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Effect of Speckle Filtering On SAR High Resolution Data for Image Fusion

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Abstract: Image fusion is the process of combining significant information from two or more images into a single image. The resulting image will be more informative than any of the input images. Image fusion is powerful technique for merging similar sensor and/or multi-sensor images to enhance the information. In remote sensing applications, the increasing availability of space borne sensors gives a motivation for different image fusion algorithms. Several situations in image processing require high spatial and high spectral resolution in a single image. Most of the available equipment is not capable of providing such data convincingly. The image fusion techniques allow the mixing of different information sources. The fused output image can have complementary spatial and spectral resolution characteristics.

Index Terms: **SAR, Fusion, Speckle Filter and Image.**

I. INTRODUCTION

In satellite imaging, two types of images are available. The panchromatic image acquired by satellites is transmitted with the better resolution available and the multispectral data are transmitted with lesser resolution. This will usually be two or four times lower. At the receiver station, the panchromatic image is merged with the multispectral data to convey more information. Multi-sensor data fusion has become a discipline which demands more general formal solutions to a number of application cases. Several situations in real life require both high spatial and high spectral information in a single image. Image fusion is the process of combining information of interest in two or more images of same scene into a single highly informative image. Information of interest depends on the application under consideration [1], [3] -[6] .

II. SPECKLE FILTERING

Unlike optical remote sensing images, characterized by very neat and uniform features, SAR images are affected by speckle. Speckle confers to SAR images a granular aspect with random spatial variations. Speckle is a scattering phenomenon and not a noise. The discrimination of different natural media by comparing intensity to a fixed threshold leads, in general to numerous errors due to the high variability of SAR speckled response [7].

There are various speckle reduction filters available in image processing to process SAR images. Some give better visual interpretations while others have good noise reduction or smoothing capabilities. The use of each filter depends on the specification for a particular application. In image processing, the standard speckle filters like Median, Mean, Statistical Lee, Kuan, Frost, enhanced Frost and Gamma filters are generally used. Each of these speckle filters performs the filtering based on either local statistical data given in the filter window to determine the noise variance within the filter window, or estimating the local noise variance using the effective equivalent number of looks (ENL) of a SAR image. The estimated noise variance is then used to determine the amount of smoothing needed for each speckle image. The noise variance determined from the local filter window is more applicable if the intensity of an area is constant".

The most commonly used speckle reduction technique is multiple-look processing. The principle behind the technique is that the sum of N identically distributed, real-valued, uncorrelated random variables has a mean value which is N times the mean of any one component. ENL is a parameter to be used as an indicator of the quality of SAR images generated. ENL is defined as [2]

$$ENL=(E(P))2 / VAR(P)$$

Where P is the intensity of a pixel in the multiple-look image, E and VAR represents the expectation value and the variance of P respectively.

III. MATERIAL AND METHODOLOGY

A. ABOUT THE SATELLITE: The input SAR imagery is acquired by a German earth observation satellite, TerraSAR-X which is launched on 15th June, 2007. TerraSAR-X is a 1m resolution class radar satellite, which delivers earth observation data for scientific, institutional and commercial uses. These characteristics of the satellite have improved mapping of ground surfaces with high ground resolution and high temporal resolution. The following are the characteristics of the TerraSAR-X satellite:

Table-1: Characteristics of TerraSAR-X

Radar Carrier Frequency	9.65 GHz(X-band)
Incidence angle range for: Strip map/ScanSAR modes SpotLight modes	20°-45° full performance 20°-55° full performance (15°-60° accessible)
Polarizations	HH,VH,HV,VV
Pulse Repetition frequency	2.2KHz-6.5KHz
Nominal orbit height at the equator	Appox. 514 km
Revisit time (Orbit repeat cycle)	11 days
Inclination	97.44°
Ascending node Equatorial Crossing time	18:00 +/- 0.25h(local time)

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Imagery from the Landsat satellites has been acquired since 1972, with a variety of characteristics to consider. There have been six operational Landsat satellites, with three different useful sensors, all of which are available through the GLCF. The MSS sensor provides the oldest and lowest quality Landsat data, from 1972 – present. The TM sensor has improved quality and is available from 1984. The ETM+ sensor on the Landsat 7 satellite was the best quality of all, until a mechanical a nomaly occurred on the sensor in May, 2003. Landsat 7 imagery is still being collected, even with this unfortunate defect.

