How to integrate visual and acoustic methods for monitoring of heavy duty machinery?

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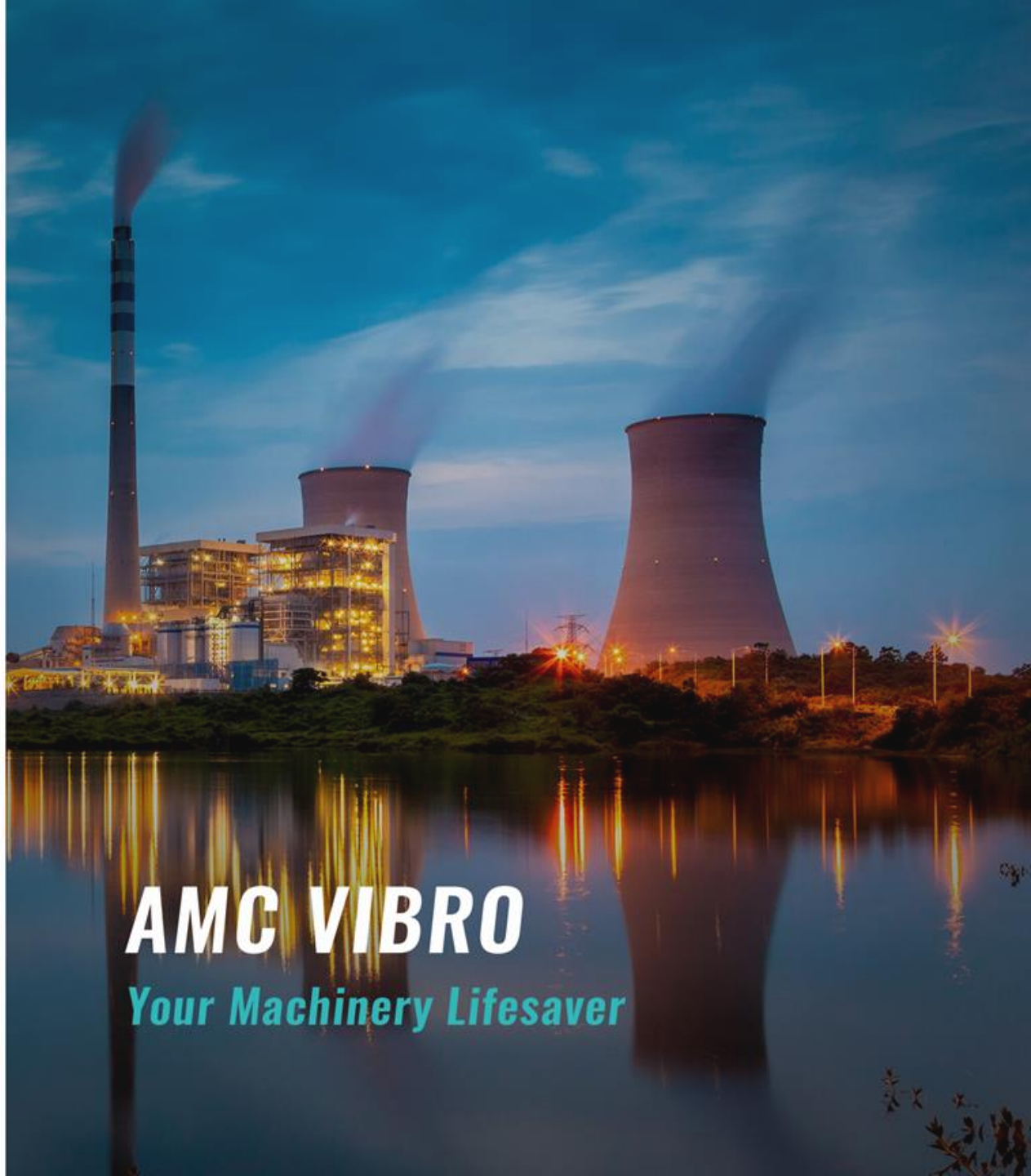

