Computer Vision

Classification with Neural Networks

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Classification with Neural Networks

Overview:

- **Introduction classification**
- **Introduction neural networks**
- **Image classification**
- **Exercise**
- **Feature vector classification (*)**
- **Exercise (*)**

Related presentations:

- **Classification with neural networks part II**
  with examples how to use neural networks in scripts
- **Genetic Algorithms**
  how to tune the parameters of a neural networks

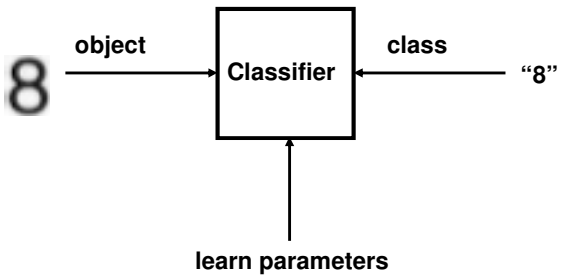
Introduction classification

Classification:
the assignment of an object characterized by a set of features to one of a number of predefined classes.

Example: Optical Character Recognition

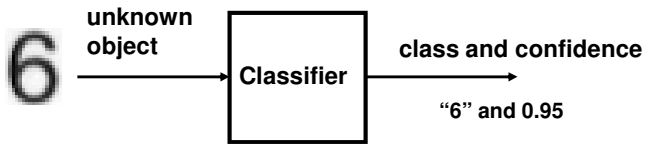
Introduction classification

- **Learning mode**
  - **Learn set: set of objects with known classes**
  - **Each time the total learn set is trained is called an epoch, for successful learn normally many epochs are necessary**



Introduction classification

- **Production mode**



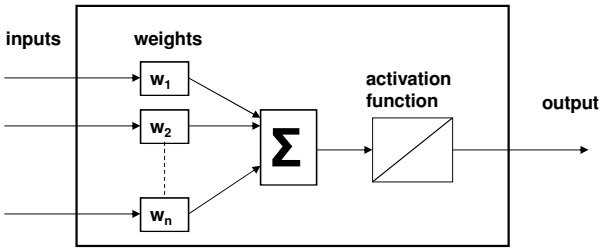
Introduction classification

- **Image classification**
  - **'raw' image data**
- **Feature vector classification**
  - **features are extracted from image and used for the classification**
  - **data reduction**

Introduction neural networks

- **Based on a model of our brain**
- **Neuron**
- **Neural networks**
- **Multilayer perceptron neural Network with back propagation learning**
- **Example: learning sinus function**

Neuron

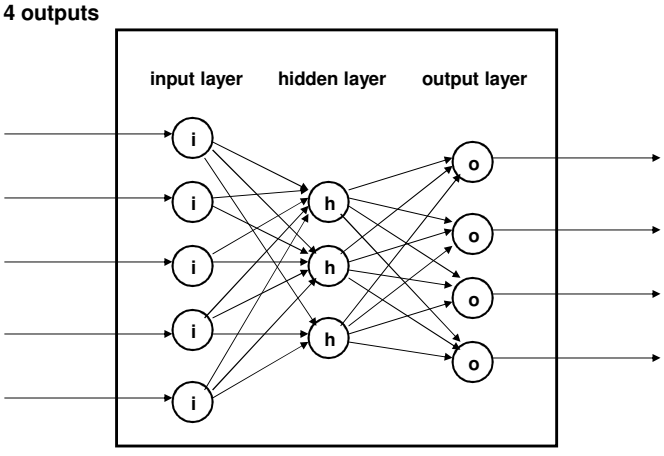


Neural networks

- Neural network consists of multiple neurons organised in different layers
- There are several different architectures for the organization and for the learning algorithms
  - Supervised learning
  - Unsupervised learning
- Most common used architecture is a multilayer perceptron neural Network with back propagation learning also called Back Propagation Network (BPN)

Back Propagation Network

Example with:
- 5 inputs
- one hidden layer with 3 neurons
- 4 outputs



Example: learning sinus function

- Create BPN with
  - Input layer of 1 neuron
  - One hidden layer of 100 neurons
  - Output layer of 1 neuron
- Train the BPN with 100 random examples: x, sin(x)
  - $in = random –1 1
  - $out = sin $in
  - Note the behaviour of the training error ($t_err)
- Test the BPN with 5 random values
  - $in = random –1 1
  - $res = sinus of $in learned by BPN
  - $exp = sin $in
  - $error = error in result

- use script bpn_sinus.jls

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Example: learning sinus function

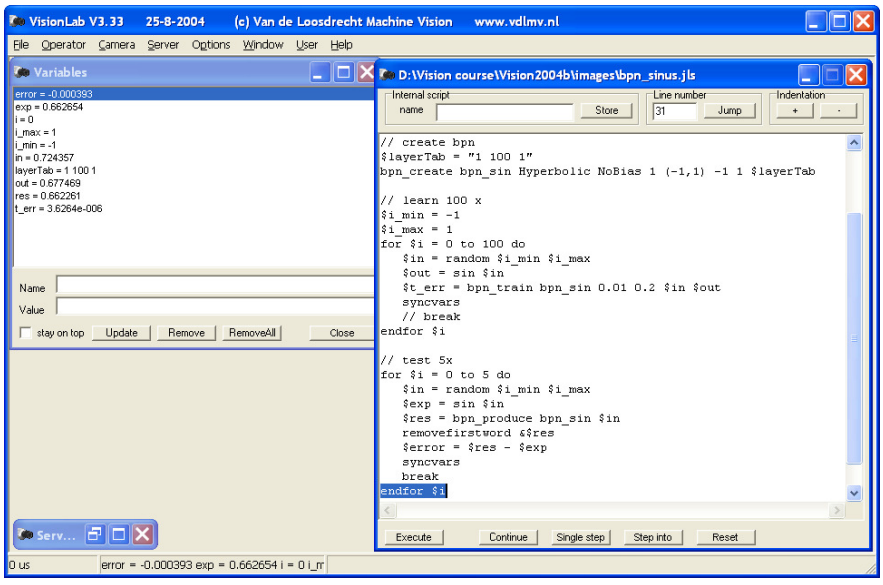

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Image classification

- Introduction
- Class Image Sets (CIS)
  - Train set
  - Evaluation sets
- Training the BPN
- Using the BPN

Image classification

- Pixels of image are inputs,
  nr of pixels = size input layer
- Nr of classes = size output layer
- Scale, rotation and lighting variations
  - Train BPN with all combinations
  - Use computer vision operations to make images invariant by normalizing:
    - Scale, use Zoom
    - Rotation, use Rotate(Full)
    - Lighting, use Contrast Stretch

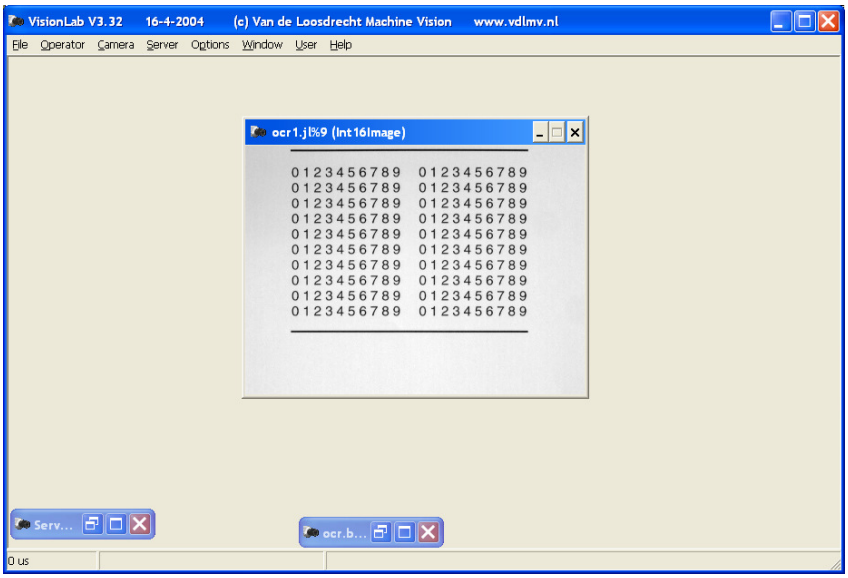
Class Image Set (CIS)

- **A CIS is a collection of images with their associated classes. For usage with Neural Networks, all images in a CIS must have the same image type and size**
- **CIS:**
  - **Class table with the name and id of each class**
  - **For each class an image table, each image in an image table has its unique image index number**

Demonstration Class Image Set (CIS) (*)

- **Create new CIS and add some classes and images (no slides) use correct image type and image size**

Image ocr1.jl used to generate CIS



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Script gen_ocr1_cis.jls

- Create cis
- Threshold image
- Remove big blobs
- Label image
- BlobAnalyse SortDown TopLeft UseX Height TopLeft Width
- for $group = 0 to 1 do
  - for $num = 0 to 9 do
    - for $i = 0 to 9 do
      - Roi $t $l $h $w
      - Contraststretch
      - Zoom NearestPixelInterpolation
      - Add normalized image to cis

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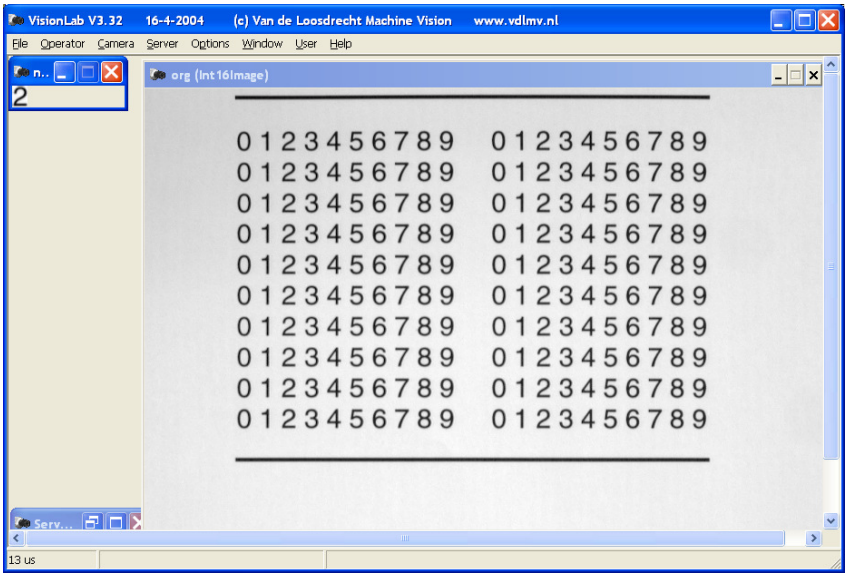
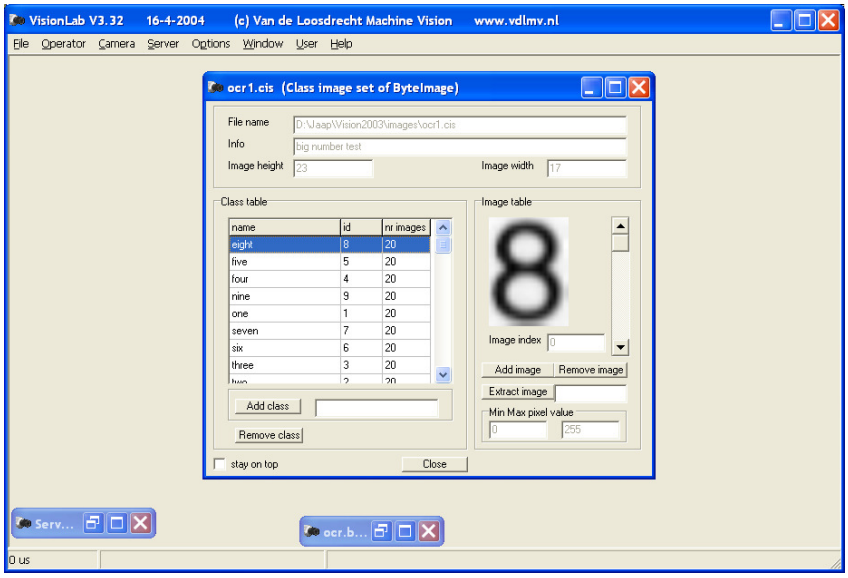
Demonstration Class Image Set (CIS)

- Use script gen_ocr1_cis.jls to generate ocr1.cis,
- Open and examine ocr1.cis

Generation of ocr.cis



ocr1.cis



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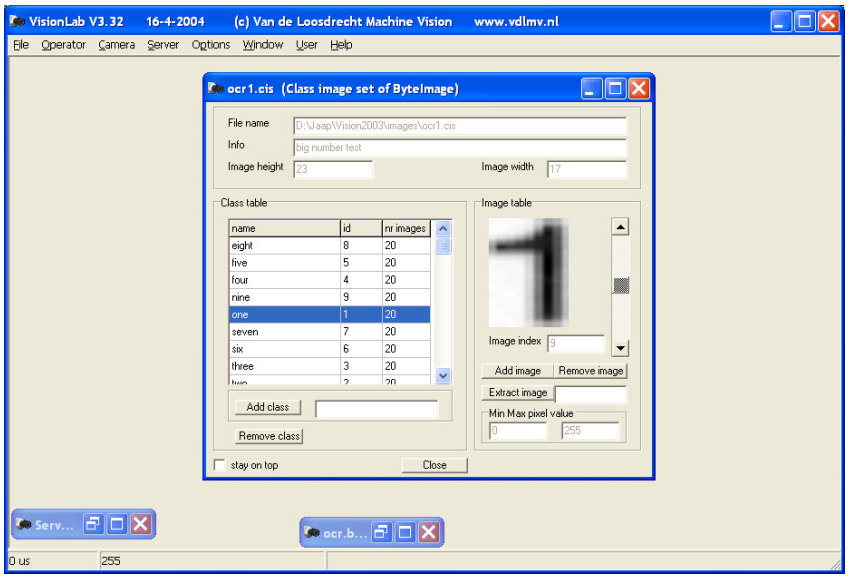
ocr1.cis



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Different sizes of numbers

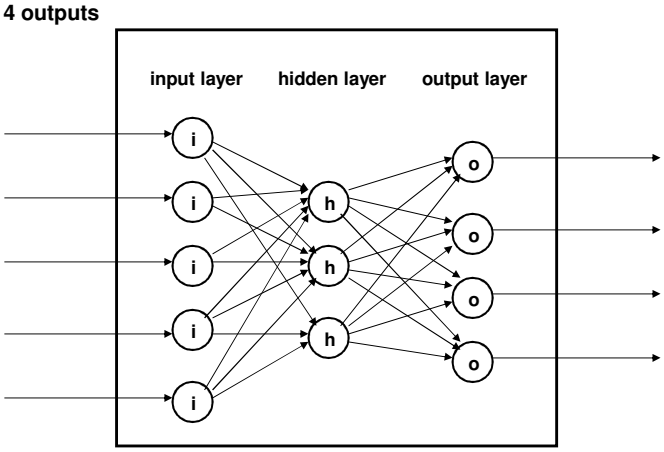
- **Note that number 1 is much smaller in width as number 8**
- **A BPN always works with a fixed number of inputs.**
- **So all numbers have to be rescaled in size to the same height and width of the learn image**

Training the BPN

- **Learning parameters**
- **Train set**
  balancing the train set
- **Evaluation set**
- **Testing the result**

Back Propagation Network

Example with:
- **5 inputs**
- **one hidden layer with 3 neurons**
- **4 outputs**



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Learning parameters

- **Learn rate:**
  The learn rate is a small positive value and determines how fast the BPN will learn. If the learn rate is too low learning will be very slow. If the learn rate is too high the training error will oscillate and stay at an high value.
- **Momentum:**
  The momentum is zero or a small positive value. This parameter influences the speed of convergence of the learing process and specifies which fraction of the "learn effect" of the previous training sample should be added to the "learn effect" of the next training sample.

