SPECTRO AI

Thermal Patrol Detection

Performance & Operating Guide

PREPARED BY	Spectro-AI	SUBJECT	Thermal patrol detection algorithm
RUNS ON	DJI Matrice 4T / 4TD (on-board)	MORE INFO	spectroai.ai
ALGORITHM	PatrolWhiteHot-SAI-V2	DOCUMENT	v1.0 · Public
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Contents

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 people, vehicles and bicycles during aerial thermal observation. It can highlight areas requiring further investigation, but should not be used as a replacement for visual verification, operator assessment or any procedure your organisation applies.

OBSERVING PEOPLE: PRIVACY AND PROPORTIONALITY This algorithm detects people. Thermal imagery does not show faces, clothing or other identifying features, which limits what can be learned about an individual, but a flight that records where people are and when remains a form of surveillance, and in most jurisdictions is regulated as such. Before deploying it, confirm your legal basis, any notification or signage obligations, how long footage and detections will be retained, and who may access them. A detection is not an identification, and must never be treated as one.

1 About this guide

This guide describes how the Spectro-AI thermal patrol detection algorithm performs when running on-board a DJI Matrice 4 Series thermal aircraft, and how to fly and configure the payload to obtain the most reliable results. It is written for drone operators and field users rather than for specialists.

The algorithm runs directly on the aircraft and reports detections in real time during the flight through the DJI Pilot 2 application. It works from the thermal camera using the White Hot palette and recognises three classes: Person, Vehicle and Bicycle.

Its purpose is to give an operator a faster read of a scene than watching a thermal feed unaided: marking where people, vehicles and bicycles are in the picture so that attention can be directed to the right part of it. Because it works from heat rather than light, it functions in darkness, which is where a thermal camera earns its place.

A DETECTION AID, NOT A DECISION The algorithm supports human judgement. It does not replace visual verification, operator assessment, or any procedure your organisation applies. Every detection is a prompt for a person to look: never a conclusion in itself, and never on its own a basis for acting.

Performance figures presented in this guide were established under validated conditions and should be used as operational guidance rather than guaranteed performance. Detection accuracy varies with thermal contrast, flight height, camera angle, weather, and how much of an object is exposed to the sensor.

2 System and sensor description

Thermal imaging and the White Hot palette

A thermal camera measures emitted heat rather than reflected light. In the White Hot palette, warmer parts of a scene are rendered lighter and cooler parts darker, so a person appears as a bright shape against cooler ground. This is what allows the algorithm to work at night as readily as by day.

It also sets the algorithm's central limitation. What matters is not whether an object is visible to the eye but whether it is at a different temperature from its surroundings. An object at the same temperature as

the ground around it produces little or no signature, however plainly a human observer would see it in daylight.

> **WHITE HOT ONLY** The algorithm is trained exclusively on the White Hot palette and must only be used with White Hot selected in DJI Pilot 2. Black Hot inverts the image and the other palettes recolour it; the algorithm has not been trained on any of them, and performance on them is not validated and should not be relied upon.

Sensor and viewing geometry

The table below separates what is directly observable in the validation imagery from what has been estimated or assumed. Estimates are marked as such and should be confirmed on your own site.

Table 2.1 *Sensor and viewing configuration*

Parameter	Value	Basis
Sensor type	**Thermal (infrared)**	Confirmed. The algorithm reads the thermal feed only and does not use the visible camera.
Palette	**White Hot**	Confirmed. Mandatory: no other palette is supported.
Image size	**640 × 512**	Observed in the validation imagery. This matches the native thermal resolution of the supported aircraft.
Viewing direction	**Top-down to moderately oblique**	Observed. The validation imagery is captured looking down at the ground, from directly overhead through to a distinctly angled view.
Camera angle	**30° to 90° from horizontal**	Recorded in the capture data. 90° is straight down; 30° is a strongly angled view. Wider than most Spectro-AI algorithms tolerate: see Section 5.
Flight height	**60 – 130 m above ground**	Recorded in the capture data. The validated band.
Lighting	**Day and night**	Thermal imaging does not depend on visible light. Both conditions are covered.
Zoom	**[Insert validated zoom settings]**	Not recorded in the validation imagery.

> **HOW BIG A PERSON ACTUALLY IS IN THE PICTURE** At the upper end of the height band, a person occupies roughly fifteen pixels across in a 640-pixel-wide thermal image: a small bright mark, not a recognisable human shape. This is worth seeing before the first flight, because it sets a realistic expectation of what the operator will be looking at and why verification always requires a closer look.

3 Detection classes

The algorithm reports three classes. Each detection appears on the live thermal image as a box, a label and a confidence score, and every object in the image is boxed separately.

