Lógica Fuzzy com Python: O guia para Iniciantes: Exemplo do aspirador de pó

Antecedentes (entradas)

Superfície: qual nível de dificuldade da superfície, em uma escala de 0 a 5?

- fácil, moderada, difícil

Sujeira: qual a quantidade de sujeira, em uma escala de 0 a 5?

- leve, moderada, pesada

Consequente (saída)

Sucção: qual o nível de sucção que o aspirador de pó deve ser configurado, entre 0% e 10%?

- baixa, média, alta

regras

- se a superfície for fácil e a sujeira for leve então a sucção será baixa
- se a superfície for moderada e a sujeira for leve então a sucção será média
- se a superfície for dificil ou a sujeira for pesada então a sucção será alta
- se a superfície for moderada então a sucção será média

instalação e importação das bibliotecas

- Documentação: https://pythonhosted.org/scikit-fuzzy/overview.html

In [89]:
```
import numpy as np
import skfuzzy as fuzz
from skfuzzy import control as ctrl
import matplotlib
```

Antecedentes e consequentes

In [90]:
```
superficie = ctrl.Antecedent(np.arange(0,6,1),'superficie')
sujeira = ctrl.Antecedent(np.arange(0,6,1),'sujeira')
```

In [91]:
```
superficie
```

Out[91]:
```
Antecedent: superficie
```

In [92]:
```
superficie.universe
```

Out[92]:
```
array([0, 1, 2, 3, 4, 5])
```

In [93]:
```
sujeira
```

Out[93]:
```
Antecedent: sujeira
```

In [94]:
```
sujeira.universe
```

Out[94]:
```
array([0, 1, 2, 3, 4, 5])
```

In [95]:
```
succao = ctrl.Consequent(np.arange(0,11,1),"succao")
```

In [96]:
```
succao.universe
```

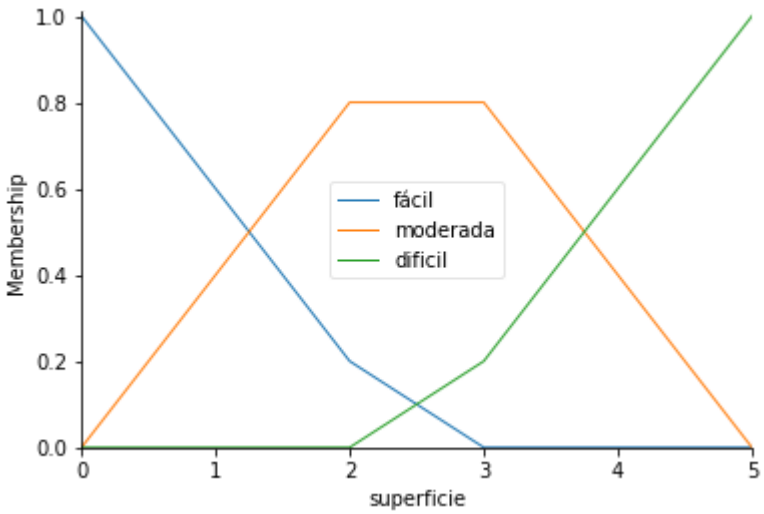
Out[96]:
```
array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10])
```

Membership functions

In [97]:
```
superficie.automf(number=3, names=['fácil','moderada','dificil'])
sujeira.automf(number=3, names=['leve','moderada', 'pesada'])
```

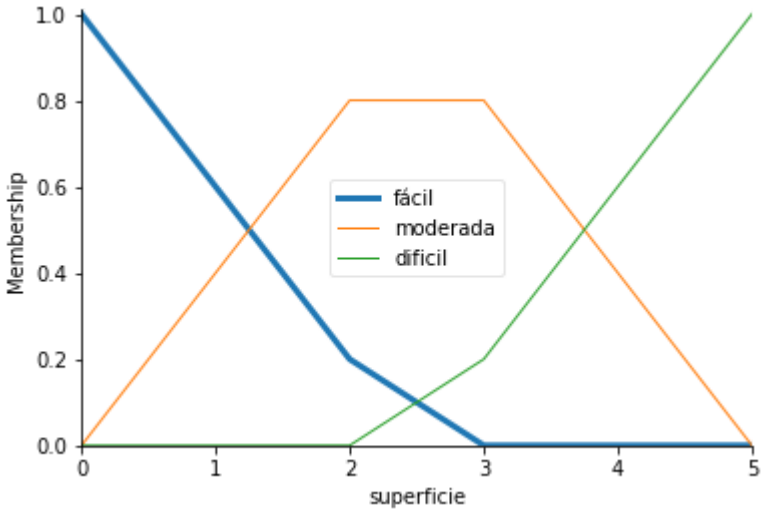
In [98]:
```
superficie.view()
```

```
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\fuzzyvariable.py:122: User
Warning: Matplotlib is currently using module://matplotlib_inline.backend_inline, whi
ch is a non-GUI backend, so cannot show the figure.
  fig.show()
```



