Preliminary Report: Automated Hotspot Segmentation for Airflow Leakage

Date: June 20, 2025

Objective:

To conduct a preliminary evaluation of methods for automatically identifying and segmenting two distinct airflow leakage spots (holes) from a raw transient infrared (IR) video of a brick cladding material sample. The ultimate goal is to assess the feasibility of using the Segment Anything Model (SAM) for this task.

1. Initial Visual Analysis & Methodology

I performed an initial analysis using our existing method to confirm the location of the two leaking holes in one of the IR videos.

Dynamic Temperature Analysis: Identifying regions of high thermal activity by calculating the pixel-wise rate of temperature change (slope) over time.

Results of Initial Analysis:

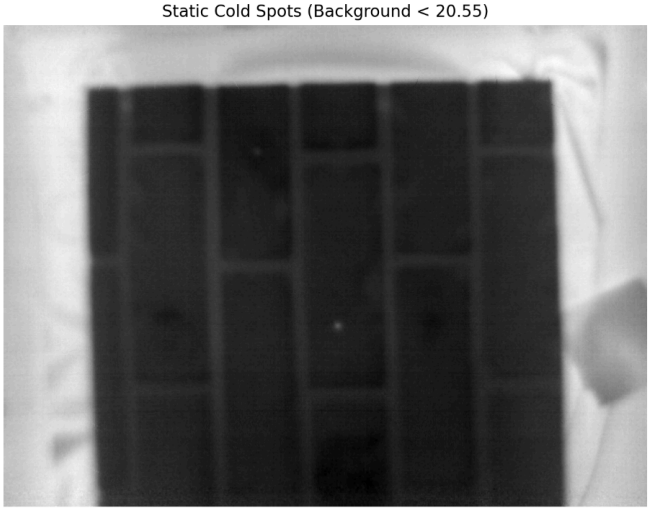
Temperature Slope Map (Top-Right): This map clearly shows two distinct red spots, indicating a positive temperature slope (heating), which correctly identifies the two leak locations.
Activity Map (Bottom-Left): While the two leaks are visible as bright spots, significant activity is also present along the top and left edges of the material, representing potential confounding signals (noise).
Combined Overlay (Bottom-Right): The "Active Regions" (magenta) correctly identify the two holes but also highlight the noisy edge regions, confirming that a selection mechanism is required to distinguish true leaks from artifacts.

Conclusion from Initial Analysis:

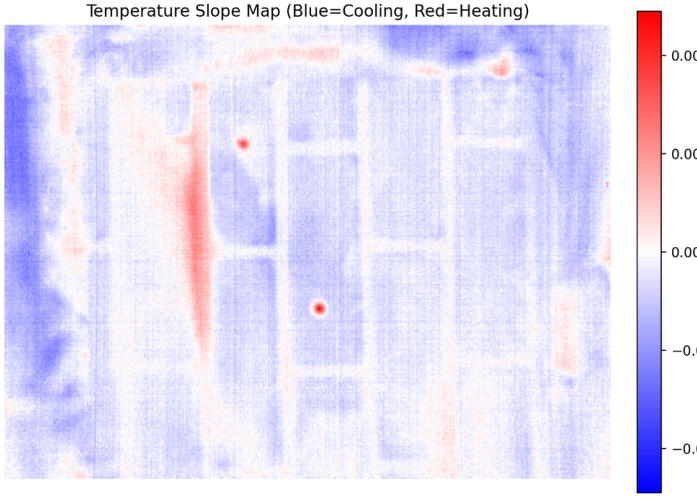
Initial analysis shows us the location of the two leaking holes using activity maps.

Hole Detection Analysis for: T1.4V_2.2Pa_2025-6-16-16-33-25_20_34_14_.mat

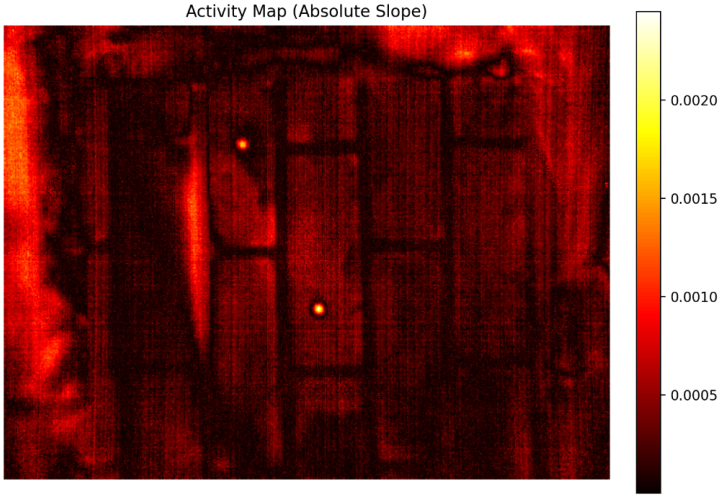
Static Cold Spots (Background < 20.55)