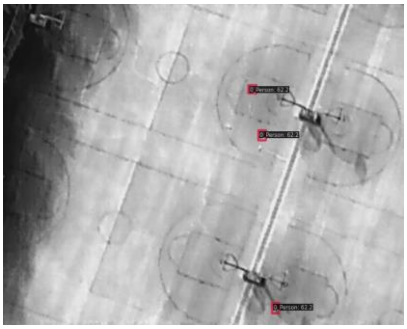
Table 3.1 *Detection classes*

Class	How it appears in thermal	Relative difficulty and what affects it
Vehicle	A large, clearly defined shape. A vehicle that has been running is bright and unmistakable: the engine bay and wheels hold heat well after it stops.	The easiest class. Large and usually warm. A vehicle parked and cold for hours has little thermal signature and reads only as a shape against the ground, which is harder.
Person	A small, compact bright mark. Body heat gives good contrast against most cool surfaces, but the object itself is small from height.	Moderate. Contrast is usually good; size is the constraint. Heavy clothing reduces the heat reaching the sensor, and warm ground in summer narrows the contrast.
Bicycle	A thin, faint outline. A bicycle generates no heat of its own and is mostly narrow metal tube.	The hardest class. Small, cool and thin. A bicycle in use is generally easier because the rider is the warm part of the picture; a parked one may be barely distinguishable from the surface it stands on.

THE PRINCIPLE BEHIND ALL THREE Larger and warmer objects are easier to detect. Small, cool objects are harder. Vehicles are both large and often warm, so they detect well; bicycles are small, cool and thin, so they detect worst; people sit in between: warm but small. Everything in Section 5 follows from this.

Table 3.2 *Example detections*

Detection (with bounding boxes)	What it shows
	**Nadir view, 100 m: bicycles** A straight-down view with numerous bicycles detected together. Even the hardest class is found reliably in a well-contrasted scene, though the scores sit lower than for larger objects.
	**Oblique view, 100 m: vehicles** A distinctly angled view rather than a top-down one, with several vehicles boxed at good confidence. This frame is the evidence that the algorithm tolerates oblique geometry.

Detection (with bounding boxes)	What it shows
	**Near-nadir, 110 m: people** People detected near the top of the height band, each only about fifteen pixels across. Scores here are modest, which is exactly why the recommended threshold is set low.

4 Detection performance

Validation was performed on an independent dataset that was held out from training and evaluated separately. The results below describe performance under the validated conditions and should be regarded as estimates of expected performance rather than guarantees.

0.936	0.598
mAP@0.50	mAP@0.50–0.95

What these numbers mean

- **mAP@0.50 (0.936).** The headline measure of whether objects are found and correctly located. For most operational users this is the figure that reflects the question that matters: was it spotted? At this level, an object present and reasonably exposed to the sensor is usually found.
- **mAP@0.50–0.95 (0.598).** A stricter measure that also rewards how precisely the box is drawn. Targets here are often only a few pixels across, so a tight box is hard to draw: this says little about whether the object was seen.

Broken down by how large objects appear in the image, the picture is unusually even for a thermal algorithm.

Table 4.1 *How reliability changes with apparent size*

How it appears in frame	Reliability	What this means in the air
Large	**Strong**	Vehicles at working height, and anything close beneath the aircraft. Found consistently.
Medium	**Good**	People and bicycles through most of the height band. Generally found, with occasional misses.
Small	**Moderate**	Small targets hold up better here than in most detection algorithms: this one is built for looking down from height. Expect some misses, but not a collapse.

Small-object reliability is roughly two-thirds that of large objects, a much flatter fall than is usual, and the practical reason the algorithm can be flown high. What it does not change is thermal contrast: an object the sensor cannot distinguish from its background will be missed at any size. Per-class figures were not measured for this build, so these results should not be read as applying equally to Person, Vehicle and Bicycle, the class table in Section 3 sets out where the differences lie.

CONFIDENCE-THRESHOLD SLIDER Start at approximately 0.40. This is lower than it might appear necessary, and deliberately so: thermal targets seen from height are small and their scores sit modestly, so a threshold set to make the display look clean will discard real detections. Lower it further when the priority is to miss as little as possible and you are prepared to check more false alarms. Raise it in thermally cluttered scenes, sun-warmed hard standing, machinery, industrial plant, where too much is being flagged.

IMPORTANT: DETECTIONS ARE NOT COUNTS The algorithm identifies where warm objects appear in the image. It does not produce a count of the people or vehicles present. Anything under cover is not seen at all, and objects close together may be merged into a single box, so a detection total will generally understate what is present. An absence of detections is never evidence that an area is clear.