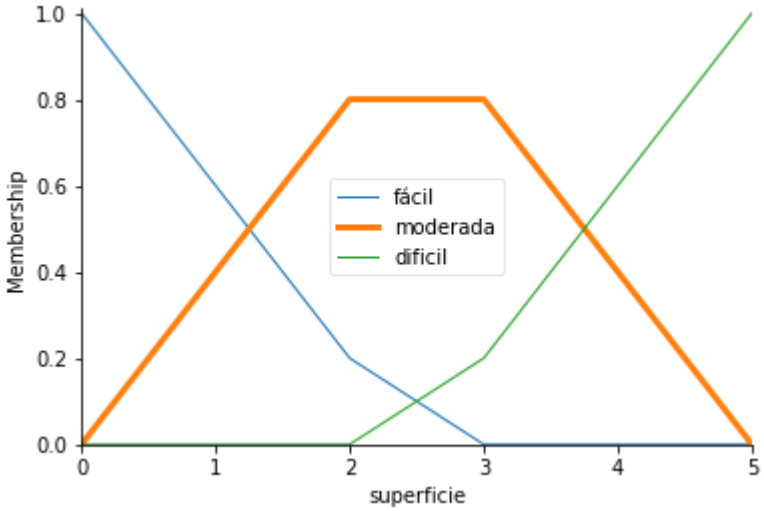
In [99]:
```
superficie['fácil'].view()
```

```
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\term.py:74: UserWarning: M
atplotlib is currently using module://matplotlib_inline.backend_inline, which is a no
n-GUI backend, so cannot show the figure.
  fig.show()
```



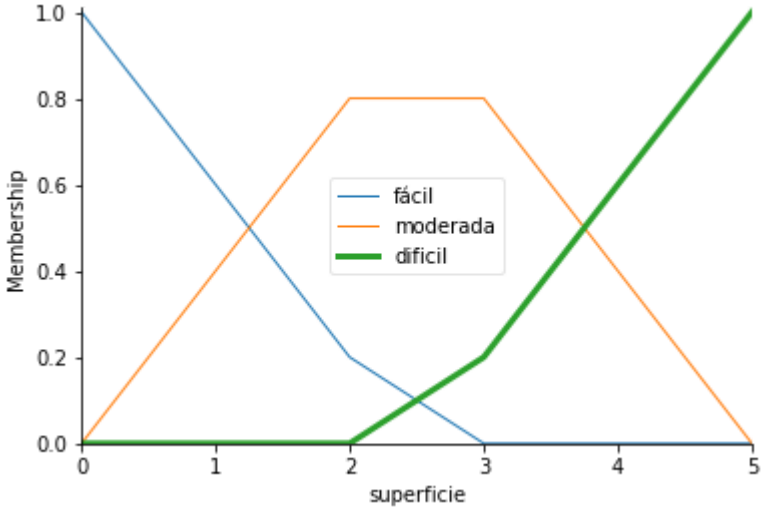
In [100…
```
superficie['moderada'].view()
```

```
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\term.py:74: UserWarning: M
atplotlib is currently using module://matplotlib_inline.backend_inline, which is a no
n-GUI backend, so cannot show the figure.
  fig.show()
```



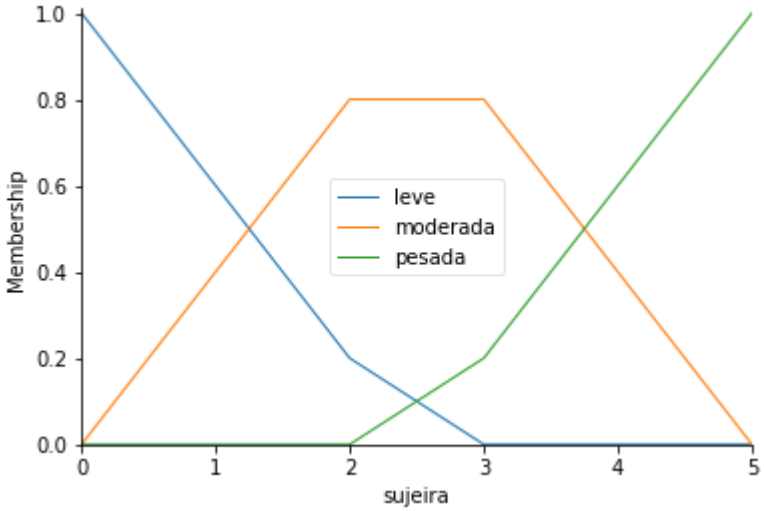
In [101…
```
superficie['dificil'].view()
```

```
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\term.py:74: UserWarning: M
atplotlib is currently using module://matplotlib_inline.backend_inline, which is a no
n-GUI backend, so cannot show the figure.
  fig.show()
```



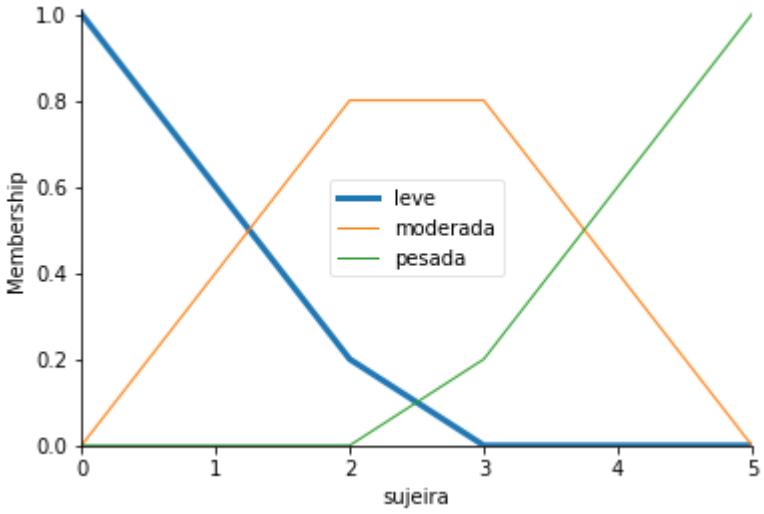
In [102…
```
sujeira.view()
```

```
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\fuzzyvariable.py:122: User
Warning: Matplotlib is currently using module://matplotlib_inline.backend_inline, whi
ch is a non-GUI backend, so cannot show the figure.
  fig.show()
```



