

Fuzzy Logic based adaptive phase information preserved de-speckled filter for dual polarized SAR data

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Source code:

```
#importing all the required libraries
from datetime import datetime
start_time = datetime.now()
import scipy.io as sio
import os
import numpy as np
from sklearn.feature_extraction import image
from sklearn.preprocessing import minmax_scale
import matplotlib as plt
import skfuzzy as fuzz
from skfuzzy import control as ctrl
from matplotlib import pyplot as plt
from skimage import io

wsizer=5 #window size as 5
total=[]
size= 500 #work with 500*500 image patch
defuzz_values= np.zeros((size,size))
names_ea= ['/Stokes1_A new.mat', '/Stokes1_phi new.mat', '/lambda new.mat']
#these .mat files are related to ALOS PALSAR 1.1 satellite data
key=['a']
for i in range(len(names_ea)):
    total.append((sio.loadmat(os.getcwd()+names_ea[i])[key[0]][0:size,0:size]))
print(len(total))

mdiff_amplitude= np.amax(total[0][:,:])-
np.amin(total[0][:,:]) #dynamic range for amplitude
mdiff_phase= np.amax(total[1][:,:])-
np.amin(total[1][:,:]) #dynamic range for phase
mdiff_lambda= np.amax(total[2][:,:])-
np.amin(total[2][:,:]) #dynamic range for lambda

mship_amplitude = ctrl.Antecedent(np.linspace(0,mdiff_amplitude,num=100,
:=True), 'mship_amplitude') #creating universe of discourse for
le
```



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```

mship_phase = ctrl.Antecedent(np.linspace(0,mdiff_phase,num=100,endpoint=True), 'mship_phase') #creating universe of discourse for phase
mship_lambda = ctrl.Antecedent(np.linspace(0,mdiff_lambda,num=100,endpoint=True), 'mship_lambda') #creating universe of discourse for lambda
wt = ctrl.Consequent(np.linspace(0,1,num=100,endpoint=True), 'wt') ##creating universe of discourse for output weight

#To ensure the ouput dimension remain same
amplitude= np.pad(total[0][:,:],int(wsize//2),mode='median')
phase= np.pad(total[1][:,:],int(wsize//2),mode='median')
lamb = np.pad(total[2][:,:],int(wsize//2),mode='median')

#dividing the amplitude , phase and lambda into overlapping patches
amplitude= image.extract_patches_2d(amplitude, (wsize,wsize))
phase= image.extract_patches_2d(phase, (wsize,wsize))
lamb= image.extract_patches_2d(lamb, (wsize,wsize))

```

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```

#The mathematical expression for a Gaussian function is given by
#  $\mu_j(x) = \exp\{-0.5 * [(x - c_j) / \sigma_j]^2\}$ 
# where
#  $j = \{1, 2, 3, 4, 5\}$ ,
#  $c$  is the center of the peak,
#  $\sigma = 0.5 * (c_j - c_{j-1}) / \sqrt{-2 * \ln(\dagger)}$ , determines the width of the curve,
#  $\dagger$  = crossing point of adjacent MFs (default for  $\dagger$  is 0.5).
# To determine the centers,  $c_j$ , you need to compute the sub-
interval between each peak,  $(c_j - c_{j-1})$ , where the 5 fuzzy sets are unif-
ormly distributed to cover the domain of  $e$ :
#  $n$  = number of MFs,
#  $\text{range} = b - a$ ,
#  $\text{partition} = n - 1$ ,
#  $\text{sub-interval} = \text{range} / \text{partition}$ .
# For example, if the universe of discourse for "ERROR" would be the in-
terval  $[-5, 5]$ , then the sub-
interval  $= 10 / 4 = 2.5$ , and the centers would be  $\{-5, -2.5, 0, 2.5, 5\}$ .
# The standard deviation,  $\sigma = 0.5 * (2.5) / \sqrt{-2 * \ln(0.5)} \approx 1.06165$ .

#calculating the width of the gaussian curve
sd1= 0.5*mdiff_amplitude/(np.sqrt(-2*np.log(0.5))*4)
sd2= 0.5*mdiff_phase/(np.sqrt(-2*np.log(0.5))*4)
sd3= 0.5*mdiff_lambda/(np.sqrt(-2*np.log(0.5))*4)

sd4= 0.5*1/(np.sqrt(-2*np.log(0.5))*4)

