IPNDV Working Group 3: Technical Challenges and Solutions
Chain of Custody (3) Technology Data Sheet

September 16, 2016

Chain of Custody (CoC) Technology Name: 3D Surveillance

Physical Principle/Methodology of Technology:

Real-time 3D sensors continuously acquire depth information and can be used to complement standard video surveillance systems. Most systems use the time-of-flight (ToF) principle and measure the distance to an object by emitting a laser pulse (typically in the near-IR wavelength) and measuring the time for the signal to be returned.

Different technologies are commercially available, e.g.:

(1) Scanner-based systems work similarly to normal 3D laser scanners,[1] but only rotate around one axis at 10 Hz or more. Scanners using one laser/detector pair generate a line scan (2.5D); scanners using multiple laser/detector pairs generate a full 3D image.

(2) 3D cameras without scanning mechanism are based on the ToF principle and use custom imaging chips to acquire a complete depth image with a single light pulse.[2] The frame rate can be up to 80 Hz, but the measurement range is shorter than with scanner-based systems.

The accuracy of real-time 3D cameras is typically around 1cm.

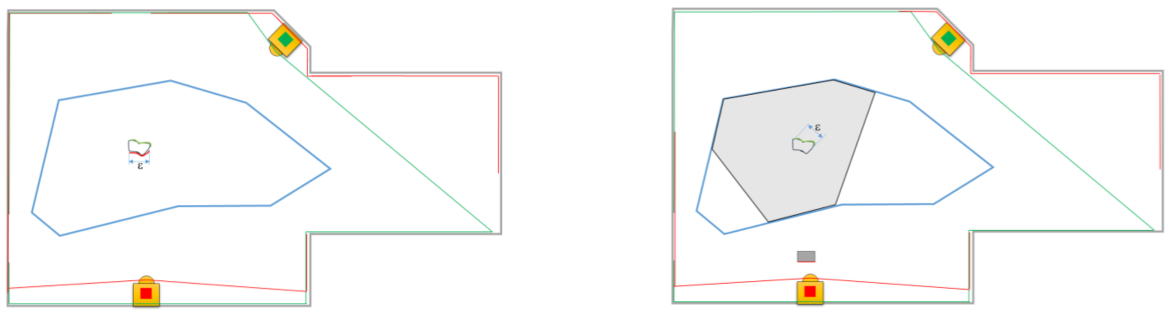
The analysis software continuously analyzes the data for relevant events, e.g., changes and movements in a specific area of interest. Because the analysis software works on measurements in 3D space, event detection is much more robust than optical video surveillance (which is influenced by ambient light conditions) and can be restricted to a pre-defined area of interest (intrusion zone). Although optical video surveillance cameras can also be set up for areas of interest, they are limited to a 2D imaging plane, which often does not map to a confined area in the real world. 3D "intrusion zones," however, are defined in the 3D space of the monitored area.

Potential Monitoring Use Cases (pre-dismantlement, dismantlement, post-dismantlement, storage stage):

3D surveillance is applicable to all phases of the dismantlement process where a specific area needs to be monitored for potentially undeclared activities (area monitoring) or the containment of a storage area needs to be ensured (containment monitoring). It can be used in combination with optical video surveillance to reduce the burden of imagery review.

The video surveillance systems that are currently installed in complex nuclear facilities generate hundreds of hours of video footage that need to be reviewed manually by inspectors. Although basic optical change detection methods are applied, many false alarms can be generated due to variations in the ambient light and legitimate movements in the image scene. Adding real-time 3D cameras to the surveillance system reduces the false alarm rate significantly and thus improves the efficiency and effectiveness. Because 3D cameras are active sensors, they are not influenced by changing ambient light, which is a frequent cause for false alarms in optical surveillance systems. Furthermore, 2D surveillance systems define the "intrusion zone" in the 2D image plane, which often leads to false alarms due to legitimate movement that occurs in the background. 3D cameras define the intrusion zone in the physical 3D space thus generating fewer false alarms.

The measurements acquired by multiple 3D sensors can be merged into a common reference frame to create a single 3D surveillance system that minimizes the number of blind spots and further increases the effectiveness of the surveillance system. Figure 1 illustrates the use of two laser scanners for effective monitoring of an intrusion zone.



