3D-FORENSICS - MOBILE HIGH-RESOLUTION 3D SCANNER AND 3D DATA ANALYSIS FOR FORENSIC EVIDENCE

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3D-Forensics - Mobile high-resolution 3D-Scanner and 3D data analysis for forensic evidence

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Abstract

This paper presents the 3D-Forensics project to develop a mobile high-resolution 3D scanning system for the recovery and analysis of footwear and tyre impression trace evidence left at crime scenes halfway through the project's duration.

Keywords: Forensic evidence, crime scenes, footwear impressions, tyre impressions, forensic intelligence, fringe projection, structured-light 3D scanner, handheld scanner.

1 INTRODUCTION

1.1 Footwear and tyre impression traces at "High Volume Crimes"

Table 1 provides an indication of the diversity of traces at "High Volume Crime" (HVC) scenes in the region of Zeeland in the Netherlands collected by the Politie Zeeland-West-Brabant. The figures have been collected since 2010 and each year they have been approximately the same. In HVCs there is mostly material damage with strong emotional effects, e.g. burglary and car crime. Compared to "Severe Crimes", which cover crimes with dead or seriously injured people, HVC happen much more frequently. The investigation teams get a lot less budget and time to investigate and analyse the crimes. Footwear and tyre impressions are one of the most frequent trace types at HVC.

Table 1: Diversity of traces at HVC from 2010 in region Zeeland (The Netherlands)

Trace type	Frequency [%]
Biological	10.38
Dactyloscopical	2.26
Gloves	5.54
Clothing	0.04
Microsopic traces (fibers / glass / …)	28.22
Digital Recordings (surveillance cameras, etc.)	0.16
Footwear and tyre impressions	22.91
Toolmarks	30.48

The research project 3D-Forensics focuses on footwear and tyre impressions found at “High Volume Crimes”. Footwear and tyre impressions left at crime scenes are important evidence for both criminal investigations and proceedings in court. The common operational methodology to record these impressions is through the making of plaster casts. Plaster casts have many disadvantages, including the amount of time required to make them and the need to remove other trace artefacts (Fig. 1 and Table 2) before casting. In fact tyre impressions are used for prosecution in only a small amount of cases compared to footwear impressions. This does not mean that there are not a lot of tyre traces but rather that they have not been recorded because of the tedious way to collect them.

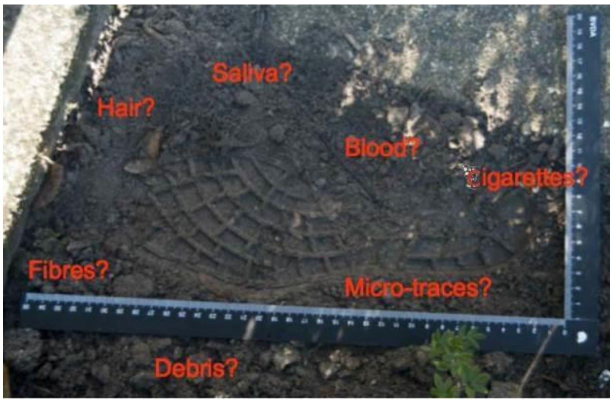

Fig. 1: Cast of a footwear impression (left) and other traces that do not need removal to be conserved before recording impression if contactless 3D scanning used (right)

1.2 Objectives of 3D-Forensics

3D-Forensics has objectives to both improve the workflow of capturing and also analysing footwear and tyre impressions left at crime scenes. The specific workflow from crime scene to court has been built into the design of the system. 3D-Forensics’ data capturing methodology is based on optical 3D scanning by projection of fringe patterns onto a surface implemented in a compact, handheld scanner device for direct use at crime scenes. This provides for contactless 3D measurement, no trace contamination, µm-accurate digital 3D-data in high resolution and fast data acquisition in some seconds. The scanner is being combined with new analysis tools that support the determination of class and identification characteristics of footwear and tyre impressions out of the digital 3D data.

