Mandami Fuzzy Inference Example

May 18, 2023

[1]:
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#Example extracted from https://pythonhosted.org/scikit-fuzzy/auto_examples/
 ↪plot_tipping_problem.html#example-plot-tipping-problem-py
# The scikit-fuzzy tool must be installed -> https://pythonhosted.org/
 ↪scikit-fuzzy/install.html
import numpy as np
import skfuzzy as fuzz
import matplotlib.pyplot as plt

# Generate universe variables
#   * Quality and service on subjective ranges [0, 10]
#   * Tip has a range of [0, 25]
x_qual = np.arange(0, 11, 1)
x_serv = np.arange(0, 11, 1)
x_tip  = np.arange(0, 26, 1)
#x_qual = np.linspace(0,10,101)
#x_serv = np.linspace(0,10,101)
#x_tip  = np.linspace(0,25,251)

# Generate fuzzy membership functions
qual_lo = fuzz.trimf(x_qual, [0, 0, 5])
qual_md = fuzz.trimf(x_qual, [0, 5, 10])
qual_hi = fuzz.trimf(x_qual, [5, 10, 10])
serv_lo = fuzz.trimf(x_serv, [0, 0, 5])
serv_md = fuzz.trimf(x_serv, [0, 5, 10])
serv_hi = fuzz.trimf(x_serv, [5, 10, 10])
tip_lo = fuzz.trimf(x_tip, [0, 0, 13])
tip_md = fuzz.trimf(x_tip, [0, 13, 25])
tip_hi = fuzz.trimf(x_tip, [13, 25, 25])
print(qual_lo)
print(qual_md)
print(qual_hi)

# Visualize these universes and membership functions
fig, (ax0, ax1, ax2) = plt.subplots(nrows=3, figsize=(8, 9))

ax0.plot(x_qual, qual_lo, 'b', linewidth=1.5, label='Bad')
ax0.plot(x_qual, qual_md, 'g', linewidth=1.5, label='Decent')
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ax0.plot(x_qual, qual_hi, 'r', linewidth=1.5, label='Great')
ax0.set_title('Food quality')
ax0.legend()

ax1.plot(x_serv, serv_lo, 'b', linewidth=1.5, label='Poor')
ax1.plot(x_serv, serv_md, 'g', linewidth=1.5, label='Acceptable')
ax1.plot(x_serv, serv_hi, 'r', linewidth=1.5, label='Amazing')
ax1.set_title('Service quality')
ax1.legend()

ax2.plot(x_tip, tip_lo, 'b', linewidth=1.5, label='Low')
ax2.plot(x_tip, tip_md, 'g', linewidth=1.5, label='Medium')
ax2.plot(x_tip, tip_hi, 'r', linewidth=1.5, label='High')
ax2.set_title('Tip amount')
ax2.legend()

# Turn off top/right axes
for ax in (ax0, ax1, ax2):
    ax.spines['top'].set_visible(False)
    ax.spines['right'].set_visible(False)
    ax.get_xaxis().tick_bottom()
    ax.get_yaxis().tick_left()