(1) **(2)**

Figure 1: Schematics of a dual sensor zone-monitoring case. (1) **An intrusion in a zone as seen by two sensors.** (2) **An occlusion case where the red-marked sensor is occluded by an object close to the sensor but continuity of knowledge is maintained by the green-marked sensor** that **identifies the foreign object. (Photo Credit: JRC)**

Physical Description of Technology (e.g., approximate size, weight):

Several types of 3D cameras are commercially available. The dimension varies between a few centimeters and up to 20 cm. The weight is between a few hundred grams and approximately 4 kg. (see Figure 3 and Figure 4).

Time Constraints (e.g., measurement times, time to install the equipment):

Installation: The 3D surveillance system is a fixed installation, which can be installed in different configurations, i.e., as a single-sensor system, as a multi-sensor system, or integrated with a video surveillance system. The time to install the equipment depends on the configuration.

Acquisition: The measurements are continuous, real-time, and unattended.

Data analysis: The system generates and stores a series of events that needs to be reviewed periodically by the inspector. If used in combination with a video system, the 3D surveillance can reduce the overall review load significantly.

Technology Complexity (e.g., hardware, software, and ease of use by personnel):

The system is easy to install and operate. It is based on industrial and standard components and the analysis functionality is enabled by a few configurational properties.

Infrastructure Requirements (e.g., electrical, liquid nitrogen, etc.):

A simple, single-sensor system only requires the power supply for the sensor and a co-located analysis PC (see Figure 3). An integrated system requires also cabling for connecting different components such as multiple sensors, the video surveillance systems, and a potential review station.

Technology Limitations (e.g., detection limits for nuclear material, operational temperature range):

[1] "LIDAR," available at https://en.wikipedia.org/wiki/Lidar.

[2] "Time-of-Flight Camera," available at https://en.wikipedia.org/wiki/Time-of-flight_camera.

Each sensor can cover only a limited area, which varies according to the sensor used. For areas that are far away from the sensor, the capacity to detect small objects is reduced. The problem can be addressed by using multiple sensors placed in close proximity to the monitored area.

Information Collected by the Technology (used to help determine if an information barrier is required for use):

The cameras acquire 3D geometric measurements with centimeter accuracy. The processing of the 3D information can be done in the background so that the structural information of the facility is not exposed to the inspector. The inspector would only receive the event information (e.g., "Object detected in intrusion zone") and associated data, such as images from optical cameras that can be triggered through the event.

Safety, Security, Deployment Concerns:

All relevant 3D cameras are eye-safe (Class 1, typically using near-IR laser).

If the system is linked with optical surveillance cameras, inspectors access and review the imaging data, which could be a potential security concern from an operational and structural standpoint.

Installation of equipment by mounting to the facility would require facility reviews for deployment.

Technology Development Stage (e.g., commercially available, development stage):

Laser scanners monitoring a single plane (2.5D) have been used extensively in packaging and manufacturing industry for many years, e.g., for safety applications in robotic cells. The sensors are built with security and stability in mind.

Real-time 3D laser-array scanners have emerged recently, mainly for applications in robotics autonomous vehicles.

Scanner-less 3D cameras are currently entering the consumer and industrial markets and will, for example, be integrated in future mobile devices.

In the near future, 3D cameras will become common industrial and consumer equipment and therefore significant improvements in performance, size, and costs can be expected.

Cost Estimate:

The costs for real-time 3D cameras range from hundreds of Euro for short-range, scanner-less sensors to approximately €10,000 for 3D laser-array scanners. Additional cost of up to €3,000 incur for industrial PC and accessories. Once installed, the system has no running costs apart from ordinary maintenance.

