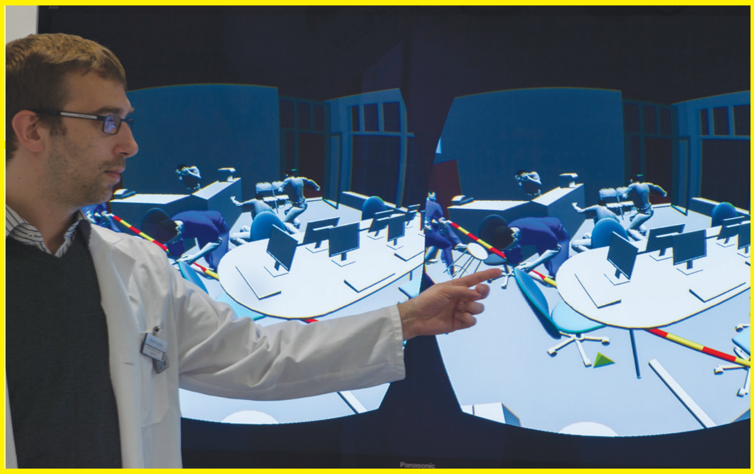
Transforming the work of forensic pathologists, the Virtopsy project is a suite of non-invasive imaging techniques that is revolutionising police investigations in both the living and the dead. By **Louise Murray**



Could crime scene reconstruction and virtopsies change the forensic world?

