```
In [ ]: !pip install scikit-fuzzy
```

Fuzzy Logic: Grading Student Performance

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Fuzzy Logic Grading System

```
In [97]:
import numpy as np
import pandas as pd
import seaborn as sns
import skfuzzy as fuzz

from skfuzzy import control as ctrl
from random import choice
from collections import defaultdict, namedtuple
from pprint import pprint

from IPython.display import display

sns.set()
```

Project Evaluation Attributes

```
In [33]:
project_features = dict(
    documentation=['excellent', 'good', 'satisfying', 'moderate', 'limited', 'bad'],
    presentation=['excellent', 'very_good', 'good', 'average', 'fair', 'bad'],
    security_auth=['excellent', 'very_good', 'good', 'average', 'fair', 'bad'],
    functionality=['excellent', 'very_good', 'good', 'average', 'fair', 'bad'],
    design_ui=['excellent', 'very_good', 'good', 'average', 'fair', 'bad'],
    modularity=['very_high', 'high', 'medium', 'low', 'very_low', 'nil']
)
```

Dataset

```
In [49]:
MAX_STUDENTS = 50
MAX_EVALUATORS = 3
```

```
In [57]:
dataset = {}

for evaluator in range(MAX_EVALUATORS):
    df = pd.DataFrame(data={
                        feat: [choice(attrs) for _ in range(MAX_STUDENTS)]
                        for feat, attrs in project_features.items()
                    }, index=[f'student_{num+1:02}' for num in range(MAX_STUDENTS)], dtype ="category")

    dataset[f'evaluator_{evaluator:02}'] = df.copy()
```

```
In [58]: dataset.keys()
Out[58]: dict_keys(['evaluator_00', 'evaluator_01', 'evaluator_02'])
```

```
In [68]:
for evaluator, data in dataset.items():
    print(f"Data for {evaluator}")
    display(data.info())
    print()
```

```
Data for evaluator_00
<class 'pandas.core.frame.DataFrame'>
Index: 50 entries, student_01 to student_50
Data columns (total 6 columns):
 #   Column         Non-Null Count  Dtype
---  ------         --------------  -----
 0   documentation  50 non-null     category
 1   presentation   50 non-null     category
 2   security_auth  50 non-null     category
 3   functionality  50 non-null     category
 4   design_ui      50 non-null     category
 5   modularity     50 non-null     category
dtypes: category(6)
memory usage: 1.9+ KB

None

Data for evaluator_01
<class 'pandas.core.frame.DataFrame'>
Index: 50 entries, student_01 to student_50
Data columns (total 6 columns):
 #   Column         Non-Null Count  Dtype
---  ------         --------------  -----
 0   documentation  50 non-null     category
 1   presentation   50 non-null     category
 2   security_auth  50 non-null     category
 3   functionality  50 non-null     category
 4   design_ui      50 non-null     category
 5   modularity     50 non-null     category
dtypes: category(6)
memory usage: 1.9+ KB

None

Data for evaluator_02
<class 'pandas.core.frame.DataFrame'>
Index: 50 entries, student_01 to student_50
Data columns (total 6 columns):
 #   Column         Non-Null Count  Dtype
---  ------         --------------  -----
 0   documentation  50 non-null     category
 1   presentation   50 non-null     category
 2   security_auth  50 non-null     category
 3   functionality  50 non-null     category
 4   design_ui      50 non-null     category
 5   modularity     50 non-null     category
dtypes: category(6)
memory usage: 1.9+ KB

None
```

```
In [67]:
for evaluator, data in dataset.items():
    print(f"Data for {evaluator}")
    display(data.head())
    print()
```

Data for evaluator_00

	documentation	presentation	security_auth	functionality	design_ui	modularity
student_01	bad	very_good	bad	bad	fair	high
student_02	satisfying	average	bad	fair	good	very_low
student_03	excellent	bad	excellent	good	good	medium
student_04	satisfying	good	average	very_good	bad	medium
student_05	moderate	average	bad	bad	bad	medium

Data for evaluator_01

	documentation	presentation	security_auth	functionality	design_ui	modularity
student_01	limited	fair	excellent	average	very_good	low
student_02	limited	excellent	bad	good	very_good	very_low
student_03	good	average	fair	average	good	very_low
student_04	good	fair	very_good	fair	good	medium
student_05	moderate	average	bad	average	good	low

