10장. 차원 축소 (Dimension Reduction) 과제

In [1]:
```
!pip install seaborn
```

```
Requirement already satisfied: seaborn in c:\users\이준용\.conda\envs\data_mining\lib\site-packages (0.11.0)
Requirement already satisfied: pandas>=0.23 in c:\users\이준용\.conda\envs\data_mining\lib\site-packages (from seaborn) (1.1.3)
Requirement already satisfied: scipy>=1.0 in c:\users\이준용\.conda\envs\data_mining\lib\site-packages (from seaborn) (1.5.2)
Requirement already satisfied: matplotlib>=2.2 in c:\users\이준용\.conda\envs\data_mining\lib\site-packages (from seaborn) (3.3.2)
Requirement already satisfied: numpy>=1.15 in c:\users\이준용\.conda\envs\data_mining\lib\site-packages (from seaborn) (1.19.2)
Requirement already satisfied: pytz>=2017.2 in c:\users\이준용\.conda\envs\data_mining\lib\site-packages (from pandas>=0.23->seaborn) (2020.1)
Requirement already satisfied: python-dateutil>=2.7.3 in c:\users\이준용\.conda\envs\data_mining\lib\site-packages (from pandas>=0.23->seaborn) (2.8.
1)
Requirement already satisfied: cycler>=0.10 in c:\users\이준용\.conda\envs\data_mining\lib\site-packages (from matplotlib>=2.2->seaborn) (0.10.0)
Requirement already satisfied: certifi>=2020.06.20 in c:\users\이준용\.conda\envs\data_mining\lib\site-packages (from matplotlib>=2.2->seaborn) (2020.
6.20)
Requirement already satisfied: kiwisolver>=1.0.1 in c:\users\이준용\.conda\envs\data_mining\lib\site-packages (from matplotlib>=2.2->seaborn) (1.3.0)
Requirement already satisfied: pillow>=6.2.0 in c:\users\이준용\.conda\envs\data_mining\lib\site-packages (from matplotlib>=2.2->seaborn) (8.0.1)
Requirement already satisfied: pyparsing!=2.0.4,!=2.1.2,!=2.1.6,>=2.0.3 in c:\users\이준용\.conda\envs\data_mining\lib\site-packages (from matplotlib>
=2.2->seaborn) (2.4.7)
Requirement already satisfied: six>=1.5 in c:\users\이준용\.conda\envs\data_mining\lib\site-packages (from python-dateutil>=2.7.3->pandas>=0.23->seabo
rn) (1.15.0)
```

1. 데이터셋

In [2]:
```
import matplotlib.pyplot as plt
import os
from typing import List, Tuple
import csv
from scratch.linear_algebra import Vector, get_column
```

1.1 데이터셋 다운로드

In [3]:
```
import requests

dataset_path = os.path.join('data', 'wdbc.data')
if os.path.exists(dataset_path) is False:
    data = requests.get("https://archive.ics.uci.edu/ml/machine-learning-databases/breast-cancer-wisconsin/wdbc.data")

    with open(dataset_path, "w") as f:
      f.write(data.text)
```

1.2 데이터 파싱

In [4]:
```
def parse_cancer_row(row: List[str]) -> Tuple[Vector, int]:
    measurements = [float(value) for value in row[2:]]
    label = row[1]
    label = 1 if label == 'M' else 0
    return measurements, label
```

1.3 데이터 읽기

위스콘신 유방암 진단 데이터셋 (Wisconsin Breast Cancer Diagnostic dataset) https://www.kaggle.com/uciml/breast-cancer-wisconsin-data (https://www.kaggle.com/uciml/breast-cancer-wisconsin-data)

In [5]:
```
X_cancer : List[Vector] = []
y_cancer : List[int] = []
with open(dataset_path) as f:
    reader = csv.reader(f)
    for row in reader:
        x, y = parse_cancer_row(row)
        X_cancer.append(x)
        y_cancer.append(y)
```

In [6]:
```
print(X_cancer[0])
print(y_cancer[0])
```

```
[17.99, 10.38, 122.8, 1001.0, 0.1184, 0.2776, 0.3001, 0.1471, 0.2419, 0.07871, 1.095, 0.9053, 8.589, 153.4, 0.006399, 0.04904, 0.05373, 0.01587, 0.030
03, 0.006193, 25.38, 17.33, 184.6, 2019.0, 0.1622, 0.6656, 0.7119, 0.2654, 0.4601, 0.1189]
1
```