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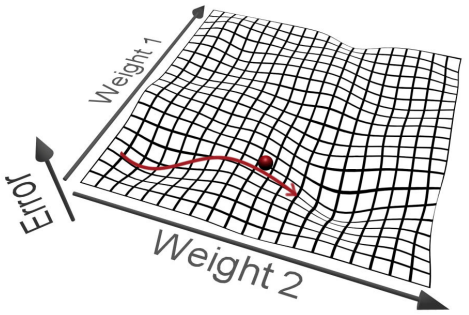
Learn rate and momentum



the direction of the change for the weights is calculated using the derivative of the error function

the 'step size' for the adaptation of the weights is proportional to the the learning rate

the momentum is the fraction of the previous weight change which is added to the new calculated weight change

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Learning parameters

- **Size first hidden layer:**
  If too small the training error will remain high, if too high training will be very slow
- **Size second hidden layer:**
  The use of a second hidden layer may speed up the learning process. Advice: start first with an empty 2nd hidden layer.

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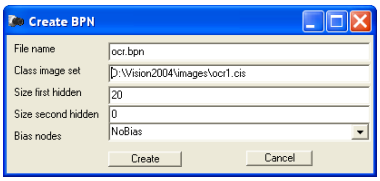
Training the BPN

- **Stopping the training process:**
  - **Max nr of epochs**
  - **Stop error**
- **Confidence:**
  Indication how confident the classifier is about the result,
  [1 = confident .. 0 = unconfident]
  In normal conditions a confidence > 0.7 is fine
- **Reset network:**
  all weights are random initialised with value [min ..max]

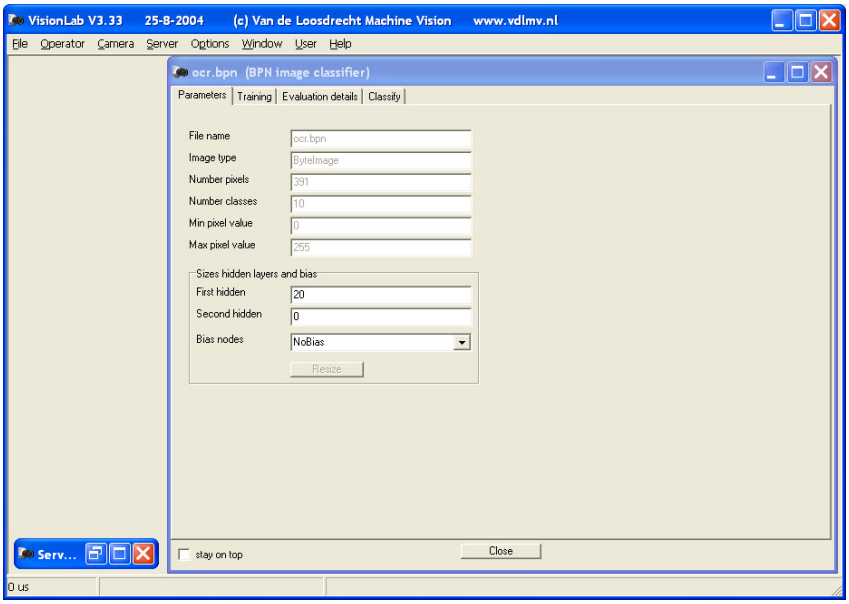
Demonstration Training BPN

- **Create new BPN ocr.bpn (File menu),**
  use ocr1.cis and size first hidden layer = 20, second = 0, NoBias
- **Go to Training form, learnRate = 0.001, momentum = 0.001**
- **Start training, note evaluation set and training set are the same**
  reset: -0.1 .. 0.1
- **Open ocr1.cis and select from a random class a random image and extract that image with name test**
- **Select image with name test as "second selected"**
- **Go to BPN and select Classify form and classify "second selected" image**

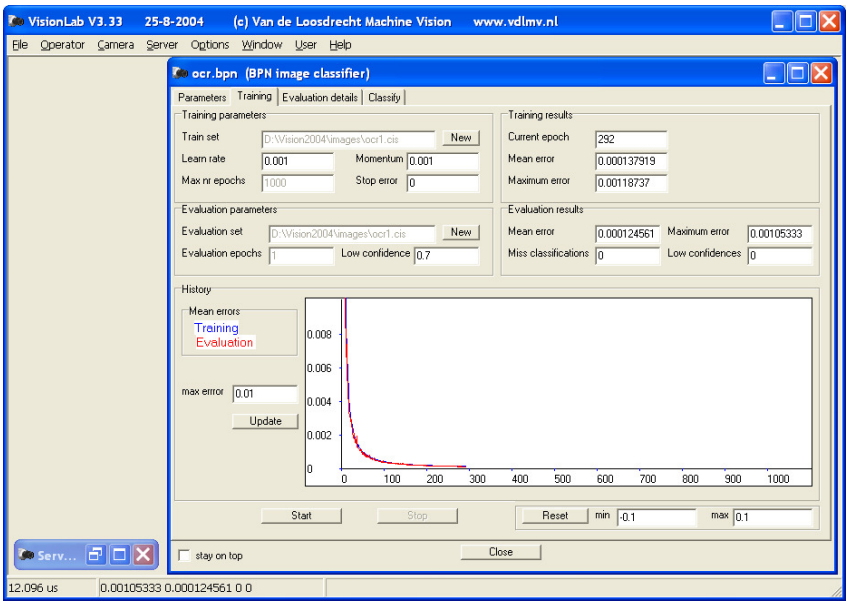
Demonstration Training BPN



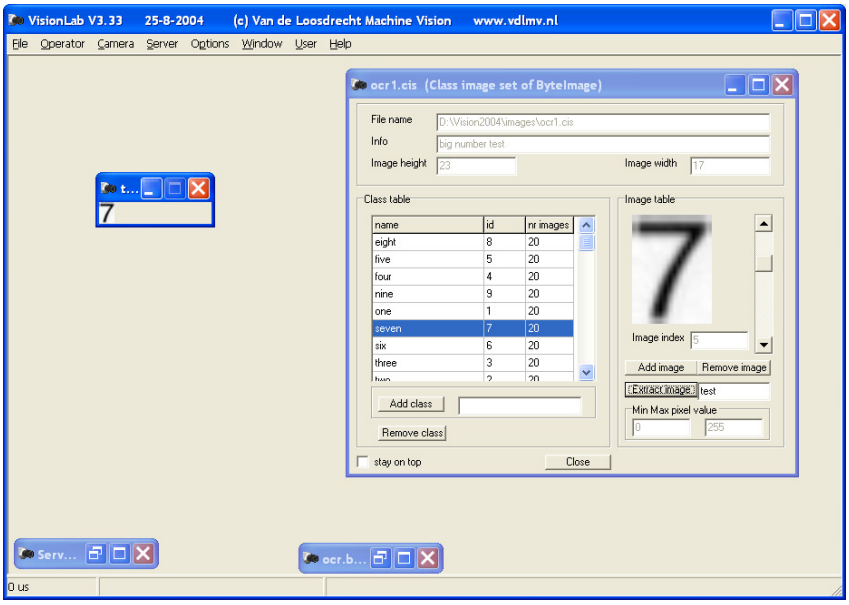
Demonstration Training BPN



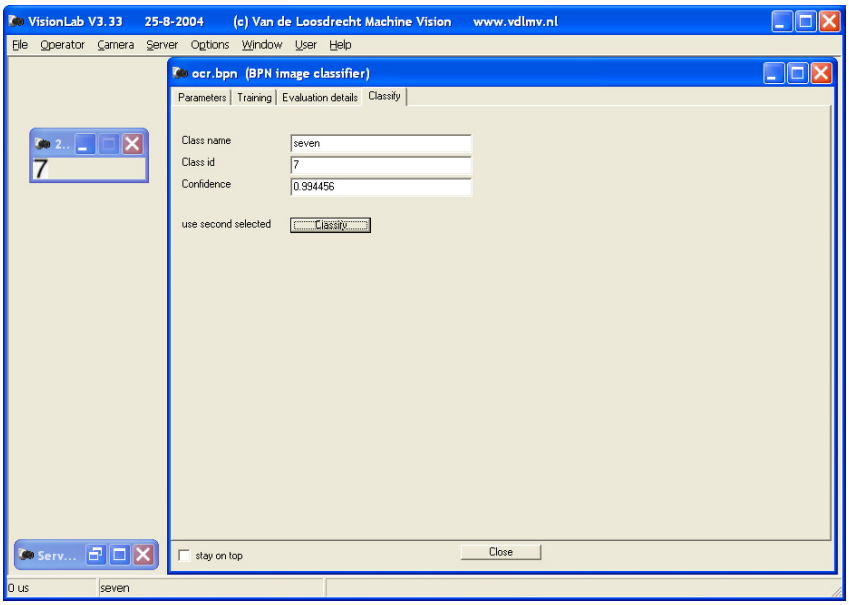
Demonstration Training BPN



Select random image from random class



Classify image



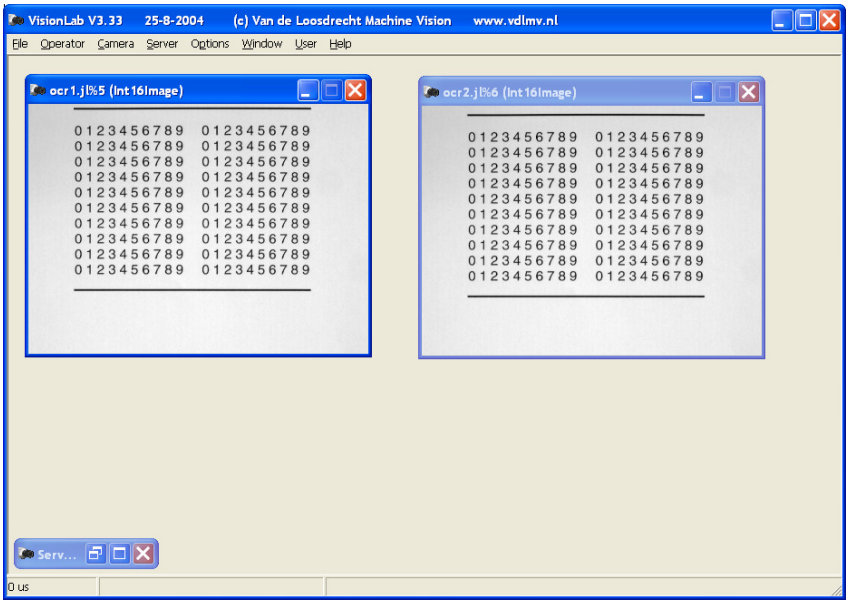
Training with evaluation set

In order to avoid inbreed, it's better to use a separate training and evaluation set

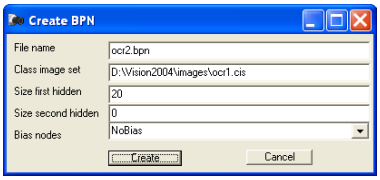
Demonstration Training BPN with evaluation set

- Create new CIS and some classes (no slides)
- Open image ocr1.jl and ocr2.jl, same object slightly different position and lighting condition
- Use script gen_ocr2_cis.jls to generate ocr2.cis
- Create new BPN ocr2.bpn (File menu),
  use ocr1.cis and size first hidden layer = 20, second = 0 , NoBias
- Go to Training form
- Start training, and select as evaluation set ocr2.cis, learnRate = 0.001, momentum = 0.001
- Open ocr2.cis and select from a random class a random image and extract that image with name test
- Select image with name test as "second selected"
- Go to BPN and select Classify form and classify "second selected" image

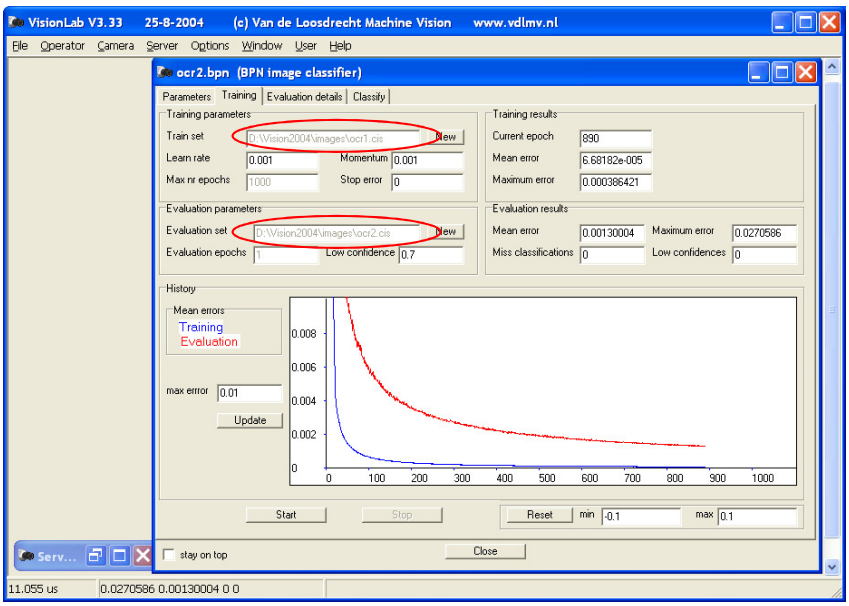
Compare image ocr1.jl and ocr2.jl



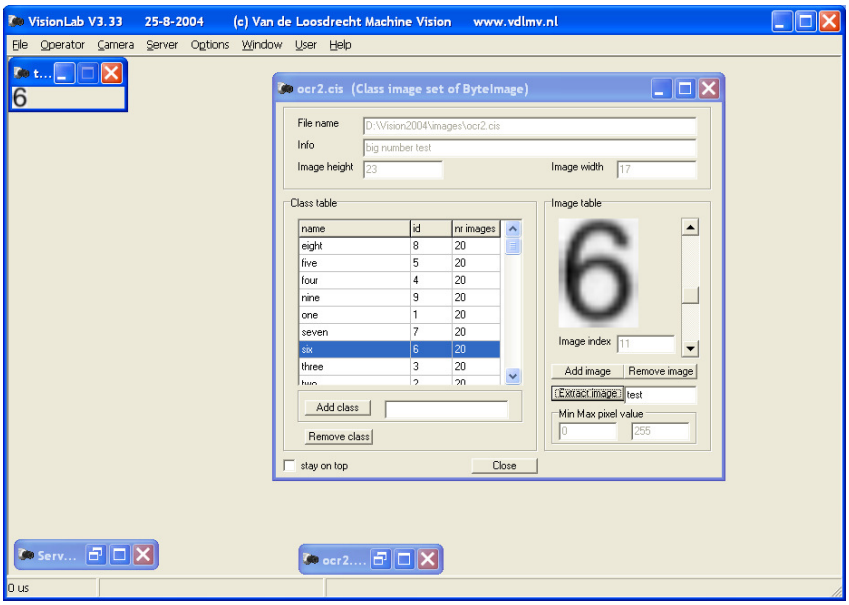
Demonstration Training BPN with evaluation set