Data for evaluator_02

	documentation	presentation	security_auth	functionality	design_ui	modularity
student_01	good	excellent	very_good	excellent	very_good	high
student_02	bad	fair	bad	bad	good	high
student_03	limited	excellent	fair	good	bad	high
student_04	bad	excellent	average	fair	excellent	nil
student_05	satisfying	average	very_good	excellent	average	low

Fuzzy Logic

```
In [3]:
def get_tri_vals(vals, x_min=1, x_max=6):
    start_val = vals[0]
    end_val = vals[-1]
    max_point, max_x = max(vals), vals.index(max(vals))
    max_x += 1

    # x = (y - y1)*(x2 - x1)/(y2 - y1) + x1

    # (x1    , y1        ), (x2    , y2       )
    # (x_min, start_val), (max_x, max_point)
    line_one_fun = lambda y: (y - start_val) * (max_x - x_min) / (max_point - start_val) + x_min

    # (x1    , y1        ), (x2    , y2       )
    # (max_x, max_point), (x_max, end_val)
    line_two_fun = lambda y: (y - max_point) * (x_max - max_x) / (end_val - max_point) + max_x

    if max_point == start_val:
        x_left = x_min
    else:
        x_left = line_one_fun(0)

    if end_val == max_point:
        x_right = x_max
    else:
        x_right = line_two_fun(0)

    return [x_left, max_x, x_right]
```

```
In [4]: get_tri_vals([1, 0.8, 0.6, 0.4, 0.2, 0])
Out[4]: [1, 1, 6.0]
```

```
In [5]:
def get_fuzzy_set_grid(val_min, val_max, grid_size=6):

    init_vals = np.linspace(val_max, val_min, grid_size)
    grid_vals = np.array([init_vals])

    for val in np.linspace(val_max, val_min, grid_size)[1:]:
        init_vals = init_vals[:-1]
        init_vals = np.concatenate((np.array([val]), init_vals))

        grid_vals = np.append(grid_vals, np.array([init_vals.copy()]), axis=0)

    return grid_vals
```

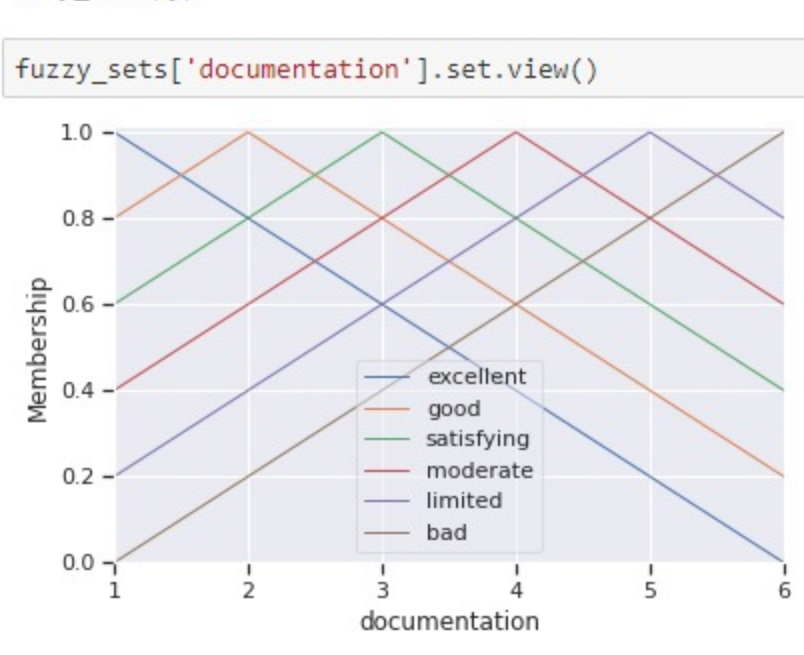
```
In [6]: get_fuzzy_set_grid(0, 1, grid_size=6)
Out[6]: array([[1. , 0.8, 0.6, 0.4, 0.2, 0. ],
               [0.8, 1. , 0.8, 0.6, 0.4, 0.2],
               [0.6, 0.8, 1. , 0.8, 0.6, 0.4],
               [0.4, 0.6, 0.8, 1. , 0.8, 0.6],
               [0.2, 0.4, 0.6, 0.8, 1. , 0.8],
               [0. , 0.2, 0.4, 0.6, 0.8, 1. ]])
```

```
In [74]: FuzzySet = namedtuple('FuzzySet', field_names=['attrs', 'set'])
```