1.4 데이터 컬럼명

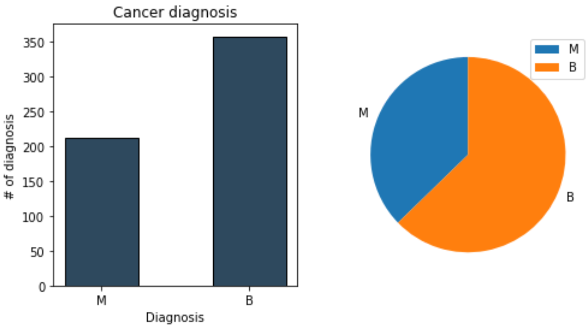
In [7]:
```
columns = [
    "radius_mean", "texture_mean", "perimeter_mean", "area_mean", "smoothness_mean",
    "compactness_mean", "concavity_mean", "points_mean", "symmetry_mean", "dimension_mean",
    "radius_se", "texture_se", "perimeter_se", "area_se", "smoothness_se",
    "compactness_se", "concavity_se", "points_se", "symmetry_se", "dimension_se",
    "radius_worst", "texture_worst", "perimeter_worst", "area_worst", "smoothness_worst",
    "compactness_worst", "concavity_worst", "points_worst", "symmetry_worst", "dimension_worst",
    ]
```

2. 데이터 탐색

2.1 클래스 비율 확인

In [8]:
```
from collections import defaultdict
label_type = defaultdict(int)
for y in y_cancer:
    label = 'M' if y == 1 else 'B'
    label_type[label] += 1
```

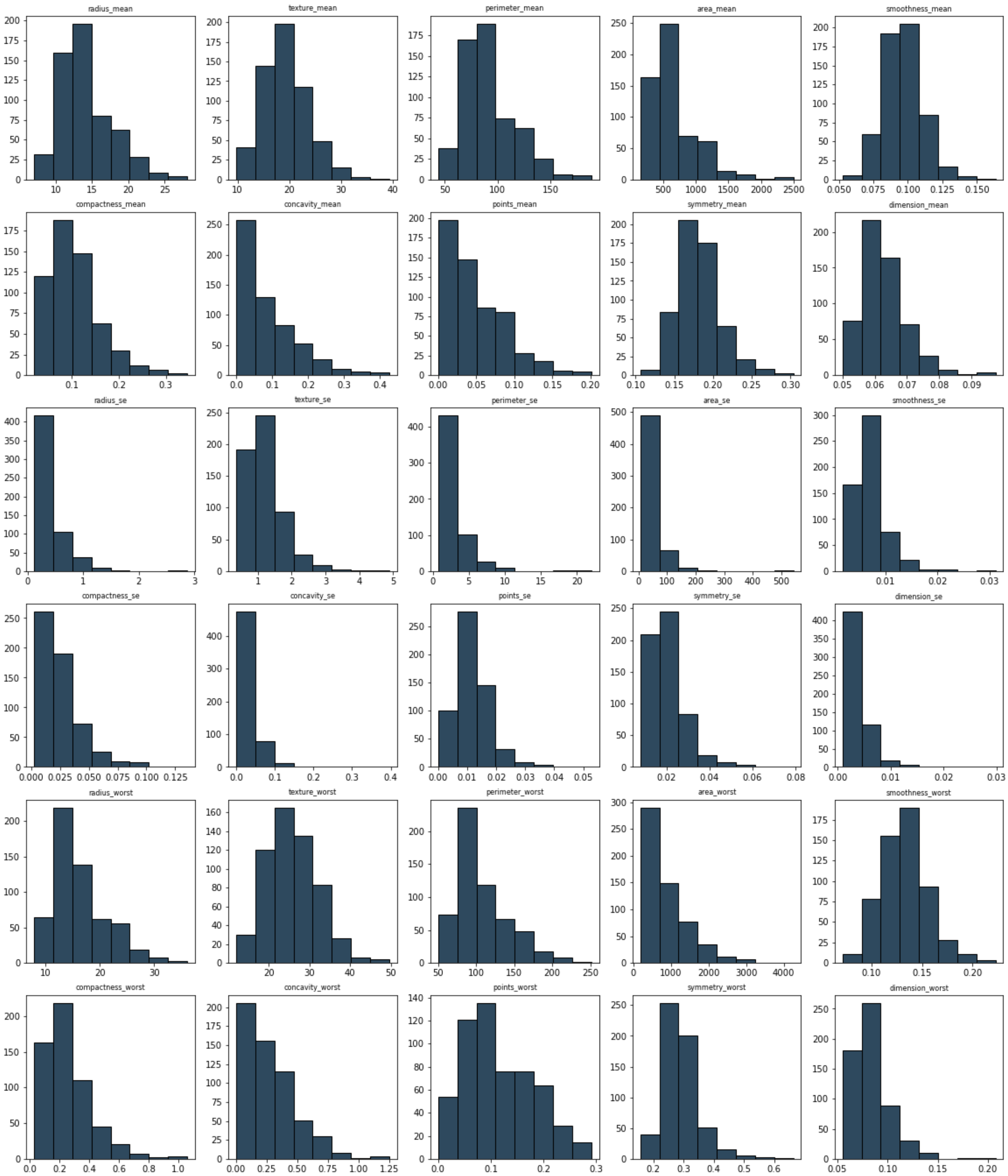
In [9]:
```
plt.figure(figsize=(8,4))
plt.subplot(1, 2, 1)
plt.bar(label_type.keys(),
        label_type.values(),
        0.5,
        facecolor="#2E495E",
        edgecolor=(0, 0, 0))                # Black edges for each bar

plt.xlabel("Diagnosis")
plt.ylabel("# of diagnosis")
plt.title("Cancer diagnosis")

plt.subplot(1, 2, 2)
pies = plt.pie(label_type.values(),
               labels=label_type.keys(),
               startangle=90)
plt.legend()
plt.show()
```



