



FOD Detection

Performance & Operating Guide



PREPARED BY	Spectro-AI	SUBJECT	Airside FOD detection algorithm
RUNS ON	DJI Matrice 4 Series (on-board)	MORE INFO	spectroai.ai
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OPERATIONAL SAFETY The algorithm is an operator-assistance tool and does not replace the pilot's responsibility to maintain safe flight or comply with applicable aviation regulations. All detections should be verified before operational decisions are made.

INTENDED USE This algorithm is designed to assist operators in locating foreign object debris during aerial inspection of paved airside surfaces. It can highlight areas requiring further investigation, but should not be used as a replacement for visual confirmation or for the required airside inspection.

NOT A SUBSTITUTE FOR THE REQUIRED INSPECTION This algorithm supports an airside inspection; it does not constitute one. It must not be used as the sole means of clearing a runway, taxiway or apron for operations, and an absence of detections is never evidence that a surface is clear of debris.

1 About this guide

This guide describes how the Spectro-AI foreign-object-debris (FOD) detection algorithm performs on paved airside surfaces when running on-board a DJI Matrice 4 Series aircraft, and how to fly and configure the camera to obtain the most reliable results. It is written for the teams who fly inspections and review the results.

The algorithm runs directly on the aircraft and reports detections in real time during the flight through the DJI Pilot 2 application. It detects ten categories of debris and airside objects from the visible-light (RGB) camera, each returned with a class label and a confidence score.

The algorithm assists operators in locating potential FOD. It does not replace visual confirmation, and every detection must be checked by the operator before any recovery or reporting action is taken.

Performance figures presented in this guide were established under validated operating conditions and should be used as operational guidance rather than guaranteed performance. Detection accuracy varies with light, surface condition, flight height, zoom setting and the size of the object.

2 Supported aircraft

This is a visible-light algorithm. It uses the RGB camera, not the thermal payload, and therefore runs on every aircraft in the Matrice 4 Series.

Table 2.1 *Aircraft compatibility*

Aircraft	Status	Reason
DJI Matrice 4E	Supported	RGB camera fitted
DJI Matrice 4T	Supported	RGB camera fitted
DJI Matrice 4D	Supported	RGB camera fitted (dock variant)
DJI Matrice 4TD	Supported	RGB camera fitted (dock variant)

NO THERMAL PAYLOAD NEEDED The algorithm places no constraint on the payload. Any Matrice 4 Series aircraft will run it. On the thermal variants it still works from the visible camera: it does not read the thermal feed. What it does depend on is optical zoom, which is what brings small objects up to a detectable size.

3 What the algorithm recognises

The algorithm detects ten classes and displays each detection as a bounding box, a class label and a confidence score on the live image in DJI Pilot 2. Every object in the image is boxed separately.

Table 3.1 *Detection classes*

Group	Classes	Typical size and character
Fasteners	Bolt · Nut · Screw	Roughly 15–30 mm. The smallest and hardest objects the algorithm handles, and the ones that dictate how low or how zoomed-in you need to fly.
Tools	Screwdriver · Pincer	Roughly 150–300 mm. Large, distinctive shapes that are detected readily.
General debris	Metallic debris · Non metal debris	Two catch-all classes covering a wide range of loose material. Size varies enormously, and so does the height at which any given piece can be found.
Surface and natural	Rock · Bird droppings	Naturally occurring material on the surface, typically in the tens of millimetres.
Infrastructure	Runway light	Installed equipment rather than debris. Useful as a fixed reference in the image.

What changed from the Brain-box release

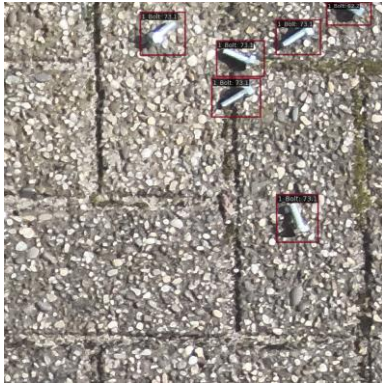
The on-board algorithm reports ten classes, consolidated from the nineteen used by the Brain-box release. Two changes matter operationally.

- **Several specific classes are now grouped.** Coins, washers, hooks, metal strips, batteries and miscellaneous tools are now reported as Metallic debris; rubber, plastic, cartons and gloves are reported as Non metal debris. The object is still flagged in the same place: only the label is broader. In practice this rarely matters, because the operator goes and looks at what has been found.
- **Crack and repaired crack have been removed.** The two surface-condition classes are not part of the on-board algorithm. It reports debris and objects on the surface, not the condition of the pavement itself. Teams who used those advisory classes on the Brain-box should not expect them here, and pavement condition remains a matter for dedicated inspection.

