SmartRay

WHITE PAPER

# THE CHALLENGE OF FILTERING REFLECTION ARTEFACTS IN 3D MATERIALS INSPECTION


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The issues caused by light reflection pose significant challenges for 3D materials inspection, especially when the materials require fast, highly accurate checking with very short cycle times. Shiny or reflective surfaces can create significant inconsistencies in the data, corrupting the integrity of the result. Consequently, it is critical that the many different and complicated adverse effects of reflections are successfully identified and filtered.

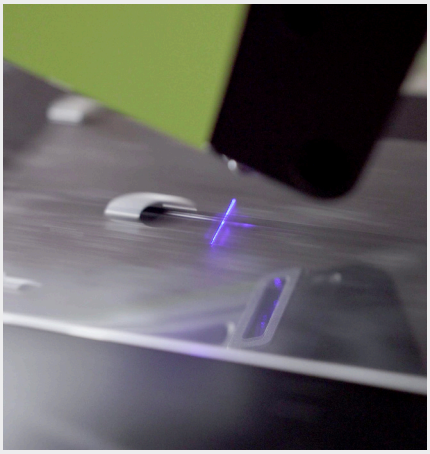
While metal and glass materials are generally associated with possessing reflective properties, the reality is that a much wider variety of materials give some degree of reflection, such as glues and adhesives. This presents a complex challenge for any automated inspection system. It requires the software and/or the sensor to determine a correct reflective signal at a range of intensities, and filter out unwanted reflection artefacts.

There are two components in a reflection. One is specular light – a direct reflection – where the angle of the reflected light is the same as that of the incident light; the other is diffused light, reflecting in all directions at the same time. Both components depend on the reflective properties of the material. Shiny metal has mainly specular reflections, which tends to cause measurement issues, and white paper has mainly diffused reflection, which is not generally problematic to filter.

The core requirement for a vision inspection system is to achieve the highest possible accuracy and repeatability of a result. This is critical to avoid users constantly having to check and recalibrate the measurement being made. Users require the data produced to remain consistent throughout a production timescale, which in some cases can last months, or even years.

This creates extra challenges, as the measurement needs to account for any changes in the process environment or process conditions, while the properties of what is being inspected has natural characteristics that may change in consistency. The presence of reflections, exacerbated by these changing conditions, can seriously affect the accuracy and repeatability level required to ensure product quality remains consistent.

3D vision sensors based on laser triangulation are designed to project a laser line onto a surface, with the laser light reflected back to the imager

3D imagers are mounted at an angle to the light source, so the height of the surface can be computed based on the triangulation principle

(see Fig. 1 for a 2D sketch). The imager is mounted at a certain triangulation angle to the laser source, such that the 3D height of the surface can be computed based on the imaged laser line and the triangulation principle. Ideally, the imager sees only the true laser line based on diffuse reflection of the surface (see Fig. 1, left).

However, reflective surfaces can affect the returned results. If the surface exhibits significant specular (direct) reflection, some part of the light might be reflected to a different part of the surface from where it could also reach the imager. Therefore, the imager receives light from different parts of the surface where only one reflection is the true laser line, while the other reflections are artefacts (see Fig. 1, right). This effect is further complicated when the reflected light hits another part of the surface, which in turn is reflected again, possibly leading to multiple reflection artefacts seen by the imager.

These adverse reflection effects vary according to the type and shape of a material, which can be flat, convex or concave in shape – all of which will produce different reflective signal properties and consequently present different challenges to identify.

Normally when a surface is inspected with a 3D sensor, the imager sees not a specular (direct) reflection, but just the diffuse reflection of the laser line. In this case the imaged laser line can be easily identified, and the 3D height of the surface can be accurately computed. In some cases, however, the specular reflection of shiny parts can lead to one or more reflections on the imager where, unfortunately, the reflection can be brighter than the true signal (see left side of Figs. 2 and 3 for examples of reflection artefacts, partly highlighted by yellow arrows). Such specular reflection presents a significant risk of being mistakenly picked as the true signal, which results in an erroneous computed 3D height value.

For each column of an image, a decision needs to be taken as to which is the correct reflection. Due to limited processing power on the sensor, usually a 'local' criterion is used to select the best possible decision from limited data. Typically, the brightest signal in a column is selected, but the top-most or bottom-most signals are sometimes used instead.

Aside from the assumption that this is a correct signal, there is no single decision path that covers all scenarios, so while a certain signal signature might be correct for one surface, it could be the incorrect decision for another.