Table-2: Characteristics of Landsat-7

Launch Date	April 15, 1999
Sensors	ETM+
Altitude	705 km
Inclination	98.2°
Orbit	polar, sun-synchronous
Equatorial Crossing Time	nominally 10 AM (± 15 min.) local time (descending node)
Period of Revolution	99 minutes; ~14.5 orbits/day
Repeat Coverage	16 days

Table-3: Characteristics of Landsat-5

Launch Date	March 1, 1984
Sensors	TM, MSS
Altitude	705 km
Inclination	98.2°
Orbit	polar, sun-synchronous
Equatorial Crossing Time	nominally 10 AM (± 15 min.) local time (descending node)
Period of Revolution	99 minutes; ~14.5 orbits/day
Repeat Coverage	16 days

Table-4: ETM+ technical specifications

Sensor type	opto-mechanical
Spatial Resolution	30 m (60 m -thermal,15-m pan)
Spectral Range	0.45 - 12.5 µm
Number of Bands	8
Temporal Resolution	16 days
Image Size	183 km X 170 km
Swath	183 km

Table-5: TM technical specifications

Sensor type	opto-mechanical
Spatial Resolution	30 m (120 m - thermal)
Spectral Range	0.45 - 12.5 µm
Number of Bands	7
Temporal Resolution	16 days
Image Size	183 km X 170 km
Swath	183 km

B. ABOUT THE SOFTWARES USED: "The software used to de-speckle the data is "nest-5.0.5 beta version Next ESA SAR toolbox". NEST is used for reading, post-processing, analyzing and visualizing the large archive of data (from Level 1) of ESA SAR missions including ERS1 & 2, ENVISAT, as well as third party SAR-data from JERS SAR, ALOS PALSAR, TerraSAR-X, Radarsat-1&2 and Cosmo-Skymed. NEST helps the remote sensing community by handling ESA SAR products and complimenting existing commercial packages [8].

The other software used to fuse the data is erdas imagine 9.2. ERDAS IMAGINE is the raster geoprocessing software GIS, Remote Sensing and Photogrammetry professionals use to extract information from satellite and aerial images. Easy to learn and easy to use, ERDAS IMAGINE is perfect for beginners and experts alike. The vast array of tools allows users to analyze data from almost any source and present it in formats ranging from printed maps to 3D models, making ERDAS IMAGINE a comprehensive toolbox for geographic imaging, image processing, and raster GIS needs. Version 9.2 of the ERDAS IMAGINE suite adds sophisticated tools largely geared toward the more expert user, and forms a foundation for less complex versions in future releases of ERDAS IMAGINE.

C. STUDY AREA: The imagery used to compare the fusion process of SAR imagery with LANDSAT images is of Visakhapatnam Port area. Visakhapatnam is coined as "The City of Destiny" due to its natural beauty along the coast line. The city is rich in geological and geo-morphological features and has natural harbor. The study area is located on the east coast of India at a latitude of 17°42' 00" North and longitude of 83°23' 00" East and the time zone is GMT + 5:30. It is one of 13 major ports in India and the only major port of Andhra Pradesh. It is India's second largest port by volume of cargo handled. The port area is surrounded by highly populated urban area on one side and industrial area along the other side. The port area is located near to heart of Visakhapatnam city, hence it is highly connected with the road and rail networks for easy transportation.

D.METHODOLOGY

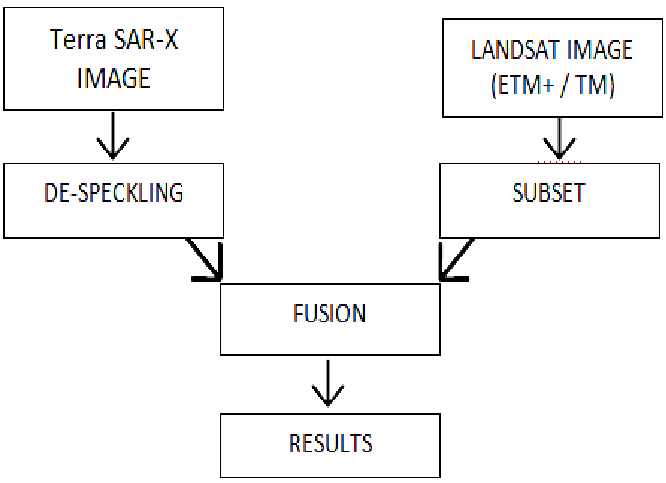

Fig-1: Steps involved

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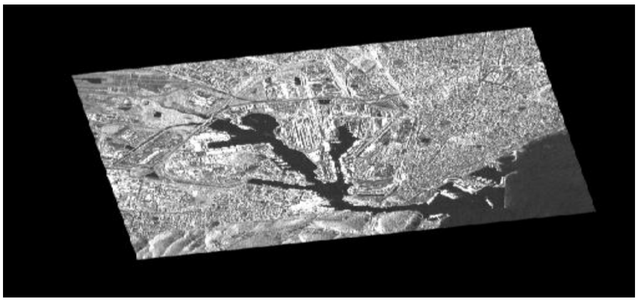
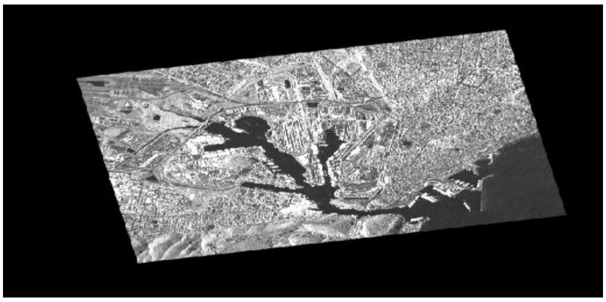
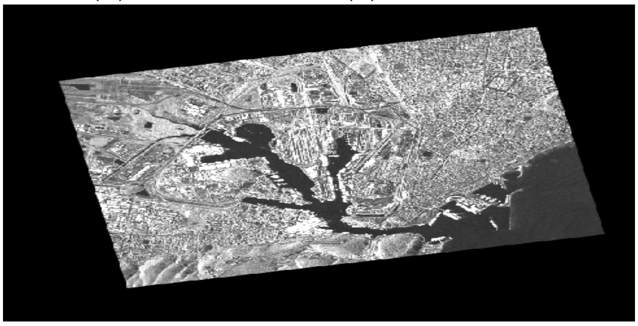
IV.RESULTS AND DISCUSSIONS

