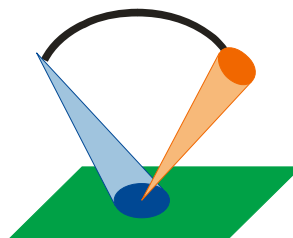


Methods for the improvement of pixelwise classification results for the automatic detection of leaf diseases



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GK 722

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Goal: Classification of leaf diseases



Input:
Healthy
or
Unhealthy??

Output:
Unhealthy!
Infected with
Cercospora
beticola

Prerequisite for precision farming:
Obtaining information about the spatial distribution of the
infected areas in the field

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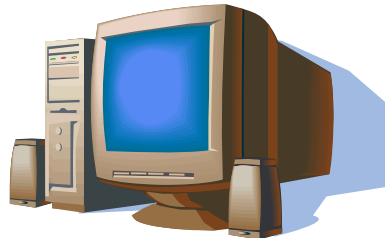
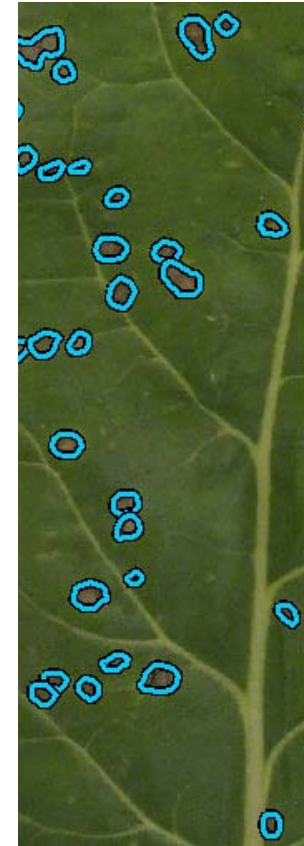
Input:



Manual Classification



Output:



Automatic Classification

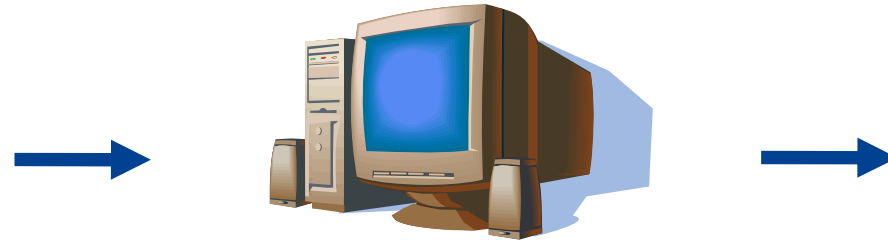
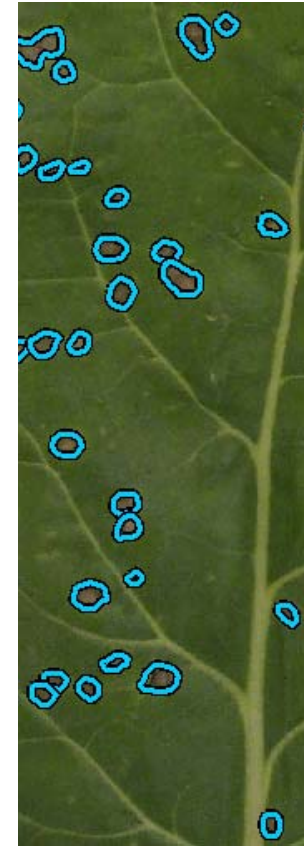
Input:



Manual Classification



Output:

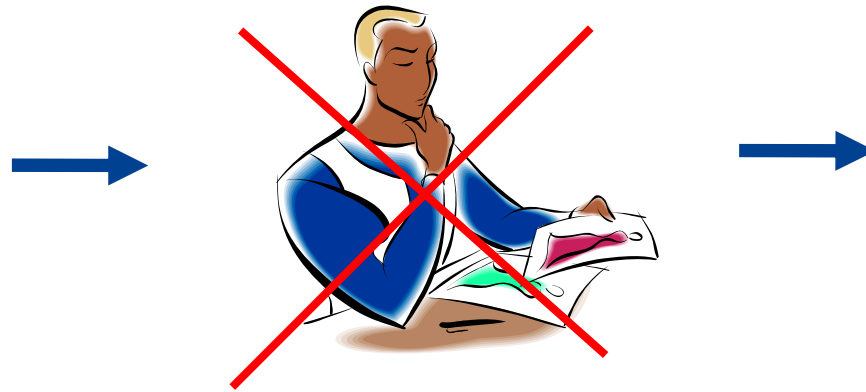


Automatic Classification

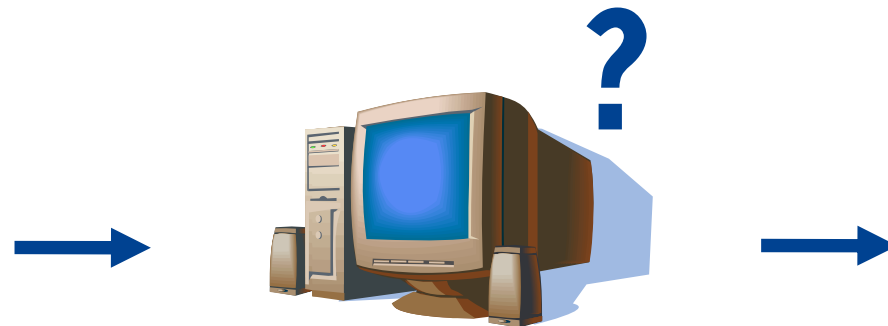
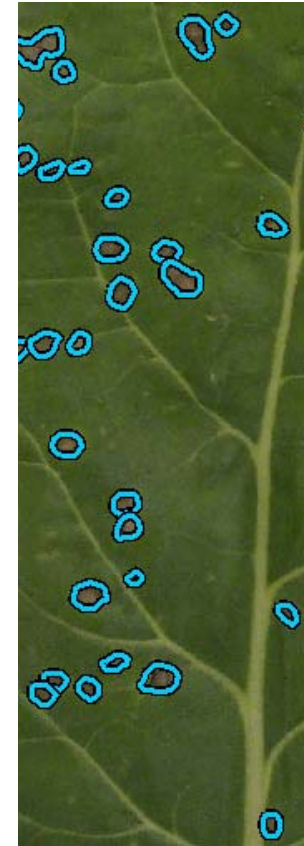
Input:



Manual Classification



Output:



Automatic Classification

INPUT IMAGES

Feature selection



Training of the classifier



Classifying of the leaves

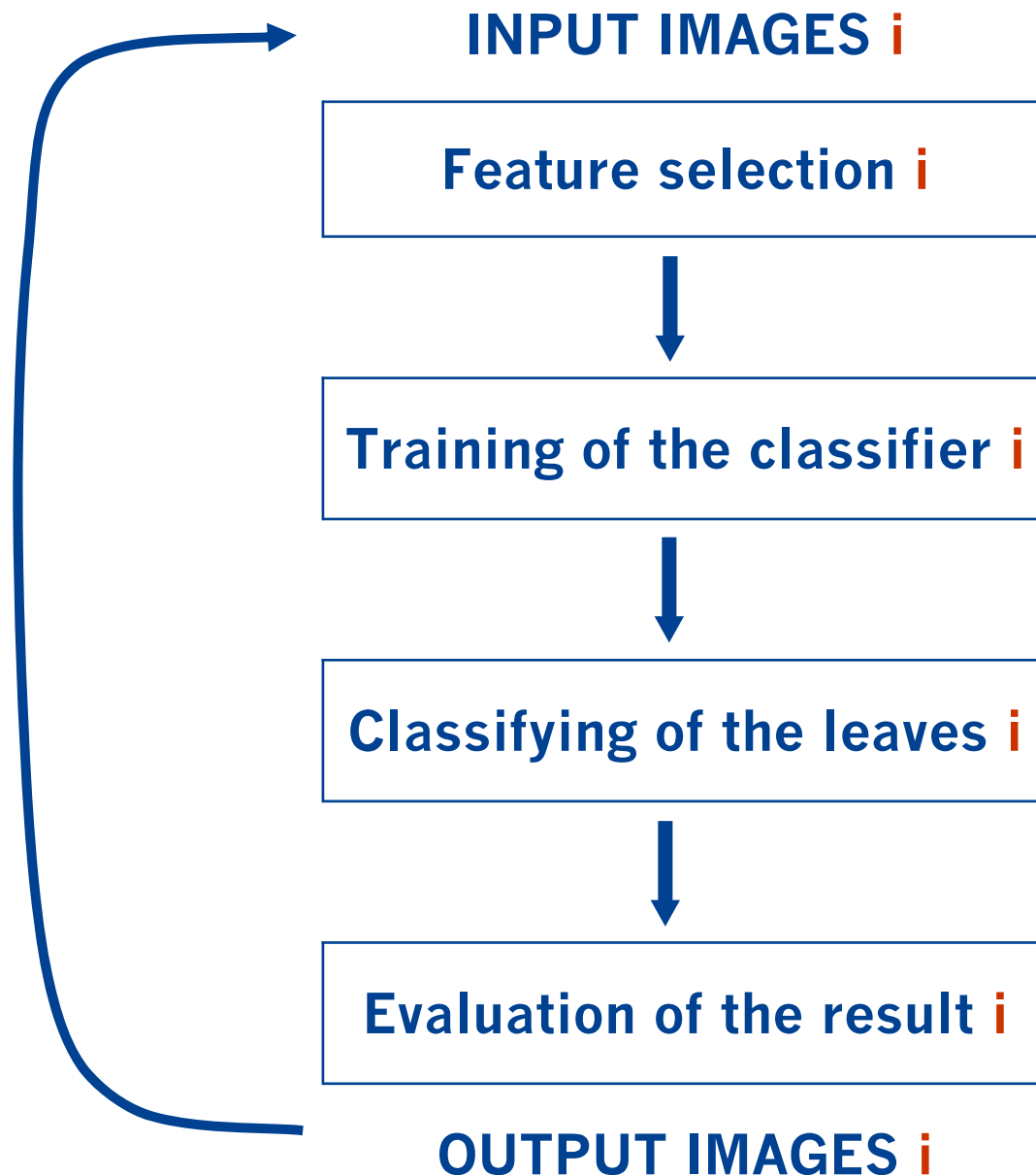


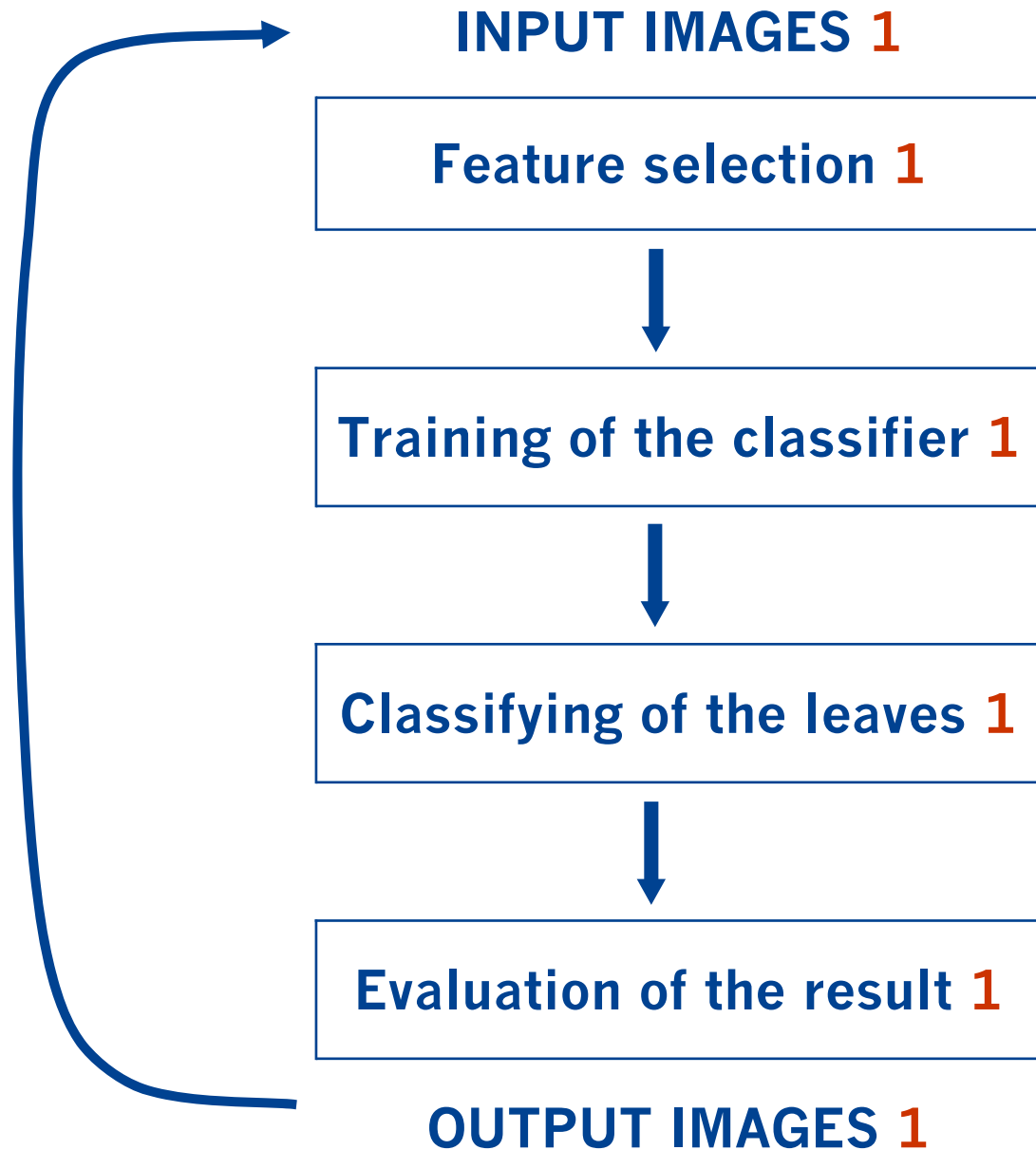
Evaluation of the result

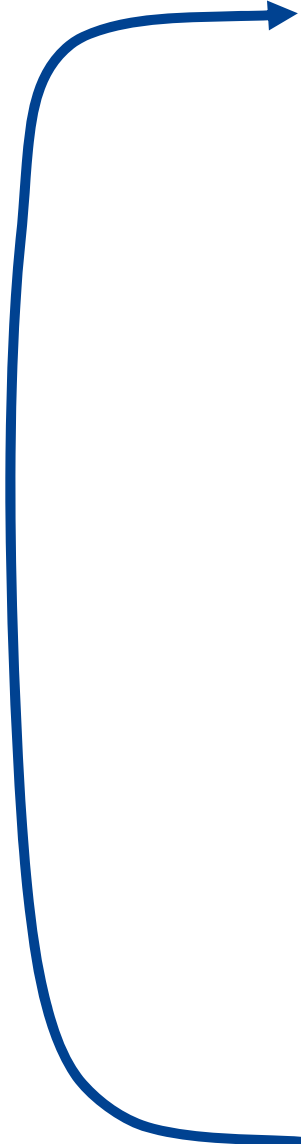
OUTPUT IMAGES

-
-
-
-
-
-
-

7



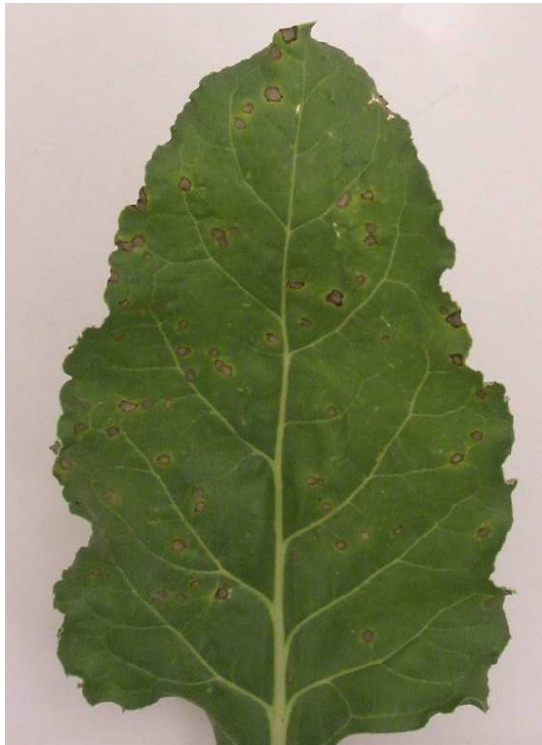


INPUT IMAGES 1Feature selection **1**Training of the classifier **1**Classifying of the leaves **1**Evaluation of the result **1****OUTPUT IMAGES 1**

-
-
-
-
-
-
-

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- Leaves of sugar beet plants
- Healthy or Infected with ...