Common causes of missed detections

- **Poor thermal contrast.** The single biggest cause. Warm ground in summer, sun-heated asphalt and concrete, and thermal crossover around dawn and dusk all narrow the difference between target and background.
- **Cold objects.** A vehicle parked for hours or an unattended bicycle may have no heat of its own to give away.
- **Obstruction.** Anything under trees, canopies, structures or vehicles is hidden from the sensor entirely.
- **Excessive height.** Above the validated band, targets become too few pixels to work with.
- **Insulation.** Heavy clothing, blankets and sheeting hold heat in and reduce what reaches the sensor.

5 Operating recommendations

Flight height, camera angle and palette

Table 5.1 *Operating envelope*

Parameter	Setting	Notes
Thermal palette	**White Hot**	Mandatory. No other palette is supported.
Flight height	**60 – 130 m above ground**	The validated band. Lower gives larger, clearer targets; higher covers more ground per pass.
Camera angle	**30° to 90° from horizontal**	An unusually wide validated range. 90° is straight down; 30° is a strongly angled view. Both work.
Preferred angle	**Near-nadir for searching**	A top-down view gives the most even coverage of ground and the least overlap between objects. Use oblique angles when you need to see under an obstruction or work a scene from standoff.
Confidence threshold	**0.40 to start**	Adjustable in DJI Pilot 2. Tune to the scene and to how much checking you are prepared to do.
Detection range	**[Insert validated detection ranges]**	No slant-range figures can be quoted from the available data. Establish them on your own ground: see Section 7.

THE ANGLE RANGE IS A REAL ADVANTAGE Most thermal detection algorithms are trained on top-down imagery alone and lose reliability the moment the camera tilts. This one has been validated from straight down through to a markedly oblique view, which means the operator can angle the camera to see under a tree line, along the face of a building, or across ground from standoff without leaving the validated envelope. Use it, but prefer near-nadir when the task is to search an area methodically.

Thermal conditions and time of day

The algorithm works by day and by night. What matters is not light but heat: the difference in temperature between a target and its background.

- **Best conditions.** Cool ambient temperatures, cool ground and a clear sky: typically at night, in the early hours, or in the colder months. People and running vehicles then stand out sharply.
- **Degraded conditions.** Warm days and sun-heated ground raise surface temperatures towards those of the targets and the contrast narrows. Thermal crossover around dawn and dusk has the same effect. Hard standing, asphalt and roofs retain heat well after sunset.
- **Obstruction.** Rain, fog and wet vegetation attenuate the signature. Anything fully beneath canopy or a structure cannot be detected by any algorithm.
- **Reflective surfaces.** Water, glass and polished metal reflect heat from elsewhere in the scene and can produce bright marks unrelated to what is actually there.

How distance and object size interact

Detection depends on how many pixels a target occupies. Height sets that, and target size compounds it: at any given height a vehicle occupies many pixels, a person considerably fewer, a bicycle fewer still and with less contrast to work with.

- **Searching for vehicles.** Work the upper end of the height band. They remain detectable and you cover far more ground per pass.
- **Searching for people.** The middle of the band is a sensible compromise between coverage and reliability.
- **Searching for bicycles, or anything cold.** Work lower. This is the hardest case and it sets the height for the sortie if it is the objective.
- **If detections thin out, descend before adjusting the threshold.** No confidence setting recovers a target the sensor never resolved.

Lens cleanliness

Dirt, water droplets or condensation on the thermal lens reduce image contrast and may degrade detection performance, and a target 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

Each limitation below is paired with what the operator should actually do about it.

Table 6.1 *Limitations and operator response*

Limitation	What to do
Objects hidden by vegetation or structures	A thermal camera cannot see through canopy, roofs, canopies or vehicles. Anything fully covered is invisible. Work the scene from more than one bearing, and use the oblique angle range to look under tree lines and along building faces rather than only down onto them.
Low thermal contrast	Detection may be reduced when a target is close in temperature to its background. Fly when the ground is cold, at night, in the early hours, or in cooler months, rather than in the afternoon over sun-heated surfaces.
Environmental temperature	Hot weather compresses the whole scene towards a similar temperature and costs detections across all three classes. Expect materially worse results on a summer afternoon than on a winter night, and plan the sortie accordingly.
Reflections and other heat sources	Water, glass, polished metal, machinery, exhausts, lighting and recently used hard standing can all appear bright and be reported as targets. Confirm what a detection actually is before acting on it, and raise the threshold in thermally busy scenes.
Objects too small or too far away	Above the validated height band, targets become too few pixels to detect. Descend rather than lowering the threshold: the threshold cannot recover detail the sensor never captured.
Cold objects	A vehicle parked cold or an unattended bicycle may produce almost no signature. Do not treat an absence of vehicle or bicycle detections as evidence that none are present.
Unusual viewing angles	Detection may be reduced outside the 30°–90° range: in particular from a near-level view, which is not validated. Keep the camera within the range in Table 5.1.
It reports a class, not an identity	A Person detection means a warm, person-shaped mark was seen. It says nothing about who, and thermal imagery carries no identifying features. Never treat a detection as an identification, and confirm before acting.
An absence of detections proves nothing	It is not evidence that an area is clear. Fly the pattern, use your own eyes on the feed, and follow your normal procedure regardless of what the algorithm has or has not reported.