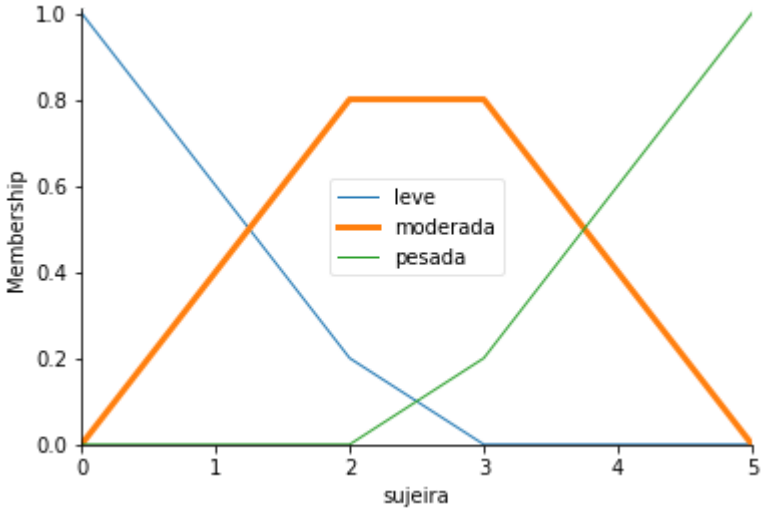
In [103…
```
sujeira['leve'].view()
```

```
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\term.py:74: UserWarning: M
atplotlib is currently using module://matplotlib_inline.backend_inline, which is a no
n-GUI backend, so cannot show the figure.
  fig.show()
```



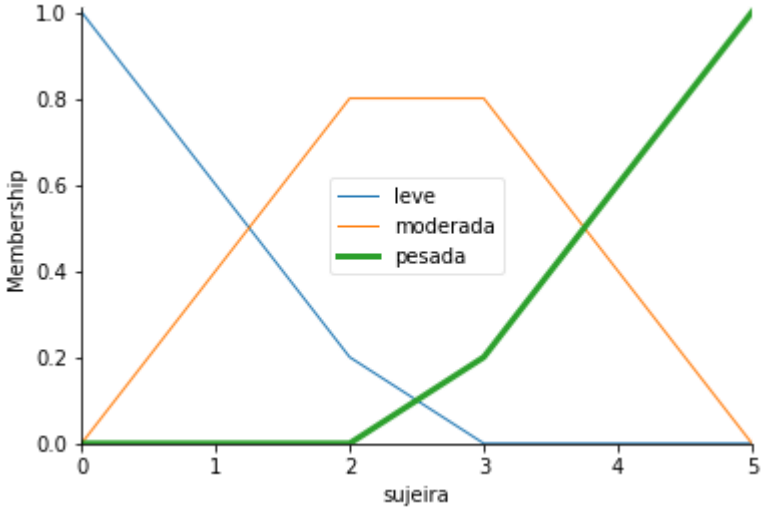
In [104…
```
sujeira['moderada'].view()
```

```
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\term.py:74: UserWarning: M
atplotlib is currently using module://matplotlib_inline.backend_inline, which is a no
n-GUI backend, so cannot show the figure.
  fig.show()
```



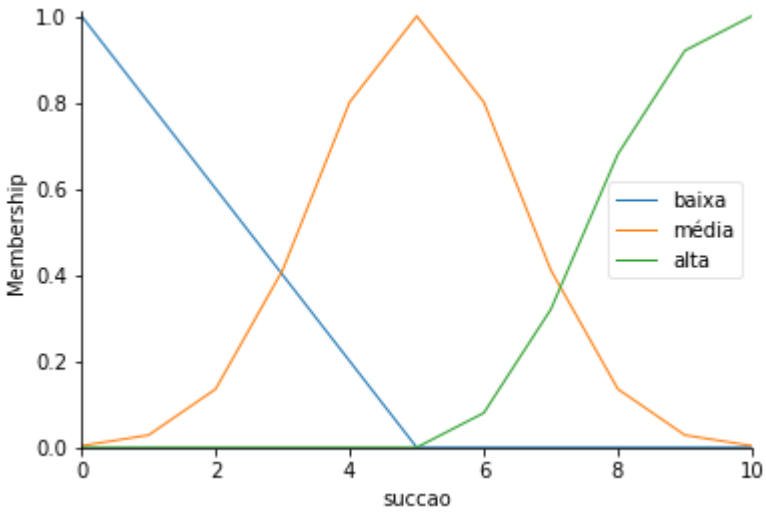
In [105…
```
sujeira['pesada'].view()
```

```
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\term.py:74: UserWarning: M
atplotlib is currently using module://matplotlib_inline.backend_inline, which is a no
n-GUI backend, so cannot show the figure.
  fig.show()
```