A.RESULTS OF DE-SPECKLING METHODS

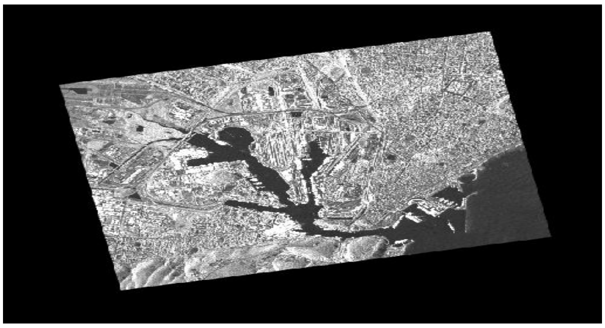




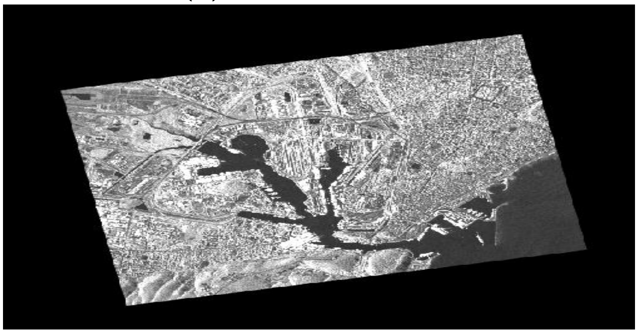
(A)INPUT (B) MEAN 3*3



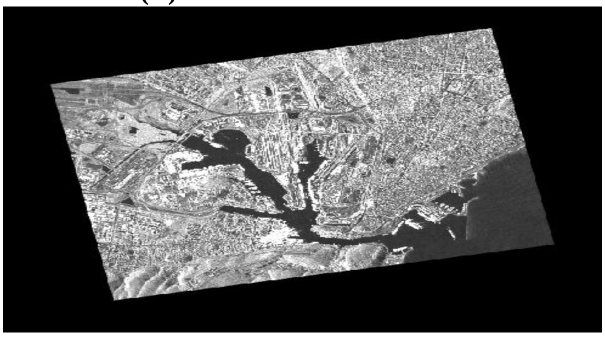
(C) MEAN 5*5



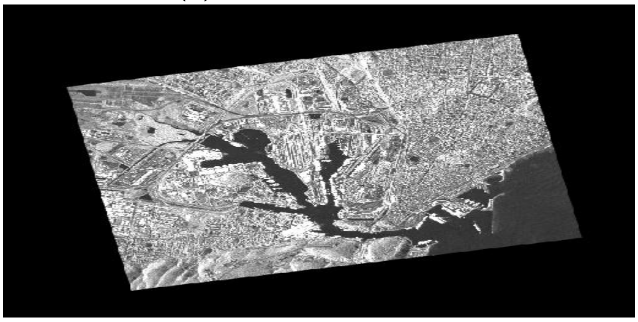
(D) MEDIAN 3*3



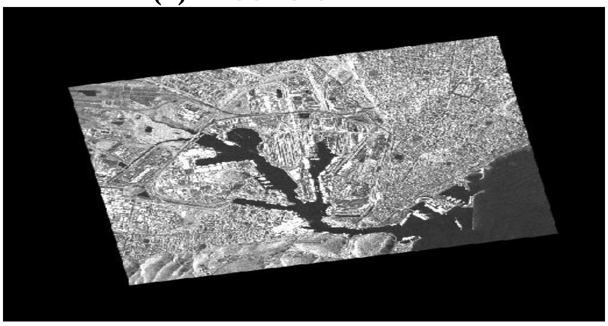
(E) MEDIAN 5*5



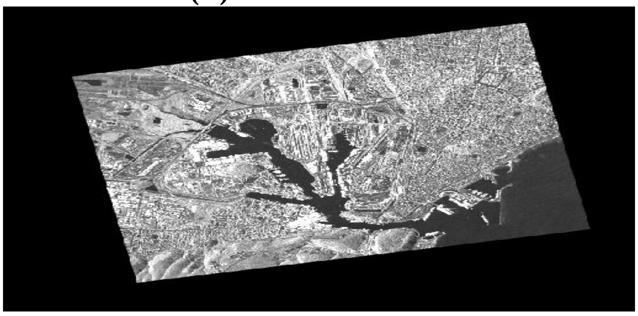
(F) FROST 3*3



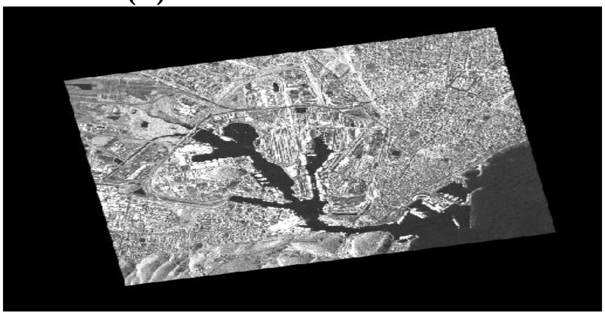
(G) FROST 5*5



(H) GAMMA 3*3



(I) GAMMA 5*5



(J) GAMMA 7*7