```

"""

VLT EVTD -> Very Low First Variable Difference [VLDPD]
 Low First Variable Difference [LDPD]
 Average First variable Difference [ADPD]



Signature

VHFVD - Very High First Variable Difference [VHDPD]

HFVD - High First Variable Difference [HDPD]

VLSDV -> Very Low Second Variable Difference [VLSDD]

LSVD - Low Second Variable Difference [LSDD]

ASVD = Average Second variable Difference [ASDD]

VHSVD - Very High Second Variable Difference [VHSDD]

HSVD - High Second Variable Difference [HSDD]

VLTVD -> Very Low Third Variable Difference [VLSPD]

LTVD - Low Third Variable Difference [LSPD]

ATVD = Average Third variable Difference [ASPD]

VHTVD - Very High Third Variable Difference [VHSPD]

HTVD - High Third Variable Difference [HSPD]

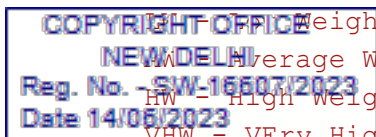
VLW - Very Low Weight

PLW - Low Weight

AW - Average Weight

HW - High Weight

VHW - Very High Weight



"""

```
mship_amplitude['VLFVD'] = fuzz.gaussmf(mship_amplitude.universe, 0.01, sd1)
```

```
mship_amplitude['LFVD'] = fuzz.gaussmf(mship_amplitude.universe, 0.2, sd1)
```

```
mship_amplitude['AFVD'] = fuzz.gaussmf(mship_amplitude.universe, 0.4, sd1)
```

```
mship_amplitude['HFVD'] = fuzz.gaussmf(mship_amplitude.universe, 0.6, sd1)
```

```
mship_amplitude['VHFVD'] = fuzz.gaussmf(mship_amplitude.universe, 0.8, sd1)
```

```
mship_phase['VLSVD'] = fuzz.gaussmf(mship_phase.universe, 0.01, sd2)
```

```
mship_phase['LSVD'] = fuzz.gaussmf(mship_phase.universe, 0.2, sd2)
```

```
mship_phase['ASVD'] = fuzz.gaussmf(mship_phase.universe, 0.4, sd2)
```

```
mship_phase['HSVD'] = fuzz.gaussmf(mship_phase.universe, 0.6, sd2)
```

```
mship_phase['VHSVD'] = fuzz.gaussmf(mship_phase.universe, 0.8, sd2)
```

```
mship_lambda['VLTVD'] = fuzz.gaussmf(mship_lambda.universe, 0.01, sd3)
```

```
mship_lambda['LTVD'] = fuzz.gaussmf(mship_lambda.universe, 0.2, sd3)
```

```
mship_lambda['ATVD'] = fuzz.gaussmf(mship_lambda.universe, 0.4, sd3)
```

```
mship_lambda['HTVD'] = fuzz.gaussmf(mship_lambda.universe, 0.6, sd3)
```

```
mship_lambda['VHTVD'] = fuzz.gaussmf(mship_lambda.universe, 0.8, sd3)
```

```
] = fuzz.gaussmf(wt.universe, 0.01, sd4)
```

```
= fuzz.gaussmf(wt.universe, 0.2, sd4)
```



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```
wt['AW'] = fuzz.gaussmf(wt.universe, 0.4, sd4)
wt['HW'] = fuzz.gaussmf(wt.universe, 0.6, sd4)
wt['VHW'] = fuzz.gaussmf(wt.universe, 0.8, sd4)
```

```
# You can see how these look with .view()
mship_amplitude['VLFVD'].view()
```

