



Graphical User Interface of Phase Unwrapping in InSAR, MRI and enhanced by Ashmit transform 2 post-processing step

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Abstract: As a key technology for remote sensing applications, Synthetic Aperture Radar (SAR) offers high-resolution images for a range of Earth observation uses. In order to improve picture interpretation, feature extraction, and information retrieval, this work explores the incorporation of phasor mapping approaches into SAR data analysis. The first section of the study explains the basics of SAR and the difficulties in deciphering complicated SAR images. The introduction of phasor mapping presents a potent tool for streamlining the analysis and representation of SAR signals, allowing for a more intuitive comprehension of amplitudes, phase correlations, interferometry and polarimetric data. Phasor mapping is a crucial method used in Synthetic Aperture Radar (SAR) to handle complex-valued radar information. Radar pulses are first sent in the direction of the earth, and the backscattered signals that arise are gradually sampled. After enhancing the signal for better resolution using range compression, the SAR signal is represented as complex phasors. The amplitude and phase information of the received signals at certain spatial locations are captured by these phasors. Each pixel in the SAR picture is given a phasor using phasor mapping, which converts the complex-valued data into a visual representation. With the phase information being especially useful for applications like interferometry for Digital Elevation Models (DEMs) and terrain motion detection, the generated pictures provide light on the scattered distribution on the ground. In the end, phasor mapping is essential to deriving valuable insights from SAR data, paves a way of multitude possibilities for geospatial research and remote sensing applications. We provide a graphical user interface (GUI) and performance enhancing Ashmit transform 2 post processing step. The visual light provides an eye on path contained with stones (dihedrals), mud-water (volume scattering) and table top flat modulation or path (surface scattering). But our motivation on dihedral and volume scattering in InSAR and MRIs. So phase unwrapping or phasor mapping is an indispensable for radiologist or geologist. The GUI of phase unwrapping and Ashmit transform 2 post processing helps to detect the radio transceiver in pixel range hence in medical, military, and civil services, it is a good modular change.

Keywords: radar, scattering, image processing, phasor technology, Ashmit transform 2.

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1. Introduction

One of the most important procedures used in the deciphering of complex-valued data from satellite-borne remote sensing devices is phasor mapping. Satellites gather electromagnetic signals from the surface of the Earth, and the data they collect—which is frequently complex—is represented using phasors. In order to depict the satellite image, each pixel is given a complex phasor; the phase contains information about the location or makeup of objects on Earth's surface, and the magnitude contains information about signal intensity or reflectivity. The resulting phasor-mapped pictures allow for a more thorough examination and are useful for applications like monitoring ground deformation or mapping terrain elevation using Synthetic Aperture Radar (SAR) with interferometry. An essential component of improving the use of satellite images across a range of sensors and applications, contributing to a deeper understanding of Earth's features and changes over time. In the context of satellite photography, phasor mapping is an advanced method that entails the processing and interpretation of complex-valued signals obtained by remote sensing devices that are positioned in orbit. Sensor-equipped satellites record a broad spectrum of electromagnetic waves that the Earth's surface emits or reflects. These signals frequently have phase and amplitude components, which combine to generate complex-valued data. Translating this complicated data into a format that is easier to understand and analyze requires the use of phasor mapping. Each pixel in the satellite picture is given a complex phasor during the phasor mapping process, which captures the minute features of the corresponding place on the Earth's surface. The intensity or reflectivity of the signal is represented by the phasor's magnitude, while the composition or spatial properties of the detected objects are conveyed by the phase. Comparing this complicated representation to more conventional amplitude-based methods provides a more thorough comprehension of the data. Phasor mapping has a wide range of uses in satellite photography, depending on the particular sensor and goals of the mission. Phasor information is very useful for interferometric applications when it comes to Synthetic Aperture Radar (SAR), a kind of satellite sensor. For example, it allows precise mapping of terrain elevation by taking use of phase changes in radar data to create Digital Elevation Models (DEMs). Phasor mapping also helps with applications like geological hazard assessment by tracking ground deformation over time. Furthermore, phasor mapping may be used across these diverse data types as satellite missions progressively integrate data from various sensors gathering distinct spectral or polarimetric information. Through this integration, the seen scene may be analysed holistically and cohesively, offering a more in-depth understanding of the features and changes of Earth. In the field of satellite remote sensing, phasor mapping is a crucial method that improves the usability and interpretability of satellite imagery for a broad range of scientific, environmental, and geographical applications. Phasor mapping in Synthetic Aperture Radar (SAR) is a crucial step in the processing of radar signals for remote sensing applications. As SAR systems collect backscattered signals from the Earth's surface, the received data, inherently complex in nature, undergoes range compression to enhance resolution. The subsequent representation of these complex SAR signals as phasors involves decomposing them into magnitude and phase components. Each pixel in the resulting SAR image is then assigned a complex

