Heat of the Moment: Characterizing the Efficacy of Thermal Camera-Based Attacks

Keaton Mowery (UC San Diego)
Sarah Meiklejohn (UC San Diego)
Stefan Savage (UC San Diego)

Code-based access control

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The problem: what if there is a camera watching you type in your code?

Filming keypads

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Our attack: this residue can then be recorded by a thermal camera

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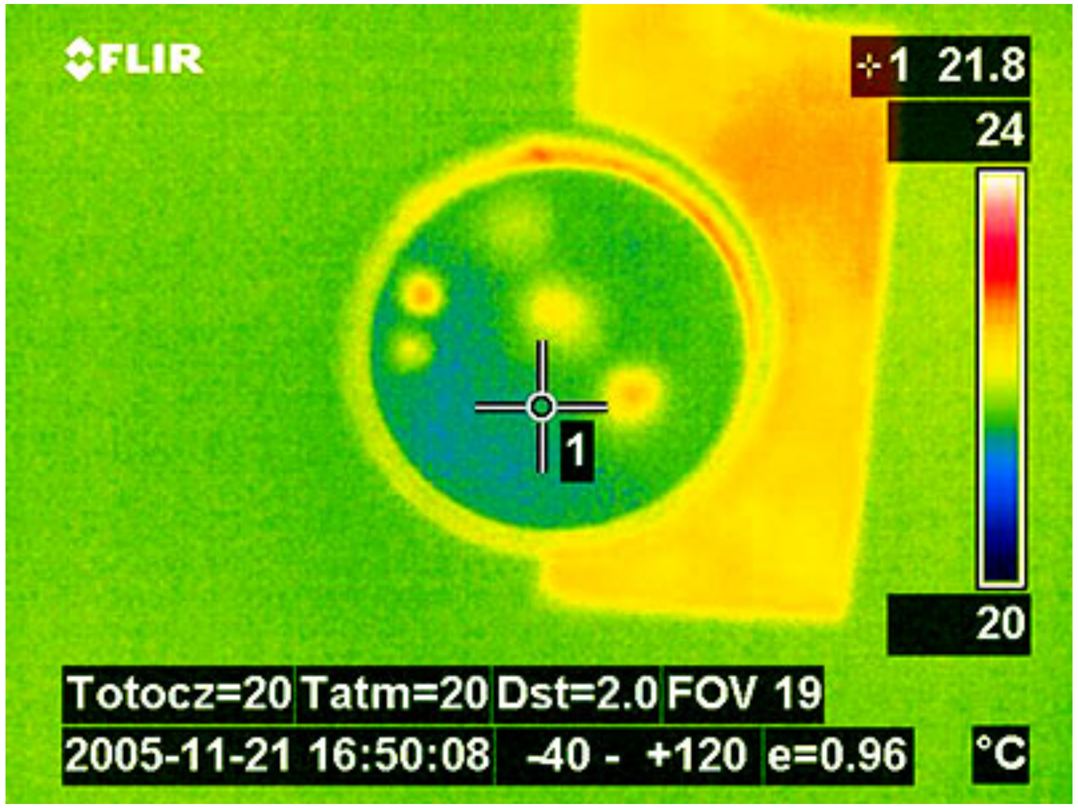

(images from lcamtuf.coredump.cx/tsafe)

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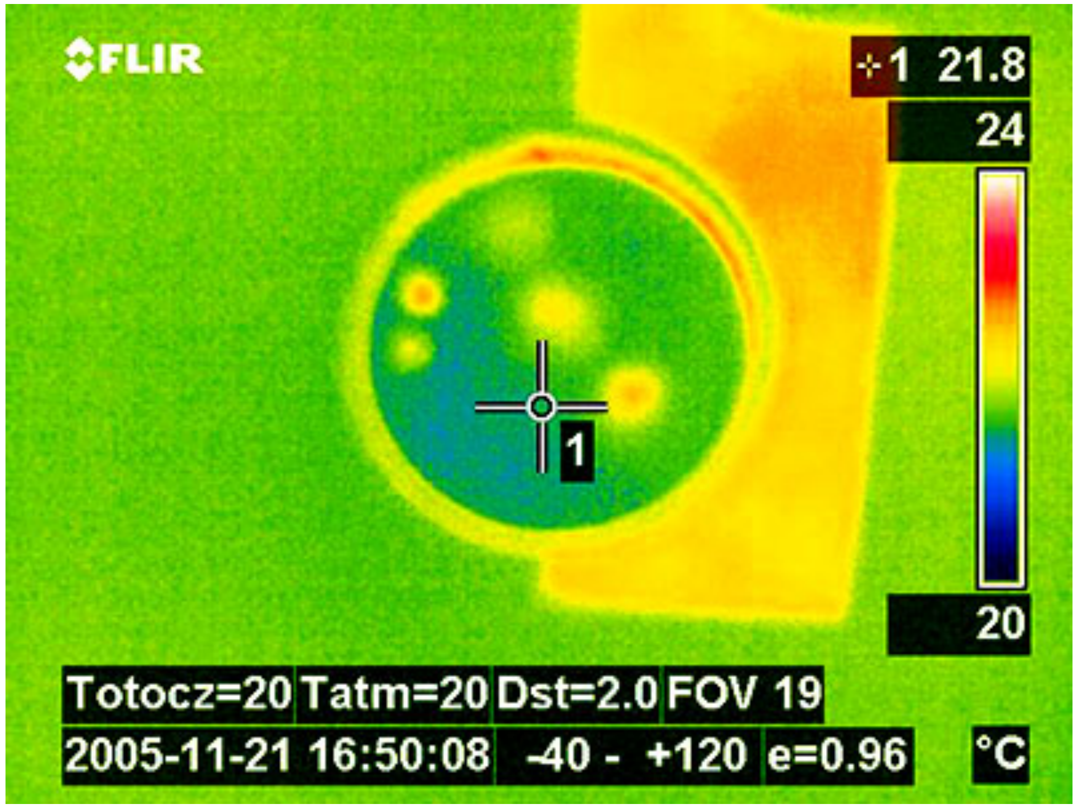

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He was able to retrieve thermal residue for between five and ten minutes after code was entered

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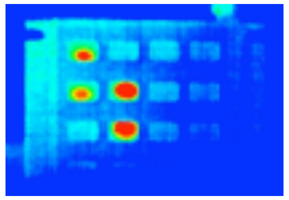
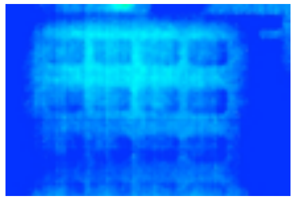
- Keypad users (cold- vs. warm-blooded, etc.)  

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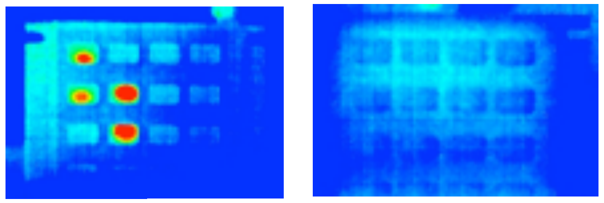

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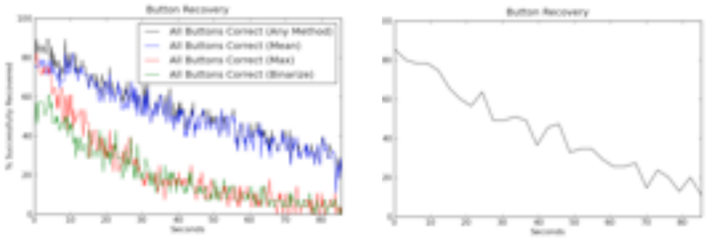

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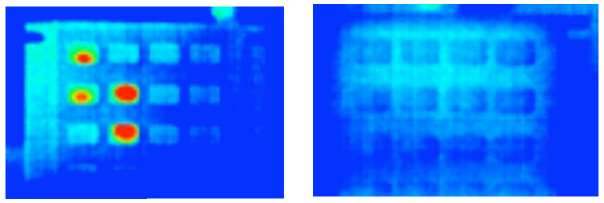
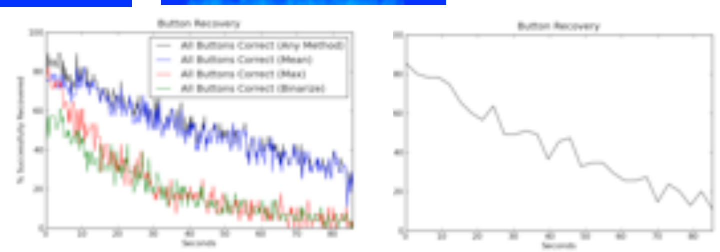
- Keypad users (cold- vs. warm-blooded, etc.) 
- Review methods (automated vs. visual inspection) 

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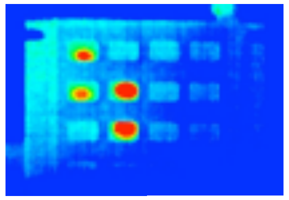
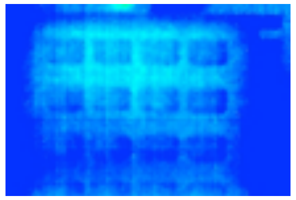
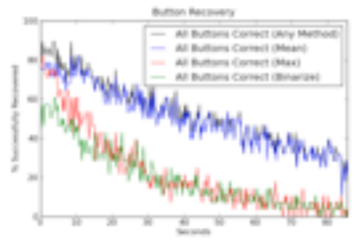
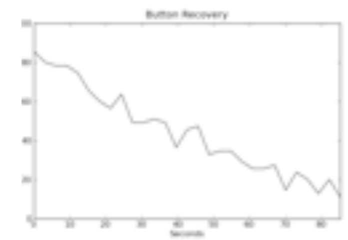
- Keypad users (cold- vs. warm-blooded, etc.)  
- Review methods (automated vs. visual inspection)  
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Find that results vary substantially as we change above variables

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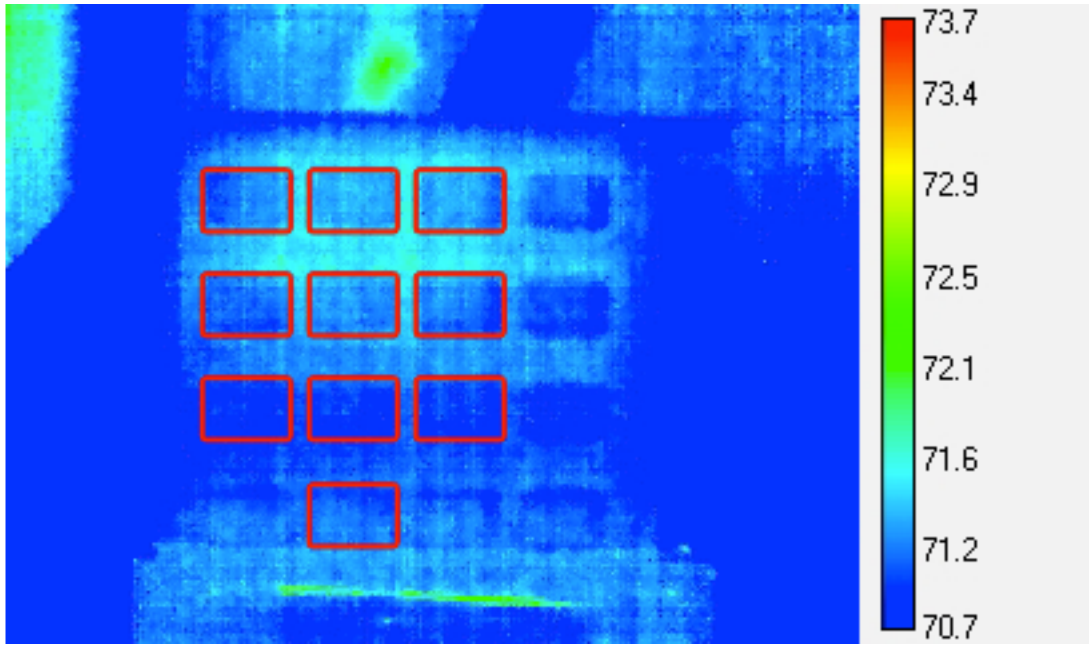
Used software to indicate ten regions of interest on the keypad (0-9)



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Filmed the keypad for 3 seconds before code entry, then 100 seconds after, recorded 3 frames per second

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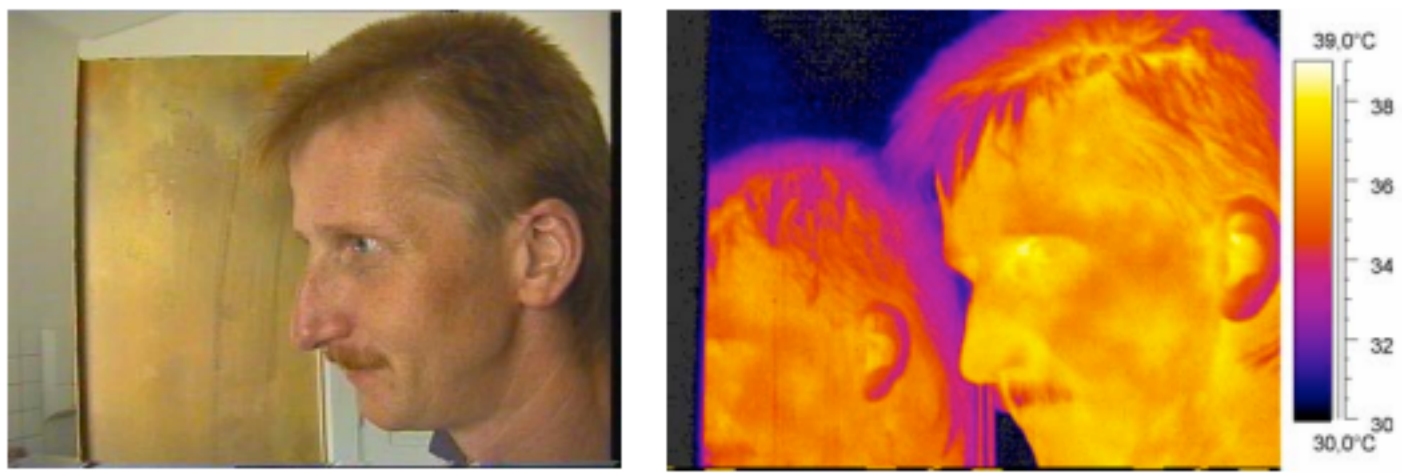

Figure 5. *An oxidized old brass plate with a lot of surface roughness in the 1µm scale or below is scattering light diffusely for visible light, but at least in part specularly for thermal IR radiation of $\lambda \approx 10\mu m$.*

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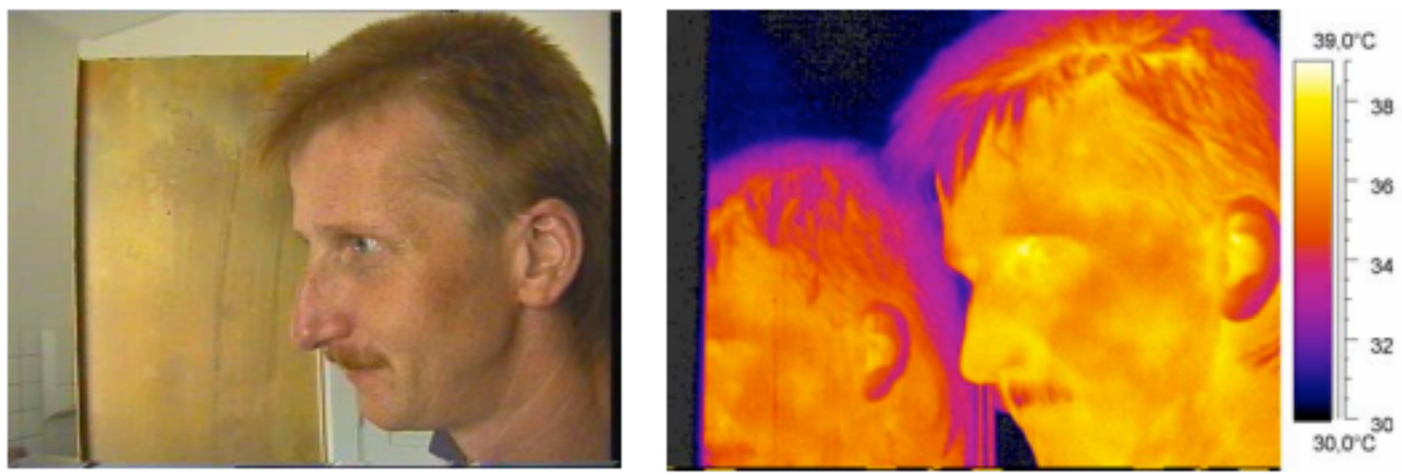

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So the rest of our results are only for plastic keypads

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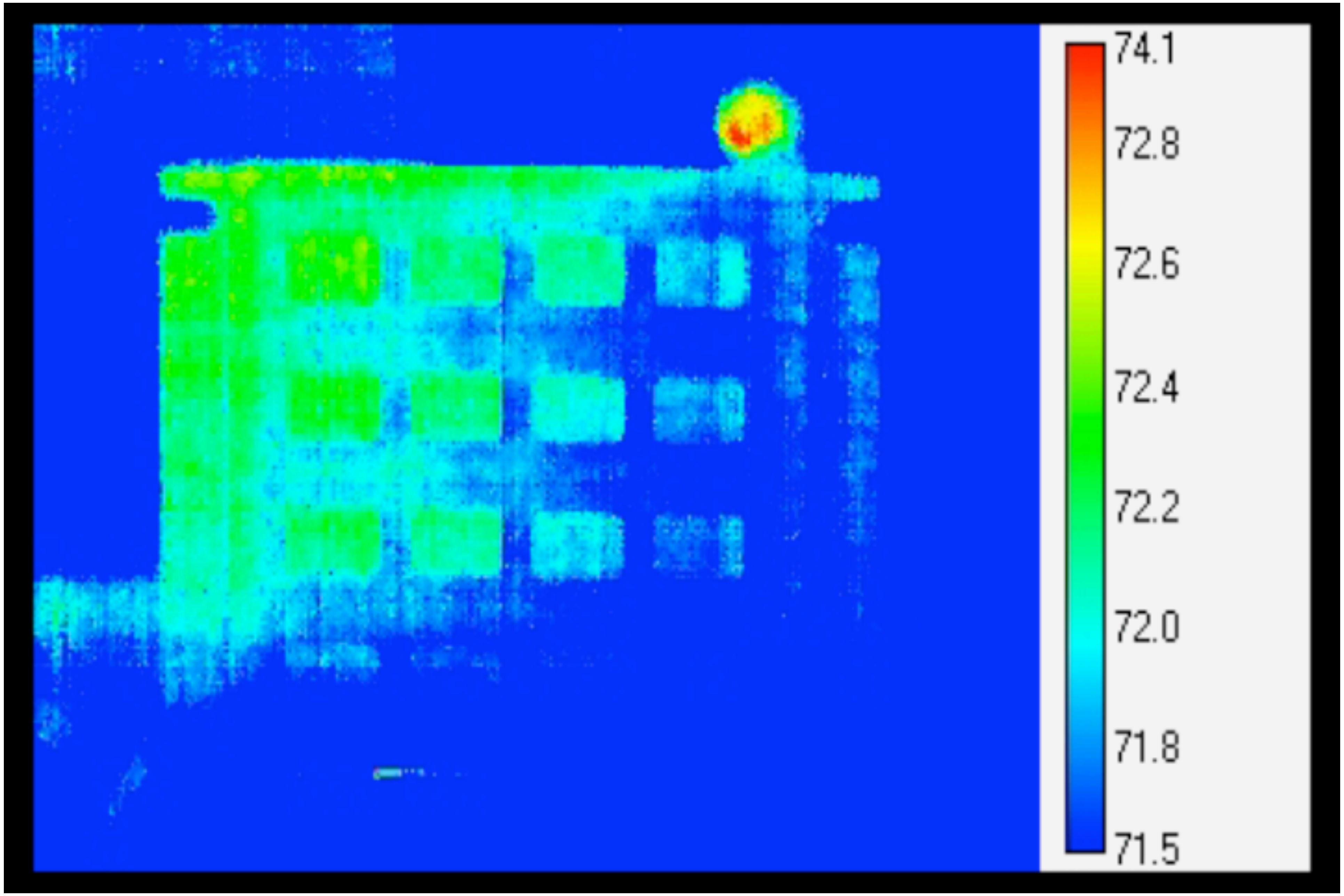