```
mship_phase['VLSVD'].view()
```

```
mship_lambda['VLTVD'].view()
```

```
wt['VLW'].view()
```

```
"""
```

Design of fuzzy rules wrt to antecedent and consequent membership values

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```
rule1 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['VLSVD'] &mship_
_lambda['VLTVD'], wt['VHW'])
rule2 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['VLSVD'] &mship_
_lambda['LTVD'], wt['VHW'])
rule3 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['VLSVD'] &mship_
_lambda['ATVD'], wt['VHW'])
rule4 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['VLSVD'] &mship_
_lambda['HTVD'], wt['VHW'])
rule5 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['VLSVD'] &mship_
_lambda['VHTVD'], wt['VHW'])
```

```
rule6 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['LSVD'] &mship_
_lambda['VLTVD'], wt['VHW'])
rule7 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['LSVD'] &mship_
_lambda['LTVD'], wt['VHW'])
rule8 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['LSVD'] &mship_
_lambda['ATVD'], wt['VHW'])
rule9 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['LSVD'] &mship_
_lambda['HTVD'], wt['HW'])
rule10 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['LSVD'] &mship_
_lambda['VHTVD'], wt['HW'])
```

```
rule11 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['ASVD'] &mship_
_lambda['VLTVD'], wt['VHW'])
rule12 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['ASVD'] &mship_
_lambda['LTVD'], wt['HW'])
rule13 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['ASVD'] &mship_
_lambda['ATVD'], wt['AW'])
```



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```

rule14 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['ASVD'] &mship_
_lambda['HTVD'], wt['AW'])
rule15 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['ASVD'] &mship_
_lambda['VHTVD'], wt['LW'])

rule16 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['HSVD'] &mship_
_lambda['VLTVD'], wt['VHW'])
rule17 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['HSVD'] &mship_
_lambda['LTVD'], wt['AW'])
rule18 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['HSVD'] &mship_
_lambda['ATVD'], wt['AW'])
rule19 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['HSVD'] &mship_
_lambda['HTVD'], wt['LW'])
rule20 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['HSVD'] &mship_
_lambda['VHTVD'], wt['LW'])

rule21 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['VHSVD'] &mshi
p_lambda['VLTVD'], wt['HW'])
rule22 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['VHSVD'] &mshi
p_lambda['LTVD'], wt['HW'])
rule23 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['VHSVD'] &mshi
p_lambda['ATVD'], wt['AW'])
rule24 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['VHSVD'] &mshi
p_lambda['HTVD'], wt['AW'])
rule25 = ctrl.Rule(mship_amplitude['VLFVD'] &mship_phase['VHSVD'] &mshi
p_lambda['VHTVD'], wt['AW'])

```

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```

rule26 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['VLSVD'] &mship_
_lambda['VLTVD'], wt['VHW'])
rule27 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['VLSVD'] &mship_
_lambda['LTVD'], wt['VHW'])
rule28 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['VLSVD'] &mship_
_lambda['ATVD'], wt['VHW'])
rule29 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['VLSVD'] &mship_
_lambda['HTVD'], wt['HW'])
rule30 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['VLSVD'] &mship_
_lambda['VHTVD'], wt['AW'])

rule31 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['LSVD'] &mship_
_lambda['VLTVD'], wt['VHW'])
rule32 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['LSVD'] &mship_
_lambda['LTVD'], wt['HW'])
rule33 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['LSVD'] &mship_
_lambda['ATVD'], wt['HW'])
: ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['LSVD'] &mship_
HTVD'], wt['HW'])

```



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```
rule35 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['LSVD'] &mship_
lambda['VHTVD'], wt['AW'])
```

```
rule36 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['ASVD'] &mship_
lambda['VLTVD'], wt['HW'])
```

```
rule37 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['ASVD'] &mship_
lambda['LTVD'], wt['HW'])
```

```
rule38 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['ASVD'] &mship_
lambda['ATVD'], wt['AW'])
```

```
rule39 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['ASVD'] &mship_
lambda['HTVD'], wt['AW'])
```

```
rule40 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['ASVD'] &mship_
lambda['VHTVD'], wt['AW'])
```

```
rule41 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['HSVD'] &mship_
lambda['VLTVD'], wt['HW'])
```

