Project 36

A NEW SATELLITE IMAGE FUSION METHOD BASED ON DISTRIBUTED COMPRESSED SENSING

Team Members :

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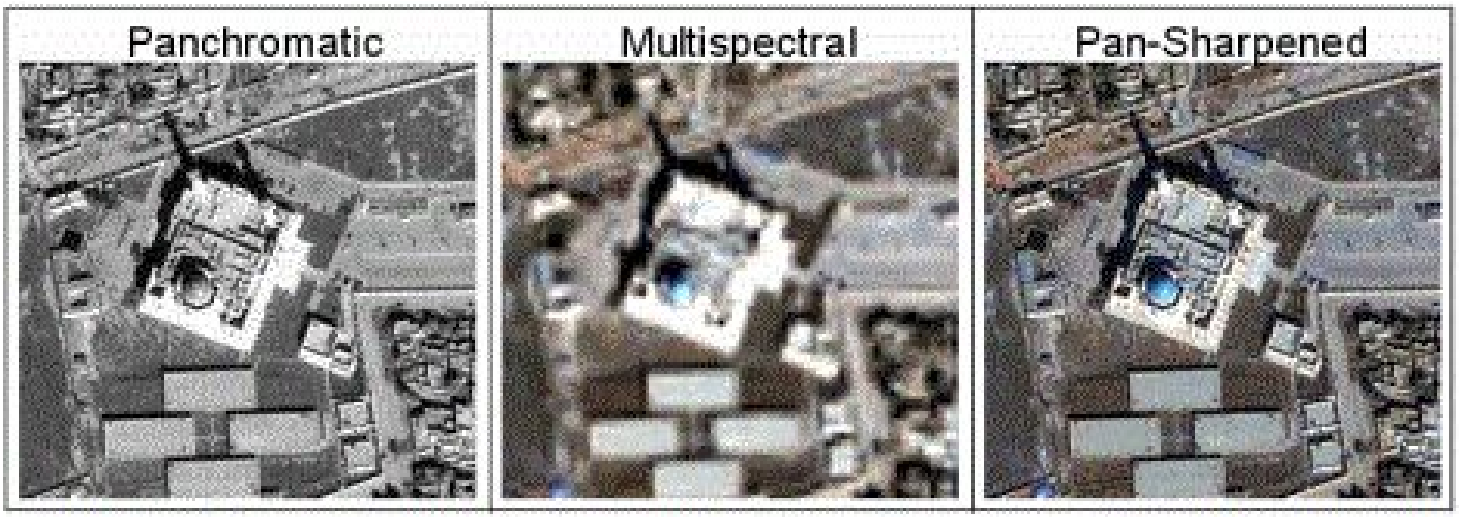
Problem Statement :

Due to constraints of received energy and physics of sensors, the **multispectral image** detected by multispectral sensors is of **high spectral resolution and low spatial resolution**, named as LRM image, while **PAN image** (panchromatic) detected by PAN sensors is of **low spectral resolution and high spatial resolution**, named as HRP image.



To **optimally benefit** from the advantages of multispectral images (i.e., high spectral resolution) and panchromatic images (i.e., high spatial resolution), the two are often combined or fused for improved visual image interpretation and information retrieval.

This image fusion procedure, which is known as pan-sharpening or intensity substitution, combines three bands from the multispectral image with the high spatial resolution panchromatic image to produce an output (color composite) that has the spatial and spectral properties of both

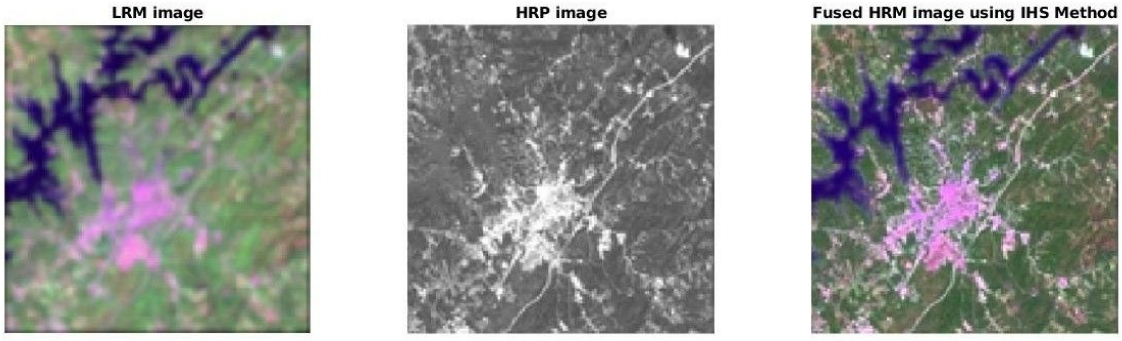
image types. This procedure is extremely useful in object-based image analysis, in which very high-resolution images are required to extract the objects of interest.

