# Lógica Fuzzy com Python: O guia para Iniciantes: Exemplo das gorjetas

## Antecedentes (entradas)

Serviço: que nota você daria para o serviço, emuma escala de 1 a 10?

```
- ruim, aceitável, ótimo
```

Qualidade da comida: quão boa estava a comida, em uma escala de 0 a 10?

```
- ruim, boa, saborosa
```

## Consequentes (saídas)

Gorjeta: quanta gorgeta você daria entre 0% e 20%?

```
- baixa, média, alta
```

Regras

```
- Se a qualidade da comida for ruim ou o serviço for ruim então a
gorjeta será baixa
- Se o serviço for médio então a gorjeta será média
- Se o serviço for bom e a qualidade da comida for saborosa então a
gorjeta será alta
```

## Instalação e importação das bibliotecas

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

In [2]:
```python
import numpy as np
import skfuzzy as fuzz
from skfuzzy import control as ctrl
import matplotlib
```

## Antecedentes e consequentes

In [3]:
```python
qualidade = ctrl.Antecedent(np.arange(0,11,1), 'qualidade')
servico = ctrl.Antecedent(np.arange(0,11,1),'servico')
```

```
In [4]:  qualidade
```

Out[4]:  Antecedent: qualidade

```
In [5]:  qualidade.universe
```

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

```
In [6]:  gorjeta = ctrl.Consequent(np.arange(0,21,1), 'gorjeta')
```

```
In [7]:  gorjeta.universe
```

Out[7]:  array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15, 16,
         17, 18, 19, 20])

# Membership functions

```
In [8]:  qualidade.automf(number=3, names = ['ruim','boa','saborosa'])
         servico.automf(number=3, names = ['ruim','aceitável','ótimo'])
```

```
In [9]:  qualidade.view();
```
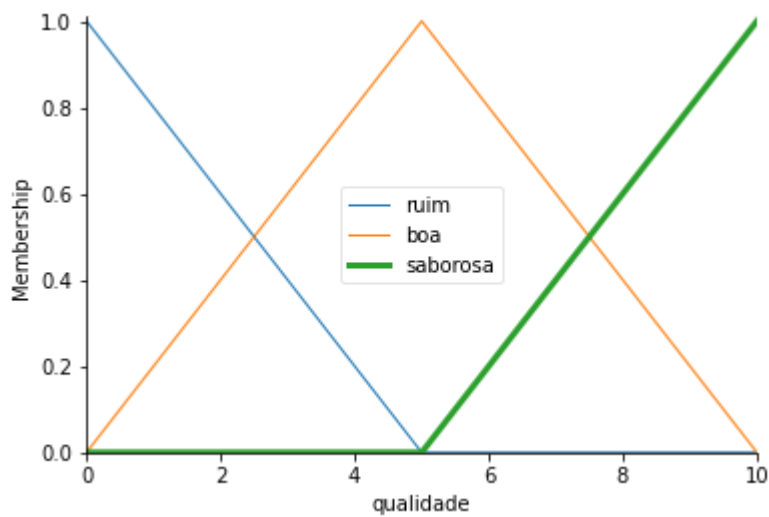
C:\Users\clist\anaconda3\lib\site-packages\skfuzzy\control\fuzzyvariable.py:122: User
Warning: Matplotlib is currently using module://matplotlib_inline.backend_inline, whi
ch is a non-GUI backend, so cannot show the figure.
  fig.show()
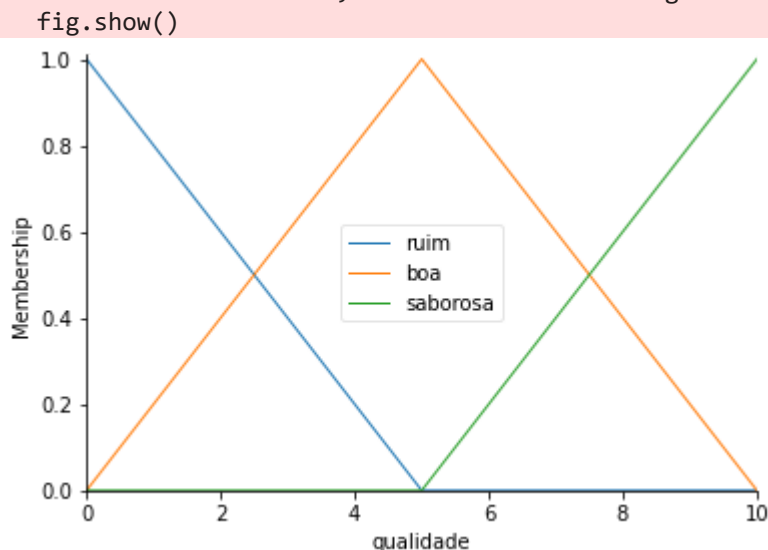


```
In [10]:  qualidade['saborosa'].view()
```