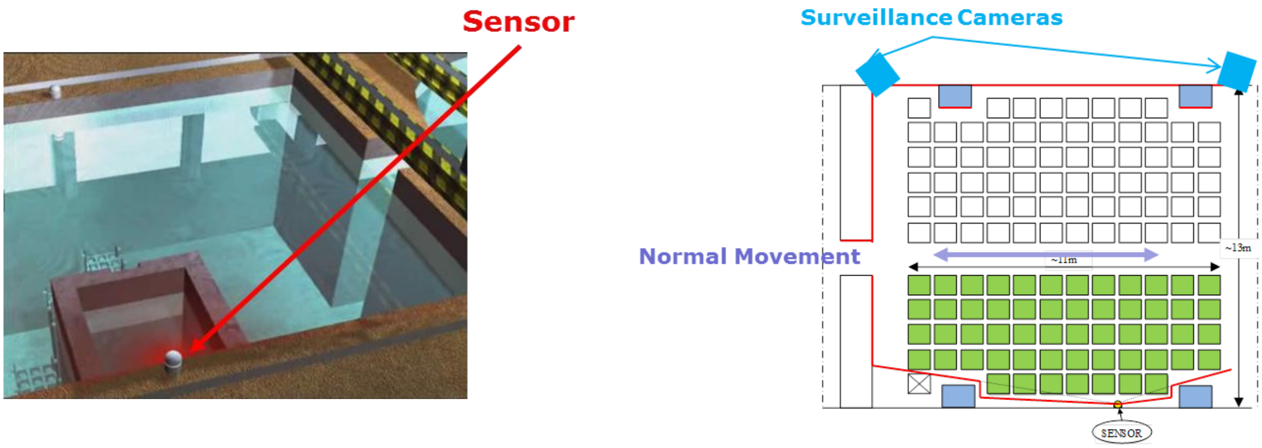
Additional System Functionality (e.g., outside the monitoring use case):

Discussed in the sections above.

Where/How the Technology Is Currently Used (e.g., international safeguards, border protection):

On request of Euratom, JRC developed and installed a Laser Surveillance System (LASSY) for monitoring a spent fuel pond in the reprocessing facility at La Hague, France. It is based on a 2.5D laser scanner that is mounted horizontally to monitor the material movement over the pond. It raises an alarm and sends a trigger to the video surveillance system if an activity is detected in a pre-defined intrusion zone. The events and associated video surveillance system images are stored locally and can be periodically reviewed by the inspector.[3] Figure 2 shows a schematic view of the LASSY system as installed in La Hague.

A variant of the LASSY system using a full 3D laser array scanner will soon be installed in a European nuclear facility for evaluation by IAEA.



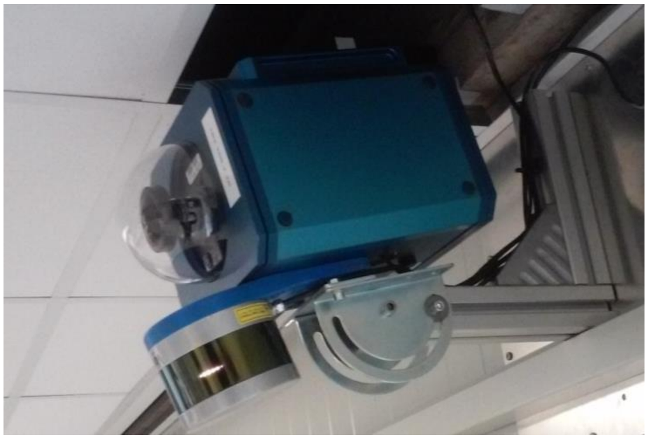
(1) **(2)**

Figure 2: (1) CAD drawing of the LASSY setup in La Hague showing the laser scanner over the spent fuel pond. (2) Schematic top-down view of the LASSY system. It illustrates the position of the 3D sensor (bottom) and of the video surveillance cameras that are triggered when the 3D sensor detects movement in the green zone. Movement along the purple line is permitted and does not trigger an event. (Photo Credit: JRC)

Examples of Equipment:

[3] "Laser Surveillance System (LASSY)—Internal JRC Report," JRC, Ispra, 2016.

Figure 3: Prototype of the single-sensor LASSY system based on the commercially available SICK S3000 scanner.[4] The blue box contains the control and analysis computer, which can be connected via ethernet to an integrated surveillance system. (Photo Credit: JRC)



(1)

(2)

Figure 4: (1) The image shows the NGSS surveillance camera used by IAEA and Euratom, which has been extended with 3D laser array scanner (Velodyne VLP-16[5]). (2) IFM 030 Smart Sensor.[6] Scanner-less 3D camera for industrial applications with a maximum range of 5 m. Similar sensors might be integrated directly into future (safeguards) surveillance cameras. (Photo Credits: JRC, IFM)

[4] SICK, "S3000 Data Sheet," available at https://www.sick.com/media/pdf/4/14/614/dataSheet_S30A-4011BA_1028934_en.pdf.
[5] "VLP-16 Data Sheet," Velodyne, available at http://velodynelidar.com/docs/datasheet/63-9229_Rev-C_VLP16_Datasheet_Web.pdf.
[6] "O3D Smart Sensor," IFM, available at https://www.ifm.com/ifmus/web/pmain020_020_010.htm.