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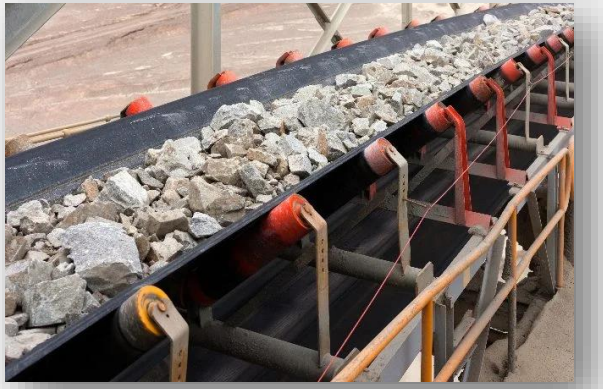
The Importance of heavy machinery maintenance in harsh environments

- Heavy construction equipment are used for various purposes in large projects in different industries including: Mining, oil, road & highway construction etc.
- Maintenance is so vital that around 35% to 50% of the annual operating budget can be spent on equipment maintenance and repair alone in the mining industry

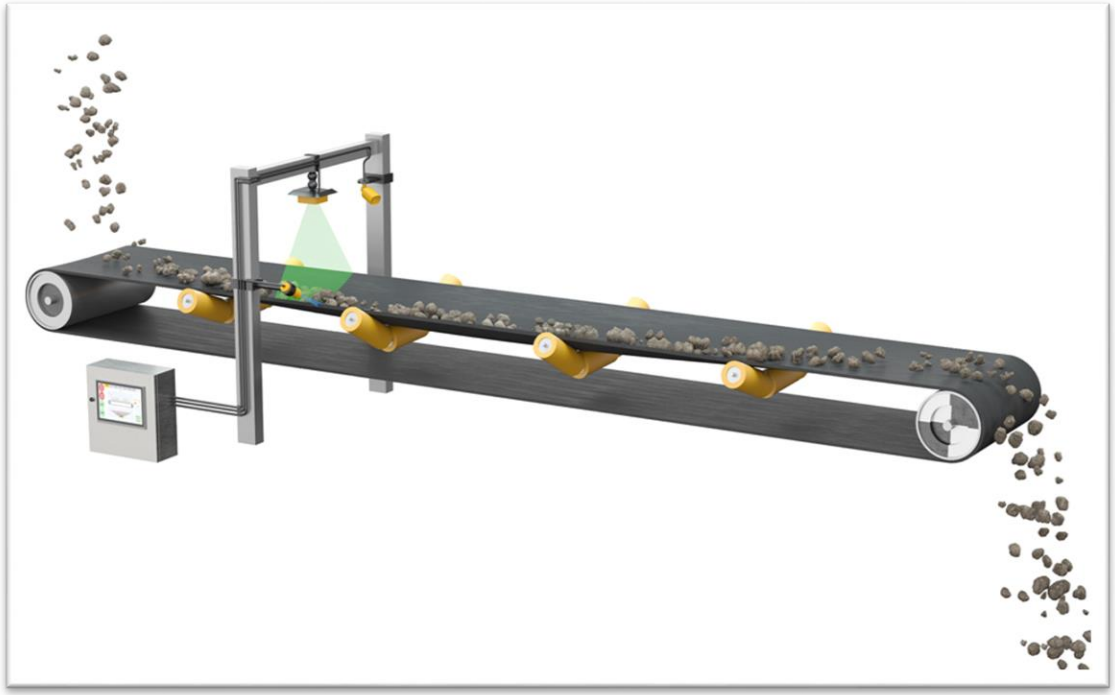
drilling machines

