### Main program

Process the different types of defect images. Generates and trains convolutional networks for defect detection from the processed defect images

Authors: Antonis Kantounias - Eleutherios Kantounias, Email: [antonis.kantounias@gmail.com](mailto:antonis.kantounias@gmail.com), Date: 2022.12.29

unprocessedImageDirectory = "C:\Users\Antonis Kantounias\Documents\ergasies\inteligentMachiningSystems\excersise3\Codes\Data";

## Create all possible data sets

% Possible processes  
optionNames = {  
 'process\_imadjust', 'process\_average', 'process\_imbinarize', 'process\_filter2laplacian', 'process\_filter2prewitt', 'process\_bwareopen', 'process\_imfill'  
 };  
  
% Combinations of possible processes  
optionValuesCombinations = [  
 false, false, false, false, false, false, false % Filter1  
 true, false, false, false, false, false, false % Filter2  
 false, false, true, false, false, false, false % Filter3  
 false, false, false, true, false, false, false % Filter4  
 false, false, true, true, false, false, false % Filter5  
 false, false, false, false, true, false, false % Filter6  
 false, false, false, false, true, false, false % Filter7  
 false, true, true, false, false, false, false % Filter8  
 false, true, true, true, false, false, false % Filter9  
 false, true, true, false, true, false, false % Filter10  
 false, false true, false, false, false, false % Filter11  
 false, false, false, true, false, false, false % Filter12  
 false, false, false, false, true, false, false % Filter13  
 false, true, false, true, false, false, false % Filter14  
 false, true, false, false, true, false, false % Filter15  
 ];  
  
% Equivalent names for each process combination  
aliasses = {  
 'Filter1'  
 'Filter2'  
 'Filter3'  
 'Filter4'  
 'Filter5'  
 'Filter6'  
 'Filter7'  
 'Filter8'  
 'Filter9'  
 'Filter10'  
 'Filter11'  
 'Filter12'  
 'Filter13'  
 'Filter14'  
 'Filter15'  
 };

% Generate dataset  
for iDataCombination = 12:15%1:length(aliasses)  
 % Generate the option values for current combination  
 optionValues = optionValuesCombinations(iDataCombination,:);  
 alias = aliasses{iDataCombination};  
 % Generate varagin file  
 varargin = cell(1,2\*length(optionNames));  
 for iOption = 1:length(optionNames)  
 varargin{2\*iOption-1} = optionNames{iOption};  
 varargin{2\*iOption} = optionValues(iOption);  
 end  
 % Generate processed image data base  
 processDBImages(unprocessedImageDirectory,alias,varargin{:})  
end

## Generate all possible neural networks

% Network possible layers  
networkLayerCombinations = {  
 [16,32,64,16]  
 [16,64,128,32]  
 [16,32,64]  
 [16,64,32]  
 };  
% Network equivalent names  
networkAliasses = {  
 'Network1'  
 'Network2'  
 'Network3'  
 'Network4'  
 };  
  
% Generate and train the networks  
for iNetworkCombination = 1:length(networkAliasses)  
 for iDataCombination = 1:length(aliasses)  
 networkAlias = networkAliasses{iNetworkCombination};  
 networkLayers = networkLayerCombinations{iNetworkCombination};  
 processedImageDirectory = join([unprocessedImageDirectory,"Processed\_",string(aliasses{iDataCombination})],"");  
 createDeepLearningNetwork(processedImageDirectory,networkLayers,networkAlias)  
 end  
end

## Generate all possible neural networks

% Network possible layers  
networkLayerCombinations = {  
 [16,32,64,16]  
 [16,64,128,32]  
 [16,32,64]  
 [16,64,32]  
 };  
% Network equivalent names  
networkAliasses = {  
 'Network1'  
 'Network2'  
 'Network3'  
 'Network4'  
 };  
  
% Generate and train the networks  
for iNetworkCombination = 1:length(networkAliasses)  
 for iDataCombination = 1:length(aliasses)  
 networkAlias = networkAliasses{iNetworkCombination};  
 networkLayers = networkLayerCombinations{iNetworkCombination};  
 processedImageDirectory = join([unprocessedImageDirectory,"Processed\_",string(aliasses{iDataCombination})],"");  
 createDeepLearningNetwork(processedImageDirectory,networkLayers,networkAlias)  
 end  
end

### createDeepLearningNetwork

function [networkResult,dirNameResult] = createDeepLearningNetwork(datasetPath,networkLayers,networkAlias)

## createDeepLearningNetwork

Creates and trains a convolutional neural network for image recognition. The network is saved at the datasetPath folder.

