current links.</li> </ul>
6.4.7.7	Nominal impressions linked to scene marks: <ul style="list-style-type: none"> <li>Nominal's fingerprints compared to any available outstanding finger marks in that particular case.</li> <li>Nominal's fingerprints compared to any available outstanding finger marks in any linked case.</li> </ul>
6.4.7.8	If no reportable intelligence is achieved update findings accordingly.
<b>6.4.8</b>	<b>Intelligence Match</b>
6.4.8.1	All intelligence matches should be reported 6.4.9.
6.4.8.2	If no intelligence matches are achieved then proceed to update findings 6.4.10.
<b>6.4.9</b>	<b>Intelligence Reporting</b>
6.4.9.1	The National Intelligence Model (NIM) must be used.
6.4.9.2	Intelligence produced must be in a simple and informative format.
6.4.9.3	Can be disclosed.
6.4.9.4	It should be clearly marked that it is for intelligence purposes only.
6.4.9.5	Suggested warning caveat: <i>information on footwear sole patterns and uppers is intended for intelligence use only. Please be aware that other manufactures may produce the same or similar patterns and other styles and colours may be available.</i>
6.4.9.6	Dissemination/made available to all relevant units and individuals: <ul style="list-style-type: none"> <li>Investigating officer.</li> <li>Crime scene investigators.</li> <li>Convertor units.</li> <li>Intelligence staff.</li> <li>National Operational staff.</li> <li>Forensic Departments.</li> </ul>
6.4.9.7	Intelligence and relevant management systems updated.
6.4.9.8	Intelligence produced should be tracked and resulted.
<b>6.4.11</b>	<b>Evidential Screening</b>
6.4.11.1	Review exhibits and case details
6.4.11.2	Do not proceed with screening if exhibits are required for other forensic examination.
6.4.11.3	Consider cross contamination issues.
6.4.11.4	Only trained/experienced staff should carry out screening.
6.4.11.5	Screening results should be quality assured/checked by trained staff.
6.4.11.6	Detailed paperwork should be completed for all screenings.
6.4.11.7	Crime scene marks: <ul style="list-style-type: none"> <li>Marks should be suitably enhanced.</li> <li>1:1 scale images of marks produced.</li> </ul>
6.4.11.8	Footwear items <ul style="list-style-type: none"> <li>Suitable sole impressions made to ensure best possible comparison, with reference to case details: dynamic or static.</li> <li>Produce transparencies for overlaying.</li> </ul>
6.4.11.9	Carry out manual visual comparison between sole impressions and enhanced crime scene mark images with respect to: pattern, size, wear, and damage.
<b>6.4.12</b>	<b>Write Report?</b>
6.4.12.1	Report writing should only be considered if suitable qualified staff is available.
6.4.12.2	Only accredited personal can/should produce S9 statements.
6.4.12.3	Stage reporting by non-accredited personal can be considered with CPS agreement.
6.4.12.4	Statements written by non-accredited personal can lead to footwear evidence/use being discredited.
<b>6.4.13</b>	<b>Submit to Forensic Service Provider</b>
6.4.13.1	Cases should be submitted in accordance with Force Policy.
6.4.13.2	All cases should be suitably screened before submission.
6.4.13.3	All costs free options should be exhausted.
6.4.13.4	Stage reporting should be adopted.
6.4.13.5	Suspects should be interviewed, whenever possible, about the offence before the submission is considered.
<b>6.4.11</b>	<b>Write Evidence Report</b>

6.4.11.1	Stage reporting should be considered
6.4.11.2	Level of reporting is related to experience, training and accreditation of reporting officer.
6.4.11.3	All evidential statements and reports to be independently reviewed and QA approved by suitably qualified staff.
<b>6.4.10</b>	<b>Update Findings</b>
6.4.10.1	Management systems to be updated
6.4.10.2	Intelligence systems to be updated
6.4.10.3	Rejected items: <ul style="list-style-type: none"> <li>• Documentation updated with reason for rejection.</li> <li>• Management system updated with reason for rejection</li> <li>• Items returned to relevant individual or unit for rectification, by secure means to ensure integrity and continuity.</li> </ul>
6.4.10.4	All items should be stored in accordance with current Force, HOSDB and NPIA guidelines.
6.4.10.5	Items can be destroyed in accordance with current Force policy and correctly recorded.
6.4.10.6	Items should only be returned in a secure manner which ensures integrity and continuity.
6.4.10.7	Degradable exhibits should be preserved in accordance with Force, HOSDB and NPIA guidelines, for example in a digital format.

