DATA FUSION USING IHS TRANSFORMATIONS FOR EXPLORING ORE DEPOSITS IN NORTHEASTERN PART OF THE SAHARAN METACRATON

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ABSTRACT:

The main objective of the remotely sensed data fusion is to create an integrated composite image of improved information and enhanced interpretability. This data have geospatial details about earth's surface for substantial assessment of land resources and mineral exploration. Fusion of Visible-Infrared (VIR) and Synthetic Aperture Radar (SAR) images provides complementary data to increase the amount of information that can be extracted from the individual input images. It contains the details beneath the surface cover of the respective SAR data while maintaining the basic color content of the original VIR data. Image fusion can be performed at three different processing levels which are pixel level, feature level and decision level according to the stage at which the fusion takes place. In this work, a pixel based image fusion from different sensors, namely Landsat TM and RADARSAT-1 was performed using the Intensity, Hue, and Saturation (IHS) transformations procedures. The northeastern part of the Saharan Metacraton is dominated by medium to high-grade gneisses and migmatites, disrupted by belts of low-grade volcano-sedimentary sequences representing arc assemblages and highly dismembered ophiolites and intruded by a-type granitoids. Banded Iron Formation (BIF) and gold mineralization are associated with the high grade gneisses and migmatites. According to the fusion results, the fused image have enhanced subsurface structures such as foliation, faults and folding that control mineralization of several deposits and reveals the fluvial features which are not observable in Landsat TM images.

1. INTRODUCTION

Earth observation satellites provide data at a broad range of characteristics and multisource imageries including; spectral, spatial, and temporal resolutions. By combining these data that use different physical principals and record different properties of the objects, this may generate datasets that have more information than each of the input data alone. This process of combining several kinds of imagery is known as data fusion (Park and Kang, 2004). Several definitions can be found: "Data fusion is capable of integrating different imagery data to produce more information than can be derived from a single sensor" (Pohl and Van Genderen, 1998). Another comprehensive definition: "Data fusion deals with the synergistic combination of information made available by various knowledge sources such as sensors, in order to provide a better understanding of a given scene" (Dasarthy, 1994). The benefits from the fused images vary, they may detect the changes occurred over a period of time, enhance spatial resolution of multispectral images, generate an interpretation of the scene not obtainable with data from a single sensor, and reduce the uncertainty associated with the data from individual sensor (Kim et al., 2005). They generally offer increased interpretation capabilities, achieve more specific inferences and produce more reliable results.

Data fusion can be performed at three different processing levels namely; pixel level, feature level and decision level. In pixel level fusion, the combination mechanism works directly on the data obtained from the outputs of sensors. Feature level fusion, on the other hand, works on features extracted from the source data or the features which are available from different other sources of information. Decision level fusion works at an even higher level, and merges the interpretations of different objects obtained from different source of information (Samadzadegan et al., 2006). In this work we have used pixel level image fusion to obtain a new image that has superior properties over the individual input images with different properties. A general survey of pixel level image fusion techniques can be found in (Pohl and van Genderen, 1998).

In order to enhance some features like spatial and textural features as well as features that are not visible in optical images, data fusion of optical VIR and SAR imagery is used. VIR sensors offer spectral information about terrain cover types, while SAR sensors are active sensors and can penetrate materials which are optically opaque, and thus not visible by optical or IR techniques. Therefore, SAR images complement photographic and other optical imaging capabilities to increase the amount of information that can be extracted from the individual input images (Gungor and Shan, 2006). In this paper, we integrated RADARSAT-1 features into co-registered TM image using IHS transformations for geological and mineral exploration in the study area. It enhanced subsurface structures such as foliation, faults and folding. The remainder of the paper is arranged as follows: Section two explains the IHS transformations with their equations. Section three presents the data acquisition and methodology. Where, the data, the software used, and the processing steps are introduced. Section four focuses on the results and discussions. Finally, our conclusions are given in section five.