```
rule42 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['HSVD'] &mship_
lambda['LTVD'], wt['HW'])
```

```
rule43 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['HSVD'] &mship_
lambda['ATVD'], wt['AW'])
```

```
rule44 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['HSVD'] &mship_
lambda['HTVD'], wt['LW'])
```

```
rule45 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['HSVD'] &mship_
lambda['VHTVD'], wt['LW'])
```

```
rule46 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['VHSVD'] &mship_
_lambda['VLTVD'], wt['HW'])
```

```
rule47 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['VHSVD'] &mship_
_lambda['LTVD'], wt['HW'])
```

```
rule48 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['VHSVD'] &mship_
_lambda['ATVD'], wt['AW'])
```

```
rule49 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['VHSVD'] &mship_
_lambda['HTVD'], wt['LW'])
```

```
rule50 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['VHSVD'] &mship_
_lambda['VHTVD'], wt['LW'])
```

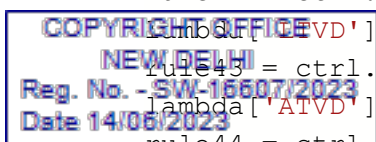
```
rule51 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['VLSVD'] &mship_
_lambda['VLTVD'], wt['VHW'])
```

```
rule52 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['VLSVD'] &mship_
_lambda['LTVD'], wt['HW'])
```

```
rule53 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['VLSVD'] &mship_
_lambda['ATVD'], wt['HW'])
```

```
rule54 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['VLSVD'] &mship_
_lambda['HTVD'], wt['AW'])
```

```
rule55 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['VLSVD'] &mship_
_lambda['VHTVD'], wt['LW'])
```



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```
rule56 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['LSVD'] &mship_
lambda['VLTVD'], wt['HW'])
rule57 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['LSVD'] &mship_
lambda['LTVD'], wt['HW'])
rule58 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['LSVD'] &mship_
lambda['ATVD'], wt['HW'])
rule59 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['LSVD'] &mship_
lambda['HTVD'], wt['AW'])
rule60 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['LSVD'] &mship_
lambda['VHTVD'], wt['LW'])
```

```
rule61 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['ASVD'] &mship_
lambda['VLTVD'], wt['HW'])
rule62 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['ASVD'] &mship_
lambda['LTVD'], wt['HW'])
rule63 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['ASVD'] &mship_
lambda['ATVD'], wt['AW'])
rule64 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['ASVD'] &mship_
lambda['HTVD'], wt['AW'])
rule65 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['ASVD'] &mship_
lambda['VHTVD'], wt['LW'])
```

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```
rule66 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['HSVD'] &mship_
lambda['VLTVD'], wt['AW'])
rule67 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['HSVD'] &mship_
lambda['LTVD'], wt['AW'])
rule68 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['HSVD'] &mship_
lambda['ATVD'], wt['AW'])
rule69 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['HSVD'] &mship_
lambda['HTVD'], wt['LW'])
rule70 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['HSVD'] &mship_
lambda['VHTVD'], wt['LW'])
```

```
rule71 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['VHSVD'] &mship_
_lambda['VLTVD'], wt['AW'])
rule72 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['VHSVD'] &mship_
_lambda['LTVD'], wt['AW'])
rule73 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['VHSVD'] &mship_
_lambda['ATVD'], wt['LW'])
rule74 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['VHSVD'] &mship_
_lambda['HTVD'], wt['LW'])
rule75 = ctrl.Rule(mship_amplitude['AFVD'] &mship_phase['VHSVD'] &mship_
_lambda['VHTVD'], wt['LW'])
```

```
= ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['VLSVD'] &mship_
_lambda['VLTVD'], wt['HW'])
```



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```
rule77 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['VLSVD'] &mship_
_lambda['LTV D'], wt['HW'])
rule78 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['VLSVD'] &mship_
_lambda['ATVD'], wt['AW'])
rule79 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['VLSVD'] &mship_
_lambda['HTVD'], wt['LW'])
rule80 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['VLSVD'] &mship_
_lambda['VHTVD'], wt['LW'])
```

```
rule81 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['LSVD'] &mship_
_lambda['VLTVD'], wt['HW'])
rule82 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['LSVD'] &mship_
_lambda['LTV D'], wt['HW'])
rule83 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['LSVD'] &mship_
_lambda['ATVD'], wt['AW'])
rule84 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['LSVD'] &mship_
_lambda['HTVD'], wt['LW'])
```

