



Fire & Smoke Detection

Performance & Operating Guide



PREPARED BY	Spectro-AI	SUBJECT	Fire and smoke detection algorithm
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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 fire and smoke during aerial observation. It can highlight areas requiring further investigation, but should not be used as a replacement for visual confirmation, and it is not a certified fire-detection system.

NOT A FIRE DETECTION SYSTEM This algorithm is a situational-awareness aid for a pilot who is already looking. It is not a certified fire-detection or fire-alarm system, it does not provide continuous or automatic monitoring, and it must not be relied upon as the means by which a fire is discovered. An absence of detections is never evidence that there is no fire.

SMALL OR DISTANT FIRES MAY BE MISSED Small or distant fires are significantly more difficult to detect than larger ones and may be missed entirely. A developed fire with an established plume is found readily; an early or far-off fire is a genuinely hard target. Use this algorithm to assess a fire, not to discover one.

1 About this guide

This guide explains how the Spectro-AI fire and smoke detection algorithm performs when running on-board DJI Matrice 4 Series aircraft, and how to fly and configure the payload to obtain the most reliable 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 two classes, Fire and Smoke, from the visible-light (RGB) camera. It is intended to support incident awareness: marking fire and smoke on the live image so that a pilot can see the extent of what they are looking at and direct attention to it.

The algorithm assists operators in locating potential fires and smoke. It does not replace visual confirmation, and every detection must be checked by the pilot before any operational response is initiated.

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, weather, visibility, the size and distance of the fire, the zoom level in use and image stability.

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 4T	Supported	RGB camera fitted
DJI Matrice 4TD	Supported	RGB camera fitted (dock variant)
DJI Matrice 4E	Supported	RGB camera fitted

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

NO THERMAL PAYLOAD NEEDED Unlike the Spectro-AI thermal algorithms, this one places no constraint on the payload and none on the thermal palette. Any Matrice 4 Series aircraft will run it. On the thermal variants, the algorithm still works from the visible camera: it does not read the thermal feed.

3 What the algorithm recognises

The algorithm detects two classes and displays each detection as a bounding box, a class label and a confidence score on the live image in DJI Pilot 2. Fire and Smoke are reported separately, so a single incident will usually produce boxes of both kinds.

Fire and smoke are not the same problem

The two classes look nothing alike to a camera, and they do not behave alike in the air. Understanding the difference explains most of what an operator will see on screen.

Table 3.1 *How the two classes behave*

Class	What it is like	What that means in the air
Fire	Compact. Bright. Makes its own light. A flame front is a small, high-contrast, self-luminous object with a reasonably definite edge.	Boxes are tight and stable. Because flame emits light rather than reflecting it, fire can be found at night. But it is small, and small objects are what this algorithm finds hardest.
Smoke	Diffuse. Shapeless. Seen by reflected light. A plume has no fixed outline. It grows, drifts, thins and changes shape from one second to the next.	Boxes shift and resize between images: this is the plume changing, not the algorithm being unstable. Smoke is usually the larger object and is often what draws the eye first, but because it depends on reflected light it fades in poor light and at night.

WHY THE SMOKE BOXES MOVE A smoke box that jumps and resizes from frame to frame is normal and expected. Smoke genuinely has no stable boundary, so there is no single correct box to draw around it. Read a smoke box as a marker of roughly where the plume is, never as a measurement of how big it is.

Size is the dividing line

Whatever the class, the single strongest influence on whether something is detected is how large it appears in the image. Large, developed fires with established plumes are found readily. Small or distant fires are significantly more difficult to detect and may be missed entirely, and this is true even at a low confidence threshold, because the algorithm cannot find what the camera has not resolved.

Fly this algorithm to understand a fire you already know about. If it is being used to search, treat it as an aid to a human search rather than a substitute for one.

Table 3.2 *Example detections*

Detection (with bounding boxes)	What it shows
	Fire and smoke boxed separately The plume is boxed as Smoke and the flame as Fire on the same incident. The operator can see at a glance which part of the picture is which.
	Multiple seats of fire One smoke plume and two separate flame fronts, each boxed individually. This is what makes the extent of a fire legible from the air.
	Smoke scores higher than fire A pattern that holds across the samples: the smoke plume is scored more confidently than the flame beneath it. This is why the recommended threshold sits as low as 0.30: set it higher and the flames start to drop out while the plumes remain.

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.

0.784 mAP@0.50	0.535 mAP@0.50–0.95
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What these numbers mean

- **mAP@0.50 (0.784).** The headline measure of whether fire and smoke are found. It is the lowest of the Spectro-AI on-board range, and that is worth stating plainly: fire and smoke are shapeless, shifting, constantly changing subjects, and they are a harder detection problem than a vehicle or an animal.
- **mAP@0.50–0.95 (0.535).** A stricter measure that also rewards how precisely the box is drawn. A smoke plume has no true edge, so a lower figure here reflects the difficulty of boxing a shapeless object: not a failure to see it.

What actually governs performance in the field is size. Large, developed fires with established plumes are detected reliably. Small or distant fires are significantly more difficult and may be missed entirely. These figures are also averaged across both classes: the two behave differently, as Section 3 sets out, and the headline number should not be read as applying equally to Fire and to Smoke.

CONFIDENCE-THRESHOLD SLIDER Start at approximately 0.30: far lower than the other algorithms in this range, and deliberately so. The costs here are not symmetrical: a false positive costs a look, a missed fire may cost a great deal more. Fire is also scored consistently below smoke, so a threshold set to make the plume detections look clean will quietly discard the flames. Accept the additional false alarms and check them.