phasor, encapsulating both amplitude and phase information. This phasor mapping process is fundamental for extracting valuable insights from SAR data. Notably, the phase information is instrumental in applications such as interferometric SAR (InSAR), where it facilitates the measurement of ground deformation and elevation changes over time. Additionally, phasor mapping contributes to terrain mapping and 3D reconstruction, offering a comprehensive tool for geoscientific analyses and environmental monitoring using SAR technology.

2. Methodology

In Synthetic Aperture Radar (SAR), phasor mapping refers to a methodical approach to the processing and interpretation of radar data obtained from remote sensing missions. The process of acquiring data is started by SAR systems by the transmission of pulses and the reception of backscattered signals. Range compression methods are used after data capture to improve resolution by matching filters. Next, using complex numbers called phasors, the resultant SAR signal—which is intrinsically complex with both amplitude and phase components—is represented. The two components of a phasor are its phase and magnitude components. The phase component represents the radar signal's travel distance, while the former indicates the signal's reflectivity. After that, a complex phasor is assigned to every pixel in the SAR picture, resulting in a phasor-mapped image. Phase information may also be used for more complex tasks like polarization characterization and terrain mapping in applications like interferometry and polarimetry. In order to produce high-resolution pictures and enable a wide range of applications in geoscience, environmental monitoring, and emergency management, phasor mapping in SAR is essential. Because of its adaptability, it is an effective tool for deriving insightful conclusions from SAR data. These phasors may be broken down into magnitude and phase components. The phase tells us how far the radar signal went, while the magnitude indicates the strength of the radar return, or reflectivity. The amplitude and phase properties of the phasors change in the context of several scattering types, including surface, volume, and double bounce scattering. For example, complex interactions inside the observed target's volume are linked to volume scattering, which produces distinct phasor patterns. A phasor-mapped picture is produced by allocating a complicated phasor to each pixel in the SAR image. The phase information is used in advanced applications such as polarimetry and interferometry for polarization characterization and terrain mapping. Phasor mapping, for instance, may be used to differentiate surface scattering—the interaction of radar waves with the Earth's surface—which offers information on the roughness and composition of the surface. Because polarimetry SAR takes into account various polarization states, it adds even more complexity. Based on the polarization characteristics of the complex signals, phasor mapping in polarimetry SAR allows the identification of various scattering processes. This is especially helpful for distinguishing between different kinds of scattering, such double and single bounce scattering. When combined with considerations for various forms of scattering, phasor mapping in SAR improves the interpretation of radar signals and makes it easier to comprehend the seen picture in more detail. This thorough method is crucial for a variety of applications, from geological research to environmental monitoring, since it enables the

extraction of important information on the scattering behavior of various surfaces and materials.

The examination of various forms of scattering, including double bounce scattering, is relevant to phasor mapping in Synthetic Aperture Radar (SAR). When a radar signal is reflected twice before it reaches the antenna, it is known as double bounce scattering. Usually, a twofold reflection process occurs when a signal bounces off a surface and subsequently comes into contact with a nearby target. By examining the complex-valued SAR signal, the phasor mapping approach accounts for the features of double bounce scattering. Double bounce scattering adds characteristic patterns to the breakdown of phasors into magnitude and phase components. In the event of double bounce scattering, the amplitude of the phasor may reveal surfaces that are angled to allow for two consecutive reflections in addition to reflecting the target's reflectivity. In particular, the phase information is useful for detecting and describing double bounce scattering occurrences. The phasor's phase component encodes data on the radar signal's distance traveled. The phase may show certain fingerprints in the double bounce scattering environment, which correspond to the additional travel route incurred during the double reflection process. The practical applications of phasor mapping for the detection and analysis of double bounce scattering are significant. For instance, double bounce scattering might affect how SAR imagery is interpreted in metropolitan areas with intricate features like roads, buildings, and bridges. Gaining an understanding of these scattering mechanisms can aid with both topography mapping accuracy and item identification within the seen picture. Double bounce scattering is taken into account in the phasor mapping process, which improves the ability of SAR applications to identify intricate interactions between radar waves and Earth's surfaces. Consequently, this enhances the precision and in-depth remote sensing evaluations, especially in settings where structures give rise to the phenomenon of double bounce scattering.

