Leveraging Machine Learning for High-Resolution Restoration of Satellite Imagery

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Space Situational Awareness

Goal: Know what’s up there
Space
Situational
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Our Results

Truth → Observed → Reconstruction

3m → Machine Learning
THE FOLLOWING PREVIEW HAS BEEN APPROVED FOR ALL AUDIENCES BY THE MOTION PICTURE ASSOCIATION OF AMERICA INC.

THE FILM ADVERTISED HAS BEEN RATED R

RESTRICTED

UNDER 17 REQUIRES ACCOMPANYING PARENT OR GUARDIAN

PARTIAL NUDEITY & OPTIMIZATION

www.filmratings.com  www.mpaa.org
Really, we have many observations
The Key is: Selecting The Right Frames

Good IN, Good OUT
The Key is: Selecting The Right Frames

Garbage IN, Garbage OUT
How do we Select The Right Frames?
A Flavor of our Ideas

Write $x$ as Sparse Linear Combination of $y_i$'s
arg \min_{\omega \in \mathbb{R}^N} \|\omega\|_0 \quad \text{subject to} \quad X = \sum_{i=1}^{N} \omega_i y_i

A Flavor of our Ideas

Write $X$ as Sparse Linear Combination of $y_i$'s
A Flavor of our Ideas

Write $\mathbf{x}$ as Sparse Linear Combination of $\mathbf{y}_i$'s
This Work

State-of-the-Art

Random

RMSE=0.337

RMSE=0.352

RMSE=0.431

The Numbers

Outperforms State-of-the-Art
But wait…

These are NOT even the Good News!

The good news are:

We are Just Scratching the Surface!
The Good News Are…

• This is the “Basic” formulation:

\[
\arg \min_{\omega \in \mathbb{R}^N} \|\omega\|_1 \quad \text{subject to} \quad x = \sum_{i=1}^{N} \omega_i y_i
\]

We can include:

• Outliers

\[
\arg \min_{\omega \in \mathbb{R}^N} \|\omega\|_1 \quad \text{subject to} \quad x = \sum_{i=1}^{N} \omega_i y_i + s
\]

• More Regularizers

\[
\arg \min_{\omega \in \mathbb{R}^N} \|\omega\|_1 + \lambda \|\omega\|_2 \quad \text{subject to} \quad x = \sum_{i=1}^{N} \omega_i y_i
\]

• Dimensionality Reduction

\[
\arg \min_{U,D,V} \|x - UDVT\|_F
\]
The Good News Are…

Extend Machine Learning to Develop A Robust System
The Good News Are…

Extend Machine Learning to Develop A Neural Network That Learns to Reconstruct (Deep Learning)
What Else Can We Learn?

Are we Online?

Model, Position, Orientation

What is it Observing/Doing?
Mahalo!

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