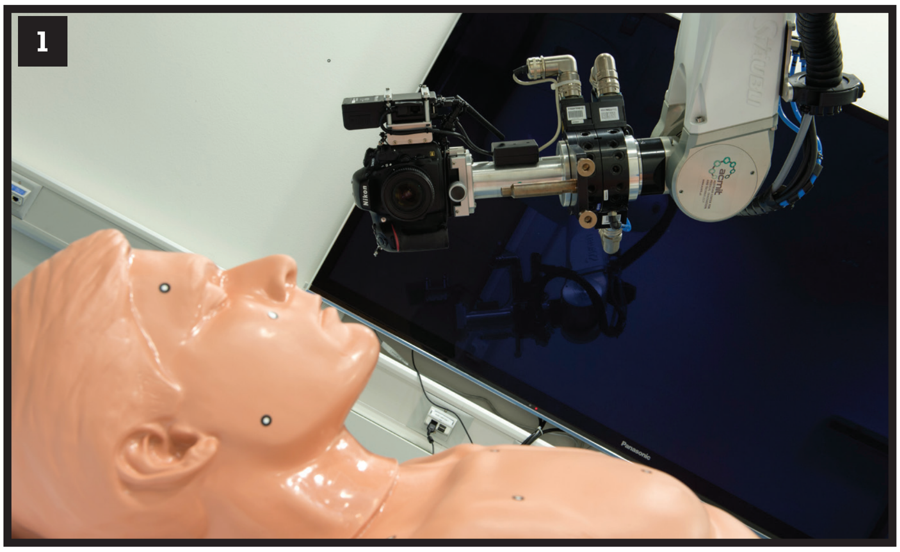
VIRTOPSY the future of forensics

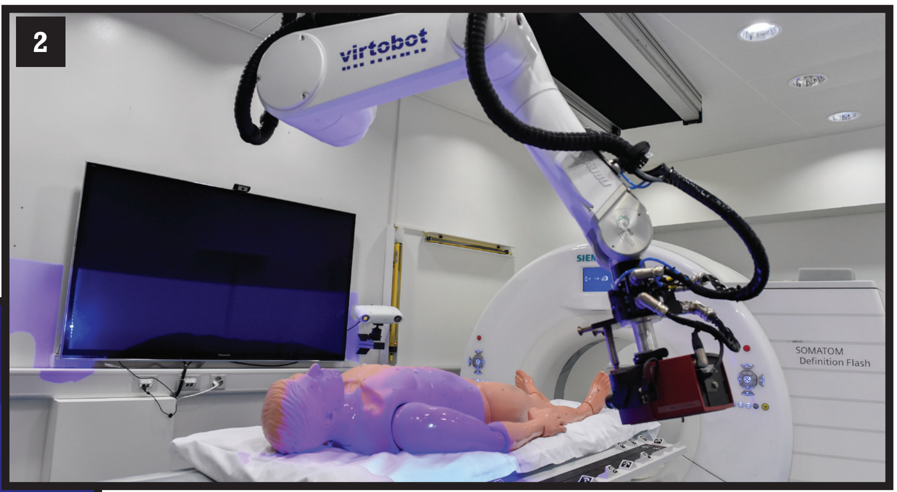
LOUISE MURRAY

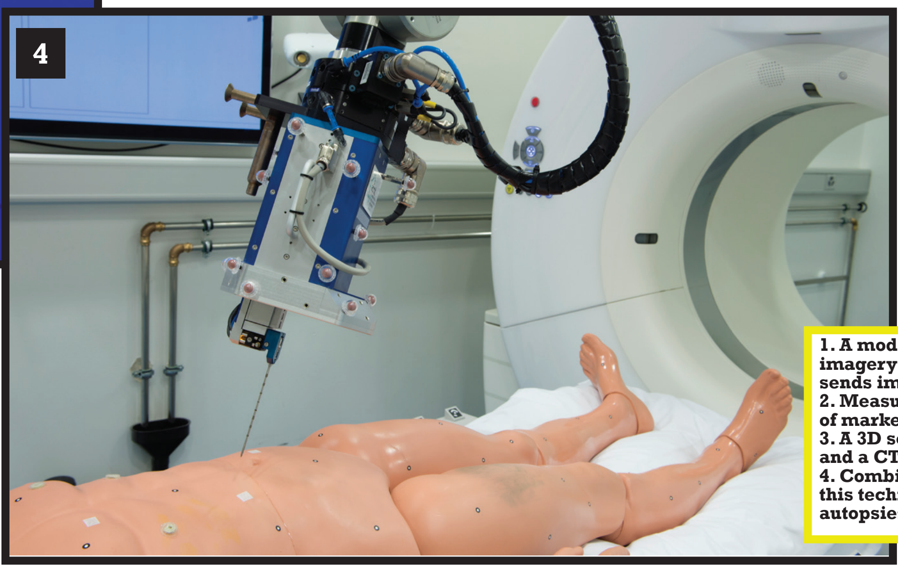
THE SLEEPING BEAUTY of forensic science is forensic pathology – post-mortem examination to determine the cause of a death. While there have been groundbreaking innovations in the fields of DNA analysis and toxicology in recent years, most forensic pathologists continue to rely on techniques developed in the 19th century or even earlier. Their day-to-day work differs little from that of their medieval predecessors – dissecting corpses in a basement morgue and writing reports of the findings. That may be about to change.

A quiet revolution is happening in Switzerland, where visionary forensic scientists have joined forces with engineers, radiologists, computer scientists and roboticists to integrate the latest developments in 3D imagery and radiological medical scanning – CT and MRI – and apply them to the understanding of death and its causes. This is the Virtopsy project.

Virtual autopsy or digital autopsy is a non-invasive attempt to answer the questions that would normally require a conventional autopsy. The digital autopsy can also help in cases where religious faith may make a







conventional dissection difficult.

The co-founder of the project, Professor Michael Thali of the Zurich-based Institute for Forensic Medicine and Imaging, explains: "We bridge forensic science and radiology, which has brought about the new field of forensic imaging. Virtopsy can act as a triage system for full scalpel autopsies, making many unnecessary. It can also up-skill the pathologists by allowing them to spend more time on analysis and interpretation rather than dissection and recording.

"We are also proud that Virtopsy results are now accepted within the Swiss court system," Thali adds. Ten per cent of all conventional autopsies in Zurich are now cancelled as the cause of death is evident from Virtopsy scanning alone. The system has also detected three additional murder cases from strangulation that had not been flagged by an autopsy.

Virtual autopsy tools

The first step in a virtual autopsy procedure is to photograph and scan the outer surface of the body. Markers placed at specific points on the skin will later be used to integrate and align the results from surface and interior CT or MRI scans.

The Virtobot is a modified automotive robotic arm that has three tools: a Nikon D800 camera with a wireless transmitter, which shoots surface images of the body – front and back from pre-programmed positions – and will pick up any injuries present on the skin surface.

Next, a 3D scanner, which uses blue light to record the surface topography, creating a digital and permanent version of the body that can later be animated or placed in a 3D crime scene reconstruction when combined with CT scan data. This will also map surface wounds, which will be photographed manually at 1:1 or greater magnification. The 3D scanner was originally developed in the automotive industry for accurate quality-control measurements.

The final tool is a biopsy needle for taking precise tissue samples, but this is only deployed if required after a CT scan and if the pathologist deems it necessary. All this can be done without exposing pathologists to harmful radiation or bodily contaminants. "Virtopsy removes the element of subjectivity," adds Thali. "You no longer have to rely on the judgment of a single pathologist as the data set can be reviewed by anyone, anywhere in the world."