Demonstration Training BPN with evaluation set



Select random image from random class from evaluation CIS



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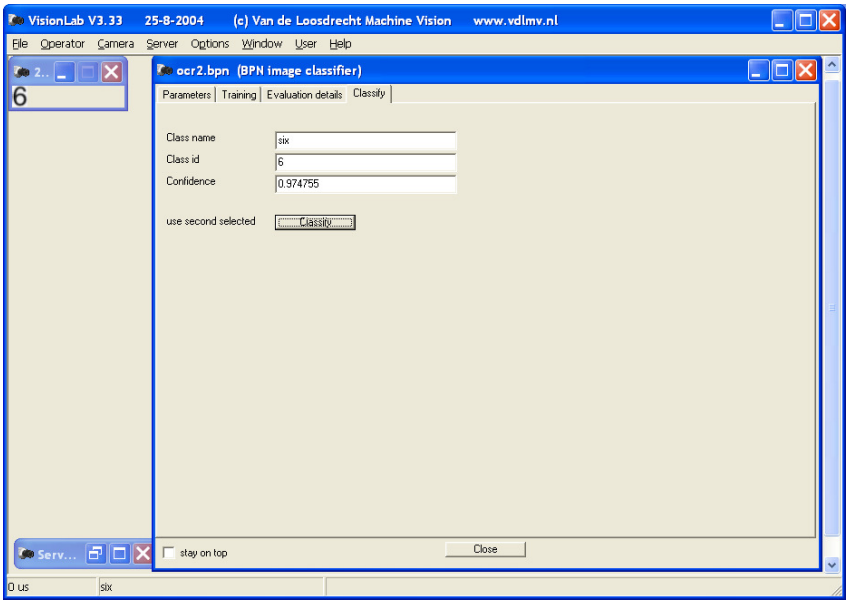
Classify image



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Optimizing the settings for a image BPN

This function uses a Genetical Algorithm (GA) in order to find the best solution.

NOTE: this optimalization process is very time consuming and for real problems it may take hours or even days.

In the Low/High box the user must specify the search space for size of hidden layers, learn rate and momentum, by specifying the lowest and highest border values.

In the settings box must be specified:
- **the population size for the GA algorithm**
- **the number of epochs the BPN is trained before being evaluated**
- **the low confidency factor used in the evaluation**
- **the maximum number of generation for the GA algorithm**

Optimizing the settings for a image BPN

In the detailed setting box, specialized setting can be set, it is advised to use the standard values.
- **the MinError is the minimal target error**
- **the DeltaError is the minimal error for start of hill climbing**
- **the MicroP is the probability during self mate that parameter is a micro mutation**

With the Start button the optimising process is started. With the Stop button the optimising process is stopped, but first the current generation is optimised completely, note this can take some time!

In the best result box the best values found sofar for hidden layers, learn rate and momentum are displayed. Also the current generation number and the best error value found.

With the Accept button the best solution found is used to initialse the settings in the Parameters and Training tab. Then the normal full training is started.

Demonstration genetic algorithm for optimizing image BPN

- **Go to GA Optimize form, this can be used to find the optimal setting for the BPN**
  Use settings:
  Low and High first hidden = 20 (is fixed for the demo)
  Low and High second hidden = 0
  LearnRate: 0.0005 – 0.001
  Momentum: 0 – 0.001
  Populationsize: 4
  NrEpochs: 10
  LowConfidence: 0.5
  MinError: 0
  DeltaError: 1
  MircoP: 0.25
- **Click start to start optimise process**
  Note this process is very time consuming, for the demo PopulationSize and NrEpochs have been set to low values. Also the first hidden layers is fixed to 10
- **Click stop button to interrupt the optimise process**
- **Click accept button to initialise the settings in the Parameters and Training tab. Then the normal full training is started.**

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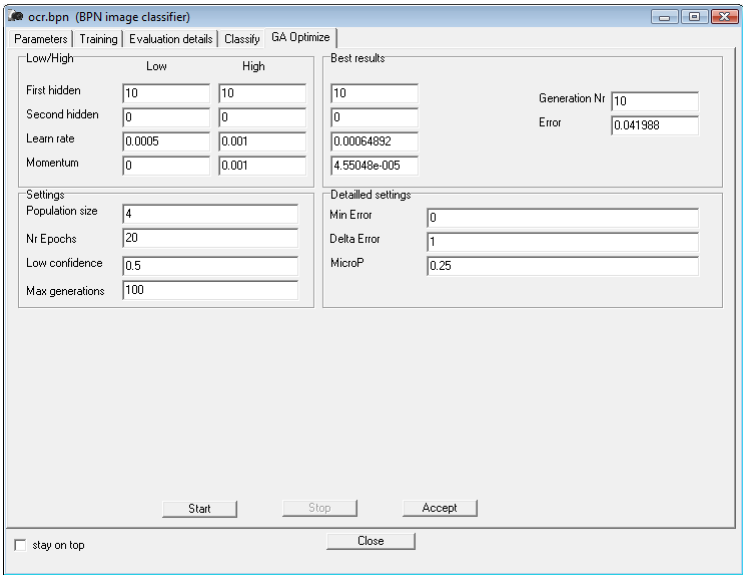
Set the parameters for the optimising process



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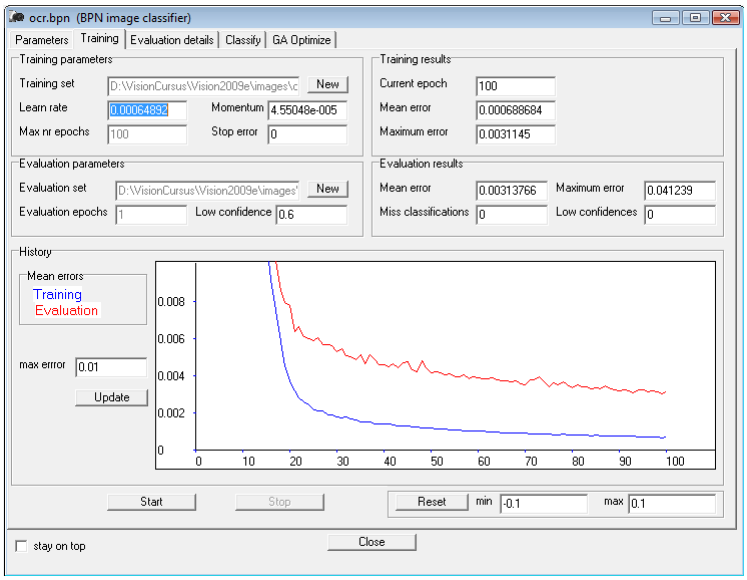
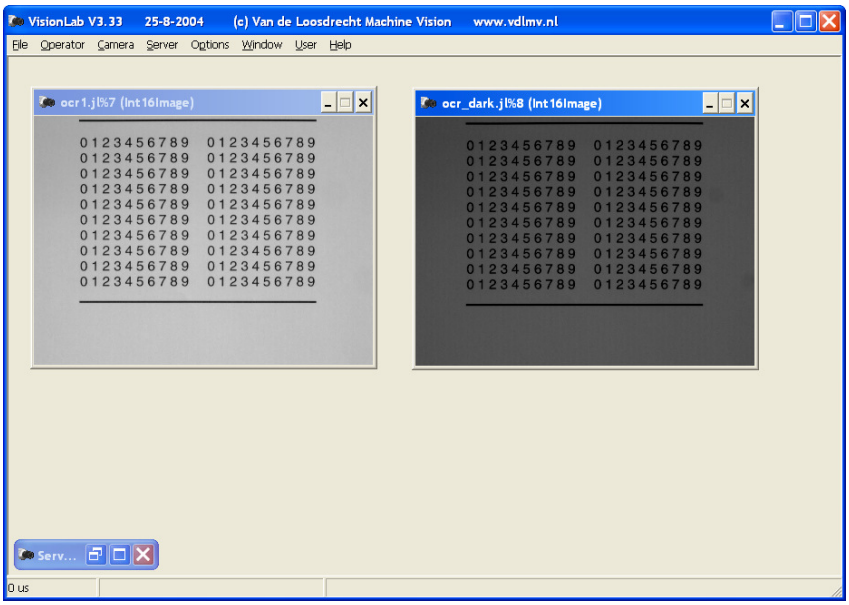
Used find optimal parameters to start the full training



Demo analyzing learning problems (*)

- **Compare images ocr1.jl and ocr_dark.jl with LUT clip**
- **Change evaluation set to ocr_dark.cis,**
  this is generated from image ocr_dark.jl under very low lighting conditions
- **Reset network with –0.5 and 0.5, ([-0.1 .. 0.1] will give better results)**
- **Start training and stop after 12 epochs,**
  due to the low number of epochs there are now 11 miss classifications and 99 low confidences
- **This can be analyzed on the Evaluation details form,**
  use low details
- **By selecting a row and specifying a name at the Extract Image button the offending image can be extracted for examination**
- **By changing to high details the individual outputs in the output layer can be examined.**
  Output values are in the range [-1..1]. A class is 'strong' if the output value is close to 1 and weak if close to –1.
  On the first row an 'Eight' is classified as a 'Three'

Comparing ocr1.jl and ocr_dark.jl (*)



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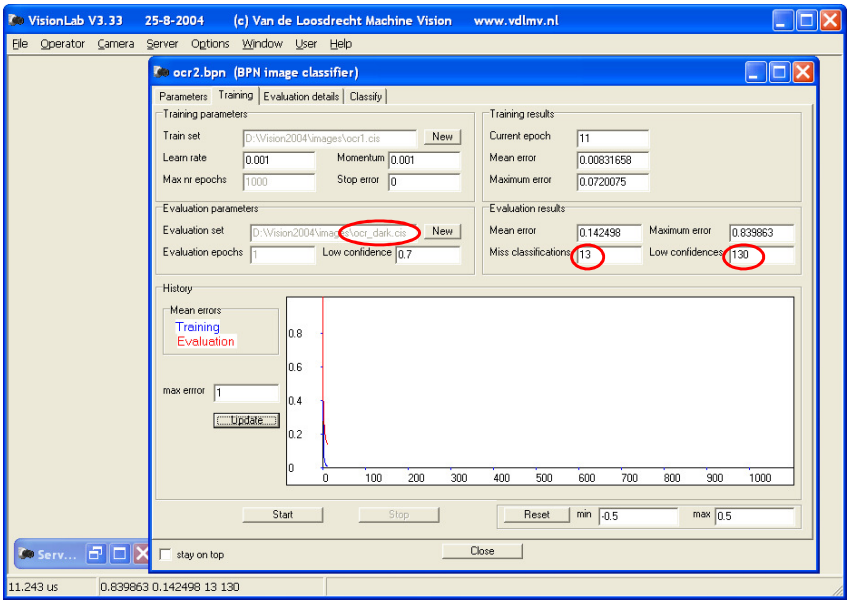
Evaluate using ocr_dark.cis (*)



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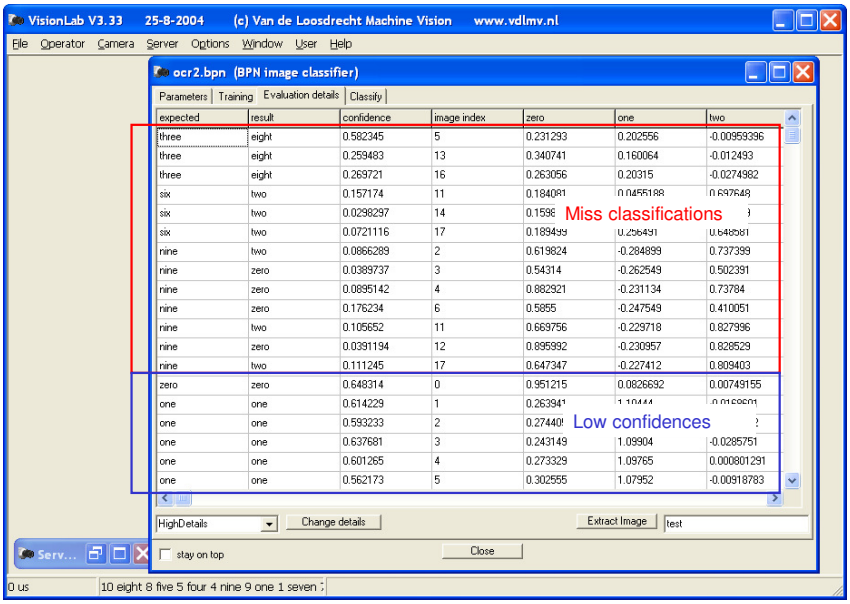
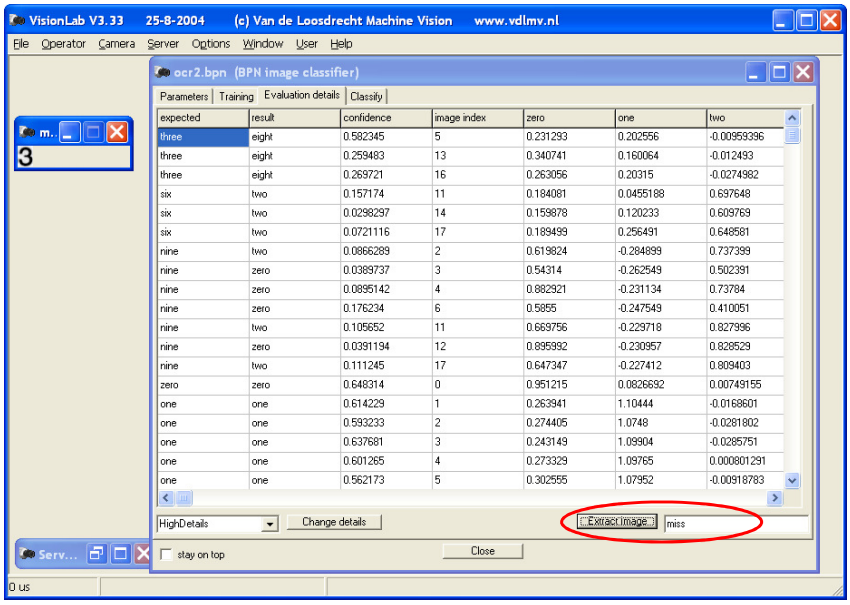
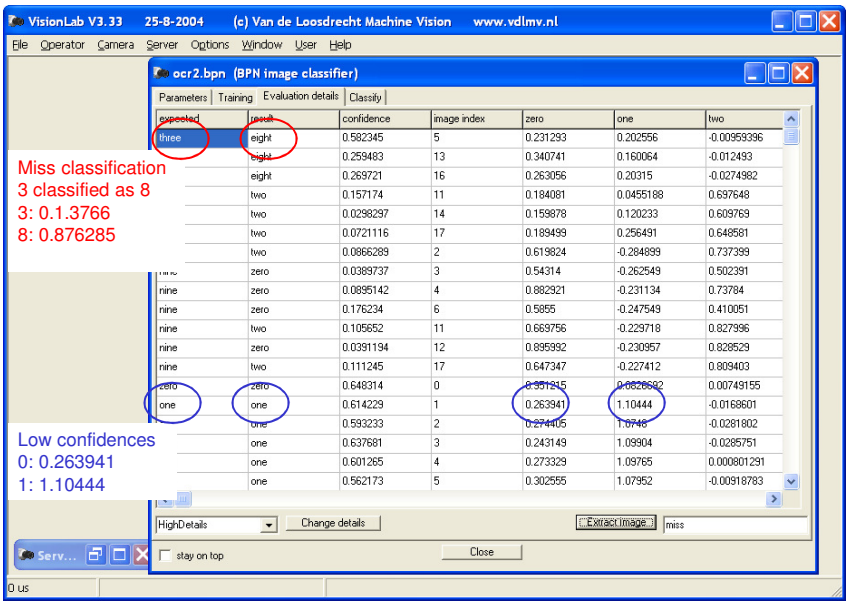
Evaluation details form (*)