*Table A1: Details of Process Map shown in Figure A1.*

## Appendix II: Footwear Procedures - DigTrace

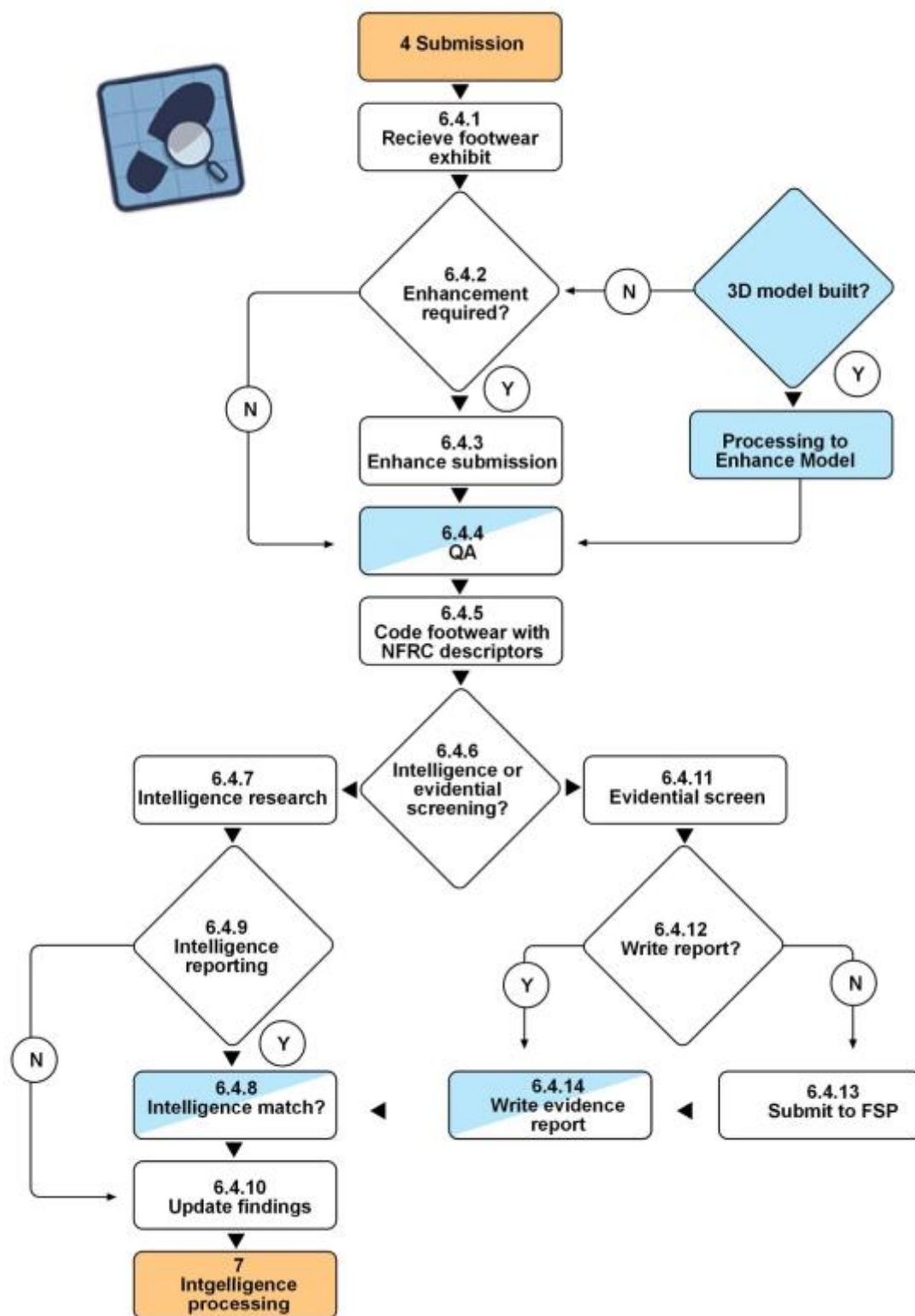


Figure A2: Process map for dealing with footwear evidence in the UK based on National Policing Improvement Agency guidelines 2007 and modified to include processing of 3D models via DigTrace. See Table A2 or detailed description of each stage.

Stage	Process/Decision
-------	------------------

<b>6.4.1</b>	<b>Receipt</b>
6.4.1.1	Footwear staff should follow health and safety procedures at all times, particularly in respect of any contaminated item.
6.4.1.2	ISO procedures should be in place and followed.
6.4.1.3	Received item, should be dated to evidence continuity.
6.4.1.4	Every item received should be correctly packaged and labelled in accordance with Force, ISO, HOSDB and NPJA guidelines to ensure continuity and integrity.
6.4.1.5	Items should be checked against all relevant documentation to ensure correct number of items is received in any particular case.
6.4.1.6	Force case management system should be updated.
6.4.1.7	Items, case managed system and documentation should be checked for any other forensic opportunities or forensic examination requests.
6.4.18	All received items must be handled and stored in accordance with current Force, ISO, HOSDB and NPJA guidelines.
	<b>DigTrace</b>
	Digital images should be assessed for 3D model creation.
	If 3D model fails proceed to 6.4.2
	If 3D model created undertake basic processing/enhancement: <ul style="list-style-type: none"> <li>• Scale, crop and auto-rotate.</li> <li>• Experiment with visualisation tools in Measure.</li> <li>• Save to files and outputs at all stages/steps.</li> </ul>
<b>6.4.2</b>	<b>Enhancement Required?</b>
6.4.2.1	All marks and items should be considered for enhancement.
6.4.2.2	Crime scene marks examined and enhancement techniques considered.
6.4.2.3	If no enhancement is required proceed to Quality Assurance 6.4.4
6.4.2.4	If enhancement is required proceed to Enhancement 6.4.3
6.4.2.5	Marks and footwear items submitted for evidential screening should be enhanced to ensure that the best possible result can be achieved.