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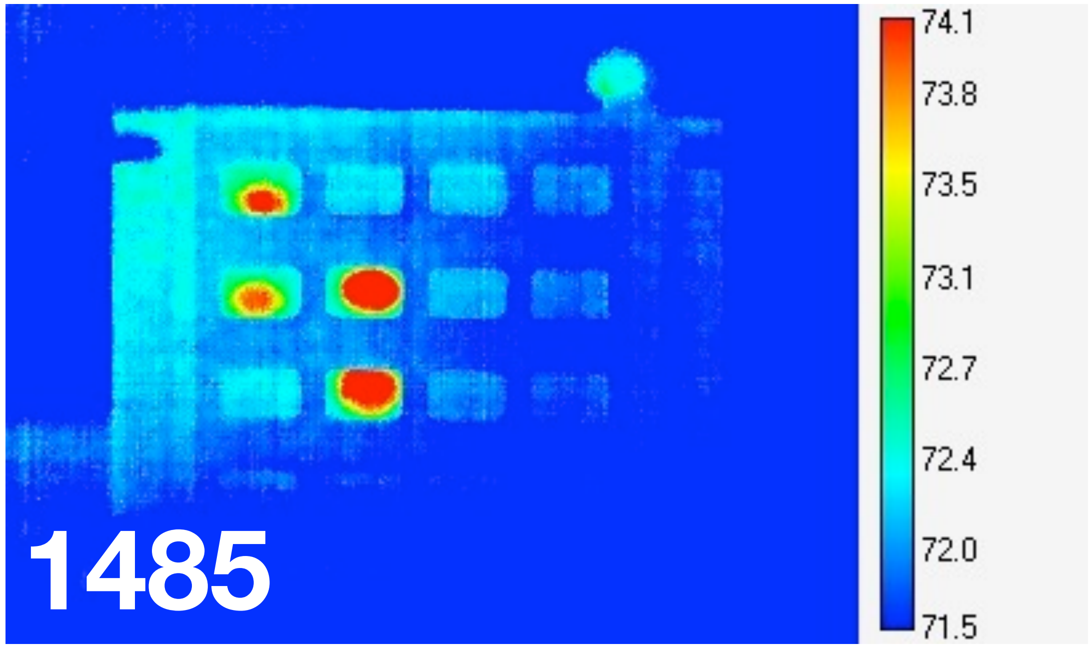

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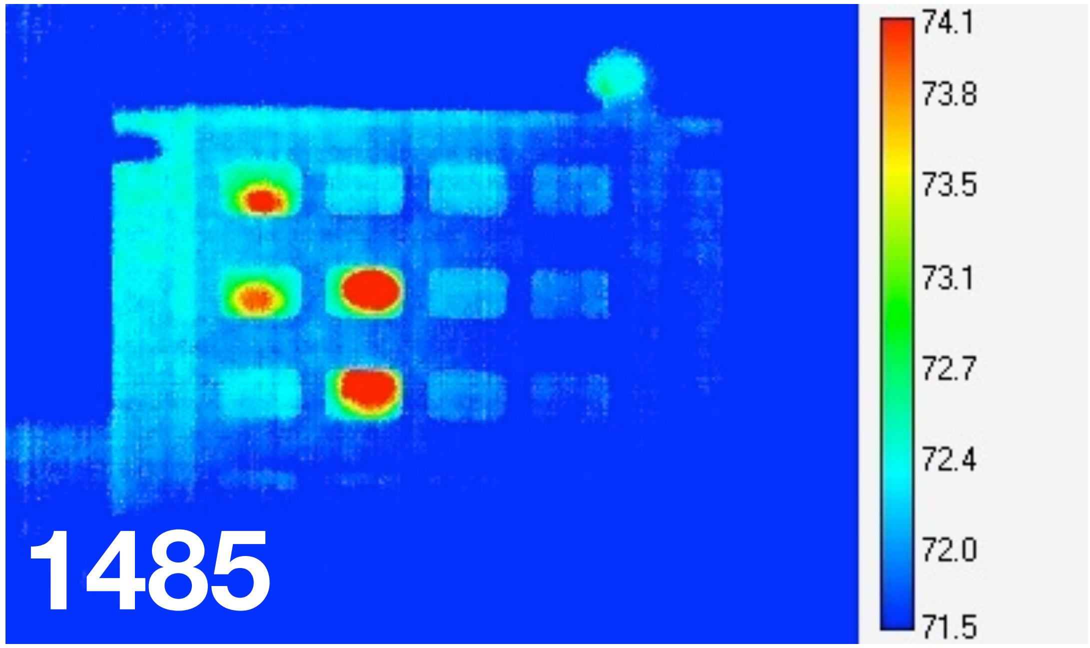

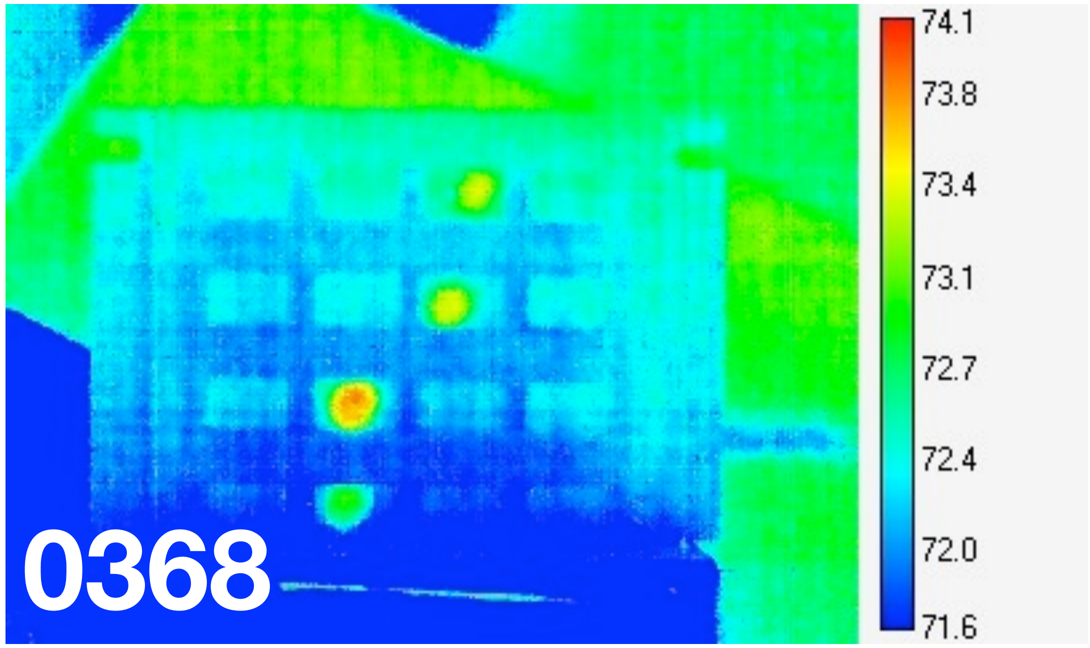

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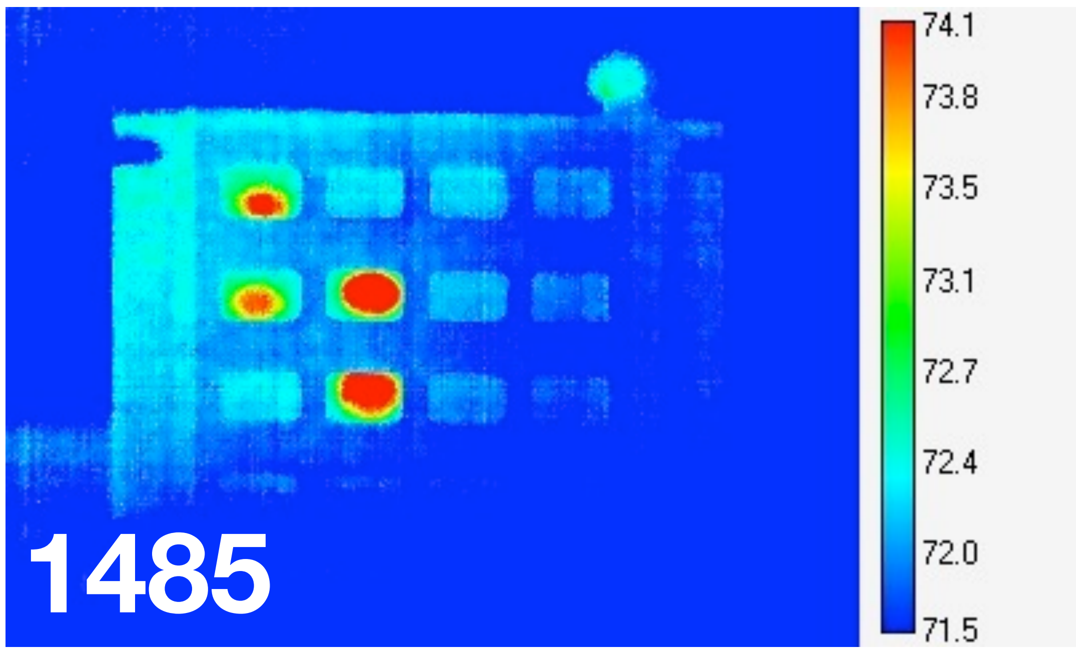

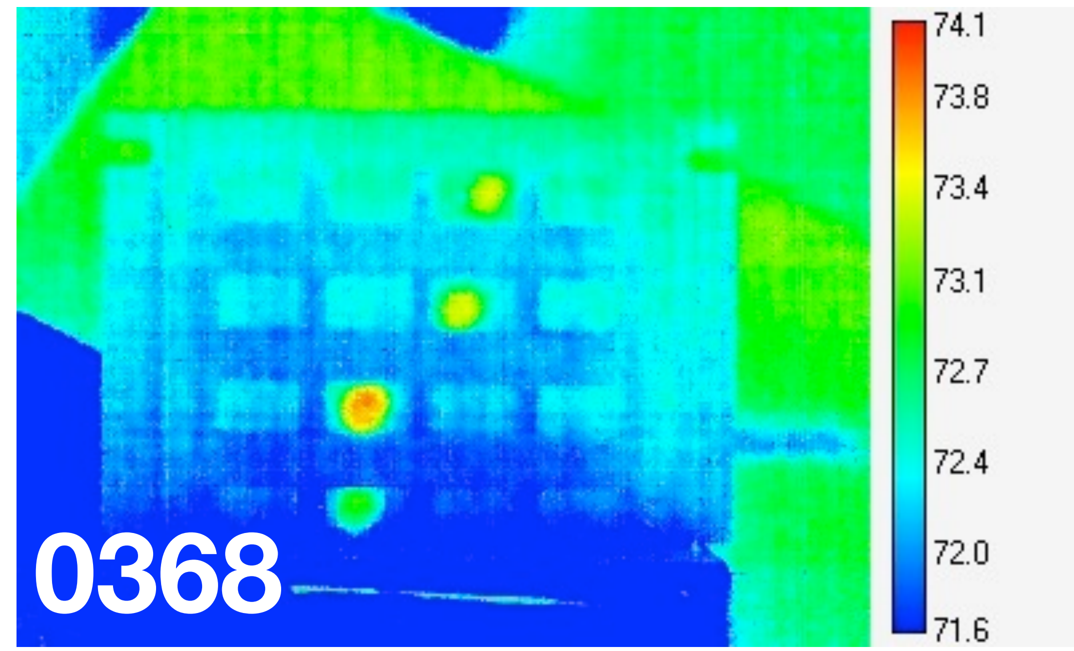

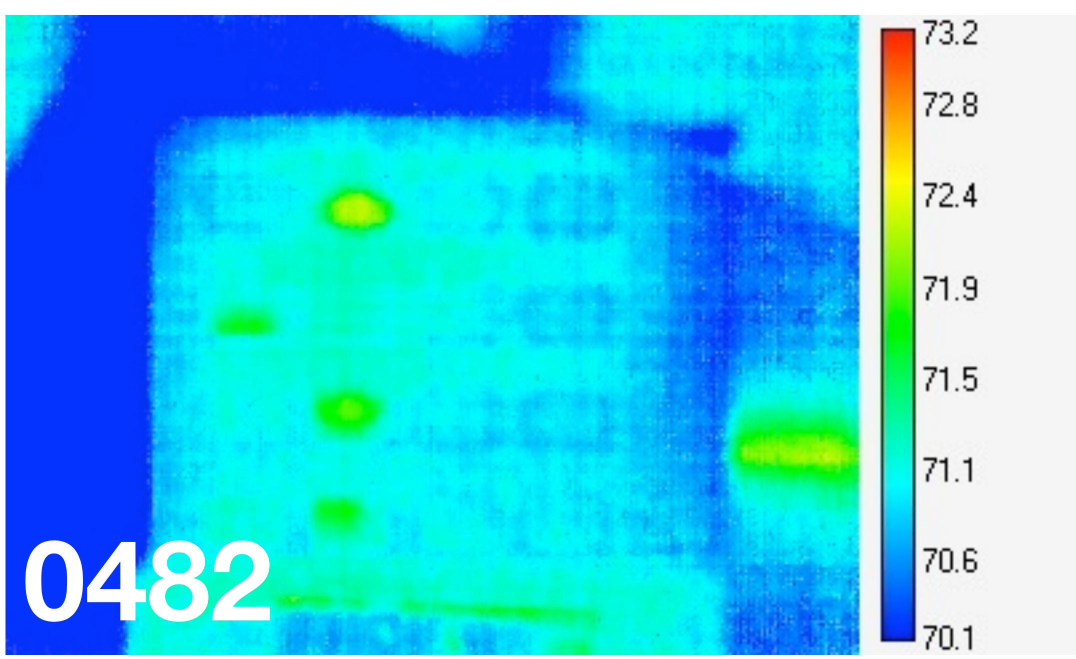

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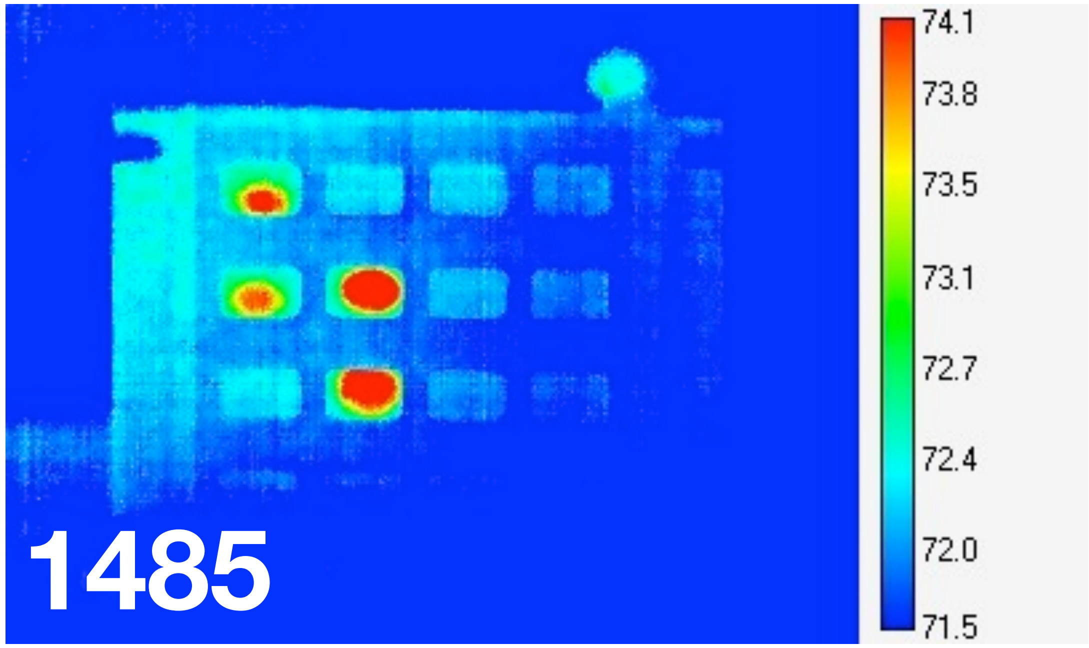

