# Data Fusion Techniques

**Image Fusion and Algorithm Fusion**

Data fusion techniques combine data from different sources together. The main objective of employing fusion is to produce a fused result that provides the most detailed and reliable information possible. Fusing multiple information sources together also produces a more efficient representation of the data. AUG Signals has been involved in research and development in the area of data fusion for over a decade. The company has developed techniques in all three categories of data fusion:

1. Pixel / Data level fusion
2. Feature level fusion
3. Decision level fusion

Pixel level fusion is the combination of the raw data from multiple source images into a single image. Feature level fusion requires the extraction of different features from the source data – before features are merged together. Decision level fusion combines the results from multiple algorithms to yield a final fused decision. AUG Signals' fusion algorithms have been applied to various types of data including:

- Multi-sensor data
- Multi-temporal data
- Multi-resolution data
- Multi-parameter data

The two main application areas are Image Fusion and Algorithm Fusion. Image Fusion techniques use different fusion techniques to combine multiple images into a single fused image. Algorithm Fusion techniques fuse the decision results from multiple algorithms to yield a more accurate decision.

## Image Fusion

Image Fusion produces a single image by combining information from a set of source images together, using pixel, feature or decision level techniques. The fused image contains greater information content for the scene than any one of the individual image sources alone. The reliability and overall detail of the image is increased, because of the addition of analogous and complementary information. Image fusion requires that images be registered first before they are fused.

Image fusion of multi-temporal and multi-sensor images is of considerable importance to earth and space observation applications, such as environmental, agricultural and maritime monitoring. Satellites sensors alone often cannot offer the necessary spatial resolution required for certain applications. Fusion of multiple temporal satellite images is used for resolution enhancement, creating a single high-resolution image. Depending on the number of input images, the resolution can be enhanced *2 to 5 times* using fusion algorithms.

In a multi-sensor environment, pixel level fusion can generate a fused image that provides the best description of a scene. Each sensor provides complementary information that can be combined together into a fused image. Fused images can be used by other algorithms for further processing, such as for target detection or tracking. Fused images are also ideal for human end users, who cannot easily visualize and combine the results from multiple sensors.

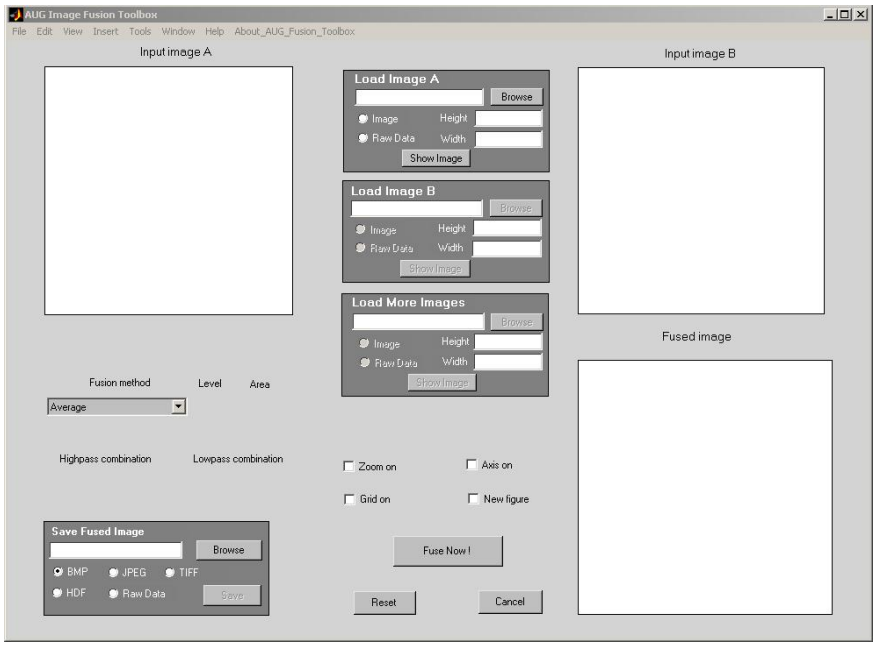
The Image Fusion Toolbox developed by AUG Signals, currently available for MATLAB and IDL, contains different image fusion algorithms. This includes well-known approaches and unique and innovative algorithms developed by AUG Signals. The following is a selected list of algorithms provided by the toolbox:

- Statistical Methods
- Markov Random Fields
- Dempster-Shafer Theory
- Neural Networks
- Fuzzy Logic
- Wavelets
- Super-resolution
- AUG Signals' Super-resolution

AUG Signals' Image Fusion Toolbox, along with the Image Registration and the Blur Estimation, Restoration and Speckle Reduction tools, form the AUG Signals' Image Processing Suite, which is accessible under one easy to use, yet highly configurable Graphical User Interface. It provides effective tools to:

- Generate an enhanced spatial resolution image using registered spatio-temporal images with minimal misregistration errors.
- Eliminate deterministic blurs that are introduced with the spatial resolution improvements in the image and avoid singularity and regularization artifacts.
- Estimate and reduce additive and multiplicative image noise using optimal statistical criteria.
- Eliminate blurs introduced by the sensors or atmosphere without introducing artifacts.

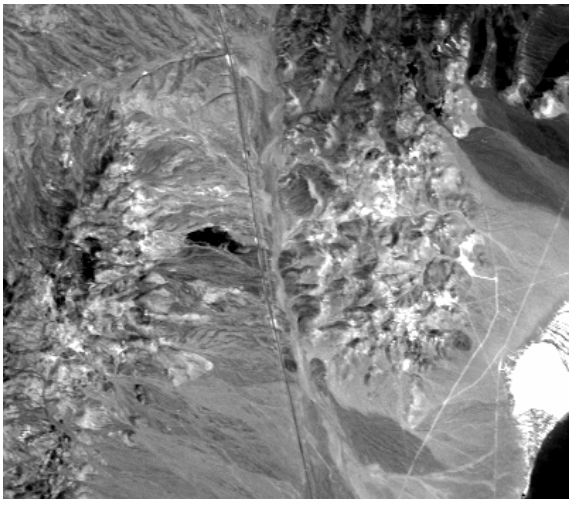
The figure below shows the Matlab user interface for the Image Fusion Toolbox. Two examples follow, demonstrating the applications of fusion algorithms.