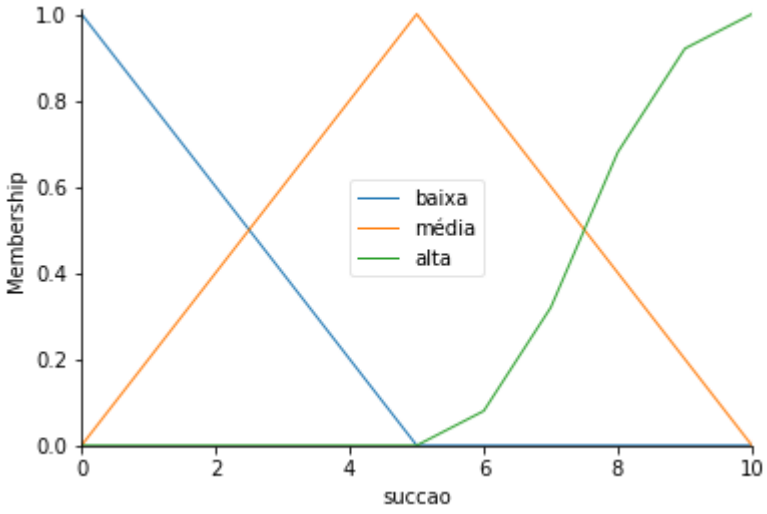
In [129…
```
succao['baixa'] = fuzz.trimf(succao.universe,[0,0,5])
succao.view()
```

```
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\fuzzyvariable.py:122: User
Warning: Matplotlib is currently using module://matplotlib_inline.backend_inline, whi
ch is a non-GUI backend, so cannot show the figure.
  fig.show()
```



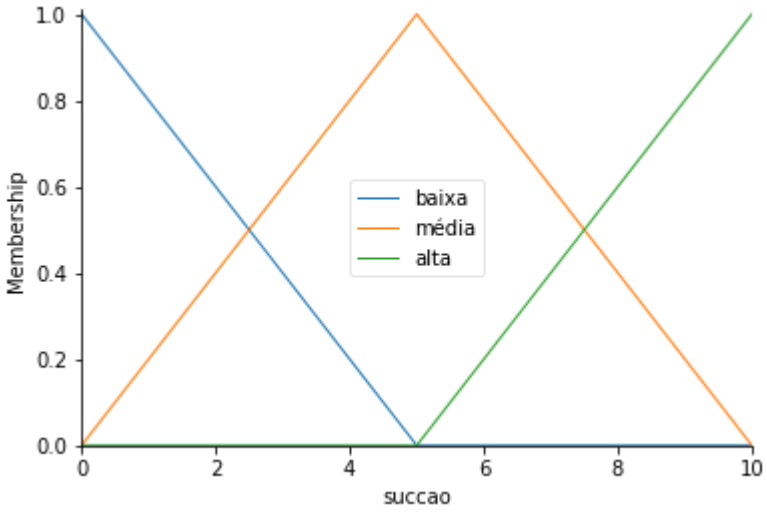
In [131…
```
succao['média'] = fuzz.trimf(succao.universe,[0,5,10])
succao.view()
```

```
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\fuzzyvariable.py:122: User
Warning: Matplotlib is currently using module://matplotlib_inline.backend_inline, whi
ch is a non-GUI backend, so cannot show the figure.
  fig.show()
```



In [132…]
```
succao['alta'] = fuzz.trimf(succao.universe,[5,10,10])
succao.view()
```

```
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\fuzzyvariable.py:122: User
Warning: Matplotlib is currently using module://matplotlib_inline.backend_inline, whi
ch is a non-GUI backend, so cannot show the figure.
  fig.show()
```



In [133…]
```
regra1 = ctrl.Rule(superficie['fácil'] | sujeira['leve'], succao['baixa'])
regra2 = ctrl.Rule(superficie['moderada'] | sujeira['leve'], succao['média'])
regra3 = ctrl.Rule(superficie['dificil'] | sujeira['pesada'], succao['alta'])
#regra4 = ctrl.Rule(superficie['moderada'], succao['média'])
```

Sistema de controle

In [134…]
```
#sistema_controle = ctrl.ControlSystem([regra1,regra2,regra3, regra4])
sistema_controle = ctrl.ControlSystem([regra1,regra2,regra3])
```

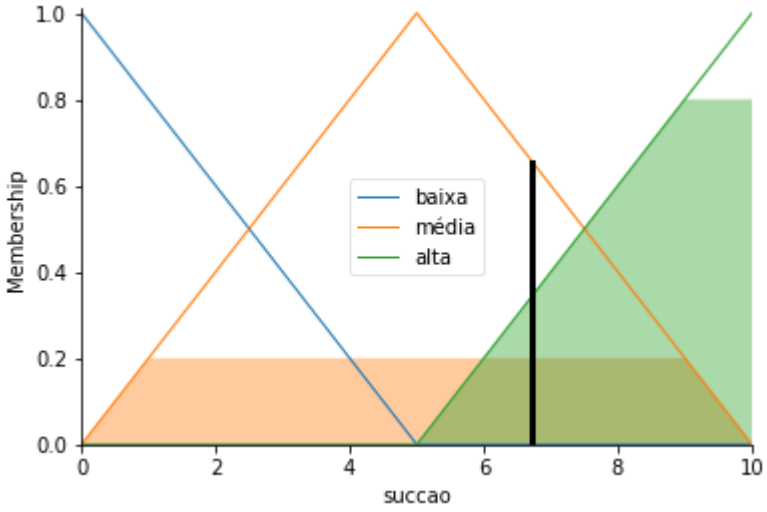
In [135…]
```
sistema = ctrl.ControlSystemSimulation(sistema_controle)
```

In [145…]
```
sistema.input['superficie'] = 4.5
sistema.input['sujeira'] = 4
sistema.compute()
```

In [146…
```
print(sistema.output['succao'])
succao.view(sim=sistema)
```

```
6.725490196078432
```