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()

`qualidade['ruim'].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()
```
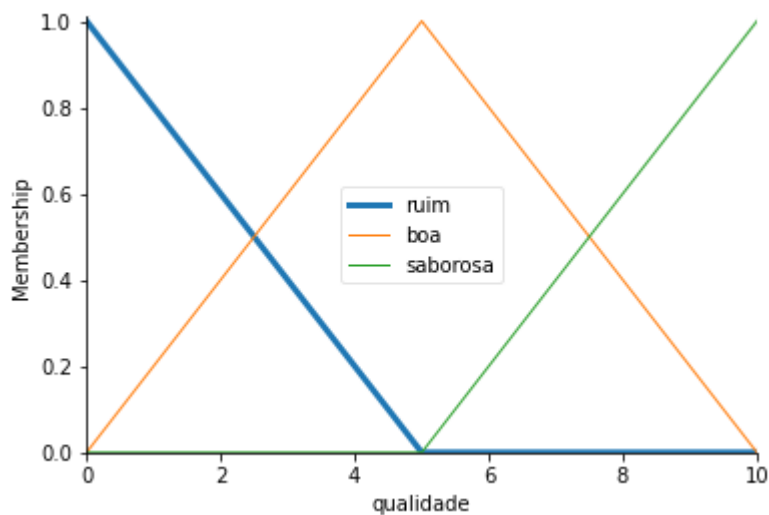


`qualidade['boa'].view()`

```
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()
```
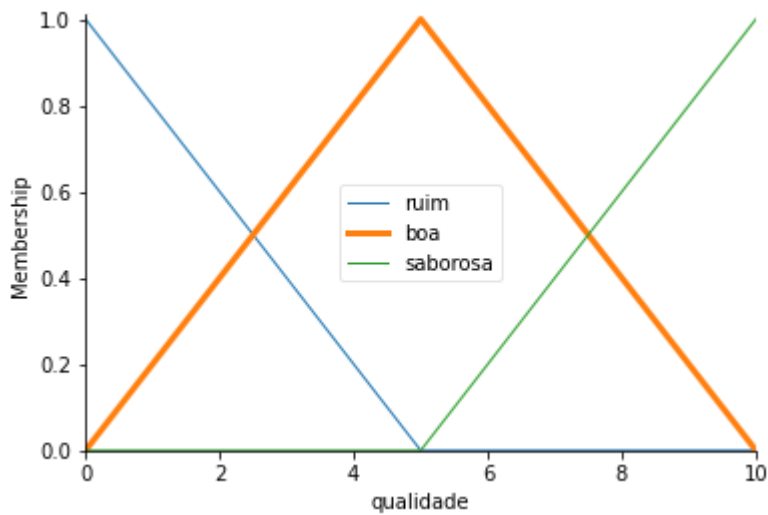
In [13]: `servico.view()`

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 [14]: `gorjeta.universe`

Out[14]:
```
array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15, 16,
       17, 18, 19, 20])
```

In [15]:
```python
# função triangular
gorjeta['baixa'] = fuzz.trimf(gorjeta.universe,[0,0,10])
```

In [16]: `gorjeta.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
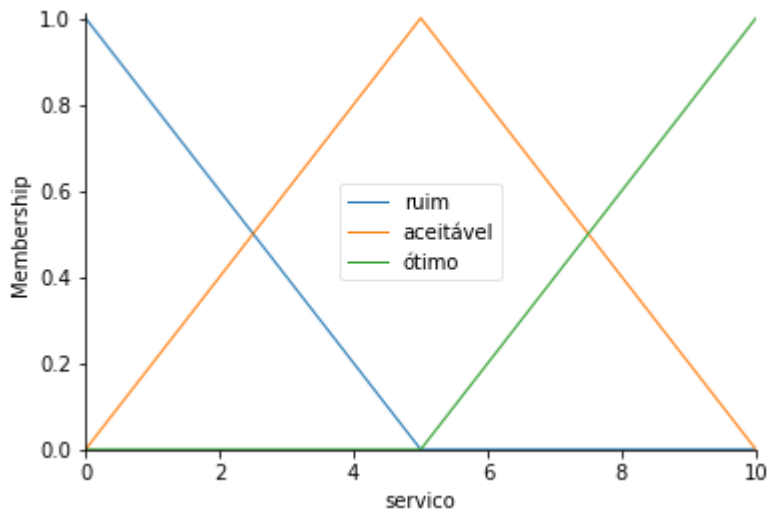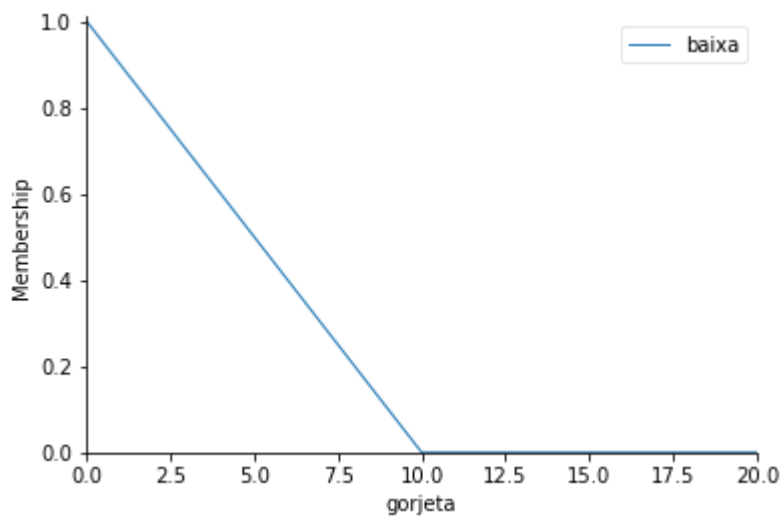ch is a non-GUI backend, so cannot show the figure.
  fig.show()

`gorjeta['média'] = fuzz.trimf(gorjeta.universe,[0,10,20])`

`gorjeta.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()
```