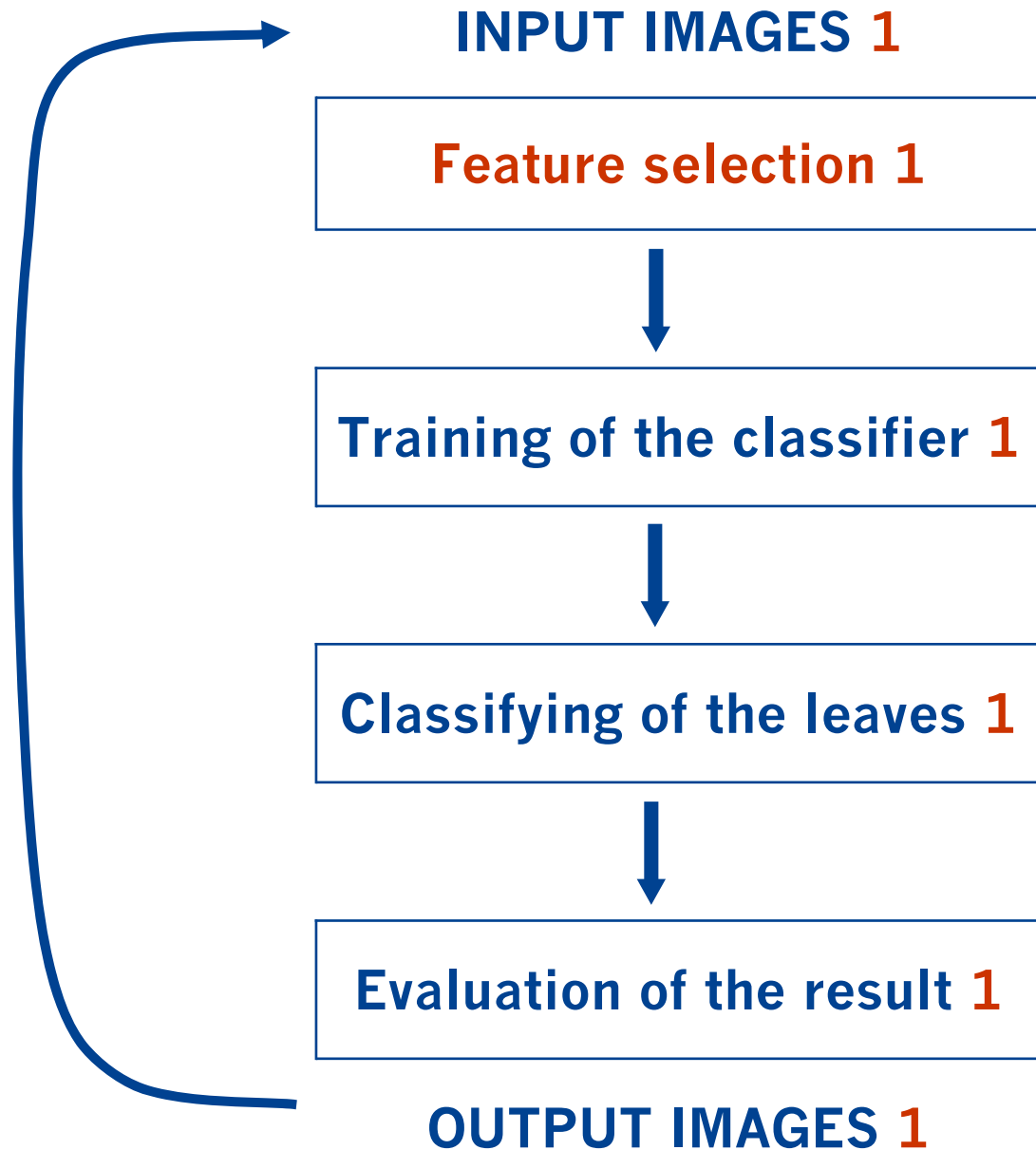


Leaf spot disease:
Cercospora beticola



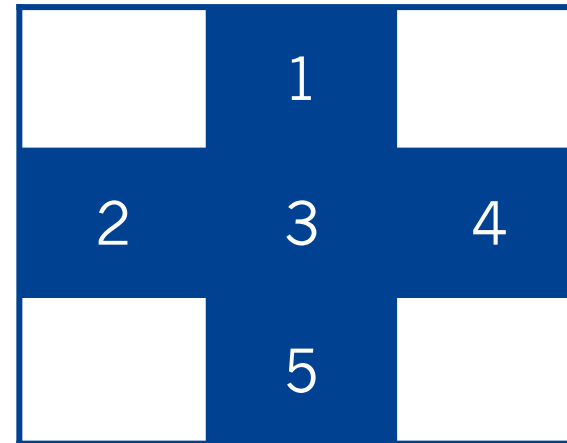
Rust:
Uromyces betae

... in different disease stages



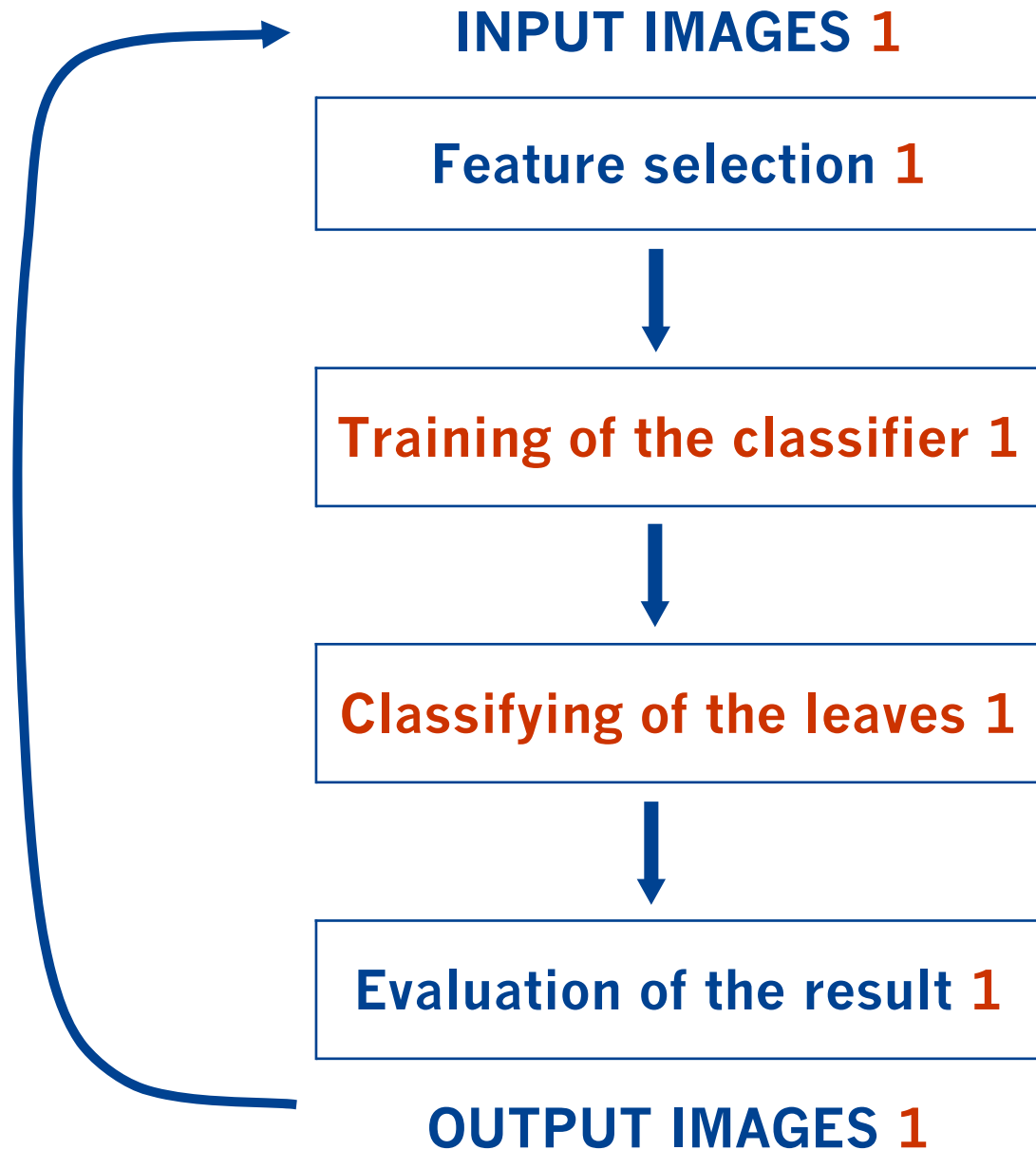
- Feature vector $e_n = [e_{n,j}]$ with $n = 1, \dots, N$ pixels