Inputs: datasetPath Directory where the processed image data are located [string] networkAlias Network archietecture related naming [string]

Output: network Contains the trained network file and the accuracy result [structure] datasetPath Trained network file location [string]

Authors: Antonis Kantounias - Eleutherios Kantounias, Email: [antonis.kantounias@gmail.com](mailto:antonis.kantounias@gmail.com), Date: 2022.12.29

## Constant data

PERCENTAGEOFTRAINFILES = 0.80;

## Load image data

% Load sample data as an image datastore  
imageData = imageDatastore( datasetPath,...  
 'IncludeSubFolders',true,...  
 'LabelSource','foldernames');  
  
% Specify the size of the images in the input layer  
imageExample = readimage(imageData,1);  
[resolutionX, resolutionY] = size(imageExample);  
resolutionZ = 1; % 2d image  
  
% Specify the categorical label number  
labelCount = countEachLabel(imageData);  
[numOfLabels,~] = size(labelCount);

## Specify training and validation sets

% Split the homogenous datastore into the train data store and the validation datastore randomly  
[imageDataTrain,imageDataValidation] = splitEachLabel(imageData,PERCENTAGEOFTRAINFILES,'randomize');

## Define network architecture (generate network's layers)

layers = imageInputLayer([resolutionX resolutionY resolutionZ]);  
  
for iLayer = 1:length(networkLayers)  
 layers(end+1:end+4,1) = [  
 convolution2dLayer(3,networkLayers(iLayer),'Padding','same')  
 batchNormalizationLayer  
 reluLayer  
 maxPooling2dLayer(2,'Stride',2)  
 ];  
end  
  
layers(end:end+2,1) = [  
 fullyConnectedLayer(numOfLabels)  
 softmaxLayer  
 classificationLayer  
 ];

## Specify training options

options = trainingOptions(...  
 'sgdm', ...  
 'InitialLearnRate',0.01, ...  
 'MaxEpochs',30, ...  
 'Shuffle','every-epoch', ...  
 'ValidationData',imageDataTrain, ...  
 'ValidationFrequency',15, ...  
 'Verbose',false, ...  
 'Plots','training-progress'...  
 );

## Train the network

networkTrained = trainNetwork(imageDataTrain,layers,options);

## Compute the accuracy of the network

classificationPredicted = classify(networkTrained,imageDataValidation);  
classificationReal = imageDataValidation.Labels;  
networkAccuracy = sum(classificationPredicted == classificationReal)/numel(classificationReal);

## Save network training results

networkResult.networkTrained = networkTrained;  
networkResult.networkAccuracy = networkAccuracy;  
  
% Create result directory  
dirNameSplit = split(datasetPath,string(filesep));  
dirNameResult = join([dirNameSplit(1:end-1)',"Results"],string(filesep));  
resultName = dirNameSplit(end);  
  
if ~exist(dirNameResult, 'dir')  
 mkdir(dirNameResult)  
end  
  
% Create result figure directory  
dirNameResultsFigures = join([dirNameResult,"Figures"],string(filesep));  
  
if ~exist(dirNameResultsFigures, 'dir')  
 mkdir(dirNameResultsFigures)  
end  
  
% Create result network directory  
dirNameResultsNetworks = join([dirNameResult,"Networks"],string(filesep));  
  
if ~exist(dirNameResultsNetworks, 'dir')  
 mkdir(dirNameResultsNetworks)  
end  
  
% Save generated figure  
FigList = findobj(allchild(0), 'flat', 'Type', 'figure');  
FigHandle = FigList(1);  
FigHandle.Name = resultName;  
savefig(FigHandle, join([dirNameResultsFigures,"\", resultName, string(networkAlias), ".fig"],""));  
  
% Save generated network structure  
save(join([dirNameResultsNetworks,"\",resultName, string(networkAlias),".mat"],""),'networkResult')

end

### processDBImages

function processDBImages(unprocessedImageDirectory,alias,varargin)

## processDBImages

Loads all image files from a specific directory, process the images and save them to an equivalent, processed directory

Inputs: unprocessedImagesDirectory Directory where the unprocessed data are stored, full name [string]

alias Name extension for the processed data [string]

Authors: Antonis Kantounias - Eleutherios Kantounias, Email: [antonis.kantounias@gmail.com](mailto:antonis.kantounias@gmail.com), Date: 2022.12.29

## Get a list of all files and folders in this folder.

unprocessedImageDir = dir(unprocessedImageDirectory);  
unprocessedImageFiles = unprocessedImageDir(~[unprocessedImageDir.isdir]);