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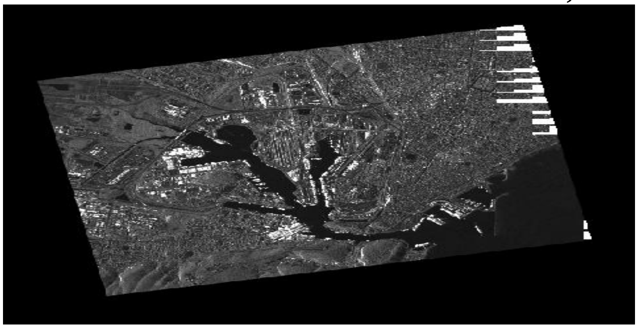
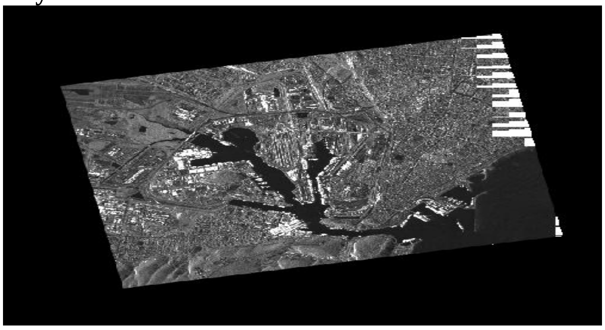
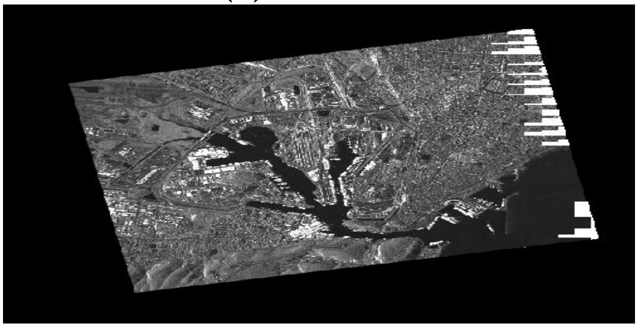


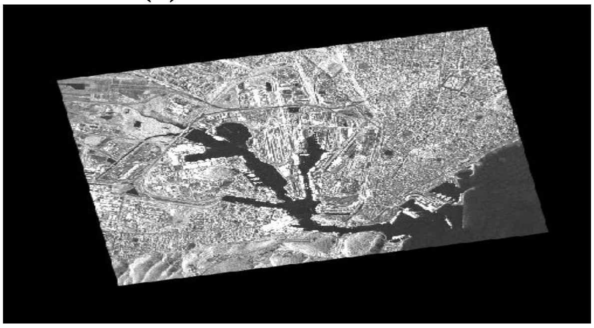
(K) LEE 3*3



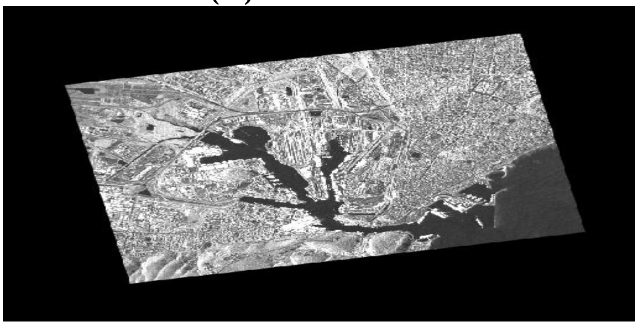
(L) LEE 5*5



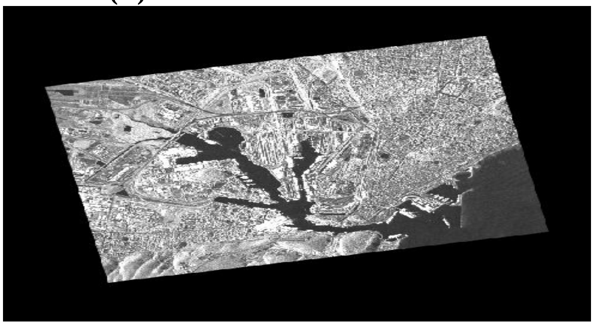
(M) LEE 7*7



(N) REFINED LEE-5000



(O) REFINED LEE-6000



(P) REFINED LEE-7000

Fig-2: SAR input (A) and different speckle filter outputs (B to P)