`gorjeta['alta'] = fuzz.trimf(gorjeta.universe,[10,20,20])`

`gorjeta.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()
```
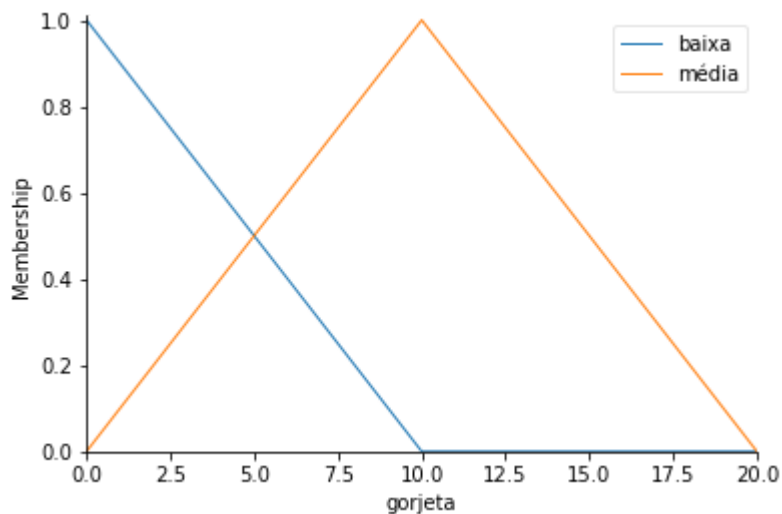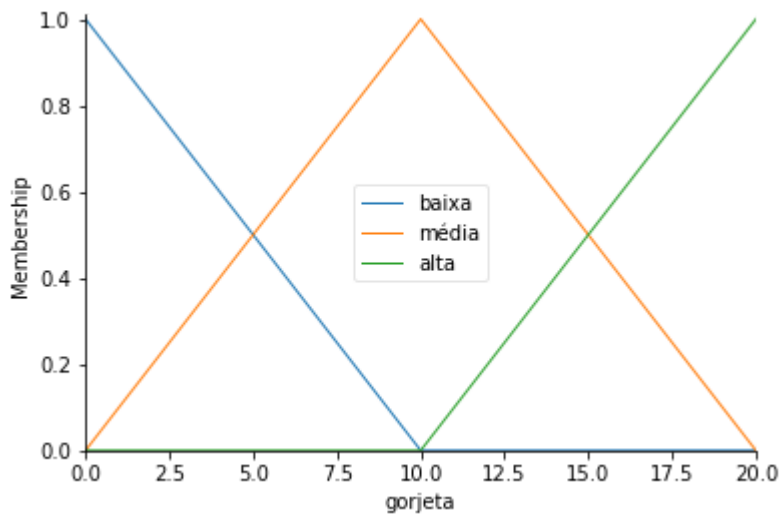
```
In [21]: regra1 = ctrl.Rule(qualidade['ruim'] | servico['ruim'], gorjeta['baixa'])
         regra2 = ctrl.Rule(servico['aceitável'], gorjeta['média'])
         regra3 = ctrl.Rule(qualidade['saborosa'] | servico['ótimo'], gorjeta['alta'])
```

## Sistema de controle