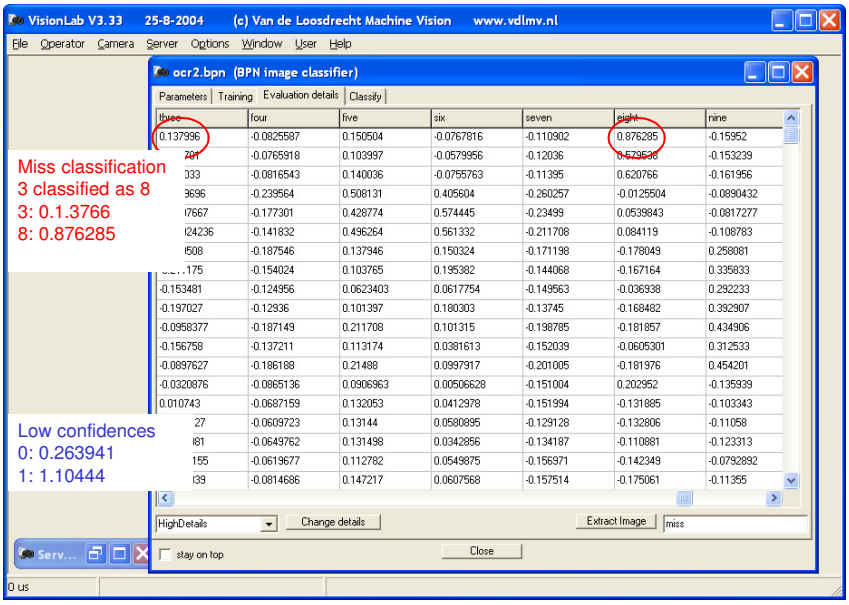
Extract offending image (*)



Examine high details (*)



Examine high details, scrolled to the right (*)



Exercise OCR dark (*)

- **Experiment with learning parameters to get better results**

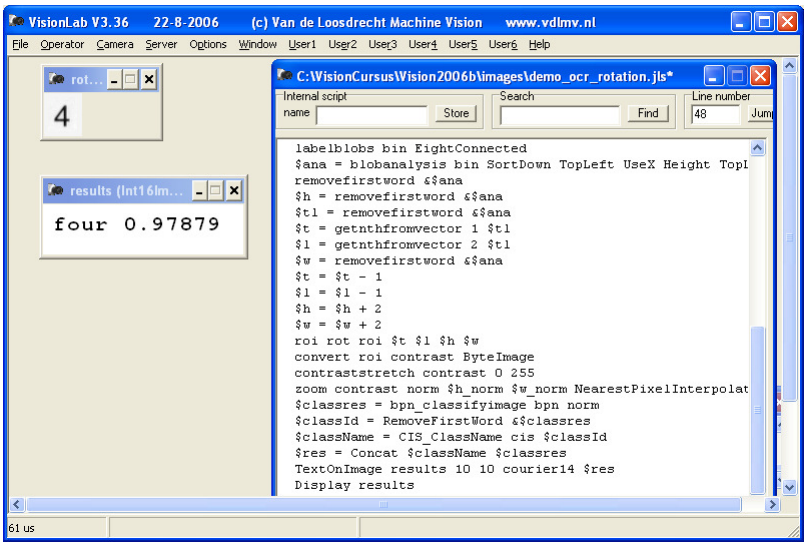
Notes for applications

- **It's better to control the lighting conditions so this kind of dark image can not occur**
- **It's also possible to use more sophisticated contrast normalization algorithms to deal with changing light conditions**
- **The training set can be extended with images under different lighting conditions to make the application more robust**

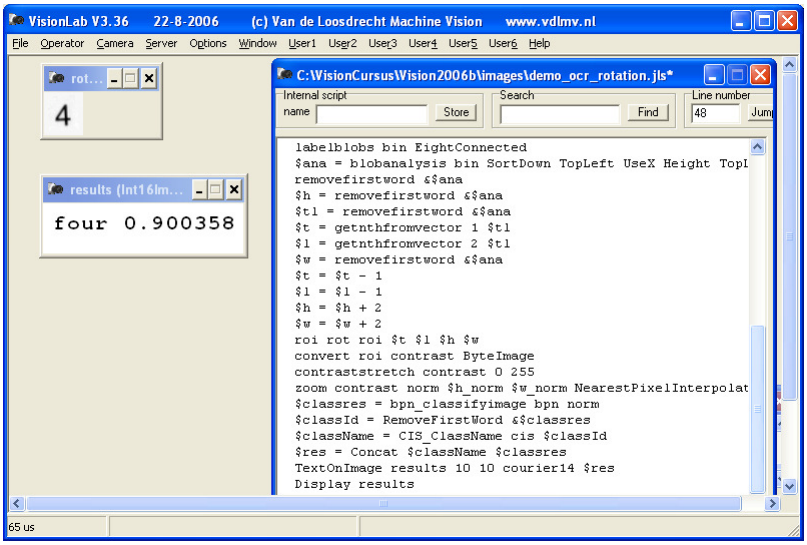
Demo robustness of BPN

- **Execute script demo_ocr_rotation.jls**
- **Execute script demo_ocr_size.jls**
- **Execute script demo_ocr_contrast.jls**