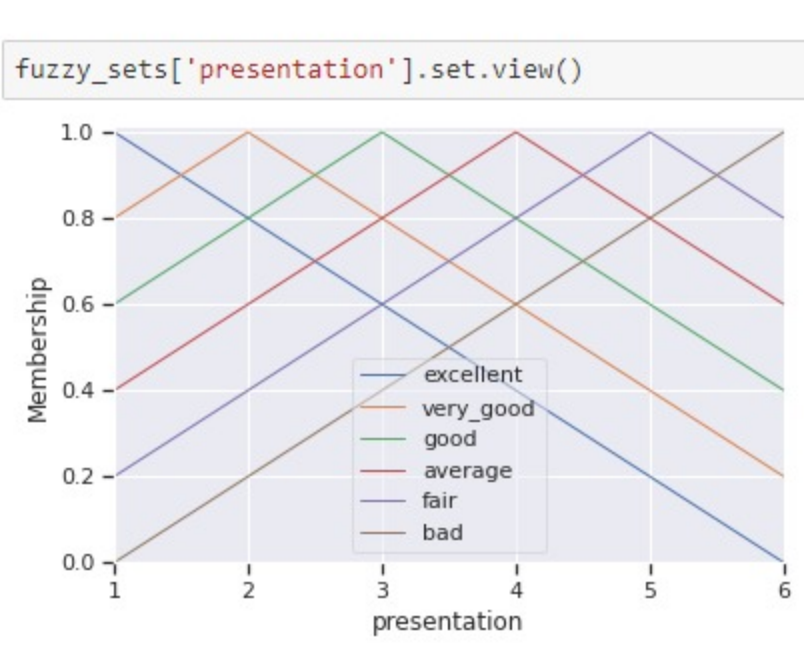
```
In [76]:
fuzzy_sets = defaultdict(dict)
for proj_feat, proj_attrs in project_features.items():
    num_terms = len(proj_attrs)

    fuzzy_grid = get_fuzzy_set_grid(0, 1, grid_size=num_terms)

    # create the fuzzy set
    proj_set = ctrl.Antecedent(np.arange(1, num_terms + 1, 1), proj_feat)

    fuzzy_sets[proj_feat] = FuzzySet(proj_attrs, proj_set)

    # assign the membership function
    for idx, attr in enumerate(fuzzy_sets[proj_feat].attrs):
        fuzzy_sets[proj_feat].set[attr] = fuzz.trimf(fuzzy_sets[proj_feat].set.universe, get_tri_vals(list(fuzzy_grid[idx, :])))
```

```
In [108]: fuzzy_sets
Out[108]: defaultdict(dict,
            {'design_ui': FuzzySet(attrs=['excellent', 'very_good', 'good', 'average', 'fair', 'bad'], set=Antecedent: design_u
i),
             'documentation': FuzzySet(attrs=['excellent', 'good', 'satisfying', 'moderate', 'limited', 'bad'], set=Antecedent:
documentation),
             'functionality': FuzzySet(attrs=['excellent', 'very_good', 'good', 'average', 'fair', 'bad'], set=Antecedent: func
tionality),
             'modularity': FuzzySet(attrs=['very_high', 'high', 'medium', 'low', 'very_low', 'nil'], set=Antecedent: modularit
y),
             'presentation': FuzzySet(attrs=['excellent', 'very_good', 'good', 'average', 'fair', 'bad'], set=Antecedent: prese
ntation),
             'security_auth': FuzzySet(attrs=['excellent', 'very_good', 'good', 'average', 'fair', 'bad'], set=Antecedent: secu
rity_auth)})
```