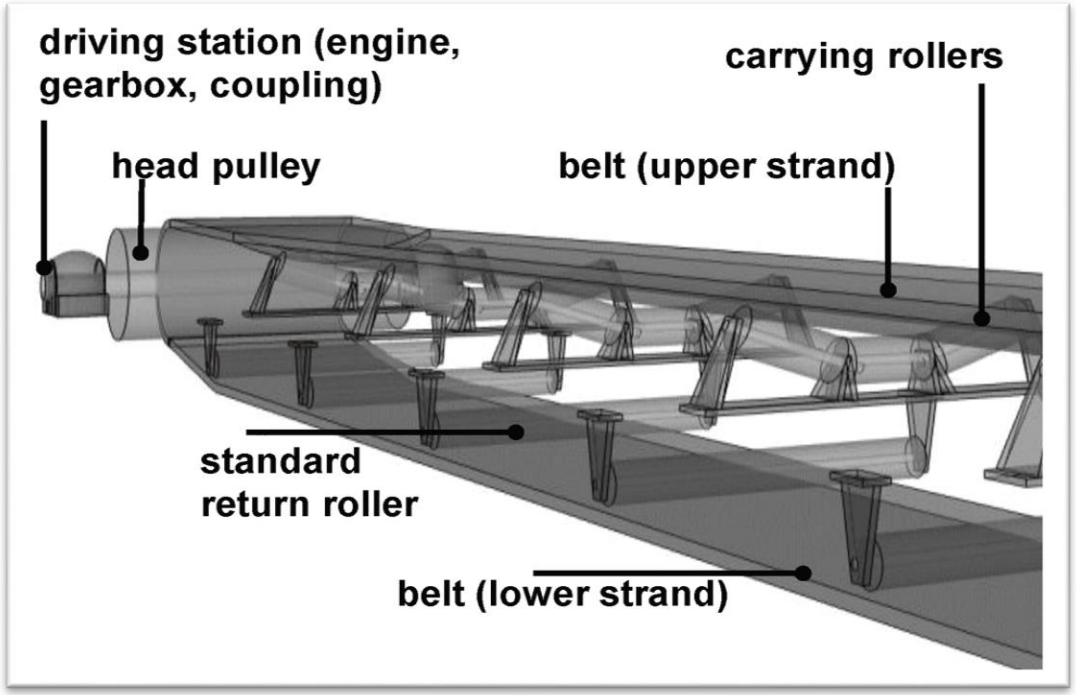
Excavators



Conveyor belts

Heavy duty belt conveyor (BC) systems in the mining industry





The BC systems are the main means of horizontal transport of bulk materials in mining sites

Common causes of conveyor belt damages in mining sites

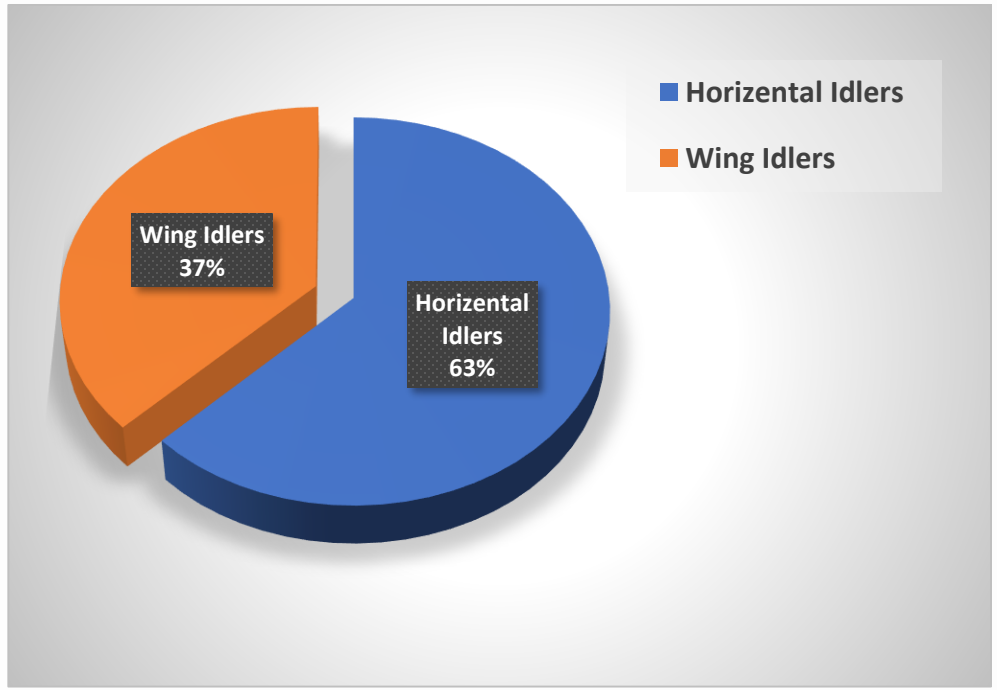
Heavy duty CB Conveying bulk materials with temperatures of up to +800 °C or as low as –60 °C in low temperature environments

BC systems are often particularly stressed by coarse and sharp-edged bulk material.