The CT scan is the most common form of forensic imaging used worldwide and takes place at the Zurich Institute after surface photography and scanning. It forms a permanent record of the corpse by >

1. A modified industrial robot makes comprehensive digital imagery of a body using a mounted Nikon D800 camera, which sends images wirelessly to the operator.
2. Measurements and positioning are aided by the placement of markers on the 'corpse'.
3. A 3D scanner using blue light completes the surface imaging and a CT-guided biposy needle takes invasive samples.
4. Combined with a full CT scan and postmortem angiography, this technology can act as a triage system for conventional autopsies, rendering many of them unnecessary.

Left: 3D-printed reconstruction of a fractured skull shows the force of the blow. These reconstructions in plastic can be passed around a courtroom and examined by members of the court.

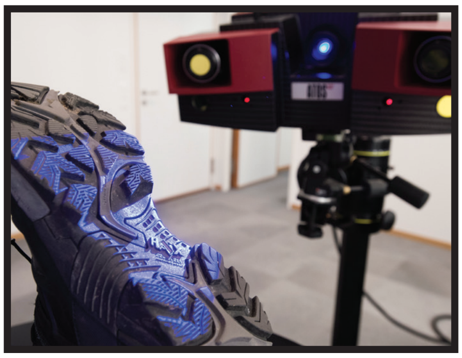
Right: Full 3D body scanning stage at the Institute of Forensic Medicine in Zurich. The stage has 64 Canon EOS cameras simulaneously firing and the images are integrated using software to build a 3D image of the person.

THE BOTSCAN CHAMBER

WHERE DISNEY MEETS CSI

CCTV footage showed two people committing a bank robbery. Both were the same height – 1.76m tall. A defence expert witness testified that calculating from the measurement of pixels in the CCTV footage the height of both robbers was 1.65m. One of the defence lawyers said: "My client is 1.76m tall, therefore it cannot possibly be him who robbed the bank."

Police made a 3D laser scan of the scene, then Marcel Braun, imaging expert at the Forensic Institute, conducted a full-body scan of the suspect using the Botscan system of 64 linked Canon cameras firing simultaneously in a chamber. These cover (almost) 360 degrees of the body (the soles of the shoes and parts like the inner arms/legs can be missing or poorly represented). From this, using a professional 3D computer graphics program for 3D animation and visualisation, a surface mesh of the body can be constructed then mapped to a virtual skeleton in an anatomically correct way, replicating the suspect. Moving this animation in the same way as the suspect's gait from CCTV footage showed how conclusively the 1.76m person's height becomes 1.65m in an identical walking motion. The bank robber was convicted.



The ATOS 3D scanner and camera projects a moving fringe pattern on to the surface of an object using blue light. By combining information from the distortion of the fringe patterns, a detailed surface can be represented.

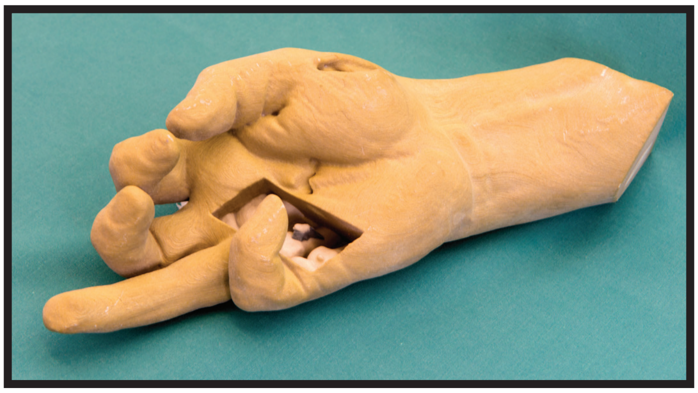
< bombarding the body with X-rays while it is moved slowly forward on a table – creating a non-destructive digital record. This can be used in later trials or appeals when the physical evidence has long since decayed, or has been destroyed during cremation. In living victims it can – of course – maintain a record of an assault long after healing.

There are often concerns in many institutions regarding the sharing of such expensive resources between the living and the dead, but forensic science research in Switzerland is so well funded that this is not an issue. The Virtopsy research team have their own dedicated scanners in the morgue area and the team scan every death referred to autopsy by the prosecutors, about 550 a year. Where CT and MRI scanners have to be shared between the living and the dead, pathologists need to liaise with radiology staff to ensure that the high-demand devices used for investigations of living patients are not blocked by post-mortem examinations.

X-ray computed tomography

Post-mortem CT – or, to give it its full name, X-ray computed tomography – can be completed in 10 minutes, producing 13,000 image slices of the whole body. It can identify the exact position and size of foreign objects such as knife fragments or bullets and can assist in their extraction. Precise measurements can lead to a very specific weapons search.