- $e_{n,1} = \text{Red}$
 - $e_{n,2} = \text{Green}$
 - $e_{n,3} = \text{Blue}$
 - $e_{n,4} = \text{Infrared}$
 - ...
 - $e_{n,17} = \text{Red}$
 - $e_{n,18} = \text{Green}$
 - $e_{n,19} = \text{Blue}$
 - $e_{n,20} = \text{Infrared}$
- } **1**
- } **5**



- Classes

- $\omega_1 = \text{Healthy leaf areas}$
- $\omega_2 = \text{With } \textit{Cercospora beticola} \text{ infected leaf areas}$
- $\omega_3 = \text{With } \textit{Uromyces betae} \text{ infected leaf areas}$



$$\min_j \sum_{i=1}^I (c_{ij} - c_{ii}) P(\omega_i) L(\omega_i)$$

- Minimization of the sum of the product from the cost function c , the *a-priori* probability $P(\omega_i)$ and the likelihood function $L(\omega_i)$
- Computation of the *a-priori* probability $P(\omega_i)$ based on the frequency of the occurrence of the different classes
- Determination of the likelihood function $L(\omega_i)$ using the expectation maximization (EM) algorithm
- Assumed number of Gaussian distributions per class
 - Healthy 2
 - *Cercospora beticola* 3
 - *Uromyces betae* 1

- Generation of a basis cost function c_{basis} depending on the *a-priori* probabilities of the different classes to give rare classes more weight

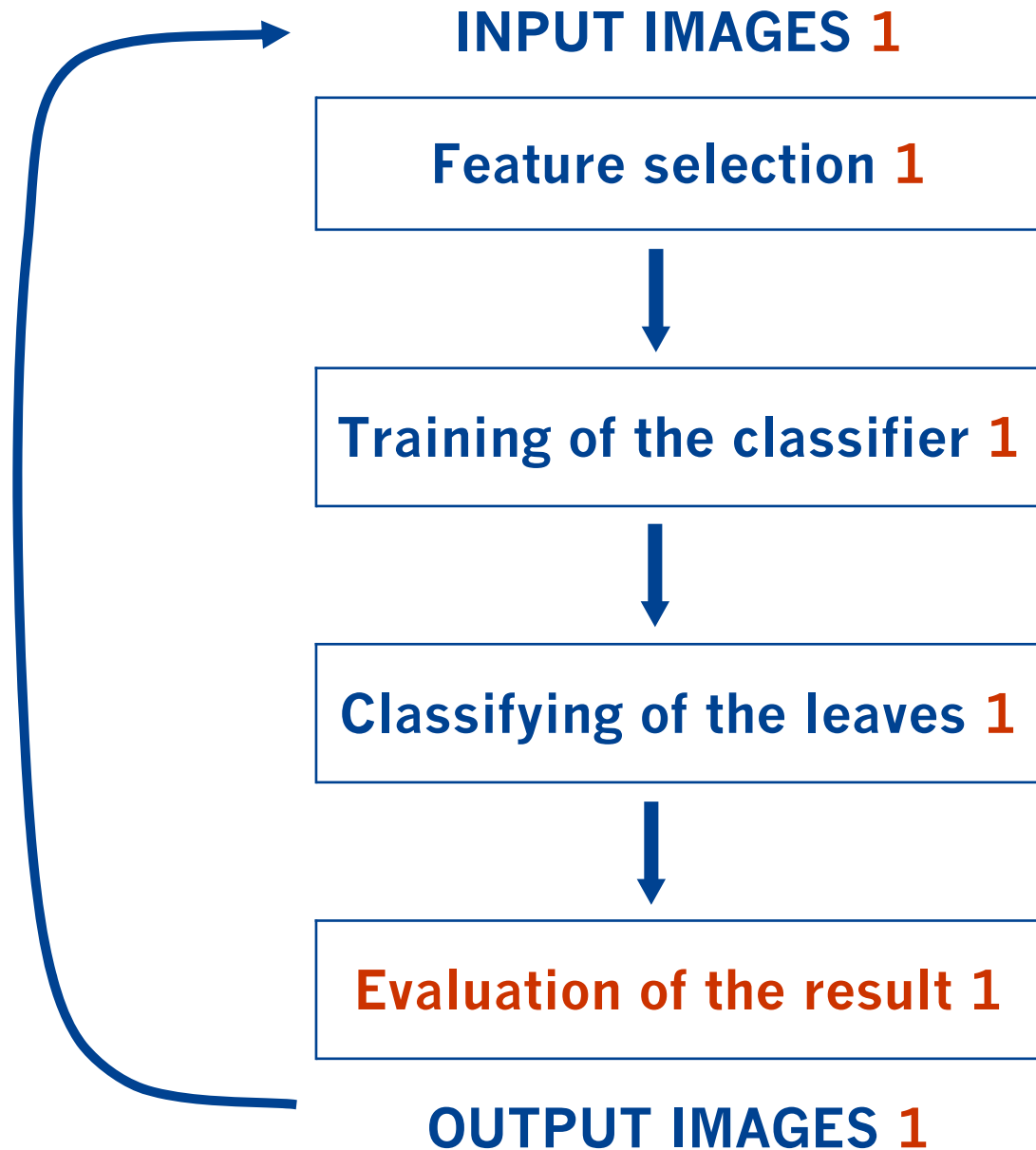
$$c_{basis}(i, j) = \begin{cases} \frac{1}{P(\omega_i)} & \text{if } i \neq j \\ 0 & \text{if } i = j \end{cases}$$

