Conceptual Design of Ice Detection/ Mitigation System Based on Infrared Thermography

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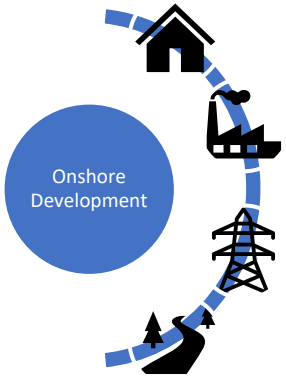
Introduction: Cold Climate Operations

- *"The extent of the sea ice in the Arctic varies significantly through the year and from year to year"* – Sebastian Gerland (Norwegian Polar Institute)
- Development & operations in cold onshore & offshore regions have fairly increased
- Cold climatic conditions !
- Atmospheric & sea-spray icing



* Photo: Audun Mathiassen, *Spray icing on a boat*. UiT The Arctic University of Norway, accessed: Dec 5, 2022 <https://uit.no/project/sprice>

Cold Climate Challenges

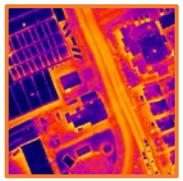
- In case of oil extraction, cold climate zones require specialised drilling vessels
- Search & Rescue (SAR) operations
  - Life-boats can not be launched
- In Europe, shores of Barents Sea & Arctic Ocean are a great potential for wind energy
  - Practical yield is lesser than theoretical yield
  - Ice shedding
  - Ice induced power losses may reach 80%
- Icing on power transmission lines/railway infrastructure may cause flashovers [1]

[1] M. Farzaneh, "Insulator icing flashover," 2013 Annual Report Conference on Electrical Insulation and Dielectric Phenomena, 2013, pp. 1-15, doi: 10.1109/CEIDP.2013.6748324

Detection Of Ice

- Mitigation of ice requires detection of ice as a preliminary step
- Direct Methods (based on)
  - Vibration
  - Acoustics
  - Capacitance/Inductance
  - Optical
  - Thermal IR
- Indirect (based on)
  - Statistical Analysis/Field Measurements
    - Output Power Analysis
    - Double Anemometer
    - Meteorological Icing Stations

Infrared Thermography & Ice Detection



Wide area scan

Non-destructive, remote sensing technique (no retrofitting required)

Ice shape[1] & location

Cost !?

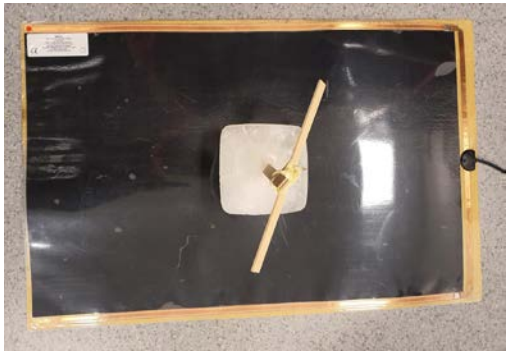
Objective: Comparison of ice detection via low-end Vs high-end IR camera!?

[1] Taimur Rashid, Hassan Abbas Khawaja, Kåre Edvardsen, Measuring thickness of marine ice using IR thermography, Cold Regions Science and Technology, Volume 158, 2019, Pages 221-229, ISSN 0165-232X, https://doi.org/10.1016/j.coldregions.2018.08.025