Table 2: Benefits of 3D-Forensics v classic method for collection and analysis of footwear and tyre impressions

Classic method	3D-Forenscis
• Time up to 1,5 hour on scene • Multiple processes at the impression • Choose priority of technique • Influence of weather • Storage of evidence • Transport (fragile) • Selection because of amount of work • Dirty • All work done by expert	• Time (2…3 sec) on scene • Non-destructive & No contamination • More evidence because of easiness = more identifications • Clean • Almost no influence of weather • Digital storage • Pre-selection evidence • Evidence can be sent digitally and even printed by 3D printer • Forensic intelligence

The project started in May 2013 and runs until April 2015. At the time of writing the project has reached approximately the halfway point. In what follows we present the overall approach and initial results. In the second half of the project prototypes will be built-up and tested in the field with users from within the forensic police and other forensic experts within the consortium.

2 TECHNICAL METHODOLOGY OF 3D-FORENSICS

2.1 Handheld 3D-Scanner for capturing footwear and tire impressions at crime scenes

The capturing of footwear and tyre impressions directly at crime scenes requires a 3D scanning system that can be used quickly and easily in an outdoor environment. The measuring principle of stereo camera fringe projection is a suitable technique [1]. Several millions of 3D-points are measured in one scan within a fraction of a second. Such a 3D scanning system consists basically of two cameras acquiring images of the object from a slightly different angle, a projector to illuminate the object with fringe patterns and a processing unit to calculate the 3D point cloud out of the camera images. The simple setup gives the potential to fit all components into a compact sensor head, which can be used as easily as a digital photo apparatus. Preliminary knowledge about handheld 3D scanning devices was provided to 3D-Forensics by results from the "kolibri Cordless" 3D-scanner from Fraunhofer IOF (Fig. 2) [2].

Fig. 2: Handheld 3D-Scanner "kolibri Cordless" for outdoor data capturing

The 3D-Forensics sensor specifications were designed by the multi-disciplinary consortium to ensure the best trade-off between user requests and technological possibilities within the project. A design has been agreed which the user representatives in the consortium are confident will be welcomed by the crime scene forensic community.

The field of view of the 3D-sensor is 325 x 200 mm² at a local resolution of 0.17 mm. Thus a footwear impression can be scanned in one "shot" in a level of detail that is comparable to a high resolved photo, but with 3D information (Fig. 3). Larger traces, such as tyre tracks, can be measured in several overlapping patches. A simple alignment procedure is developed to merge the patches into a large 3D point cloud.

The scanner equipment is being developed as a complete system with integrated processing unit and including a battery. The sensor head includes all the components for 3D scanning. Its weight will be between 2 to 3 kg and the size comparable to the "kolibri Cordless" device (Fig. 2).

In the field the user will be able to start-up the system within a few minutes. The sensor head is positioned by hand or by tripod over the trace. Two laser pointers will guide the user to keep the sensor in the optimal working distance. The user will get additional feedback from the live image of the cameras and will be able to set optimal brightness settings for the underground. The scan will be started by a button directly on the sensor head. The acquisition of the fringe image will last 0.1…0.5 sec, depending on the brightness and accuracy settings. The post processing of the acquired data to the 3D point cloud will last approximately 3 seconds. The result will be given to the user in a preview and the scanner will be ready for further scans immediately. After the evidence recovery at the crime scene the user will transfer and import the measurement data into dedicated analysis software.