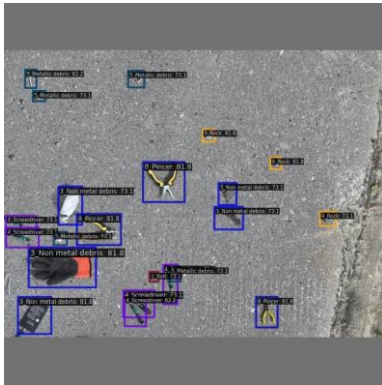
Table 3.2 *Example detections*

Detection (with bounding boxes)

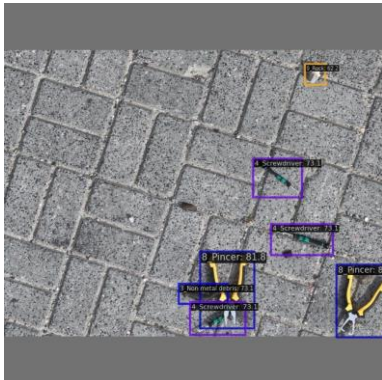
What it shows

**Fasteners on paving**

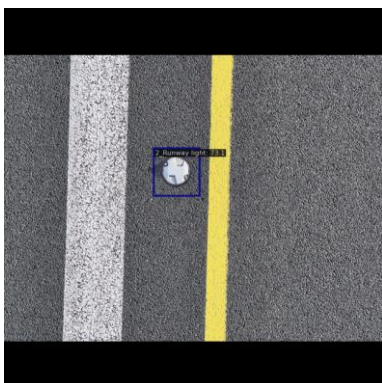
Several bolts boxed individually on a paved surface. Objects of this size are only found when they have been brought close enough: by flying low, by zooming in, or both.

**Mixed debris in one image**

Metallic debris, non metal debris, rock, screwdriver and pincer detected together, each with its own label and score. A frame like this shows the class groups working side by side.

**Tools and loose material**

Screwdrivers and pincers alongside rock and non metal debris. Large, distinctive items such as these are the easiest objects for the algorithm and are found at the greatest heights.

**Installed infrastructure**

A runway light detected as such. This class marks installed equipment rather than debris, and is not a defect report: it does not indicate that anything is wrong with the fitting.

4 Detection performance

Validation was performed on an independent dataset that was held out from training and evaluated separately. The results below describe the algorithm's performance under the validated operating

conditions and should be regarded as estimates of expected performance. Actual performance may vary with conditions and operating practices.

0.941

mAP@0.50

0.570

mAP@0.50–0.95

What these numbers mean

- **mAP@0.50 (0.941).** The headline measure of whether debris on the surface is found and correctly located. For most operational users this is the figure that best reflects the question that matters: was the object spotted?
- **mAP@0.50–0.95 (0.570).** A stricter measure that also rewards how precisely the box is drawn. FOD items are often only a few pixels across, so drawing a pixel-tight box around one is hard: a lower figure here reflects that difficulty, not a failure to see the object.

What actually governs performance in the field is size. Large items such as tools and gloves are detected readily and from a considerable height. Small fasteners are significantly more difficult and will be missed entirely unless they have been brought close enough by flying lower or zooming in. Section 5 turns this into concrete guidance. Per-class figures were not measured for this build, so the numbers above should not be read as applying equally to every class.

CONFIDENCE-THRESHOLD SLIDER Start at approximately 0.30 and adjust to conditions. Lower the threshold when the priority is to miss as little FOD as possible, and accept that more false positives will need checking. Raise it on cluttered or heavily marked surfaces where too much is being flagged. If small items are being missed, change the flight height or the zoom before touching the threshold: no confidence setting can recover an object the camera never resolved.

5 Operating recommendations

How object size drives detection

The algorithm analyses each camera image as a whole, in real time. The frame is not divided into high-resolution tiles, so detection depends on how many pixels an object occupies in the picture. As a working rule, an object needs to span at least about 5–6 % of the image width to be detected reliably. Anything smaller, a distant bolt a few pixels across, is detected with low confidence or missed altogether.

THE PRACTICAL CONSEQUENCE Apparent size is the single biggest control on detection, and you have two levers over it: flying height and optical zoom. Flying lower or zooming in makes objects larger in the image. Everything else in this section follows from that.

Flight height and zoom

The validated detection ranges were established at very low level: roughly 1.5 m for small fasteners, 4.5 m for medium debris and 13 m for large items at the base zoom setting. Flying below about 10 m is impractical or unacceptable on most airside operations, so those figures are recorded here for reference rather than offered as a flight plan.

The useful question is the one operators actually face: if I fly at a sensible height, how much magnification do I need to hold the same level of detail? Because detail scales in direct proportion to magnification, that can be worked out from the validated figures. The table below gives the magnification required to preserve the validated level of detail at practical survey heights.

Table 5.1 Magnification required to hold the validated level of detail, by height

Object size and examples	10 m	15 m	20 m	30 m
Large (~180 mm) tools, larger debris, runway lights	~5×	~8×	~11×	~16×
Medium (~60 mm) rocks, smaller debris items	~15×	~23×	~31×	~46×
Small (~20 mm) bolts, nuts, screws	~46×	~69×	~93×	beyond range

Green: achievable on the telephoto camera's optical zoom alone. Blue: requires hybrid zoom beyond the optical range. Amber: requires very heavy hybrid zoom, or exceeds the aircraft's zoom range entirely. Figures are derived by proportion from the validated low-level ranges and have not themselves been flight-validated: [Insert DJI-validated height and zoom values].