Design Of Experiment

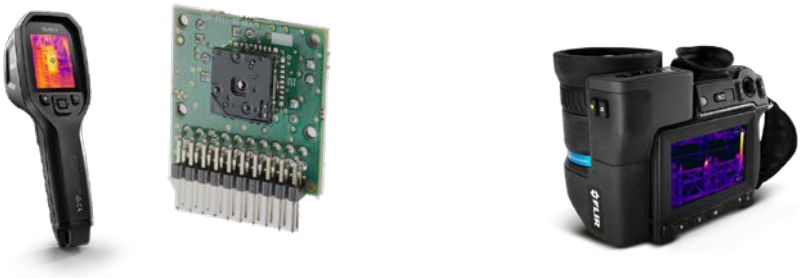
- $785mm \times 515mm$ coated Poly-Ethylene Terephthalate (PET) sheet by EBECO® (230V, 75W)
- Ice-block ($13.5cm \times 13.5cm$)
- FLIR® TG-165 (FLIR® Lepton 80X60 LWIR camera)
  - Uncooled Vox microbolometer
  - Frame-rate: 8.6Hz; NETD: <50mK
  - ~0.9g
  - Cost: ~$250
- FLIR® T1030SC 1024X768 LWIR camera
  - FPA uncooled microbolometer
  - Frame-rate: 30Hz; NETD: <20mK
  - 1.9-2.1kg; -40℃ – 150 ℃
  - Cost: ~$50000
- Software Tool (MATLAB ®)

200x less expensive !



Experimental Setup

Image Capturing



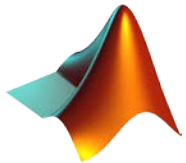
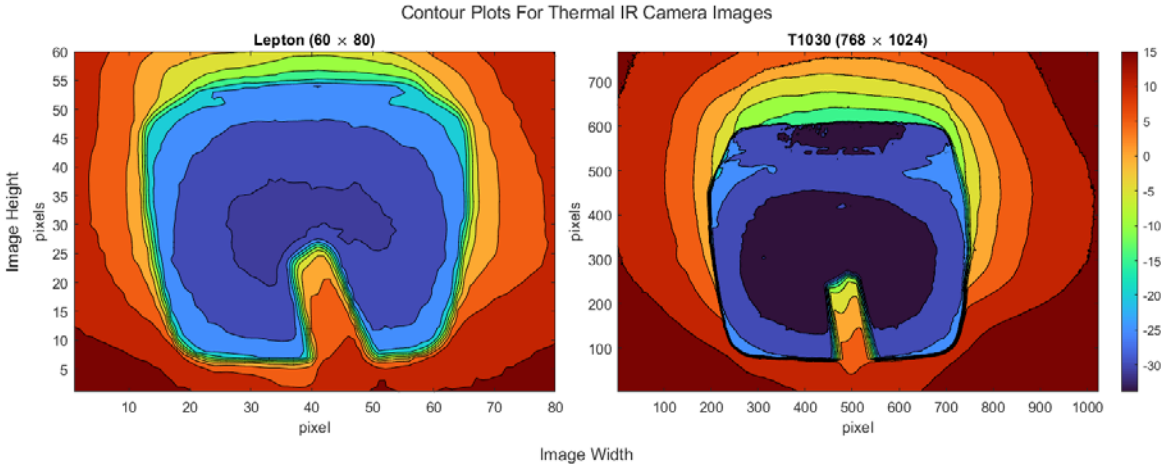
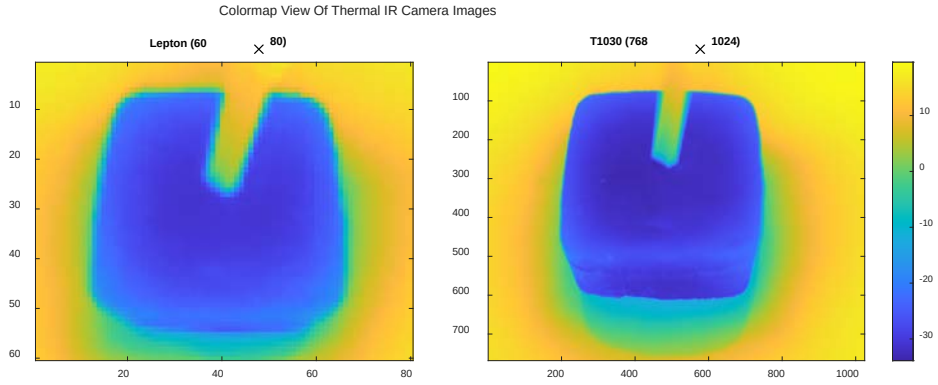