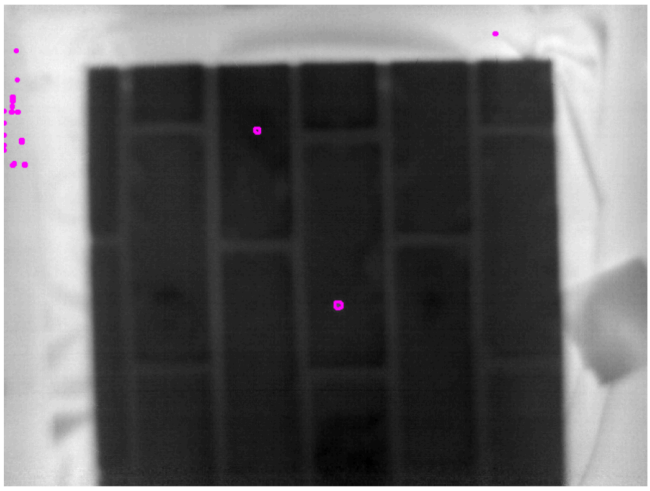
Temperature Slope Map (Blue=Cooling, Red=Heating)



Activity Map (Absolute Slope)



Combined: Static Holes (Green) & Active Regions (Magenta)



2. Evaluation of Zero-Shot Segmentation using Segment Anything Model (SAM)

To asses the performance of SAM model using only raw IR video frame as a raw input without any prompts.

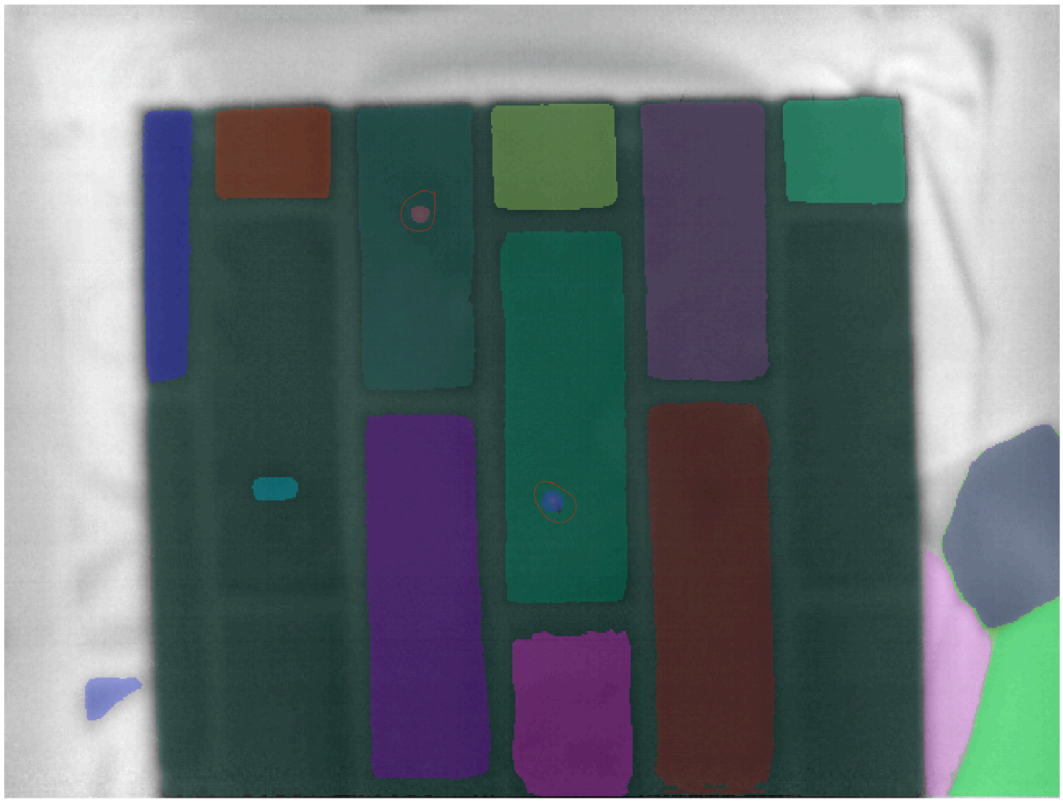
Results of "Segment Everything":

The model generated 19 potential masks, successfully segmenting the large, structurally obvious components of the image, such as individual bricks and the surrounding frame.

Crucially, SAM was able to identify the two small thermal hotspots corresponding to the leak locations (visible as two small, dark-colored masks in the center of the image and highlighted with red circles).

Interpretation: This result demonstrates that the thermal signature of the leaks, even if subtle, is distinct enough to be recognized as a valid "object" by SAM's powerful image understanding capabilities.
However, **the primary challenge remains:** the model also identified 17 other, larger objects. For a fully automated system, a method is needed to filter these numerous masks and select only the two corresponding to the leaks.