2.2 특징 별 히스토그램

In [10]:
```
from matplotlib import pyplot as plt
from typing import Dict

def draw_histogram(data: List[Vector],
                   column_names: List[str],
                   max_columns: int = 5):

    num_variables = len(data[0])
    num_rows = (num_variables-1)//max_columns + 1
    num_cols = num_variables if num_rows == 1 else max_columns

    def get_ax(row, col):
        if num_rows == 1 and num_cols == 1 :
            current_ax = ax
        elif num_rows == 1:
            current_ax = ax[col]
        else:
            current_ax = ax[row][col]

        return current_ax

    def histogram(ax, data, column_name):

        n, bins, patches = ax.hist(data,
                                   8,
                                   facecolor="#2E495E",
                                   edgecolor=(0, 0, 0))

        ax.set_title(column_name, fontsize=8)

    fig, ax = plt.subplots(num_rows,
                           num_cols,
                           figsize=(num_cols*4, num_rows*4))

    for row in range(num_rows):
        for col in range(num_cols):
            data_index = num_cols * row + col
            current_ax = get_ax(row, col)
            histogram(current_ax,
                      get_column(data, data_index),
                      column_names[data_index])

    plt.show()
```

In [11]:
```
draw_histogram(X_cancer, columns)
```



2.3 특징 쌍 별 산포도

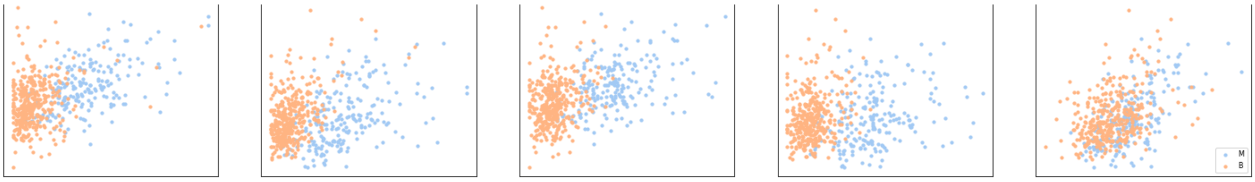
In [12]:
```
from matplotlib import pyplot as plt
import seaborn as sns

def draw_scatter(points_by_class: Dict[str, List[Vector]],
                 column_names: List[str],
                 index_pairs: List[List],
                 max_columns:int = 5):

    num_rows = (len(index_pairs)-1)//max_columns + 1
    num_cols = len(index_pairs) if num_rows == 1 else max_columns

    fig, ax = plt.subplots(num_rows, num_cols,
                           figsize=(num_cols*5, num_rows*5))
    rgb_values = sns.color_palette("pastel", len(points_by_class))

    def get_ax(row, col):
        if num_rows == 1 and num_cols == 1 :
            current_ax = ax
        elif num_rows == 1:
            current_ax = ax[col]
        else:
            current_ax = ax[row][col]

        return current_ax

    for row in range(num_rows):
        for col in range(num_cols):
            i, j = pairs[num_cols * row + col]
            current_ax = get_ax(row, col)
            current_ax.set_title(f"{column_names[i]} vs {column_names[j]}",
                                 fontsize=8)
            current_ax.set_xticks([])
            current_ax.set_yticks([])

            for k, (class_type, points) in enumerate(points_by_class.items()):
                xs = [point[i] for point in points]
                ys = [point[j] for point in points]
                current_ax.scatter(xs, ys, color=rgb_values[k], s=10,
                                   label=class_type)

    last_ax = get_ax(-1, -1)
    last_ax.legend(loc='lower right', prop={'size': 8})
    plt.show()
```

In [13]:
```
from typing import Dict
points_by_diagnosis: Dict[str, List[Vector]] = defaultdict(list)
for i, x in enumerate(X_cancer):
    y = y_cancer[i]
    label = 'M' if y == 1 else 'B'
    points_by_diagnosis[label].append(x)
```

In [14]:
```
start = 0
end = start + 10
pairs = [(i, j) for i in range(start, end) for j in range(i+1, end) if i < j]
marks = ['+', '.']  # 추가함.
print(pairs)
```