TABLE-6: STATISTICS OF SPECKLE FILTERS

		NO. OF PIXELS	MEAN	STD	CV	ENL
1	**INPUT**	418000000	32.03	127.98	64.36	0.0002
2	**MEAN 3*3**	418000000	34.52	113.57	45.42	0.0005
3	**MEAN 5*5**	418000000	37.46	102.36	31.85	0.0010
4	**MEDIAN 3*3**	418000000	30.69	107.77	50.79	0.0004
5	**MEDIAN 5*5**	418000000	32.75	86.17	32.75	0.0009
6	**FROST 3*3**	418000000	34.27	113.49	47.50	0.0004
7	**FROST 5*5**	418000000	32.62	104.63	44.48	0.0005
8	**Gamma map 3*3**	418000000	34.52	113.72	45.37	0.0005
9	**Gamma map 5*5**	418000000	37.46	102.36	31.85	0.0010
10	**Gamma map 7*7**	418000000	38.87	95.85	23	0.0018
11	**Lee 3*3**	416006815	-1920.92	164.19	-	-
12	**Lee 5*5**	415239385	-276.13	108.95	-	-
13	**Lee 7*7**	414647163	-30.97	78.39	-	-

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14	**REFINED LEE (5000)**	418000000	33.13	100.63	40.44	0.0006
15	**REFINED LEE (6000)**	418000000	33.21	100.66	40.39	0.0006
16	**REFINED LEE (7000)**	418000000	33.29	100.68	40.35	0.0006

B. CONCLUSION OF DESPECKLING

From above table, we can say that gamma map filter of 7*7 window is giving high ENL value among 16 filters. A larger value of ENL usually corresponds to a better quantitative performance. The value of ENL also depends on the size of the tested region, theoretically a larger region will produces a higher ENL value than over a smaller region but it also tradeoff the accuracy of the readings. So, the output of that gamma map filter of 7*7 window will be taken for fusion process.

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C. RESULTS OF DIFFERENT FUSION METHODS

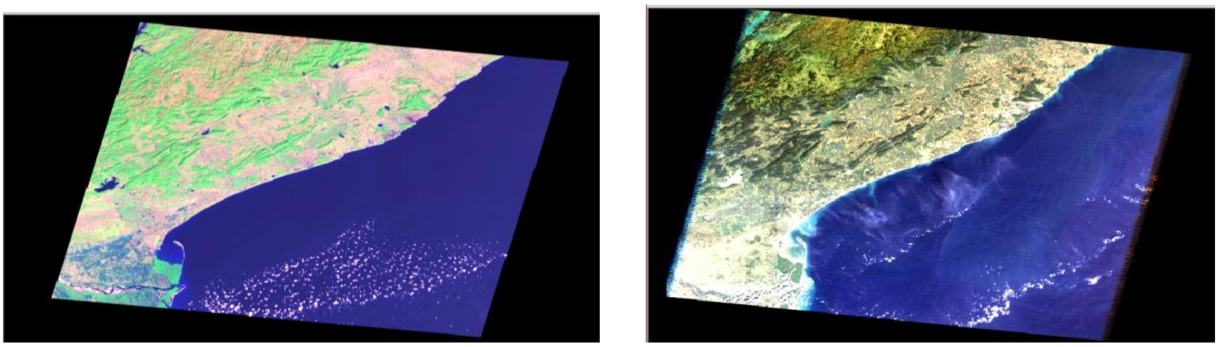

Fig-3: LANDSAT ETM+ image and LANDSAT TM image

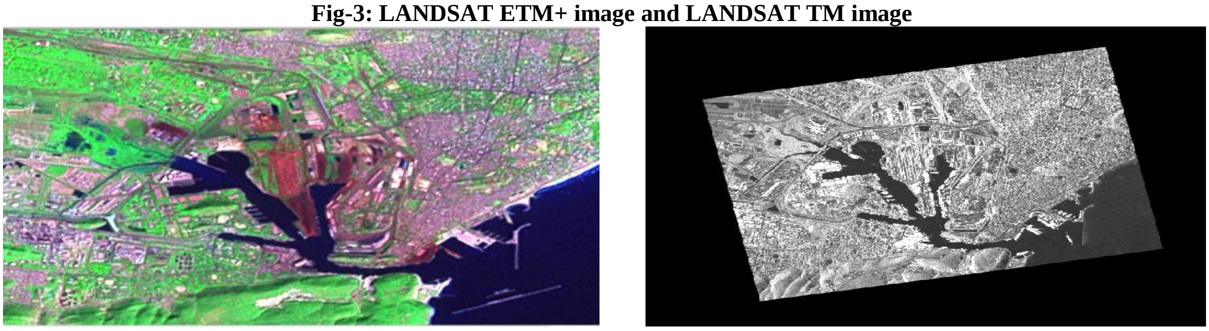

Fig-4: LANDSAT ETM+ subset image and SAR de-speckled image

(A)