5 Operating recommendations

Altitude, gimbal angle and zoom

Table 5.1 *Operating envelope*

Parameter	Setting	Notes
Camera	Visible (RGB)	The algorithm reads the visible feed. It does not use the thermal camera, even where one is fitted.
Altitude	Any permitted altitude	No altitude constraint of its own, but height governs how large the fire appears, and apparent size is what performance turns on.
Gimbal angle	All angles	Every angle the aircraft supports is usable. Nadir shows the footprint of a fire; an oblique or level view shows the plume and where it is going.
Zoom	As the situation requires	No fixed level. Zoom in to bring a small or distant fire up to a detectable size; zoom out to take in the whole incident.
Confidence threshold	0.30 to start	Deliberately low. Adjustable in DJI Pilot 2, but think hard before raising it.

HOW TO USE THIS There is no envelope to stay inside. Fly at whatever altitude and angle the incident demands, start the threshold at 0.30, and use zoom to bring the fire up to a size the algorithm can work with. That last point is the one that actually moves the needle, because apparent size is what this algorithm is most sensitive to.

Environmental conditions

Fire and smoke are shaped by the weather around them, and so are the detections. The conditions below change what the camera sees and therefore what the algorithm can report.

- **Day and night: fire yes, smoke maybe.** Flame makes its own light, so fire can be detected in darkness as readily as by day. Smoke is seen by reflected light, so at night there may be little or nothing for the camera to pick up. Expect the algorithm to box the flames while reporting little or no plume.
- **Wind and dispersal.** Wind shears a plume, flattens it and thins it out. A wind-torn plume is lower in contrast and harder to detect than the tall, dense column of a fire burning in still air, and its box will shift and resize as it moves. A plume blown across the line of sight can also obscure the fire itself.
- **Sunlight and glare.** A plume viewed against a bright sky can be washed out and lose the contrast that makes it visible. Low sun, sun glint off water, glass and metal, and strong reflections can be

reported as Fire. Where possible, position the aircraft so that the sun is behind it rather than behind the incident.

- **Atmosphere and visibility.** Haze, fog, rain and the smoke of the fire itself all reduce contrast at distance. A second fire seen through the plume of the first may not be found at all.
- **Things that resemble fire or smoke.** Bright, warm-coloured or self-luminous sources, vehicle lights, flares, worked metal, some artificial lighting at night, may be reported as Fire. Dust, mist, low cloud, steam and exhaust plumes may be reported as Smoke. False positives become more likely when operating at lower confidence thresholds, for example around 0.30.

NIGHT: FIRE YES, SMOKE MAYBE At night the algorithm can still find the fire, but it may not capture the full extent of the smoke. Anything that depends on knowing how far a plume has spread, downwind risk, evacuation, air quality, must not be judged from the smoke boxes alone in darkness. Treat the fire boxes as real and the absence of smoke boxes as uninformative rather than reassuring.

Verifying a detection

Every detection must be confirmed by the operator before any operational response is initiated. The algorithm is an aid to detection; it does not replace human judgement, and it carries no information about what is burning, how severe it is, or whether it is a fire at all.

Confirm on the live visible imagery: zoom in on the box and look at what is inside it. Where the aircraft carries a thermal payload, the thermal camera is an independent cross-check available at the touch of a button: a genuine fire will present as a strong heat source, whereas a reflection, a vehicle light or a dust plume will not. The algorithm itself does not read the thermal feed, so this cross-check is entirely independent of it.

- **Confirm before you act.** Look at what is inside the box before reporting or responding. A detection is a prompt to look, not a finding.
- **Cross-check with thermal where you have it.** On the Matrice 4T and 4TD, switching to the thermal camera is the fastest way to separate a real fire from something that merely looks like one.
- **Do not report extent from the boxes.** The boxes show roughly where fire and smoke appear. They are not a measurement of how large the incident is.
- **Nothing found is not nothing there.** An absence of detections is never confirmation that there is no fire. Fly the search, and use your own eyes.

Lens cleanliness

Dirt, water droplets, soot or condensation on the camera lens soften the image and may degrade detection performance. Inspect the lens before each flight and clean it as required, and check it again after flying near a fire, where airborne particulate can settle on the optics.

6 Limitations

- **Not a fire-detection system, and an absence of detections proves nothing.** The algorithm is a situational-awareness aid, not a certified detection system or alarm. It does not monitor continuously, it must not be the means by which a fire is discovered, and the fact that it has reported nothing is never evidence that there is no fire.
- **Small or distant fires may be missed entirely.** Small or distant fires are significantly more difficult to detect than larger ones. This is the algorithm's principal weakness, and no confidence setting compensates for it.
- **Smoke behaves differently from fire, particularly at night.** Fire can be detected in darkness; the plume often cannot. Never judge the extent of smoke from the boxes alone at night. The published performance figures are averaged across both classes and should not be assumed to apply equally to each.

- **Bounding boxes indicate approximate location only.** They should not be interpreted as the true size, boundary or severity of the incident, and the algorithm reports nothing about what is burning.
- **False positives are more likely at a low threshold.** Bright warm-coloured sources may be reported as Fire; dust, mist, cloud, steam and exhaust may be reported as Smoke. This becomes more likely at thresholds around 0.30, which is the price of not missing the flames. Every detection requires verification.
- **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, FireSmoke-RGB-SAI-V4. 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.