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

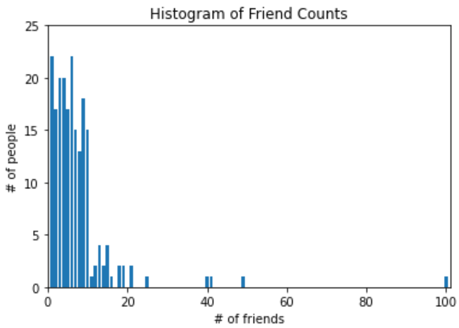
In [15]:
```
draw_scatter(points_by_diagnosis, columns, pairs)
```



3. 데이터 전처리

3.1 데이터 표준화 (Standardization)

In [16]:
```
from scratch.working_with_data import scale, rescale

def normalization(data: List[Vector],
                  means : Vector = None,
                  stdevs : Vector = None) -> List[Vector]:
    dim = len(data[0])
    if means is None :
        means, stdevs = scale(data)

    rescaled = [v[:] for v in data]

    for v in rescaled:
        for i in range(dim):
            if stdevs[i] > 0:
                v[i] = (v[i] - means[i]) / stdevs[i]

    return rescaled, means, stdevs
```



4. 로지스틱 회귀

4.1 모델 훈련

In [17]:
```
import random
import tqdm
import IPython.display as display
from scratch.linear_algebra import Vector, vector_mean, dot
from scratch.gradient_descent import gradient_step
from scratch.logistic_regression import logistic, negative_log_gradient
from scratch.logistic_regression import negative_log_likelihood

def logistic_regression(xs: List[Vector],
                        ys: List[float],
                        learning_rate: float = 0.001,
                        num_steps: int = 1000,
                        batch_size: int = 1) -> Vector:

    # Start with a random guess
    beta = [random.random() for _ in range(len(xs[0]))]

    with tqdm.trange(num_steps) as t:
        for epoch in t:
            for start in range(0, len(xs), batch_size):
                batch_xs = xs[start:start+batch_size]
                batch_ys = ys[start:start+batch_size]

                gradient = negative_log_gradient(batch_xs, batch_ys, beta)
                beta = gradient_step(beta, gradient, -learning_rate)
                loss = negative_log_likelihood(batch_xs, batch_ys, beta)
            t.set_description(f"epoch {epoch} : loss - {loss:.3f}")

    return beta
```

4.2 모델 테스트

In [18]:
```
# 모델테스트를 과제로 제출 했었던 16.Logistic Regression에서 (Q6)을 가져와서 변형
# 시켰습니다.
def test(inputs, labels, beta, x_test_normed):  # 함수에 x_test_normed 인자 추가
    i=0   # i 변수 추가
    TP = FP = FN = TN = 0
    for x, y in zip(inputs, labels):
        # x_test_normed 으로 로지스틱하는 prediction(모델예측)변수 추가
        prediction = [logistic(dot(beta, x_i)) for x_i in x_test_normed]

        if y == 1 and prediction[i] >= 0.5:  # TP: paid and we predict paid
            TP += 1
        elif y == 1:                        # FN: paid and we predict unpaid
            FN += 1
        elif prediction[i] >= 0.5:            # FP: unpaid and we predict paid
            FP += 1
        else:                               # TN: unpaid and we predict unpaid
            TN += 1
        i +=1
    confusion_matrix = [[TP, FP], [FN, TN]]
    return confusion_matrix
```

5. 차원 축소 적용

5.1 차원 축소

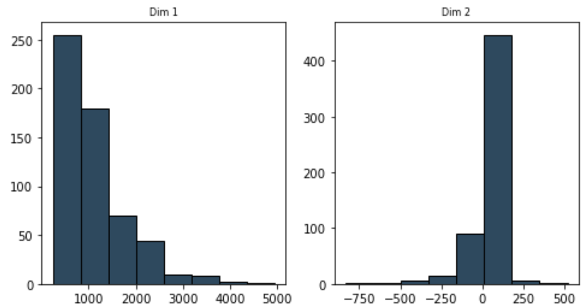
In [19]:
```
from scratch.working_with_data import pca, transform
num_components = 2
components = pca(X_cancer, num_components)
X_cancer_dimension_reducted = transform(X_cancer, components)
```

```
dv: 947805172.756: 100%|██████████████████████████████████████████████████| 100/100 [00:07<00:00, 13.49it/s]
dv: 6152606.816: 100%|████████████████████████████████████████████████████| 100/100 [00:07<00:00, 13.91it/s]
```

In [20]:
```
columns_dimension_reducted = ['Dim '+ str(i+1) for i in range(num_components)]
```

5.2 차원 축소 후 특징 별 히스토그램

In [21]:
```
draw_histogram(X_cancer_dimension_reducted, columns_dimension_reducted)
# print(columns_dimension_reducted)
```