2. INTENSITY-HUE-SATURATION TRANSFORMATIONS

The IHS color space is very useful for image processing because it separates the color information in ways that correspond to the human visual system's response. It is an

alternate, application oriented, color space to represent multispectral data more objectively (Nasr et al., 2001). It uses three positional parameters in lieu of the Red, Green and Blue (RGB); Intensity, Hue and Saturation. Intensity relates to the overall brightness of a color or energy level of the light and is devoid of any color content. It shows how close it is to black or white. Hue refers to the dominant or average wavelength of light contributing to a color, i.e. the actual perceived color such as red, blue, yellow, orange, etc. Saturation specifies the degree to which the color is pure from white light (grayscale) dilution or pollution. It runs from neutral gray through pastel to saturated colors. The transformation from RGB color space to IHS space is nonlinear, lossless and reversible. One can vary each of the IHS components without affecting the others. It is performed by a rotation of axis from the first orthogonal RGB system to a new orthogonal IHS system. The equations describing the transformation to the IHS are as follows (Pellemans, et al., 1993):

$$
\begin{Bmatrix} x \\ y \\ z \end{Bmatrix} = \begin{Bmatrix} \frac{1}{\sqrt{3}} & \frac{\sqrt{2}}{\sqrt{3}} & 0 \\ -\frac{\sqrt{2}}{\sqrt{3}} & \frac{1}{\sqrt{3}} & 0 \\ 0 & 0 & 1 \end{Bmatrix} \begin{Bmatrix} \frac{1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} \\ 0 & 1 & 0 \\ \frac{-1}{\sqrt{2}} & 0 & \frac{1}{\sqrt{2}} \end{Bmatrix} \begin{Bmatrix} B \\ G \\ R \end{Bmatrix}
$$

The value of H, S and I can then be computed as:

$$
H = \tan^{-1}\left(-\frac{\sqrt{z}}{\sqrt{x}}\right)
$$

$$
S = \cos^{-1}\left(\frac{\sqrt{y}}{\sqrt{x+y+z}}\right) / \Phi_m(H)
$$

$$
I = (x + y + z) / I_m(H,S)
$$

Where $\Phi_m(H)$ is the maximum co-latitude permitted at a given hue and $I_m(H,S)$ is the maximum intensity permitted at a given hue and co-latitude.

3. DATA ACQUISITION AND METHODOLOGY

To aid the extraction of the information by visual interpretation, data fusion is used to provide a new refined image and contribute to a better understanding of the objects observed within that image. Fusion of different imaging sensors data involves two major steps. First, the digital images from both sensors are geometrically registered in respect to one another. Next, the information contents (spatial and spectral) are mixed to generate a single data set that contains the best of both sets (Eldougdoug and Nasr, 1994). The geometric registration plays an essential role because misregistration causes artificial features in the multisensor data sets, which falsify the interpretation later on. It includes the resampling of image data to a common pixel spacing and map projection (Onsi, 2002).

The study area covers approximately 30.8 km by 45.4 km as shown in the location map (Figure 1). Two sets of multisensor data are used in this study. Part of landsat TM scene (Path: 177, Row: 45) 28.5 m resolution, acquired on October, 1984 (Figure 2) and part of RADARSAT-1 scene, 12.5 m resolution, acquired on September, 1998 (Figure 3). These images were processed using the ERDAS Imagine, version 8.7 software. IHS method is applied to three bands at a time, whose fusion output is displayed in either true or false color. Therefore, three selected bands from the Landsat scene; 7 (2.08 - 2.35 µm), 4 (0.76 - 0.90 µm) and 2 (0.52 - 0.60 µm) were used since they contain most of the information about the surface geological features of the study area.
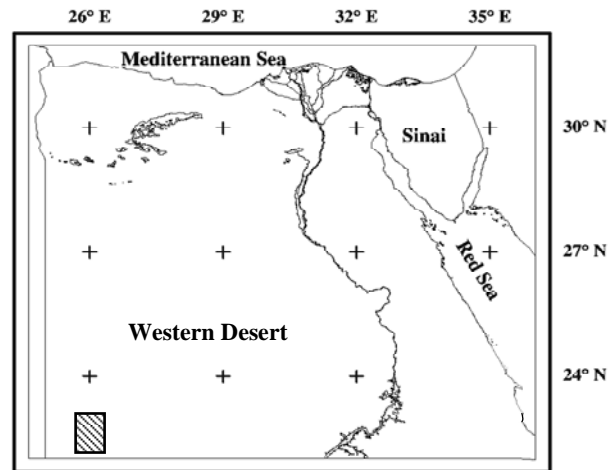