- Computation of the cost function c under consideration of the basis cost function c_{basis} and the confusion matrix k :

$$c(i, j) = c(i, j) + c_{basis}(i, j) * k(i, j)$$

- Iterative optimization until $a \leq 0.01$

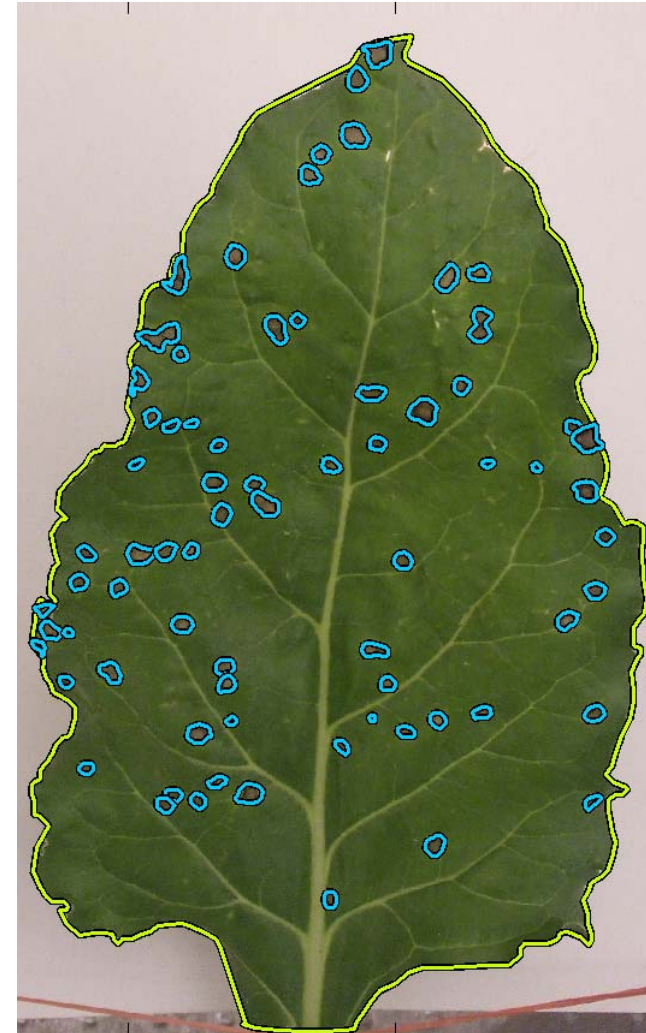
$$a = \sum_{ij} |o(i, j) - k_{old}(i, j)|$$



- Pixel level



- Object level, e.g. leaf spots
- Leaf level



On *Cercospora* infected leaves

17 days after inoculation:

	Healthy areas	C. leaf spots	U. leaf spots
Healthy areas	93 %	5 %	2 %
C. leaf spots	1 %	97 %	2 %

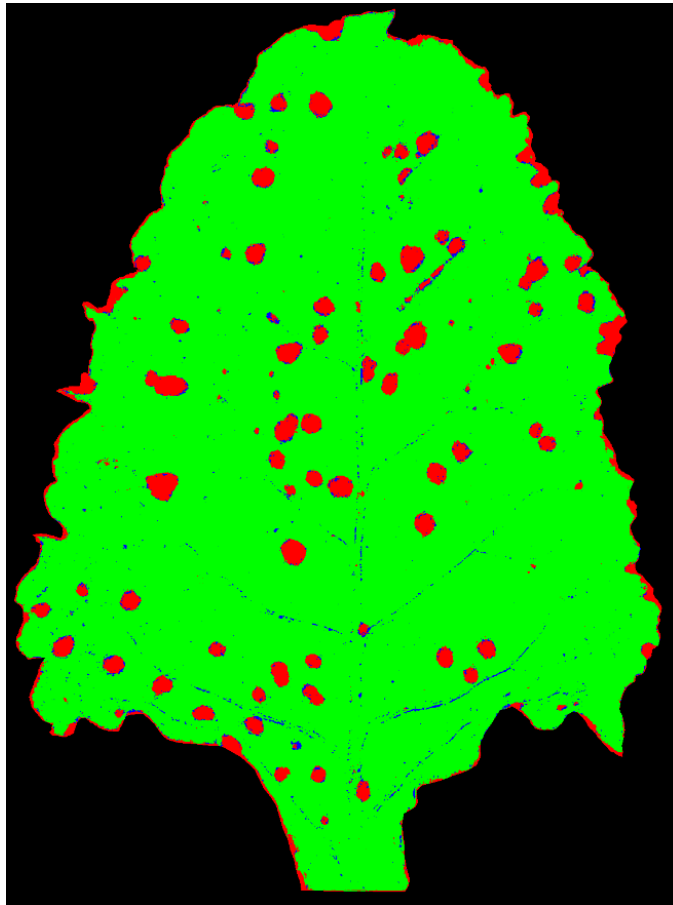
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On *Uromyces* infected leaves

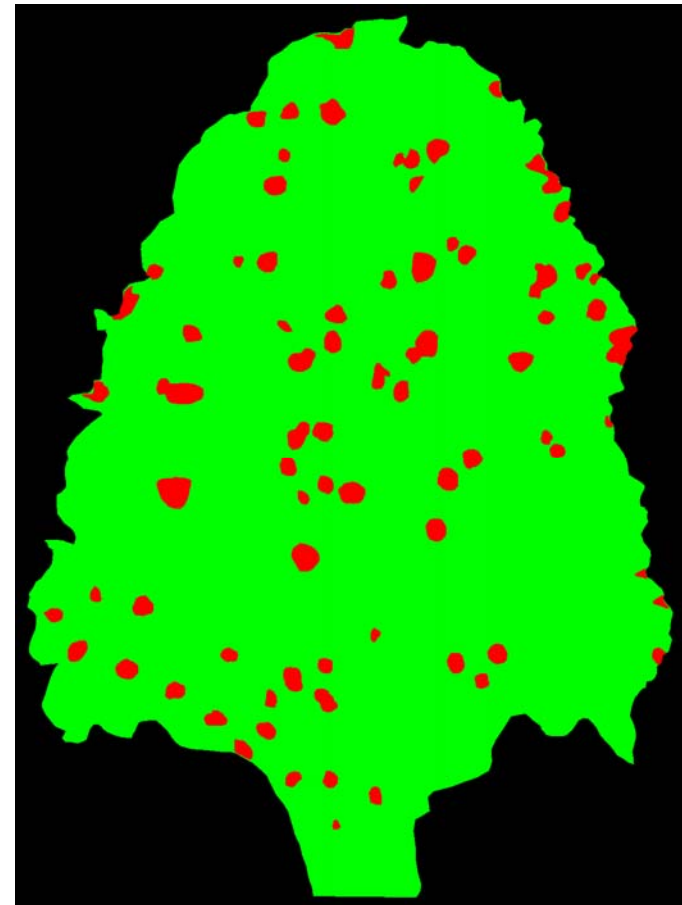
18 days after inoculation:

	Healthy areas	C. leaf spots	U. leaf spots
Healthy areas	97 %	2 %	1 %
U. leaf spots	6 %	2 %	92 %