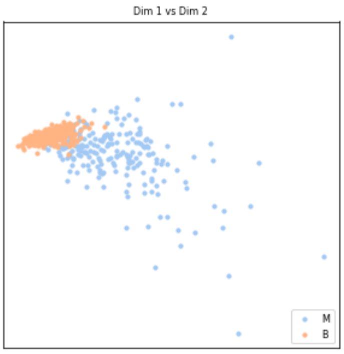
5.3 차원 축소 후 특징 쌍 별 산포도

In [22]:
```
from typing import Dict
points_by_diagnosis_reducted: Dict[str, List[Vector]] = defaultdict(list)
for i, x in enumerate(X_cancer_dimension_reducted):
    y = y_cancer[i]
    label = 'M' if y == 1 else 'B'
    points_by_diagnosis_reducted[label].append(x)
```

In [23]:
```
start = 0
end = start + num_components
reducted_pairs = [(i, j) for i in range(start, end)
                          for j in range(i+1, end) if i < j]
print(reducted_pairs)
```

```
[(0, 1)]
```

In [24]:
```
draw_scatter(points_by_diagnosis_reducted, columns_dimension_reducted, reducted_pairs)
```



5.4 차원 축소 후 회귀 분석 (Q1)

차원 축소 후 회귀 분석을 하는 코드를 작성하시오.

In [25]:
```
import random
from scratch.machine_learning import train_test_split
from typing import Tuple

def logistic_regression_dimension_reduction(
                        xs: List[Vector],
                        ys: List[float],
                        num_components: int) -> Tuple[List[Vector], Vector, List[List]]:
    # 1. 차원 축소
    components = pca(xs, num_components)
    xs_dimension_reducted = transform(xs, components)
    # print(len(xs_dimension_reducted[0]))
    # 2. 데이터 분할
    random.seed(12)
    x_train, x_test, y_train, y_test = train_test_split(xs_dimension_reducted, ys, 0.25)
    # print(y_train)
    # 3. 데이터 표준화
    x_train_normed, x_train_means, x_train_stdevs = normalization(x_train)
    x_test_normed, _, _  = normalization(x_test, x_train_means, x_train_stdevs)
    # 4. 회귀 분석 및 테스트
    beta = logistic_regression(x_train_normed, y_train)


    confusion_matrix = test(x_test, y_test, beta, x_test_normed)

    return xs_dimension_reducted, beta, confusion_matrix
```

2차원에 대해서 테스트 했을 때 결과는 다음과 같이 나오는 것을 확인해 보세요.

- [[36, 0], [15, 92]]
- accuracy : 0.8951048951048951
- precision : 1.0
- recall : 0.7058823529411765
- f1_score : 0.8275862068965517

In [26]:
```
from scratch.machine_learning import accuracy, precision, recall, f1_score
num_components = 2
X_cancer_dimension_reducted, beta, confusion_matrix = \
    logistic_regression_dimension_reduction(X_cancer, y_cancer, num_components)

# 성능 분석
print(confusion_matrix)
[TP, FP], [FN, TN] = confusion_matrix
print("accuracy :", accuracy(TP, FP, FN, TN))
print("precision :", precision(TP, FP, FN, TN))
print("recall :", recall(TP, FP, FN, TN))
print("f1_score :", f1_score(TP, FP, FN, TN))
```

```
dv: 947805172.756: 100%|██████████████████████████████████████████████████| 100/100 [00:07<00:00, 13.80it/s]
dv: 6152606.816: 100%|████████████████████████████████████████████████████| 100/100 [00:07<00:00, 14.21it/s]
epoch 999 : loss - 0.009: 100%|███████████████████████████████████████████| 1000/1000 [00:07<00:00, 126.80it/s]

[[36, 0], [15, 92]]
accuracy : 0.8951048951048951
precision : 1.0
recall : 0.7058823529411765
f1_score : 0.8275862068965517
```

6. 최적의 차원 찾기 (Q2)

1차원에서 15차원까지 각 차원 별로 성능을 확인하고 성능 그래프를 그려보시오.