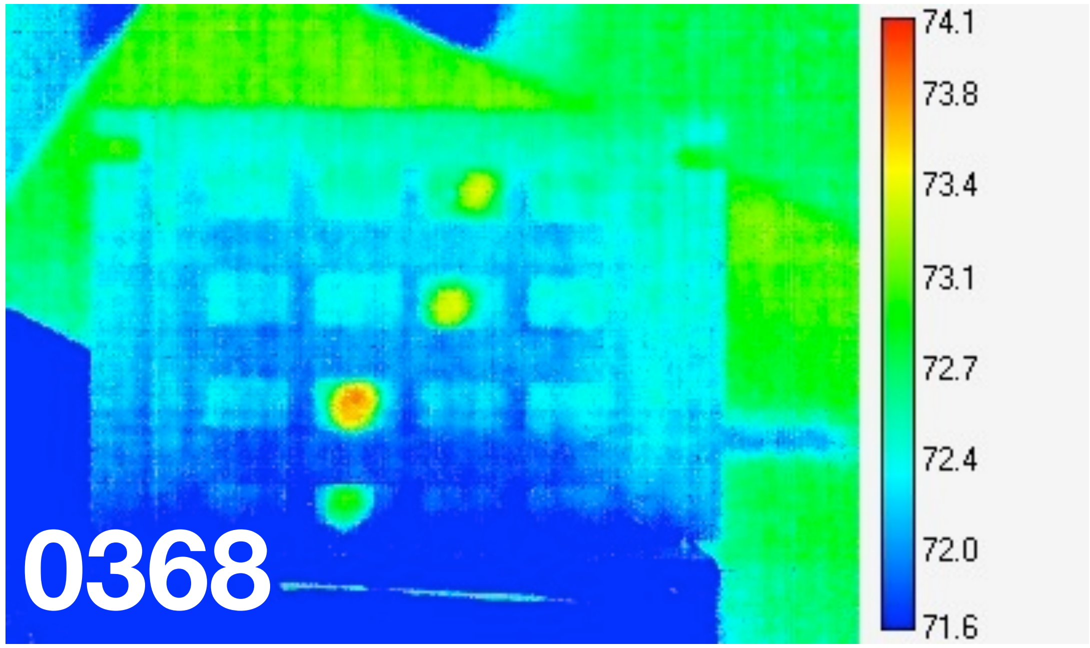

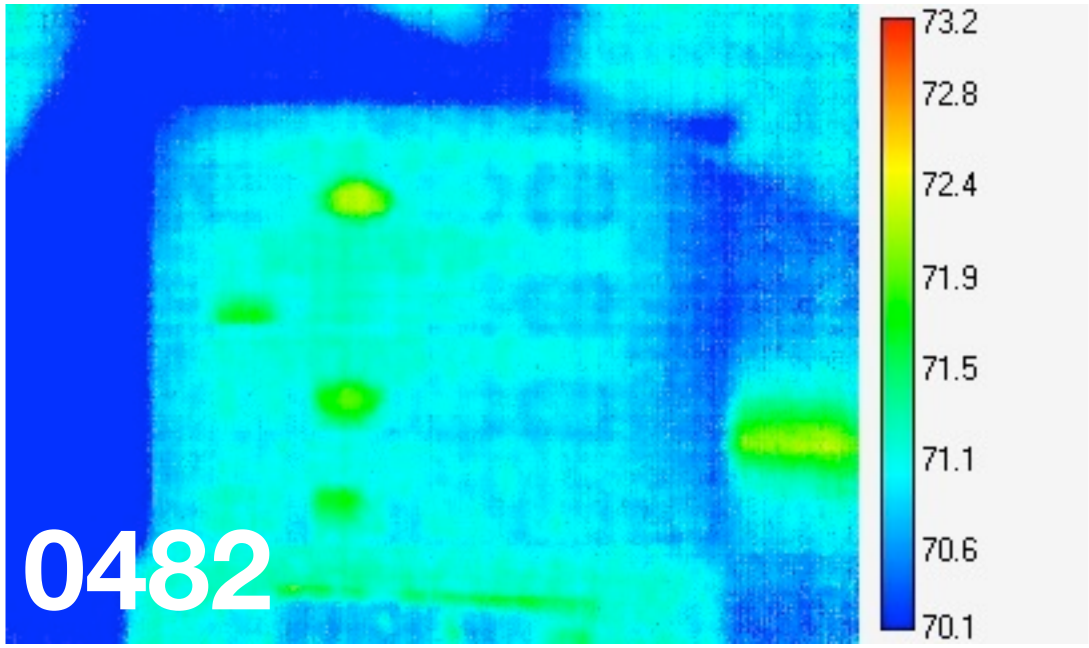

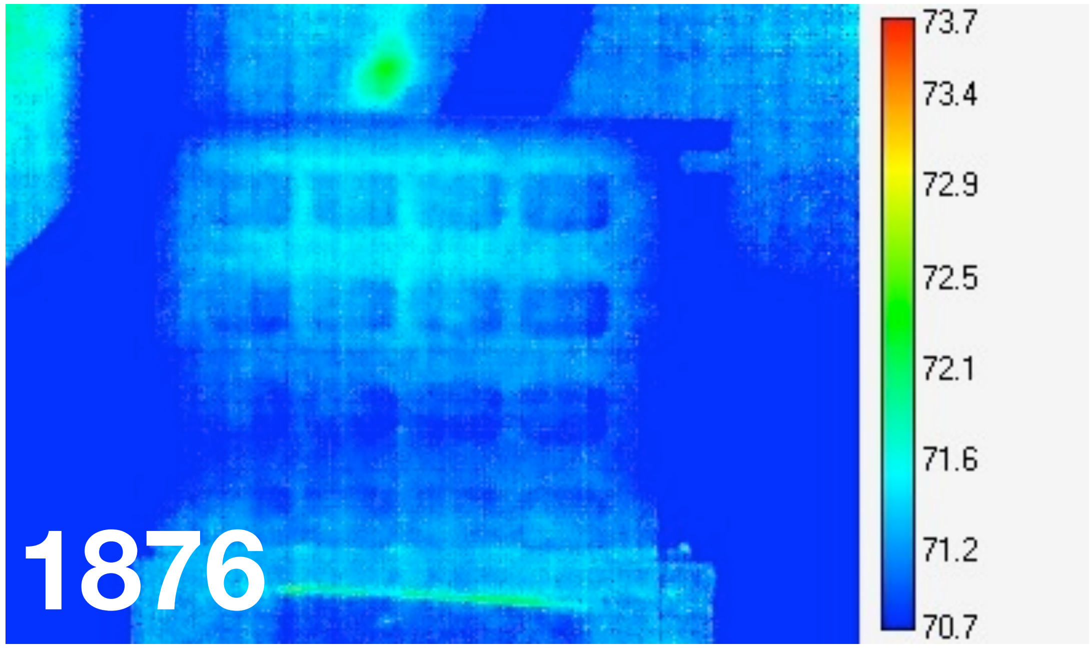

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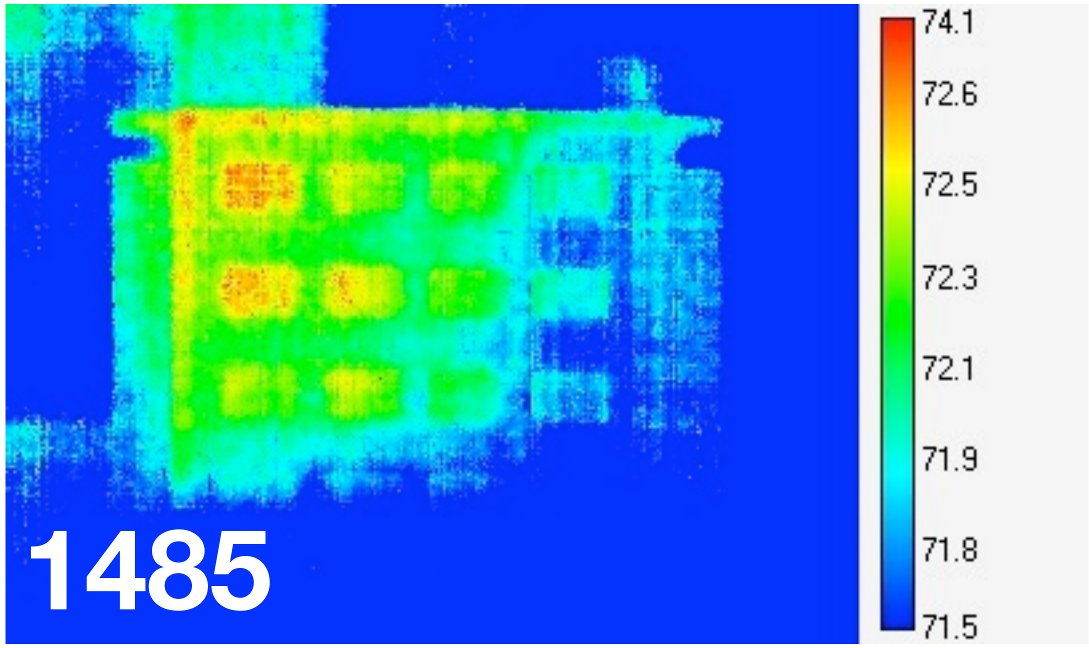

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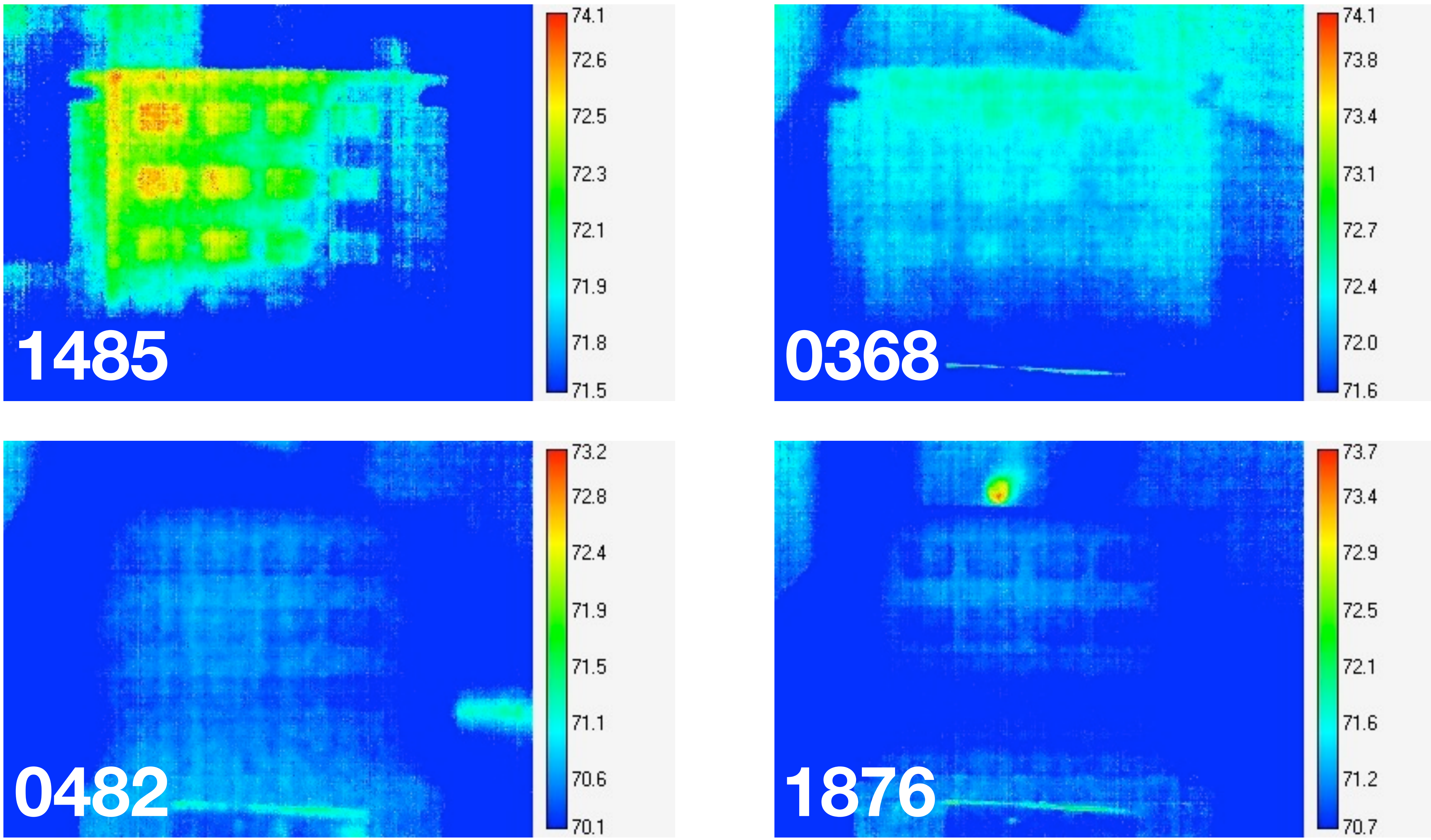

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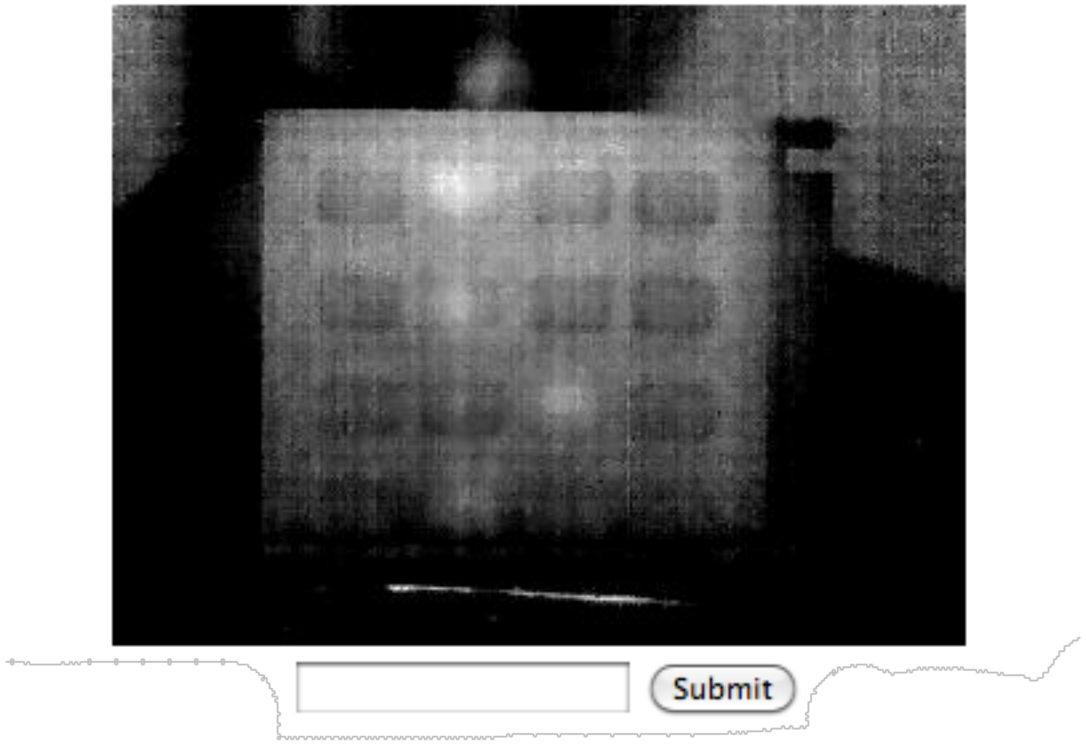

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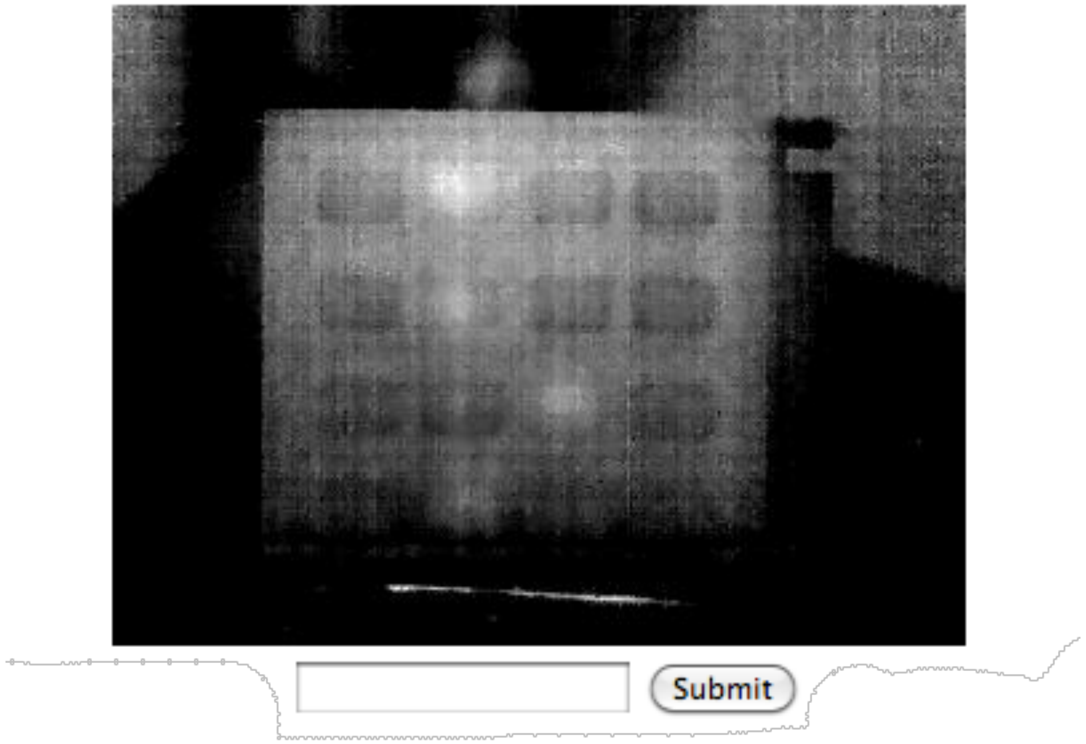

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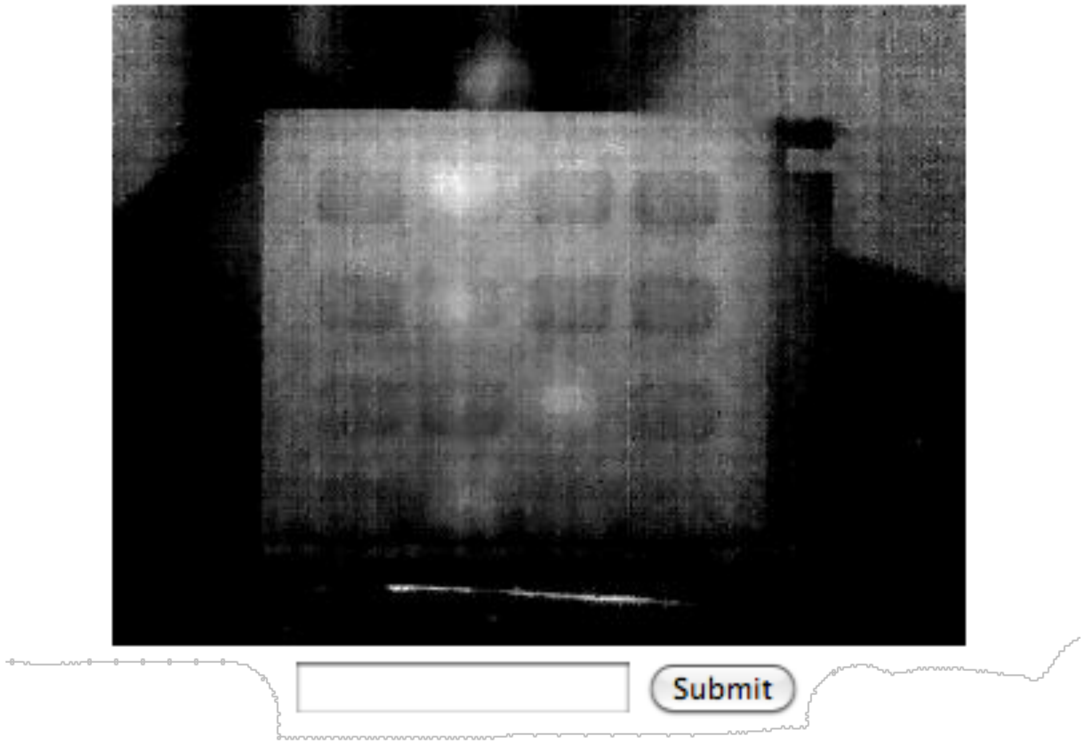

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- Second approach: automated review

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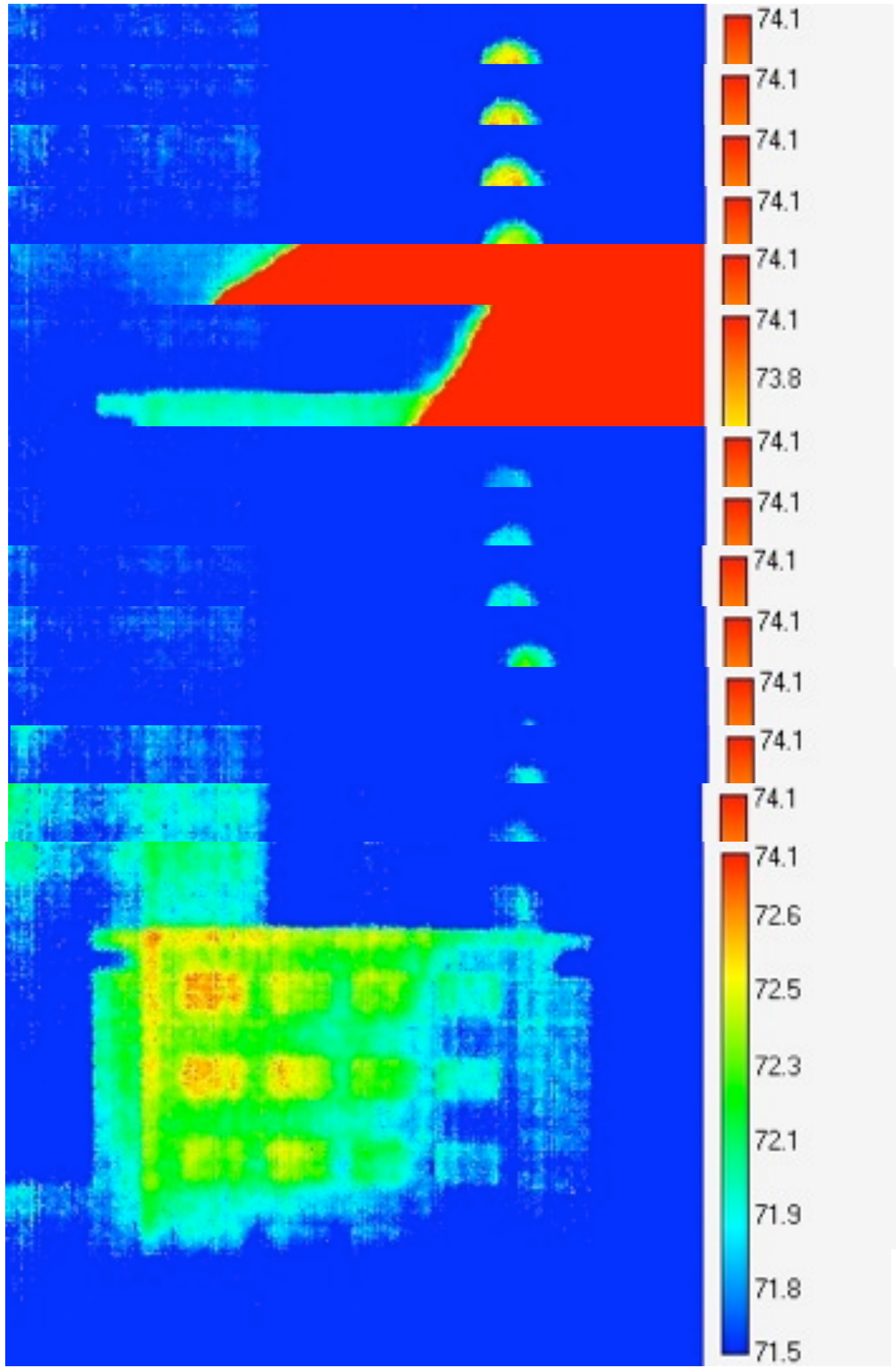