plt.tight_layout()
```

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Intel MKL WARNING: Support of Intel(R) Streaming SIMD Extensions 4.2 (Intel(R)
SSE4.2) enabled only processors has been deprecated. Intel oneAPI Math Kernel
Library 2025.0 will require Intel(R) Advanced Vector Extensions (Intel(R) AVX)
instructions.
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Library 2025.0 will require Intel(R) Advanced Vector Extensions (Intel(R) AVX)
instructions.
[1.  0.8 0.6 0.4 0.2 0.  0.  0.  0.  0.  0. ]
[0.  0.2 0.4 0.6 0.8 1.  0.8 0.6 0.4 0.2 0. ]
[0.  0.  0.  0.  0.  0.  0.2 0.4 0.6 0.8 1. ]
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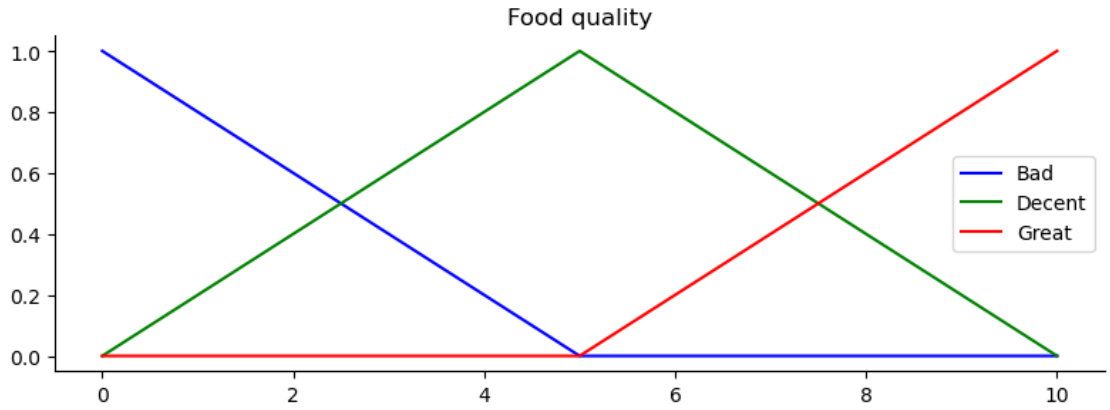

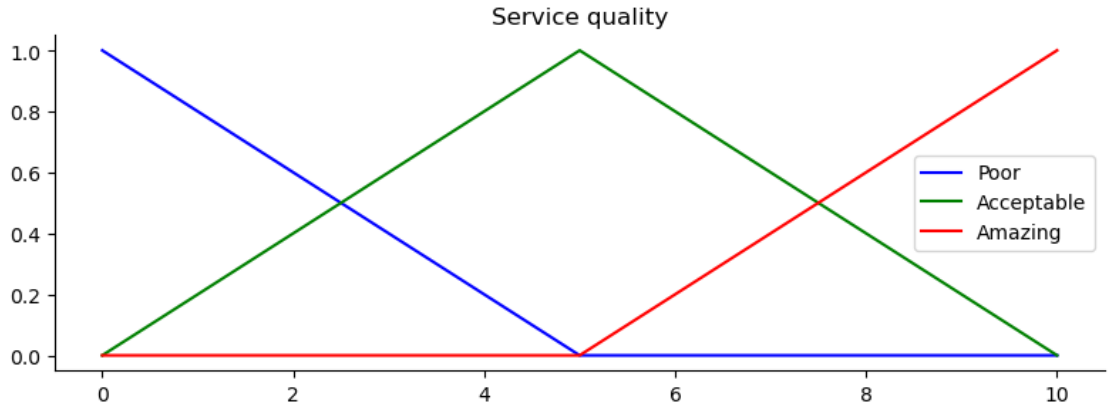

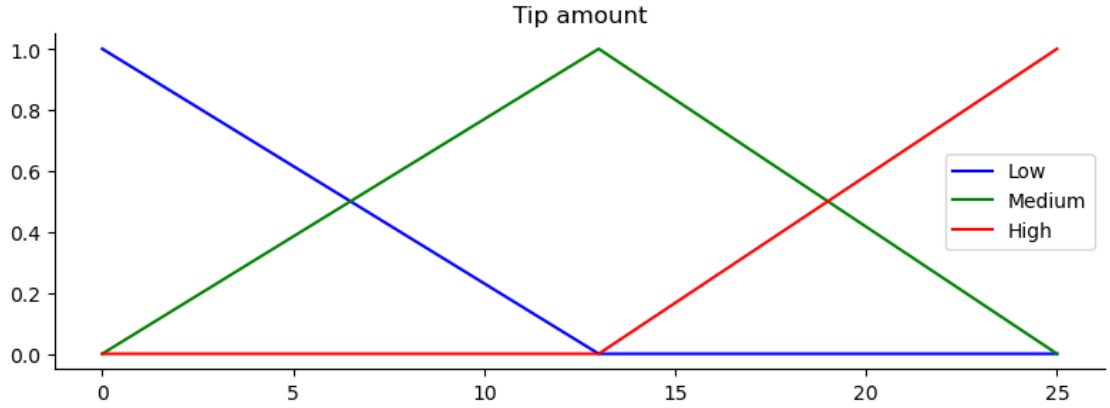

[2]:
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#Rule Base
# If the food is bad OR the service is poor, then the tip will be low
# If the service is acceptable, then the tip will be medium
# If the food is great OR the service is amazing, then the tip will be high.



# We need the activation of our fuzzy membership functions at these values.
# This is what fuzz.interp_membership exists for!
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qual_level_lo = fuzz.interp_membership(x_qual, qual_lo, 6.5)
qual_level_md = fuzz.interp_membership(x_qual, qual_md, 6.5)
qual_level_hi = fuzz.interp_membership(x_qual, qual_hi, 6.5)

serv_level_lo = fuzz.interp_membership(x_serv, serv_lo, 9.8)
serv_level_md = fuzz.interp_membership(x_serv, serv_md, 9.8)
serv_level_hi = fuzz.interp_membership(x_serv, serv_hi, 9.8)

# Now we take our rules and apply them. Rule 1 concerns bad food OR service.
#If the food is bad OR the service is poor, then the tip will be low

# The OR operator means we take the maximum of these two.
active_rule1 = np.fmax(qual_level_lo, serv_level_lo)