```
In [22]: sistema_controle = ctrl.ControlSystem([regra1,regra2,regra3])
```

```
In [23]: sistema = ctrl.ControlSystemSimulation(sistema_controle)
```

```
In [24]: sistema.input['qualidade'] = 6.5
         sistema.input['servico'] = 7.5
         sistema.compute()
```

```
In [25]: print(sistema.output['gorjeta'])
         gorjeta.view(sim=sistema)
```

11.19047619047619

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()
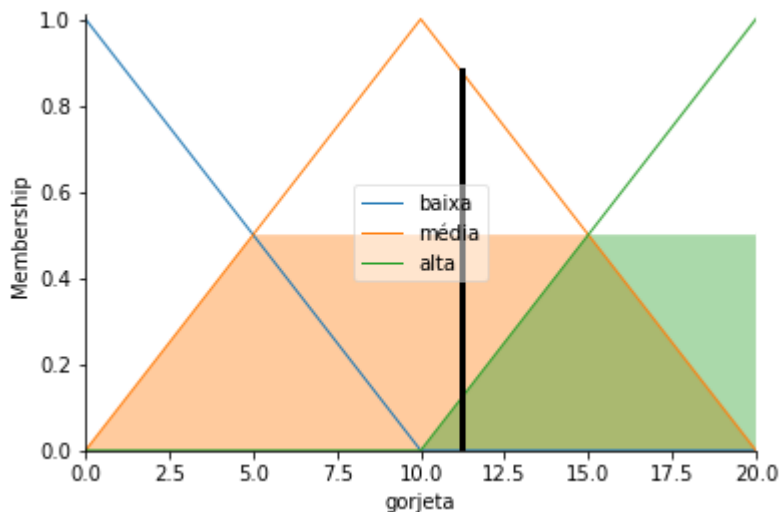
# Outras funções

```
In [1]:  gorjeta['baixa'] = fuzz.sigmf(gorjeta.universe, 5, -1)
         gorjeta['média'] = fuzz.gaussmf(gorjeta.universe, 10, 3)
         gorjeta['alta'] = fuzz.pimf(gorjeta.universe,10,20,20,21)
         gorjeta.view();
```

```
---------------------------------------------------------------------------
NameError                                 Traceback (most recent call last)
Input In [1], in <cell line: 1>()
----> 1 gorjeta['baixa'] = fuzz.sigmf(gorjeta.universe, 5, -1)
      2 gorjeta['média'] = fuzz.gaussmf(gorjeta.universe, 10, 3)
      3 gorjeta['alta'] = fuzz.pimf(gorjeta.universe,10,20,20,21)

NameError: name 'fuzz' is not defined
```

```
In [27]:  regra1 = ctrl.Rule(qualidade['ruim'] | servico['ruim'], gorjeta['baixa'])
          regra2 = ctrl.Rule(servico['aceitável'], gorjeta['média'])
          regra3 = ctrl.Rule(qualidade['saborosa'] | servico['ótimo'], gorjeta['alta'])
```

```
In [28]:  sistema_controle = ctrl.ControlSystem([regra1,regra2,regra3])
```

```
In [29]:  sistema = ctrl.ControlSystemSimulation(sistema_controle)
```

```
In [30]:  sistema.input['qualidade'] = 6.5
          sistema.input['servico'] = 7.5
          sistema.compute()
```

```
In [51]:  print(sistema.output['gorjeta'])
          gorjeta.view(sim=sistema)
```