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```
rule85 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['LSVD'] &mship_
_lambda['VHTVD'], wt['LW'])
```

```
rule86 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['ASVD'] &mship_
_lambda['VLTVD'], wt['AW'])
rule87 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['ASVD'] &mship_
_lambda['LTV D'], wt['AW'])
rule88 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['ASVD'] &mship_
_lambda['ATVD'], wt['LW'])
rule89 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['ASVD'] &mship_
_lambda['HTVD'], wt['LW'])
rule90 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['ASVD'] &mship_
_lambda['VHTVD'], wt['LW'])
```

```
rule91 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['HSVD'] &mship_
_lambda['VLTVD'], wt['AW'])
rule92 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['HSVD'] &mship_
_lambda['LTV D'], wt['LW'])
rule93 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['HSVD'] &mship_
_lambda['ATVD'], wt['LW'])
rule94 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['HSVD'] &mship_
_lambda['HTVD'], wt['LW'])
rule95 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['HSVD'] &mship_
_lambda['VHTVD'], wt['VLW'])
```

```
rule96 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['VHSVD'] &mship_
_lambda['VLTVD'], wt['AW'])
rule97 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['VHSVD'] &mship_
_lambda['LTV D'], wt['LW'])
```

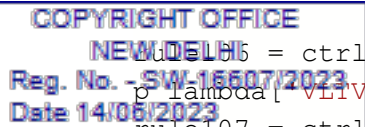
```
rule98 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['VHSVD'] &mship_
_lambda['ATVD'], wt['LW'])
```



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```
rule99 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['VHSVD'] &mship_
_lambda['HTVD'], wt['VLW'])
rule100 = ctrl.Rule(mship_amplitude['HFVD'] &mship_phase['VHSVD'] &mshi
p_lambda['VHTVD'], wt['VLW'])
```

```
rule101 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['VLSVD'] &msh
ip_lambda['VLTVD'], wt['HW'])
rule102 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['VLSVD'] &msh
ip_lambda['LTVD'], wt['HW'])
rule103 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['VLSVD'] &msh
ip_lambda['ATVD'], wt['AW'])
rule104 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['VLSVD'] &msh
ip_lambda['HTVD'], wt['AW'])
rule105 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['VLSVD'] &msh
ip_lambda['VHTVD'], wt['AW'])
```



```
rule106 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['LSVD'] &mshi
p_lambda['VLTVD'], wt['HW'])
rule107 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['LSVD'] &mshi
p_lambda['LTVD'], wt['HW'])
rule108 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['LSVD'] &mshi
p_lambda['ATVD'], wt['AW'])
rule109 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['LSVD'] &mshi
p_lambda['HTVD'], wt['LW'])
rule110 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['LSVD'] &mshi
p_lambda['VHTVD'], wt['LW'])
```

```
rule111 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['ASVD'] &mshi
p_lambda['VLTVD'], wt['AW'])
rule112 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['ASVD'] &mshi
p_lambda['LTVD'], wt['AW'])
rule113 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['ASVD'] &mshi
p_lambda['ATVD'], wt['AW'])
rule114 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['ASVD'] &mshi
p_lambda['HTVD'], wt['LW'])
rule115 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['ASVD'] &mshi
p_lambda['VHTVD'], wt['LW'])
```

```
rule116 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['HSVD'] &mshi
p_lambda['VLTVD'], wt['LW'])
rule117 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['HSVD'] &mshi
p_lambda['LTVD'], wt['LW'])
rule118 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['HSVD'] &mshi
p_lambda['ATVD'], wt['LW'])
rule119 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['HSVD'] &mshi
p_lambda['HTVD'], wt['VLW'])
```



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```
rule120 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['HSVD'] &msh  
p_lambda['VHTVD'], wt['VLW'])
```