7 Operator workflow

Before flight

- **Thermal sensor checked.** Confirm the thermal camera is producing a live image and that the scene looks sensible: warm objects light, cool objects dark.
- **Palette set to White Hot.** Check this every flight. It is the most common set-up error and the algorithm will not work correctly on any other palette.
- **Lens inspected and clean.** Dirt and condensation cost small targets first.
- **Condensation allowed to clear.** If the aircraft has come from a cold vehicle into warm, humid air, give the optics time to settle.
- **Environmental conditions assessed.** Note ground temperature, recent sunshine and rain. Warm ground after a sunny day will reduce what you can expect.

- **Confidence threshold set.** 0.40 to start; lower if the priority is to miss as little as possible.
- **Height and angle planned.** Within 60–130 m and 30°–90°. Choose according to what you are looking for: lower for cold or small objects.
- **Permissions confirmed.** Where the flight will observe people, confirm your legal basis and any notification obligations have been met.

During flight

- **Hold the planned height.** Climbing above the validated band shrinks targets below what the algorithm can use.
- **Keep the camera within the validated angle range.** Near-nadir for methodical searching; angled when you need to see under or behind something.
- **Fly at a steady, moderate speed.** Motion blur in a thermal frame costs detections.
- **Work in overlapping passes.** Objects hidden on one pass may be visible from another bearing.
- **Watch the scores as well as the boxes.** Consistently low scores across a pass usually mean poor thermal contrast or too much height.
- **Re-tune between scenes.** Contrast changes with surface and time of night; a threshold that suited a grass field may not suit a car park.

After a detection

- **Verify on the live image.** Zoom in and look at what is actually inside the box before treating it as anything.
- **Cross-check with the visible camera where light allows.** The algorithm does not use the visible feed, so it is an independent check.
- **Do not rely on the label alone.** The class may be wrong while the detection is still real, and a warm mark is not an identification.
- **Search around the detection.** Where one target has been found, look for others nearby that may be cooler, smaller or partly obstructed.
- **Follow your organisation's procedure.** The algorithm informs that procedure; it does not replace it and does not authorise any action on its own.
- **Record the conditions.** Note height, angle, ground temperature and time alongside anything you keep. It explains the result later.

> **BUILD YOUR OWN RANGE CARD** No validated detection distances are published. On an early flight, have a colleague stand in a known position and note the heights and angles at which they are reliably detected, then repeat with a cold parked vehicle or bicycle. An hour spent doing this gives you numbers that apply to your ground, your aircraft and your climate: worth more than any general figure, and worth repeating between summer and winter.

8 Deployment

The algorithm is licensed to the individual aircraft serial number and delivered through DJI Pilot 2. Once activated it runs entirely on-board: all processing happens on the aircraft, and no network connection is required during operation.

Table 8.1 *Deployment summary*

Item	Detail
Where it runs	On-board the aircraft, in real time, from the thermal camera feed.

Item	Detail
Network connection	Not required in flight. Imagery is not sent off the aircraft for processing, which also means detections are not transmitted anywhere by the algorithm itself.
Licensing	Tied to the aircraft serial number.
Version identification	The algorithm name and version are shown in the DJI Pilot 2 interface. Note that the algorithm version and the version of this guide are numbered separately: record the algorithm version shown on the aircraft alongside any results you keep, so that findings can be matched to the build that produced them.
Firmware compatibility	Keep aircraft firmware and DJI Pilot 2 at compatible versions. Updating one and not the other is the most common cause of an algorithm failing to load. [Insert minimum firmware / DJI Pilot 2 version.]
If it does not load	Confirm the licence is active for that airframe, check firmware and Pilot 2 versions, and restart the aircraft and controller. If it still does not appear, fly the task using the thermal feed directly and report the fault: the algorithm is an aid, and its absence should not stop the sortie.
If detections look wrong	Check the palette first: White Hot is required. Then check height and angle against Table 5.1, then the lens, then the threshold. In that order: most reported problems are a palette or a height problem rather than a fault.

> **VALIDATED VERSION** The validated performance described in this guide applies to the released algorithm version identified on the cover of this document, PatrolWhiteHot-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.