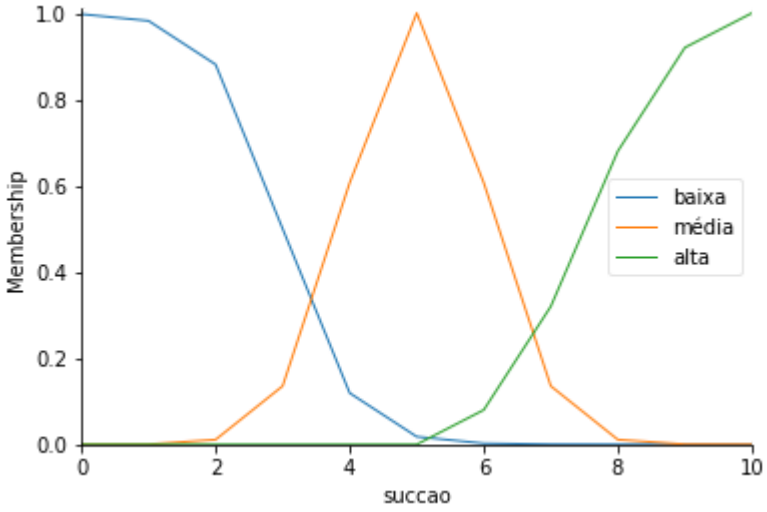
```
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\fuzzyvariable.py:122: User
Warning: Matplotlib is currently using module://matplotlib_inline.backend_inline, whi
ch is a non-GUI backend, so cannot show the figure.
  fig.show()
```



Outras funções

In [147…
```
succao['baixa'] = fuzz.sigmf(succao.universe,3,-2)
succao['média'] = fuzz.gaussmf(succao.universe, 5, 1)
succao['alta'] = fuzz.pimf(succao.universe,5,10,10,11)
succao.view()
```

```
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\fuzzyvariable.py:122: User
Warning: Matplotlib is currently using module://matplotlib_inline.backend_inline, whi
ch is a non-GUI backend, so cannot show the figure.
  fig.show()
```



In [148…
```
regra1 = ctrl.Rule(superficie['fácil'] | sujeira['leve'], succao['baixa'])
regra2 = ctrl.Rule(superficie['moderada'] | sujeira['leve'], succao['média'])
```

```
regra3 = ctrl.Rule(superficie['dificil'] | sujeira['pesada'], succao['alta'])
#regra4 = ctrl.Rule(superficie['moderada'], succao['média'])
```

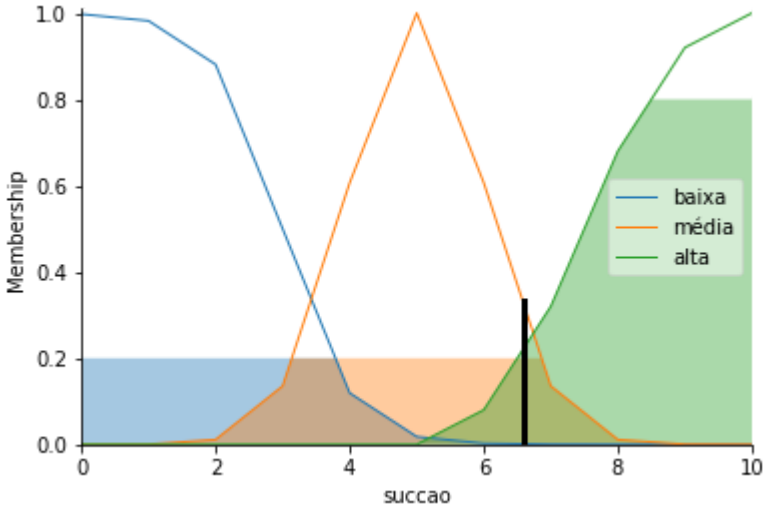
In [149…
```
#sistema_controle = ctrl.ControlSystem([regra1,regra2,regra3, regra4])
sistema_controle = ctrl.ControlSystem([regra1,regra2,regra3])
```

In [150…
```
sistema = ctrl.ControlSystemSimulation(sistema_controle)
```

In [153…
```
sistema.input['superficie'] = 4.5
sistema.input['sujeira'] = 2
sistema.compute()
```

In [154…
```
print(sistema.output['succao'])
succao.view(sim=sistema)
```

```
6.582062331030227
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\fuzzyvariable.py:122: User
Warning: Matplotlib is currently using module://matplotlib_inline.backend_inline, whi
ch is a non-GUI backend, so cannot show the figure.
  fig.show()
```



HARD FUZZY

instalação e inportação das bibliotecas

- Documentação: https://pythonhosted.org/scikit-fuzzy/overview.html

In [1]:
```
import numpy as np
import skfuzzy as fuzz
from skfuzzy import control as ctrl
import matplotlib.pyplot as plt
```

Antecedentes e consequentes

In [2]:
```
x_superficie = np.arange(0,6,1)
x_sujeira = np.arange(0,6,1)
```

```
x_succao = np.arange(0,11,1)
```