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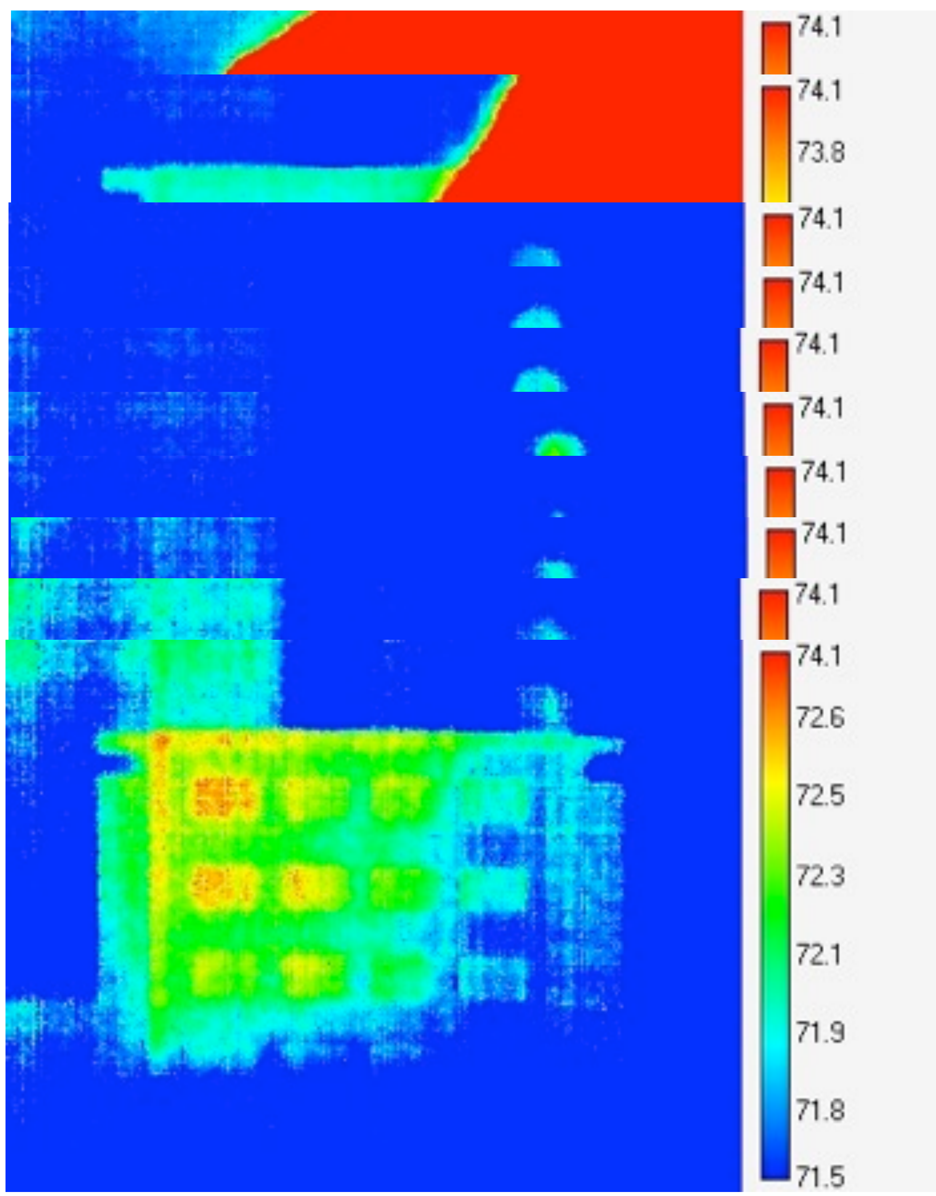

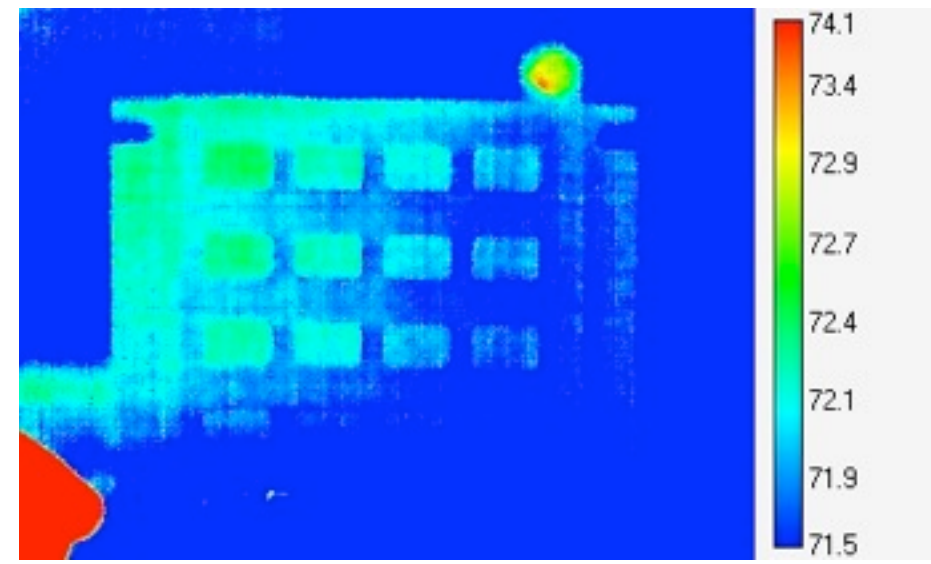

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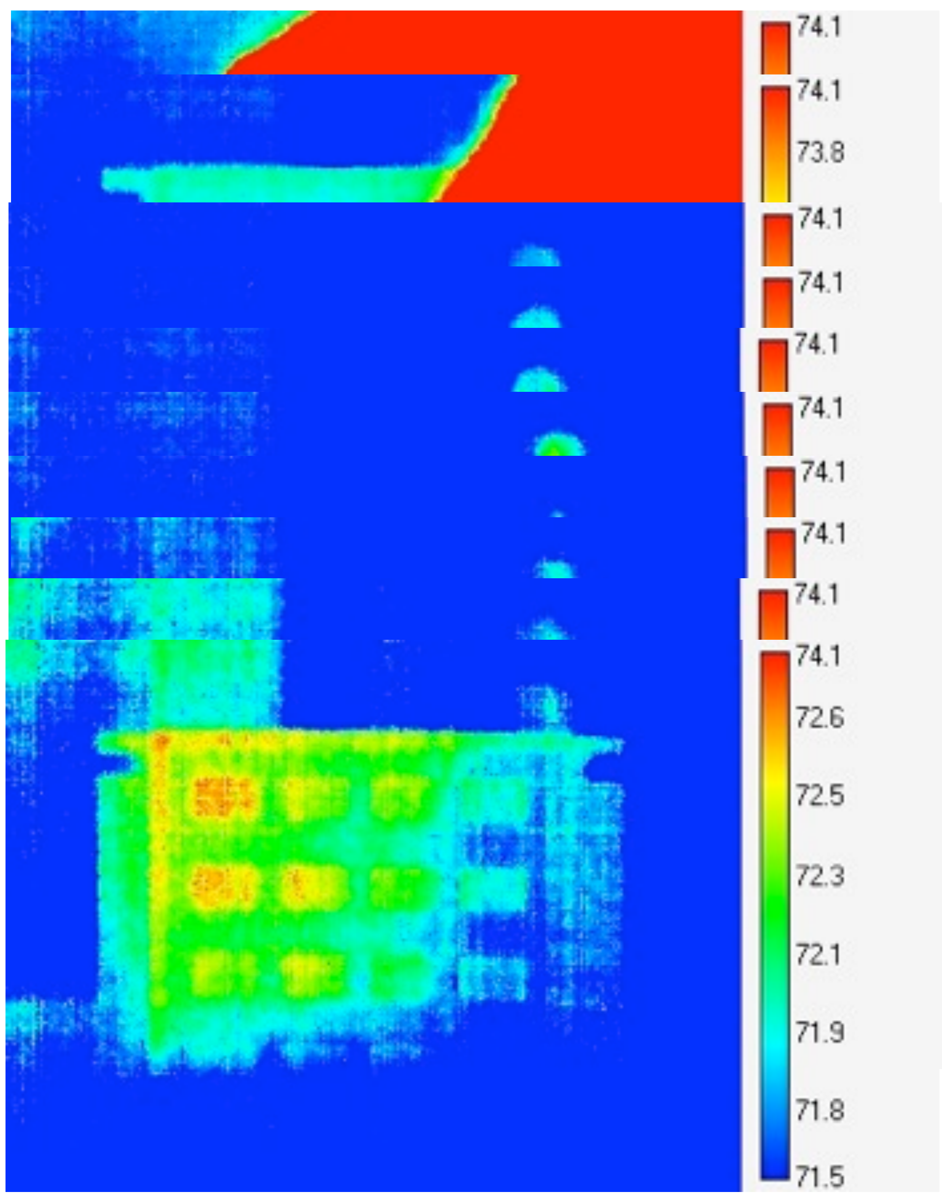

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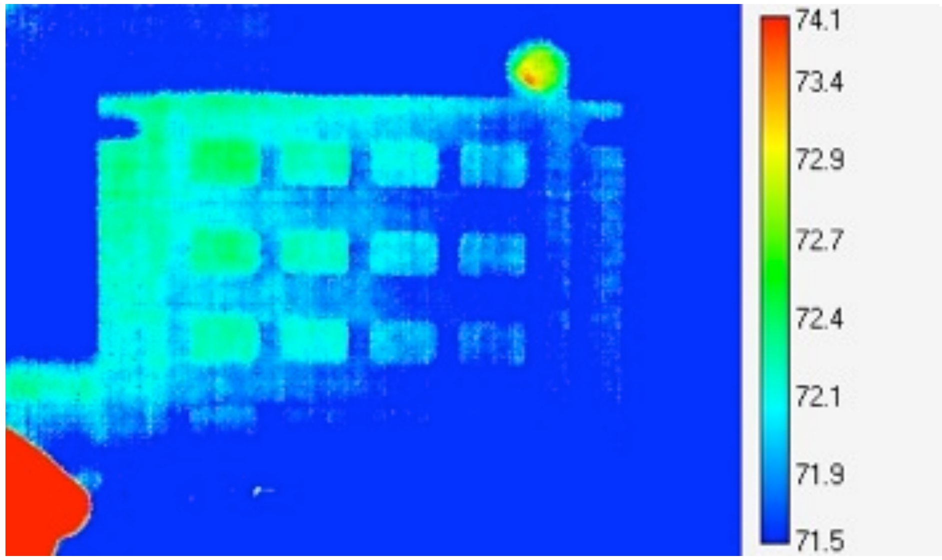

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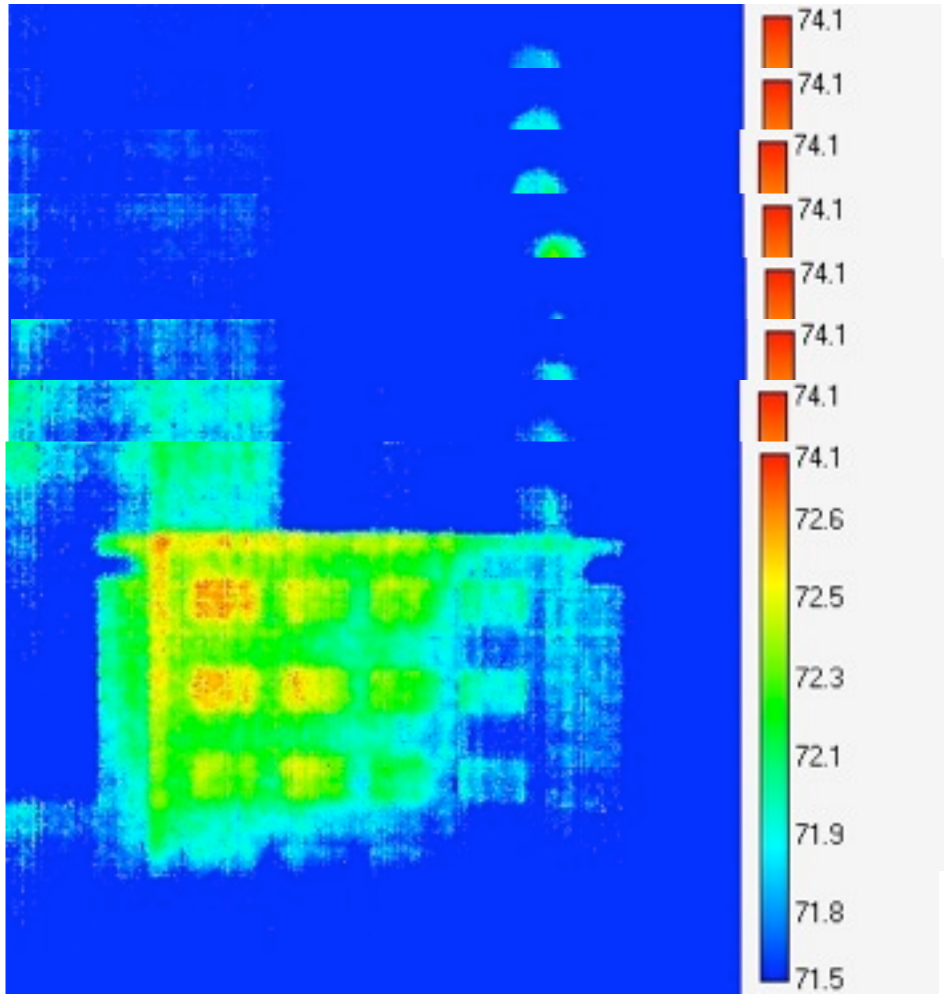

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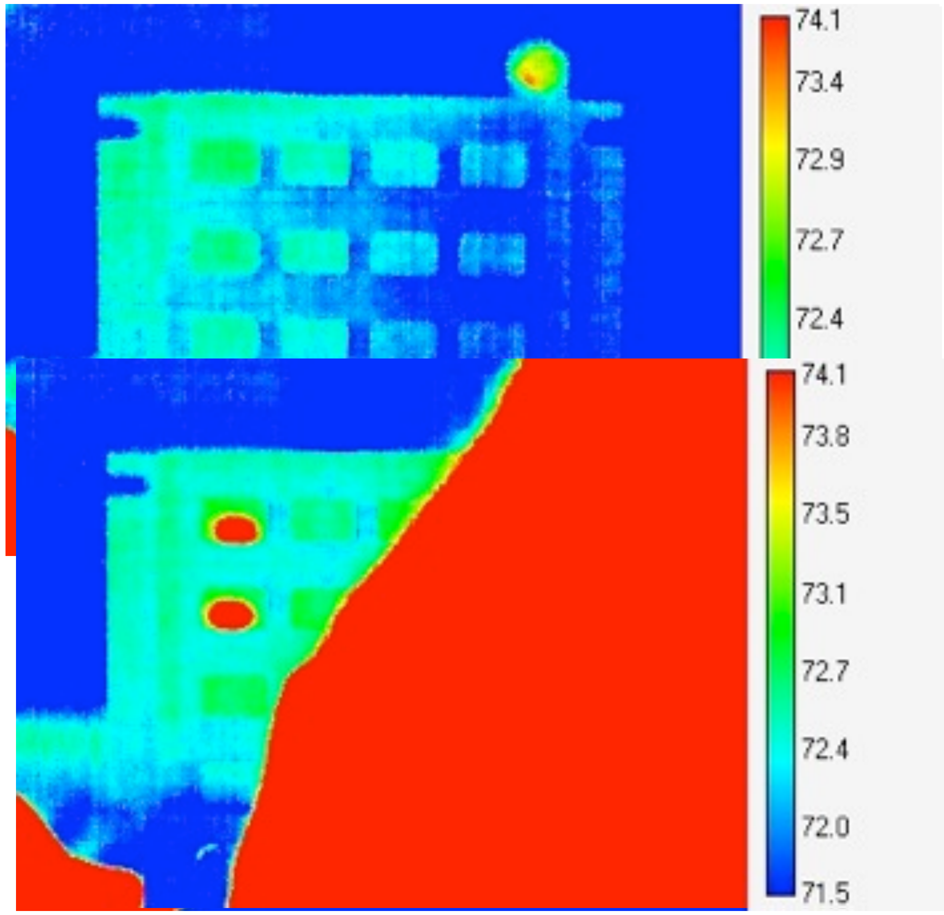

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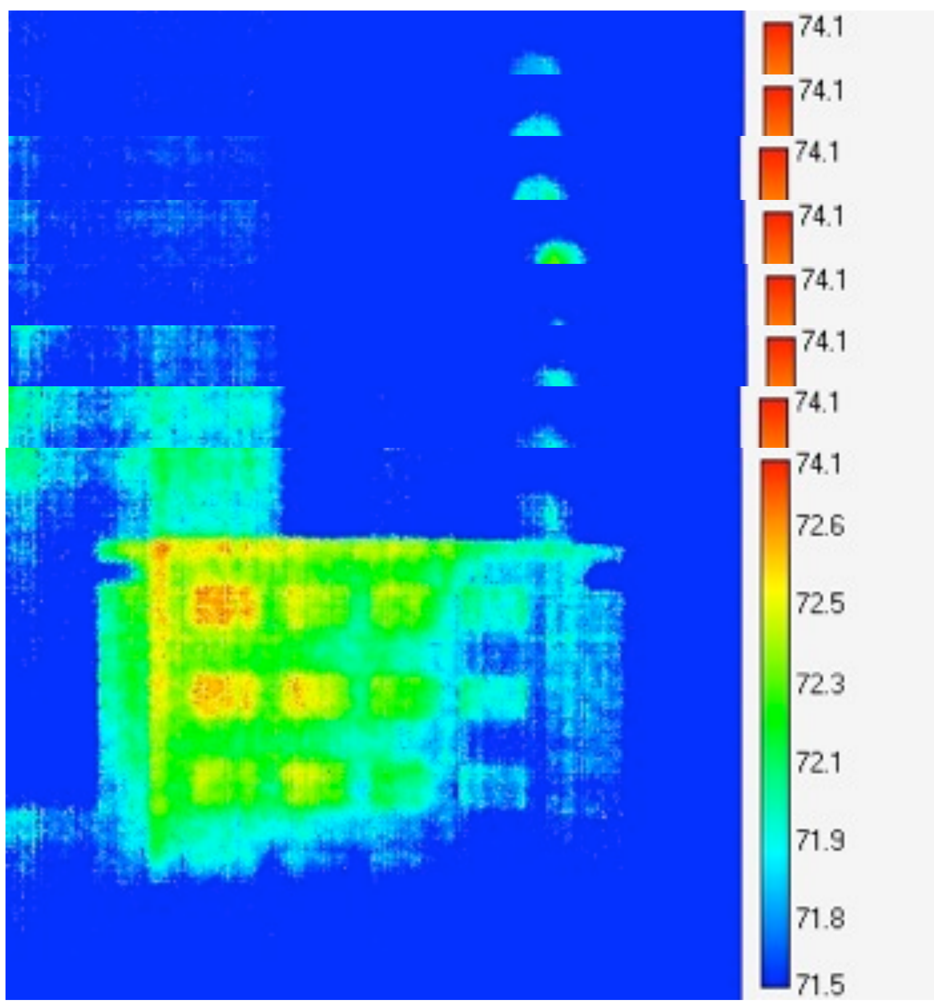

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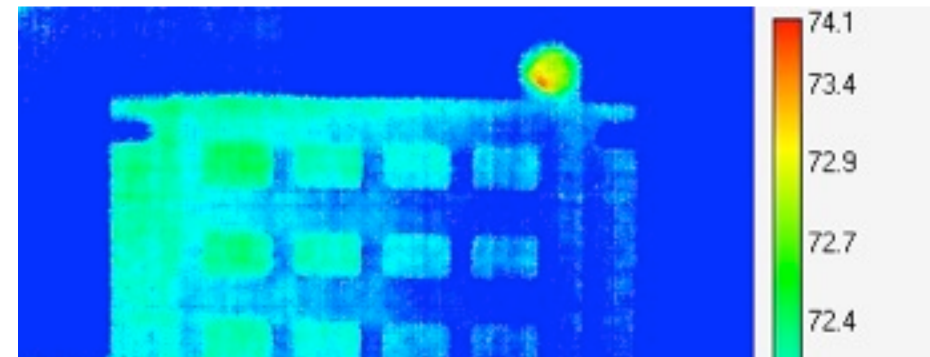