Leaf infected with *Cercospora beticola*

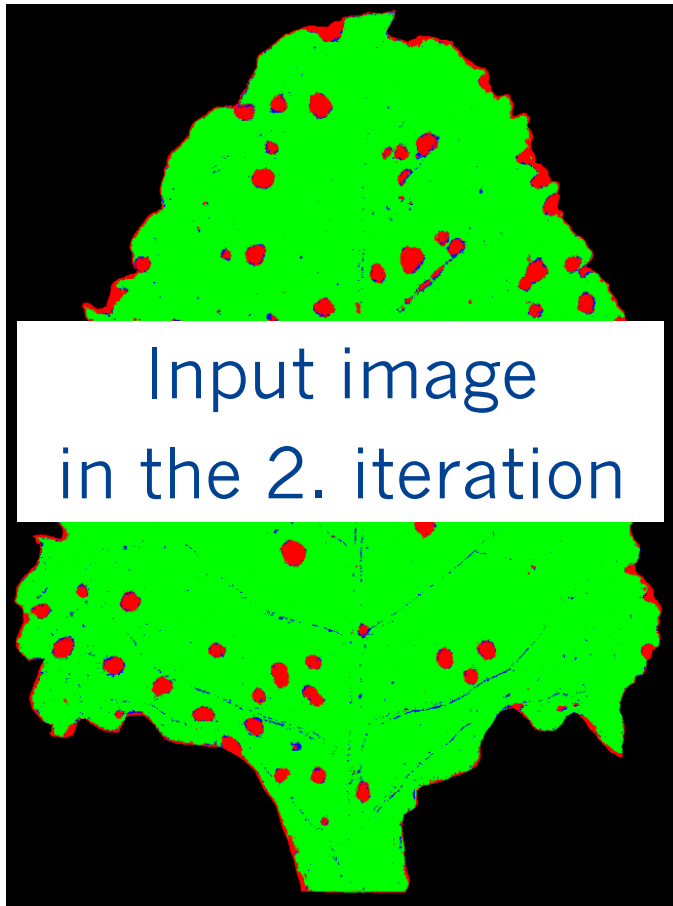


**Result of the 1. Iteration:
Pixelwise adaptive Bayes**

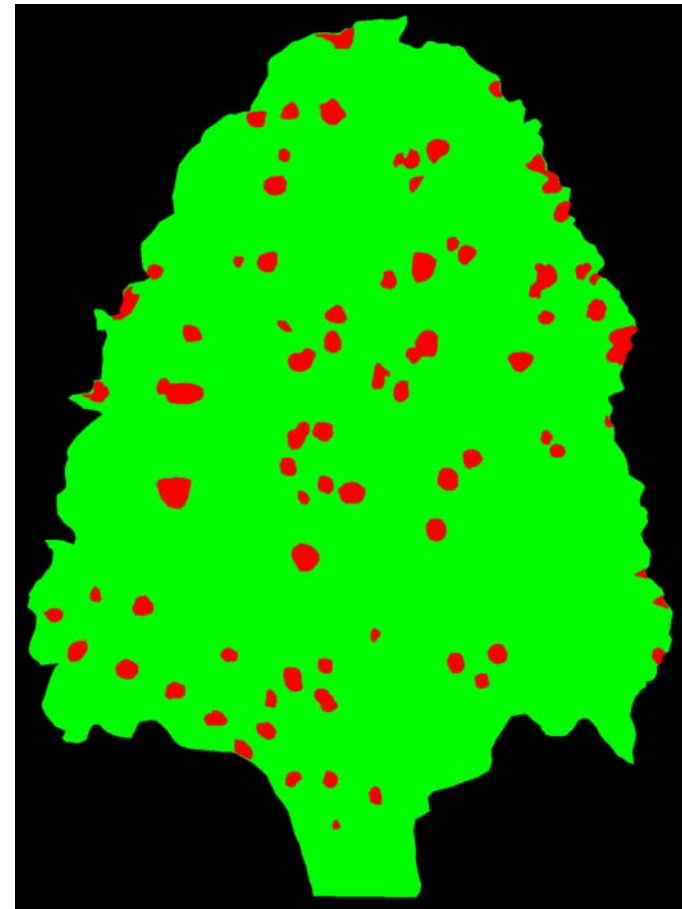


Ground Truth

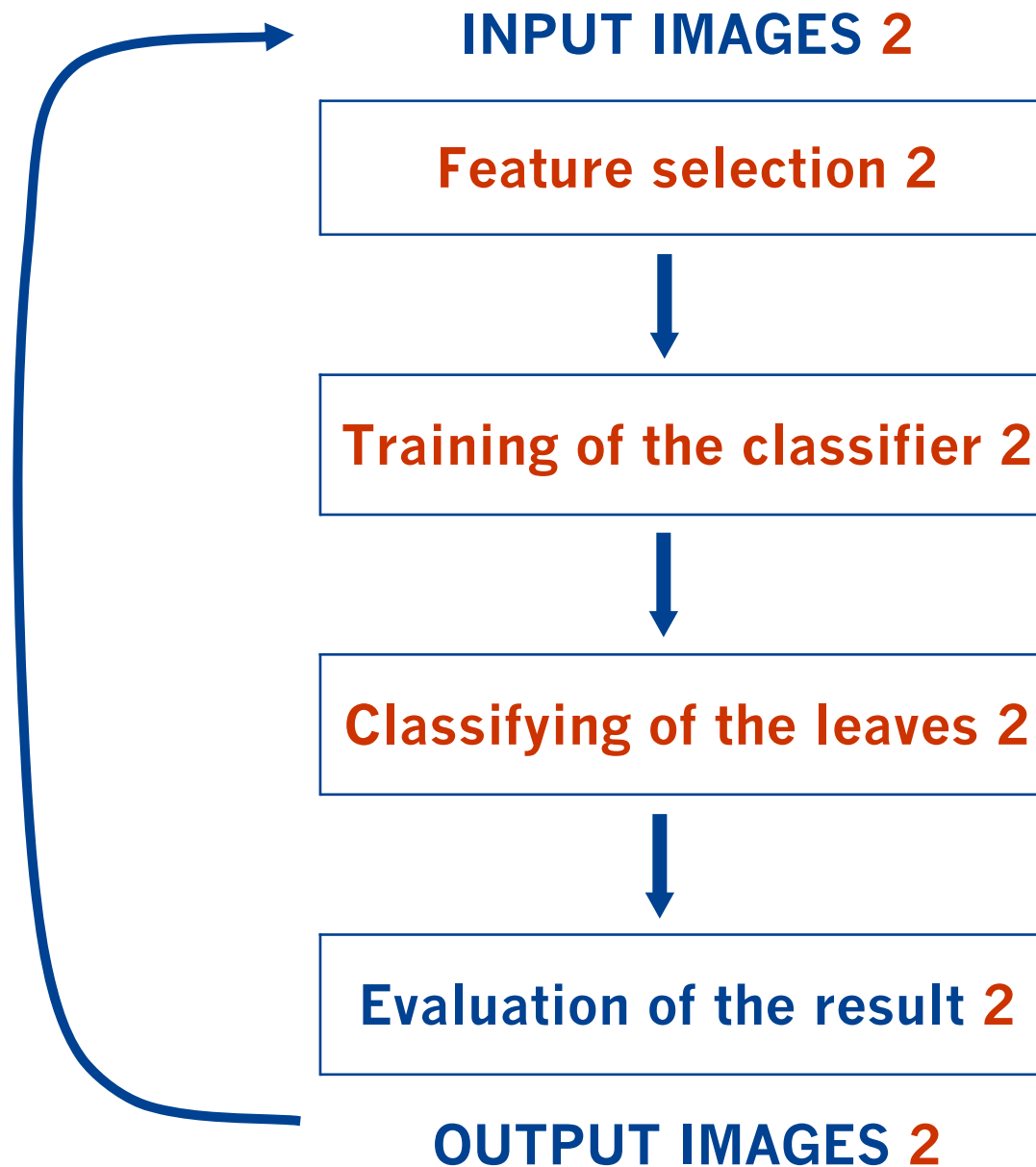
Leaf infected with *Cercospora beticola*