Blood or gas accumulations in the body are also very apparent in the imaging. Gas distribution, for example, is important in the diagnosis of fatal scuba diving accidents. The CT scan can also tell the investigator a great deal about the composition of the embedded object in a corpse. Different materials have a different opacity to the X-rays of CT. This variable opacity can be measured in Hounsfield Units (HUs). Where there has been a bomb explosion, victims could have the fragments of many different objects embedded in them – for example glass, wood, bone or building materials as well as metallic bomb fragments. Critical to



3D-printed reconstruction of a corpse's hand shows defence injuries below the thumb and in the palm of the hand. Internal opening shows embedded pieces of the fatal knife.

EVIDENCE

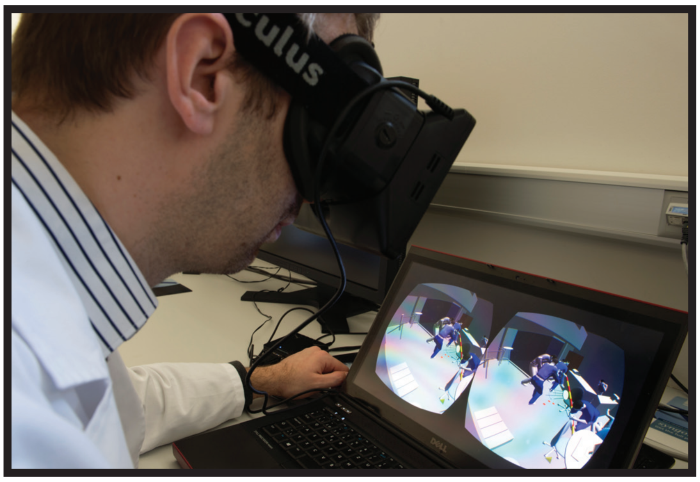
3D PRINTING BECOMES A COURTROOM TOOL

In a brutal assault, a middle aged man was kicked repeatedly in the head, the trunk and the armpit by a number of young men. One of the perpetrators' shoes left a recoverable imprint. 3D photogrammetry and surface scanning of the injury was matched to a 3D-printed construct of the boot sole allowing direct linking of the injury-causing instrument, the injury and the perpetrator.

Life-size 3D-printed models of footprints are useful to present evidence to a jury without having to pass around the actual footwear. 3D prints of evidence can be used to demonstrate 3D data on a smaller or bigger scale to improve understanding and help to deliver information from experts to laypeople.

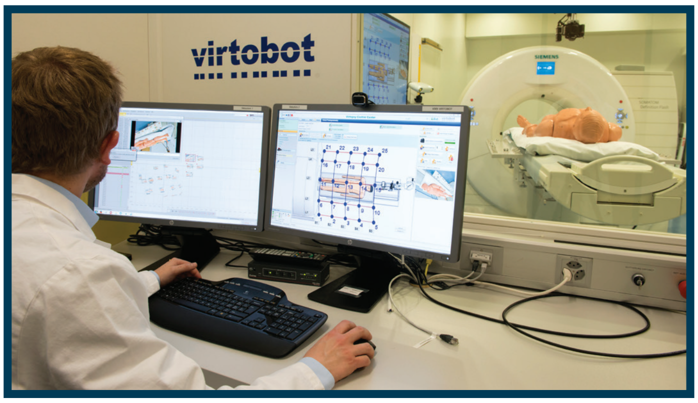
The handling of 3D models is preferred since the original objects (bones, skulls, weapons, etc) can make people feel uncomfortable. Reconstructions in plastic can be passed around and examined by members of the court.

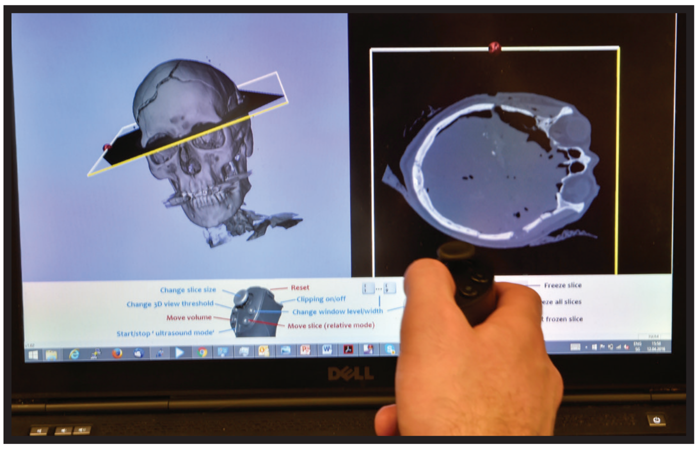
These have also been used to demonstrate the force of a blow that caused a multiple fracture of a victim's skull; and in another case, a full-size print of a corpse's hand was made, complete with defence wounds. A cutaway could show the court the position of knife fragments left inside the body and visibly show how these matched the missing tip of a knife recovered at the scene, and linked to the perpetrator. None of these models could be created without surface scanning technology.