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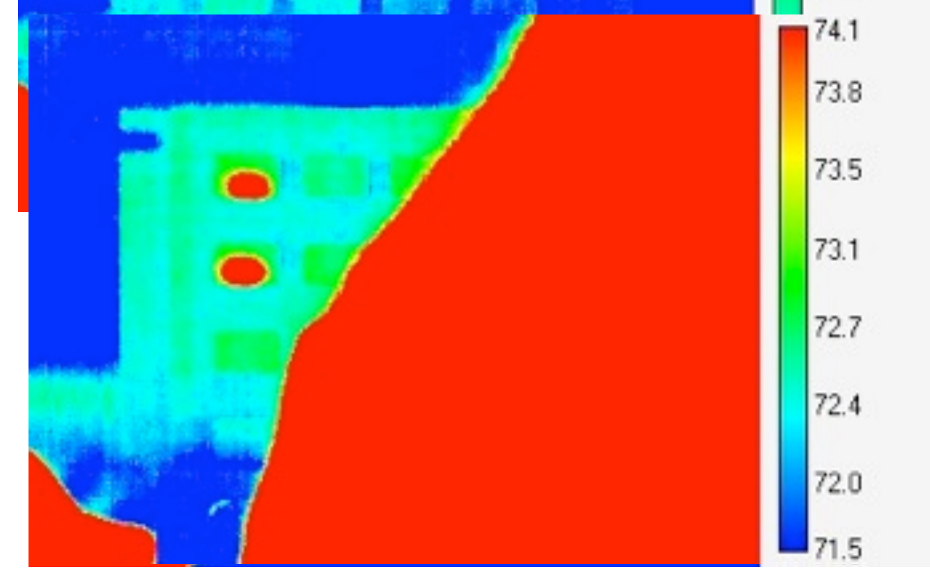

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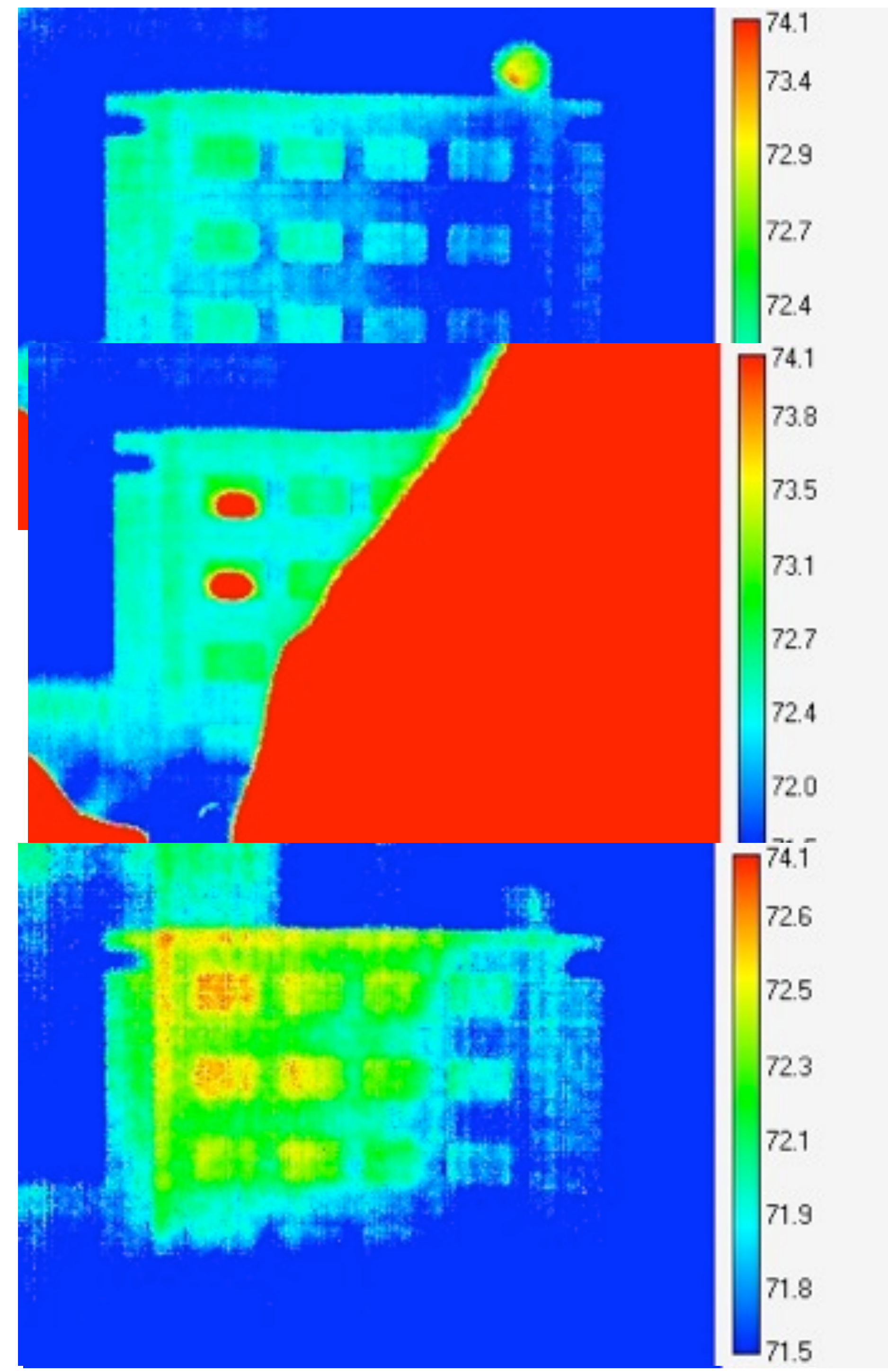

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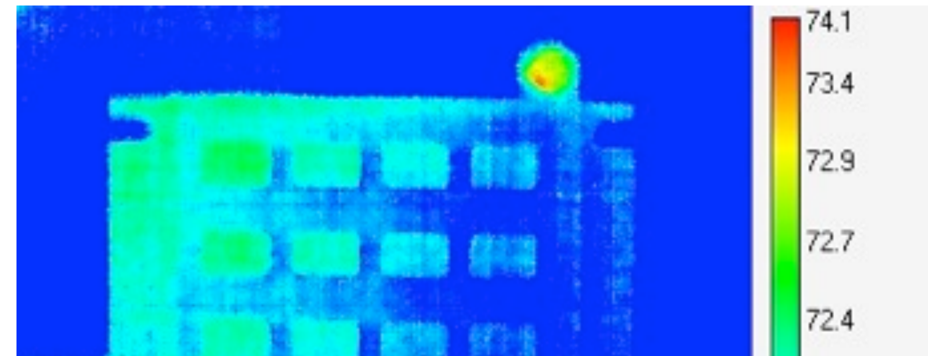

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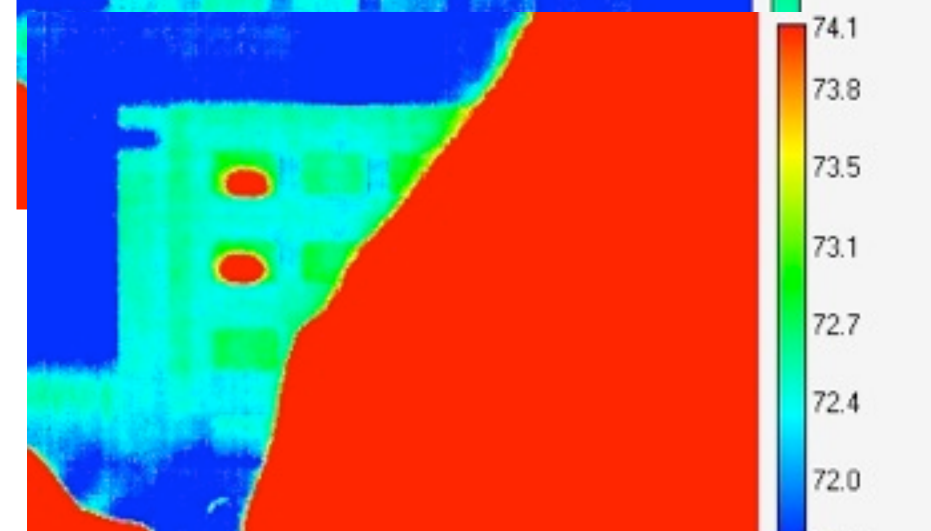

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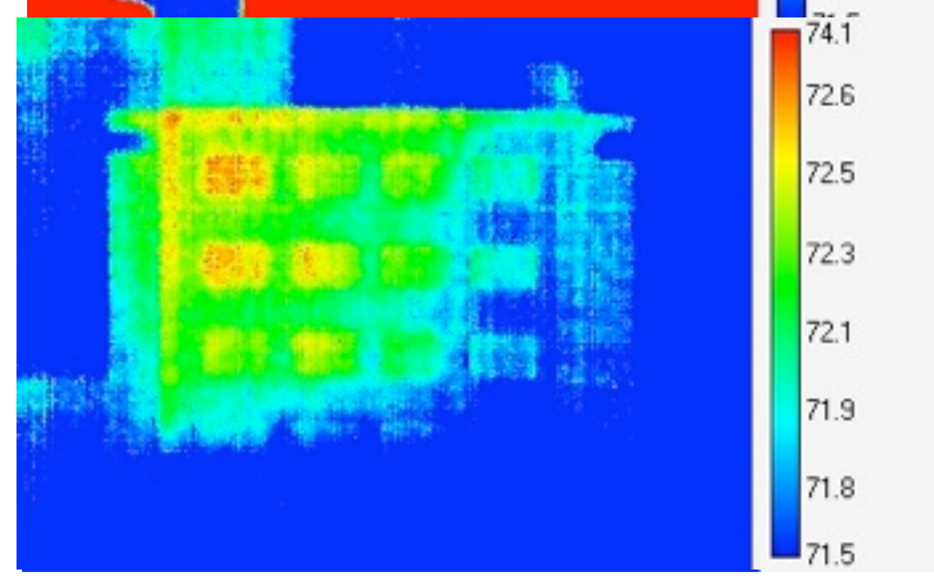

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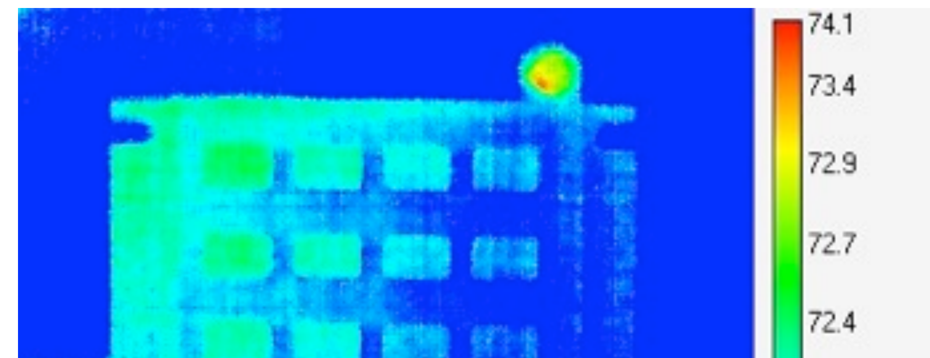

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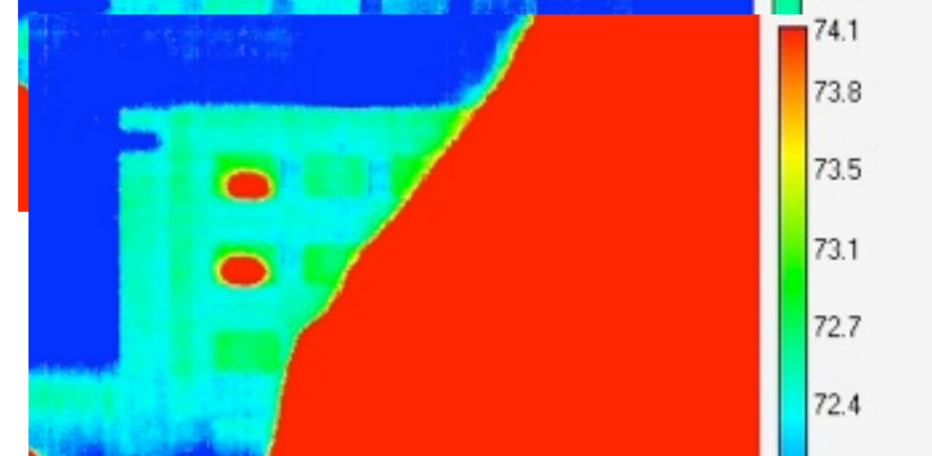

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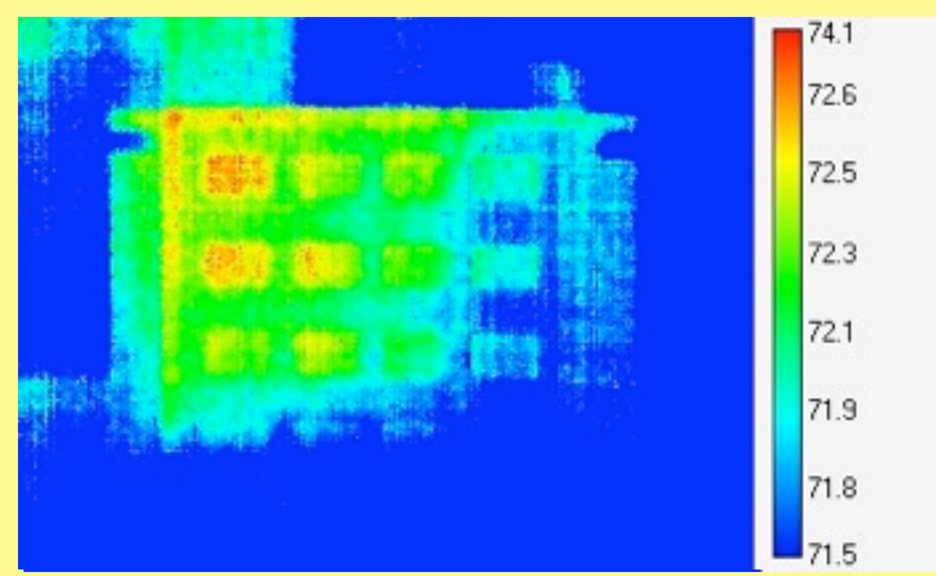

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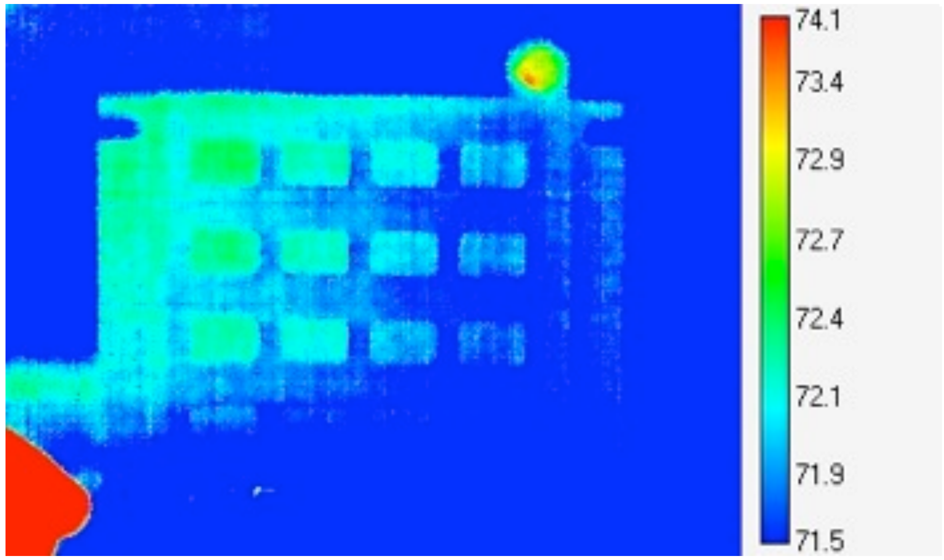

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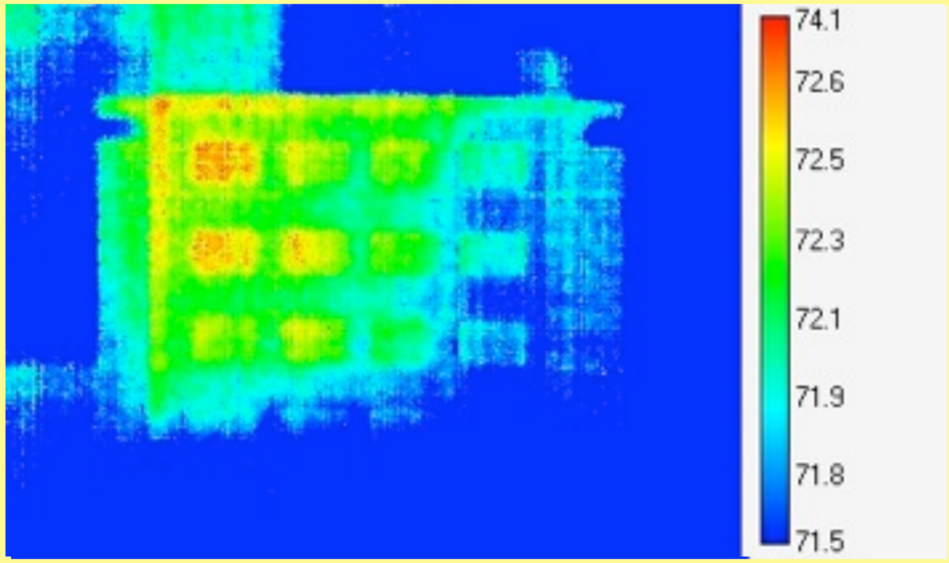

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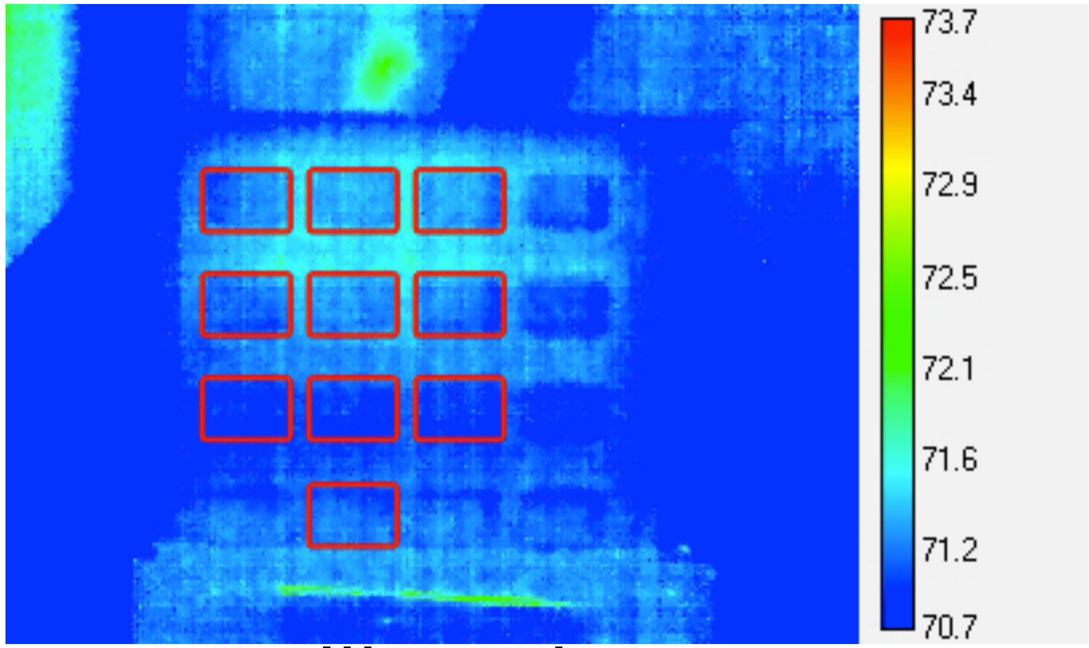

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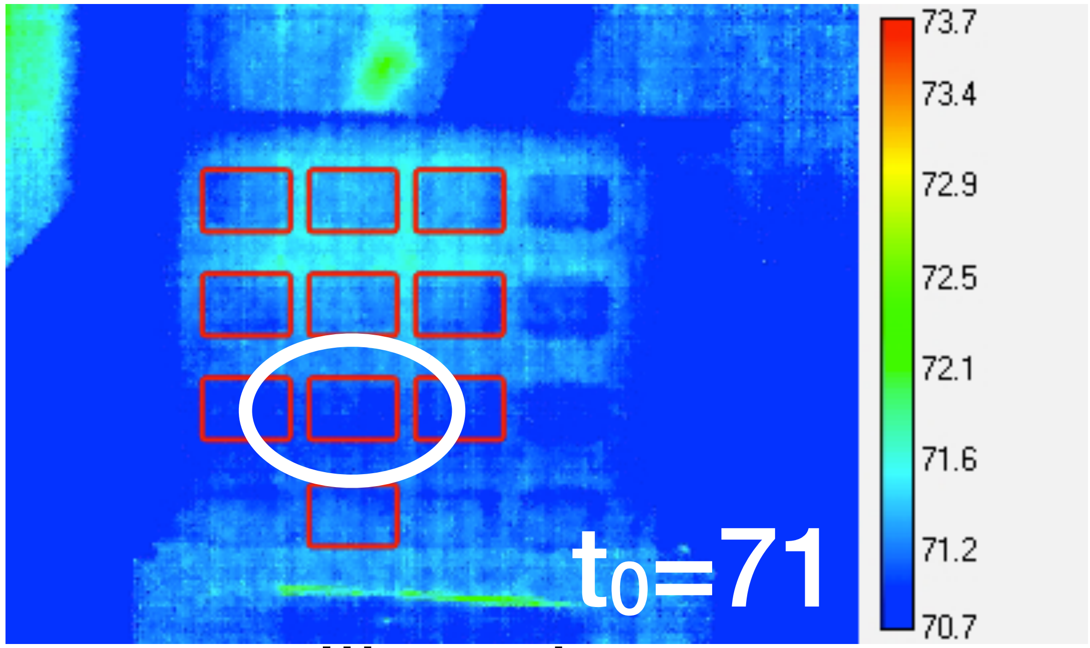