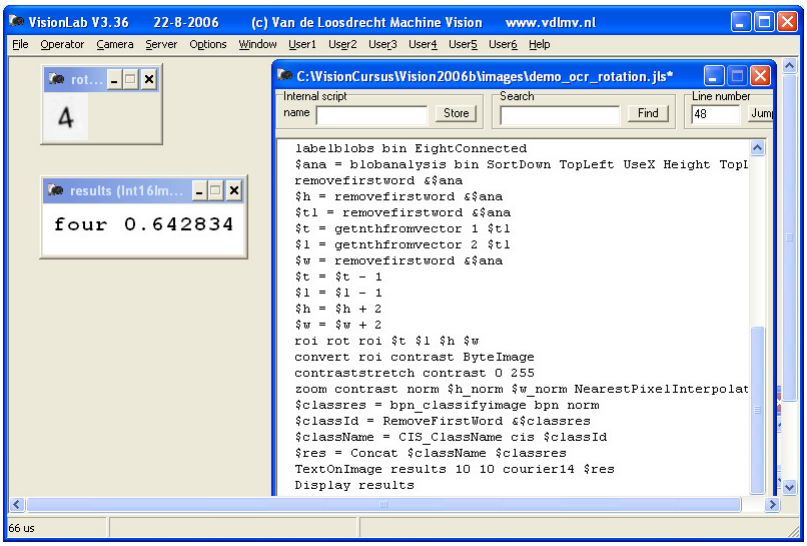
Demo with rotated input images



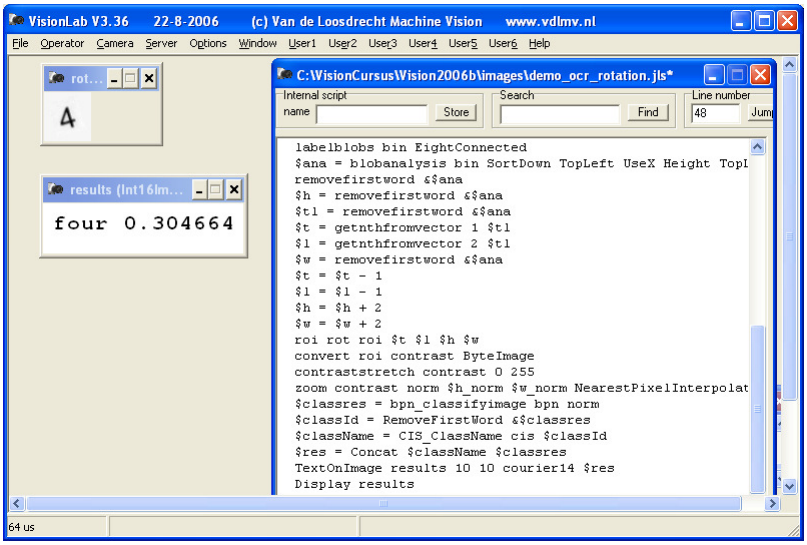
Demo with rotated input images



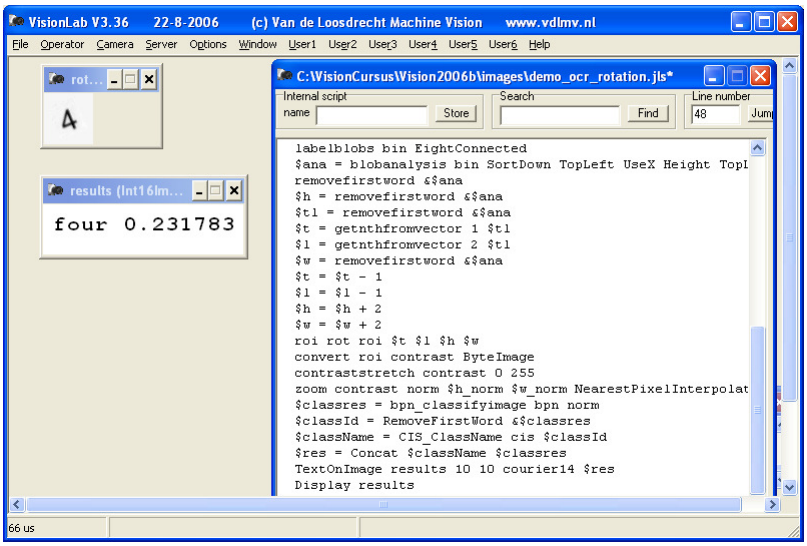
Demo with rotated input images



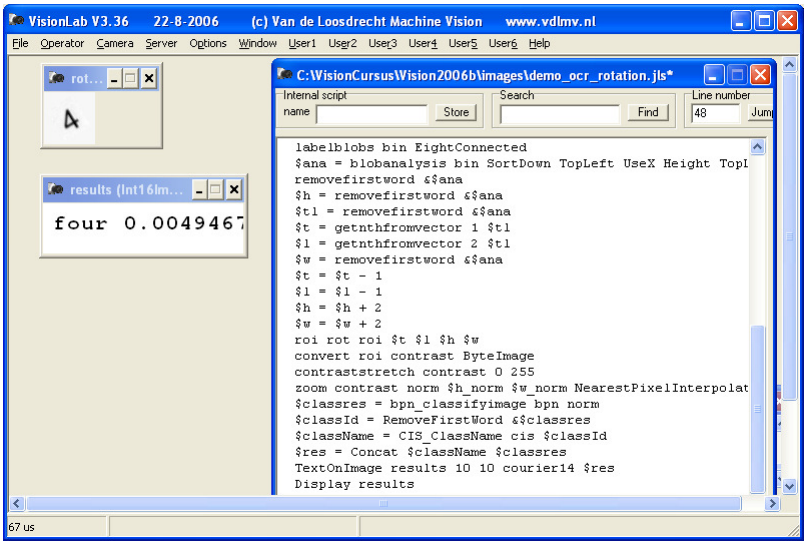
Demo with rotated input images



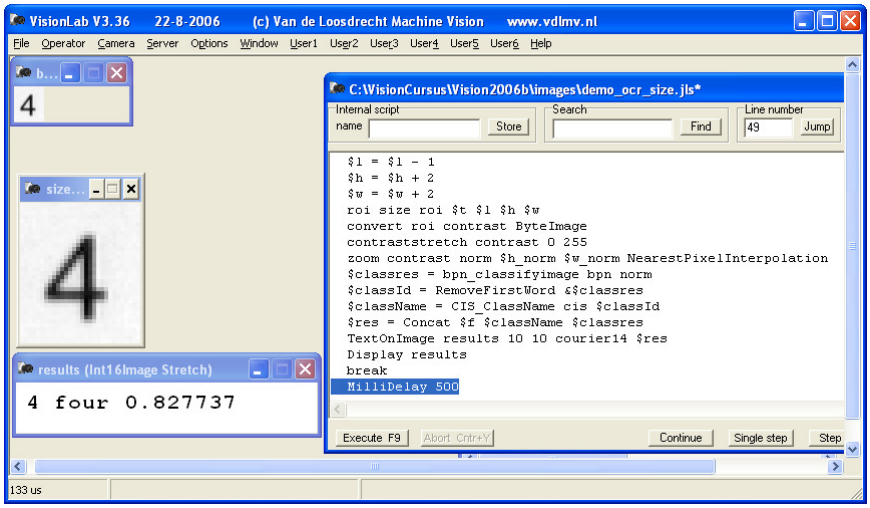
Demo with rotated input images



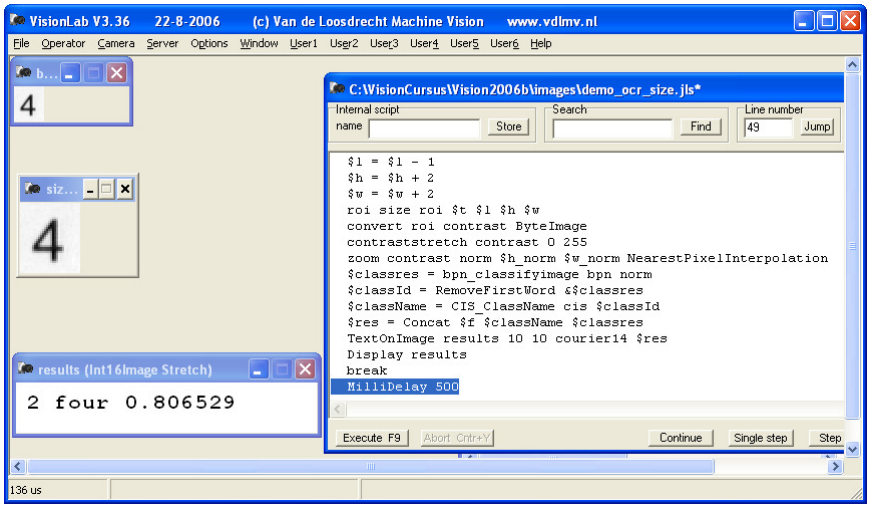
Demo with rotated input images



Demo with zoomed input images



Demo with zoomed input images



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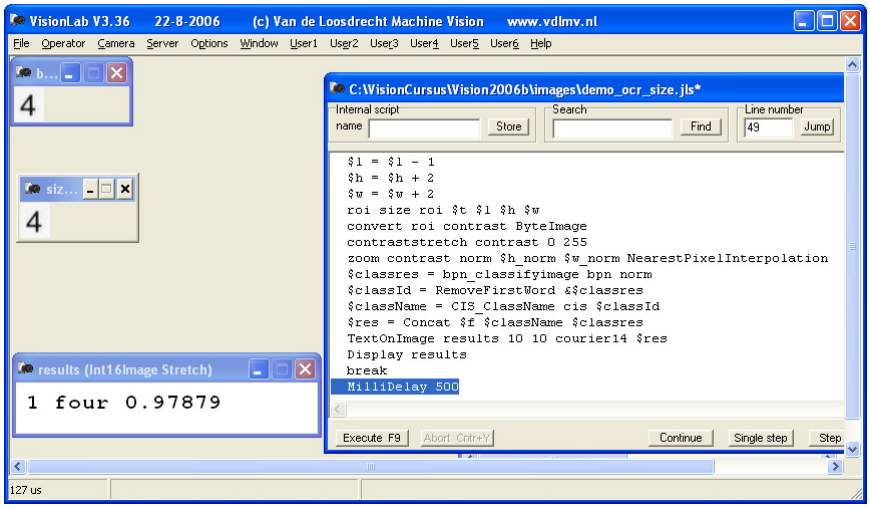
Demo with zoomed input images



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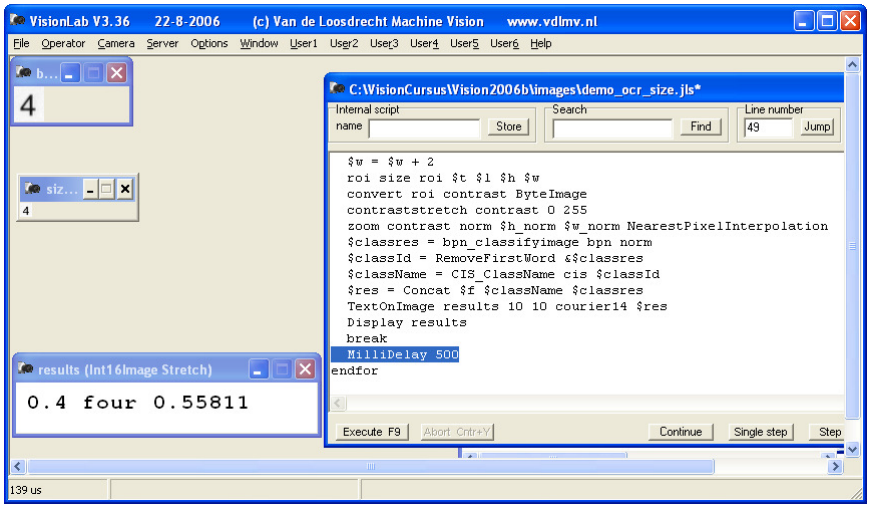
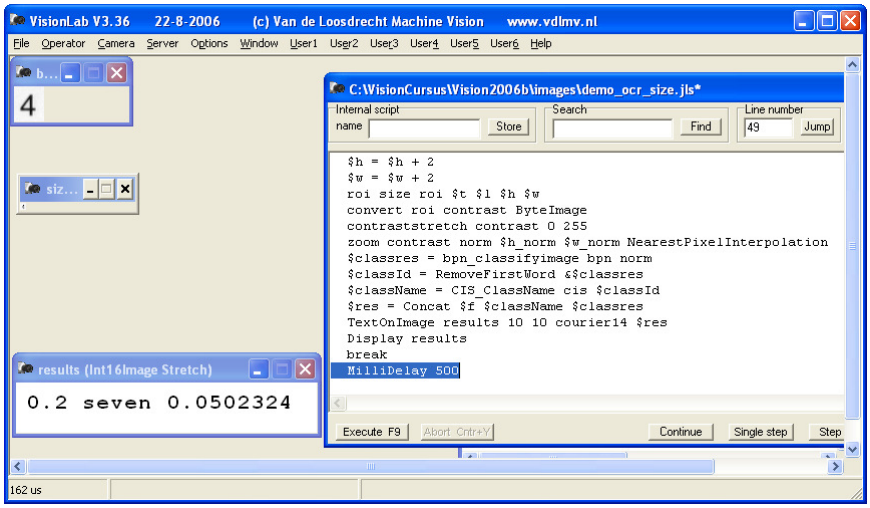
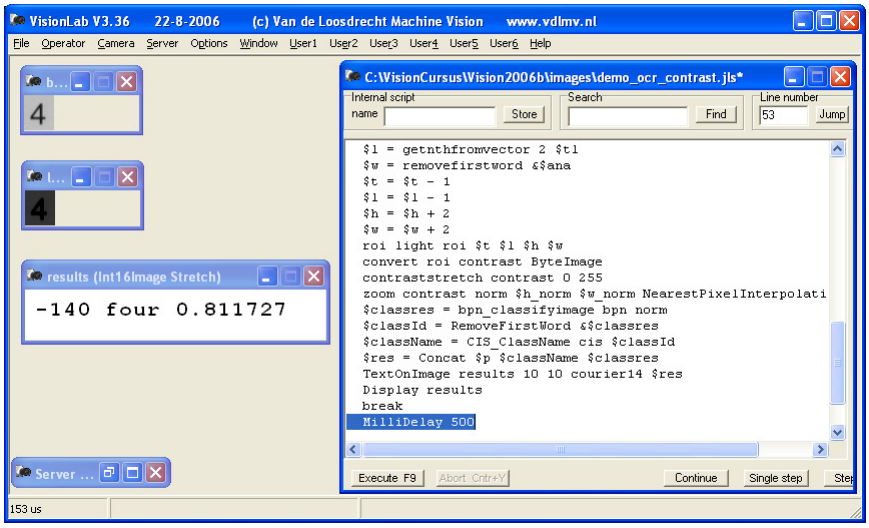
Demo with zoomed input images



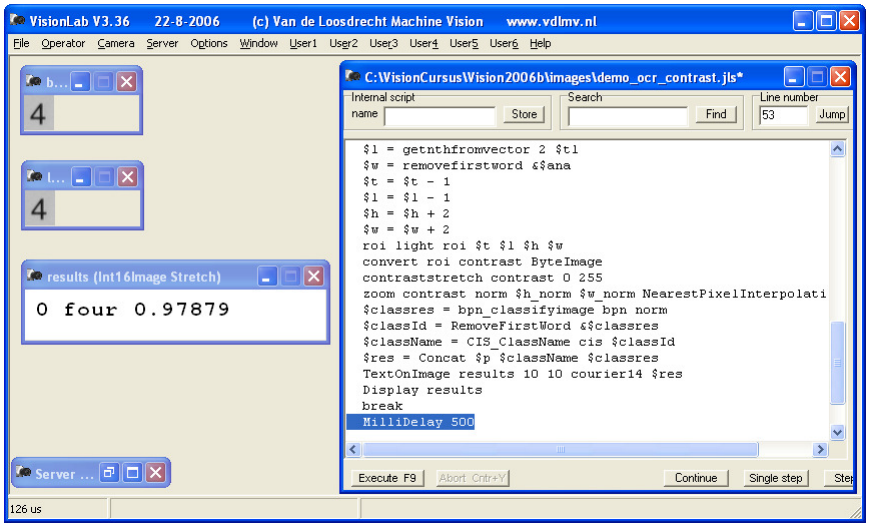
Demo with zoomed input images



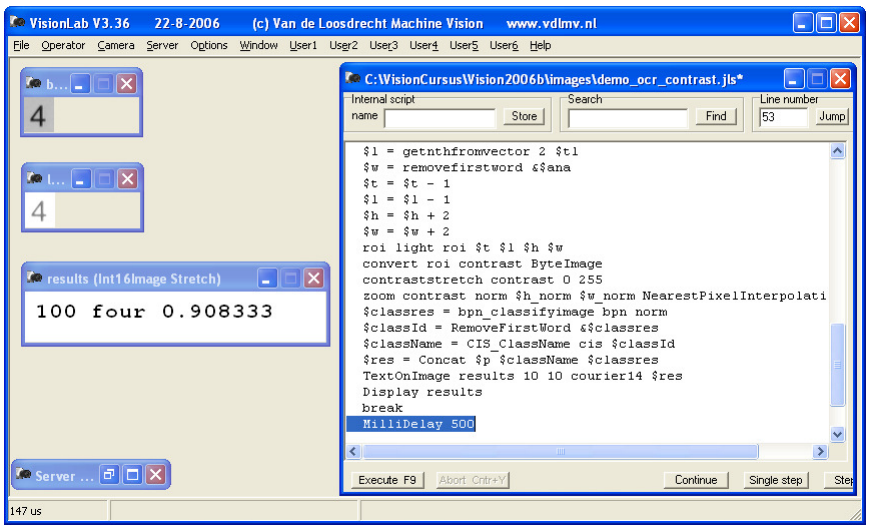
Demo with changed light conditions



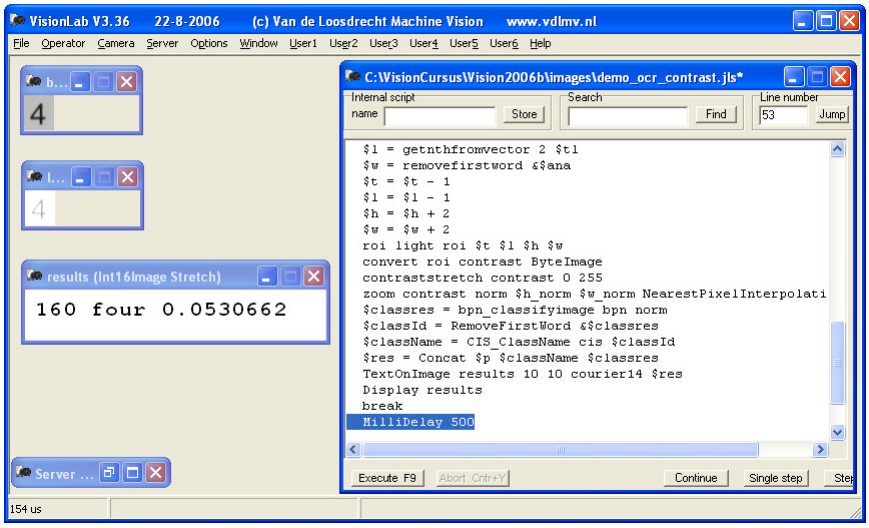
Demo with changed light conditions



Demo with changed light conditions



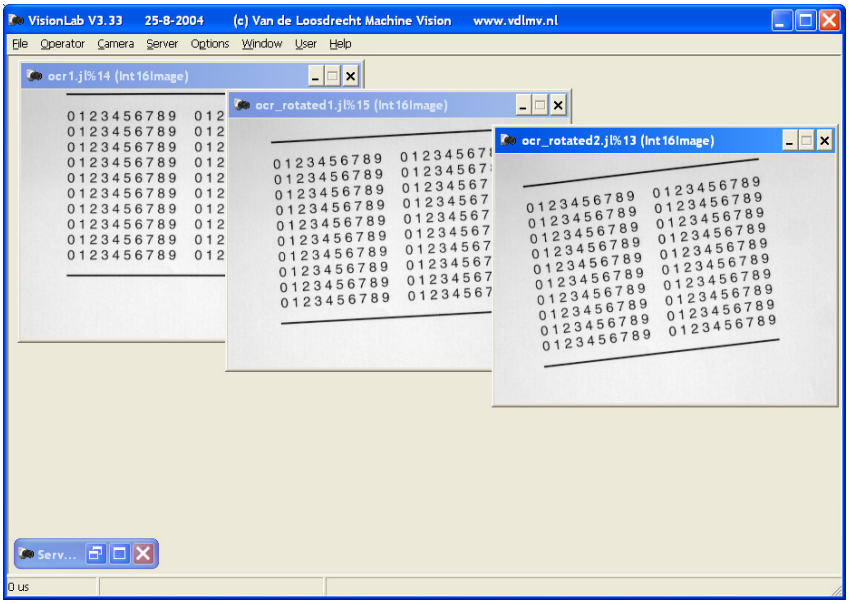
Demo with changed light conditions



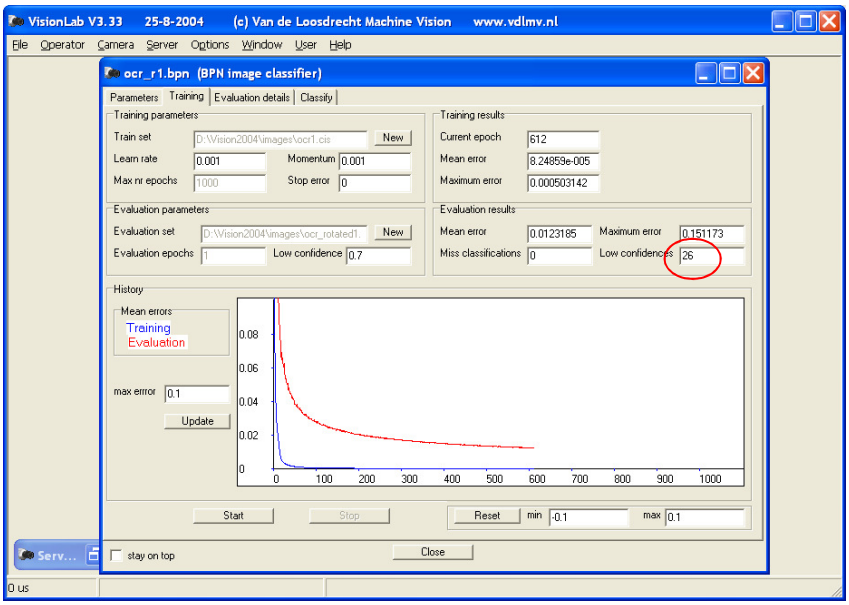
Demo with wrong evaluation set (*)

- The BPN was trained with numbers without rotation and is expected to perform worse if the digits are rotated
- Compare test images ocr1.jl, ocr_rotated1.jl and ocr_rotated2.jl
- For the rotated image ocr1 a CIS is generated with gen_ocr_rotated1_cis.jls
- For the rotated image ocr2 a CIS is generated with gen_ocr_rotated2_cis.jls
- Demonstrate training with ocr1.cis and evaluation sets the rotated CIS's, compare the results.
  - Analyse bad results for rotated2, have a look at the generated CIS !