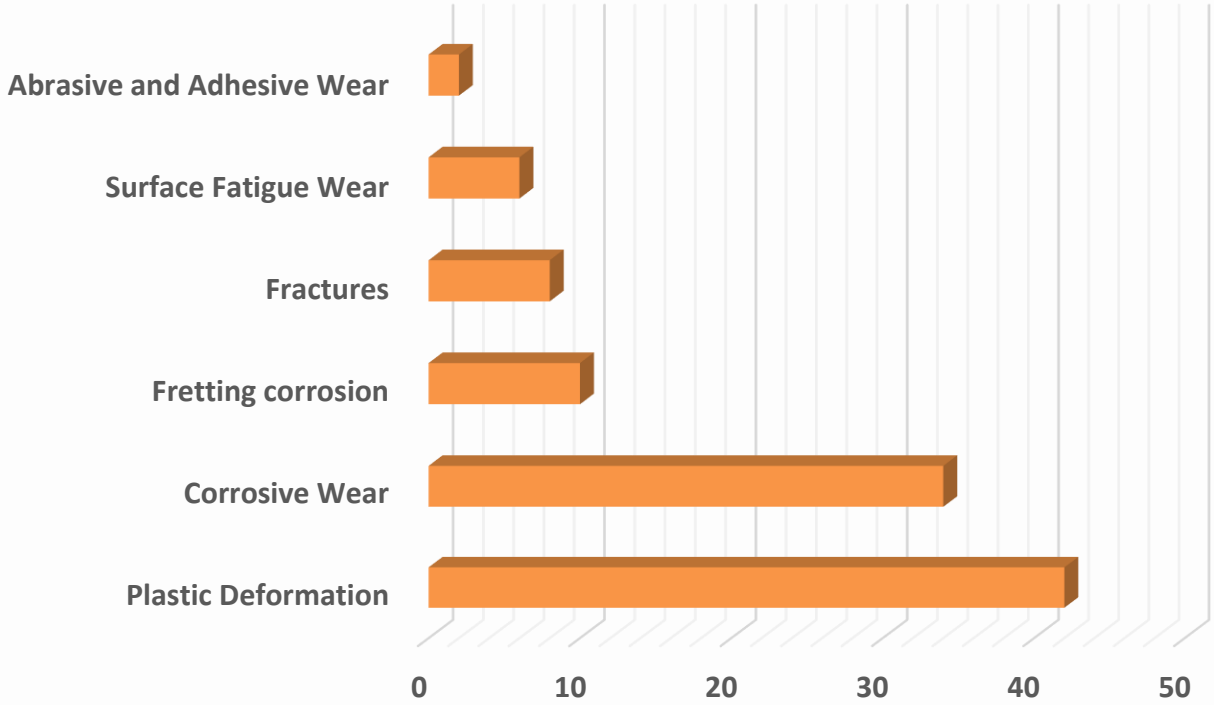
In the event of fire hazards the flame-resistant and identification equipment are essential to prevent fire propagation along the conveyor belt.

In long range BC systems dozens of rotating components including idlers need to be inspected individually by inspectors

Common causes of conveyor belt damages in mining sites



Percentage of roller bearing failures in relation to the installation position



Percentage chance of different types of bearing damage in conveyor belt idlers

Application of mobile robots for performing CM tasks

- Inspection mobile robots can capture various types of data including RGB images, IR images, sound, lidar data
  - Vibro-diagnostics of conveyor gearbox
  - Infrared thermography of conveyor gearbox
  - General inspection for belt conveyor image analysis
  - Acoustic based CM ng methods


Lidar


RGB CAMERA


Microphone


Thermal Camera

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Integration of visual and acoustic methods for CM of idlers in BC systems

- Single-sensor measurements are complementary for the condition monitoring of rotating machines
- To accomplish more complex tasks, multi-sensor configurations are becoming increasingly important
- Due to the nature of the harsh operating environments, the installation of CM sensors can be rather complicated or costly
- IR images and acoustic signals can be captured with non-contact instruments that are relatively less expensive and can be implemented on mobile robots

General comparison of the acoustic and IR images based CM methods

Acoustic signal processing methods

- ✓ They can be specifically used to identify the structural damage, such as gear fracture and bearing outer race crack
- ✗ The acoustic signals can be highly influenced by the are sensitive to environmental noises AE sensor has to be close to its source

IR images processing methods

- ✓The thermal imaging methods can be used to identify the non-structural faults, such as gear box oil shortages
- ✗The single infrared thermal image is very sensitive and is easily affected by external factors