In [3]:
```
x_superficie, x_sujeira, x_succao
```

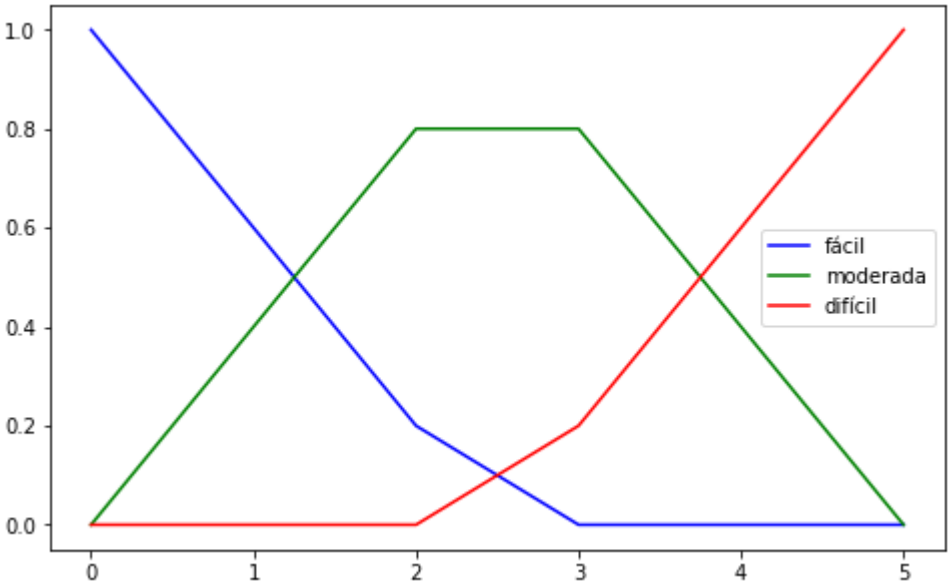
Out[3]:
```
(array([0, 1, 2, 3, 4, 5]),
 array([0, 1, 2, 3, 4, 5]),
 array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10]))
```

Tipo de superfície

In [4]:
```
y_superficie_facil = fuzz.trimf(x_superficie, [0,0,2.5])
y_superficie_moderada = fuzz.trimf(x_superficie,[0,2.5,5])
y_superficie_dificil = fuzz.trimf(x_superficie, [2.5, 5,5])
```

In [10]:
```
fig, ax = plt.subplots(figsize = (8,5))
ax.plot(x_superficie, y_superficie_facil, 'b', label="fácil")
ax.plot(x_superficie, y_superficie_moderada, 'g', label="moderada")
ax.plot(x_superficie, y_superficie_dificil, 'r', label="difícil")
ax.legend()
```

Out[10]:
```
<matplotlib.legend.Legend at 0x174bf3dcf70>
```

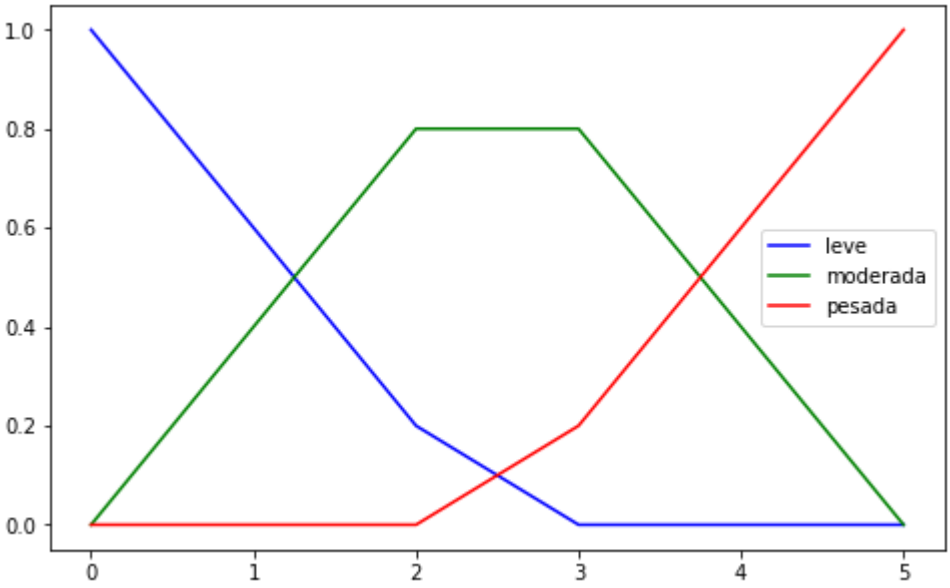


Tipo de sujeira

In [11]:
```
y_sujeira_leve = fuzz.trimf(x_sujeira, [0,0,2.5])
y_sujeira_moderada = fuzz.trimf(x_sujeira, [0,2.5,5])
y_sujeira_pesada = fuzz.trimf(x_sujeira, [2.5,5,5])
```

In [12]:
```
fig, ax = plt.subplots(figsize = (8,5))
ax.plot(x_sujeira, y_sujeira_leve, 'b', label="leve")
ax.plot(x_sujeira, y_sujeira_moderada, 'g', label="moderada")
ax.plot(x_sujeira, y_sujeira_pesada, 'r', label="pesada")
ax.legend()
```

Out[12]:
```
<matplotlib.legend.Legend at 0x174bf56ba90>
```

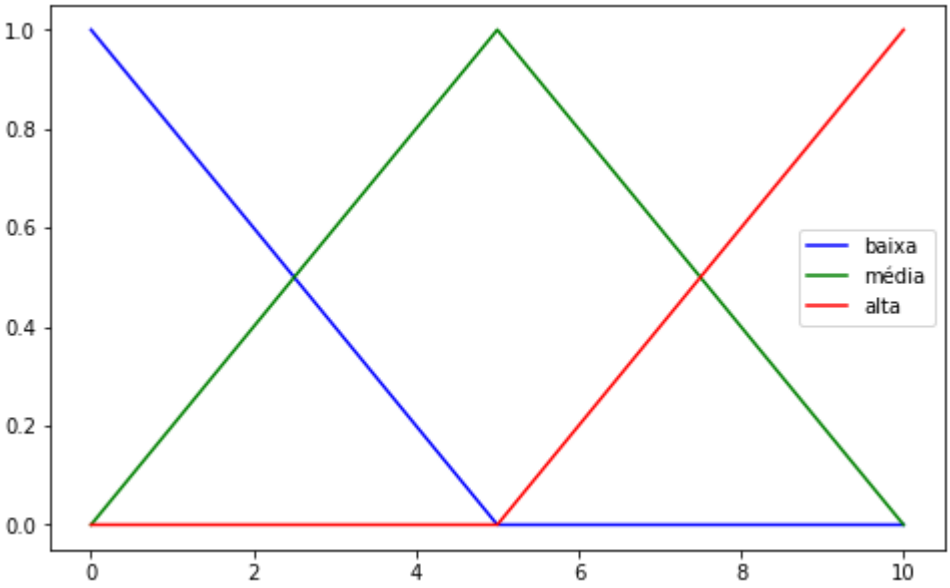


Sucção

In [13]:
```
y_succao_baixa = fuzz.trimf(x_succao,[0,0,5])
y_succao_media = fuzz.trimf(x_succao,[0,5,10])
y_succao_alta = fuzz.trimf(x_succao,[5,10,10])
```