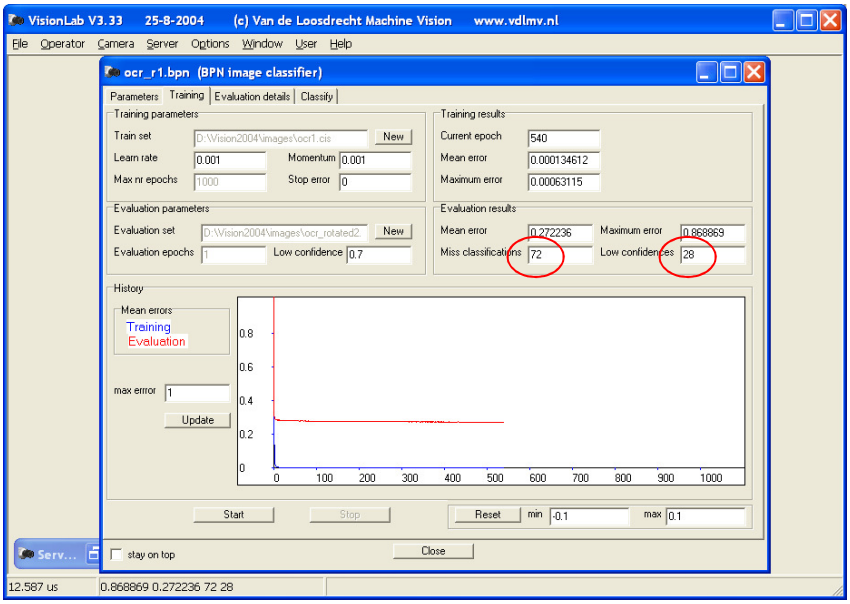
Comparing the rotated images (*)



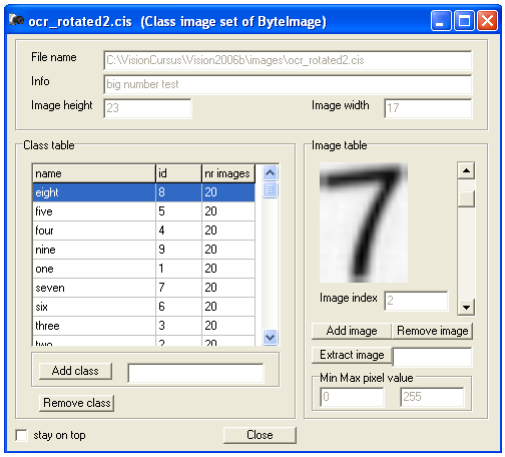
Evaluation set ocr_rotated1.cis (*)



Evaluation set ocr_rotated2.cis (*)



Wrong test data, seven in class “eight” ???? (*)



Testing with rotated input images (*)

- **Conclusion:**
  - **The BPN can cope with small rotations, but the confidence level will drop for classifying**
- **For applications:**
  - **The training set can be extended with rotated images, but training will then be more difficult**
  - **All image are normalized for rotation before training or classification**

Exercises rotation robustness OCR (*)

- **Normalize the training and evaluation sets for rotation and evaluate the BPN.**
  Hints:
  - **adapt script gen_ocr_rotated2_cis.jls**
  - **use the horizontal bars**
- **Make new versions of image ocr2.jl and generate new CIS's for evaluation:**
  - **Scale, use zoom**
  - **Lighting, add pixel value**
- **Use new CIS's to evaluate the BPN**

- **Answer first exercise: gen_ocr_rotated_norm_cis.jls,**

Robustness OCR (*)

- **Image classification with BPN can be reasonable robust for**
  - **Scale**
  - **Rotation**
  - **Lighting**

  This is because the images are normalized for these aspects

Feature vector classification (*)

- Introduction
- Class Feature Sets (CFS)
- Training the BPN
- Using the BPN
- Exercise

OCR feature vector classification (*)

- Features are extracted from image and used for the classification
- Learning from features instead of pixels
- Data reduction

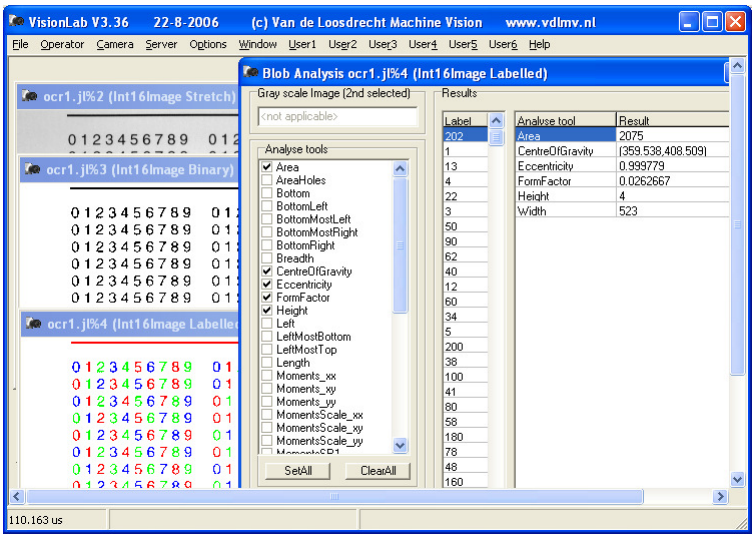
- OCR example:
  - Image: 23 x 17 = 391 pixels
  - Use features like:
    Area, AreaHoles , Breadth, CentreOfGravity,
    MomentsScale_xy, NrOfHoles, SumRows, SumCols, etc

Demo feature classifying (*)

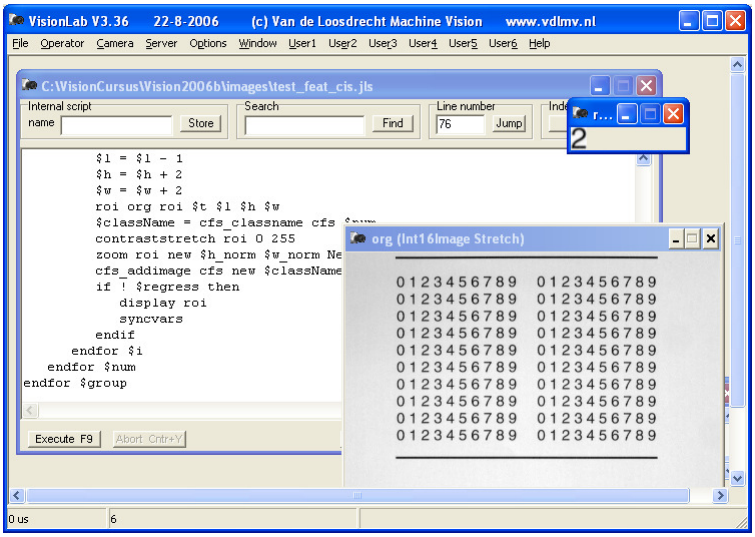
- { Demonstrate how to perform measurements
  - Open ocr1.jl (grayscale image)
  - ThresholdIsodata (binair image)
  - LabelBlobs (labelled image)
  - BlobAnalyse (measurement)
- use test_feat_cfs.jls to generate test.cfs }

- Open test.cfs, show measurements
- CreateFeatureBPN with test.cfs, first hidden = 40 and nobias
- Demo learning, no feature: cg.x, cg.y and SumXXX
  (use keyboard space to de-select and and activate selection with select button)
  - Learnrate = 0.002, momentum = 0.01
  - Problem with learning, about 20 miss classifications
  - Look at evaluation details:
    - Problems in classifying 6
    - Neuron output 6 and 9 = ~0.5, others ~0
- Use centre of gravity to distinguish between 6 and 9
  see feature table in class feature set
  - 'six' : 7.3 < cg.x < 8.4, 10.7 < cg.y < 12.1
  - 'nine' : 8.0 < cg.x < 8.8, 10.5 < cg.y < 11.6

Perform measurements (*)



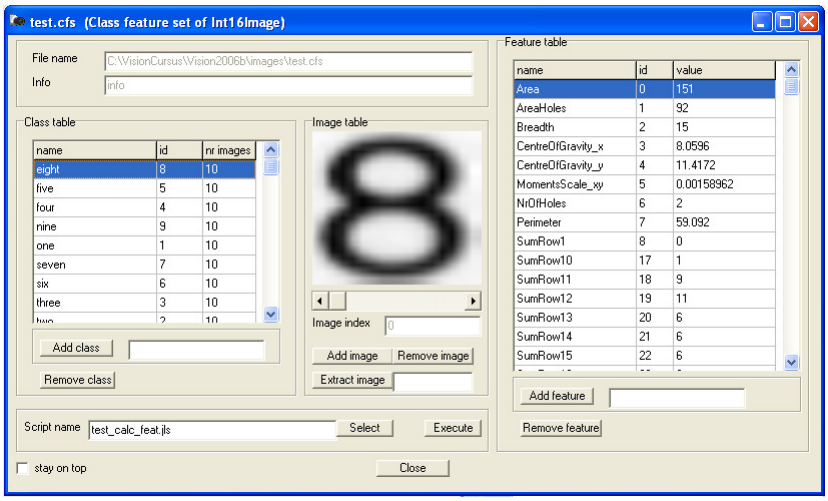
Generate Class Feature Set (*)



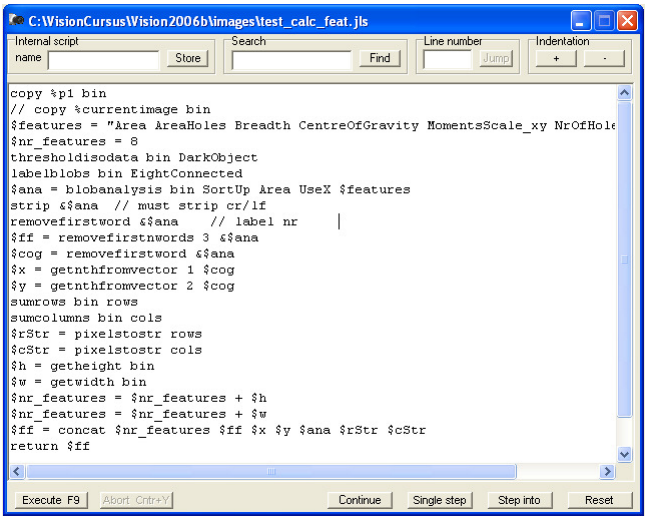
Class Feature Set (CFS) (*)

- **A CFS is a collection of images with their associated classes. All images in a CFS must have the same image type**
- **CFS:**
  - **Class table with the name and id of each class**
  - **For each class an image table, each image in an image table has its unique image index number**
  - **For each image a feature table, the features are the result of executing the script on the image**

Class Feature Set (*)



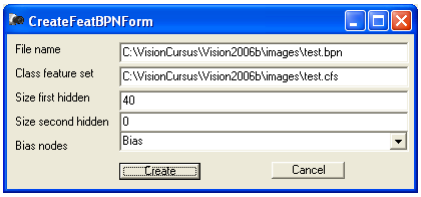
Script for calculating features (*)



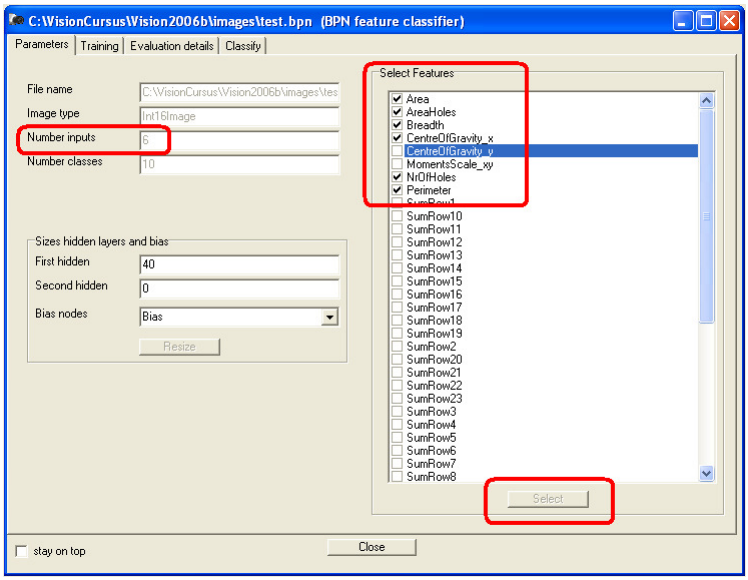
Conventions for script used for CFS (*)

- Script is used for calculating the features for each image in the CFS
- First parameter (%p1) is name of image
- Function result is string with features separated by a space and in order of feature id

Create BPN Feature Classifier (*)



Select Features (*)



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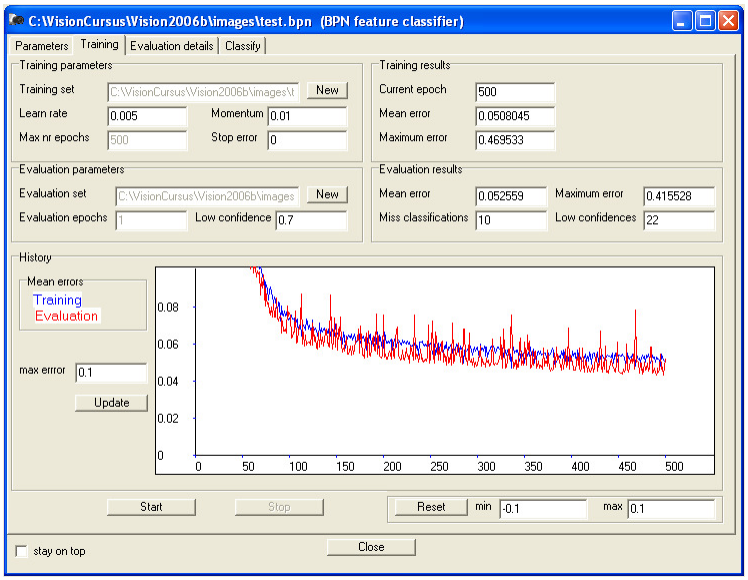
Train (*)