Types of conditions that can influence the single sensor CM tasks

Manual collection of acoustic data

belt joint

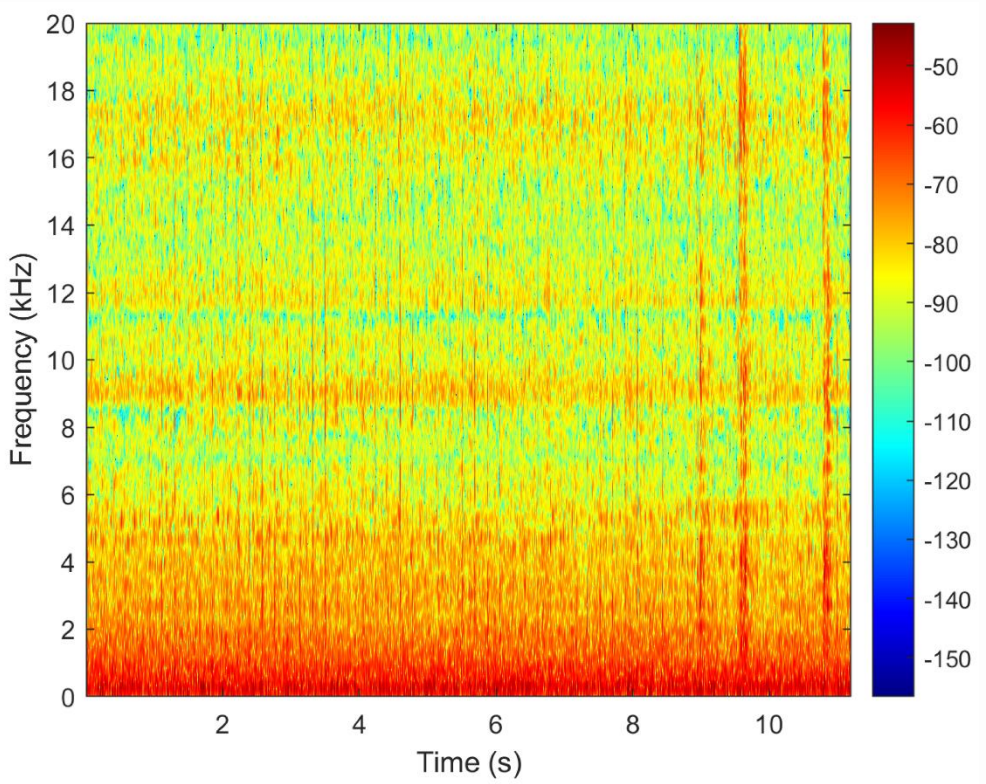
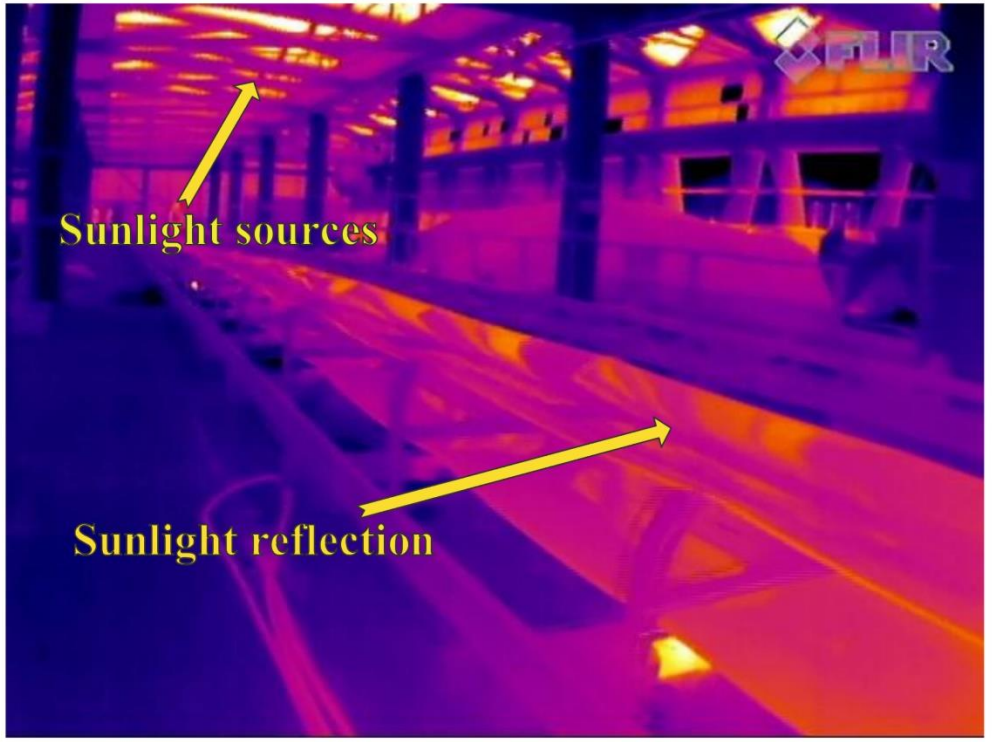


Image based methods in condition monitoring of conveyor systems

Examples of hotspots that are not related to idlers



Location of sunlight sources and sun reflections on belt that captured in a raw IR image.