Figure 1. Figure placement and numbering
Figure 1. Location map of the study area indicated by hatches in a rectangular form
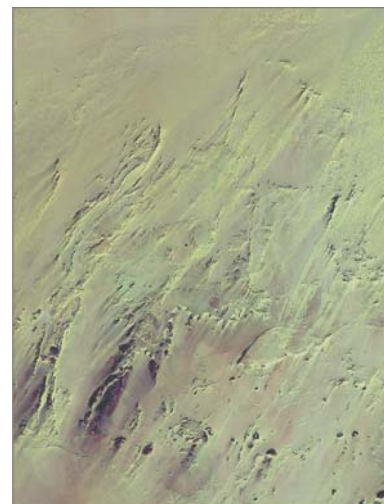
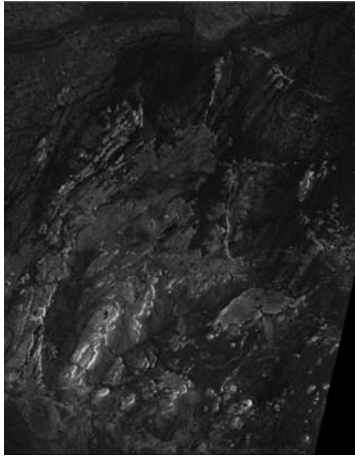

Figure 2. Landsat TM scene, October 1984

Figure 3. RADARSAT-1 scene, September 1998

Since geometric distortions are normally introduced to satellite data during acquisition due to satellite drift and Earth's rotation, highly accurate geometric correction is crucial before any image processing. Therefore, the RADARSAT-1 and the Landsat TM images were geometrically corrected and registered. Well distributed control points were interactively selected on both images. The coordinates of these points were compared to determine a polynomial equation for adjustment between them. The images were thus rectified according to the Universal Transverse Mercator (UTM) projection. Finally, they resampled at (15 m) resolution using cubic convolution technique. Once the geometric correction was completed, the images have been fused using the IHS transformations as follows; the Landsat TM image is transformed into the IHS perceptual color space. Since intensity is related mainly to the brightness of the spectral responses, RADARSAT-1 image histogram has been stretched to match the variance and average of this computed intensity. Then, it was directly substituted and the inverse IHS-to-RGB transformation is performed as shown in the schematic diagram (Figure 4).
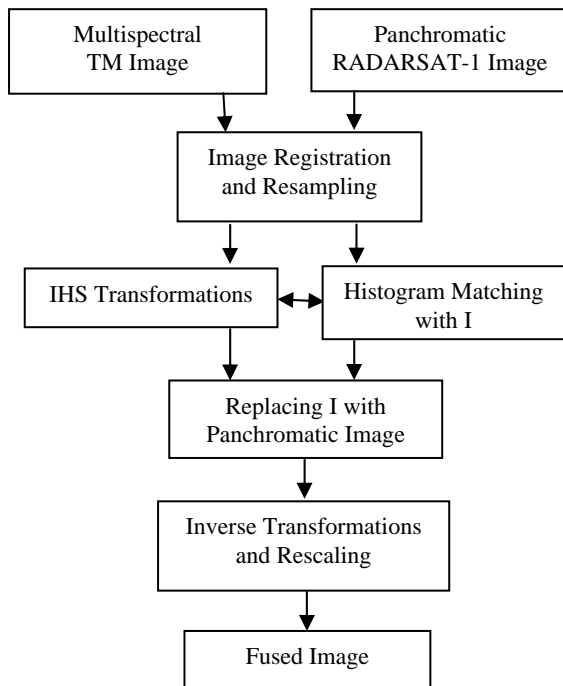

Figure 4. Schematic diagram of the fusion technique

The resulted fused image has high spatial enhanced details and spectral parameters, because the component of intensity has high correlation with spatial variation and the components hue and saturation correspond with the spectral characteristics of the image, as depicted in the false color composite (Figure 5).
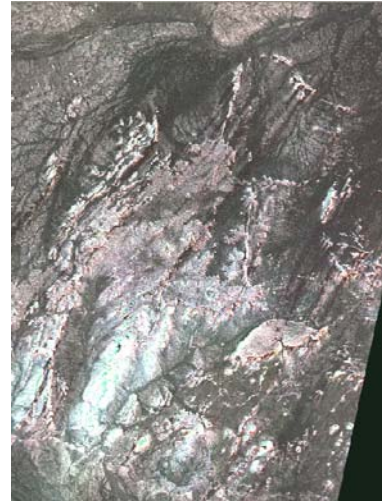