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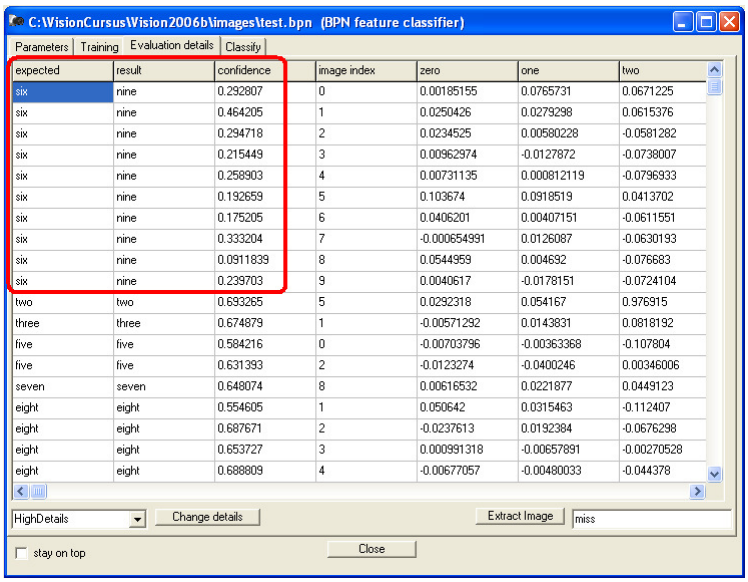
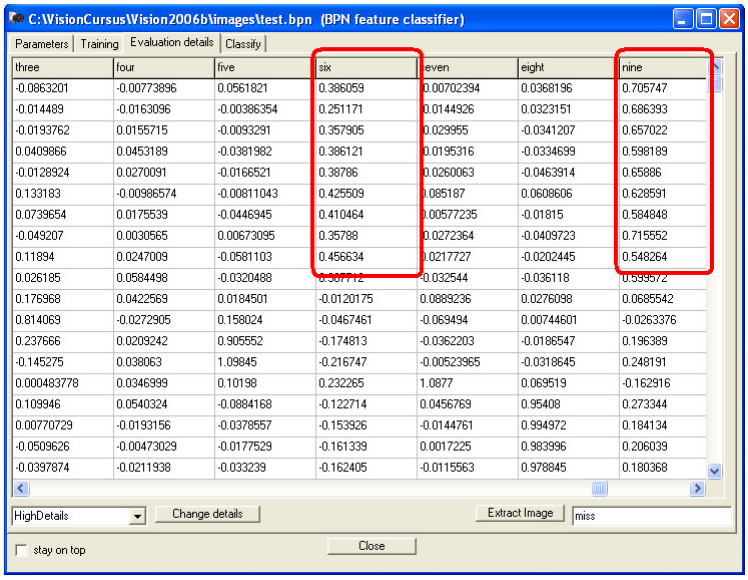
Problems in classifying ‘six’ and ‘nine’ (*)



expected	result	confidence	image index	zero	one	two
six	nine	0.292807	0	0.00185155	0.0765731	0.0671225
six	nine	0.464205	1	0.0250426	0.0279298	0.0615376
six	nine	0.294718	2	0.0234525	0.00580228	-0.0581282
six	nine	0.215449	3	0.00962974	-0.0127872	-0.0738007
six	nine	0.258903	4	0.00731135	0.000812119	-0.0796933
six	nine	0.192659	5	0.103674	0.0918519	0.0413702
six	nine	0.175205	6	0.0406201	0.00407151	-0.0611551
six	nine	0.333204	7	-0.000654991	0.0126087	-0.0630193
six	nine	0.0911839	8	0.0544959	0.004692	-0.076683
six	nine	0.239703	9	0.0040617	-0.0178151	-0.0724104
two	two	0.693265	5	0.0292318	0.054167	0.976915
three	three	0.674879	1	-0.00571292	0.0143831	0.0818192
five	five	0.584216	0	-0.00703796	-0.00363368	-0.107804
five	five	0.631393	2	-0.0123274	-0.0400246	0.00346006
seven	seven	0.648074	8	0.00616532	0.0221877	0.0449123
eight	eight	0.554605	1	0.050642	0.0315463	-0.112407
eight	eight	0.687671	2	-0.0237613	0.0192384	-0.0676298
eight	eight	0.653727	3	0.000991318	-0.00657891	-0.00270528
eight	eight	0.688809	4	-0.00677057	-0.00480033	-0.044378

Classifier hesitates between ‘six’ and ‘nine’ (*)

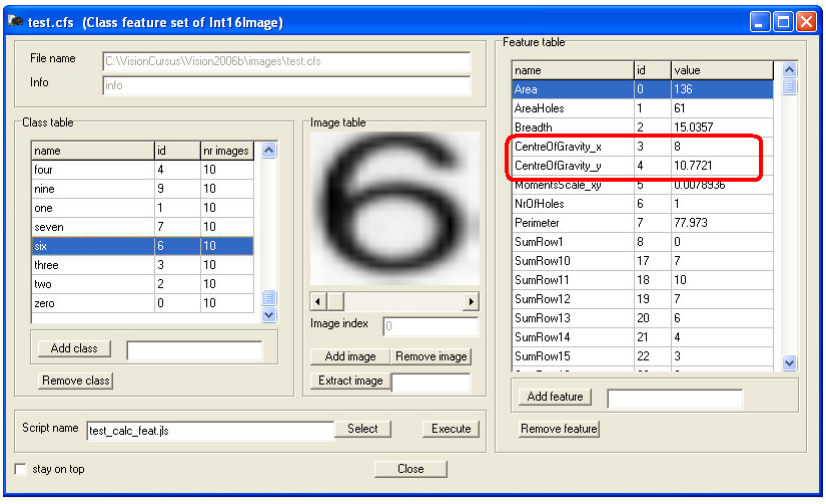


three	four	five	six	seven	eight	nine
-0.0863201	-0.00773896	0.0561821	0.386059	0.00702394	0.0368196	0.705747
-0.014489	-0.0163096	-0.00386354	0.251171	0.0144926	0.0323151	0.686393
-0.0193762	0.0155715	-0.0093291	0.357905	0.029955	-0.0341207	0.657022
0.0409866	0.0453189	-0.0381982	0.386121	0.0195316	-0.0334699	0.598189
-0.0128924	0.0270091	-0.0166521	0.38786	0.0260063	-0.0463914	0.65886
0.133183	-0.00986574	-0.00811043	0.425509	0.085187	0.0608606	0.628591
0.0739654	0.0175539	-0.0446945	0.410464	0.00577235	-0.01815	0.584848
-0.049207	0.0030565	0.00673095	0.35788	0.0272364	-0.0409723	0.715552
0.11894	0.0247009	-0.0581103	0.456634	0.0217727	-0.0202445	0.548264
0.026185	0.0584498	-0.0320488	0.387712	-0.032544	-0.036118	0.593572
0.176968	0.0422569	0.0184501	-0.0120175	0.0889236	0.0276098	0.0685542
0.814069	-0.0272905	0.158024	-0.0467461	-0.069494	0.00744601	-0.0263376
0.237666	0.0209242	0.905552	-0.174813	-0.0362203	-0.0186547	0.196389
-0.145275	0.038063	1.09845	-0.216747	-0.00523965	-0.0318645	0.248191
0.000483778	0.0346999	0.10198	0.232265	1.0877	0.069519	-0.162916
0.109946	0.0540324	-0.0884168	-0.122714	0.0456769	0.95408	0.273344
0.00770729	-0.0193156	-0.0378557	-0.153926	-0.0144761	0.994972	0.184134
-0.0509626	-0.00473029	-0.0177529	-0.161339	0.0017225	0.983996	0.206039
-0.0397874	-0.0211938	-0.033239	-0.162405	-0.0115563	0.978845	0.180368

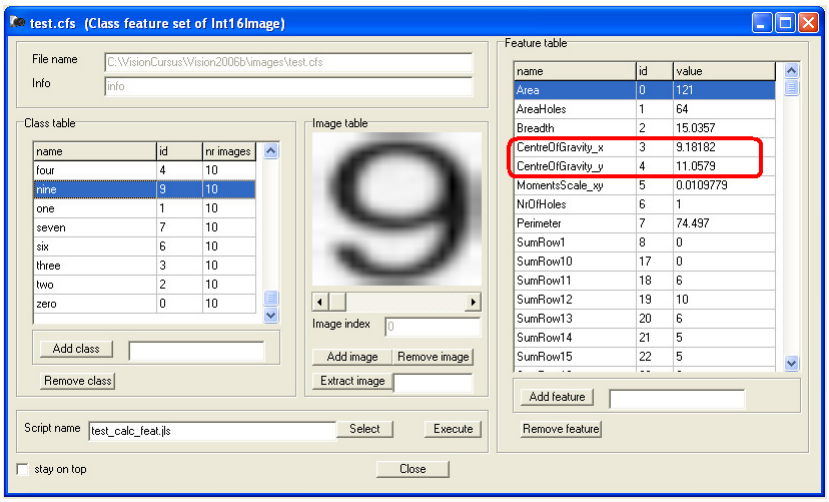
Add extra features (*)

- **Analyse evaluation details:**
  - **Problems in classifying 'six'**
  - **Neuron output 'six' and 'nine' ~ 0.5, others ~0**
- **Use centre of gravity to distinguish between 6 and 9 see feature table in class feature set**
  - **'six' : 7.3 < cg.x < 8.4, 10.7 < cg.y < 12.1**
  - **'nine' : 8.0 < cg.x < 8.8, 10.5 < cg.y < 11.6**
- **cg.x does NOT discriminates between 6 and 9, there is overlap between 8.0 and 8.4 testing shows the cg depends on threshold number (and its cg) moves up and down**

Features for 'six' (*)



Features for 'nine' (*)



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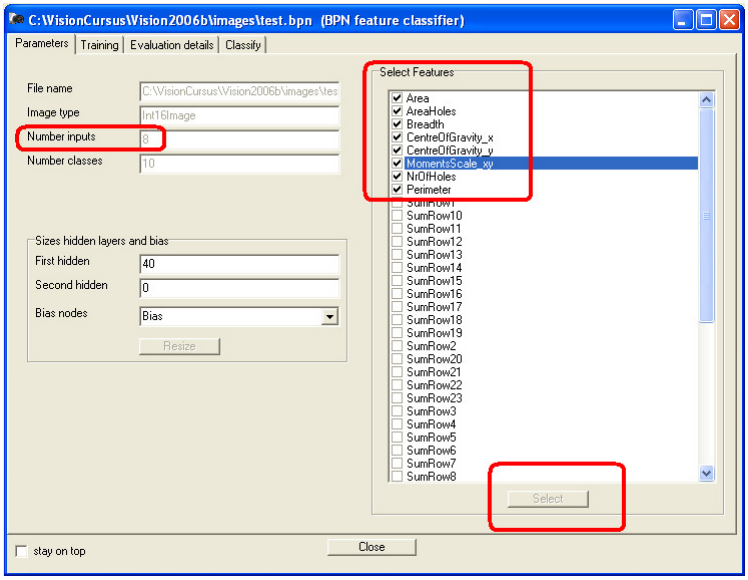
Select extra features cg.x and cg.y (*)



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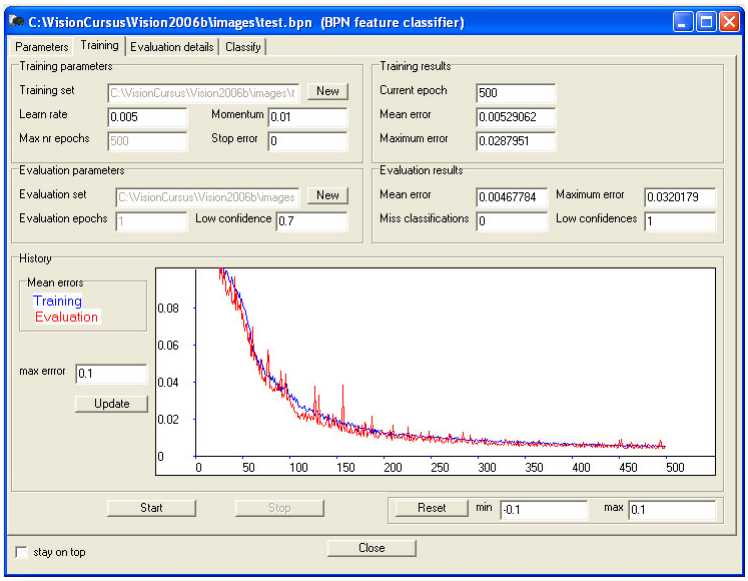
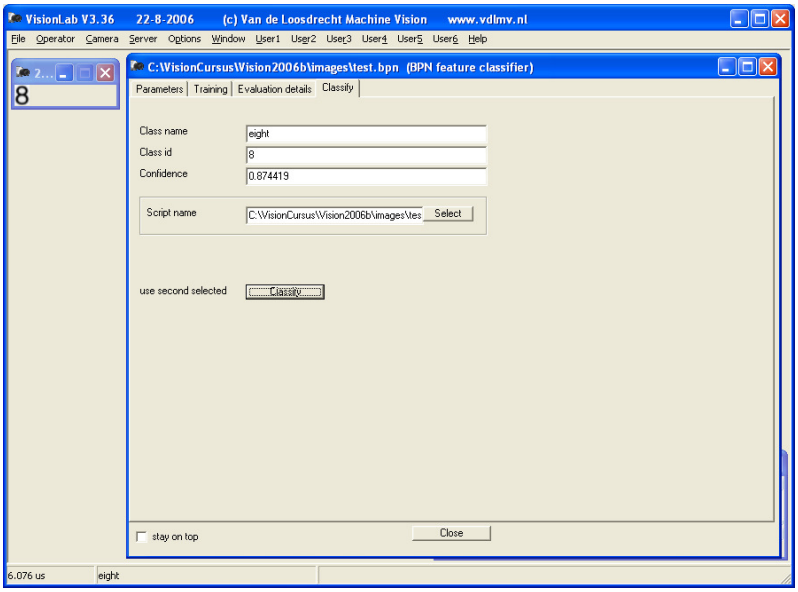
Train with centry of gravity (*)



Classify image (*)



OCR feature vector classification (*)

Conclusions:

- **Complexity has been reduced from 391 dimensions to 8**
- **Selection of which features to use is can be quite difficult**

Note:
Invariant to scale, rotation and lighting can be implemented:

- **In feature extraction**
- **By normalizing the images**

Optimizing the settings for a feature BPN (*)

This function uses a Genetical Algorithm (GA) in order to find the best solution.

NOTE: this optimalization process is very time consuming and for real problems it may take hours or even days.

In the Low/High box the user must specify the search space for size of hidden layers, learn rate and momentum, by specifying the lowest and highest border values.

In the settings box must be specified:

- **the population size for the GA algorithm**
- **the number of epochs the BPN is trained before being evaluated**
- **the low confidency factor used in the evaluation**
- **the maximum number of generation for the GA algorithm**

Optimizing the settings for a feature BPN (*)

In the detailed setting box, specialized setting can be set, it is advised to use the standard values.

