Leaf Disease Using Fuzzy Inference System

1. Preprocessing:

- The preprocessing step involves resizing the input image to a fixed size (in this case, 224x224 pixels) to ensure uniformity in the dataset.

2. Feature Extraction:

- After preprocessing, the image undergoes feature extraction. In this example, we extract two features: the mean and standard deviation of pixel intensities. These features are numerical representations of the image characteristics.

3. Fuzzy Logic Classification:

- Fuzzy logic allows for imprecise reasoning and decision-making by defining linguistic variables and fuzzy rules.
- The FuzzyLeafDiseaseClassifier class initializes fuzzy variables (lesion size, lesion density, and disease degree) along with their membership functions.
- Membership functions define how numerical inputs map to linguistic terms (e.g., small, medium, large).
- Fuzzy rules define the relationship between input variables and output classes (healthy or diseased).
- The degree of membership of the output variable (degree of disease) is calculated based on the input features (lesion size and density) using the defined fuzzy rules and membership functions.
- The degree of membership represents the confidence level of the classification result.

4. Classification Result:

- The degree of membership is compared to a threshold (0.5 in this case) to determine the final classification result.
- If the degree of membership is greater than 0.5, the leaf is classified as "Healthy"; otherwise, it's classified as "Diseased".

Lesion size refers to the size or extent of the abnormal or damaged area on the leaf caused by a disease, injury, or other factors. In the context of leaf disease classification, lesion size is an important feature used to characterize the severity of the disease.
Lesion density refers to the concentration or density of lesions on the leaf surface. It represents the spatial distribution of lesions and how densely they are distributed across the leaf area. In the context of leaf disease classification, lesion density is another important feature used to characterize the severity and spread of the disease.

Example:

- We provide an example usage where an image of a leaf with a disease (potato late blight) is loaded and processed.
- The image is pre-processed and features (mean intensity and standard deviation) are extracted.
- The FuzzyLeafDiseaseClassifier class is used to classify the leaf based on the extracted features.
- The classification result ("Healthy" or "Diseased") is printed based on the degree of membership calculated by the fuzzy logic classifier.

This outlines the workflow of leaf disease classification using fuzzy logic, from preprocessing and feature extraction to fuzzy logic classification and obtaining the final classification result. Let me know if you need further clarification on any aspect!

Code

```
import numpy as np
import skfuzzy as fuzz
from skfuzzy import control as ctrl
from PIL import Image


class Preprocessor:
    def __init__(self, image_size=(224, 224)):
        self.image_size = image_size


    def preprocess_image(self, image_path):
        try:
            image = Image.open(image_path)
            image = image.resize(self.image_size)
            return np.array(image)
        except Exception as e:
            print(f"Error processing image: {e}")
            return None
```

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```
class FeatureExtractor:
    def __init__(self):
        pass

    def extract_features(self, image):
        # Example: Using mean and standard deviation of pixel intensities as features
        mean_intensity = np.mean(image)
        std_intensity = np.std(image)
        return mean_intensity, std_intensity

class FuzzyLeafDiseaseClassifier:
    def __init__(self):
        # Define fuzzy variables and membership functions
        self.lesion_size = ctrl.Antecedent(np.arange(0, 256, 1), 'lesion_size')
        self.lesion_density = ctrl.Antecedent(np.arange(0, 256, 1), 'lesion_density')
        self.disease = ctrl.Consequent(np.arange(0, 1.1, 0.1), 'degree_of_disease')

        # Define membership functions for lesion size
        self.lesion_size['small'] = fuzz.trimf(self.lesion_size.universe, [0, 100, 200])
        self.lesion_size['medium'] = fuzz.trimf(self.lesion_size.universe, [0, 50, 100])
        self.lesion_size['large'] = fuzz.trimf(self.lesion_size.universe, [50, 150, 255])

        # Define membership functions for lesion density
        self.lesion_density['low'] = fuzz.trimf(self.lesion_density.universe, [0, 50, 100])
        self.lesion_density['medium'] = fuzz.trimf(self.lesion_density.universe, [50, 100, 150])
        self.lesion_density['high'] = fuzz.trimf(self.lesion_density.universe, [100, 150, 255])

        # Define membership functions for disease
        self.disease['healthy'] = fuzz.trimf(self.disease.universe, [0, 0, 0.5])
        self.disease['diseased'] = fuzz.trimf(self.disease.universe, [0.5, 1, 1])

        # Define fuzzy rules
        self.rule1 = ctrl.Rule(self.lesion_size['small'] & self.lesion_density['low'], self.disease['healthy'])
        self.rule2 = ctrl.Rule(self.lesion_size['large'] | self.lesion_density['high'], self.disease['diseased'])
```

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```
        # Define fuzzy system
        self.system = ctrl.ControlSystem([self.rule1, self.rule2])
        self.simulator = ctrl.ControlSystemSimulation(self.system)

    def classify(self, lesion_size, lesion_density):
        try:
            self.simulator.input['lesion_size'] = lesion_size
            self.simulator.input['lesion_density'] = lesion_density
            self.simulator.compute()
            degree_of_membership = self.simulator.output['degree_of_disease']
            print(f"Degree of Membership: {degree_of_membership}")
            if degree_of_membership > 0.5:
                return "Healthy"
            else:
                return "Diseased"
        except Exception as e:
            print(f"Error classifying leaf: {e}")
            return None

if __name__ == "__main__":
    # Load and preprocess a single image
    image_path = r"C:\Users\Satoshi\OneDrive\Desktop\Data\PERSONAL_GROWTH\mini-projects\Images\Leaf_image_detection\potato class\potato\Potato___Late_blight\5d392db5-bf54-41f4-b76b-e3935dfe0154___RS_LB 3133.JPG"
    preprocessor = Preprocessor()
    feature_extractor = FeatureExtractor()
    classifier = FuzzyLeafDiseaseClassifier()

    image = preprocessor.preprocess_image(image_path)
    if image is not None:
        features = feature_extractor.extract_features(image)
        if features is not None:
            result = classifier.classify(features[0], features[1])
            if result is not None:
                print(f"Prediction: {result}")e:
```

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Output:

C:\Users\Satoshi\OneDrive\Desktop\Data\PERSONAL_GROWTH\mini-projects\Images\Leaf_image_detection\potato class\potato\Potato___Late_blight\5d392db5-bf54-41f4-b76b-e3935dfe0154___RS_LB 3133.JPG

Degree of Membership: 0.5333069893535619

Prediction: Healthy

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