(B)

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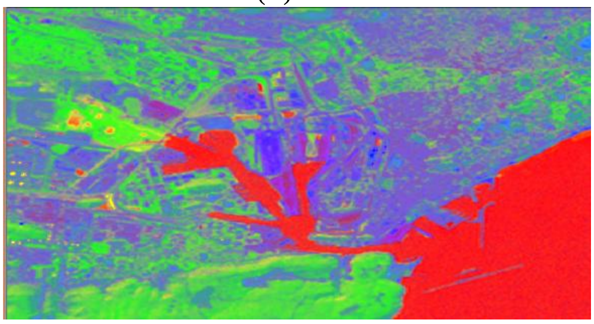
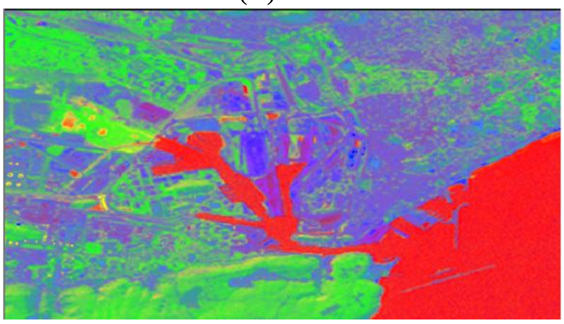
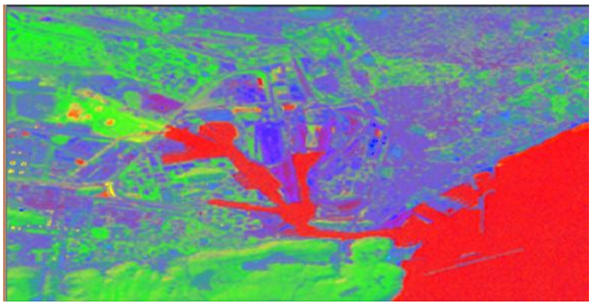
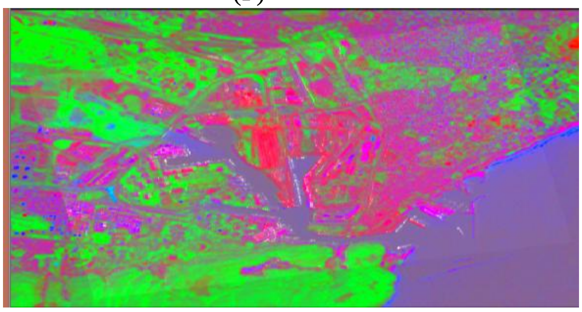
(C)

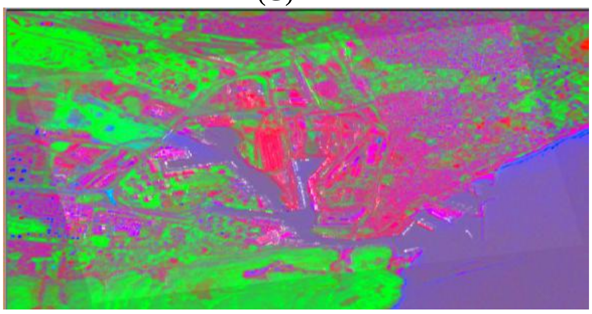

(D)


(E)


(F)


(G)


(H)


(I)

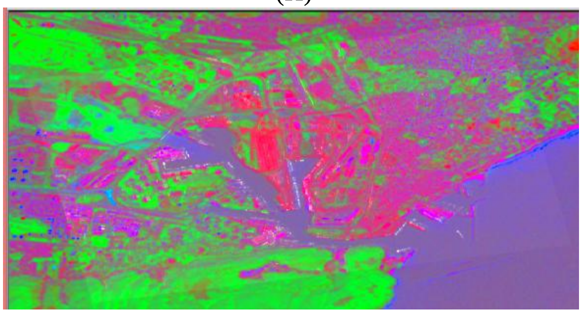

(J)

Fig-5: Fused images of Terra SAR-X and LANDSAT TEM+ images with (A) IHS & BI (B)IHS & CC (C) IHS & NN (D) M&CC (E)MIHS & BI (F)MIHS&CC (G)MIHS&NN (H)PC&BI (I)PC&CC (J)PC&NN methods