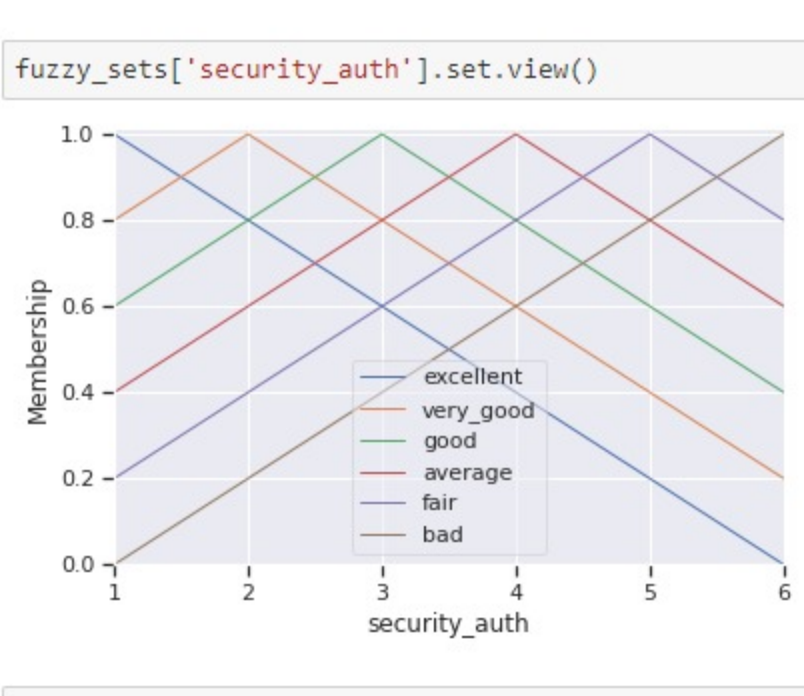
```
In [84]: fuzzy_sets['documentation'].set.view()
```



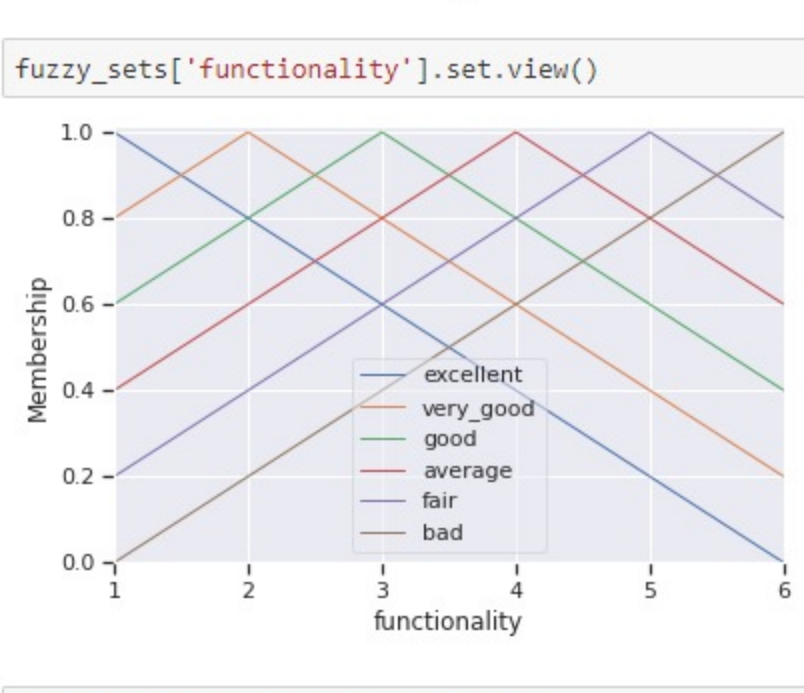

```
In [85]: fuzzy_sets['presentation'].set.view()
```



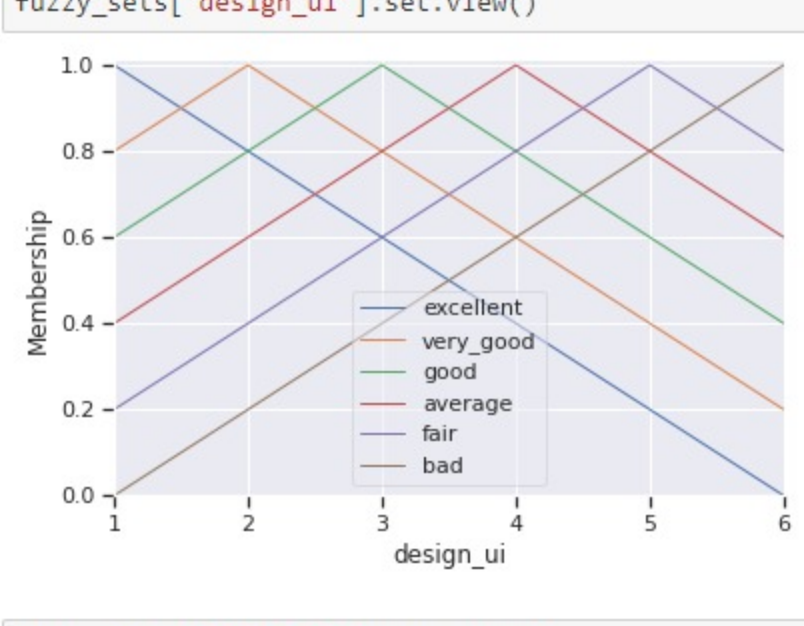

```
In [86]: fuzzy_sets['security_auth'].set.view()
```