Integrate visual and acoustic methods for condition monitoring of conveyor belt idlers

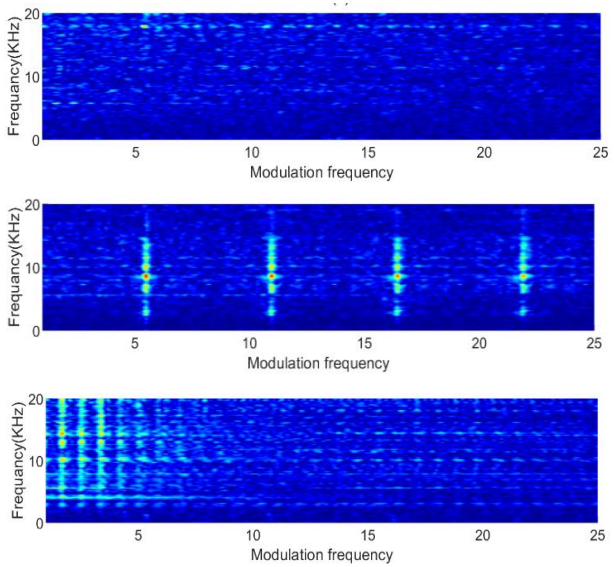
Microphone

Cyclostationary analysis

TRUE POSITIVE
FAULTY IDLERS

TRUE NEGATIVE
HEALTHY IDLERS

FALSE POSITIVE
OTHER SOURCES



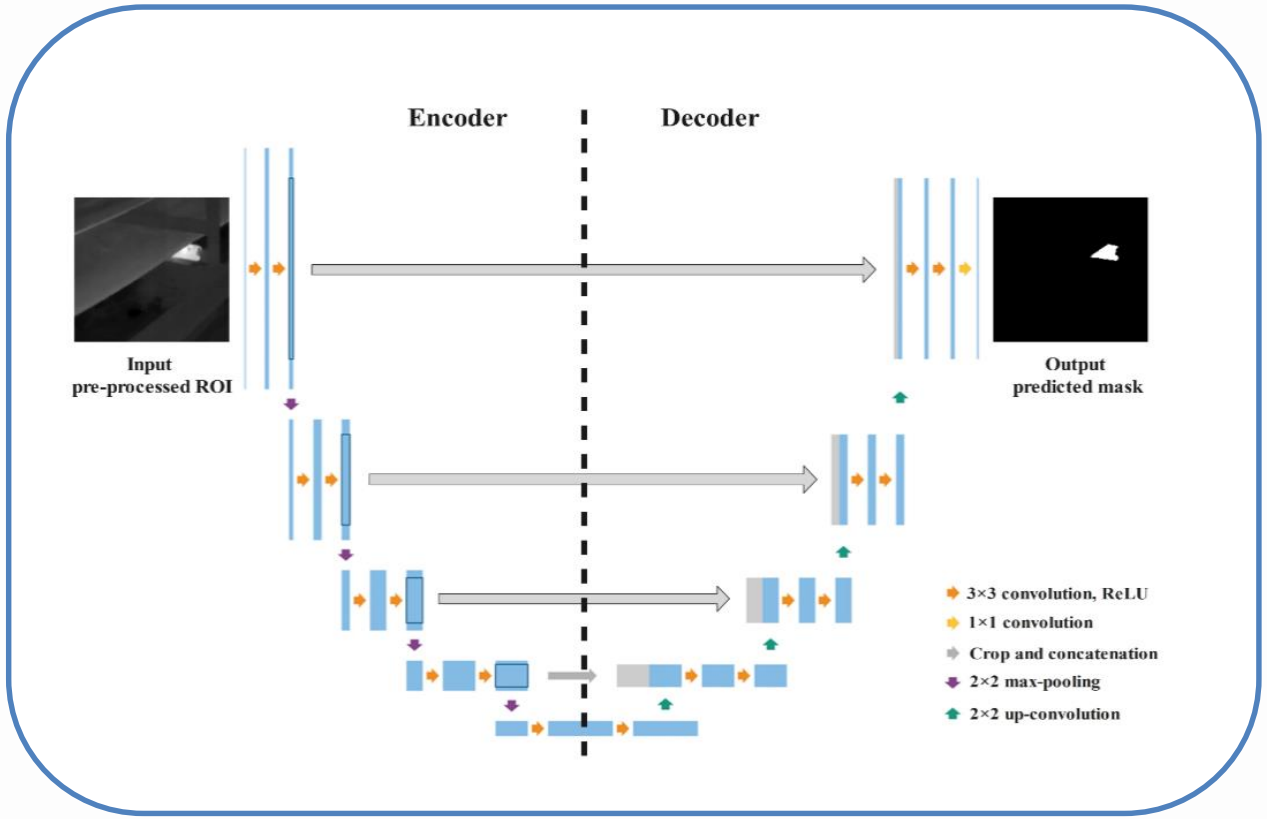
Classify the fault base on the degree of severity