print("First Rule Antecedent Firing Strength")
print(active_rule1)

# Now we apply this by clipping the top off the corresponding output
# membership function with `np.fmin`
tip_activation_lo = np.fmin(active_rule1, tip_lo)  # removed entirely to 0

# For rule 2 we connect acceptable service to medium tipping
# If the service is acceptable, then the tip will be medium
tip_activation_md = np.fmin(serv_level_md, tip_md)
print("Second Rule Antecedent Firing Strength")
print(serv_level_md)
#print(tip_activation_md)

# For rule 3 we connect high service OR high food with high tipping
# If the food is great OR the service is amazing, then the tip will be high.
active_rule3 = np.fmax(qual_level_hi, serv_level_hi)
tip_activation_hi = np.fmin(active_rule3, tip_hi)
tip0 = np.zeros_like(x_tip)
print("Third Rule Antecedent Firing Strength")
print(active_rule3)

# Visualize this
fig, ax0 = plt.subplots(figsize=(8, 3))

ax0.fill_between(x_tip, tip0, tip_activation_lo, facecolor='b', alpha=0.7)
ax0.plot(x_tip, tip_lo, 'b', linewidth=0.5, linestyle='--', )
ax0.fill_between(x_tip, tip0, tip_activation_md, facecolor='g', alpha=0.7)
ax0.plot(x_tip, tip_md, 'g', linewidth=0.5, linestyle='--')
ax0.fill_between(x_tip, tip0, tip_activation_hi, facecolor='r', alpha=0.7)
ax0.plot(x_tip, tip_hi, 'r', linewidth=0.5, linestyle='--')
ax0.set_title('Output membership activity')

#Turn off top/right axes
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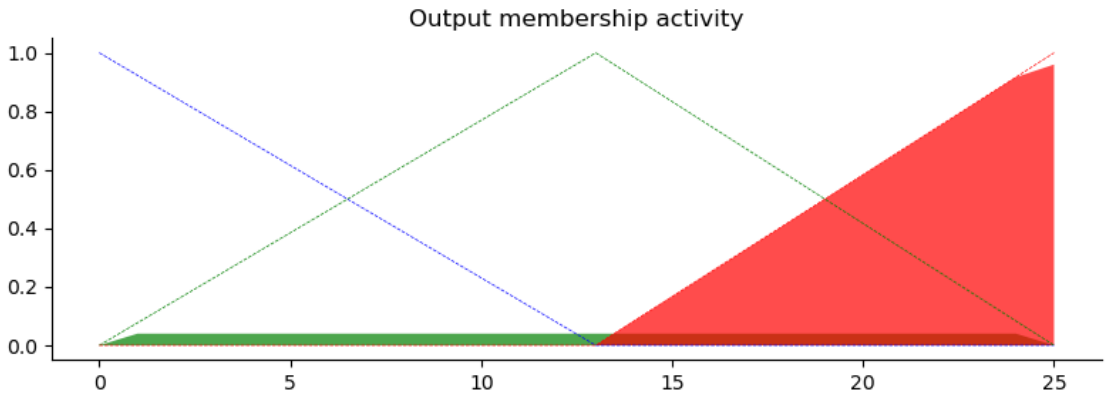
for ax in (ax0,):
    ax.spines['top'].set_visible(False)
    ax.spines['right'].set_visible(False)
    ax.get_xaxis().tick_bottom()
    ax.get_yaxis().tick_left()

plt.tight_layout()
```

```
First Rule Antecedent Firing Strength
0.0
Second Rule Antecedent Firing Strength
0.03999999999999987
Third Rule Antecedent Firing Strength
0.9600000000000002
```