In the context of phasor mapping within Synthetic Aperture Radar (SAR), the examination of various scattering types extends to phenomena such as volume scattering. Volume scattering occurs when radar signals engage with the entirety of a medium rather than just its surface, often observed in areas with intricate structures like vegetation or forests. During the phasor mapping process, the analysis of the complex-valued SAR signal considers the distinctive features associated with volume scattering. The decomposition of phasors into magnitude and phase components reveals specific patterns indicative of volume scattering. The amplitude of the phasor reflects the target's reflectivity, conveying information about the density and distribution of scatterers within the volume, such as leaves and branches in vegetation. The phase component is crucial for characterizing volume scattering, providing insights into the intricate interactions between radar waves and scatterers distributed throughout the medium. Practically, the detection and analysis of volume scattering through phasor mapping find applications in environmental monitoring and forestry, aiding in estimating parameters like vegetation density and biomass. This approach contributes to a more comprehensive interpretation of SAR data for applications such as land cover classification and ecosystem monitoring.

The phasor mapping process in Synthetic Aperture Radar (SAR) is profoundly impacted by the density of scatterers within the observed scene. Examining scenarios with high and low scattering

density yields valuable insights. In regions with a high density of scatterers, like densely vegetated areas, the SAR signal becomes intricate due to numerous interactions. The phase information in the phasor mapping process displays intricate variations reflecting multiple scattering events. Phasor amplitudes in high-density scenarios typically mirror heightened reflectivity linked to densely populated scattering environments, such as regions with dense vegetation. Conversely, in low-density scattering scenarios, like open fields, the SAR signal is simpler, showing fewer complex interference patterns. Phase information in phasor mapping exhibits more straightforward variations, and phasor amplitudes represent lower reflectivity in areas with fewer scatterers, such as open terrains. The presence repeatedly of π (pi) in the phase component introduces periodicity, influencing how changes in scattering density manifest in the SAR signal. This understanding enhances SAR imagery interpretation for applications like land cover classification, vegetation analysis, and environmental monitoring.

The phasor mapping methodology within the realm of Synthetic Aperture Radar (SAR) entails systematic and intricate process designed to transform complex radar signals into phasors. These phasors, essentially complex numbers, encapsulate both amplitude and phase components of the SAR signals. The initiation of this methodology involves the acquisition of SAR data, wherein radar pulses are emitted towards the Earth's surface, and the resulting backscattered signals are meticulously captured. Following this, the acquired signals undergo range compression, employing techniques like matched filtering to enhance the resolution of the imagery. Given the inherent complexity of SAR signals, featuring both amplitude and phase information, the representation is facilitated through the utilization of complex phasors. These complex numbers are further dissected into magnitude and phase components, elucidating the reflectivity and distance travelled by the radar signals, respectively. The culmination of this process results in the generation of a SAR image, where each pixel is assigned a complex phasor, thus creating a comprehensive phasor-mapped image. This methodology extends its utility to advanced applications, notably interferometry and polarimetry, where the phase information proves invaluable for tasks such as terrain mapping and polarization analysis. The adaptability of phasor mapping is augmented by optional considerations for interferometric and polarimetric aspects. Consequently, the methodology serves as a linchpin in the production of high-resolution SAR images, playing an instrumental role in diverse applications across geoscience, medical imaging, environmental monitoring, and disaster management, ultimately providing nuanced insights derived from radar data.

The methodology of phasor mapping in Synthetic Aperture Radar (SAR) is closely intertwined with the examination of scattering phenomena, presenting a comprehensive approach to deciphering intricate radar signals. The sequential process involves the acquisition of SAR data, where emitted radar pulses interact with the Earth's surface, and the resulting backscattered signals carry essential information about scattering properties. Subsequent steps include range compression for resolution enhancement, the representation of complex signals using phasors, and the decomposition of these phasors into magnitude and phase components. The methodology specifically lends itself to the analysis of diverse scattering types, including surface and volume

scattering, as well as double bounce scattering in urban settings. The resulting phasor-mapped image vividly illustrates the scattering characteristics of the observed scene, aiding in the identification and differentiation of various scattering phenomena. The versatility of this methodology extends to environmental applications, contributing to improved insights into changes in vegetation, land cover, and disaster-affected areas. In essence, the integration of scattering considerations enriches the phasor mapping methodology, enhancing its efficacy in extracting valuable information for remote sensing analyses.