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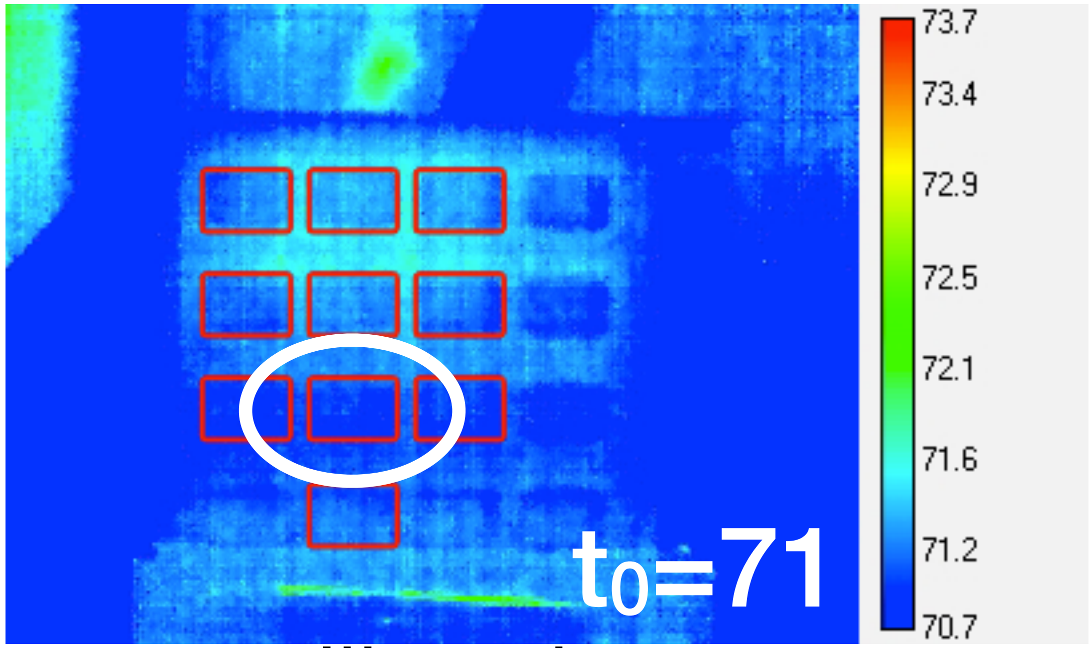

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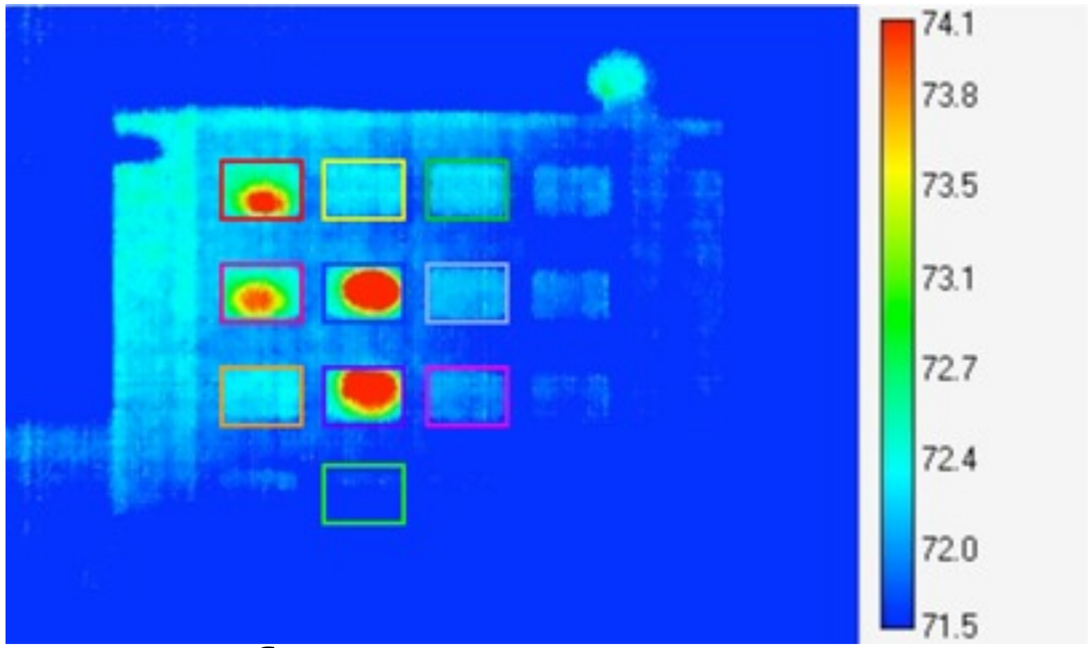

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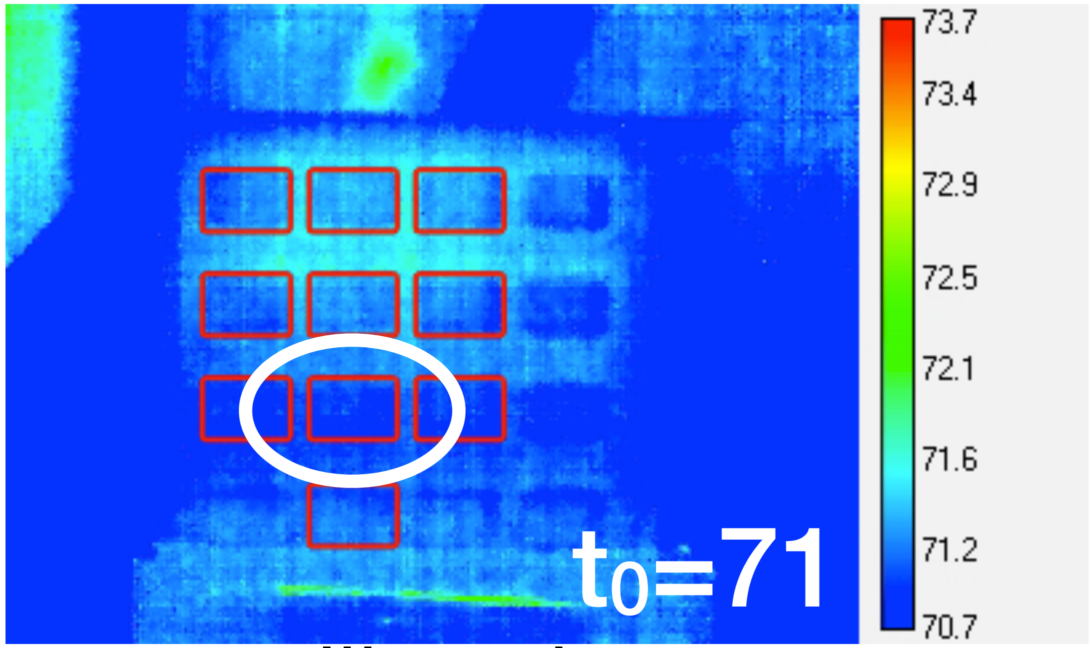

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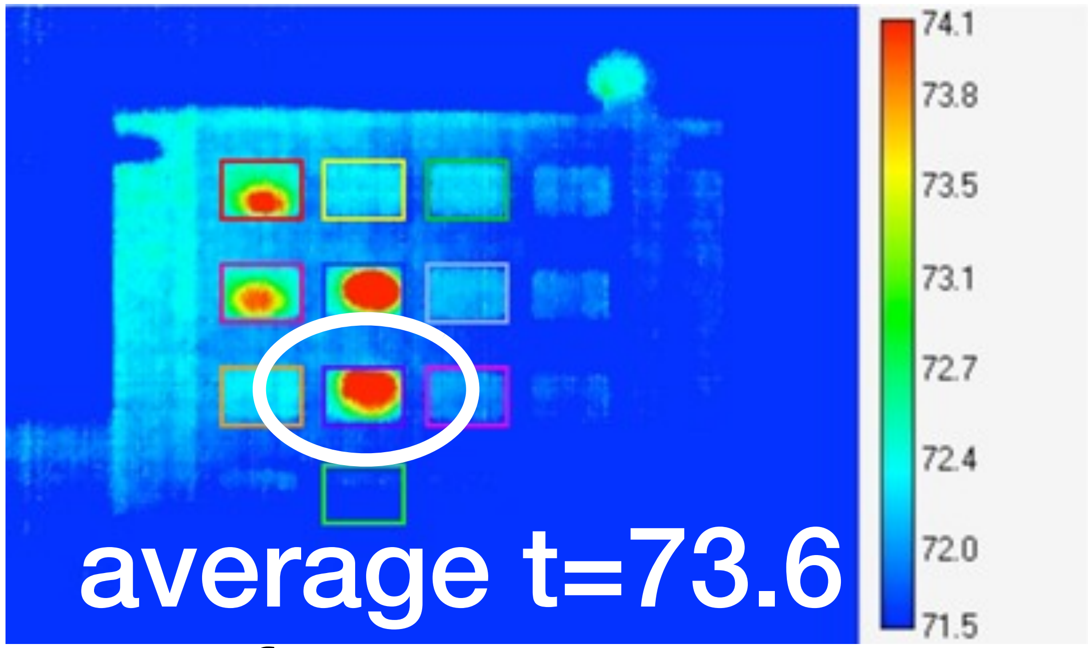
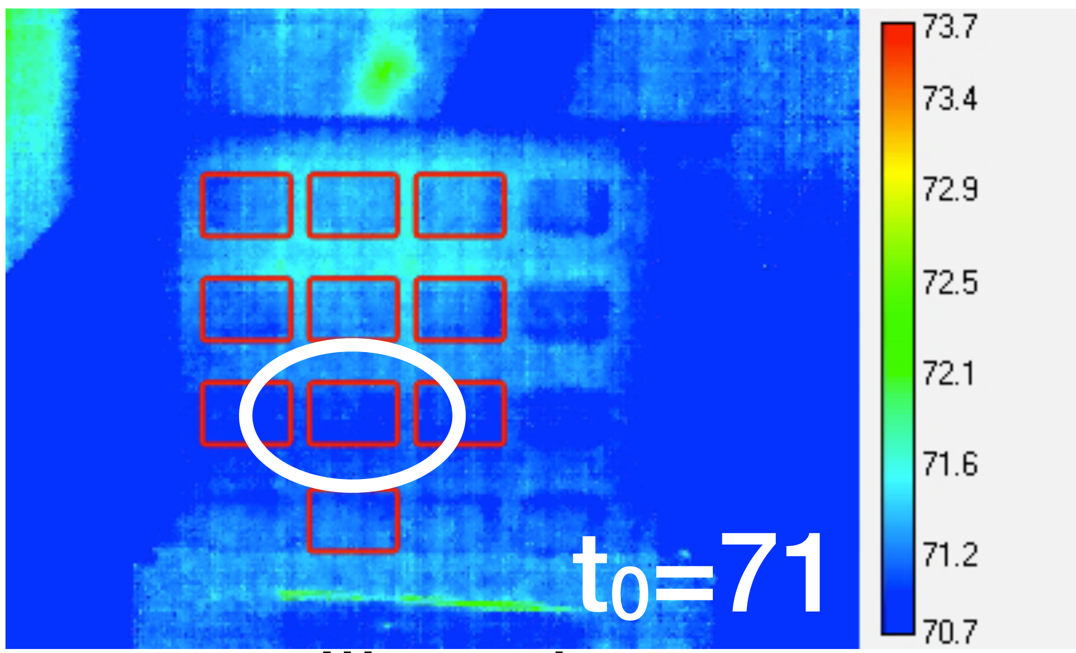


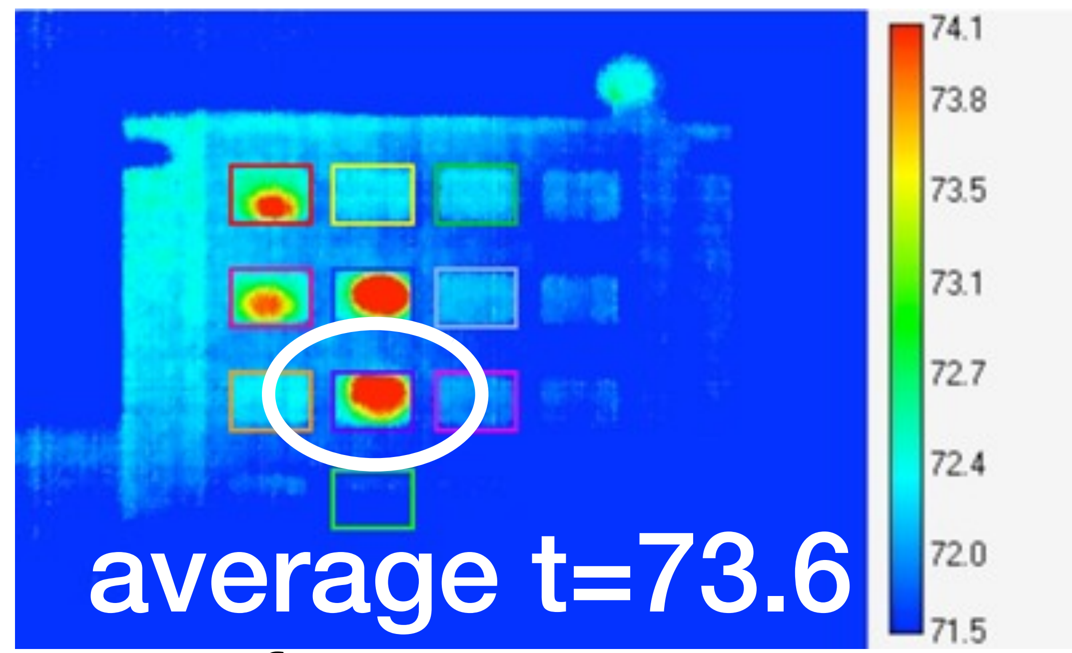
after entry

Automated review: which buttons were pressed?

Basic idea: for each region, determine if it is hot above a certain threshold



calibration



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Can repeat this process for each region, then sort in order of $\Delta = t - t_0$

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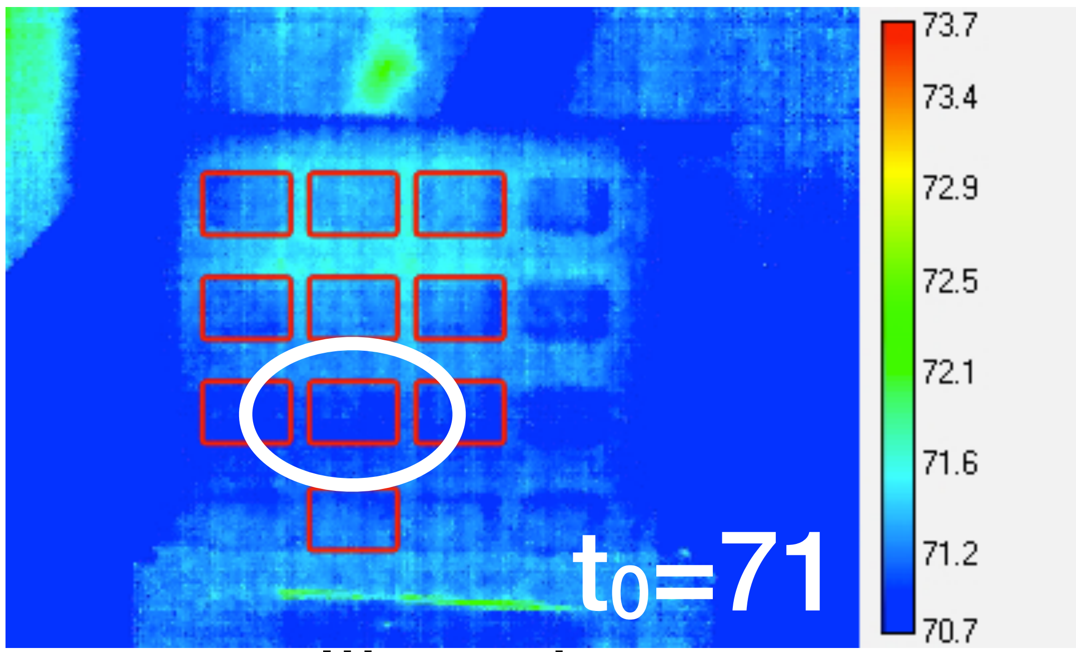
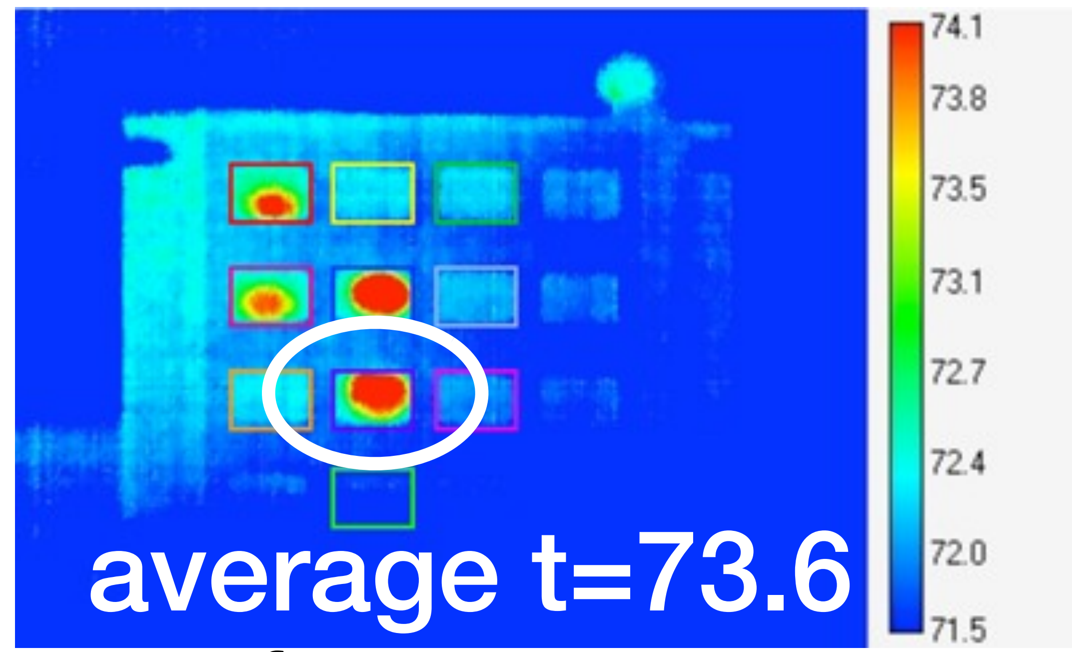


calibration



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Examined regions in isolation because we didn't observe much heat spread