For SmartRay, rather than relying on the sensor to make a decision, the sensor is better directed to acquire as much data as possible in an intelligent way, and the more powerful processing available in an Industrial PC helps make a better decision. It enables the analysis of more information from the measurement neighbourhood, so when one column is examined, the processing takes into account what is happening elsewhere. This enables a much more informed decision to be made.

Based on the mild assumption that surfaces are generally smooth – for example there are usually only few edges where the height changes drastically – continuity criteria significantly help to distinguish the correct reflection from reflection artefacts.

With SmartRay's advanced reflection filter, continuity is not only exploited along the laser line but also in transport direction. In particular, specular reflections often 'jump' quickly from frame to frame in transport direction, implicating much larger height changes than the surface itself.

Further challenges are reflection artefacts close to the true laser line, and reflection artefacts that 'jump' from above to below the true laser line and vice versa. SmartRay's advanced reflection filter uses additional techniques to address these challenges, to be able to choose the true laser line.

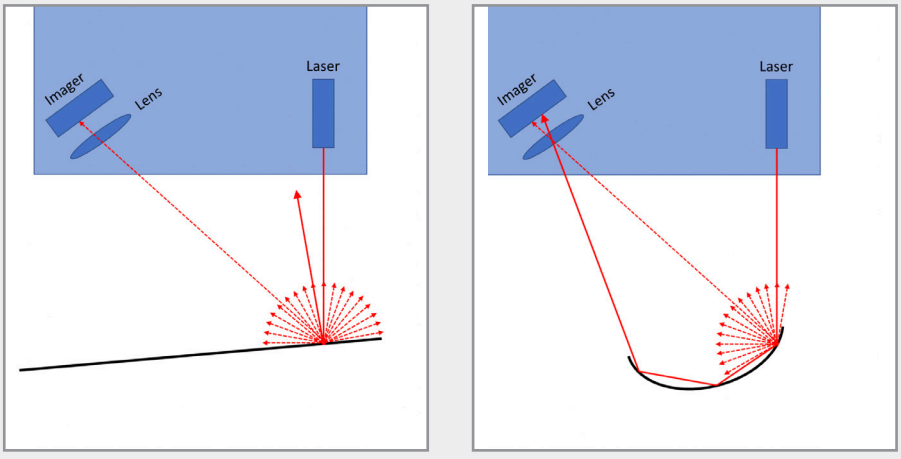
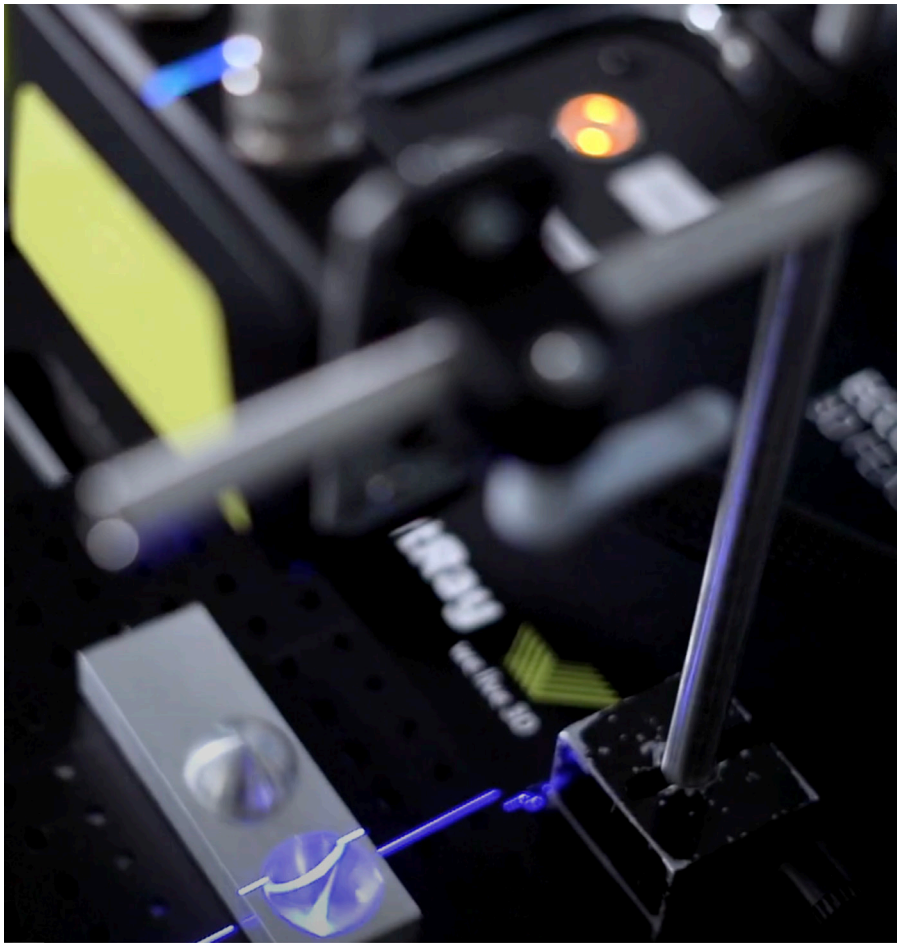