3. Results & Discussion

Phasor mapping is a pivotal process in decoding the intricate details of scattering phenomena within satellite imagery, particularly within Synthetic Aperture Radar (SAR) and other remotesensing technologies. By representing the complex nature of radar signals as phasors, encompassing both amplitude and phase aspects, this methodology enables a nuanced comprehension of diverse scattering types. For instance, in surface scattering, where radar waves interact with the Earth's surface, phasor mapping aids in discerning surface roughness and composition. The technique is equally beneficial in characterizing volumetric structures like vegetation and forests in volume scattering scenarios, and it contributes to identifying complex interactions in urban areas typical of double bounce scattering. Beyond merely categorizing scattering types, phasor mapping holds extensive applications in satellite imagery. It proves indispensable in interferometry processes like InSAR, providing accurate measurements of ground deformation and surface elevation changes. Moreover, its utility extends to land cover classification, environmental monitoring, and disaster management, offering detailed insights into alterations in vegetation density, land use, and surface deformation over time. In essence, phasor mapping stands as a transformative methodology, empowering diverse applications crucial for a comprehensive understanding of the environment and informed decision-making based on satellite remote sensing data. Phasor mapping and RGB representation are two techniques integral to the analysis of Synthetic Aperture Radar (SAR) imagery, each contributing unique perspectives to the understanding of scattering phenomena. Phasor mapping, a method for representing complex SAR signals as phasors, captures both amplitude and phase information. This approach is particularly valuable for distinguishing diverse scattering types, including surface, volume, and double bounce scattering, thus playing a crucial role in advanced applications such as interferometry. Conversely, RGB representation involves assigning SAR signal amplitudes to Red, Green, and Blue channels, providing an intuitively visual interpretation of scattering characteristics. The integration of these techniques forms a comprehensive visualization strategy wherein the intricate details revealed by phasor mapping are harmoniously fused with the visually informative RGB representation. For example, in an RGB image, distinct colors might signify different scattering behavior's, enhancing the overall interpretability of the observed scene. This amalgamation ensures a thorough analysis of SAR data, offering valuable insights into scattering phenomena for a broad range of remote sensing applications. Phasor mapping, a versatile technique in Synthetic Aperture Radar (SAR) and remote sensing, proves invaluable for unravelling intricate scattering phenomena. Its adaptability spans diverse applications, from facilitating precise interferometric measurements for ground

deformation analysis to supporting tasks like land cover classification and environmental monitoring. The technique's ability to capture both amplitude and phase details is particularly instrumental in the realm of Interferometry SAR (InSAR), [3] where it plays a pivotal role in discerning subtle changes in terrain elevation and surface deformation. While challenges persist in handling complex SAR data, ongoing technological advancements and the evolution of algorithms contribute to refining the accessibility and applicability of phasor mapping. The integration of phasor mapping with complementary visualization methods, such as RGB representation, enhances interpretability, making intricate information more comprehensible across varied audiences. Looking forward, the promising trajectory of phasor mapping involves ongoing research aimed at honing the technique, addressing challenges, and exploring synergies with emerging technologies like machine learning. As technology continues to progress, phasor mapping is poised to maintain its significance, standing as a crucial tool in remote sensing applications, fostering scientific understanding, and propelling advancements in diverse domains. Most popular methods of phase unwrapping are F2DPU and PUMA [1, 2].