```
rule121 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['VHSVD'] &msh  
ip_lambda['VLTVD'], wt['LW'])
```

```
rule122 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['VHSVD'] &msh  
ip_lambda['LTVD'], wt['LW'])
```

```
rule123 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['VHSVD'] &msh  
ip_lambda['ATVD'], wt['LW'])
```

```
rule124 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['VHSVD'] &msh  
ip_lambda['HTVD'], wt['VLW'])
```

```
rule125 = ctrl.Rule(mship_amplitude['VHFVD'] &mship_phase['VHSVD'] &msh  
ip_lambda['VHTVD'], wt['VLW'])
```



```
def ruleview()  
ctrl = ctrl.ControlSystem([rule1, rule2, rule3, rule4, rule5, rule6,  
rule7, rule8, rule9, rule10,  
rule11, rule12, rule13, rule14, rule  
15, rule16, rule17, rule18, rule19,  
rule20, rule21, rule22, rule23, rule2  
4, rule25,  
rule26, rule27, rule28, rule29, rule30, ru  
le31, rule32, rule33, rule34, rule35,  
rule36, rule37, rule38, rule39, rule  
40, rule41, rule42, rule43, rule44,  
rule45, rule46, rule47, rule48, rule4  
9, rule50,  
rule51, rule52, rule53, rule54, rule55, ru  
le56, rule57, rule58, rule59, rule60,  
rule61, rule62, rule63, rule64, rule  
65, rule66, rule67, rule68, rule69,  
rule70, rule71, rule72, rule73, rule7  
4, rule75,  
rule76, rule77, rule78, rule79, rule80, ru  
le81, rule82, rule83, rule84, rule85,  
rule86, rule87, rule88, rule89, rule  
90, rule91, rule92, rule93, rule94,  
rule95, rule96, rule97, rule98, rule9  
9, rule100,  
rule101, rule102, rule103, rule104, rule10  
5, rule106, rule107, rule108, rule109, rule110,  
rule111, rule112, rule113, rule114,  
rule115, rule116, rule117, rule118, rule119,  
rule120, rule121, rule122, rule123, r  
rule125])
```

```
['low', 'low', 'medium', 'high', 'very high']
```

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```

a=['very small','small','average','large','very large']
r=['very large weight','largeweight','averageweight','small weight']

"""
    Method of defuzzification
"""

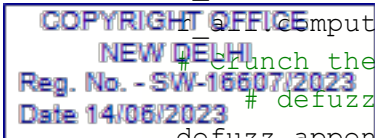
defuzz=[]
for i in range(amplitude.shape[0]):
    diff_amplitude= np.abs(amplitude[i,:,:]-
amplitude[i,wsiz//2,wsiz//2])
    diff_phase= np.abs(phase[i,:,:]-phase[i,wsiz//2,wsiz//2])
    diff_lambda= np.abs(lamb[i,:,:]-lamb[i,wsiz//2,wsiz//2])
    r_all = ctrl.ControlSystemSimulation(r_ctrl)
    r_all.input['mship_amplitude'] = diff_amplitude#pixel of amplitude
    r_all.input['mship_phase'] = diff_phase#pixel of phase
    r_all.input['mship_lambda'] = diff_lambda#pixel of lambda
    r_all.compute()
    # Crunch the numbers
    # defuzz[i]=r_all.output['wt']
    defuzz.append(r_all.output['wt'])
    # print (r_all.output['randomness'])
    # randomness.view(sim=r_all)

#filter noisy image based on defuzzified values
pau_rgb= plt.imread(os.getcwd()+'/RGB1_nosiy_0.5.jpg')[0:size,0:size] #
pauli image is generated using polsarpro
pau_rpatches= np.pad(pau_rgb,int(wsiz//2),mode='median')
#pau_gpatches= np.pad(pau_rgb[:, :,1],int(wsiz//2),mode='median')
#pau_bpatches= np.pad(pau_rgb[:, :,2],int(wsiz//2),mode='median')
plt.imshow(pau_rgb,cmap=plt.cm.gray)
pau_rpatches= image.extract_patches_2d(pau_rpatches, (wsiz,wsiz))
#pau_gpatches= image.extract_patches_2d(pau_gpatches, (wsiz,wsiz))
#pau_bpatches= image.extract_patches_2d(pau_bpatches, (wsiz,wsiz))

for i in range(pau_rpatches.shape[0]):
    wavg_r= np.sum(defuzz[i]*pau_rpatches[i]/wsiz**2)
    if wavg_r!=0:
        std= np.std(defuzz[i]*pau_rpatches[i])
        enls= (wavg_r/std)**2
        sx2= ((enls*std**2)-wavg_r**2)/(enls+1)
        xcap= wavg_r + (sx2*(pau_rpatches[i,wsiz//2,wsiz//2]-
wavg_r)/(sx2+(wavg_r**2/enls)))
        pau_rpatches[i,wsiz//2,wsiz//2] = xcap
    final= pau_rpatches[:,wsiz//2,wsiz//2].reshape(size,size)
    plt.imshow(final,cmap=plt.cm.gray)

plt.savefig(os.getcwd()+'/RGB1_nosiy_0.5_gaussf.jpg',final)
