In [27]:
```python
from scratch.machine_learning import accuracy, precision, recall, f1_score

start_num_components = 1
end_num_components = 15
a = []
p = []
r = []
f1 = []
for x in range(start_num_components,end_num_components+1):
    X_cancer_dimension_reducted, beta, confusion_matrix = ₩
        logistic_regression_dimension_reduction(X_cancer, y_cancer, x)
    [TP, FP], [FN, TN] = confusion_matrix
    a.append(accuracy(TP, FP, FN, TN))
    p.append(precision(TP, FP, FN, TN))
    r.append(recall(TP, FP, FN, TN))
    f1.append(f1_score(TP, FP, FN, TN))

plt.figure(figsize=(8,6))
x_value = [x for x in range(start_num_components,end_num_components+1)]

plt.plot(x_value, a, color = '#5f00ff', label ='accuracy')
plt.plot(x_value, p, color = '#ffaf00', label ='precision')
plt.plot(x_value, r, color = '#008000', label ='recall')
plt.plot(x_value, f1, color = '#ff0000', label ='f1_score')
plt.xlabel('component')
plt.ylabel('confusion_matrix')
plt.legend()
```

```
dv: 947805172.756: 100%|██████████| 100/100 [00:05<00:00, 17.76it/s]
epoch 999 : loss - 0.014: 100%|██████████| 1000/1000 [00:05<00:00, 168.30it/s]
dv: 947805172.756: 100%|██████████| 100/100 [00:05<00:00, 17.43it/s]
dv: 6152606.816: 100%|██████████| 100/100 [00:05<00:00, 17.78it/s]
epoch 999 : loss - 0.009: 100%|██████████| 1000/1000 [00:07<00:00, 135.94it/s]
dv: 947805172.756: 100%|██████████| 100/100 [00:07<00:00, 14.06it/s]
dv: 6152606.816: 100%|██████████| 100/100 [00:07<00:00, 13.80it/s]
dv: 774881.119: 100%|██████████| 100/100 [00:06<00:00, 16.07it/s]
epoch 999 : loss - 0.009: 100%|██████████| 1000/1000 [00:09<00:00, 106.07it/s]
dv: 947805172.756: 100%|██████████| 100/100 [00:05<00:00, 18.01it/s]
dv: 6152606.816: 100%|██████████| 100/100 [00:05<00:00, 18.17it/s]
dv: 774881.119: 100%|██████████| 100/100 [00:05<00:00, 18.01it/s]
dv: 308496.078: 100%|██████████| 100/100 [00:05<00:00, 18.07it/s]
epoch 999 : loss - 0.009: 100%|██████████| 1000/1000 [00:10<00:00, 94.70it/s]
dv: 947805172.756: 100%|██████████| 100/100 [00:05<00:00, 17.27it/s]
dv: 6152606.816: 100%|██████████| 100/100 [00:05<00:00, 17.88it/s]
dv: 774881.119: 100%|██████████| 100/100 [00:05<00:00, 17.90it/s]
dv: 308496.078: 100%|██████████| 100/100 [00:05<00:00, 17.74it/s]
dv: 23452.541: 100%|██████████| 100/100 [00:05<00:00, 17.94it/s]
epoch 999 : loss - 0.005: 100%|██████████| 1000/1000 [00:12<00:00, 79.85it/s]
dv: 947805172.756: 100%|██████████| 100/100 [00:05<00:00, 17.68it/s]
dv: 6152606.816: 100%|██████████| 100/100 [00:05<00:00, 17.92it/s]
dv: 774881.119: 100%|██████████| 100/100 [00:06<00:00, 16.64it/s]
dv: 308496.078: 100%|██████████| 100/100 [00:07<00:00, 14.18it/s]
dv: 23452.541: 100%|██████████| 100/100 [00:07<00:00, 13.93it/s]
dv: 3282.049: 100%|██████████| 100/100 [00:06<00:00, 16.00it/s]
epoch 999 : loss - 0.002: 100%|██████████| 1000/1000 [00:12<00:00, 82.84it/s]
dv: 947805172.756: 100%|██████████| 100/100 [00:06<00:00, 16.60it/s]
dv: 6152606.816: 100%|██████████| 100/100 [00:05<00:00, 17.82it/s]
dv: 774881.119: 100%|██████████| 100/100 [00:05<00:00, 18.00it/s]
dv: 308496.078: 100%|██████████| 100/100 [00:05<00:00, 18.16it/s]
dv: 23452.541: 100%|██████████| 100/100 [00:05<00:00, 17.81it/s]
dv: 3282.049: 100%|██████████| 100/100 [00:05<00:00, 17.97it/s]
dv: 1040.422: 100%|██████████| 100/100 [00:05<00:00, 17.97it/s]
epoch 999 : loss - 0.002: 100%|██████████| 1000/1000 [00:12<00:00, 79.80it/s]