'Segment Everything' Result



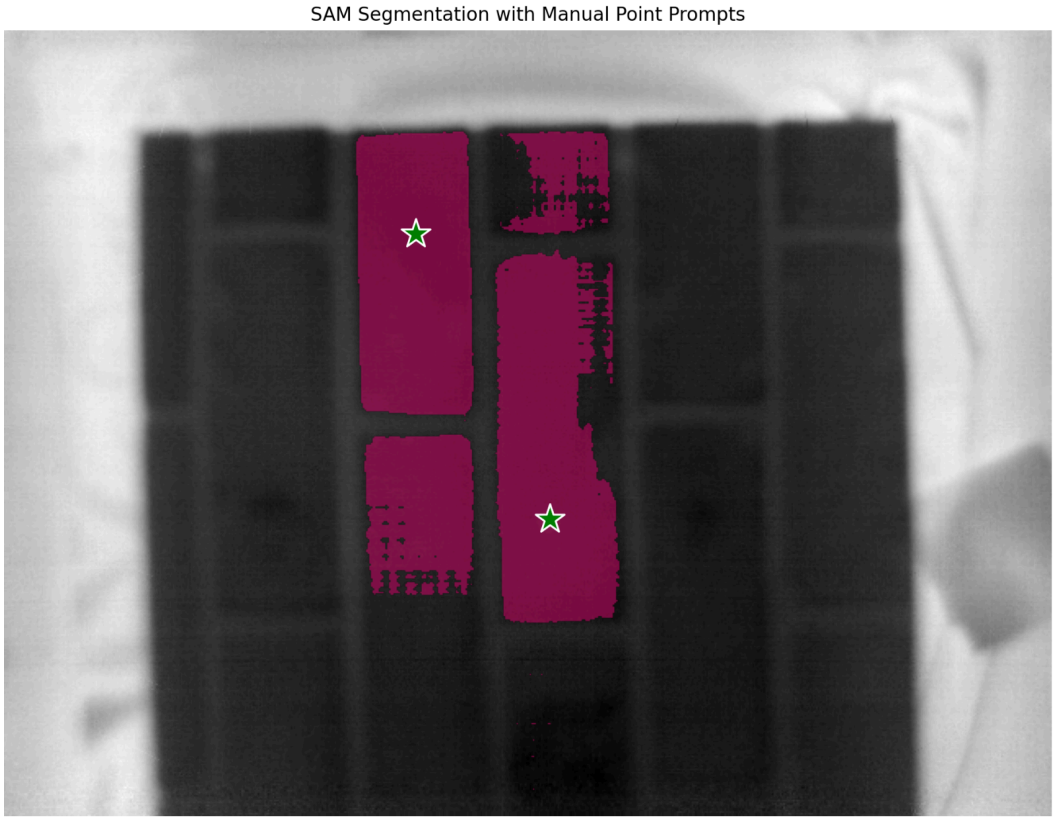
3. Evaluation of Prompted Segmentation with SAM

Next, I evaluated SAM by giving it the coordinates of the two holes a input prompts and then letting it generate new hotspot masks.

Results of Prompted Segmentation:

SAM was able to generate the hotspot mask, but it was not able to generate pinpoint masks overlaying the leaking hole; however, it selected a larger area, as shown in the figure below. *(Input prompts with the leaking hole location are marked with green stars)*

Interpretation: This demonstrates a key behavior of SAM. When prompted, it identifies the most "plausible" object at that location. In the context of a textured brick surface, the brick itself is a more structurally coherent and obvious object than the subtle thermal anomaly on top of it. Therefore, without further guidance, SAM defaults to segmenting the larger object. This confirms that a simple positive point prompt is insufficient for this task.



4. Proposed High-Level Plan: A Hybrid Approach

The proposed path forward is to create a hybrid pipeline that uses the activity map to automatically guide SAM:

Detect with Temporal Analysis: For a given input video, first generate the Activity Map using our established slope analysis method. This leverages the temporal information (change over time) to amplify the signal of the dynamic leak events.
Find Automatic Prompts: Instead of using the noisy activity map to create a final mask, we will simply find the coordinates of the top two peaks of activity. These coordinates will serve as our automatically generated positive point prompts. We can also programmatically generate negative prompts in the surrounding area to further constrain SAM.
Segment with SAM: Provide the original thermal frame (e.g., the last frame) and the automatically generated positive (and negative) prompts to SAM.
Final Mask: SAM will use these precise prompts to perform its powerful segmentation, ignoring the larger brick and focusing only on the object at the prompt location, yielding a clean and accurate final hotspot mask.

Benefits of this Hybrid Approach:

This strategy will combine the best of both worlds. It will use the temporal analysis to robustly answer "Where are the leaks?" and use SAM's superior spatial segmentation to answer "What is the exact shape of the leaks?".
This will avoid the pitfalls of each individual method and provide a clear, data-driven path to achieving fully automated and accurate hotspot segmentation across different materials.