STAGE 1

STAGE 2

Integrate visual and acoustic methods for condition monitoring of conveyor belt idlers

IR camera

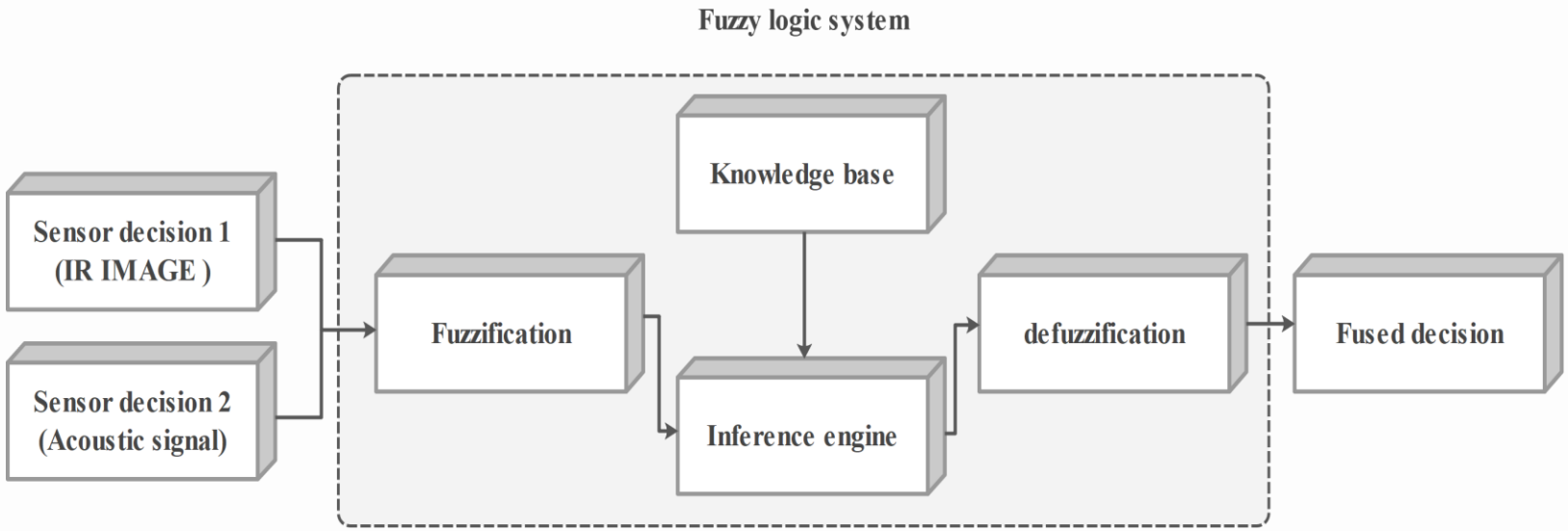


STAGE 1

Area of overheated pixels

STAGE 2

Decision-level fusion based on fuzzy inference system



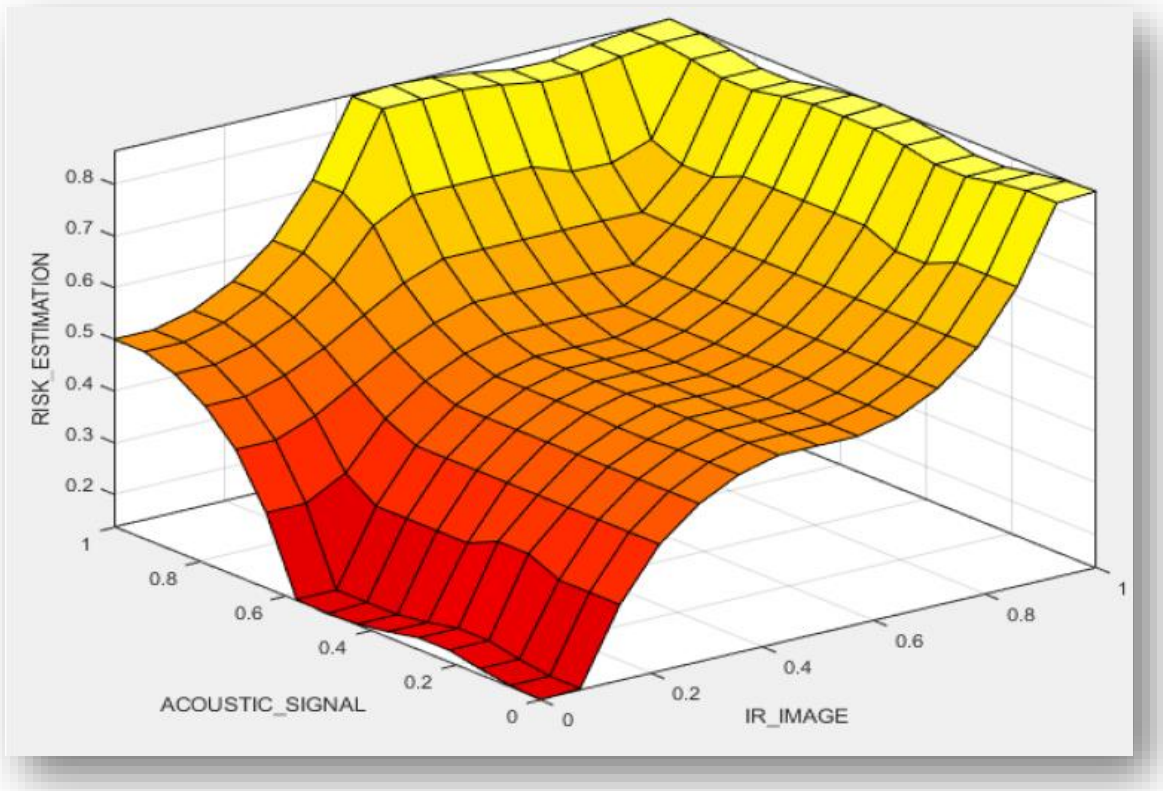
Overview of Fuzzy Inference System

Decision-level fusion based on fuzzy inference system

Risk factors	Linguistic term	Interpretation	Crisp rating
IR images (T)	Very high (VH)	The chance of thermal defects is very high	5
	High (H)	The chance of thermal defects is high	4
	Medium (M)	The chance of thermal defects is medium	3
	Low (L)	The chance of thermal defects is low	2
	Very low (VL)	The chance of thermal defects is very low	1
Acoustic signal (A)	Very high (VH)	There is a credible sign of bearing faults in proceed signal	5
	High (H)	There is a relatively credible sign of bearing faults in proceed signal	4
	Medium (M)	There is a likely sign of bearing faults in proceed signal	3
	Low (L)	There is a low evidences sign of bearing faults in proceed signal	2
	Very low (VL)	There is a no credible sign of bearing faults in proceed signal	1
Risk categoty (R)	High (H)	Immediate action is required	3
	Medium (M)	Not acceptable without review by supervisor	2
	Low (L)	No action is needed	1

Definition of fuzzy and crisp ratings

Integrate visual and acoustic methods for condition monitoring of conveyor belt idlers



Normalized surface view of the proposed fuzzy inference system

Conclusion

- This study focuses on cross-domain fault diagnosis of BC idlers via multi-source heterogeneous data.
- Infrared thermal images and vibration signals are fused to characterize the health states of the BC idlers
- The proposed method can effectively recognize structural and non-structural faults
- We could effectively detect and reduce the number of false positive cases in final results
- We show that target detection and classification problems can greatly benefit from this fusion approach and result in a performance increase.

Acknowledgments

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Thank you

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