ThermalNet

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Problem Statement

- Paired RGB-thermal cameras mounted on drones, rovers or gimbals often drift out of alignment due to vibration, zoom and pan/tilt motion. Mis-registration degrades fused analytics and operator situational awareness. **ThermalNet** learns to **extract, match and geometrically align** cross-modal key points so that both streams remain pixel-aligned in real time, whatever the movement.

System Overview

- Input: synchronous RGB–thermal frame pair (640 × 480).
- Keypoint Extraction: SuperPoint-style CNN produces {k, d, s} per modality.
- Matching: 18-layer SuperGlue GNN computes feature matches and confidence masks.
- Homography Estimation: differentiable DLT + Smooth-L1, reprojection and sub-pixel consistency losses, robust to NaN/Inf.
- Sub-Pixel Refinement: RAFT optical flow refines matches to <0.5 px accuracy, thus quantifying the movement of the matches.
- Scale aware loss applies bilinear interpolation and refines the matches by checking them in different scales.
- Output: 3 × 3 homography H that warps the thermal frame onto the RGB view; optional overlay of inlier lines.

Data & Training

- Dataset: in-house ThermalHomographyDataset, ≈ 640 × 480 RGB/thermal pairs + ground-truth H; graceful fallback to identity when missing.
- Augmentation: colour-jitter, flips, rotations, Gaussian noise & cosine pseudo-thermal synthesis.
- Optimiser: Adam, LR = 1 × 10-4, 100 epochs, mixed-precision AMP; training on A100.

Results

- After 100 epochs the network converged to stable loss and produced visually consistent alignments in both day and night scenes; green lines denote inlier matches linking RGB→thermal features.
- All functional/robustness tests (grayscale conversion, NaN safety, inference tensor shapes, overfitting sanity-check, etc.) passed.

Engineering Impact

- Global / Societal: Enables reliable dual-sensor vision for search-and-rescue, firefighting, wildlife protection and critical-infrastructure inspection, even in resource-constrained regions.
- Economic: Removes need for costly mechanical calibration rigs; retrofit to existing payloads.
- Environmental: Fewer repeat flights → lower CO_2; supports SDG 13 – Climate Action.
- Ethical & Open Science: Fully open-source stack encourages peer review and responsible dual-use oversight.

Contemporary Issues

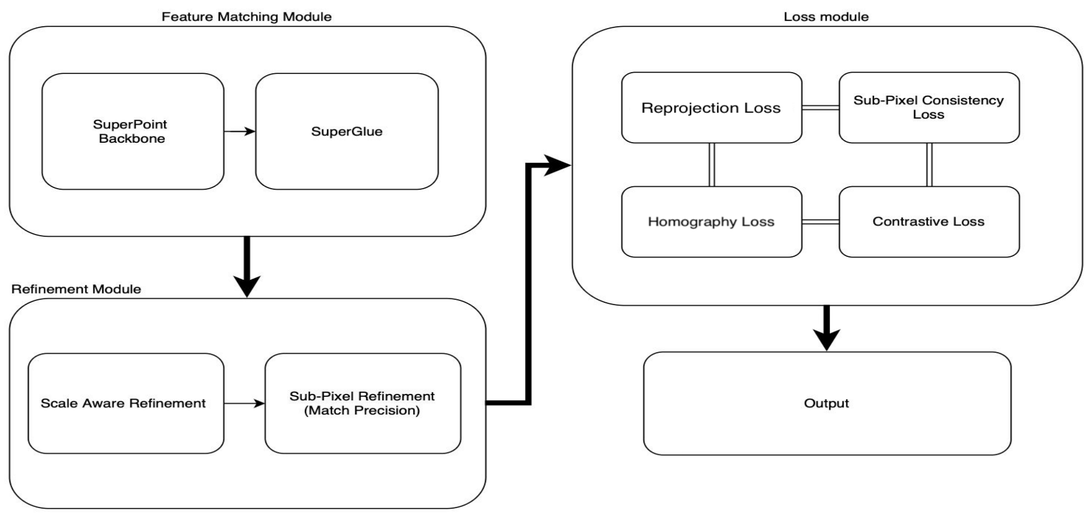
- Privacy: Drone imaging intersects GDPR / KVKK; on-device processing avoids raw data uplink.
- Dual-Use: Alignment tech has defense applications → export-control compliance required.

Key Technologies

Table 1: Core Technologies Utilized in *ThermalNet*

Category	Tool	Role
Deep CV Matcher	**SuperGlue**	Graph-NN correspondence learning
Differentiable Geometry	**Kornia**	Homography normalisation & losses
Optical Flow	**RAFT**	Sub-pixel keypoint refinement
Training Infra	**PyTorch + AMP**	40% speed-up

Figure 1: Architecture Diagram



CONCLUSION

- ThermalNet delivers real-time, pixel-level RGB–thermal alignment, validated by exhaustive tests, and is ready for pilot deployment on mobile platforms.

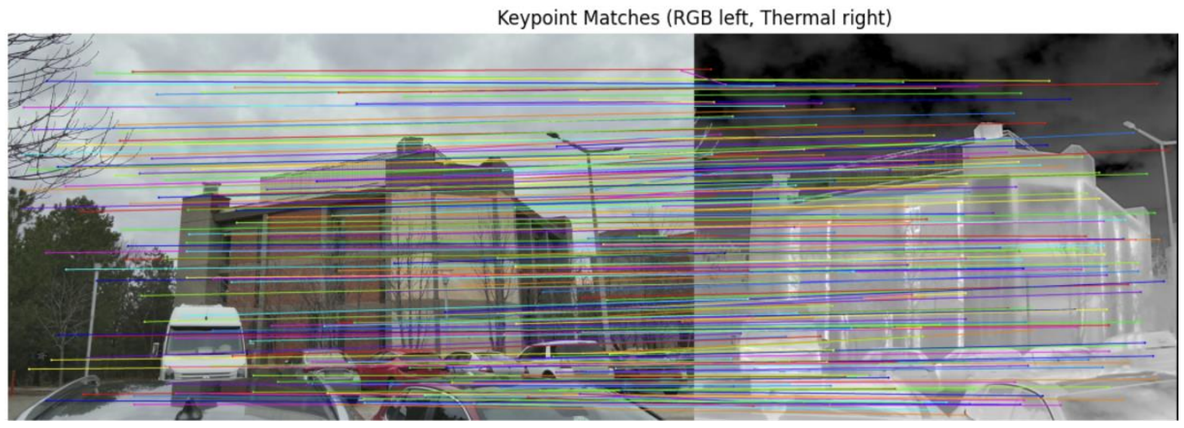


Figure 2: Sample matching

FUTURE WORK

- Curate additional urban & light-rain scenes to stress-test generalization.
- Add alignment-confidence score and inlier overlay toggle for field operators.
- Conduct live-flight trials with partner drone club to uncover edge cases.
- Environmental: Fewer repeat flights → lower CO_2; supports SDG 13 – Climate Action.
- Ethical & Open Science: Fully open-source stack encourages peer review and responsible dual-use oversight.

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