Image Analysis
(MATLAB ®)

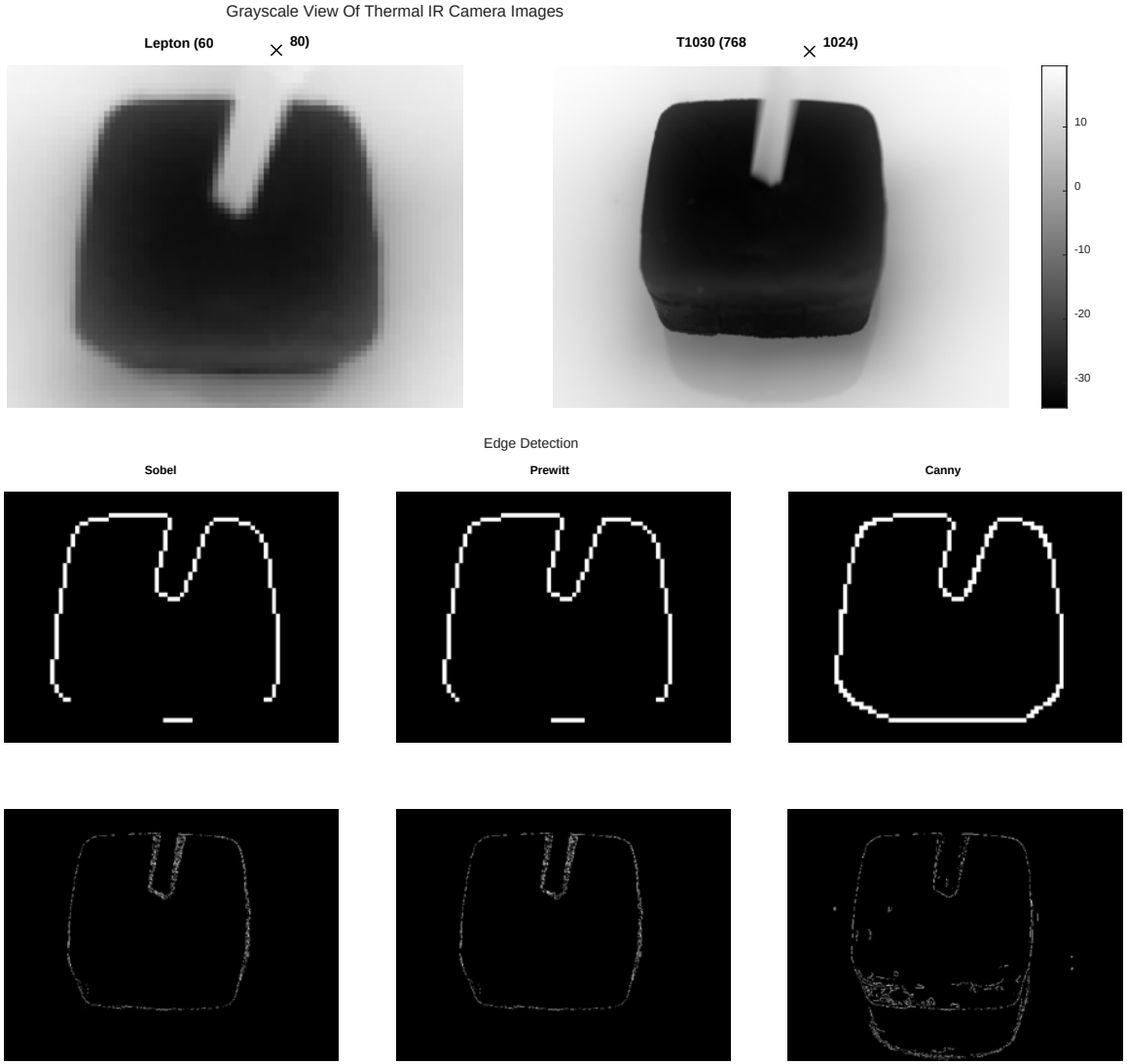
Results & Discussion





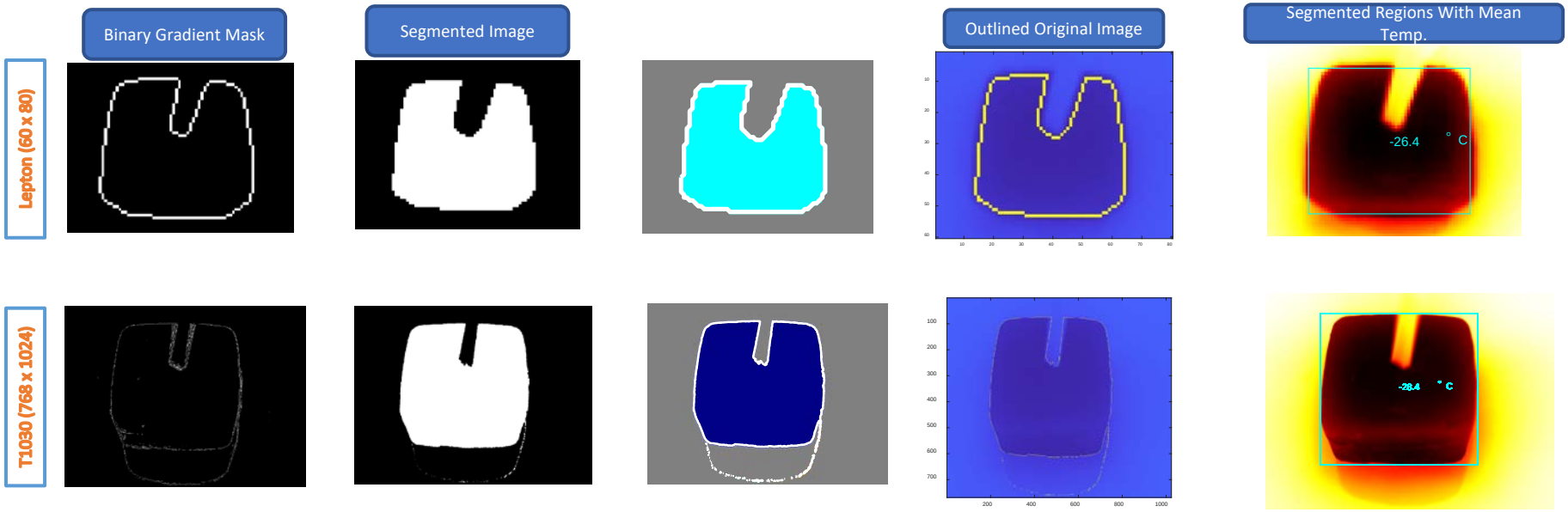
- Temperature distribution (raw data)
- Pixels as the data acquisition points
  - More datapoints → more information
  - More datapoints ↔ high resolution
- Interplay of resolution & accuracy

Results & Discussion (…cont'd)



- Binary masking & edge detection on raw binary images
- Highlights the edges

Results & Discussion (… cont'd)