```

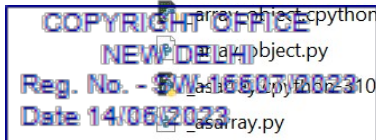


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```
time_elapsed = datetime.now() - start_time
print('Time elapsed (hh:mm:ss.ms) {}'.format(time_elapsed))
```

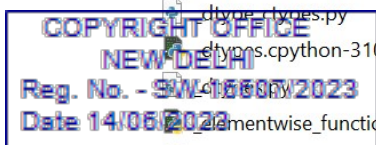
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 _init_.pyd	24-03-2022 03:51 PM	PXD File	35 KB
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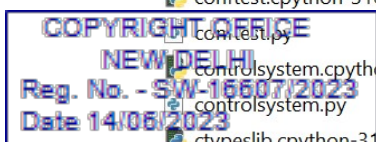
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NEW DELHI
Reg. No. - SW-16687/2023
Date 14/06/2023

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Signature






















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 matplotlib.cpython-310.pyc	24-03-2022 03:51 PM	Compiled Python File	11 KB
 matplotlib.py	24-03-2022 03:51 PM	Python Source File	11 KB
 memmap.cpython-310.pyc	24-03-2022 03:51 PM	Compiled Python File	11 KB
 memmap.py	24-03-2022 03:51 PM	Python Source File	12 KB
 memmap.pyi	24-03-2022 03:51 PM	Python Source File	1 KB
 messagestream.cp310-win_amd64.pyd	02-04-2022 02:36 PM	Python Extension Mo...	43 KB
 metrics.cpython-310.pyc	11-02-2023 12:37 PM	Compiled Python File	1 KB
 metrics.py	24-12-2015 08:58 AM	Python Source File	1 KB
 mmio.cpython-310.pyc	02-04-2022 02:36 PM	Compiled Python File	1 KB
 mmio.py	02-04-2022 02:36 PM	Python Source File	1 KB
 msvcp140.dll	02-04-2022 02:36 PM	Application extension	619 KB
 multiarray.cpython-310.pyc	24-03-2022 03:51 PM	Compiled Python File	53 KB
 multiarray.py	24-03-2022 03:51 PM	Python Source File	56 KB
 multiarray.pyi	24-03-2022 03:51 PM	Python Source File	25 KB
 netcdf.cpython-310.pyc	02-04-2022 02:36 PM	Compiled Python File	2 KB
 netcdf.py	02-04-2022 02:36 PM	Python Source File	2 KB
 numeric.cpython-310.pyc	24-03-2022 03:51 PM	Compiled Python File	72 KB
 numeric.py	24-03-2022 03:51 PM	Python Source File	78 KB
 numeric.pyi	24-03-2022 03:51 PM	Python Source File	14 KB
 numerictypes.cpython-310.pyc	24-03-2022 03:51 PM	Compiled Python File	16 KB
 numerictypes.py	24-03-2022 03:51 PM	Python Source File	18 KB



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 ordereddict.cpython-310.pyc	11-02-2023 12:37 PM	Compiled Python File	9 KB
 ordereddict.py	24-02-2016 11:18 PM	Python Source File	9 KB
 overrides.cpython-310.pyc	24-03-2022 03:51 PM	Compiled Python File	7 KB
 overrides.py	24-03-2022 03:51 PM	Python Source File	8 KB
 path.pyi	02-04-2022 07:23 PM	Python Source File	3 KB
 py.typed	24-03-2022 03:51 PM	TYPED File	0 KB
 pyplot.cpython-310.pyc	30-03-2022 12:11 PM	Compiled Python File	88 KB