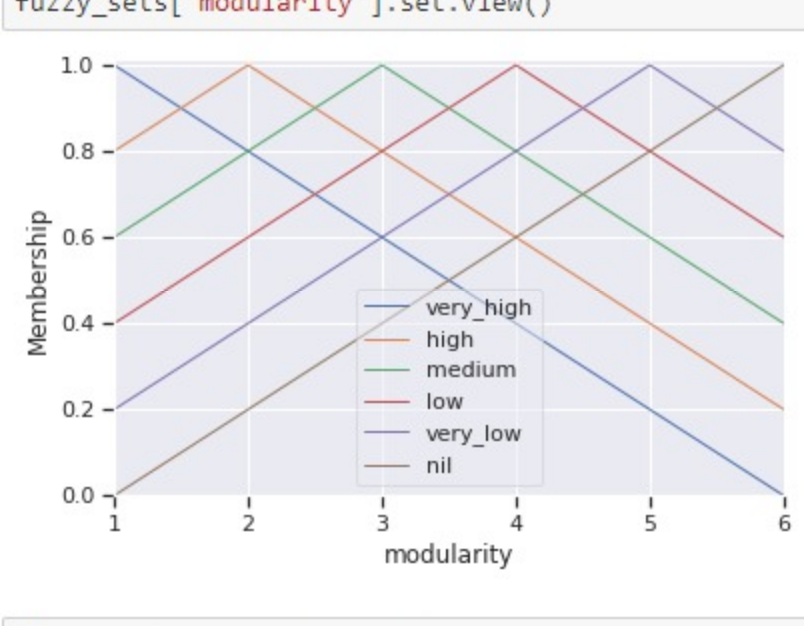

```
In [87]: fuzzy_sets['functionality'].set.view()
```




```
In [88]: fuzzy_sets['design_ui'].set.view()
```




```
In [89]: fuzzy_sets['modularity'].set.view()
```




```
In [94]:
ideal_performance_sets = {
    'documentation': fuzzy_sets['documentation'].set['excellent'].mf,
    'presentation': fuzzy_sets['presentation'].set['excellent'].mf,
    'security_auth': fuzzy_sets['security_auth'].set['excellent'].mf,
    'functionality': fuzzy_sets['functionality'].set['excellent'].mf,
    'modularity': fuzzy_sets['modularity'].set['very_high'].mf,
    'design_ui': fuzzy_sets['design_ui'].set['excellent'].mf
}
```

```
In [106]: pprint(ideal_performance_sets)

{'design_ui': array([1. , 0.8, 0.6, 0.4, 0.2, 0. ]),
 'documentation': array([1. , 0.8, 0.6, 0.4, 0.2, 0. ]),
 'functionality': array([1. , 0.8, 0.6, 0.4, 0.2, 0. ]),
 'modularity': array([1. , 0.8, 0.6, 0.4, 0.2, 0. ]),
 'presentation': array([1. , 0.8, 0.6, 0.4, 0.2, 0. ]),
 'security_auth': array([1. , 0.8, 0.6, 0.4, 0.2, 0. ])}
```

Evaluating Student Performance

```
In [110]: dataset.keys()
Out[110]: dict_keys(['evaluator_00', 'evaluator_01', 'evaluator_02'])
```

Let's see how it works out for one student

```
In [170]:
def create_student_df(student_idx, dataset):
    student_remarks = pd.DataFrame([dataset[evaluator].iloc[student_idx] for evaluator in dataset.keys()]).T
    student_remarks.columns=dataset.keys()

    return student_remarks
```

```
In [199]:
def evaluate_student(student_remarks, debug=False):
    performance_metric = {'total_dist': 0}
    for idx, evaluation in student_remarks.iterrows():
        if debug:
            print(evaluation.name)
        overall_opinion = np.array(list(map(lambda x: fuzzy_sets[evaluation.name].set[x].mf, evaluation.values))).min(axis=0)
        distance_from_ideal = np.abs(ideal_performance_sets[evaluation.name] - overall_opinion).sum()
        performance_metric[evaluation.name] = distance_from_ideal
        performance_metric['total_dist'] += distance_from_ideal

        if debug:
            print('overall opinion: ', overall_opinion)
            print('distance from ideal: ', distance_from_ideal)
            print()

    return performance_metric
```

```
In [200]:
student_evaluation = pd.DataFrame(data={eval_param: [] for eval_param in project_features.keys()})
student_evaluation['total_dist'] = []
for student_idx in range(0, MAX_STUDENTS):
    student_remarks = create_student_df(student_idx, dataset)
    display(student_remarks)

    print("\nEvaluation\n")

    evaluation = evaluate_student(student_remarks, debug=True)

    print(evaluation)
    print()

    student_evaluation.loc[f'student_{student_idx:02}'] = evaluation

    break # do only for one student

display(student_evaluation)
```