In [14]:
```
fig, ax = plt.subplots(figsize = (8,5))
ax.plot(x_succao, y_succao_baixa, 'b', label="baixa")
ax.plot(x_succao, y_succao_media, 'g', label="média")
ax.plot(x_succao, y_succao_alta, 'r', label="alta")
ax.legend()
```

Out[14]:
```
<matplotlib.legend.Legend at 0x174bcac0fd0>
```



Entradas (inputs)

In [21]:
```
superficie_nivel_facil = fuzz.interp_membership(x_superficie, y_superficie_facil, 4.5)
superficie_nivel_moderada = fuzz.interp_membership(x_superficie, y_superficie_moderada
```

```
superficie_nivel_dificil = fuzz.interp_membership(x_superficie, y_superficie_dificil,
```

In [22]:
```
superficie_nivel_facil, superficie_nivel_moderada, superficie_nivel_dificil
```

Out[22]:
```
(0.0, 0.2, 0.8)
```

In [23]:
```
sujeira_nivel_leve = fuzz.interp_membership(x_sujeira, y_sujeira_leve,4.0)
sujeira_nivel_moderada = fuzz.interp_membership(x_sujeira, y_sujeira_moderada,4.0)
sujeira_nivel_pesada = fuzz.interp_membership(x_sujeira, y_sujeira_pesada,4.0)
```

In [24]:
```
sujeira_nivel_leve, sujeira_nivel_moderada, sujeira_nivel_pesada
```

Out[24]:
```
(0.0, 0.4, 0.6)
```

Regra 1

- se a superfície for fácil e a sujeira for leve então a sucção será baixa

In [25]:
```
superficie_nivel_facil, sujeira_nivel_leve
```

Out[25]:
```
(0.0, 0.0)
```

In [26]:
```
ativacao_regra1 = np.fmax(superficie_nivel_facil, sujeira_nivel_leve)
ativacao_regra1
```

Out[26]:
```
0.0
```

In [27]:
```
ativacao_succao_baixa = np.fmin(ativacao_regra1, y_succao_baixa)
ativacao_succao_baixa
```

Out[27]:
```
array([0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.])
```

Regra 2

- se a superfície for moderada e a sujeira for leve então a sucção será média

In [28]:
```
superficie_nivel_moderada, sujeira_nivel_leve
```

Out[28]:
```
(0.2, 0.0)
```

In [31]:
```
ativacao_regra2 = np.fmax(superficie_nivel_moderada, sujeira_nivel_leve)
ativacao_regra2
```

Out[31]:
```
0.2
```

In [32]:
```
y_succao_media
```

Out[32]:
```
array([0. , 0.2, 0.4, 0.6, 0.8, 1. , 0.8, 0.6, 0.4, 0.2, 0. ])
```

In [34]:
```
ativacao_succao_media = np.fmin(ativacao_regra2, y_succao_media)
ativacao_succao_media
```

Out[34]:
```
array([0. , 0.2, 0.2, 0.2, 0.2, 0.2, 0.2, 0.2, 0.2, 0.2, 0. ])
```

Regra 3

- se a superfície for dificil ou a sujeira for pesada então a sucção será alta

In [35]:
```
superficie_nivel_dificil, sujeira_nivel_pesada
```

Out[35]:
```
(0.8, 0.6)
```

In [37]:
```
ativacao_regra3 = np.fmax(superficie_nivel_dificil, sujeira_nivel_pesada)
ativacao_regra3
```

Out[37]:
```
0.8
```

In [38]:
```
y_succao_alta
```

Out[38]:
```
array([0. , 0. , 0. , 0. , 0. , 0. , 0.2, 0.4, 0.6, 0.8, 1. ])
```

In [39]:
```
ativacao_succao_alta = np.fmin(ativacao_regra3, y_succao_alta)
ativacao_succao_alta
```