```
12.239756463508852
```

```
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()
```
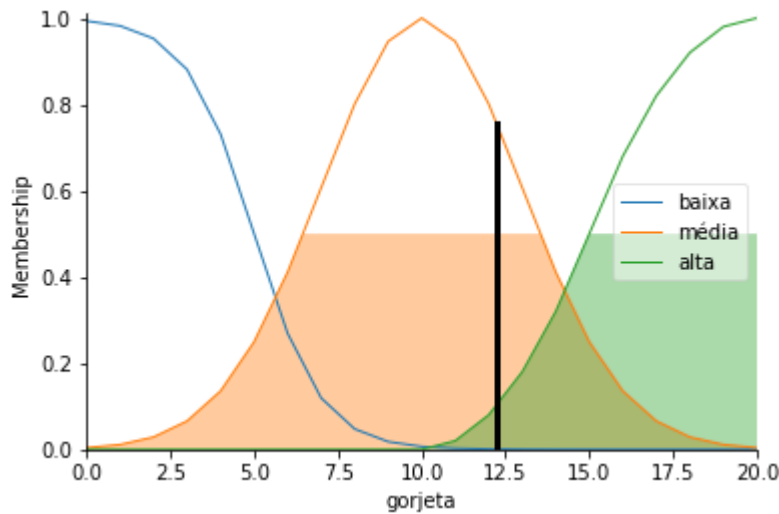


# HARD FUZZY

# Instalação e importação das bibliotecas

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

```
In [45]: import numpy as np
         import skfuzzy as fuzz
         from skfuzzy import control as ctrl
         import matplotlib.pyplot as plt
```

## Antecedentes e consequentes

```
In [46]: x_comida = np.arange(0,11,1)
         x_servico = np.arange(0,11,1)
         x_gorjeta = np.arange(0,21,1)
```

```
In [47]: x_comida, x_servico, x_gorjeta
```

```
Out[47]: (array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10]),
          array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10]),
          array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15, 16,
                 17, 18, 19, 20]))
```

### Qualidade da comida

```
In [48]: y_comida_ruim = fuzz.trimf(x_comida, [0,0,5])
         y_comida_boa = fuzz.trimf(x_comida, [0, 5, 10])
         y_comida_saborosa = fuzz.trimf(x_comida, [5,10,10])
```

```
In [50]: fig, ax = plt.subplots(figsize=(8,5))
         ax.plot(x_comida, y_comida_ruim, 'b', label='ruim')
         ax.plot(x_comida, y_comida_boa, 'g', label='boa')
         ax.plot(x_comida, y_comida_saborosa, 'r', label='saborosa')
         ax.legend();
```
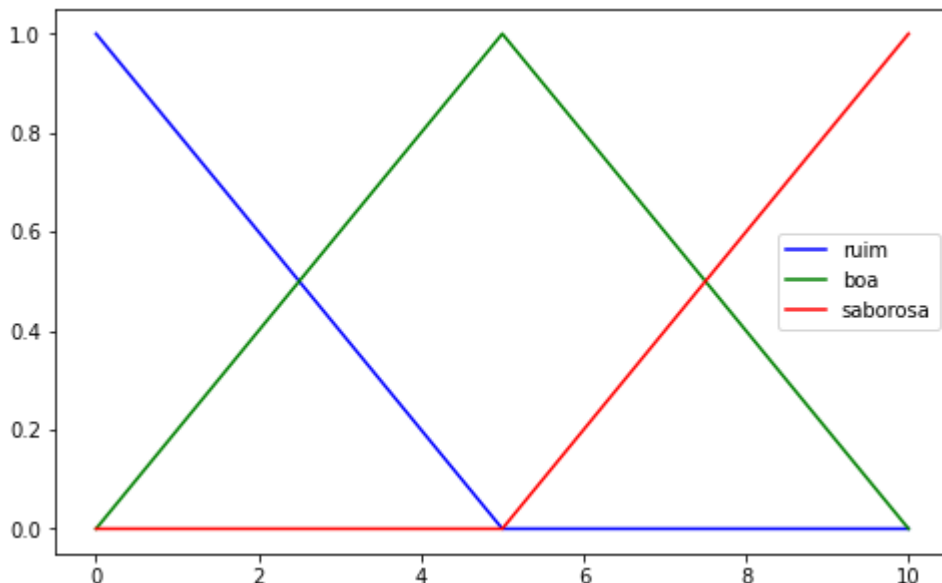


### Qualidade do serviço

```
In [53]:  y_servico_ruim = fuzz.trimf(x_servico, [0,0,5])
          y_servico_aceitavel = fuzz.trimf(x_servico, [0,5,10])
          y_servico_otimo = fuzz.trimf(x_servico, [5,10,10])
```

```
In [54]:  y_servico_ruim, y_servico_aceitavel, y_servico_otimo
```

```
Out[54]:  (array([1. , 0.8, 0.6, 0.4, 0.2, 0. , 0. , 0. , 0. , 0. , 0. ]),
           array([0. , 0.2, 0.4, 0.6, 0.8, 1. , 0.8, 0.6, 0.4, 0.2, 0. ]),
           array([0. , 0. , 0. , 0. , 0. , 0. , 0.2, 0.4, 0.6, 0.8, 1. ]))
```

```
In [55]:  fig, ax = plt.subplots(figsize=(8,5))
          ax.plot(x_servico, y_servico_ruim, 'b', label='ruim')
          ax.plot(x_servico, y_servico_aceitavel, 'g', label='acetável')
          ax.plot(x_servico, y_servico_otimo, 'r', label='ótimo')
          ax.legend();
```
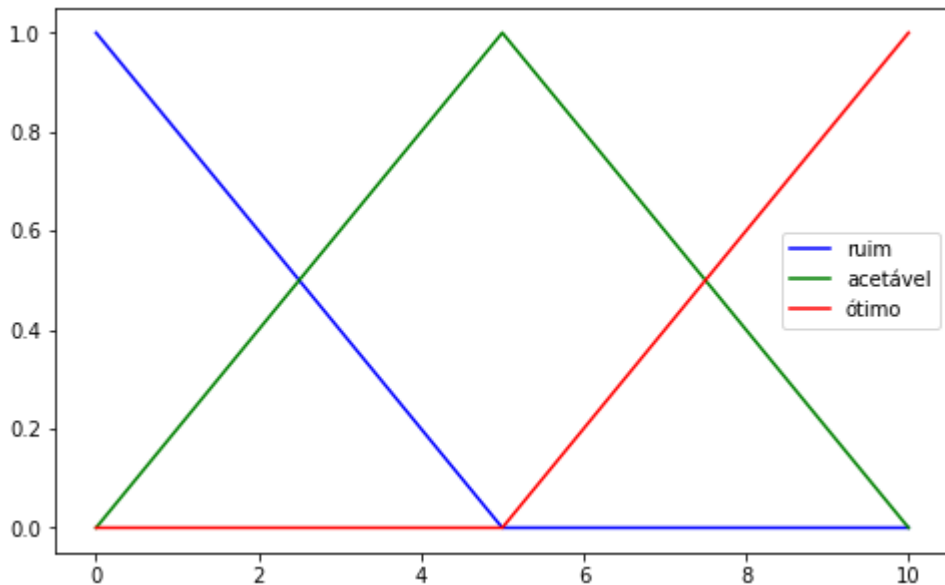


## Gorjeta

```
In [57]:  y_gorjeta_baixa = fuzz.trimf(x_gorjeta, [0,0,10])
          y_gorjeta_media = fuzz.trimf(x_gorjeta, [0,10,20])
          y_gorjeta_alta = fuzz.trimf(x_gorjeta, [10,20,20])
```

```
In [58]:  fig, ax = plt.subplots(figsize=(8,5))
          ax.plot(x_gorjeta, y_gorjeta_baixa, 'b', label='baixa')
          ax.plot(x_gorjeta, y_gorjeta_media, 'g', label='média')
          ax.plot(x_gorjeta, y_gorjeta_alta, 'r', label='alta')
          ax.legend();
```
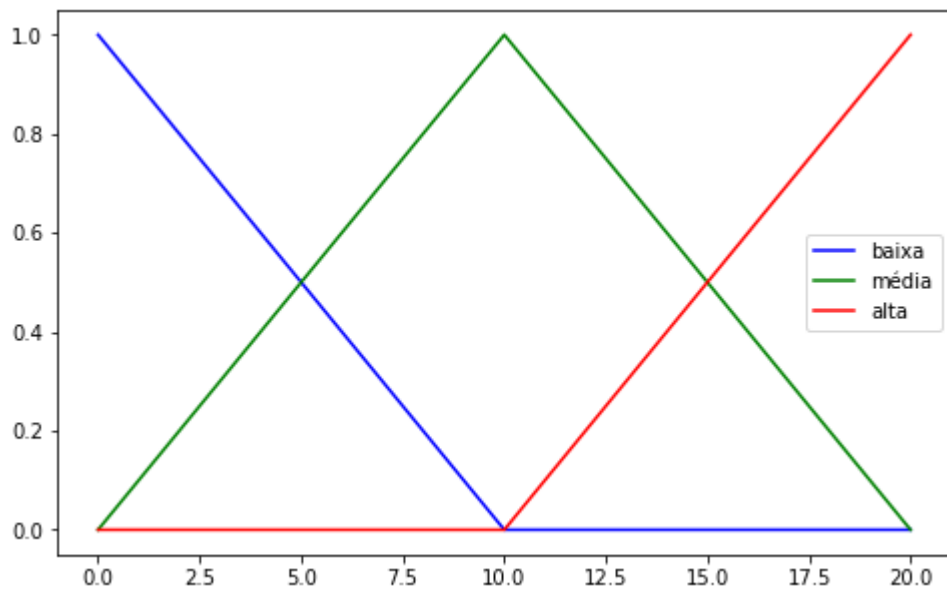
## Entradas (inputs)