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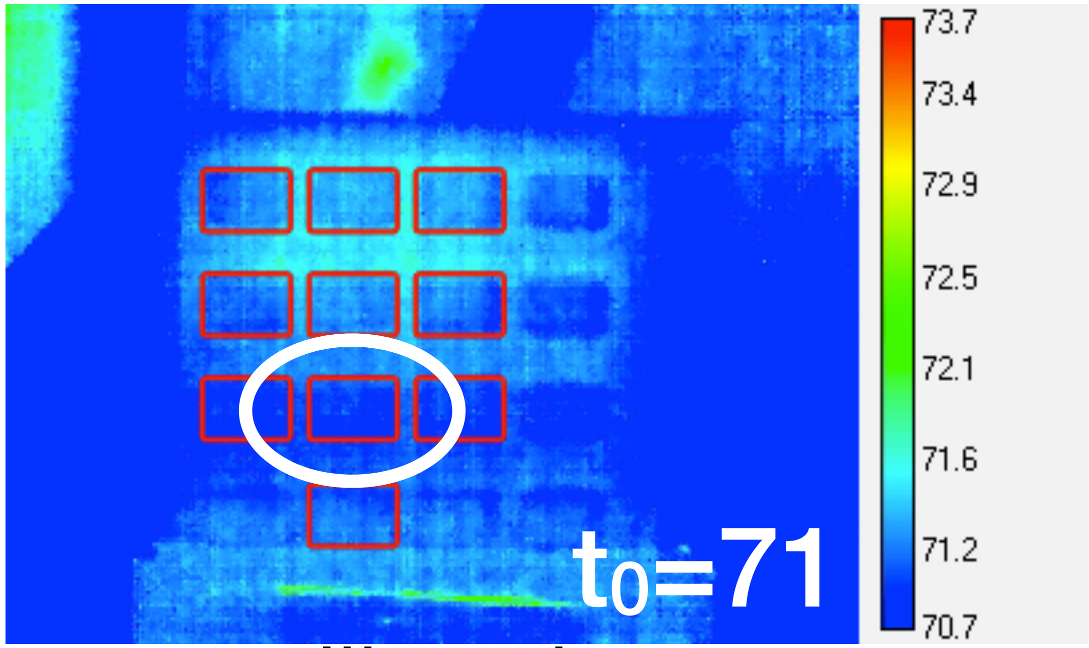

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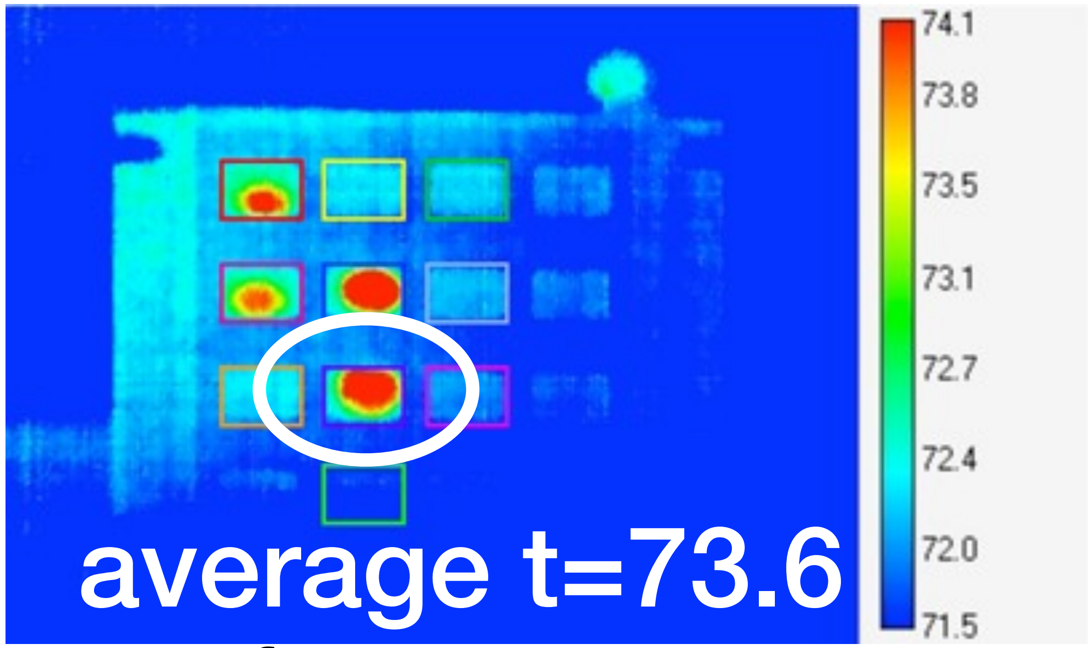

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This is the mean method, also use max and binarize variants

How did we do?

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First goal: recover the exact code entered

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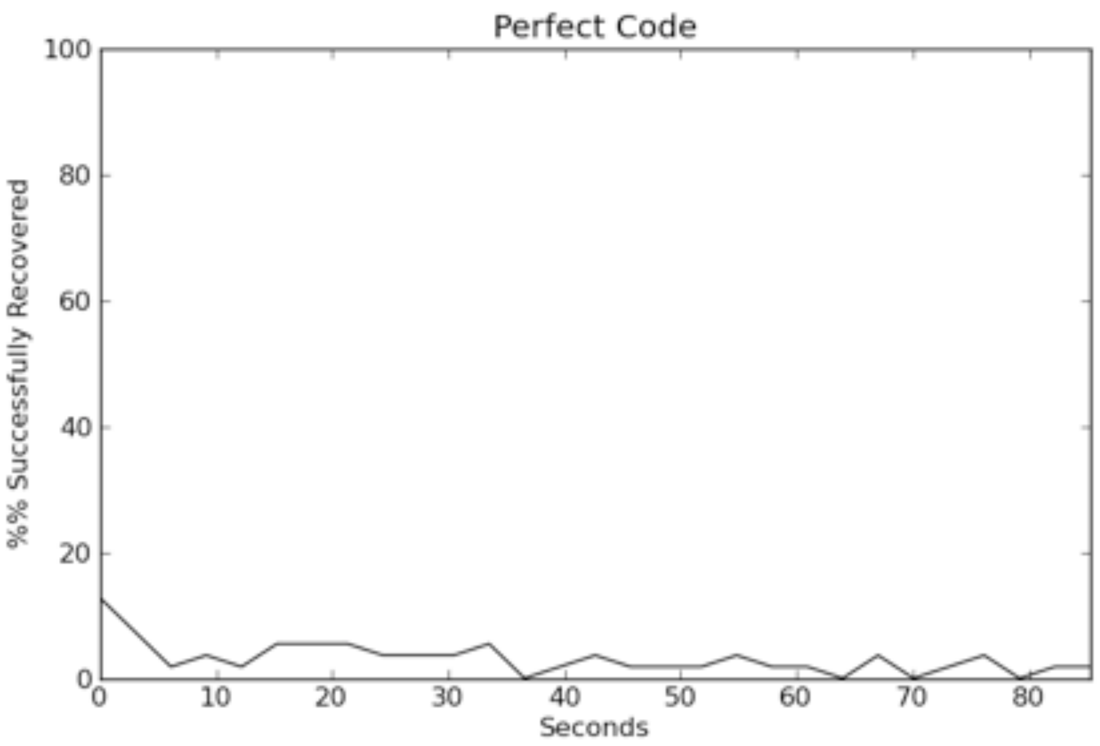

human review

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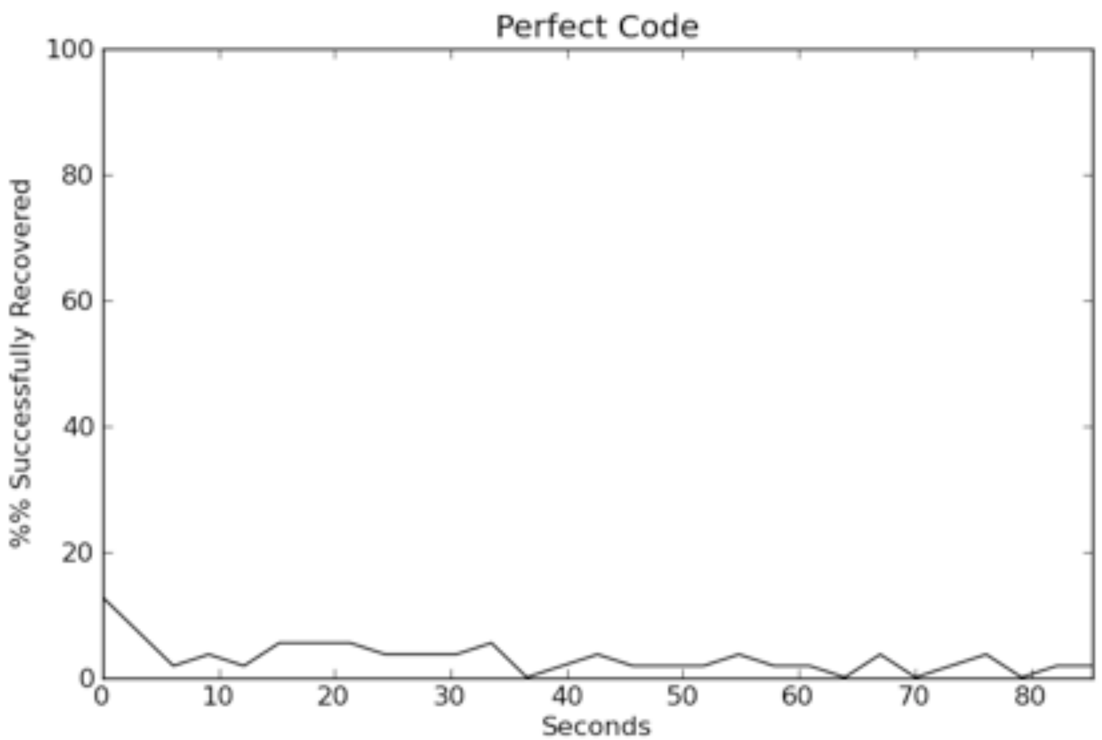
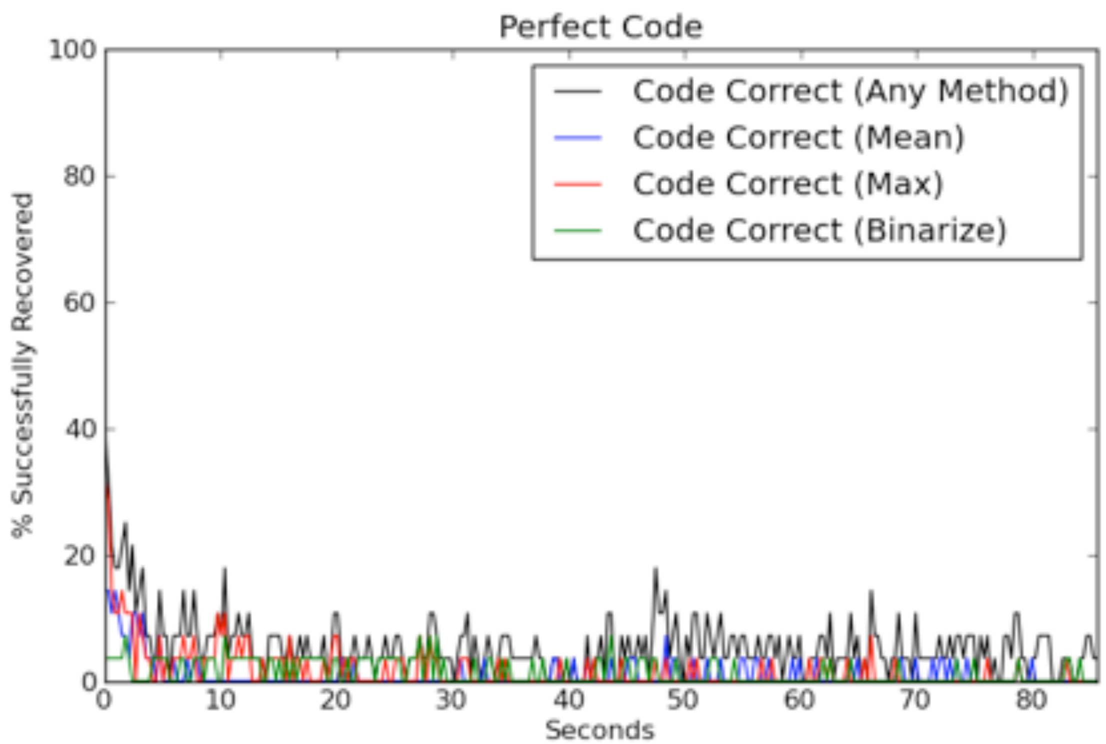


human review



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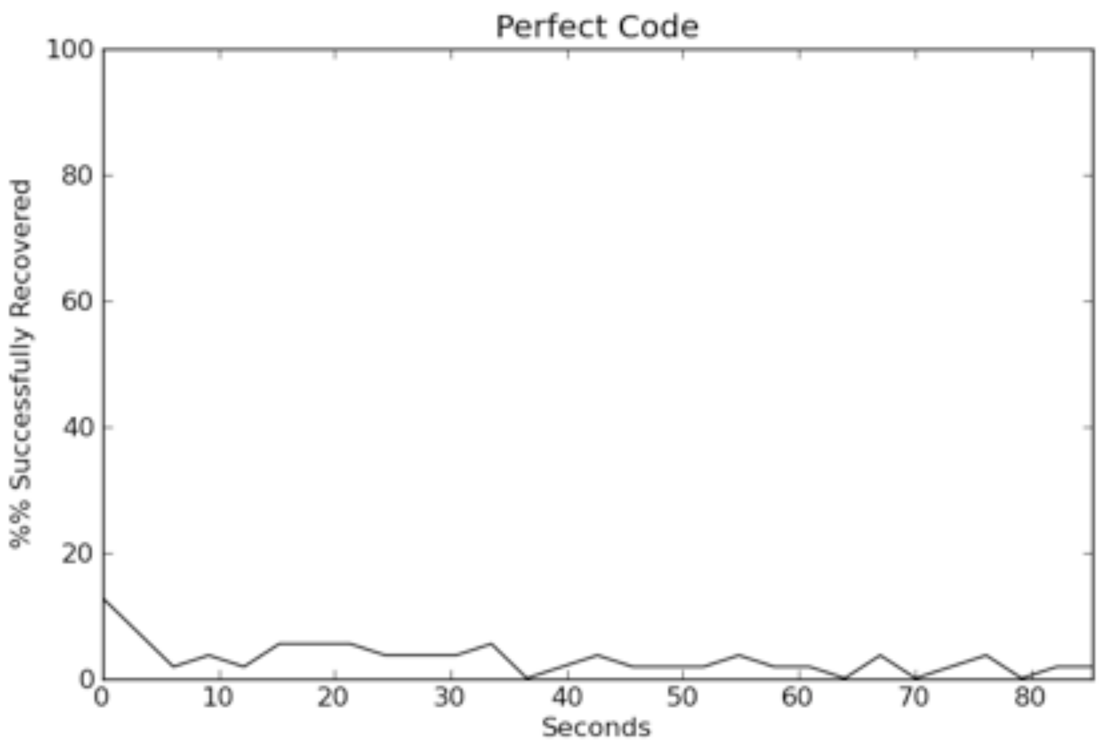

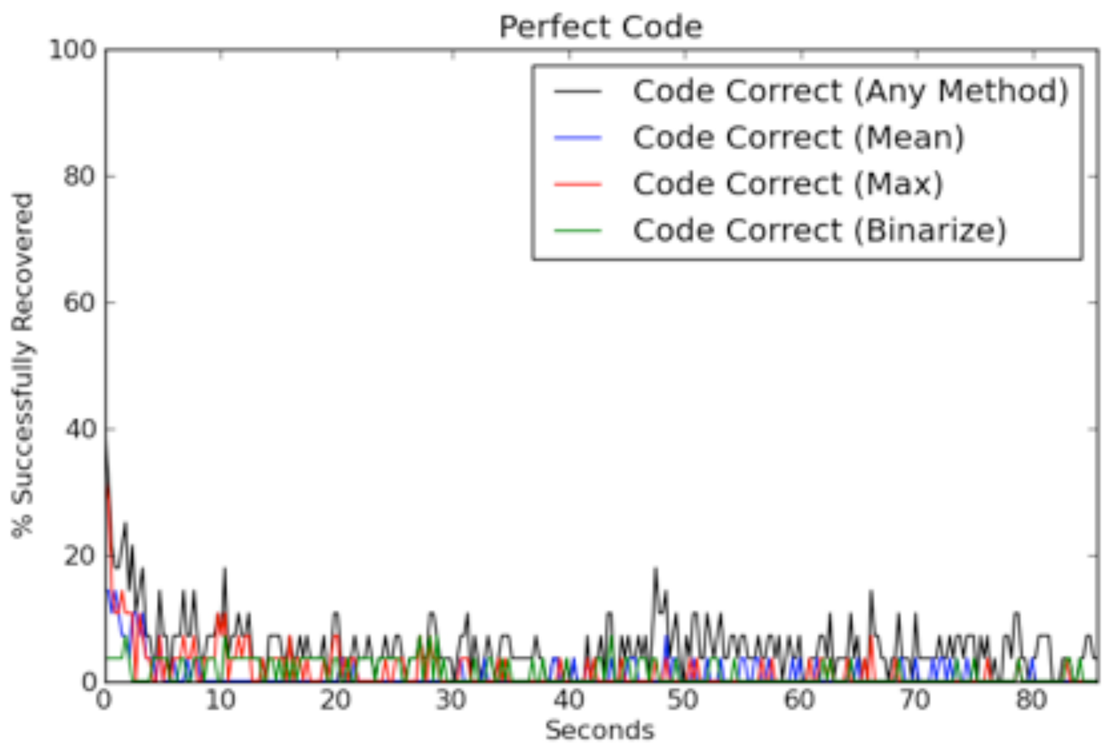

human review

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Bad news: the picture doesn't get much better if we allow for slight mistakes (transpositions, one wrong key, etc.)

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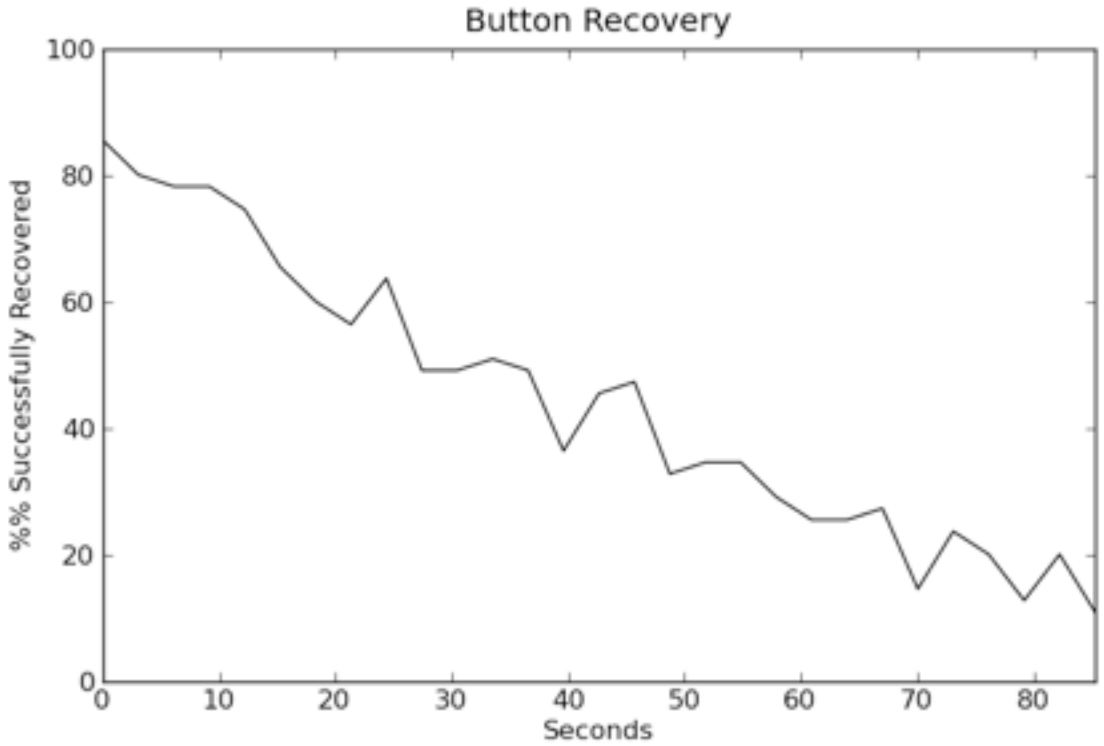