**Figure 1:** Sketch of a 3D vision sensor including laser source and imager as well as a flat surface (left) and concave surface (right): For the flat surface (left) the imager sees only the diffuse reflection of the laser and thus only the true laser line is visible, while for the concave surface (right) the imager additionally sees a reflection artefact caused by multiple specular reflection, which often is brighter than the diffuse reflection.



Shiny metal surfaces produce reflective light which must be successfully identified and filtered

Figs. 2 and 3 show example images of challenging shiny metal objects seen by the imager of the sensor that present different reflection artefacts (partly highlighted by yellow arrows). The results of the reflection filters are marked in red. A standard reflection filter (left column) chooses in some cases a reflection artefact instead of the true laser line, yielding a poorly measured 3D surface (see bottom left in Fig. 2). In contrast, with SmartRay's advanced reflection filter (right column) in almost all cases the true laser line is chosen, yielding an accurately measured 3D surface (see bottom right in Fig. 2).

In rare cases where the data is indeterminate, the customer does not get a measurement for a certain column, as the software cannot state what the correct measurement is with an acceptable level of confidence. Note that in cases where there is no true laser line present in a column but only reflection artefacts, SmartRay's advanced reflection filter will usually discard the data and correctly provide no measurement. This contrasts with other competing sensor filters that will always provide a measurement, even if it is wrong.

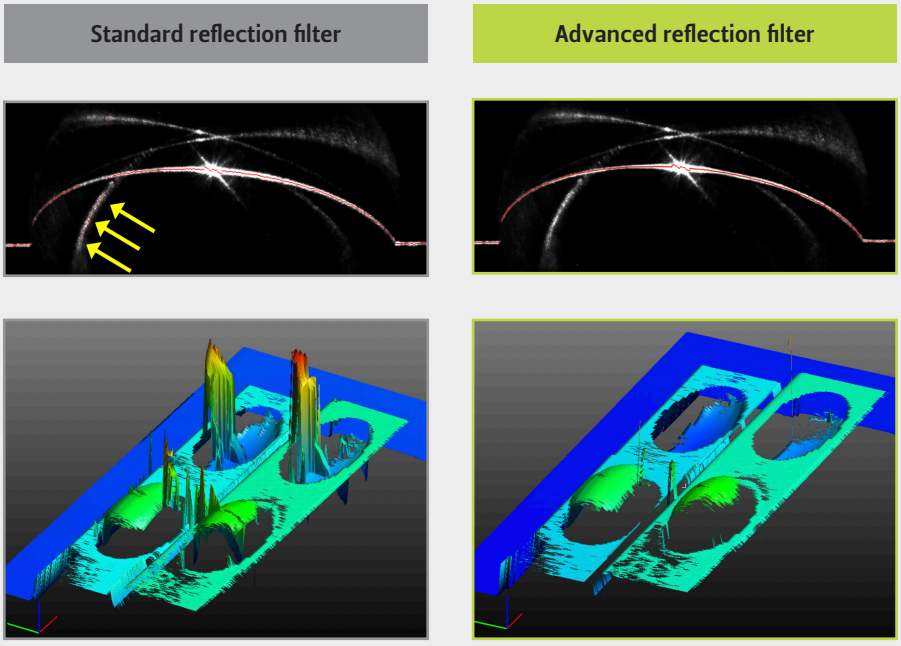



**Figure 2:** Shiny metallic convex/concave hemispheres example: 2D images (top) showing the true laser line and reflections for one profile where the results of the reflection filter are marked in red and 3D visualization (bottom), both for a standard reflection filter (left) and SmartRay's advanced reflection filter (right). The yellow arrows highlight some reflection artefacts where the standard reflection filter fails.