**Result of the 1. Iteration:
Pixelwise adaptive Bayes**



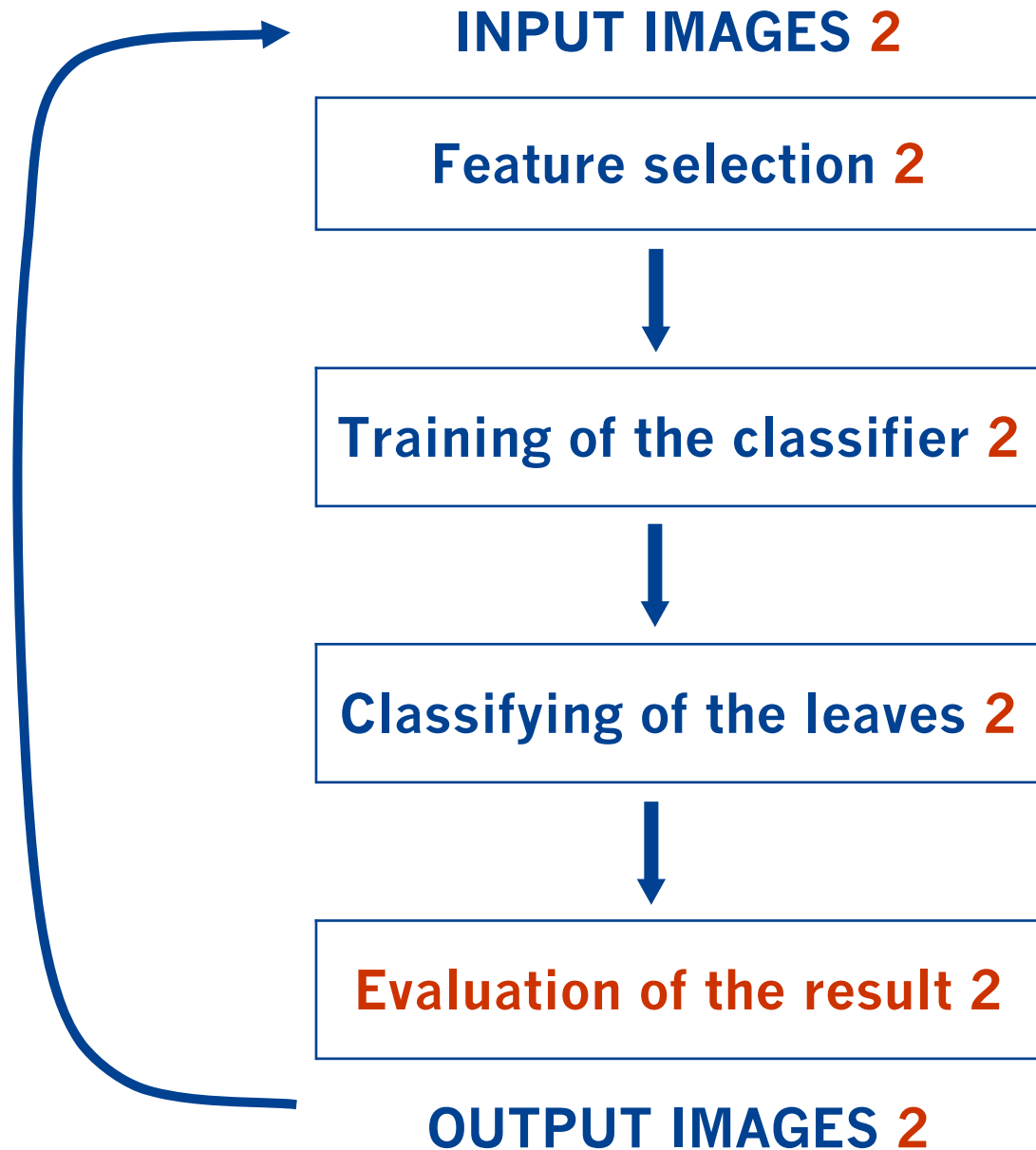
Ground Truth



- Feature vector $e_n = [e_{n,j}]$ with $n = 1, \dots, N$ regions

- $e_{n,1} = \text{Red}$
 - $e_{n,2} = \text{Green}$
 - $e_{n,3} = \text{Blue}$
 - $e_{n,4} = \text{Infrared}$
 - $e_{n,5} = \text{Area}$
 - $e_{n,6} = \text{Perimeter}$
 - $e_{n,7} = \text{Circularity}$
- Averaged colour value of the region**

- Classes
 - $\omega_1 = \text{Healthy leaf area}$
 - $\omega_2 = \text{With } \textit{Cercospora beticola} \text{ infected leaf area}$
 - $\omega_3 = \text{With } \textit{Uromyces betae} \text{ infected leaf area}$
- Maximum-Likelihood Classification



Healthy leaf

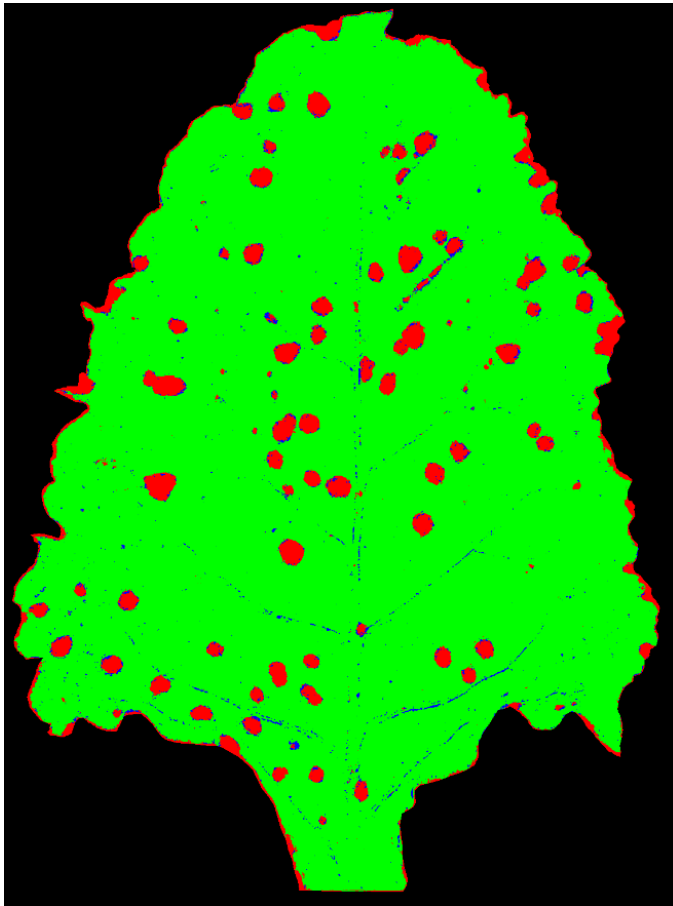


**Result of the 1. Iteration:
Pixelwise adaptive Bayes**

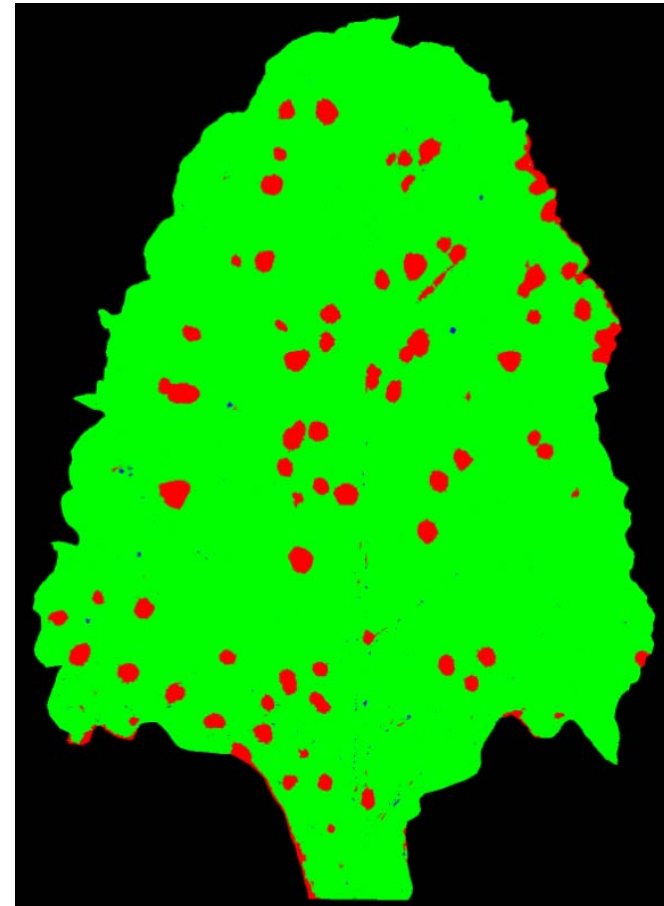


**Result of the 2. Iteration:
Region based ML**

Leaf infected with *Cercospora beticola*



**Result of the 1. Iteration:
Pixelwise adaptive Bayes**



**Result of the 2. Iteration:
Region based ML**

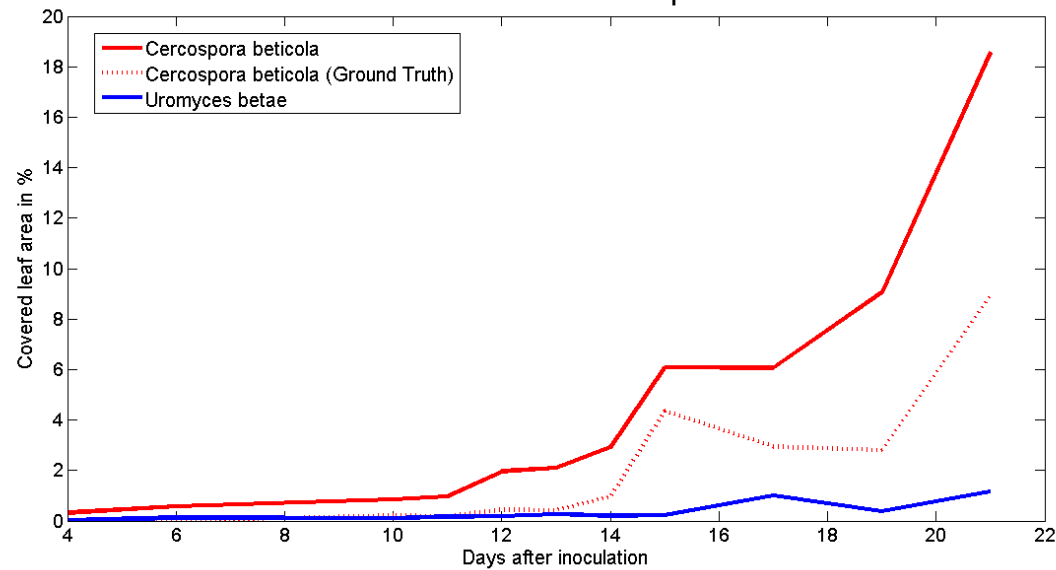
Detection rates of the leaf spots:



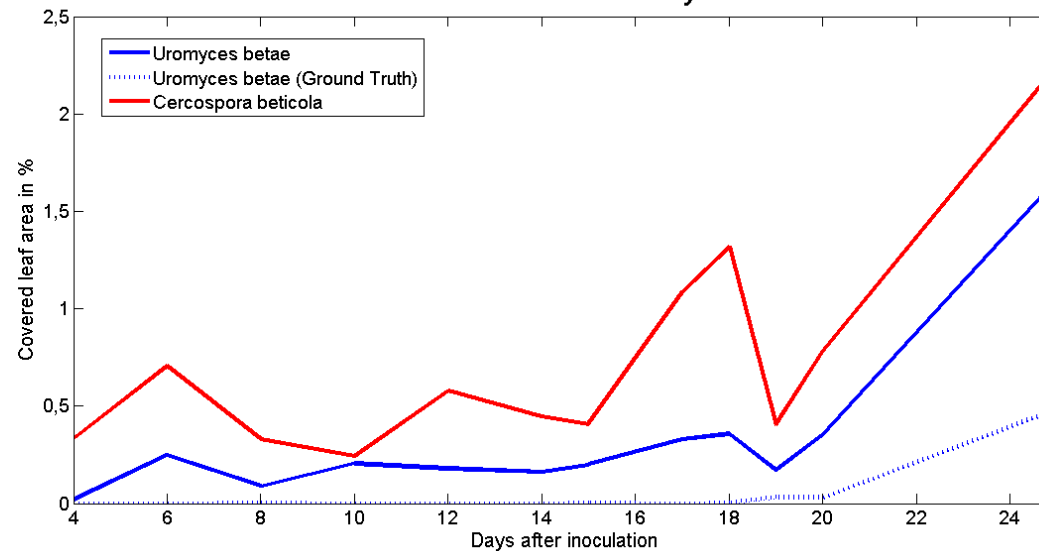
	Healthy area	C. leaf spots	U. leaf spots
C. leaf spots	9 %	88 %	3 %

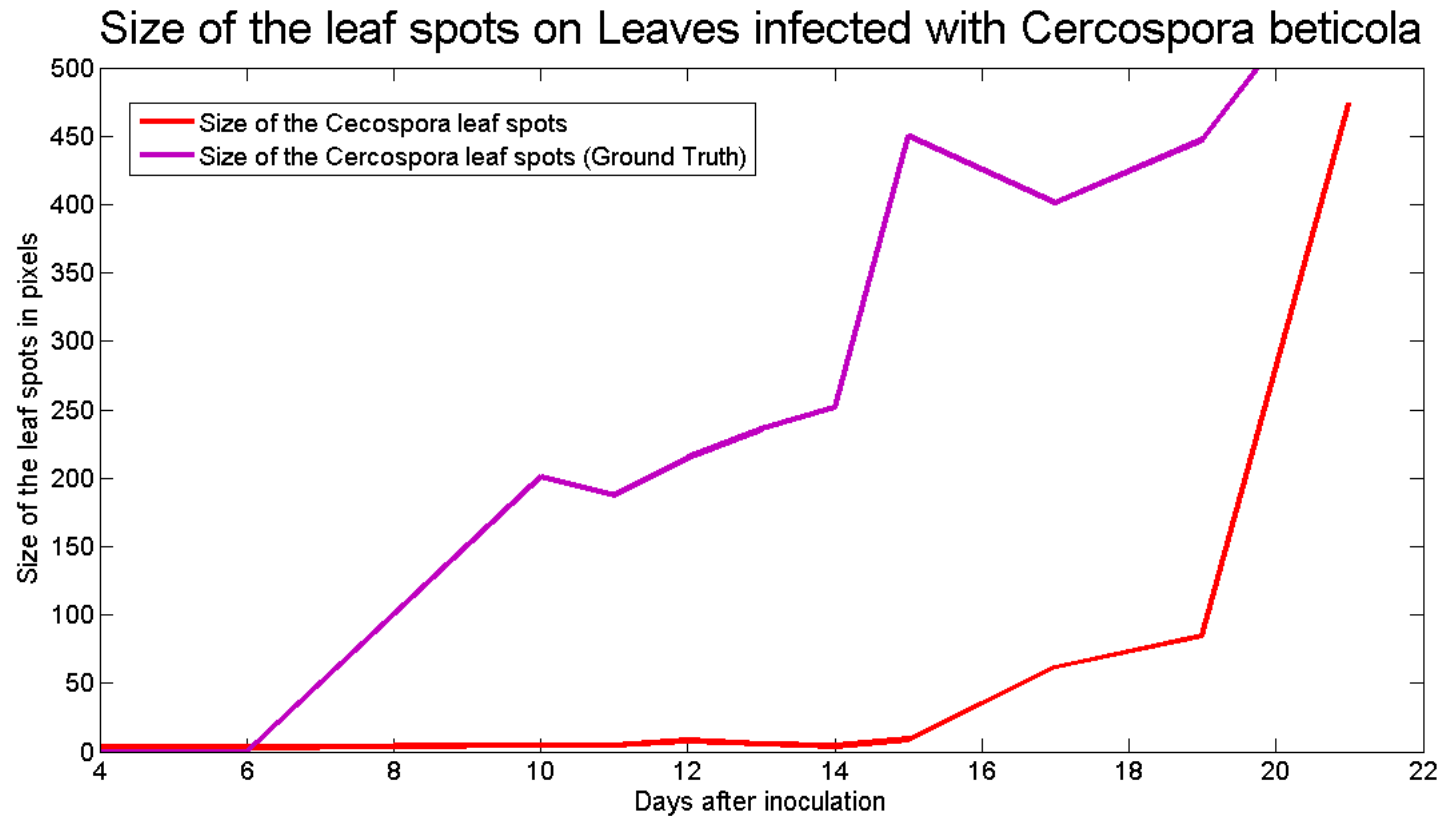
	Healthy area	C. leaf spots	U. leaf spots
U. leaf spots	21 %	24 %	55 %

Leaves infected with *Cercospora beticola*



Leaves infected with *Uromyces betae*



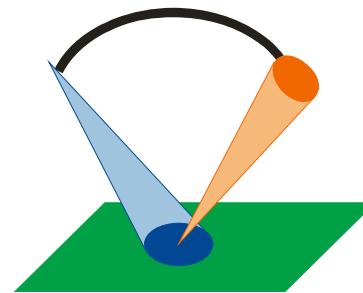


- Pixelwise classification rates on the 17/18 dai
 - Cercospora beticola 97%
 - Uromyces betae 92%
 - Healthy leaf area 93% on C. / 97% on U.
- Detection rates of the leaf spots
 - Cercospora beticola 88%
 - Uromyces betae 55%
- Continuous overestimation of the diseased areas



- Further improvement through new features, e.g. gradients
- Incorporation of a conditional random field between the 1. and 2. iteration to smooth the pixelwise classification result

Funding of this research by DFG Post Graduate Program 'Use of information technologies for precision crop protection'



GK 722



Thank you for your attention!