Commonly used Methods :

RGB to IHS transformation :

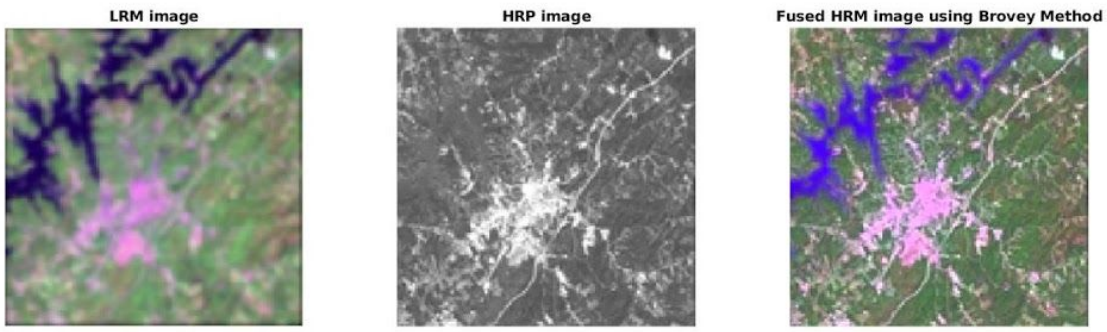
A simple and commonly used approach to fuse multispectral and panchromatic images is the RGB -IHS color space forward and inverse transformation technique.

- First, we transform the given image into **IHS color space**.
- This transformation enables a replacement of the "**intensity component**" of the IHS transform (which is derived from the multispectral image) to be **replaced by the high spatial resolution panchromatic image**.
- This new intensity image, together with the original hue and saturation images (from the multispectral image) are then transformed back into an RGB color space for visualization.



Brovey method :

- The BT is based on the **chromaticity transform**. It is a simple method for combining data from multiple sensors with the limitation that only three bands are involved.
- In this method, we **normalize the three multispectral bands** used for RGB display and to multiply the result by any other desired data to **add the intensity or brightness component to the image.**



Proposed Method in the paper:

Why is it better than other methods :

- All the methods mentioned above tend to utilize the spatial resolution of HRP image but cannot keep the spectral characteristics of the original LRM image. These methods are called component-substitution methods.
- Compressed-sensing based fusion methods, on the other hand, are capable of making better use of the high spectral resolution in LRM image and high spatial resolution in HRP image.
- The proposed method in the paper **uses distributed compressed sensing** to give better results than compressed sensing.
- **It uses Joint Sparsity Model(JSM-1) to preserve the inter-signal correlation**.

Method :

- We take the HRP image and using **Modulo-Transfer-Function(MTF)** we get a low pass and high pass versions of it.
- Using the low pass and high pass versions of the HRP image we find out the **Approximation and detail dictionaries**
- Now using **OMP Algorithm** we find out the sparse coefficients according to the compressed sensing equation. The detailed steps in the algorithm are written below.
- Now as the sparse coefficients are known we can find the details(d) and the upsampled LRM(x) image patches. Using these we can get the HRM image.

OMP Algorithm:

Problem Statement:

Given Y = MX where Y is the observation vector and M is the sensing matrix, we need to find the sparsest X that satisfies this.

This is stated as follows: **Find X such that L0 norm of X is minimized and** $\| \mathbf{Y - MX} \|_2^2$ **<= e (small quantity) is satisfied.**