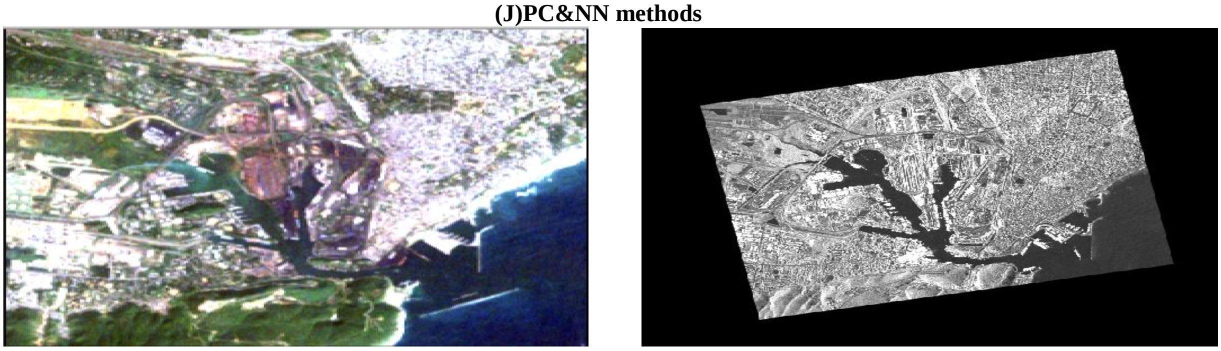


Fig-6: LANDSAT TM subset image and SAR de-speckled image

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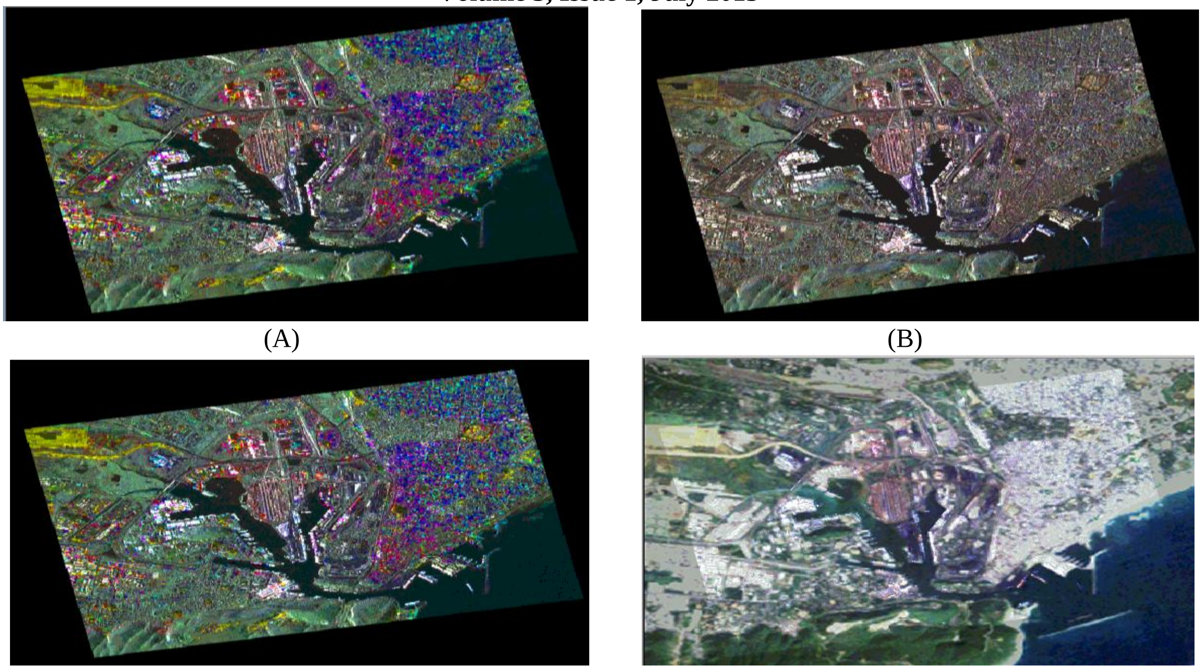
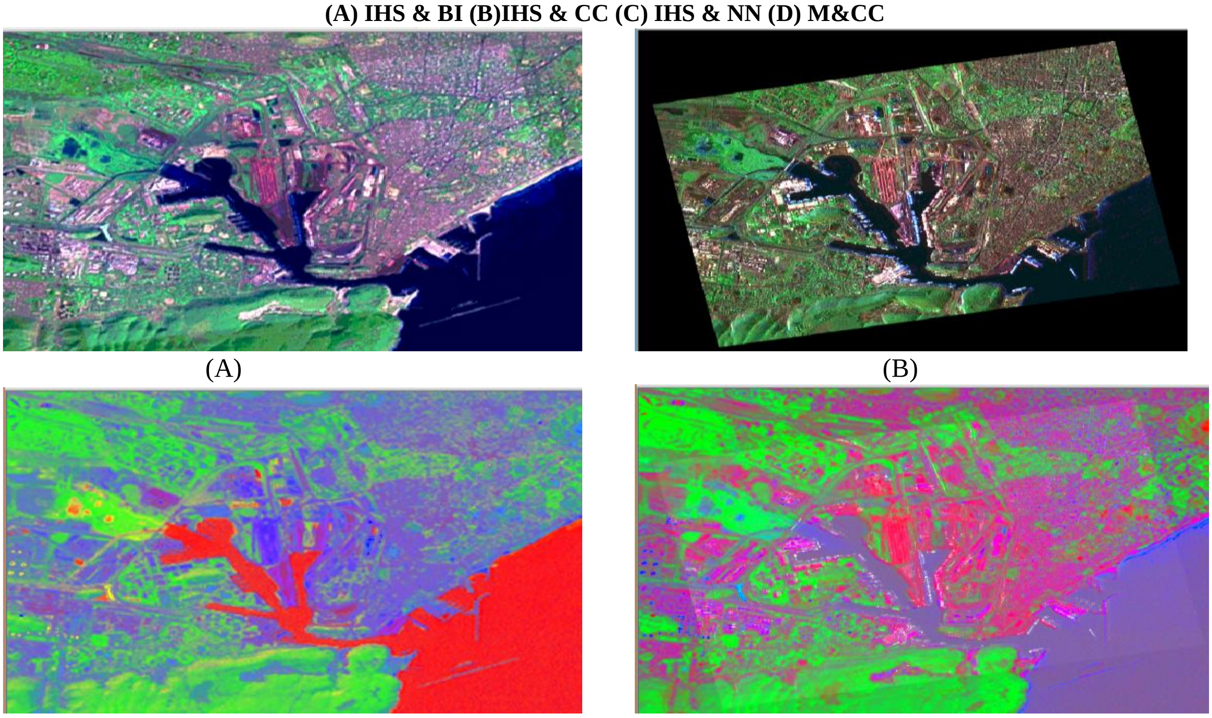