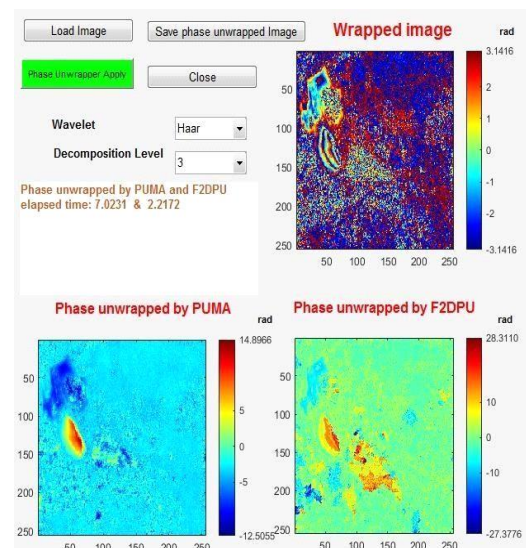


Figure 1. SAR phasor mapping by PUMA and F2DPU

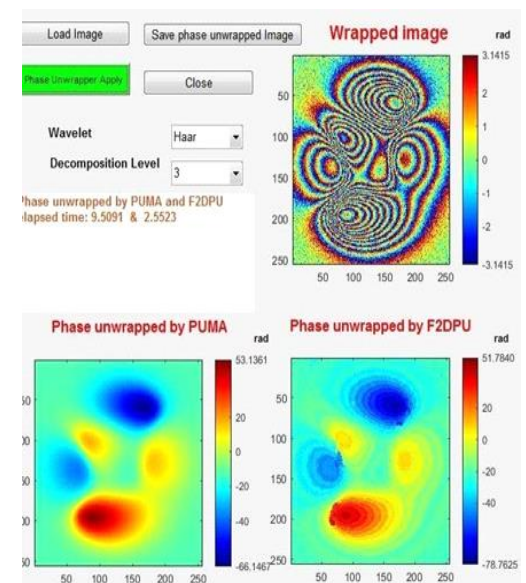


Figure 2. Simulated SAR phase unwrapping by PUMA and F2DPU

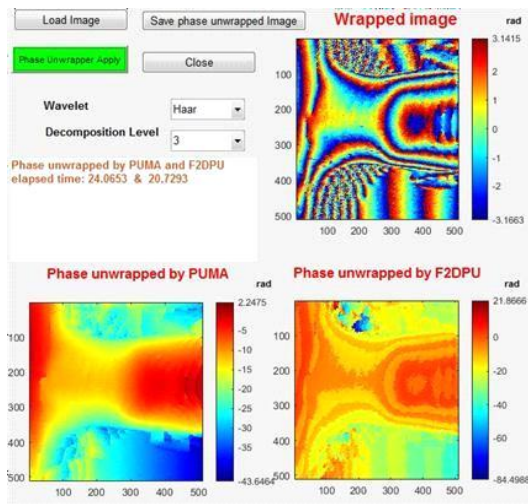


Figure 3. Phase unwrapped of MRI by PUMA and F2DPU

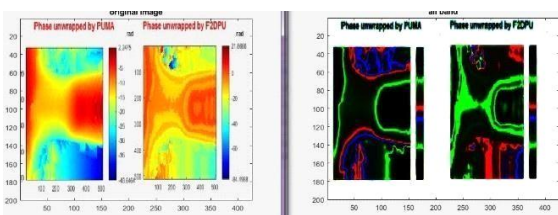


Figure 4. Phase unwrapping by PUMA and F2DPU with Haar wavelet and its detection by Ashmit 2 transform of its JPEG compression or papparazi multilook

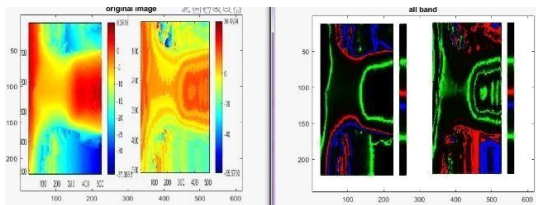


Figure 5. Phase unwrapping by PUMA and F2DPU with Db wavelet and its detection by Ashmit 2 transform of its JPEG compression or papparazi multilook

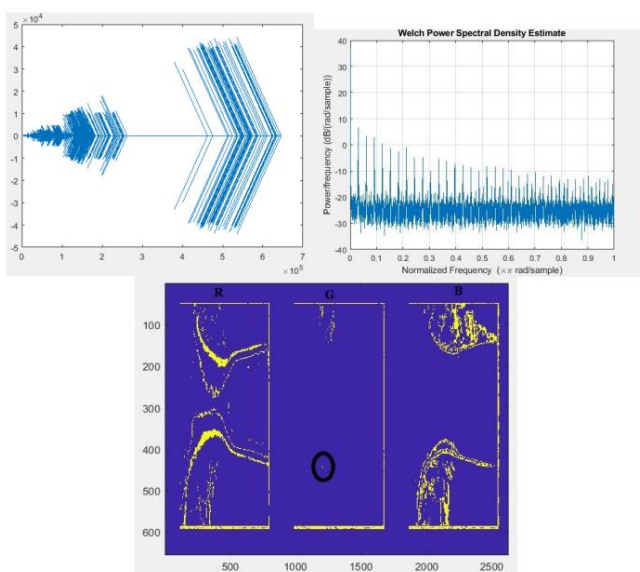


Fig 6. MRI pulse sequence and dihedral in throat using Ashmit transform 2 post processing.