<b>6.4.3</b>	<b>Enhancement</b>
6.4.3.1	Enhancement procedures should be carried out in accordance with HOSDB guidelines.
6.4.3.2	Impressions should be taken of footwear items for intelligence or comparison purposes.
6.4.3.3	All enhancements should be documented and case management systems updated.
<b>6.4.4</b>	<b>Quality Assurance</b>
6.4.4.1	Examine and assess the suitability of all submitted items for required processes.
6.4.4.2	Items of insufficient detail for any meaningful intelligence coding or screening comparison should be filed and stored.
6.4.4.3	Documentation and case management system updated.
	<b>DigTrace</b>
	Examine and assess the suitability of all submitted items for required processes.
	Produce a point density map for the track showing the coverage of points.
	Check accuracy of the scaling of the model by measuring distance between known points
<b>6.4.5</b>	<b>Code Footwear</b>
6.4.5.1	All items must be coded using national (NFRC) descriptors.
6.4.5.2	Marks identified to specific footwear types must be given national (UK, National Footwear Reference Collection) code.
<b>6.4.6</b>	<b>Intelligence or Evidential Screening</b>
6.4.6.1	Submission for intelligence research continue to 6.4.7
6.4.6.2	Screening submissions proceed to 6.4.11
6.4.6.3	Items for screening should also be considered for intelligence research.
<b>6.4.7</b>	<b>Intelligence Research</b>
6.4.7.1	All marks and impressions should be searched to a user defined search criteria, for example consistent with Force policy, Crime trends and National Policy.
6.4.7.2	Crime scene marks searched, using user defined search criteria, against: <ul style="list-style-type: none"> <li>• Outstanding similarly identified crime scene marks.</li> <li>• Outstanding crime scene marks similarly coded.</li> <li>• Other outstanding crime scene marks.</li> <li>• Identified nominal impressions.</li> <li>• Nominal impressions similarly coded.</li> </ul>
6.4.7.3	Crime marks case checked for: <ul style="list-style-type: none"> <li>• Other forensic outcomes, in particular fingerprint and DNA.</li> <li>• Forensic 'hits', i.e. fingerprint identification and DNA hits.</li> </ul>

