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 matplotlib import pyplot as plt
import skfuzzy as fuzz
from skfuzzy import control as ctrl
from matplotlib import pyplot as plt
from skimage import io

wsize=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:si
ze,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,
endpoint=True), 'mship_amplitude') #creating universe of discourse for
amplitude
```

```
mship_phase = ctrl.Antecedent(np.linspace(0,mdiff_phase,num=100,endpoin
t=True), 'mship_phase') #creating universe of discourse for phase
mship_lambda = ctrl.Antecedent(np.linspace(0,mdiff_lambda,num=100,endpo
int=True), 'mship_lambda') #creating universe of discourse for lambda
wt = ctrl.Consequent(np.linspace(0,1,num=100,endpoint=True), 'wt') ##cr
eating 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))

# The mathematical expression for a Gaussian function is given by
# µj(x) = exp{-0.5*[(x -cj) / σj]2}
# where
# j = {1, 2, 3, 4, 5},
# c is the center of the peak,
# σ = 0.5*(cj- cj-1) / √[-2*ln(†)], determines the width of the curve,
# † = crossing point of adjacent MFs (default for † is 0.5).
# To determine the centers, cj, you need to compute the sub-
interval between each peak, (cj- cj-1), where the 5 fuzzy sets are unif
ormly distributed to cover the domain of e:
# n = number of MFs,
# range = b - a,
# partition = n - 1,
# sub-interval = range / 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, σ = 0.5*(2.5) / √[-2*ln(0.5)] ≈ 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)

"""

VLFVD   -> Very Low First Variable Difference [ VLDPD]
LFVD - Low First Variable Difference [LDPD]
AFVD = Average First variable DIfference [ADPD]
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```
VHFVD - Very High FIrst Variable Difference [VHDPD]
HFVD - HIgh First Variable Difference [HDPD]

VLSVD   -> 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
LW - 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, s
d1)
mship_amplitude['AFVD'] = fuzz.gaussmf(mship_amplitude.universe, 0.4, s
d1)
mship_amplitude['HFVD'] = fuzz.gaussmf(mship_amplitude.universe, 0.6, s
d1)
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)


wt['VLW'] = fuzz.gaussmf(wt.universe, 0.01, sd4)
wt['LW'] = 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 v
alues
"""
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'])



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'])
rule34 = ctrl.Rule(mship_amplitude['LFVD'] &mship_phase['LSVD'] &mship_
lambda['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'])

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'])



rule76 = 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['LTVD'], 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['LTVD'], 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'])
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['LTVD'], 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['LTVD'], 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['LTVD'], 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'] &mshi
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'])



# rule23.view()
r_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,
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4, rule75,
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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
ule124, rule125])
e=['very low','low','medium','high','very high']
```

```
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,wsize//2,wsize//2])
  diff_phase= np.abs(phase[i,:,:]-phase[i,wsize//2,wsize//2])
  diff_lambda= np.abs(lamb[i,:,:]-lamb[i,wsize//2,wsize//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(wsize//2),mode='median')
#pau_gpatches= np.pad(pau_rgb[:,:,1],int(wsize//2),mode='median')
#pau_bpatches= np.pad(pau_rgb[:,:,2],int(wsize//2),mode='median')
plt.imshow(pau_rgb,cmap=plt.cm.gray)
pau_rpatches= image.extract_patches_2d(pau_rpatches, (wsize,wsize))
#pau_gpatches= image.extract_patches_2d(pau_gpatches, (wsize,wsize))
#pau_bpatches= image.extract_patches_2d(pau_bpatches, (wsize,wsize))


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

io.imsave(os.getcwd()+'/RGB1_nosiy_0.5_gaussf.jpg',final)
```

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

Object code:

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__config__.py	24-03-2022 03:51 PM	Python Source File	6 KB
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__init__.pxd	24-03-2022 03:51 PM	PXD File	35 KB
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shape_base.pyi	24-03-2022 03:51 PM	Python Source File	2 KB
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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