4. Conclusion

In summary, phasor mapping emerges as a pivotal and versatile technique within the domain of Synthetic Aperture Radar (SAR) and broader remote sensing applications. This methodology, involving the representation of complex radar signals through phasors that capture both amplitude and phase details, facilitates a nuanced comprehension of scattering phenomena. Its significance is particularly notable in advanced applications like interferometry, where it proves instrumental in distinguishing various types of scattering such as surface and volume scattering. Furthermore, the integration of phasor mapping with other visualization approaches, including RGB representation, enriches the interpretability of SAR imagery. The adaptability and effectiveness of phasor mapping position it as an indispensable tool, contributing to advancements in environmental monitoring, disaster management, and geospatial analysis. As technological innovations in remote sensing progress, the continued relevance of phasor mapping underscores its foundational role for researchers and practitioners in gaining comprehensive insights into Earth's features and dynamic changes.

The phasor mapping methodology within Synthetic Aperture Radar (SAR) emerges as a versatile and robust approach to unravel the complexities of scattering phenomena. From the initial acquisition of SAR data to the representation of signals as phasors, and the nuanced analysis of various scattering types, this method captures intricate details in radar signals, enhancing our comprehension of different surfaces. The optional inclusion of interferometric and polarimetric considerations further extends its applications, facilitating tasks such as terrain mapping and polarization analysis. The resultant phasor-mapped images offer a vivid portrayal of scattering characteristics, contributing to advancements in environmental monitoring, land cover classification, and disaster assessment. As technology progresses, the integration of scattering considerations into the phasor mapping process remains crucial for advancing our understanding of the intricate interactions between radar signals and the Earth's surfaces in remote sensing applications. These images SAR or optical based Ashmit 2 transform done here. In future we will explore more on phasor and velocity optimization.

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Code:

```
clear;close all;clc
load('C:\Users\Welcome\Desktop\INSAR_PU3\unwrapped_Daub4_2_PUMA_F2DPU.mat')
f=figure;imagesc(f2dpu);saveas(gcf,'f11.jpg');

%imwrite(uint8(f2dpu*8+1),'n1.jpg','jpg');data=imread('f11.jpg');
figure,imshow(data);%axis on; imgIR0=uint8(data);
imgIR0(find(imgIR0==0))=0; var0=(double(imgIR0)-
mean(imgIR0,3)).^2; mode1=double(mode(imgIR0,3));
SNR0=mean(imgIR0,3).*mode1 ./ var0; figure,imagesc(SNR0);
%Green band

SNR1=squeeze(SNR0);
SNR1(isinf(SNR1))=0;
SNR1(isnan(SNR1))=0;
```

```

out=bsxfun(@power,SNR1(:,:),SNR1(:,:));figure,imagesc(out);

[out1, out2]=meshgrid(SNR1,1);out1=downsample(out1,10)/1e5;
out2=downsample(out2,10)/1e5;out3=sqrt(out1.^2+out2.^2);
figure, stem3(out1,out2,out3,'b');

out4=minhelingier(out1,out2,40);figure, stem3(out1,out2,out4,'k');
figure,pwelch(out4);

% [R,G,B] = imsplit(SNR0);
%
% G1=G;
% G1(isinf(G1))=0;
% figure,imagesc(G1);
% title('green2')

figure, feather(SNR1(1:10:end,1:10:end,:));function delH =
minhelingier(a, b, L)

%      L = np.log(L)

% delH = (1 - trace(sqrt(a*b)./(2*(a*a + b*b))).^ L );

delH = 1 -((2*a.*b)./(a.*a + b.*b)).^ L;

end

```

For GUI

<https://drive.google.com/file/d/1stuP9I1CAXbZGgZ2lNHb-qA7xFzELOBx/view?usp=sharing>

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