[3]:
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# Aggregate all three output membership functions together
aggregated = np.fmax(tip_activation_lo,
                     np.fmax(tip_activation_md, tip_activation_hi))

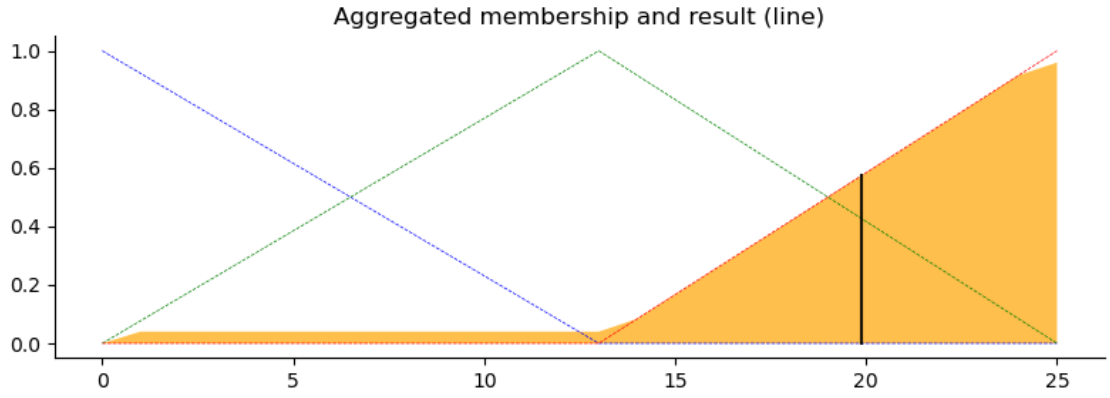
# Calculate defuzzified result
tip = fuzz.defuzz(x_tip, aggregated, 'centroid')
tip_activation = fuzz.interp_membership(x_tip, aggregated, tip)  # for plot


# Visualize this
fig, ax0 = plt.subplots(figsize=(8, 3))

ax0.plot(x_tip, tip_lo, 'b', linewidth=0.5, linestyle='--', )
ax0.plot(x_tip, tip_md, 'g', linewidth=0.5, linestyle='--')
ax0.plot(x_tip, tip_hi, 'r', linewidth=0.5, linestyle='--')
ax0.fill_between(x_tip, tip0, aggregated, facecolor='Orange', alpha=0.7)
ax0.plot([tip, tip], [0, tip_activation], 'k', linewidth=1.5, alpha=0.9)
ax0.set_title('Aggregated membership and result (line)')
```

```
# Turn off top/right axes
for ax in (ax0,):
    ax.spines['top'].set_visible(False)
    ax.spines['right'].set_visible(False)
    ax.get_xaxis().tick_bottom()
    ax.get_yaxis().tick_left()

plt.tight_layout()
```



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