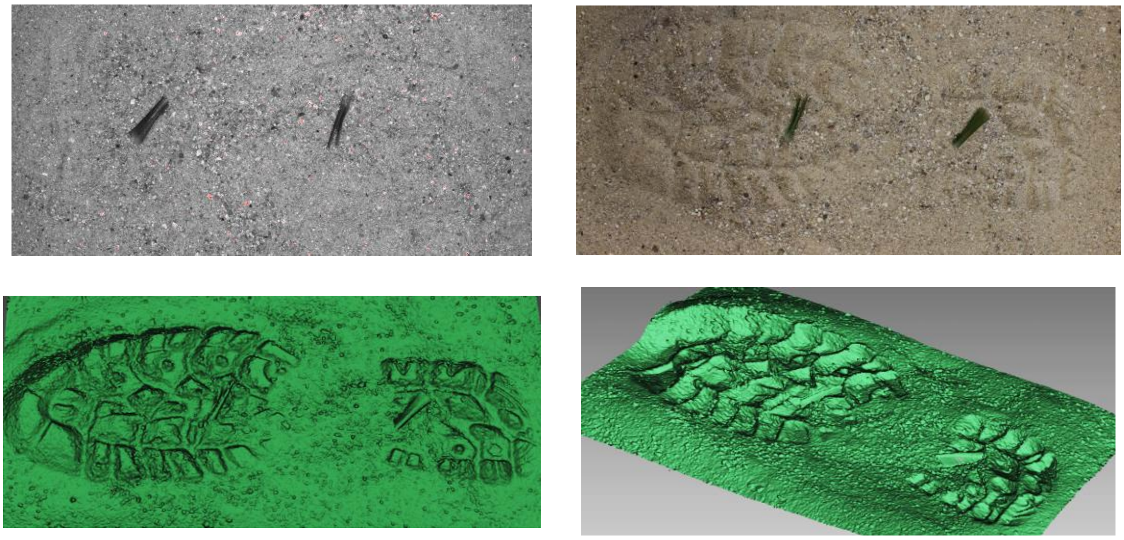

Fig. 3: Grey, colour photo and 3D scan of a footwear impression in sand

The 3D-scanner will be expandable by a dedicated photo apparatus attached on top of the 3D-scanner to acquire true-colour information for the 3D point cloud. While performing a scan the photo apparatus will capture a calibrated photo of the footwear or tyre impression in a similar field and resolution as the 3D sensor. The colour will be mapped post process onto the point cloud. The additional colour information is useful to recognize distortions in the impression, e.g. leafs or twigs, or to detect 2D texture marks, which are not visible in a solely 3D-scan.