```
In [67]:  comida_nivel_ruim = fuzz.interp_membership(x_comida, y_comida_ruim, 8.0)
          comida_nivel_boa = fuzz.interp_membership(x_comida, y_comida_boa, 8.0)
          comida_nivel_saborosa = fuzz.interp_membership(x_comida, y_comida_saborosa, 8.0)
```

```
In [69]:   comida_nivel_ruim, comida_nivel_boa, comida_nivel_saborosa
```

```
Out[69]:  (0.0, 0.4, 0.6)
```

```
In [70]:  servico_nivel_ruim = fuzz.interp_membership(x_servico, y_servico_ruim, 6.5)
          servico_nivel_aceitavel = fuzz.interp_membership(x_servico, y_servico_aceitavel, 6.5)
          servico_nivel_otimo = fuzz.interp_membership(x_servico, y_servico_otimo, 6.5)
```

```
In [71]:  servico_nivel_ruim, servico_nivel_aceitavel, servico_nivel_otimo
```

```
Out[71]:  (0.0, 0.7, 0.30000000000000004)
```

## Regras

```
In [72]:  np.fmax(10,5)
```

```
Out[72]:  10
```

```
In [73]:  np.fmin(10,5)
```

```
Out[73]:  5
```

```
In [77]:  np.fmax(5, [3,4,5,6])
```

```
Out[77]:  array([5, 5, 5, 6])
```

```
In [78]:  np.fmin(5, [3,4,5,6])
```

```
Out[78]:   array([3, 4, 5, 5])
```

## Regra 1

- Se a qualidade da comida for ruim ou o serviço for ruim então a gorjeta será baixa

```
In [79]:   comida_nivel_ruim, servico_nivel_ruim
```

```
Out[79]:   (0.0, 0.0)
```

```
In [81]:   ativacao_regra1 = np.fmax(comida_nivel_ruim, servico_nivel_ruim)
           ativacao_regra1
```

```
Out[81]:   0.0
```

```
In [82]:   ativacao_gorjeta_baixa = np.fmin(ativacao_regra1, y_gorjeta_baixa)
           ativacao_gorjeta_baixa
```

```
Out[82]:   array([0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0., 0.,
                  0., 0., 0., 0.])
```

## Regra 2

- Se o serviço for aceitável então a gorjeta será média

```
In [83]:   servico_nivel_aceitavel
```

```
Out[83]:   0.7
```

```
In [84]:   y_gorjeta_media
```

```
Out[84]:   array([0. , 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1. , 0.9, 0.8,
                  0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1, 0. ])
```

```
In [86]:   ativacao_gorjeta_media = np.fmin(servico_nivel_aceitavel, y_gorjeta_media)
           ativacao_gorjeta_media
```

```
Out[86]:   array([0. , 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.7, 0.7, 0.7, 0.7, 0.7,
                  0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1, 0. ])
```

## Regra 3

- Se a qualidade da comida for saborosa ou o serviço for bom/ótimo então a gorjeta será alta

```
In [87]:   servico_nivel_otimo, comida_nivel_saborosa
```

```
Out[87]:   (0.30000000000000004, 0.6)
```

```
In [88]:   ativacao_regra3 =np.fmax(servico_nivel_otimo, comida_nivel_saborosa)
           ativacao_regra3
```

```
Out[88]:   0.6
```

```
In [89]:  ativacao_gorjeta_alta = np.fmin(ativacao_regra3, y_gorjeta_alta)
          ativacao_gorjeta_alta

Out[89]:  array([0. , 0. , 0. , 0. , 0. , 0. , 0. , 0. , 0. , 0. , 0. , 0.1, 0.2,
                 0.3, 0.4, 0.5, 0.6, 0.6, 0.6, 0.6, 0.6])
```

## Gráfico com as intersecções

```
In [90]:  x_gorjeta

Out[90]:  array([ 0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11, 12, 13, 14, 15, 16,
                 17, 18, 19, 20])
```