dv: 947805172.756: 100%|██████████| 100/100 [00:05<00:00, 17.48it/s]
dv: 6152606.816: 100%|██████████| 100/100 [00:05<00:00, 17.66it/s]
dv: 774881.119: 100%|██████████| 100/100 [00:05<00:00, 17.72it/s]
dv: 308496.078: 100%|██████████| 100/100 [00:06<00:00, 16.02it/s]
dv: 23452.541: 100%|██████████| 100/100 [00:06<00:00, 15.04it/s]
dv: 3282.049: 100%|██████████| 100/100 [00:07<00:00, 13.77it/s]
dv: 1040.422: 100%|██████████| 100/100 [00:07<00:00, 13.90it/s]
dv: 211.696: 100%|██████████| 100/100 [00:07<00:00, 14.16it/s]
epoch 999 : loss - 0.002: 100%|██████████| 1000/1000 [00:16<00:00, 61.31it/s]
dv: 947805172.756: 100%|██████████| 100/100 [00:05<00:00, 17.70it/s]
dv: 6152606.816: 100%|██████████| 100/100 [00:05<00:00, 17.75it/s]
dv: 774881.119: 100%|██████████| 100/100 [00:05<00:00, 17.78it/s]
dv: 308496.078: 100%|██████████| 100/100 [00:05<00:00, 17.44it/s]
dv: 23452.541: 100%|██████████| 100/100 [00:05<00:00, 17.61it/s]
dv: 3282.049: 100%|██████████| 100/100 [00:06<00:00, 16.66it/s]
dv: 1040.422: 100%|██████████| 100/100 [00:05<00:00, 17.24it/s]
dv: 211.696: 100%|██████████| 100/100 [00:05<00:00, 17.61it/s]
dv: 96.695: 100%|██████████| 100/100 [00:05<00:00, 17.72it/s]
epoch 999 : loss - 0.004: 100%|██████████| 1000/1000 [00:17<00:00, 56.85it/s]
dv: 947805172.756: 100%|██████████| 100/100 [00:05<00:00, 17.53it/s]
dv: 6152606.816: 100%|██████████| 100/100 [00:05<00:00, 17.93it/s]
dv: 774881.119: 100%|██████████| 100/100 [00:05<00:00, 17.17it/s]
dv: 308496.078: 100%|██████████| 100/100 [00:07<00:00, 13.65it/s]
dv: 23452.541: 100%|██████████| 100/100 [00:07<00:00, 13.71it/s]
dv: 3282.049: 100%|██████████| 100/100 [00:06<00:00, 15.50it/s]
dv: 1040.422: 100%|██████████| 100/100 [00:05<00:00, 17.93it/s]
dv: 211.696: 100%|██████████| 100/100 [00:05<00:00, 17.64it/s]
dv: 96.695: 100%|██████████| 100/100 [00:05<00:00, 17.60it/s]
dv: 49.544: 100%|██████████| 100/100 [00:06<00:00, 16.29it/s]
epoch 999 : loss - 0.002: 100%|██████████| 1000/1000 [00:18<00:00, 52.71it/s]
dv: 947805172.756: 100%|██████████| 100/100 [00:05<00:00, 17.62it/s]
dv: 6152606.816: 100%|██████████| 100/100 [00:05<00:00, 17.74it/s]
dv: 774881.119: 100%|██████████| 100/100 [00:05<00:00, 17.38it/s]

dv: 308496.078: 100%|██████████| 100/100 [00:05<00:00, 17.22it/s]
dv: 23452.541: 100%|██████████| 100/100 [00:05<00:00, 17.87it/s]
dv: 3282.049: 100%|██████████| 100/100 [00:05<00:00, 17.89it/s]
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dv: 1040.422: 100%|██████████| 100/100 [00:05<00:00, 17.67it/s]
dv: 211.696: 100%|██████████| 100/100 [00:05<00:00, 17.91it/s]
dv: 96.695: 100%|██████████| 100/100 [00:05<00:00, 18.00it/s]
dv: 49.544: 100%|██████████| 100/100 [00:05<00:00, 17.56it/s]
dv: 20.020: 100%|██████████| 100/100 [00:07<00:00, 14.03it/s]
epoch 999 : loss - 0.001: 100%|██████████| 1000/1000 [00:20<00:00, 48.67it/s]
dv: 947805172.756: 100%|██████████| 100/100 [00:05<00:00, 17.94it/s]
dv: 6152606.816: 100%|██████████| 100/100 [00:05<00:00, 17.82it/s]
dv: 774881.119: 100%|██████████| 100/100 [00:05<00:00, 17.74it/s]
dv: 308496.078: 100%|██████████| 100/100 [00:05<00:00, 17.96it/s]
dv: 23452.541: 100%|██████████| 100/100 [00:05<00:00, 17.88it/s]
dv: 3282.049: 100%|██████████| 100/100 [00:05<00:00, 17.68it/s]
dv: 1040.422: 100%|██████████| 100/100 [00:05<00:00, 17.27it/s]
dv: 211.696: 100%|██████████| 100/100 [00:05<00:00, 17.97it/s]