	evaluator_00	evaluator_01	evaluator_02
documentation	bad	limited	good
presentation	very_good	fair	excellent
security_auth	bad	excellent	very_good
functionality	bad	average	excellent
design_ui	fair	very_good	very_good
modularity	high	low	high

```
Evaluation

documentation
overall opinion:  [0.  0.2 0.4 0.6 0.4 0.2]
distance from ideal:  2.4000000000000004

presentation
overall opinion:  [0.2 0.4 0.6 0.4 0.2 0. ]
distance from ideal:  1.2000000000000002

security_auth
overall opinion:  [0.  0.2 0.4 0.4 0.2 0. ]
distance from ideal:  1.8

functionality
overall opinion:  [0.  0.2 0.4 0.4 0.2 0. ]
distance from ideal:  1.8

design_ui
overall opinion:  [0.2 0.4 0.6 0.6 0.4 0.2]
distance from ideal:  1.8

modularity
overall opinion:  [0.4 0.6 0.8 0.6 0.4 0.2]
distance from ideal:  1.5999999999999999

{'total_dist': 10.6, 'documentation': 2.4000000000000004, 'presentation': 1.2000000000000002, 'security_auth': 1.8, 'functional
ity': 1.8, 'design_ui': 1.8, 'modularity': 1.5999999999999999}
```

	documentation	presentation	security_auth	functionality	design_ui	modularity	total_dist
student_00	2.4	1.2	1.8	1.8	1.8	1.6	10.6

Now apply the same logic over all the student

```
In [201]:
student_evaluation = pd.DataFrame(data={eval_param: [] for eval_param in project_features.keys()})
student_evaluation['total_dist'] = []
for student_idx in range(0, MAX_STUDENTS):
    student_remarks = create_student_df(student_idx, dataset)
    evaluation = evaluate_student(student_remarks)
    student_evaluation.loc[f'student_{student_idx:02}'] = evaluation
```

```
In [231]: student_evaluation.describe().T
```

Out[231]:

	count	mean	std	min	25%	50%	75%	max
documentation	50.0	1.812	0.911970	0.0	1.20	1.8	2.40	3.6
presentation	50.0	1.752	0.874640	0.2	1.20	1.8	2.40	3.4
security_auth	50.0	1.936	0.794306	0.2	1.30	1.8	2.40	3.6
functionality	50.0	1.868	0.781009	0.2	1.35	1.8	2.40	3.4
design_ui	50.0	1.728	0.749160	0.2	1.20	1.8	2.40	3.4
modularity	50.0	1.912	0.919769	0.2	1.20	1.8	2.40	3.4
total_dist	50.0	11.008	2.179294	3.2	10.10	11.1	12.35	15.6

Display the ranking of students

```
In [203]: student_evaluation.sort_values('total_dist', ascending=True)
```

Out[203]:

	documentation	presentation	security_auth	functionality	design_ui	modularity	total_dist
student_41	1.2	0.2	0.2	0.2	1.2	0.2	3.2
student_49	0.8	2.2	1.2	2.4	0.2	0.2	7.0
student_27	1.8	0.2	1.8	0.8	1.8	1.2	7.6
student_33	1.2	1.2	1.2	2.4	0.8	0.8	7.6
student_08	1.2	1.2	1.2	1.8	1.2	1.2	7.8
student_44	1.2	2.4	1.8	0.4	0.8	1.8	8.4
student_16	2.4	1.2	1.8	1.8	0.4	1.2	8.8
student_14	2.4	1.8	2.8	0.8	0.8	0.4	9.0
student_26	0.4	0.4	2.4	1.8	2.4	1.8	9.2
student_17	0.8	1.2	1.6	2.8	1.2	1.8	9.4
student_23	0.0	1.2	1.8	2.4	1.8	2.4	9.6
student_05	1.8	0.8	1.8	1.2	1.8	2.4	9.8
student_36	1.2	2.8	1.8	1.8	1.2	1.2	10.0
student_46	2.4	0.4	2.8	1.8	1.2	1.8	10.4
student_39	1.2	2.4	2.4	1.8	0.8	1.8	10.4
student_37	1.8	0.4	1.2	2.4	2.8	1.8	10.4
student_24	1.8	1.2	3.4	0.4	1.8	1.8	10.4
student_06	2.4	2.4	1.2	0.8	2.4	1.2	10.4
student_48	2.4	0.8	2.8	2.2	1.2	1.2	10.6
student_00	2.4	1.2	1.8	1.8	1.8	1.6	10.6
student_38	2.4	1.8	0.4	1.8	2.4	1.8	10.6
student_02	1.2	1.8	1.2	2.2	2.8	1.8	11.0
student_31	3.2	0.4	2.4	1.8	0.8	2.4	11.0
student_42	1.8	1.2	2.4	2.8	2.4	0.4	11.0
student_11	2.2	2.8	0.4	2.4	0.8	2.4	11.0
student_35	1.8	2.8	1.2	1.2	0.8	3.4	11.2
student_19	0.4	1.8	1.6	3.4	1.8	2.4	11.4
student_34	3.2	1.2	0.2	1.2	2.4	3.2	11.4
student_13	1.6	0.8	2.4	1.8	1.6	3.2	11.4
student_03	2.4	1.2	1.6	1.8	1.8	2.8	11.6
student_10	1.2	1.8	2.4	1.8	2.4	2.4	12.0
student_12	2.4	2.4	1.8	1.8	1.8	1.8	12.0
student_28	0.2	2.8	2.4	2.4	1.8	2.4	12.0
student_45	2.4	3.4	2.4	1.2	1.8	0.8	12.0
student_21	1.8	2.8	1.8	1.8	0.8	3.2	12.2
student_29	1.2	2.8	1.8	0.8	2.8	2.8	12.2
student_07	1.2	2.8	1.2	2.8	1.8	2.4	12.2
student_30	1.8	2.4	3.2	3.4	1.2	0.4	12.4
student_20	1.2	1.2	3.2	1.2	2.4	3.2	12.4
student_22	0.4	1.8	2.4	1.8	3.2	2.8	12.4
student_40	3.2	1.2	1.2	1.8	2.4	2.8	12.6
student_09	3.4	1.8	2.4	3.2	1.2	0.8	12.8
student_15	2.4	2.2	2.8	0.8	1.8	2.8	12.8
student_32	1.8	3.4	1.6	2.4	3.4	0.4	13.0
student_01	2.8	1.2	3.6	2.8	1.2	1.8	13.4
student_43	0.2	2.4	2.8	3.4	2.2	2.4	13.4
student_18	2.8	2.8	1.8	1.8	2.4	1.8	13.4
student_04	2.2	2.8	2.4	1.8	2.8	2.2	14.2
student_47	3.4	1.8	2.4	2.4	1.8	3.4	15.2
student_25	3.6	2.4	2.4	1.8	2.0	3.4	15.6

```
In [208]:
[fuzzy_sets['documentation'].set['good'].mf,
 fuzzy_sets['presentation'].set['very_good'].mf,
 fuzzy_sets['security_auth'].set['very_good'].mf,
 fuzzy_sets['functionality'].set['very_good'].mf,
 fuzzy_sets['design_ui'].set['very_good'].mf,
 fuzzy_sets['modularity'].set['high'].mf]

Out[208]:
[array([0.8, 1. , 0.8, 0.6, 0.4, 0.2]),
 array([0.8, 1. , 0.8, 0.6, 0.4, 0.2]),
 array([0.8, 1. , 0.8, 0.6, 0.4, 0.2]),
 array([0.8, 1. , 0.8, 0.6, 0.4, 0.2]),
 array([0.8, 1. , 0.8, 0.6, 0.4, 0.2]),
 array([0.8, 1. , 0.8, 0.6, 0.4, 0.2])]
```

```
In [213]:
grading_dists = {
    'Ex': 6 * np.abs(fuzzy_grid[0, :] - fuzzy_grid[0, :]).sum(),
    'A+': 6 * np.abs(fuzzy_grid[0, :] - fuzzy_grid[1, :]).sum(),
    'A':  6 * np.abs(fuzzy_grid[0, :] - fuzzy_grid[2, :]).sum(),
    'B+': 6 * np.abs(fuzzy_grid[0, :] - fuzzy_grid[3, :]).sum(),
    'B':  6 * np.abs(fuzzy_grid[0, :] - fuzzy_grid[4, :]).sum(),
    'C':  6 * np.abs(fuzzy_grid[0, :] - fuzzy_grid[5, :]).sum()
}
```

```
In [216]:
sorted_grading_dists = sorted(grading_dists.items(), key=lambda x: x[1])
sorted_grading_dists

Out[216]:
[('Ex', 0.0),
 ('A+', 7.199999999999999),
 ('A', 12.0),
 ('B+', 16.8),
 ('B', 19.200000000000003),
 ('C', 21.6)]
```

```
In [222]: student_evaluation['grade'] = pd.cut(student_evaluation['total_dist'], bins=[gdist[1] for gdist in sorted_grading_dists] + [np.i
nf], labels=[gdist[0] for gdist in sorted_grading_dists])
```