```
In [91]:  x_gorjeta0 = np.zeros_like(x_gorjeta)
          x_gorjeta0

Out[91]:  array([0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0])
```

```
In [92]:  x_gorjeta.shape, x_gorjeta0.shape

Out[92]:  ((21,), (21,))
```

```
In [96]:  fig, ax = plt.subplots(figsize=(8,5))
          ax.plot(x_gorjeta, y_gorjeta_baixa, 'b', label='baixa')
          ax.fill_between(x_gorjeta, x_gorjeta0, ativacao_gorjeta_baixa, facecolor='b')
          ax.plot(x_gorjeta, y_gorjeta_media, 'g', label='média')
          ax.fill_between(x_gorjeta, x_gorjeta0, ativacao_gorjeta_media, facecolor='g')
          ax.plot(x_gorjeta, y_gorjeta_alta, 'r', label='alta')
          ax.fill_between(x_gorjeta, x_gorjeta0, ativacao_gorjeta_alta, facecolor='r')
          ax.set_title('saídas interligadas')
          ax.legend();
```
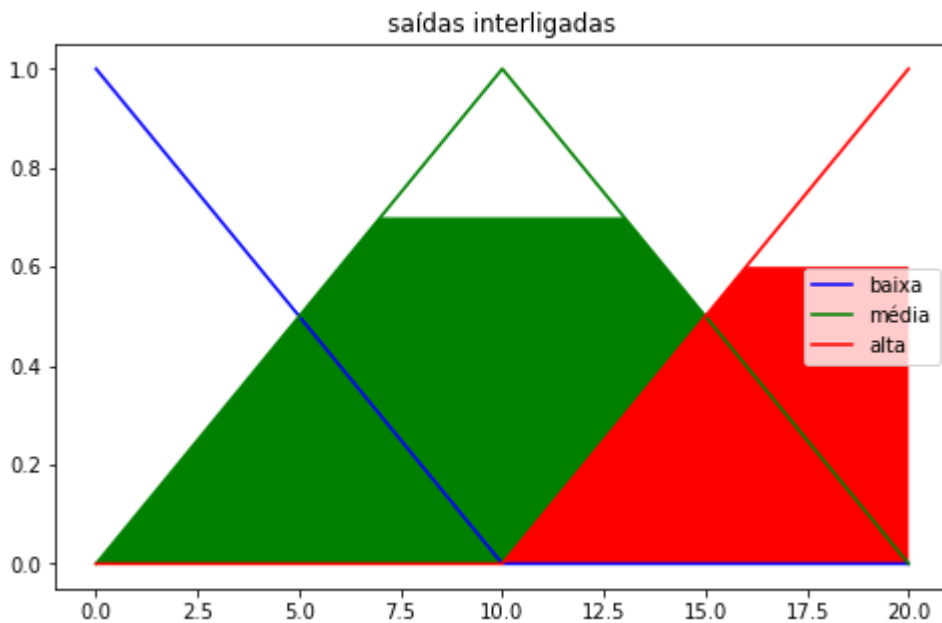


## Defuzzificação

- centroid (centroid)
- bisector (bisector)

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

```
In [97]: controle = np.fmax(ativacao_gorjeta_baixa, np.fmax(ativacao_gorjeta_media, ativacao_go
         controle
```

```
Out[97]: array([0. , 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.7, 0.7, 0.7, 0.7, 0.7,
                0.7, 0.6, 0.5, 0.6, 0.6, 0.6, 0.6, 0.6])
```

```
In [98]: gorjeta = fuzz.defuzz(x_gorjeta, controle, 'centroid')
         #gorjeta = fuzz.defuzz(x_gorjeta, controle, 'bisector')
         #gorjeta = fuzz.defuzz(x_gorjeta, controle, 'mom')
         #gorjeta = fuzz.defuzz(x_gorjeta, controle, 'som')
         #gorjeta = fuzz.defuzz(x_gorjeta, controle, 'lom')
         gorjeta
```

```
Out[98]: 11.287037037037038
```

```
In [100…  gorjeta_ativacao = fuzz.interp_membership(x_gorjeta, controle, gorjeta)
```

```
In [101…  fig, ax = plt.subplots(figsize=(8,5))
          ax.plot(x_gorjeta, y_gorjeta_baixa, 'b', label='baixa')
          ax.plot(x_gorjeta, y_gorjeta_media, 'g', label='média')
          ax.plot(x_gorjeta, y_gorjeta_alta, 'r', label='alta')
          ax.fill_between(x_gorjeta, x_gorjeta0, controle, facecolor='purple')
          ax.plot([gorjeta, gorjeta], [0, gorjeta_ativacao], 'black')
          ax.set_title('defuzificação')
          ax.legend();
```