Out[39]:
```
array([0. , 0. , 0. , 0. , 0. , 0. , 0.2, 0.4, 0.6, 0.8, 0.8])
```

Gráficos com as intersecções

In [40]:
```
x_succao
```

Out[40]:
```
array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10])
```

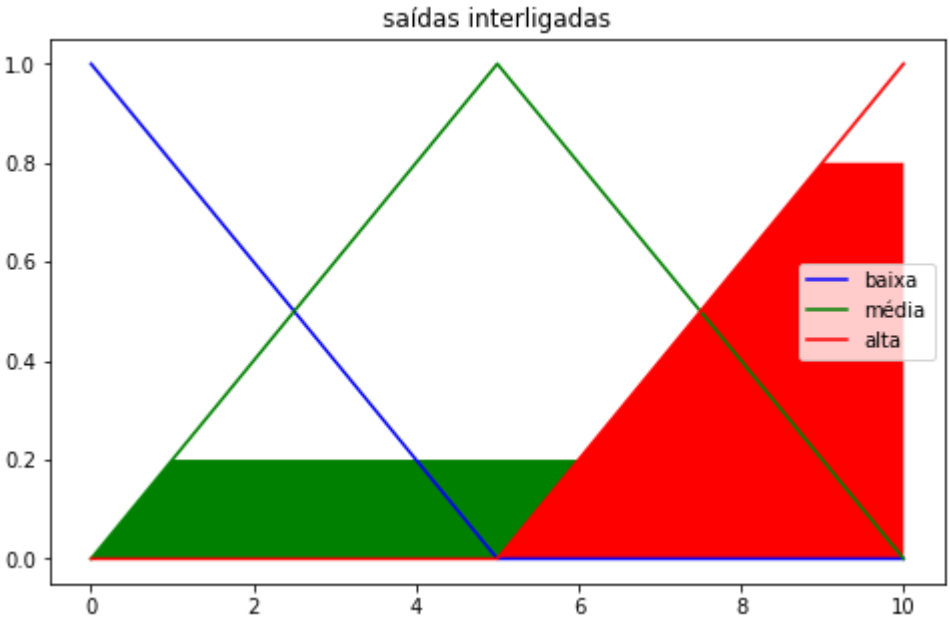
In [41]:
```
x_succao0 = np.zeros_like(x_succao)
x_succao0
```

Out[41]:
```
array([0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0])
```

In [42]:
```
x_succao.shape, x_succao0.shape
```

Out[42]:
```
((11,), (11,))
```

In [46]:
```
fig, ax = plt.subplots(figsize=(8,5))
ax.plot(x_succao, y_succao_baixa, 'b', label='baixa')
ax.fill_between(x_succao, x_succao0, ativacao_succao_baixa, facecolor='b')
ax.plot(x_succao, y_succao_media, 'g', label='média')
ax.fill_between(x_succao, x_succao0, ativacao_succao_media, facecolor='g')
ax.plot(x_succao, y_succao_alta, 'r', label='alta')
ax.fill_between(x_succao, x_succao0, ativacao_succao_alta, facecolor='r')
ax.set_title('saídas interligadas')
ax.legend();
```



Defuzzificação

- centroid (centroid)
- bisector (bisector)
- mean of maximum (mom)
- mim of maximum (som)
- max of maximum (lom)

In [47]:
```
controle = np.fmax(ativacao_succao_baixa, np.fmax(ativacao_succao_alta,ativacao_succac
controle
```

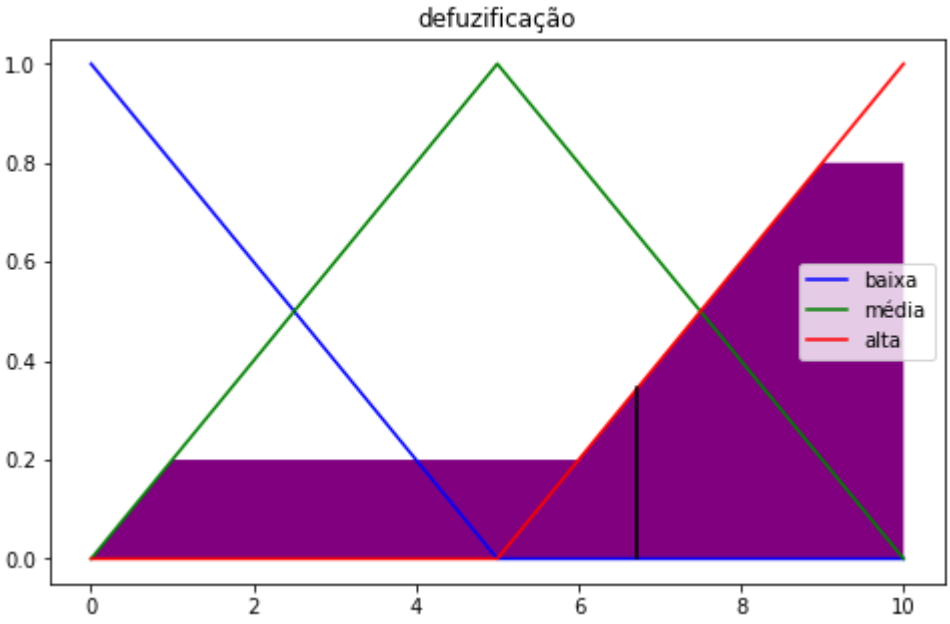
Out[47]:
```
array([0. , 0.2, 0.2, 0.2, 0.2, 0.2, 0.2, 0.4, 0.6, 0.8, 0.8])
```

In [48]:
```
succcao = fuzz.defuzz(x_succao, controle, 'centroid')
#succcao = fuzz.defuzz(x_succao, controle, 'bisector')
#succcao = fuzz.defuzz(x_succao, controle, 'mom')
#succcao = fuzz.defuzz(x_succao, controle, 'som')
#succcao = fuzz.defuzz(x_succao, controle, 'lom')
succcao
```

Out[48]:
```
6.725490196078432
```

In [49]:
```
succcao_ativacao = fuzz.interp_membership(x_succao, controle, succcao)
```

In [50]:
```
fig, ax = plt.subplots(figsize=(8,5))
ax.plot(x_succao, y_succao_baixa, 'b', label='baixa')
ax.plot(x_succao, y_succao_media, 'g', label='média')
ax.plot(x_succao, y_succao_alta, 'r', label='alta')
ax.fill_between(x_succao, x_succao0, controle, facecolor='purple')
ax.plot([succcao, succcao], [0, succcao_ativacao], 'black')
ax.set_title('defuzificação')
ax.legend();
```


defuzificação
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
baixa
média
alta