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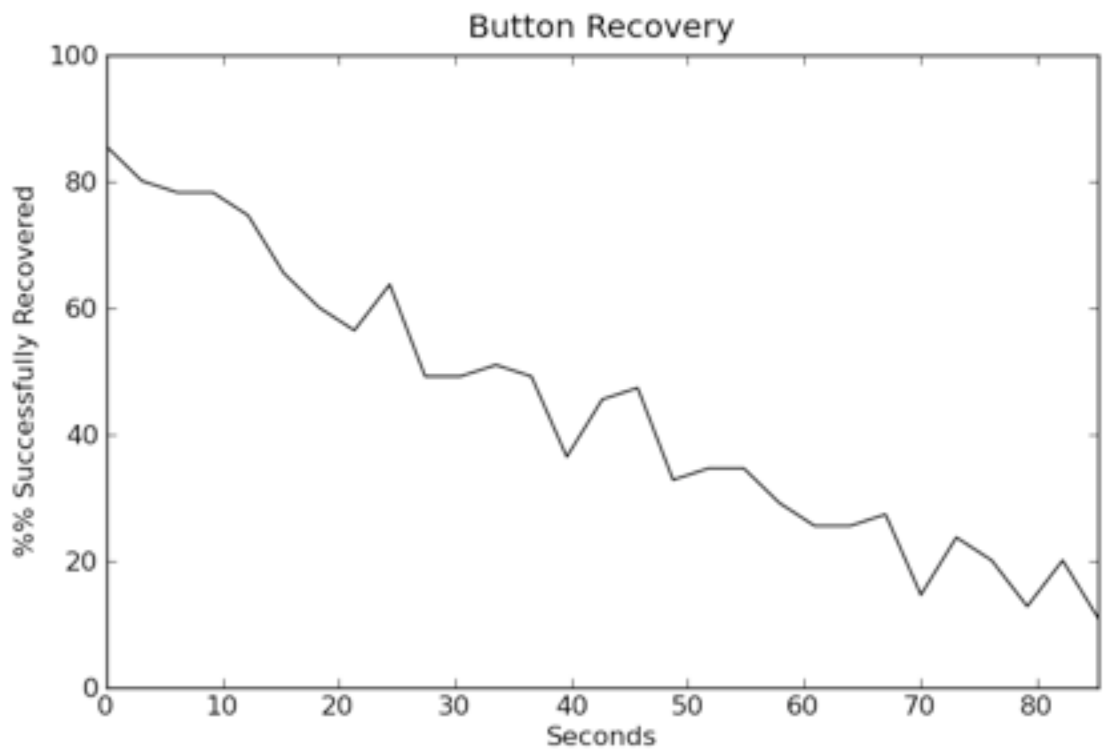

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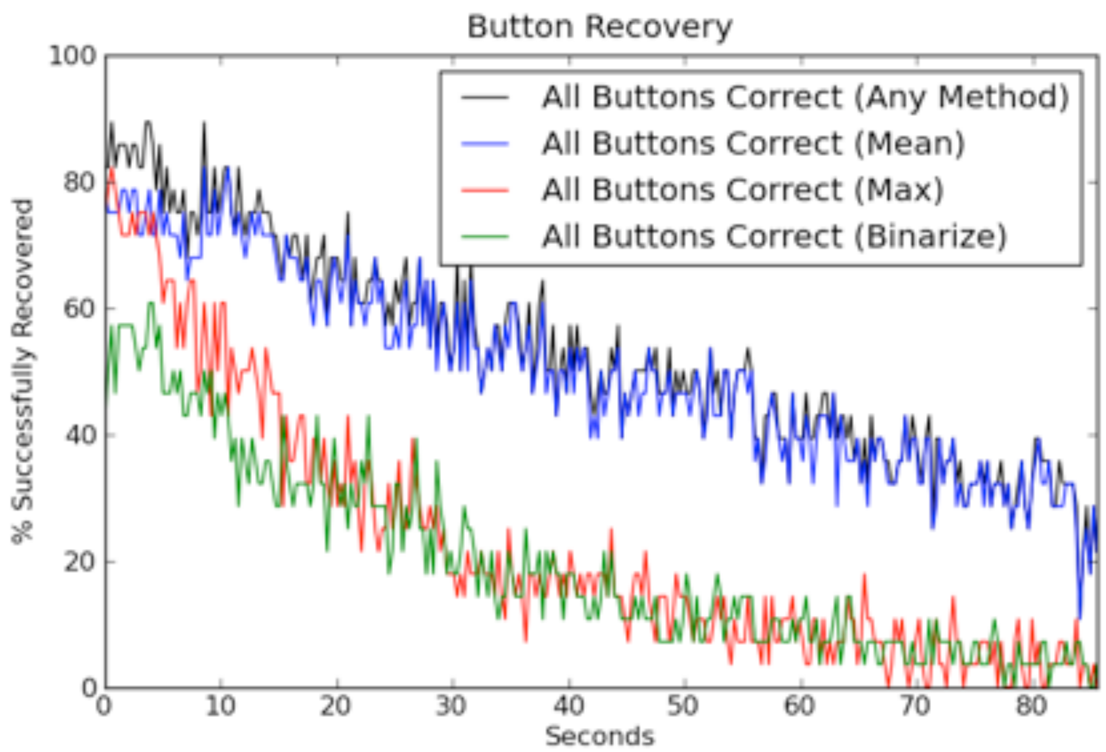

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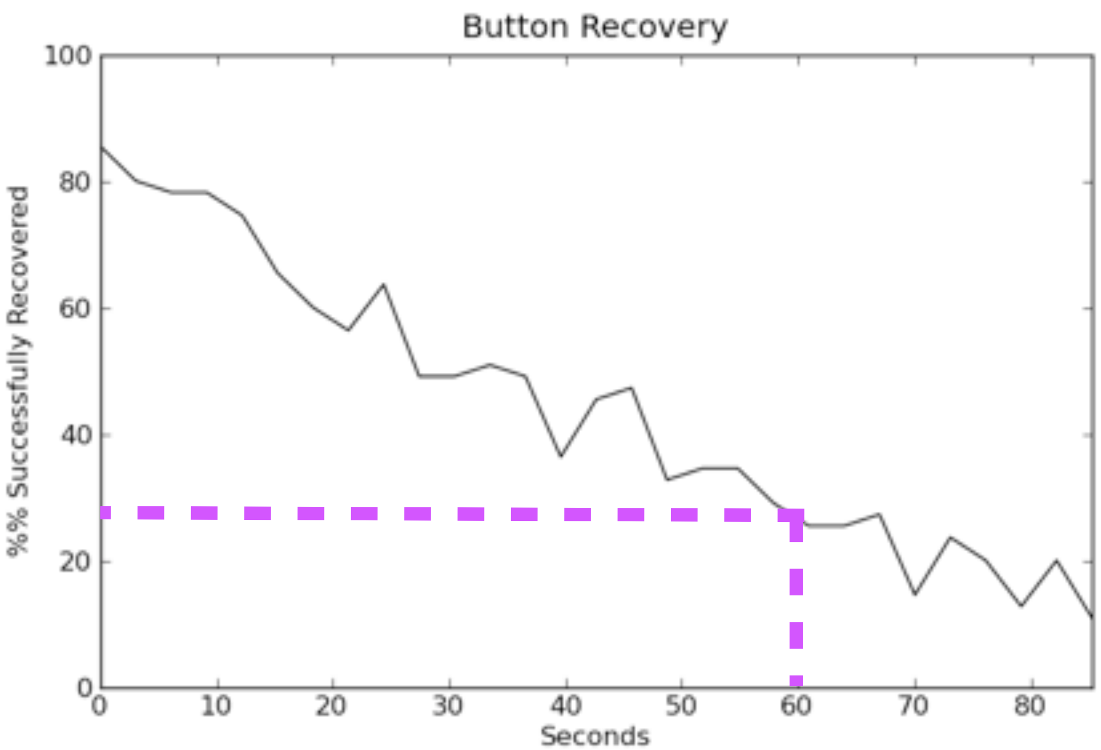
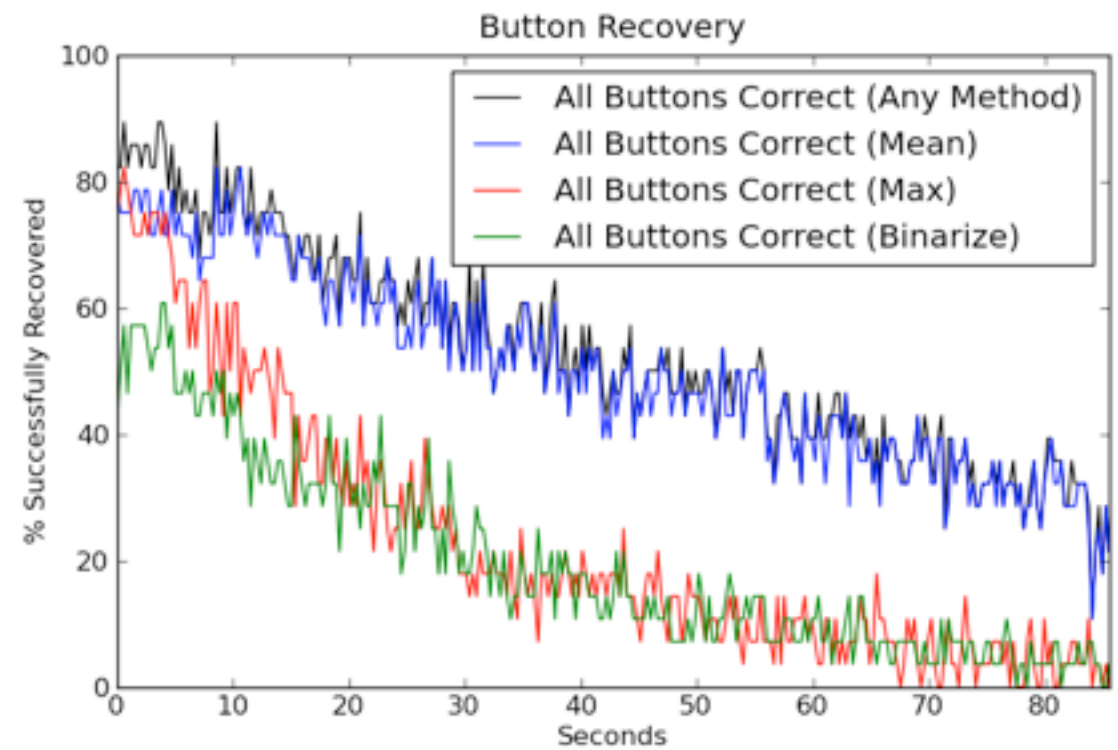


human review

recover ~30% after 1 minute



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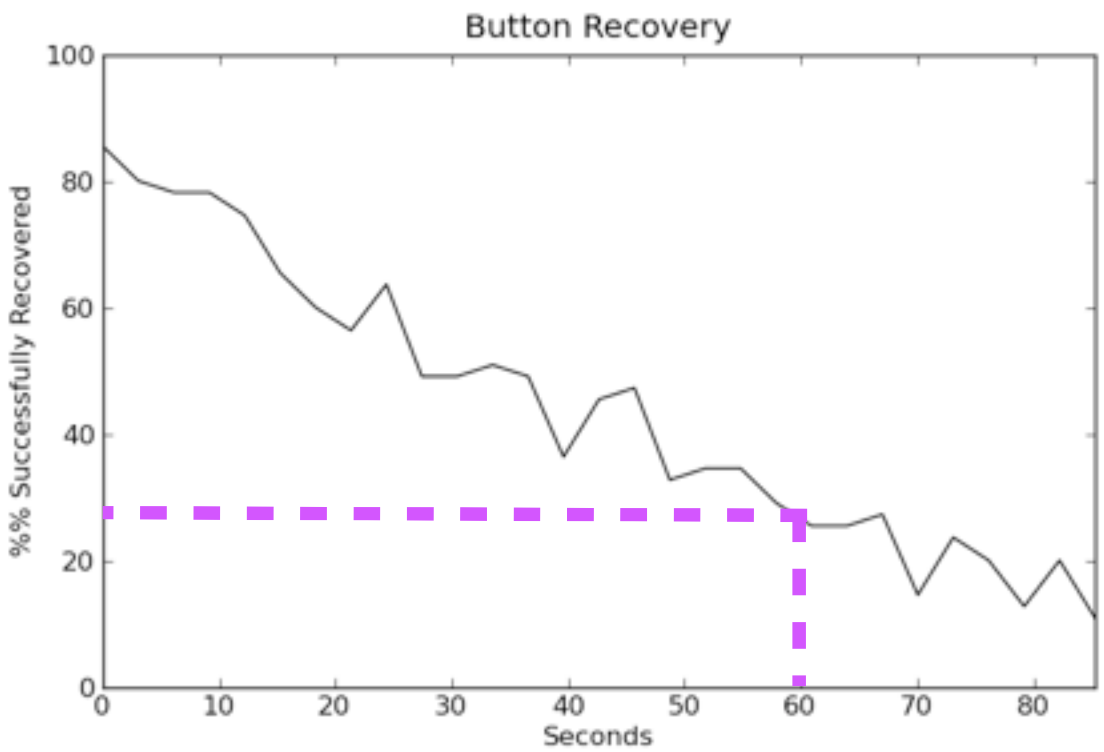

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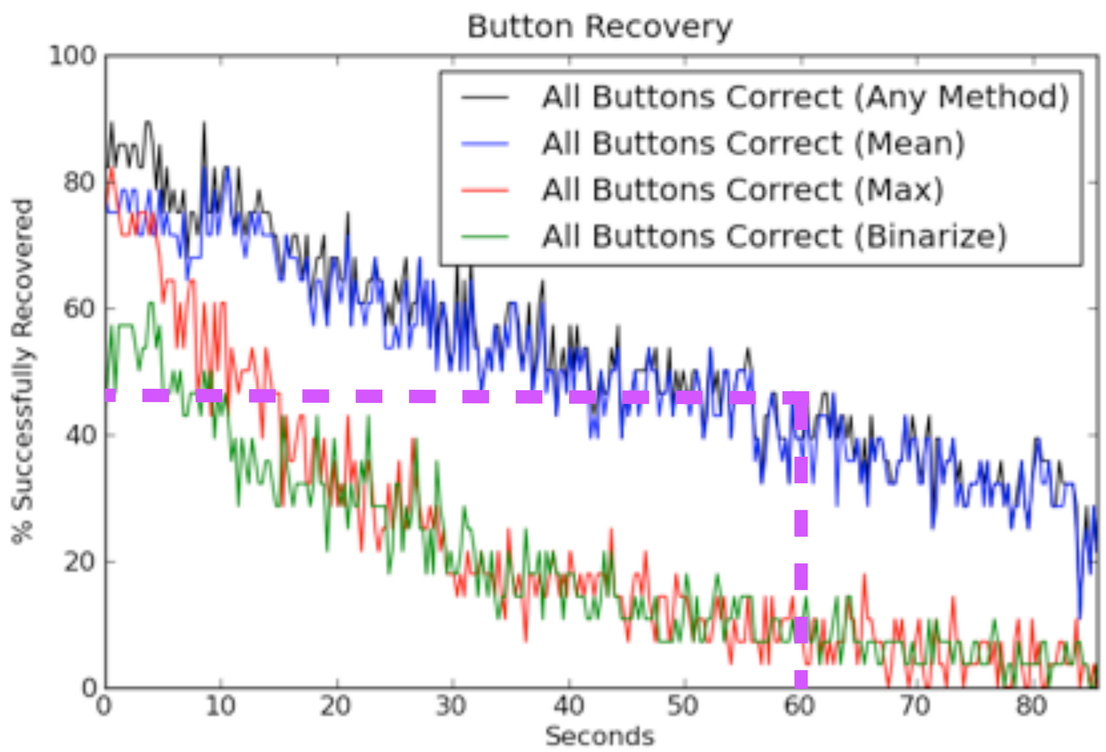
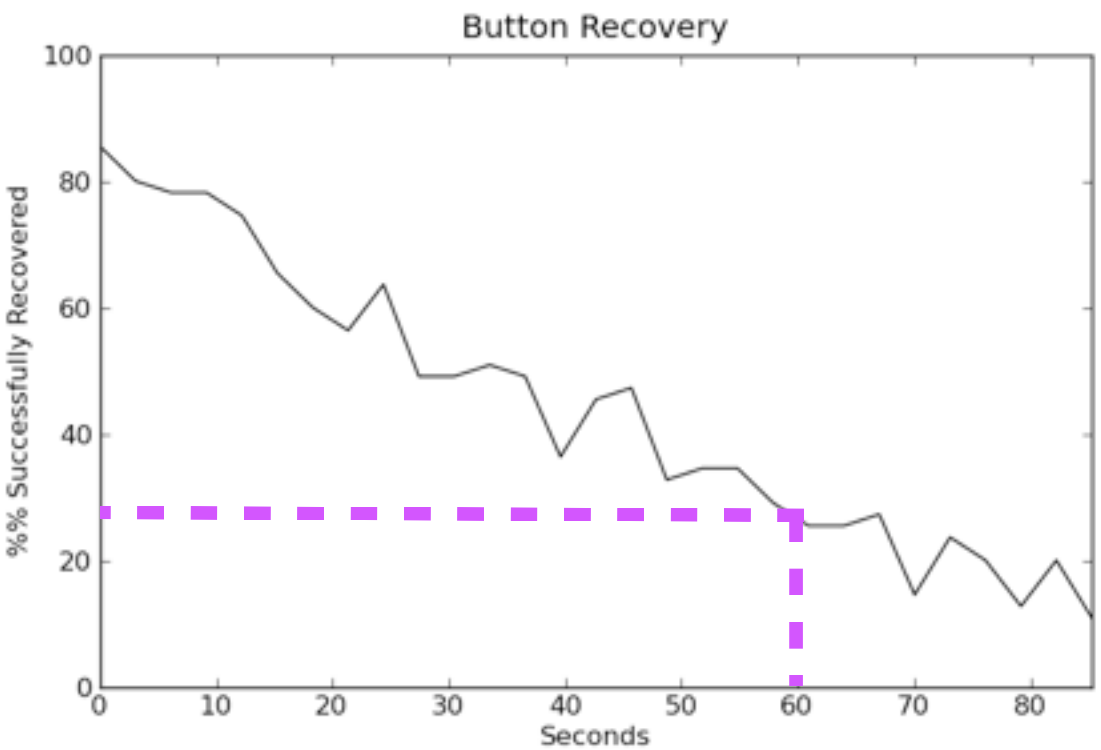


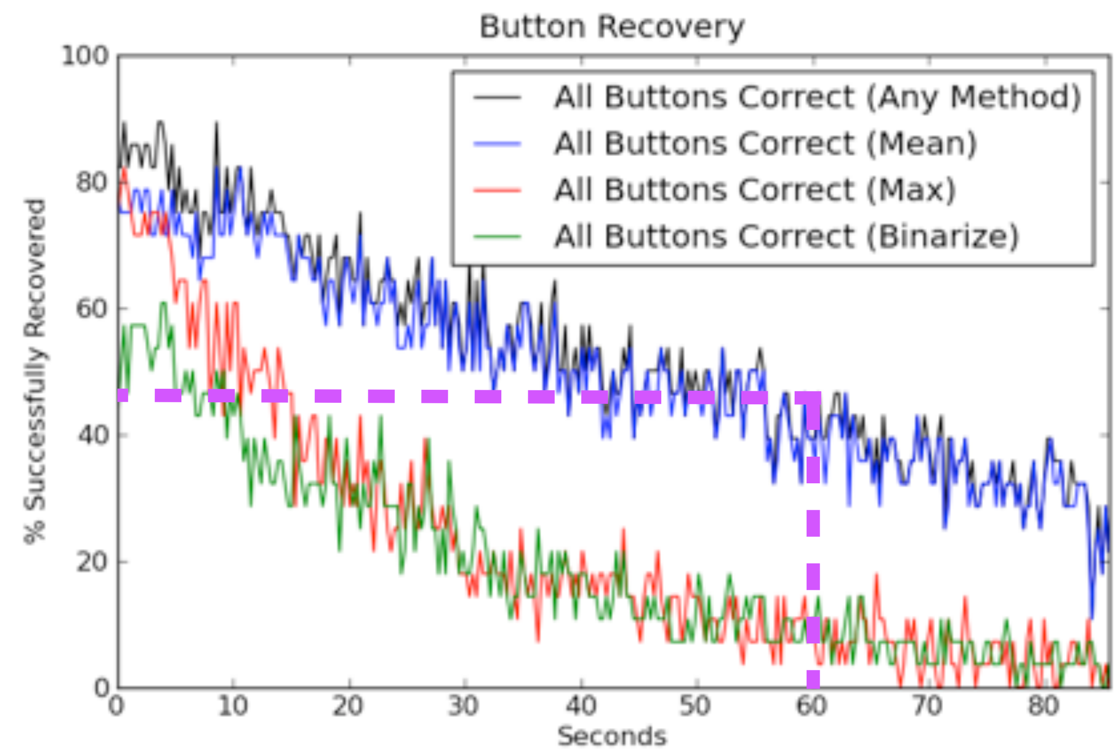
automated review

recover ~50% after 1 minute

How did we do?

Second goal: recover the buttons pressed (not necessarily the correct order)





human review

recover ~30% after 1 minute

automated review

recover ~50% after 1 minute

Not only is automated review scalable, it's also significantly more accurate

Outline

Experiment design

Camera data

Analyzing the data

Conclusions

Conclusions and future work

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Conducted study of the efficacy of thermal cameras in a variety of scenarios

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Thanks!
Any questions?

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