Experimental use of Oculus Rift VR headsets in a crime scene reconstruction. In the future, this approach may allow the jury to travel back in time to a crime scene that may no longer exist, but that was recorded in 3D.

A technician checks out the full, comprehensive data set from the Virtopsy.





3D surface scan imagery combined with CT scan slices allows a clear presentation of bullet entry and exit wounds, and its trajectory through the head.

an investigation of a bombing is determining the composition of the bomb as quickly as possible, leading to clues as to its creators. Metal fragments can be quickly located and removed after a CT scan, aiding the work of bomb scene investigators.

Computed tomography is also a fast way to rapidly screen and begin identification of victims of a disaster, say after the discovery of a mass grave or after a suicide bomb attack in a crowded place. In minutes, a CT scan can pick up unique personal identifiers such as dental anatomy, artificial hips, pacemakers, fractures and plates or screws from previous reconstructive surgery.

Post-mortem CT scanning was used to quickly identify the 11 victims of the Shoreham Airshow disaster in 2015, when a vintage aircraft crashed into road traffic. Dr Michael Briggs, a forensic pathologist at the University of Leicester, was part of the Disaster Victim Identification team: “In the acute phase after such an event, people are desperate for information about their loved ones. The CT scans certainly helped the team to achieve successful identification within a short timescale, considering the challenging conditions.”

Yet CT scans have their limitations. “While a CT scan can tell us a lot about the identity of a body and the location of any foreign bodies within; it is less good at recording soft tissue injuries and the internal organs – for that we turn to an MRI scan,” says Thali. “Magnetic resonance scanning is also our preferred choice for forensic analysis of living victims as there is no harmful ionising radiation.”

Historical case-solving

Forensic imaging can help solve cold cases where photographs still exist. Swiss serial killer Werner Ferrari was convicted of five child murders in 1995, yet the convicted killer had always denied involvement in one of the deaths, that of 12-year-old Ruth Steinmann in 1980. Twenty years later, the police exhumed the body of another suspect for her murder who had committed suicide in 1983. They were then able to match forensic imagery of the dentistry from his remains to 1980s still photography of bite marks on the child’s body, finally providing closure and justice for the young victim’s family.

The forensic imaging technologies used in Virtopsy are also applied to victims of assault. Forensic interpretation of the CT or MRI scans after an attempted strangulation can confirm the attempted assault, even where there are no visual clues on the skin.

Imagery of pattern injuries caused by bites can lead to identification of the perpetrator via dental records. Tissue damage caused by blows from particular weapons can be reverse-analysed to produce an accurate description of the instrument of violence. Of course, these records will persist long after the victim has healed.

It’s clear that the suite of technologies available through forensic imaging is a hugely powerful tool with the capability to lift forensic pathology into the 21st century. *

HOLODECK

FORENSIC CRIME SCENE RECONSTRUCTION

Dubbed the ‘Holodeck’ after the Star Trek Enterprise’s immersive experience for space-bound crew, crime scene reconstruction uses 3D laser scanning to record a crime scene as a permanent virtual reality model. Every detail in the visualisation has to be based on the facts. The scene can be populated with real representations of, say, policemen in a firefight (3D imagery derived from scanning in the Botscan), or surface real representation of a corpse derived from the other scanning techniques in the Virtopsy suite of technologies. The whole scene can then be viewed through VR headsets such as Oculus Rift.

Add in bullet trajectories that can be viewed directly from the perspective of the person being shot at or indeed any other angle, and you have potentially a very powerful tool to place the court directly in the middle of a crime scene. It can also be used as a walkthrough experience for investigators to gather clues after the event. Drone footage and plan views made by the police could also be supplemented by external data such as surveillance camera footage or cellphone videos.

Lars Ebert of the Forensic Institute advises caution in the use of VR: “We need to do a reality check on the version of reality served up by these VR devices. How do they alter our perception of what is happening? We could give a judge the perspective of the victim, which perhaps alters his perception of threat, and maybe also increases a possible sentence. It’s a whole new area to think about.”

The team are waiting for a case suitable for the full application of a 3D virtual reality reconstruction to test in a court of law for the first time. VR could also be a powerful tool to bring a crime scene to life for jurors in the courtroom, cutting out lengthy and expensive out-of-court visits.