WHAT THE AIRCRAFT CAN ACTUALLY DO The Matrice 4 Series telephoto camera is a 168 mm-equivalent lens, about 7× relative to the wide camera, and the system extends to roughly 112× using hybrid zoom. Only the largest items at the lowest survey heights fall inside the optical range. Everything else in the table above depends on hybrid zoom, which enlarges the picture without adding optical detail. Treat these figures as a planning starting point to be confirmed on your own surface, not as guaranteed settings.

HOW TO USE THIS Decide before the flight what you need to catch, then read across. Large debris is comfortably within reach at 10–30 m and covers ground quickly. Medium debris is workable at 10–20 m with substantial zoom. Small fasteners are the hard case at any practical height: they demand magnification far beyond the optical range, so verify on a test object of known size at the start of the sortie before committing to a survey height. If small items are being missed, lower the aircraft: that is the only lever that adds real detail rather than enlarging what is already there.

Camera angle, lighting and surface

- **Angle: point straight down.** Validated gimbal pitch is -83° to -90° . Nadir framing keeps the surface flat in the picture and avoids the perspective distortion and reflections that oblique angles introduce. Avoid oblique views.
- **Lighting: good daylight only.** This is the tested condition. Low light, dusk and night are outside the validated envelope. Strong low-angle sun, heavy shadow from buildings or aircraft, and glare off wet surfaces all reduce contrast and cost detections.
- **Surface: dry paved ground.** Validated on dry asphalt, block paving and concrete. Wet, snowy, icy or unusual surfaces reduce reliability. Standing water and dark wet patches both hide objects and generate false positives.
- **Zoom: optical, not digital.** Optical zoom changes the camera optics and genuinely resolves more detail on a small object. Digital zoom crops and enlarges what has already been captured and adds no new information. Use optical zoom to reach the heights in Table 5.1.

Verifying a detection

Every detection must be confirmed by the operator before any recovery or reporting action is taken. The algorithm is an aid to detection; it does not replace human judgement, and it says nothing about whether an object is hazardous.

- **Confirm before you act.** Zoom in on the box and look at what is inside it. A detection is a prompt to look, not a finding.
- **Expect the broad labels to be broad.** Metallic debris and Non metal debris cover a wide range of objects, and similar fasteners are occasionally labelled as one another. The label may be imprecise while the detection is still correct: what matters is that something is there.
- **Do not treat a clear screen as a clear surface.** An absence of detections is never confirmation that a surface is free of FOD, particularly for small items or outside the validated conditions.

Lens cleanliness

Dirt, water droplets, dust or condensation on the camera lens soften the image and may degrade detection performance, and an object only a few pixels across is exactly what a soft image loses first. Inspect the lens before each flight and clean it as required, and allow time for condensation to clear when a cold aircraft is brought into warmer, more humid air.

6 Limitations

- **Not a substitute for the required inspection, and an absence of detections proves nothing.** The algorithm supports an airside inspection; it does not constitute one, and it must not be the sole basis for declaring a surface clear.
- **Small objects need low flight or zoom.** A 15–30 mm fastener is only detectable when captured within the ranges in Table 5.1. From height without sufficient optical zoom it will be missed.
- **Pavement condition is not assessed.** The crack and repaired crack classes of the Brain-box release are not part of the on-board algorithm. It reports objects on the surface, not the state of the surface, and is no substitute for dedicated pavement inspection.
- **Broad debris classes and look-alike fasteners.** Metallic debris and Non metal debris are deliberately wide categories, and bolts, nuts and screws are occasionally labelled as one another. The debris is still flagged as present; only the label is imprecise.
- **Bounding boxes indicate approximate location only.** They should not be interpreted as the true size or extent of an object, and the algorithm reports nothing about whether an object is hazardous or how urgently it needs recovery.
- **Outside the tested envelope, performance is not validated.** Low light, dusk and night, wet, icy or unusual surfaces, heavy shadow, glare and oblique camera angles are all unvalidated conditions.
- **Per-class performance is not characterised.** The published figures are averaged across all ten classes and should not be assumed to apply equally to each.
- **Performance figures are intended for operational planning and should not be interpreted as guaranteed performance under all conditions.**

7 Deployment

The algorithm is licensed to the individual aircraft serial number and delivered through DJI Pilot 2. Once activated, it runs entirely on-board and does not require a network connection during operation.

VALIDATED VERSION The validated performance described in this guide applies to the released algorithm version identified on the cover of this document, FoDDetect-SAI-V2. Later algorithm updates, aircraft firmware changes and different camera configurations may perform differently, and the figures here should not be assumed to carry over to them. Check the algorithm version shown in DJI Pilot 2 against the cover of this guide, and record it alongside any results you keep.

Questions, or results in conditions not covered here? Visit spectroai.ai.