## Process and save the image files

for iFile = 1:length(unprocessedImageFiles)  
  
 fileName = unprocessedImageFiles(iFile).name;  
 [~,~,fileExtension] = fileparts(fileName);  
  
 if strcmp(fileExtension,'.bmp')  
 imageName = fileName;  
 loadProcessSaveImage(unprocessedImageDirectory,alias,imageName,varargin{:});  
 end  
  
end

### loadProcessSaveImage

function [processedImageDirectory] = loadProcessSaveImage(unprocessedImageDirectory,alias,imageName,varargin)

## loadProcessSaveImage

loadProcessSaveImage loads the images of the database folder. Process the images and saves them to a new database folder that will be used for network training and validation

Inputs: unprocessedImagesDirectory Directory where the unprocessed data are stored, full name [string] alias Name extension for the processed data [string]

Outpus: processedImagesDirectory Directory where the unprocessed data are stored, full name [string]

Authors: Antonis Kantounias - Eleutherios Kantounias, Email: [antonis.kantounias@gmail.com](mailto:antonis.kantounias@gmail.com), Date: 2022.12.29

## Add parameters

p = inputParser;  
p.addParameter('process\_imadjust', true);  
p.addParameter('process\_imbinarize', true);  
p.addParameter('process\_filter2laplacian', true);  
p.addParameter('process\_filter2prewitt', false);  
p.addParameter('process\_bwareopen', true);  
p.addParameter('process\_imfill', true);  
  
p.parse(varargin{:})  
process\_imadjust = p.Results.process\_imadjust;  
process\_imbinarize = p.Results.process\_imbinarize;  
process\_filter2prewitt = p.Results.process\_filter2prewitt;  
process\_filter2laplacian = p.Results.process\_filter2laplacian;  
process\_bwareopen = p.Results.process\_bwareopen;  
process\_imfill = p.Results.process\_imfill;

## Load image

% Read image file  
imageInitialName = join([unprocessedImageDirectory,string(filesep),imageName],"");  
imageFinal = imread(imageInitialName);

## Process image

% Scale correction  
imageFinal = mat2gray(imageFinal);  
  
% Adjust image intensity  
if process\_imadjust  
 imageFinal = imadjust(imageFinal,[],[0.8,1]);  
end  
  
% Convert the image into binary using adaptive thresholding  
if process\_imbinarize  
 imageFinal = imbinarize(imageFinal,'adaptive','ForegroundPolarity','dark','Sensitivity',0.5);  
end  
  
% Perform filter operation to look for edges (2nd degree derivative detection)  
if process\_filter2laplacian  
 imageFinal = filter2(fspecial('laplacian'),imageFinal);  
end  
  
% Perform filter operation to look for edges (1nd degree derivative detection)  
if process\_filter2prewitt  
 imageFinal = filter2(fspecial('prewitt'),imageFinal);  
 imageFinal = imadjust(imageFinal);  
end  
  
% Scale correction  
imageFinal = mat2gray(imageFinal);  
  
% Convert the image into binary using adaptive thresholding  
if process\_imbinarize  
 imageFinal = imbinarize(imageFinal);  
end  
  
% Remove small objects from binary image  
if process\_bwareopen  
 pixelSize = 2;  
 imageFinal = bwareaopen(imageFinal, pixelSize);  
end  
  
% Fill the holes  
if process\_imfill  
 imageFinal(1,:) = 1-imageFinal(1,:);  
 imageFinal(end,:) = 1-imageFinal(end,:);  
 imageFinal(:,1) = 1-imageFinal(:,1);  
 imageFinal(:,end) = 1-imageFinal(:,end);  
 imageFinal = imfill(imageFinal, 'holes');  
end

## Save image

% Create the processed data base folder and file name  
imageFinalNamesParts = split(imageInitialName,string(filesep));  
  
% Find the label of each image file  
if contains(imageFinalNamesParts(end),'In')  
 categoryName = "Inclusion";  
elseif contains(imageFinalNamesParts(end),'Pa')  
 categoryName = "Patch";  
elseif contains(imageFinalNamesParts(end),'PS')  
 categoryName = "Spot";  
else  
 error('Unknown image category')  
end  
  
% Insert category name folder  
imageFinalNamesParts(end-1) = join([imageFinalNamesParts(end-1),"Processed","\_",alias,"\",categoryName],"");  
  
% Change image file type  
imageFinalNamesParts(end) = replace(imageFinalNamesParts(end),'.bmp','.png');  
  
% Generate images final name  
imageFinalName = join(imageFinalNamesParts,"\");  
  
% Create the folder in case it is not exists  
processedImageDirectory = fileparts(imageFinalName);  
if ~exist(processedImageDirectory, 'dir')  
 mkdir(processedImageDirectory)  
end  
  
  
% Save processed image  
  
imwrite(imageFinal,imageFinalName);