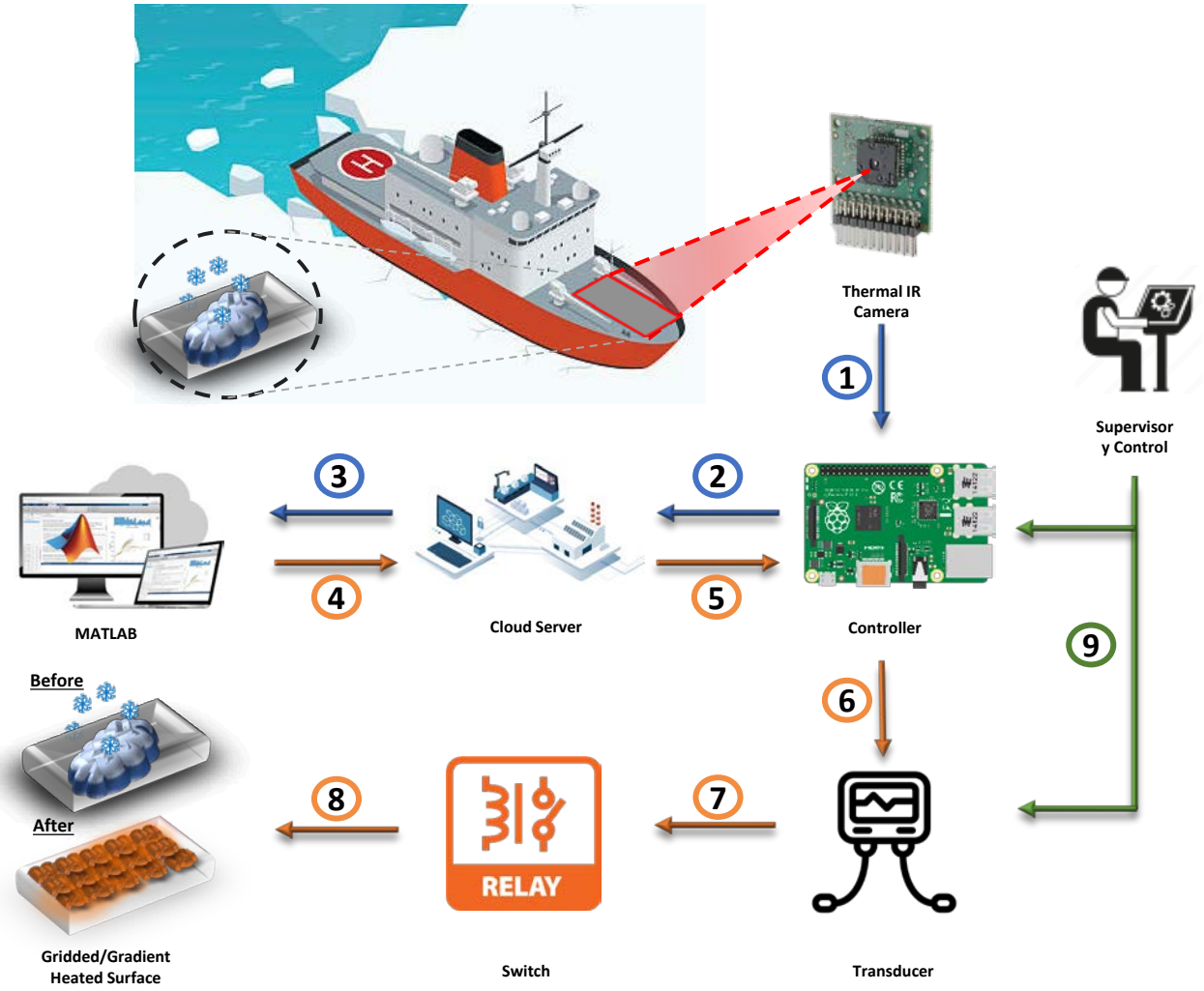


$$60 \times 80: \frac{56 pixels}{13.5 cm} \approx 4 px.cm^{-1}$$

$$768 \times 1024: \frac{609 pixels}{13.5 cm} \approx 45 px.cm^{-1}$$

- Edge-preservation filtering with «c*losing*» morphological operation
- Image *dilation* followed by image *erosion* (using linear & diamond *structuring elements*, respectively) to emphasize bright pixels (of boundary)

Conceptual Design



1. Image acquisition
2. Uploading images to server
3. Downloading images for remote image processing
4. Processed image decision (ice/no ice)
5. Reading decision from cloud server
6. Activation/deactivation of corresponding transducers
7. Energize/de-energize relays
8. Switching ON/OFF embedded heaters in the surface & supplying controlled heating
9. Supervisory control for emergency operation/system failure

Concluding Remarks

- Sustainable and economic solution
- Combating winterization through on-chip thermal-infrared cameras
  - Cost-efficient
  - Accurate to the extent of ice edge detection
- An effective control measure for sub-zero, hazardous environment

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Thanks !

Any Questions ?