	<ul style="list-style-type: none"> <li>• Previous footwear and forensic links.</li> <li>• Modus Operandi and intelligence links.</li> </ul>
6.4.7.4	Nominal impressions searched, using user defined search criteria, against: <ul style="list-style-type: none"> <li>• Outstanding similarly identified crime scene marks.</li> <li>• Outstanding crime scene marks similarly coded.</li> <li>• Other outstanding crime scene marks.</li> </ul>
6.4.7.5	Nominal checked for: <ul style="list-style-type: none"> <li>• Forensic hits that nominal, outstanding and previous.</li> <li>• Current or previous footwear and forensic links.</li> </ul>
6.4.7.6	Forensic hits/identifications (fingerprint and DNA): <ul style="list-style-type: none"> <li>• Case checked for footwear recovery.</li> <li>• Identified nominal checked for footwear impressions.</li> <li>• Available footwear impressions for named nominal searched against crime and outstanding marks.</li> <li>• Case checked for current links.</li> </ul>
6.4.7.7	Nominal impressions linked to scene marks: <ul style="list-style-type: none"> <li>• Nominal's fingerprints compared to any available outstanding finger marks in that particular case.</li> <li>• Nominal's fingerprints compared to any available outstanding finger marks in any linked case.</li> </ul>
6.4.7.8	If no reportable intelligence is achieved update findings accordingly.
	<b>DigTrace</b>
	Use Compare Workbench to co-register multiple 3D models at a scene and seek statistical similarities or differences.
	Use Compare Workbench to co-register a nominal's footwear to one or more 3D models at the scene
<b>6.4.8</b>	<b>Intelligence Match</b>
6.4.8.1	All intelligence matches should be reported 6.4.9.
6.4.8.2	If no intelligence matches are achieved then proceed to update findings 6.4.10.
<b>6.4.9</b>	<b>Intelligence Reporting</b>
6.4.9.1	The National Intelligence Model (NIM) must be used.
6.4.9.2	Intelligence produced must be in a simple and informative format.
6.4.9.3	Can be disclosed.
6.4.9.4	It should be clearly marked that it is for intelligence purposes only.
6.4.9.5	Suggested warning caveat: <i>information on footwear sole patterns and uppers is intended for intelligence use only. Please be aware that other manufactures may produce the same or similar patterns and other styles and colours may be available.</i>
6.4.9.6	Dissemination/made available to all relevant units and individuals: <ul style="list-style-type: none"> <li>• Investigating officer.</li> <li>• Crime scene investigators.</li> <li>• Converter units.</li> <li>• Intelligence staff.</li> <li>• National Operational staff.</li> <li>• Forensic Departments.</li> </ul>
6.4.9.7	Intelligence and relevant management systems updated.
6.4.9.8	Intelligence produced should be tracked and resulted.
	<b>DigTrace</b>
	Disseminate/make 3D models available to relevant units and individuals
<b>6.4.11</b>	<b>Evidential Screening</b>
6.4.11.1	Review exhibits and case details
6.4.11.2	Do not proceed with screening if exhibits are required for other forensic examination.
6.4.11.3	Consider cross contamination issues.
6.4.11.4	Only trained/experienced staff should carry out screening.
6.4.11.5	Screening results should be quality assured/checked by trained staff.
6.4.11.6	Detailed paperwork should be completed for all screenings.
6.4.11.7	Crime scene marks: <ul style="list-style-type: none"> <li>• Marks should be suitably enhanced.</li> <li>• 1:1 scale images of marks produced.</li> </ul>
6.4.11.8	Footwear items <ul style="list-style-type: none"> <li>• Suitable sole impressions made to ensure best possible comparison, with reference to case details: dynamic or static.</li> <li>• Produce transparencies for overlaying.</li> </ul>
6.4.11.9	Carry out manual visual comparison between sole impressions and enhanced crime scene mark images with respect to: pattern, size, wear, and damage.