- **the MinError is the minimal target error**
- **the DeltaError is the minimal error for start of hill climbing**
- **the MicroP is the probability during self mate that parameter is a micro mutation**

For feature classifiers the features to select from box can be used to select the features that take part in the optimizing process.

With the Start button the optimising process is started. With the Stop button the optimising process is stopped, but first the current generation is optimised completely, note this can take some time!

Optimizing the settings for a feature BPN (*)

In the best result box the best values found sofar for hidden layers, learn rate and momentum are displayed. Also the current generation number and the best error value found.

For feature classifiers the best features box shows the best combination of features found.

With the Accept button the best solution found is used to initialse the settings in the Parameters and Training tab. Then the normal full training is started.

Demonstration genetic algorithm for optimizing feature BPN (*)

- **Go to GA Optimize form, this can be used to find the optimal setting for the BPN**
  Use settings:
  Low and High first hidden = 40 (is fixed for the demo)
  Low and High second hidden = 0
  LearnRate: 0.0001 – 0.01
  Momentum: 0 – 0.01
  Populationsize: 4
  NrEpochs: 10
  LowConfidence: 0.5
  MinError: 0
  DeltaError: 1
  MircoP: 0.25
- **Select first 8 features**
  Click start to start optimise process
  Note this process is very time consuming, for the demo PopulationSize and NrEpochs have been set to low values.
- **Click stop button to interrupt the optimise process**
- **Select first all SumXX features**
  Click start to start optimise process
- **Click accept button to initialise the settings in the Parameters and Training tab. Then the normal full training is started.**

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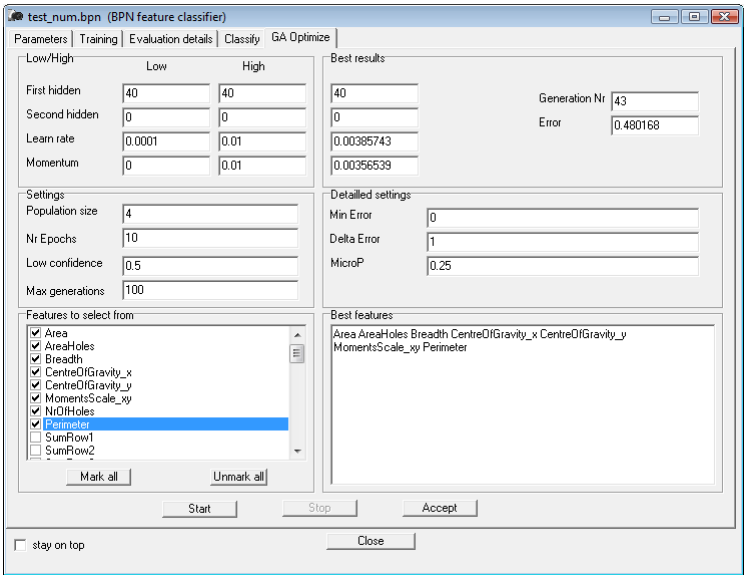
Set the parameters for the optimising process (*)



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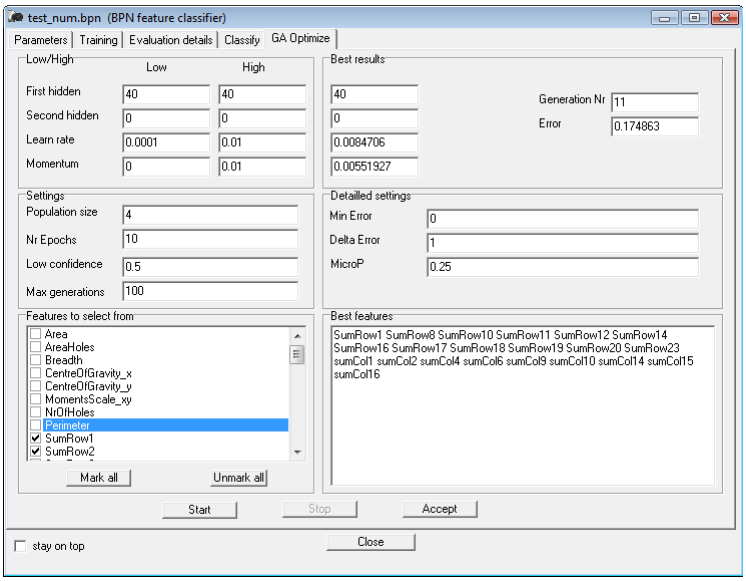
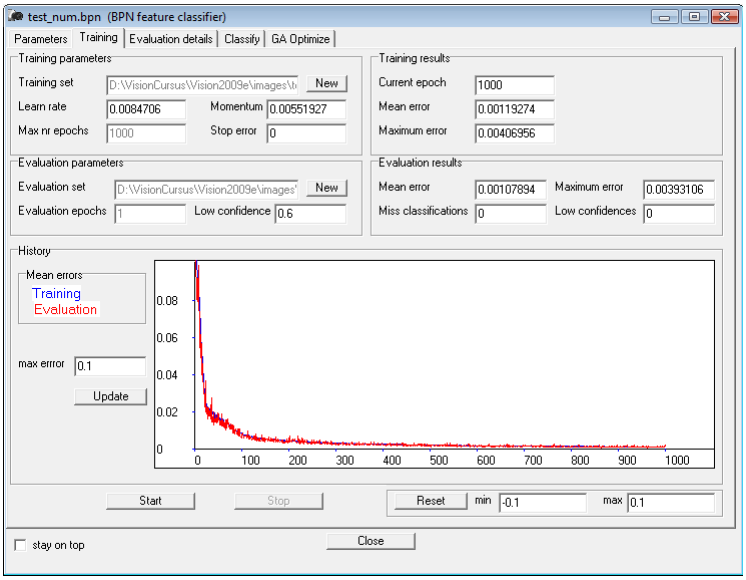
Set the parameters for the optimising process (*)



Used find optimal parameters to start the full training (*)



Exercise feature vector classification (*)

Experiment with adding and removing features

Tip: experiment with SumRows and SumCols only

OCR feature vector classification with scale, size and position invariant features (*)

Select from the BlobAnlyse tool the measurements which calculate scale, size and position independent features:

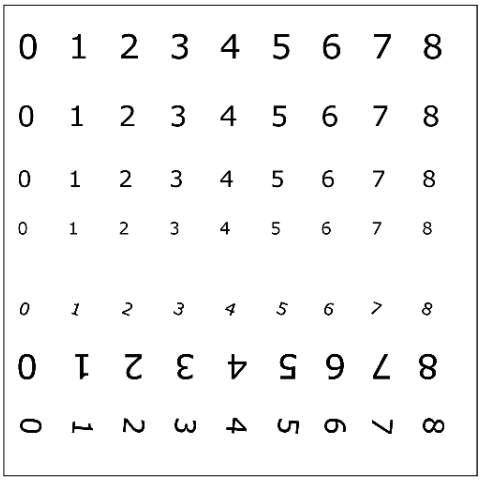
- **Eccentricity**
- **FormFacor**
- **Hu1**
- **Hu2**
- **Hu3**
- **Hu4**
- **Hu5**
- **Hu6**
- **Hu7**
- **NrOfHoles**

OCR feature vector classification with scale, size and position invariant features (*)

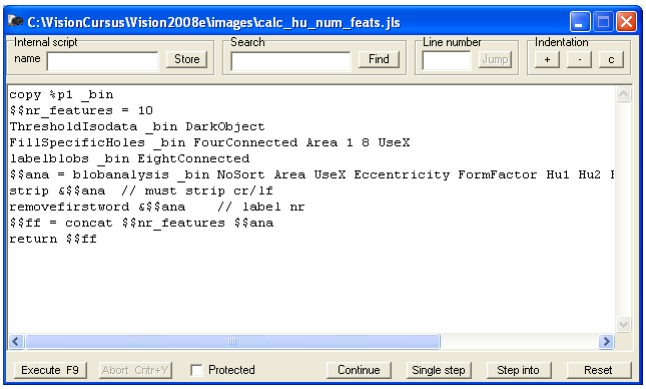
Demonstration:

- **Create train set**
- **Train Feature Classifier**
- **Evaluate Feature Classifier**

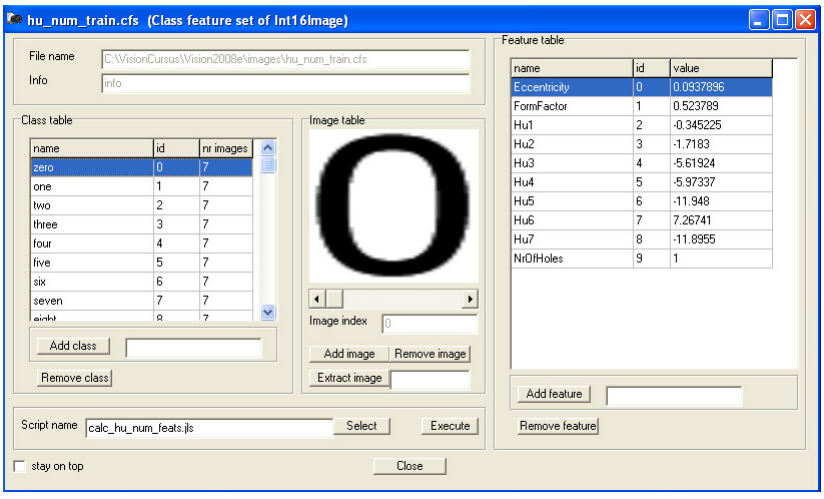
Use image hu_test_train.jl as train set (*)



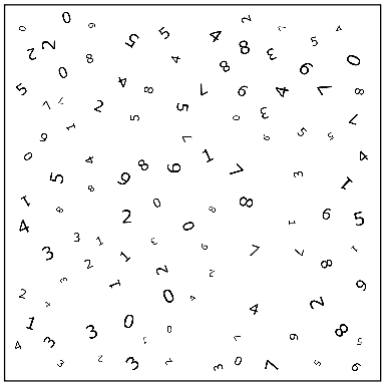
Script for calculation the features (*)



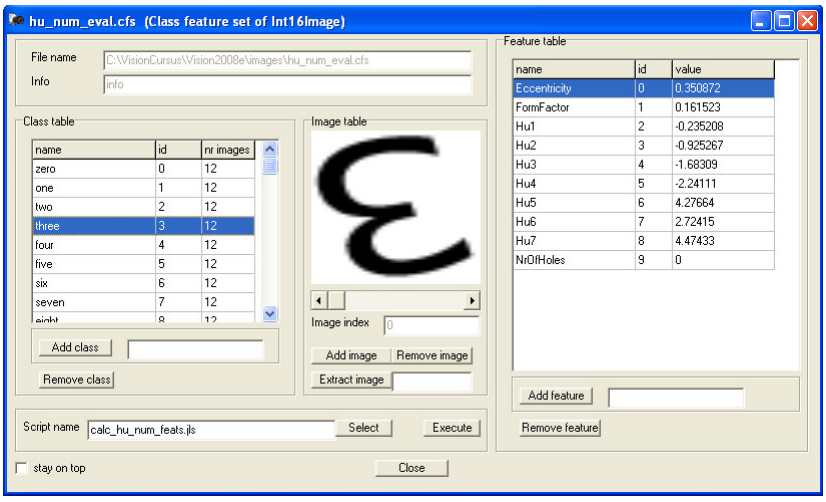
Use script gen_hu_num_train_cfs.jls to generate train CFS (*)



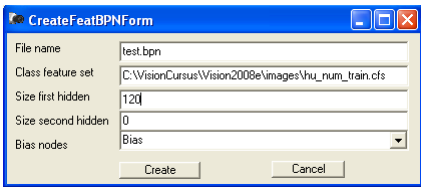
Use image hu_test_eval.jl as evaluation set (*)



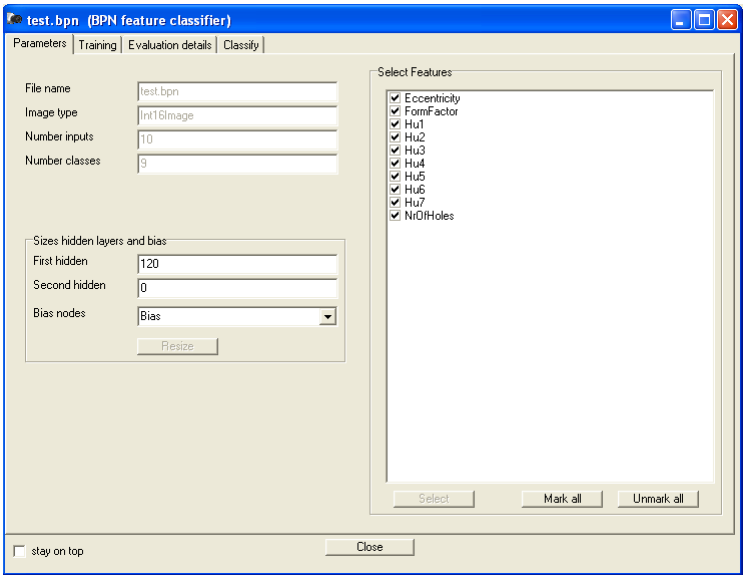
Evaluation set hu_num_eval.cfs (*)



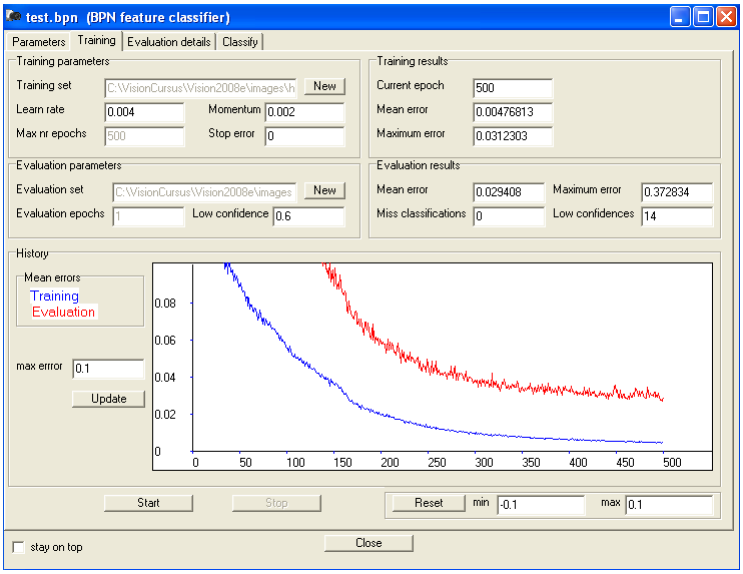
Create BPN Feature Classifier (*)



Select Features (*)



Train using hu_num_eval.cfs as evaluation CFS (*)



Exercise feature vector classification (*)

Experiment with adding and removing features and tuning parameters neural network

Switch training and evaluation set and restart training, explain why result is much better