 pyplot.py	30-03-2022 12:11 PM	Python Source File	106 KB
 pytz_support.cpython-310.pyc	11-02-2023 01:58 PM	Compiled Python File	10 KB
 pytz_support.py	11-02-2023 01:58 PM	Python Source File	12 KB
 records.cpython-310.pyc	24-03-2022 03:51 PM	Compiled Python File	30 KB
 records.py	24-03-2022 03:51 PM	Python Source File	38 KB
 records.pyi	24-03-2022 03:51 PM	Python Source File	6 KB
 rule.cpython-310.pyc	11-02-2023 12:37 PM	Compiled Python File	10 KB
 rule.py	14-11-2019 06:41 AM	Python Source File	12 KB
 setup.cpython-310.pyc	02-04-2022 02:36 PM	Compiled Python File	1 KB
 setup.py	02-04-2022 02:36 PM	Python Source File	1 KB
 setup_common.cpython-310.pyc	24-03-2022 03:51 PM	Compiled Python File	12 KB
 setup_common.py	24-03-2022 03:51 PM	Python Source File	20 KB
 shape.cpython-310.pyc	11-02-2023 12:37 PM	Compiled Python File	7 KB
 shape.py	11-03-2016 11:37 PM	Python Source File	8 KB
 shape_base.cpython-310.pyc	24-03-2022 03:51 PM	Compiled Python File	26 KB
 shape_base.py	24-03-2022 03:51 PM	Python Source File	30 KB

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 shape_base.pyi	24-03-2022 03:51 PM	Python Source File	2 KB
 state.cpython-310.pyc	11-02-2023 12:37 PM	Compiled Python File	3 KB
 state.py	19-06-2016 08:12 AM	Python Source File	3 KB
 term.cpython-310.pyc	11-02-2023 12:37 PM	Compiled Python File	7 KB
 term.py	14-11-2019 06:41 AM	Python Source File	7 KB
 test_pyplot.cpython-310.pyc	30-03-2022 12:11 PM	Compiled Python File	9 KB
 test_pyplot.py	30-03-2022 12:11 PM	Python Source File	10 KB
 text.cpython-310.pyc	06-02-2023 04:04 PM	Compiled Python File	65 KB
 text.py	06-02-2023 04:04 PM	Python Source File	78 KB
 uarray.cpython-310.pyc	02-04-2022 02:36 PM	Compiled Python File	1 KB
 uarray.py	02-04-2022 02:36 PM	Python Source File	1 KB
 umath.cpython-310.pyc	24-03-2022 03:51 PM	Compiled Python File	2 KB
 umath.py	24-03-2022 03:51 PM	Python Source File	3 KB
 umath_tests.cpython-310.pyc	24-03-2022 03:51 PM	Compiled Python File	1 KB
 umath_tests.py	24-03-2022 03:51 PM	Python Source File	1 KB
 version.cpython-310.pyc	02-04-2022 02:36 PM	Compiled Python File	1 KB
 version.py	24-03-2022 03:51 PM	Python Source File	1 KB
 visualization.cpython-310.pyc	11-02-2023 12:37 PM	Compiled Python File	7 KB
 visualization.py	04-09-2018 05:06 AM	Python Source File	8 KB
 wavfile.cpython-310.pyc	02-04-2022 02:36 PM	Compiled Python File	21 KB
 wavfile.py	02-04-2022 02:36 PM	Python Source File	26 KB



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