Algorithms: The Next Frontier for X-Ray Inspection

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Principles of x-ray inspection
The first 100 years in x-ray history focused on hardware improvements.
Developments in x-ray tube technology

Heated filament emits electrons by thermionic emission. Electrons are accelerated by a high voltage. Copper rod for heat dissipation.

Glass envelope. X-rays produced when high-speed electrons hit the metal target.

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This century, algorithms are driving x-ray innovation

• Significant improvement in computing power
• Explosive algorithm focus – see Google
• Marginal improvement in hardware
Some examples of transformational algorithms

- WISE
- Dual Energy
- Artificial Neural Networks
WISE: Wavelet Image Spectra Enhancement

- X-ray inspection enhancement algorithm based on parametric estimation of image
- Runs in real time – not an offline filter
- What is parameter estimation?

Raw data

Parameter Estimation

\[ s = A \cdot \sin(2\pi f + \phi) \]

- \( A = 2 \)
- \( f = 4\text{kHz} \)
- \( \phi = \pi \)
From Wavelet transform to Parameter Estimation

Wavelet Transform

Parameter Estimation Model

\[ WT(a,b) = \frac{1}{\sqrt{a}} \int f(t) \psi^* \left( \frac{t-b}{a} \right) dt \]
Results before and after WISE
Dual Energy X-Ray Imaging

Low Energy Image

High Energy Image

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High Energy Image

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Dual Energy: Another Example

Low Energy Image

High Energy Image

Dual Energy Image

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How can we use these innovations for counterfeit detection? What’s wrong here?
How can we use these innovations for counterfeit detection? And here?
How can we use these innovations for counterfeit detection?
Artificial Neural Networks
Artificial Neural Networks for Sample Tracking

Sample manipulation with errors <500um
Summary

• Innovation in the first century of the x-ray inspection market was driven by hardware improvements

• Massive computing power has allowed the second century to be driven by algorithm innovations

• Expect to see more algorithm improvements this century