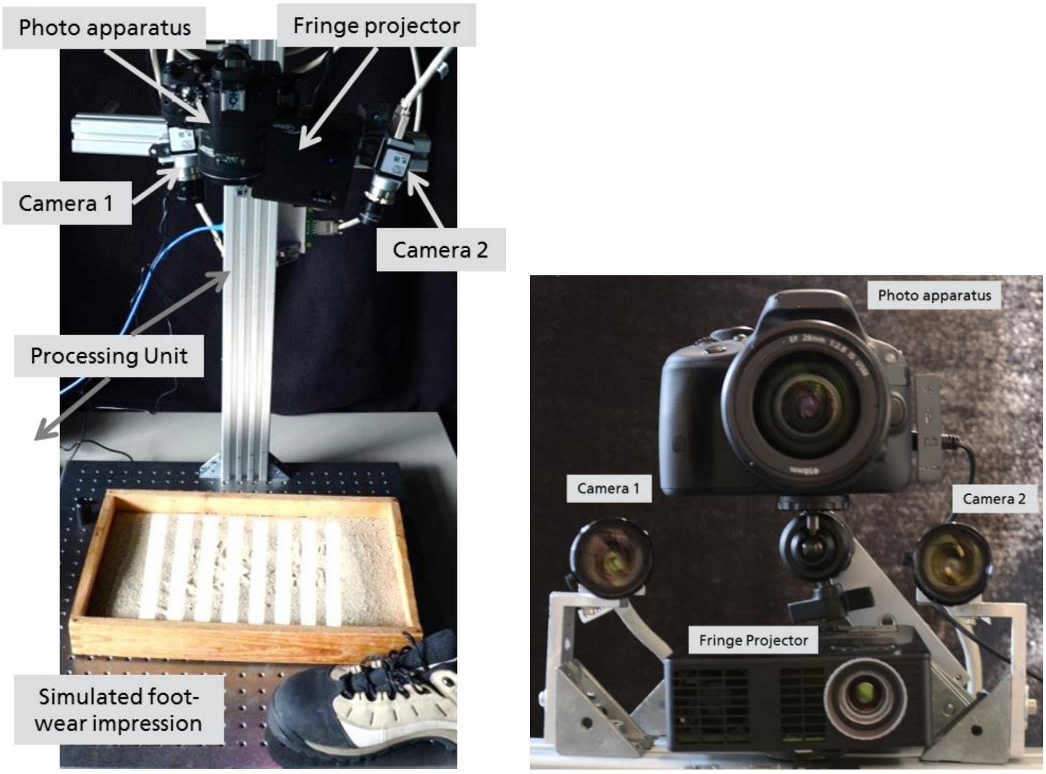

Fig. 4: Laboratory realization of the new 3D-Forensics handheld scanning system

In the actual project status the new 3D-scanner is realized as a laboratory setup (Fig. 4). The setup consists of all 3D scanning components as well as the attachable photo apparatus for true-colour acquisition. Footwear impressions are simulated by using a sand box. The laboratory setup is used to prepare the building up of the first prototype of the system.

2.2 3D data analysis and processing

After the field activity, 3D data and calibrated 2D colour images collected with the sensor need to be processed and analysed to be used in the investigation and prosecution of crime. Specific software for 3D-data analysis is designed to be used by the investigator in the office, after the acquisition at the crime scene (Fig. 5).

The software provides a workflow in line with the methodologies used by the investigators to collect information of “3D traces” with depth information that can appear in snow and different types of soil, possibly distorted by leaves and twigs or “2D flat impressions” and dust prints that can appear on all kinds of material: shiny stainless steel, mirrors, glass, cloth, human skin, blood, etc.

At present, investigators process and analyse data collected through plaster casting or foam with different tools and different procedures. Results are digitally available only to a small extent. The procedures will be unified in a single software platform and immediately digitally analysed and stored with the new 3D-Forensic system.

3D data and 2D colour images will be safely stored in an organized project structure during the field acquisition. An impression will be collected in one or more scans; in fact if the impression size is larger than the scanner field of view, more scans are required. For each crime scene ancillary data will be inserted (operator, location, case identification code); and a well identified and documented “project” will be passed to the analysis software for the next steps.

The first software processing step is data importing which implies also the calculation of points' local, normal and quality values (pre-processing phase) which immediately improves the visual quality of the data. The calibrated colour images are also imported and correctly overlapped with the 3D data. The high resolution colour images add an additional information layer to the 3D point cloud; the image can be acquired with different light sources to emphasize the details not immediately visible in the trace. The image is also fundamental to retrieve traces on hard surfaces where evidence is only 2D, but a perfectly scaled image of the trace is captured with the digital camera.