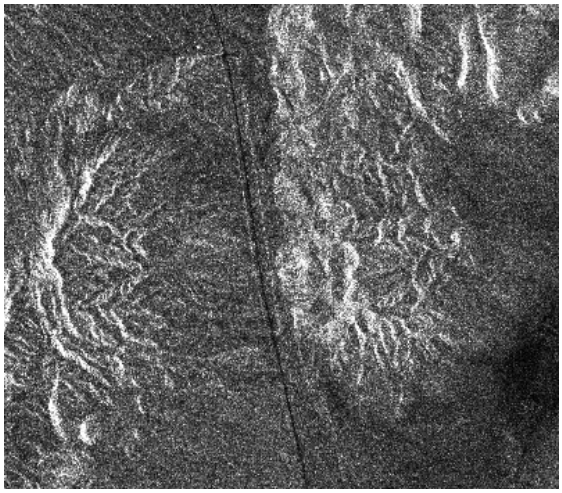

*Matlab user interface for AUG Signals' Image Fusion Toolbox*

***Example 1: Image Fusion for AVIRIS and RADARSAT data***

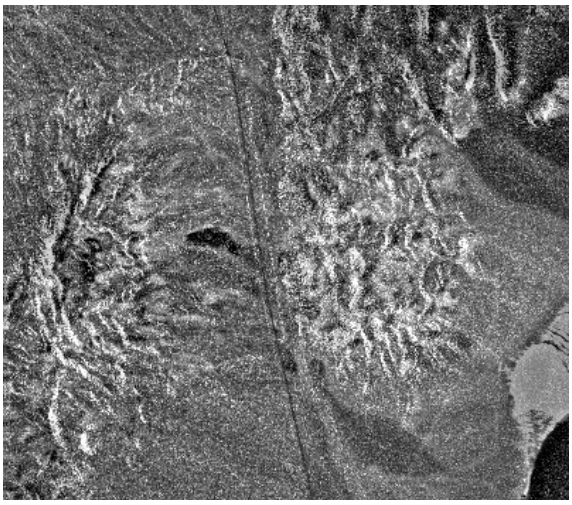
The two input images are from two different sensors: AVIRIS and RADARSAT. Although they depict the same region, each image contains complementary information. The fused image combines the details from both images.



*AVIRIS image (band 183)*



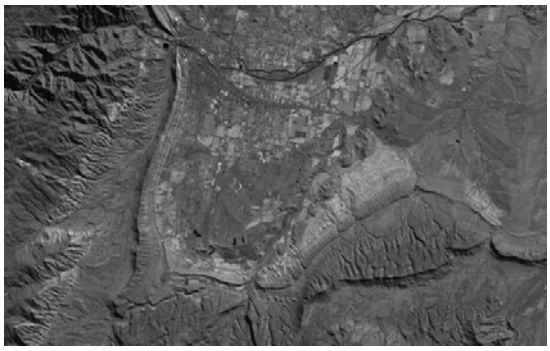
*High resolution RADARSAT image*



*The fused image, using the Shift Invariant Wavelet Transform method*

***Example 2: Image Fusion for Target Enhancement (Landsat TM)***

This example shows how targets in one image can be fused into another image that is the frame of reference.



*Frame of reference*

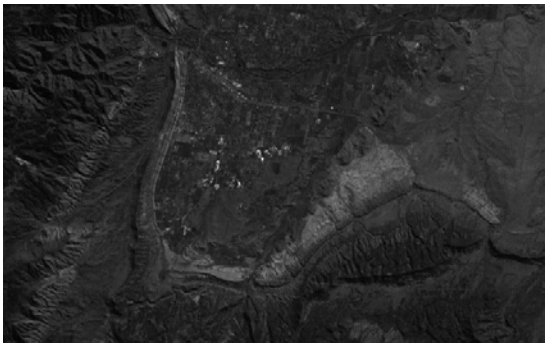
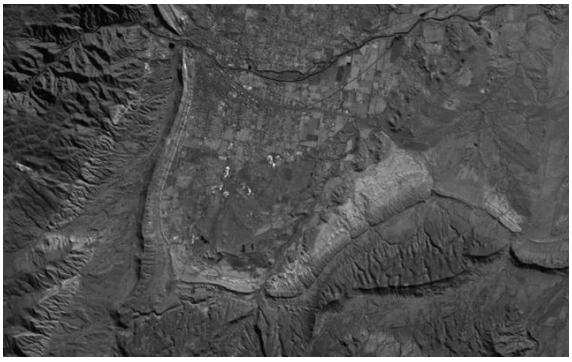


*Image with targets*



*Fused image with enhanced targets*

## Algorithm Fusion

Algorithm fusion is an unique research area in which AUG Signals has been heavily involved. Algorithm fusion uses sophisticated rules to combine decisions from multiple algorithms into a final decision, increasing the overall performance of the system. Two Algorithm Fusion techniques are discussed below, Multi-CFAR Detection and Decision Fusion of Separate Data-mining Subsystems on Multiple Data Sources.