Figure 5. The resulted fused image of the study area

4. RESULTS AND DISCUSSION

The previous procedures led to an excellent spectral discrimination and interpretation of the study area. However, a problem of slight color distortion (variation in hue) appears after the fusion process, since the panchromatic image and the intensity image are different. Such a problem has been reported by many authors (Pellemans et al., 1993) and (Wang et al., 2005). Somewhat better performance can be expected when the available data-sets have strong correlation (Kalpoma and Kudoh, 2007). The study area is underlain by metamorphic rocks which are represented by: i) mafic-ultramafic granulite and ii) orthogneisses (felsic granulite), paragneisses (quartzite, quartz-feldspar gneiss) and BIF. These rocks are intruded by younger granitic rocks with sharp intrusive contacts. These rocks are uncomfortably overlain by the Gilf Formation (Paleozoic), Abu Ras Formation (Mesozoic) and Quaternary sediments (Khattab, et al., 2002).

The most important finding of this study is the appearance of features beneath the sand surface on the fused Landsat TM and RADARSAT-1 images. These features are not observable at all on the Landsat TM image of similar spatial resolution (Figure 6). Therefore, new geological and structural information were achieved with regard to the drainage pattern, lithological and structural features. The output fused image brought up the buried drainage pattern (W) in a most revealing manner. Excavations in this area indicated that the fine-grained sand dunes in this locality have a thickness of only (0.5-1 m) and the aridity of the sand and soils permitted radar subsurface penetration and capturing of the feature in the returned signal. One major NE trending drainage lines are revealed by RADARSAT-1 data to lead into the eastern side of the study area. The fused image also revealed some subsurface precambrian structures such as foliations, folds (D1 and D2) and faults (F1 and F2) that control the distribution of the gneissic rocks and associated BIF in the study area. These are

mostly covered with recent sands. Excavations in these areas indicated that the BIF is present underneath the dry sand sheets at depths of (0.6-1 m).
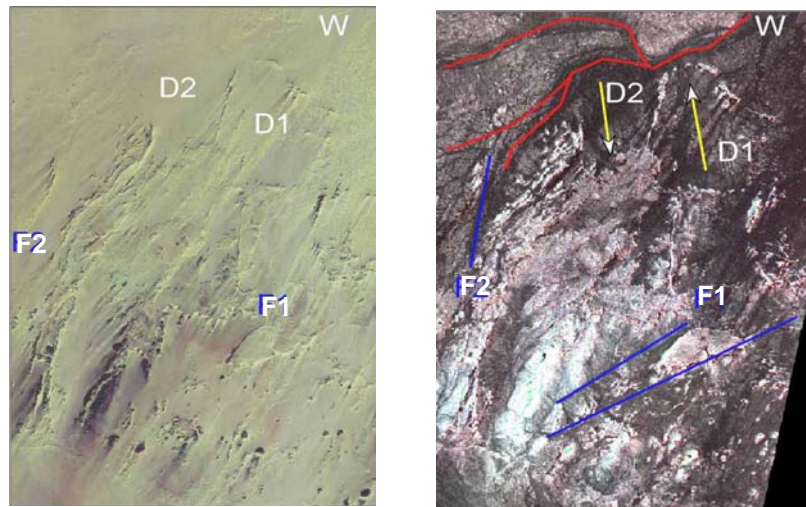
Figure 6. Interpretation from Landsat TM / RADARSAR-1 fused image, showing the subsurface features of the study area

5. CONCLUSIONS

Visual evaluation of the images produced by the multisensor data fusion indicates that the fused images represent a substantial improvement in interpretability over the original multispectral data. This paper describes the effectiveness of the fusion of SAR and optical images based on the use of IHS transformation. The output fused image improves visual detection of subsurface structures such as foliations, folding and faults in the study area. Those features are covered with sand sheets, dunes and wadi alluvium, which make them almost undetectable in Landsat TM data. Moreover, the fusion of the two data sets reveals drainage patterns and recent structures. These features are valuable for exploration of mineral deposits such as BIF and heavy minerals in placer deposits in the investigated area and similar arid regions.

Application of IHS transformations of TM data to accomplish highly detailed multispectral fused image, by direct substitution of the RADARSAT-1 data for the computed intensity, was quit useful in revealing the subsurface features, the structures and the information content of the study area.

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