display grades of students

```
In [228]: student_evaluation[['total_dist', 'grade']]
```

Out[228]:

	total_dist	grade
student_00	10.6	A+
student_01	13.4	A
student_02	11.0	A+
student_03	11.6	A+
student_04	14.2	A
student_05	9.8	A+
student_06	10.4	A+
student_07	12.2	A
student_08	7.8	A+
student_09	12.8	A
student_10	12.0	A
student_11	11.0	A+
student_12	12.0	A
student_13	11.4	A+
student_14	9.0	A+
student_15	12.8	A
student_16	8.8	A+
student_17	9.4	A+
student_18	13.4	A
student_19	11.4	A+
student_20	12.4	A
student_21	12.2	A
student_22	12.4	A
student_23	9.6	A+
student_24	10.4	A+
student_25	15.6	A
student_26	9.2	A+
student_27	7.6	A+
student_28	12.0	A
student_29	12.2	A
student_30	12.4	A
student_31	11.0	A+
student_32	13.0	A
student_33	7.6	A+
student_34	11.4	A+
student_35	11.2	A+
student_36	10.0	A+
student_37	10.4	A+
student_38	10.6	A+
student_39	10.4	A+
student_40	12.6	A
student_41	3.2	Ex
student_42	11.0	A+
student_43	13.4	A
student_44	8.4	A+
student_45	12.0	A
student_46	10.4	A+
student_47	15.2	A
student_48	10.6	A+
student_49	7.0	Ex

Display sorted Grades

```
In [232]: student_evaluation.sort_values('total_dist', ascending=True)[['total_dist', 'grade']]
```

Out[232]:

	total_dist	grade
student_41	3.2	Ex
student_49	7.0	Ex
student_27	7.6	A+
student_33	7.6	A+
student_08	7.8	A+
student_44	8.4	A+
student_16	8.8	A+
student_14	9.0	A+
student_26	9.2	A+
student_17	9.4	A+
student_23	9.6	A+
student_05	9.8	A+
student_36	10.0	A+
student_46	10.4	A+
student_39	10.4	A+
student_37	10.4	A+
student_24	10.4	A+
student_06	10.4	A+
student_48	10.6	A+
student_00	10.6	A+
student_38	10.6	A+
student_02	11.0	A+
student_31	11.0	A+
student_42	11.0	A+
student_11	11.0	A+
student_35	11.2	A+
student_19	11.4	A+
student_34	11.4	A+
student_13	11.4	A+
student_03	11.6	A+
student_10	12.0	A
student_12	12.0	A
student_28	12.0	A
student_45	12.0	A
student_21	12.2	A
student_29	12.2	A
student_07	12.2	A
student_30	12.4	A
student_20	12.4	A
student_22	12.4	A
student_40	12.6	A
student_09	12.8	A
student_15	12.8	A
student_32	13.0	A
student_01	13.4	A
student_43	13.4	A
student_18	13.4	A
student_04	14.2	A
student_47	15.2	A
student_25	15.6	A

Convert this notebook to pdf

```
In [233]:
%%capture
! apt update
! apt install texlive-xetex texlive-fonts-recommended texlive-generic-recommended
```

```
In [234]:
import subprocess
import shlex
```

Convert to pdf

```
In [235]:
s = subprocess.Popen(shlex.split(
    f'jupyter nbconvert /content/fuzzy-logic-grading-system.ipynb --to pdf'
    ), shell = False, stdout = subprocess.PIPE, stderr = subprocess.PIPE)
s.wait()
s.stdout.read()

Out[235]: b''
```

```
In [ ]:
```