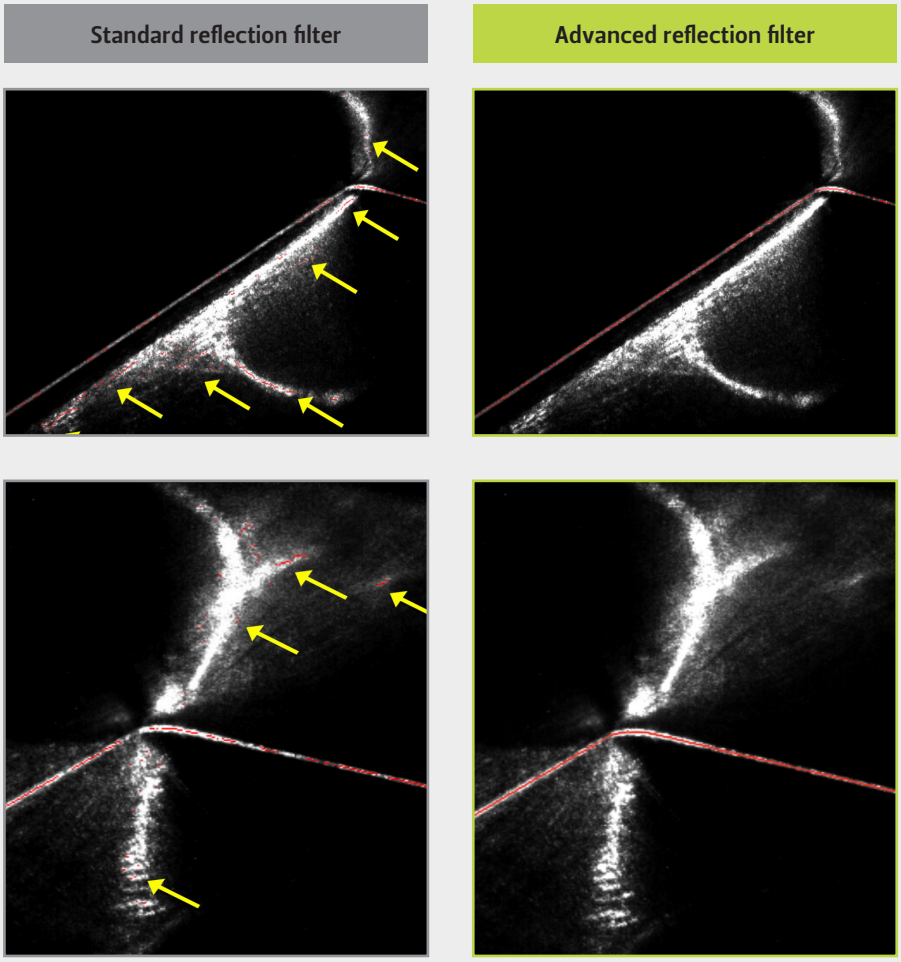



**Figure 3:** Same as fig 1 but for a different shiny metal part for two different profiles (top resp. bottom).

As mentioned before, reflection artefacts vary according to the type and shape of a material presenting quite different challenges, and there is no single reflection filter that can address all scenarios equally well. With SmartRay's advanced reflection filter, several techniques have been developed that can be combined in different ways to adapt to different scenarios. Using so-called filter presets, the advanced reflection filter has been fine-tuned to achieve good accuracy and/or dynamic range on shiny metallic parts or glass surfaces.

For challenging customer demands, specialised pre-sets can be created. To produce this, customer data is reviewed, enabling SmartRay Application engineers to adapt and optimise the filter to the precise needs of the application. In this way, the reflection issues inherent across an extensive range of customer applications can now be successfully mitigated.

## SMARTX SOFTWARE TOOLS

3D SENSOR OPTIMISATION TOOLS

The mitigation of the complex challenges encountered when measuring shiny or reflective surfaces is provided by SmartRay's SmartX firmware and software tools. These combine intelligent, high-quality 3D data generation techniques with high-end reflection filter algorithms for improved repeatability and accuracy.

SmartX enhances the performance of the ECCO 95 3D sensor range, maximising its full potential for superior image quality, ultra-high accuracy and very high-speed scanning, and meeting the performance demands of machine builders and OEM customers.

Unlike competitor technologies, which add extra software onto a sensor at additional cost and the risk of compromised measurement performance from the associated thermal interference, SmartRay's unique firmware-software configuration allows the ECCO 95 to deliver these enhanced capabilities while maintaining exceptional high speed and accuracy.

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