**Multi-CFAR Detection**

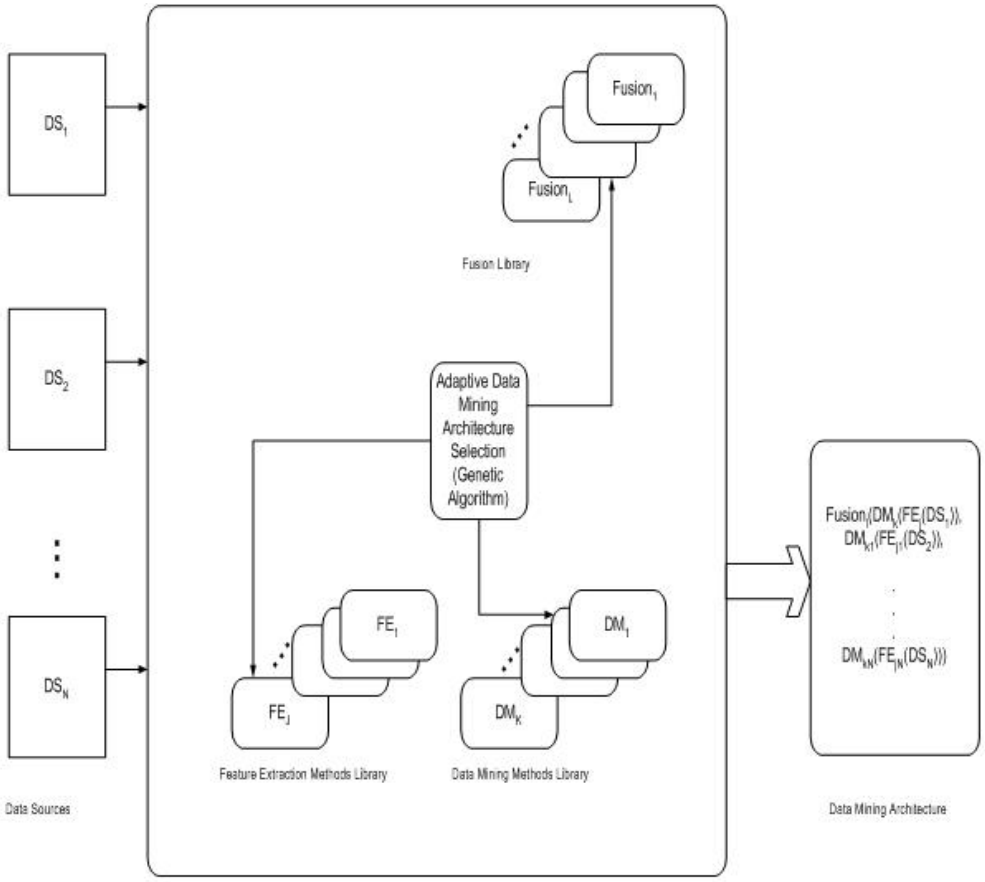
Unlike single CFAR detectors, AUG Signals' Multi-CFAR detector uses several CFAR detectors, such as the Ordered Statistics (OS) CFAR detector and the Cell Averaging (CA) CFAR detector, to perform detection on the same data. The detection decisions from each detector are fused using specific rules to obtain a final detection decision. The combination of CFAR detectors is able to provide complementary information and achieve higher detection performance than any single detector, while maintaining a constant false alarm rate. Please see *AUG Signals' Technical Brief on CFAR Detection* for more details.

**Decision Fusion of Separate Data-mining Subsystems on Multiple Data Sources**

The aim of fusing the decisions of separate data-mining subsystems operating on separate data sources is to increase the overall performance. Decision level fusion was chosen against data fusion and feature fusion in the three-level fusion hierarchy, because of its feasibility, lower computational complexity and robustness to the removal or addition of individual data sources. Decision fusion is the major component in the multi-source data-mining system developed by AUG Signals for decision support and situation assessment. It is able to automatically generate a solution given a library of features, data-mining algorithms and fusion techniques that are comparable to a tuned solution for the data set. The advantages of this system are its ability to incorporate:

- Multiple-source (sensor) data
- Multiple similar and dissimilar features
- Multiple data-mining algorithms
- Multiple fusion methodologies

This produces a system that exploits the resources of truth data, feature extraction, data-mining and fusion, while minimizing the level of expertise required for the end-user. The architecture for the system is shown on the following page.




*Multiple Source Data-mining Architecture*