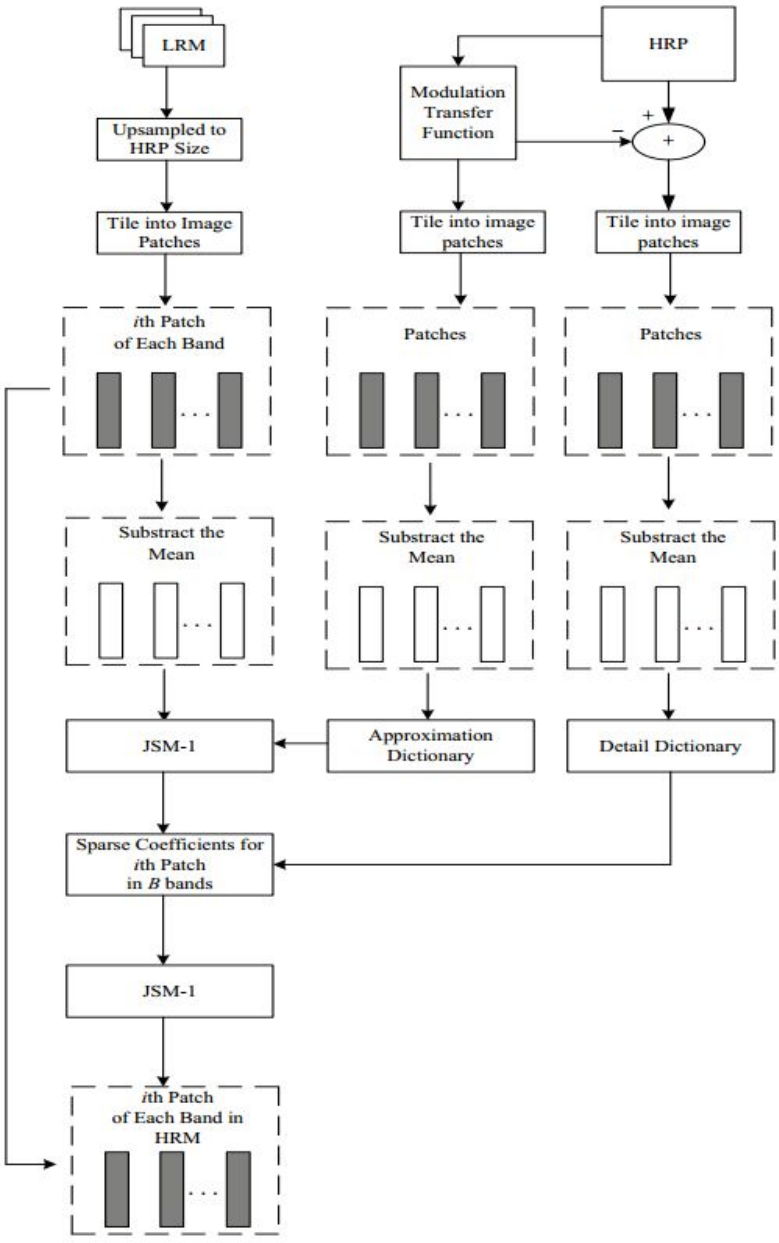
This is done by finding the basis of the column space or the effective set of vectors that are sufficient to satisfy the given conditions.

Steps in the Algorithm:

1) Initialize the basis matrix B to empty.
2) Find the projections of the columns of M on Y.

3) Add the column that is giving the maximum projection on y to B.
4) Find the best suitable X that minimizes the loss $\| Y - MX \|_2^2$.
5) Find the residue that is Y - BX. Update Y to the residue.
6) Repeat steps 2-5 until the difference in residue between two iterations is small enough.

The flow chart for the proposed method :



Evaluation Metrics:

The Results are evaluated using **Wald's synthesis protocol** as proposed in the paper.

Here we take **original LRM image as the reference image** and compare it with the image obtained after **fusion of the decimated LRM and HRP images**.

The fusion results are evaluated by

1) The Spectral Angle Mapper (SAM)
2) Erreur Relative Global Adimensionnelle de Synthese (ERGAS)
3) Quaternion-based coefficient (Q4)

Milestones Left:

- Use MTF filter to get the low pass version of HRP
- Get the Dictionaries **D**app(Approximate dictionary) and **D**det(Detail Dictionary) by tiling the low pass version of HRP.
- Get dataset mentioned in the paper and other datasets to compare
- Add Quaternion-based coefficient (Q4) metric
- Compare Performance based on the above metrics on given datasets
- Analyze failure of poorly performing cases

PCA Method :

- The aim of the method is to reduce the dimensionality of multivariate data whilst preserving as much of the relevant information as possible. It computes a compact and optimal description of the data set in the form of principal components.
- The first principal component is taken to be along the direction with the maximum variance.
- In the fusion process, the PCA method generates uncorrelated images (PC1, PC2,.... PCn, where n is the number of input multispectral bands).
- **It is observed that there is high correlation between the pan image and the first principal component.**
- The first principal component (pc1) is replaced with the panchromatic band, which has higher spatial resolution than the multispectral images.
- Afterward, the inverse PCA transformation is applied to obtain the image in the RGB color model