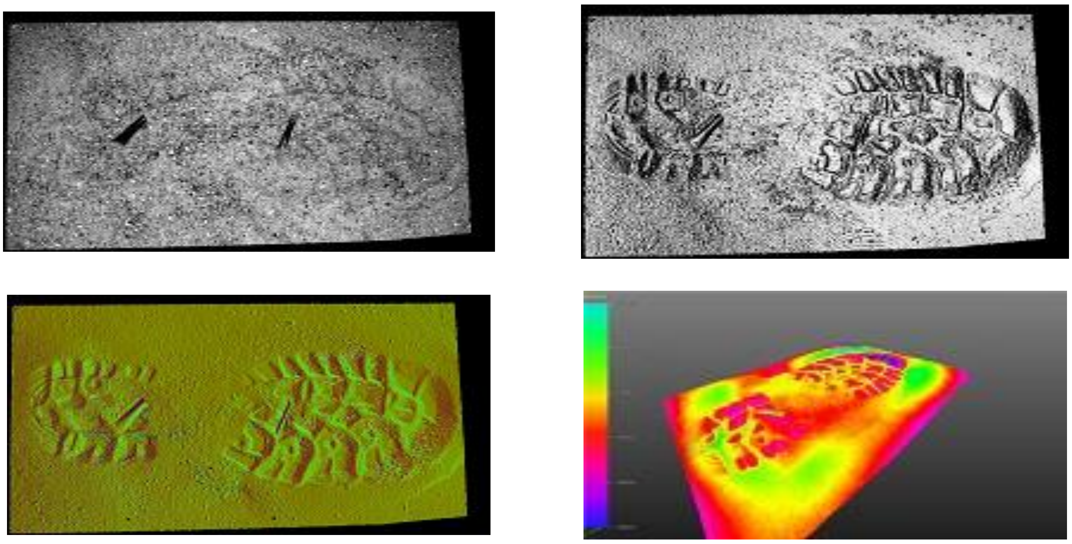

Fig. 5: Impressions of 3D-Forensics analysis software: raw data scan (top left), improved impression visualisation (top right and bottom left), 3D view with depth real-time analysis (bottom right)

If the impression is divided in more scans, the user runs a two-step procedure to stitch the scans together in a single point cloud. The procedure consists in a first step where the user has to select the approximate position of three corresponding points visible in the overlapping area within the two scans composing the impression. The two scans are set close to each other with the calculated rotation and translation. In a second step, an automatic best fitting procedure aligns the two scans in a single point cloud. The alignment is not required when the impression is included in a single scan.

The imported, pre-processed and (optionally) aligned scans are immediately visible and measurable in 3D; the experts can now start to identify and characterise the impression. Two specific tools are designed to support the investigator in the "class characteristics" and "individual characteristics" identifications.

Class characteristic consists in the identification of type and size of the impression. At the moment there are archives available of 2D prints that can be used as reference for the comparison with the measured 3D data. A software tool allows correct scaling, positioning and overlapping of the imported 2D print (a raster image) over the measured point cloud, supporting the experts to univocally assign type and size.

After this first classification a deeper analysis is required to extract "individual characteristics" visible as features that occurred randomly on a footwear outsole or tyre tread. Examples of individual characteristics include cuts, scratches, tears, holes, stone holds, abrasions and the acquisition of debris from random events. The position, orientation, size and shape of individual characteristics contribute to the uniqueness of a footwear outsole or tyre tread. For detecting these features, the investigator is supported by software tools that allow fixing different views with shaders which emphasise small details. Over the extracted views the user can digitise polylines fully measurable and stored as “individual characteristics”.

Both “class characteristics” and “individual characteristics” are archived in the software in an internal database that supports investigators for searching impressions with similarities. This searching functionality is for increasing forensic intelligence.

2.3 Forensic Intelligence

In addition to comparing footwear and tyre impression traces from crime scenes with footwear and tyres that have been recovered from specific suspects, it is possible to compare impression traces from different crime scenes and to make links. Usually this is done before there even is a suspect. Different traces and other information from different crime scenes are already being compared. The aim is to match several suspects/footwear/tyres present at different crime scenes by comparing all the traces found at these crime scenes at an early stage. Forensic intelligence also combines other traces. If a suspect is arrested later and that suspect can be matched to the series of crimes it is a significant benefit for solving crime and using resources efficiently.

The 3D-Forensics system will be an important tool for forensic intelligence as it will enable an increase in the collection of footwear and tyre impressions. The scanning of footwear impressions and especially of tyre traces will be much easier and faster than casting. The data will be available digitally and thus more accessible for comparison and reference.