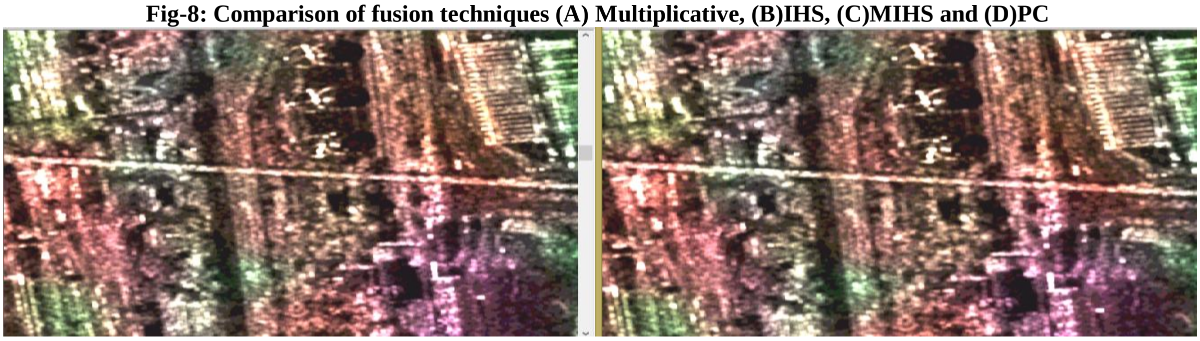
(A) (B) (C) (D)

Fig-7: Fused images of Terra SAR-X and LANDSAT TM images with (A) IHS & BI (B)IHS & CC (C) IHS & NN (D) M&CC



(A) (B) (C) (D)

Fig-8: Comparison of fusion techniques (A) Multiplicative, (B)IHS, (C)MIHS and (D)PC



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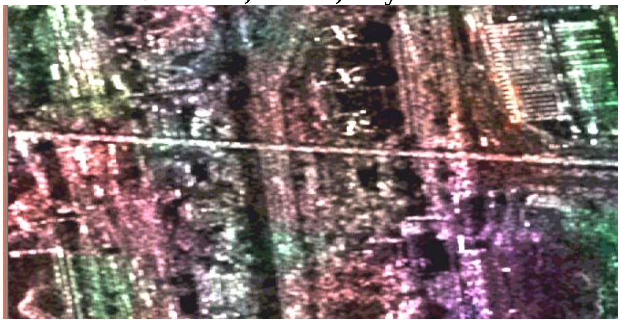

(B)

Fig-9: Comparison of re-sampling techniques
(A)Bilinear Interpolation & Cubic Convolution and (B) Nearest Neighbor

D. CONCLUSION AND EXTENSION

De-speckling of TerraSAR-X has been done with different filters and with different window sizes. Among all GAMMA MAP filter with window 7*7 size has given best ENL value, so it is the best result. That de-speckled output has been used to fuse with LANDSAT ETM+ and TM images. Among all fusion techniques IHS technique has given better image. But all re-sampling techniques has given similar fused outputs. I considered the LANDSAT ETM+ image of 2000 and TM image 2005 years respectively for our fusion methods. If we take all the images of same duration it will be good to say any conclusion. It can also be extended same process to wavelet merging, HPF merging, Ehlers merging and etc methods.

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