		<b>DigTrace</b>
		Enhance marks and prepare digital images which display the feature of interest.
		Output 1:1 images
		Carry out manual visual comparison between sole impressions and enhanced crime scene mark images with respect to: pattern, size, wear, and damage. Produce direct measurements for statistical comparison.
		Create 3D models of any relevant sole impressions.
		Use Compare Workbench to co-register a sole impression to footwear to one or more 3D models at the scene.
<b>6.4.12</b>		<b>Write Report?</b>
	6.4.12.1	Report writing should only be considered if suitable qualified staff is available.
	6.4.12.2	Only accredited personal can/should produce S9 statements.
	6.4.12.3	Stage reporting by non-accredited personal can be considered with CPS agreement.
	6.4.12.4	Statements written by non-accredited personal can lead to footwear evidence/use being discredited.
<b>6.4.13</b>		<b>Submit to Forensic Service Provider</b>
	6.4.13.1	Cases should be submitted in accordance with Force Policy.
	6.4.13.2	All cases should be suitably screened before submission.
	6.4.13.3	All costs free options should be exhausted.
	6.4.13.4	Stage reporting should be adopted.
	6.4.13.5	Suspects should be interviewed, whenever possible, about the offence before the submission is considered.
		<b>DigTrace</b>
		Pass 3D model and Project Zip files to 3D analyst for specialist examination.
<b>6.4.11</b>		<b>Write Evidence Report</b>
	6.4.11.1	Stage reporting should be considered
	6.4.11.2	Level of reporting is related to experience, training and accreditation of reporting officer.
	6.4.11.3	All evidential statements and reports to be independently reviewed and QA approved by suitably qualified staff.
		<b>DigTrace</b>
		Produce images and data for report from 3D models and comparisons.
<b>6.4.10</b>		<b>Update Findings</b>
	6.4.10.1	Management systems to be updated
	6.4.10.2	Intelligence systems to be updated
	6.4.10.3	Rejected items: <ul style="list-style-type: none"> <li>• Documentation updated with reason for rejection.</li> <li>• Management system updated with reason for rejection</li> <li>• Items returned to relevant individual or unit for rectification, by secure means to ensure integrity and continuity.</li> </ul>
	6.4.10.4	All items should be stored in accordance with current Force, HOSDB and NPIA guidelines.
	6.4.10.5	Items can be destroyed in accordance with current Force policy and correctly recorded.
	6.4.10.6	Items should only be returned in a secure manner which ensures integrity and continuity.
	6.4.10.7	Degradable exhibits should be preserved in accordance with Force, HOSDB and NPIA guidelines, for example in a digital format.

Table A2: Details of Process Map shown in Figure A2 modified to include use of DigTrace.

# Appendix III: DigTrace Licence

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Developed by: Bournemouth University  
<Institute for Studies in Landscape and Human Evolution>

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# Appendix IV: Data Templates

## DigTrace Pro

### Custody Log

### Data Collection Sheet

[www.digtrace.co.uk](http://www.digtrace.co.uk)



<b>Project Name</b>	Click here to enter text.
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<b>Field Location:</b>	Click here to enter text.
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<b>Time:</b>	Click here to enter text.
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<b>Notes:</b>	Click here to enter text.
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# DigTrace Pro

## Custody Log

### 3D Model Sheet

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# DigTrace Pro

## Custody Log

### *3D Model Processing Log*

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## Project Name

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