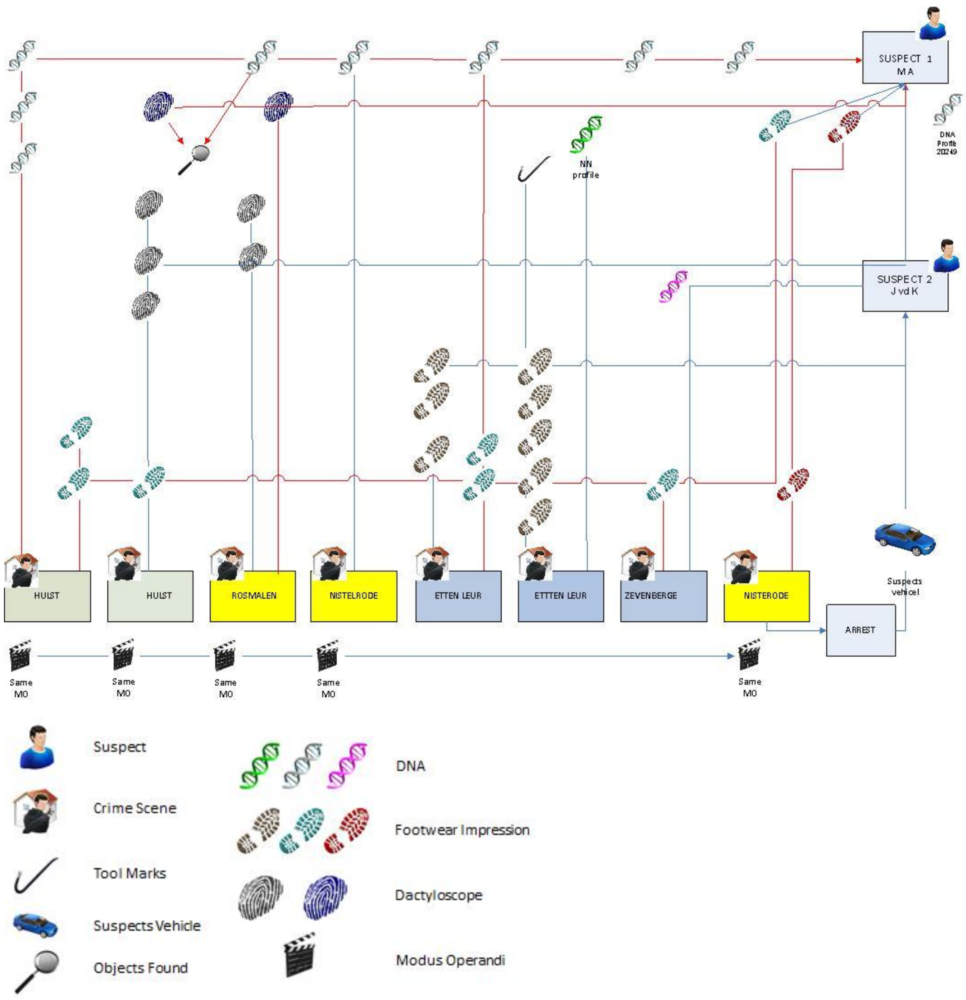

Fig. 6: Example for the application of forensic intelligence and legend

3 SUMMARY

3D-Forensics is developing a mobile high-resolution 3D scanning system for forensic evidence recovery at crime scenes, specifically for footwear and tyre impressions. Footwear and tyre impressions as well as profiles will be recorded and analysed in 3D and colour enabled through optical scanning technology. 3D data analysis and processing software tools are being developed for both the investigation and prosecution of crime. The scanner and its connected workflow promises many benefits compared to classical techniques to record and analyse footwear and tyre impressions. The digital data will provide increased accessibility for forensic intelligence methods. At the time of writing a laboratory realisation is available and initial analysis software. In the next stage of the project prototypes will be built-up and tested in the field with users from within the forensic police and other forensic experts within the consortium.

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