dv: 96.695: 100%|██████████| 100/100 [00:05<00:00, 17.86it/s]
dv: 49.544: 100%|██████████| 100/100 [00:05<00:00, 17.99it/s]
dv: 20.020: 100%|██████████| 100/100 [00:05<00:00, 18.12it/s]
dv: 4.827: 100%|██████████| 100/100 [00:05<00:00, 17.93it/s]
epoch 999 : loss - 0.001: 100%|██████████| 1000/1000 [00:20<00:00, 49.26it/s]
dv: 947805172.756: 100%|██████████| 100/100 [00:06<00:00, 16.05it/s]
dv: 6152606.816: 100%|██████████| 100/100 [00:06<00:00, 14.59it/s]
dv: 774881.119: 100%|██████████| 100/100 [00:07<00:00, 13.54it/s]
dv: 308496.078: 100%|██████████| 100/100 [00:06<00:00, 15.90it/s]
dv: 23452.541: 100%|██████████| 100/100 [00:05<00:00, 17.59it/s]
dv: 3282.049: 100%|██████████| 100/100 [00:05<00:00, 17.41it/s]
dv: 1040.422: 100%|██████████| 100/100 [00:05<00:00, 17.72it/s]
dv: 211.696: 100%|██████████| 100/100 [00:06<00:00, 16.51it/s]
dv: 96.695: 100%|██████████| 100/100 [00:05<00:00, 17.85it/s]
dv: 49.544: 100%|██████████| 100/100 [00:05<00:00, 18.00it/s]
dv: 20.020: 100%|██████████| 100/100 [00:05<00:00, 18.32it/s]
dv: 4.827: 100%|██████████| 100/100 [00:05<00:00, 18.09it/s]
dv: 1.860: 100%|██████████| 100/100 [00:05<00:00, 18.88it/s]
epoch 999 : loss - 0.001: 100%|██████████| 1000/1000 [00:23<00:00, 42.86it/s]
dv: 947805172.756: 100%|██████████| 100/100 [00:06<00:00, 15.78it/s]
dv: 6152606.816: 100%|██████████| 100/100 [00:06<00:00, 14.62it/s]
dv: 774881.119: 100%|██████████| 100/100 [00:06<00:00, 14.47it/s]
dv: 308496.078: 100%|██████████| 100/100 [00:07<00:00, 14.16it/s]
dv: 23452.541: 100%|██████████| 100/100 [00:07<00:00, 13.72it/s]
dv: 3282.049: 100%|██████████| 100/100 [00:06<00:00, 14.36it/s]
dv: 1040.422: 100%|██████████| 100/100 [00:06<00:00, 16.00it/s]
dv: 211.696: 100%|██████████| 100/100 [00:05<00:00, 17.16it/s]
dv: 96.695: 100%|██████████| 100/100 [00:05<00:00, 17.71it/s]
dv: 49.544: 100%|██████████| 100/100 [00:05<00:00, 17.63it/s]
dv: 20.020: 100%|██████████| 100/100 [00:05<00:00, 17.65it/s]
dv: 4.827: 100%|██████████| 100/100 [00:05<00:00, 17.47it/s]
dv: 1.860: 100%|██████████| 100/100 [00:05<00:00, 17.49it/s]
dv: 1.191: 100%|██████████| 100/100 [00:05<00:00, 17.62it/s]
epoch 999 : loss - 0.001: 100%|██████████| 1000/1000 [00:24<00:00, 40.65it/s]
dv: 947805172.756: 100%|██████████| 100/100 [00:05<00:00, 17.97it/s]
dv: 6152606.816: 100%|██████████| 100/100 [00:05<00:00, 17.45it/s]
dv: 774881.119: 100%|██████████| 100/100 [00:05<00:00, 17.72it/s]
dv: 308496.078: 100%|██████████| 100/100 [00:05<00:00, 17.51it/s]
dv: 23452.541: 100%|██████████| 100/100 [00:05<00:00, 17.50it/s]
dv: 3282.049: 100%|██████████| 100/100 [00:06<00:00, 15.33it/s]
dv: 1040.422: 100%|██████████| 100/100 [00:07<00:00, 13.92it/s]
dv: 211.696: 100%|██████████| 100/100 [00:06<00:00, 14.50it/s]
dv: 96.695: 100%|██████████| 100/100 [00:05<00:00, 16.87it/s]
dv: 49.544: 100%|██████████| 100/100 [00:05<00:00, 17.41it/s]
dv: 20.020: 100%|██████████| 100/100 [00:05<00:00, 17.50it/s]
dv: 4.827: 100%|██████████| 100/100 [00:05<00:00, 17.51it/s]
dv: 1.860: 100%|██████████| 100/100 [00:05<00:00, 17.44it/s]
dv: 1.191: 100%|██████████| 100/100 [00:05<00:00, 17.60it/s]
dv: 0.679: 100%|██████████| 100/100 [00:05<00:00, 17.43it/s]
epoch 999 : loss - 0.001: 100%|██████████| 1000/1000 [00:25<00:00, 38.49it/s]
```
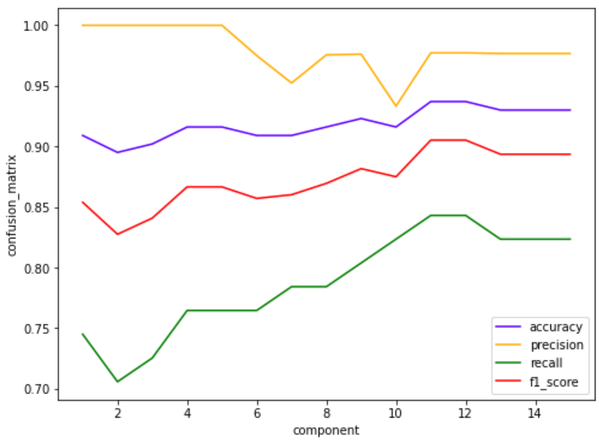

Out[27]: <matplotlib.legend.Legend at 0x1a983a63b80>



In [ ]: