COMPUTER VISION

Automatic License Plate Reading

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SCHEDULE

1. Project overview
2. Technical aspects
3. Common issues

Supplementary material

Project Overview

1. Preprocessing
2. Plate detection
3. Plate recognition

OVERVIEW - PREPROCESSING - 1/3

Original image

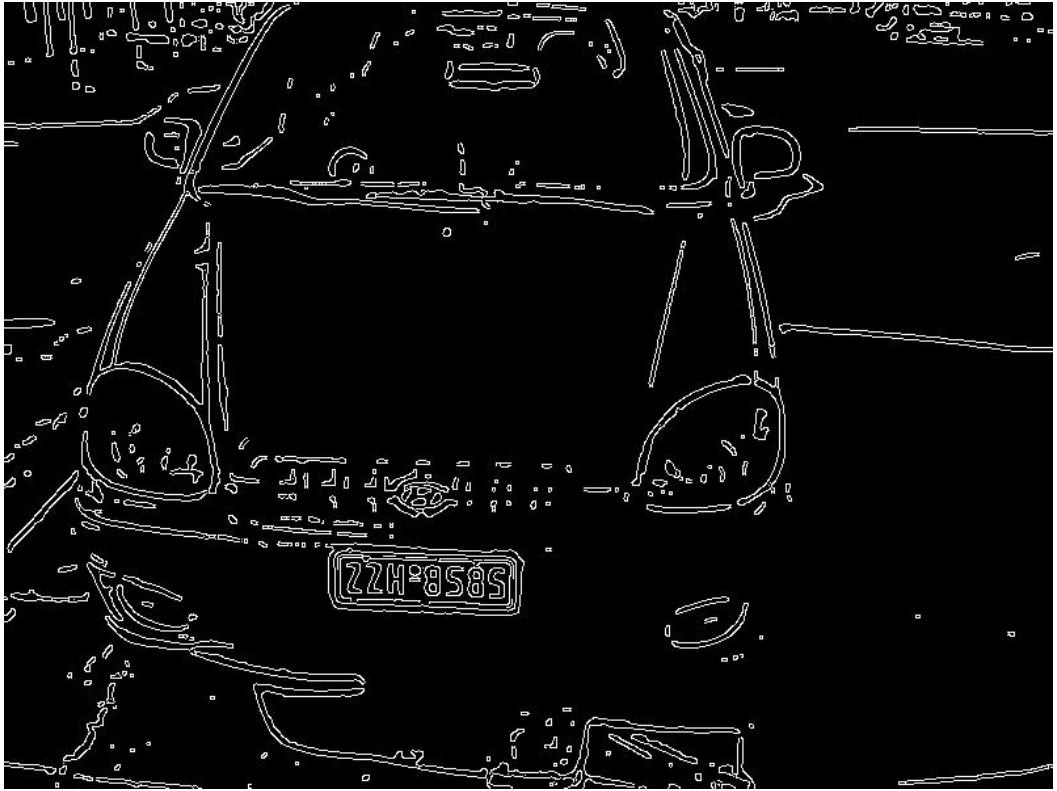
OVERVIEW - PREPROCESSING - 2/3

Grayscale +
Smoothing with
bilateral filter

OVERVIEW - PREPROCESSING - 3/3

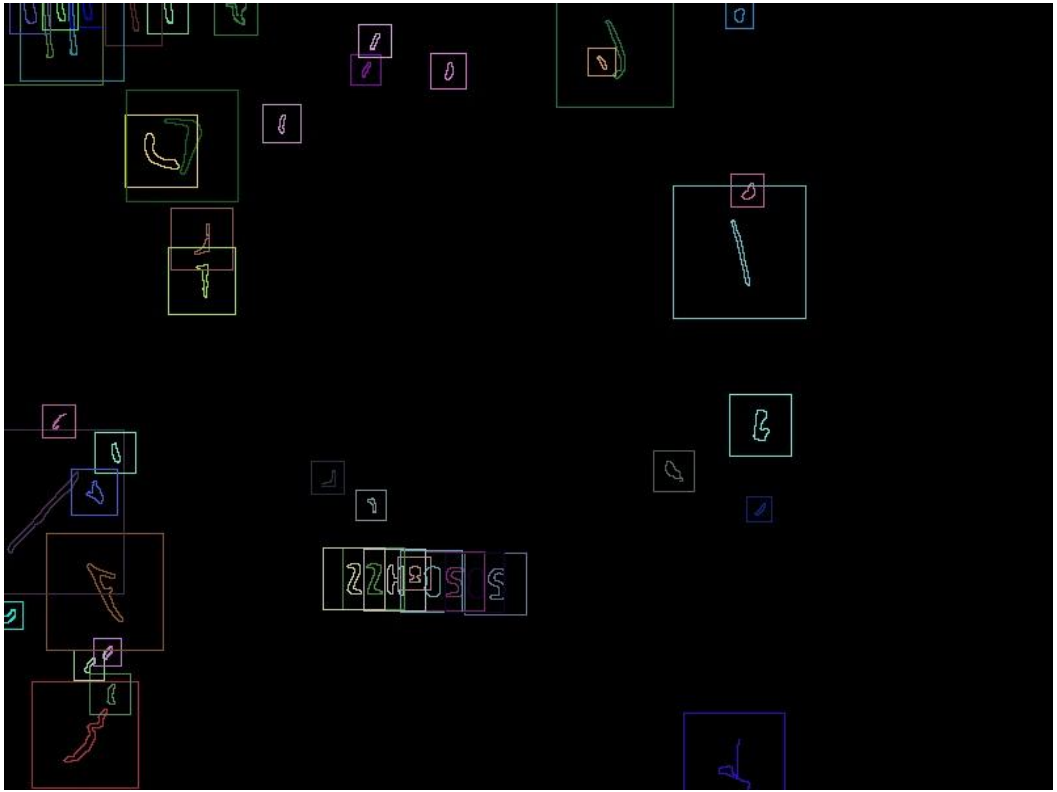
Binary image with adaptive thresholding

OVERVIEW - PLATE DETECTION - 1/5



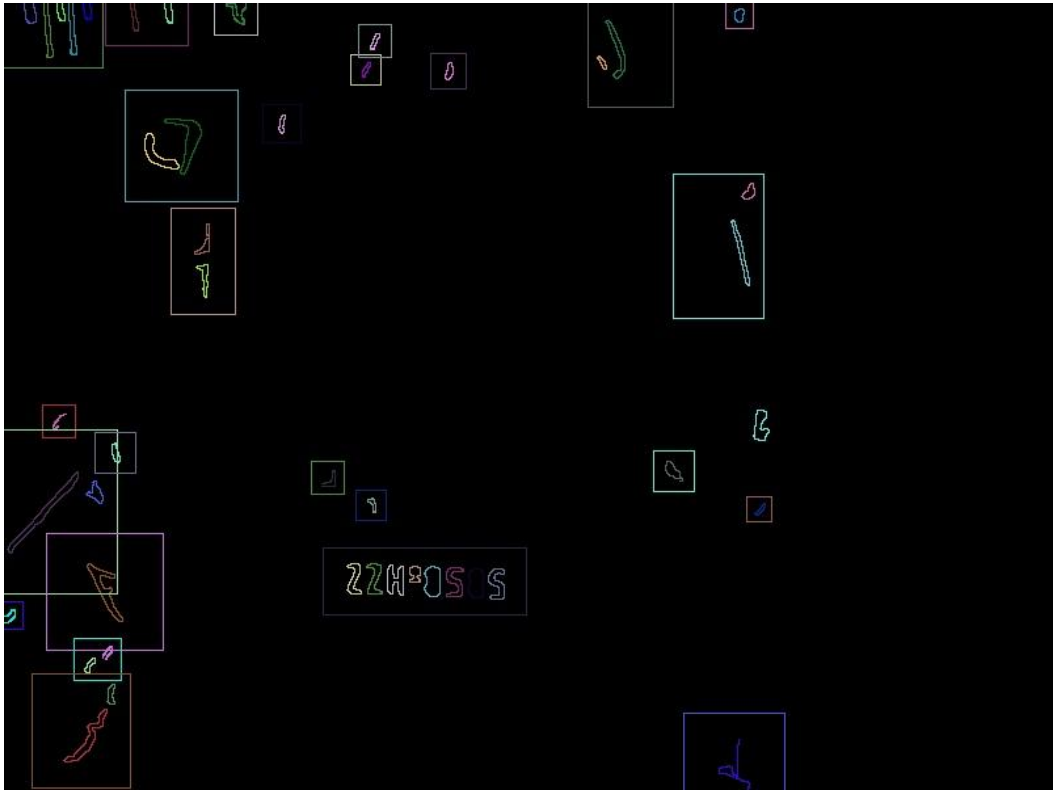
Canny edge detector

OVERVIEW - PLATE DETECTION - 2/5



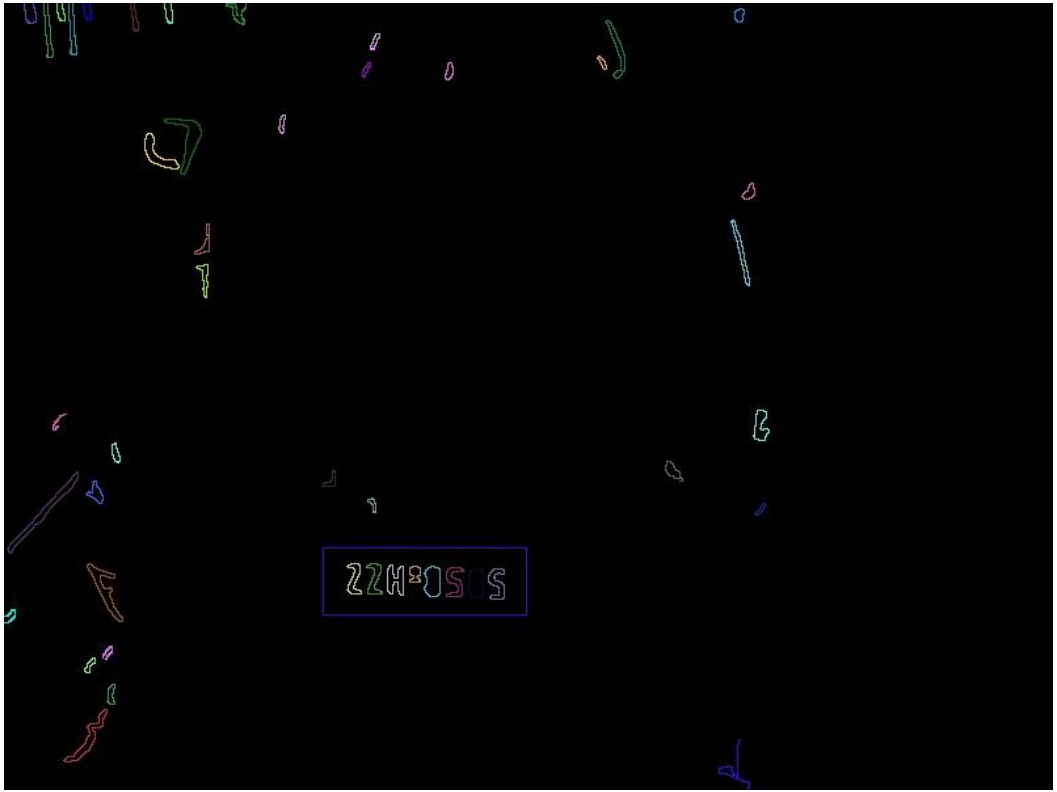
Contours detection +
PossibleChar filtering +
RectCluster initialization

OVERVIEW - PLATE DETECTION - 3/5



Merging adjacent RectClusters

OVERVIEW - PLATE DETECTION - 4/5



Require

1. Height/width ratio within 0.18 - 0.40
2. At least 6 characters inside the RectCluster

OVERVIEW - PLATE DETECTION - 5/5

Plate detection

OVERVIEW - PLATE RECOGNITION - 1/5

Canny edge detection

Contours detection

OVERVIEW - PLATE RECOGNITION - 2/5

Filter by

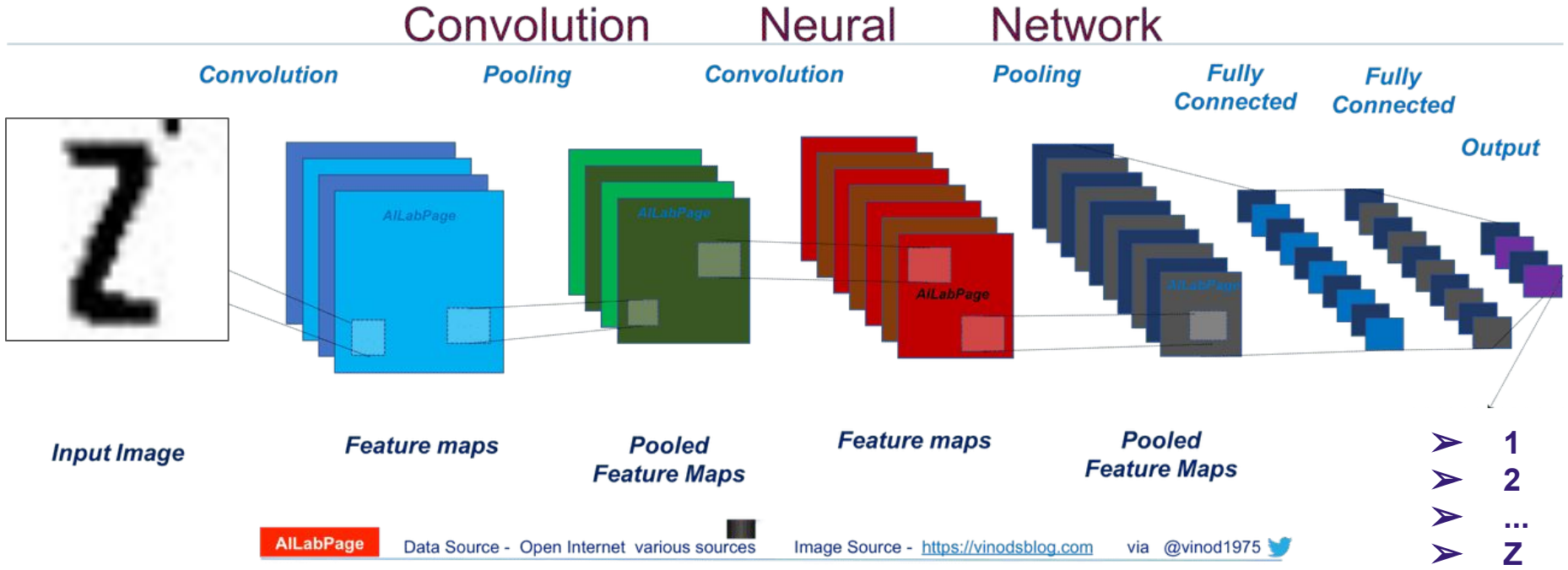
1. Width/height ratio in 0.15 - 1.00
2. Height variation from the average < 5px
3. Horizontal alignment within 2 standard deviations

OVERVIEW - PLATE RECOGNITION - 3/5

Characters preprocessing

1. Characters extraction
2. Adaptive threshold
3. Padding
4. Resize to 32 × 32

OVERVIEW - PLATE RECOGNITION - 4/5



PyTorch

OVERVIEW - PLATE RECOGNITION - 5/5

Plate reading

Technical Aspects

1. C++ code
2. Python code

TECHNICAL ASPECTS - C++ CODE - 1/9

```
#include "main.h"

// take as argument the filename with its path, e.g. /home/workdir/final_project/data/DSCN0408.jpg
int main(int argc, char* argv[]) {

	//>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
	// Import image and preprocessing

	String filename = argv[1];
	cout << "Reading image " << filename << endl;
	Mat originalImg = imread(filename);

	cout << endl << "Preprocessing image... " << endl;
	Mat binaryImg = preprocessing(originalImg);

	//>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
	// Plate detection - Canny edge detector + filter possible characters proportions

	cout << endl << "Plate detection... " << endl;
	Mat drawing = Mat::zeros(binaryImg.size(), CV_8UC3 );
	vector<PossibleChar> vecPossibleChar;
	vecPossibleChar = detectChar(binaryImg, drawing);

	//>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
	// Plate detection - clustering characters + possible plates selection

	vector<Rect> selectedPlates;
	selectedPlates = selectPlates(vecPossibleChar, drawing);

	String title0 = "Original image with contoured plate";
	drawRects(originalImg, selectedPlates, title0, 3); // last variable is the thickness of the rectangle borders
```

preprocessing.h

PossibleChar.h

CharDetection.h

RectCluster.h + Clustering.h

graphics.h

TECHNICAL ASPECTS - C++ CODE - 2/9

```cpp
#ifndef PREPROCESSING_H
#define PREPROCESSING_H


#include<opencv2/core/core.hpp>
#include<opencv2/highgui/highgui.hpp>
#include<opencv2/imgproc/imgproc.hpp>

#include "filter.h"
#include "graphics.h"

using namespace cv;
using namespace std;

const int ADAPTIVE_THRESH_BLOCK_SIZE = 19;
const int ADAPTIVE_THRESH_WEIGHT = 9;
const int S_SPACE = 80;
const  int S_RANGE = 80;
const int FILTER_SIZE = 7;


Mat preprocessing(Mat & originalImg);

#endif
```

```cpp
#include "preprocessing.h"

Mat preprocessing(Mat & originalImg)
{
        showIm(originalImg, "Original image");

        Mat greyImg;
        cvtColor(originalImg, greyImg, CV_BGR2GRAY);    //convert to greyscale
        //showIm(greyImg, "Greyscale image");

        BilateralFilter bf(greyImg, FILTER_SIZE, S_SPACE, S_RANGE);
        bf.doFilter();  //filter with bilateral filter to smooth without blurring contours
        Mat blurImg = bf.getResult();
        //showIm(blurImg, "Blurred image");
        imwrite("blurImg.jpg", blurImg);

        Mat binaryImg; //apply threshold to get binary image
        adaptiveThreshold(blurImg, binaryImg, 255.0, CV_ADAPTIVE_THRESH_GAUSSIAN_C, CV_THRESH_BINARY_INV,
                                                     ADAPTIVE_THRESH_BLOCK_SIZE, ADAPTIVE_THRESH_WEIGHT);
        //showIm(binaryImg, "Thresholded image");
        imwrite("binaryImg.jpg", binaryImg);

        return binaryImg;
}
```

graphics.h

filter.h

TECHNICAL ASPECTS - C++ CODE - 3/9

```
#ifndef POSSIBLE_CHAR_H
#define POSSIBLE_CHAR_H

#include <opencv2/core.hpp>
#include <opencv2/imgproc.hpp>

class PossibleChar {
public:
        // member variables
        std::vector<cv::Point> contour;

        cv::Rect boundingRect;

        int intCenterX;
        int intCenterY;

        int area;

        double dblAspectRatio;

        PossibleChar(std::vector<cv::Point> _contour);

};

#endif // POSSIBLE_CHAR_H
```

```
#include "PossibleChar.h"

PossibleChar::PossibleChar(std::vector<cv::Point> _contour)
{
contour = _contour;

boundingRect = cv::boundingRect(contour);

intCenterX = (boundingRect.x + boundingRect.x + boundingRect.width) / 2;
intCenterY = (boundingRect.y + boundingRect.y + boundingRect.height) / 2;

area = boundingRect.width * boundingRect.height;

dblAspectRatio = (float)boundingRect.width / (float)boundingRect.height;
};
```

TECHNICAL ASPECTS - C++ CODE - 4/9

```cpp
#ifndef RECTCLUSTER_H
#define RECTCLUSTER_H

#include <opencv2/core.hpp>

const double MIN_RATIO = 0.18;
const double MAX_RATIO = 0.4;

class RectCluster {
public:
        int xHead;
        int yHead;
        double dHead;

        int xTail;
        int yTail;
        double dTail;

        RectCluster(cv::Rect headRect, cv::Rect tailRect);

        void setTail(int x, int y, double d);
        void setHead(int x, int y, double d);

        cv::Rect getBoundingRect();

        bool isPlate();
};

#endif
```

```cpp
#include "RectCluster.h"

RectCluster::RectCluster(cv::Rect headRect, cv::Rect tailRect)
{
        xHead = (int)( headRect.x + headRect.width/2);
        yHead = (int)(headRect.y + headRect.height/2);
        dHead = headRect.height;

        xTail = (int)(tailRect.x + tailRect.width/2);
        yTail = (int)(tailRect.y + tailRect.height/2);
        dTail = tailRect.height;
};
```

TECHNICAL ASPECTS - C++ CODE - 5/9

```
cv::Rect RectCluster::getBoundingRect()
{
        int width = (int)(xTail + dTail - xHead + dHead);
        int height = (int)(std::max(yHead+dHead,yTail+dTail) - std::min(yHead - dHead, yTail - dTail));
        int xTopLeft = (int)(xHead-dHead);
        int yTopLeft = (int)(std::min(yHead-dHead,yTail-dTail));
        cv::Rect contourRect(xTopLeft, yTopLeft, width, height);
        return contourRect;
};


bool RectCluster::isPlate()
{
        cv::Rect contourRect = getBoundingRect();
        double ratio = (double)contourRect.height / contourRect.width;
        if (MIN_RATIO < ratio && ratio < MAX_RATIO)
                {return true;}
        else
                {return false;};

};
```

TECHNICAL ASPECTS - C++ CODE - 6/9

```cpp
#ifndef CHAR_DETECTION_H
#define CHAR_DETECTION_H

#include<opencv2/core/core.hpp>
#include<opencv2/highgui/highgui.hpp>
#include<opencv2/imgproc/imgproc.hpp>

#include "PossibleChar.h"
#include "graphics.h"

using namespace cv;
using namespace std;

// global constants ////////////////////////////////////////////////////////////////////////////
// constants for checkIfPossibleChar, this checks one possible char only (does not compare to another char)
const int MIN_PIXEL_WIDTH = 2;
const int MIN_PIXEL_HEIGHT = 8;
const int MAX_PIXEL_HEIGHT = 75; //all these measures are not invariant under changes of resolution/pixel size
const double MIN_ASPECT_RATIO = 0.15;
const double MAX_ASPECT_RATIO = 1.0;
const int MIN_PIXEL_AREA = 80;
const int HEIGHT_THRESH = 5;

// canny edge detector variables
const int THRESH1 = 100;
const int THRESH2 = 200;
const int CANNY_FILTER_SIZE = 5;

vector<PossibleChar> detectChar(Mat & binaryImg, Mat drawing);

vector<PossibleChar> filterByHeightVar( vector<PossibleChar> & originalVec);

vector<PossibleChar> filterByAllignment( vector<PossibleChar> & originalVec);

bool checkIfPossibleChar(PossibleChar &possibleChar);

bool doIntersect(PossibleChar & possChar1, PossibleChar & possChar2);

#endif
```

```cpp
#ifndef CLUSTERING_H
#define CLUSTERING_H


#include<opencv2/core/core.hpp>

#include "PossibleChar.h"
#include "RectCluster.h"
#include "graphics.h"

using namespace std;
using namespace cv;

const double ALPHA = 0.85; // sum of radii * alpha > distance of centers => merge clusters
const int MIN_COMPONENTS = 6; // min number of characters in a licence plate

std::vector<Rect> selectPlates(vector<PossibleChar> & vecPossibleChar, cv::Mat drawing);

std::vector<RectCluster> sortVecOfCluster(std::vector<RectCluster>& originalVec);

std::vector<PossibleChar> sortVecOfPossibleChar(std::vector<PossibleChar>& originalVec);

std::vector<RectCluster> mergeCluster(std::vector<RectCluster> VecOfCluster);

bool isInFrontOf(RectCluster& firstCluster, RectCluster& secondCluster);

double computeDistance(RectCluster& tailCluster, RectCluster& headCluster);

bool isCharInCluster(PossibleChar& possChar, RectCluster& cluster);

#endif
```

TECHNICAL ASPECTS - C++ CODE - 7/9

```
//>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
// Plate recognition (if only 1 plate is recognized) - preprocessing + CNN prediction
if (selectedPlates.size()==1)
{
        cout << endl << "Plate recognition... " << endl;
        Rect roi(selectedPlates[0]);
        recognizePlate(originalImg, roi);
        string plateID = readResult(); // reading in the results of CNN prediction
        cout << "License Plate ID: " << plateID << endl;
        putText(originalImg, plateID, Point(roi.x ,roi.y ), FONT_HERSHEY_COMPLEX_SMALL, 1.5,Scalar(0,0,255), 1, CV_AA);
        showIm(originalImg, "Plate recognized");
        }
else
{
        return 0;
}

return 0;
}
```

plateRecognition.h (annotation pointing to `recognizePlate(originalImg, roi);`)

TECHNICAL ASPECTS - C++ CODE - 8/9

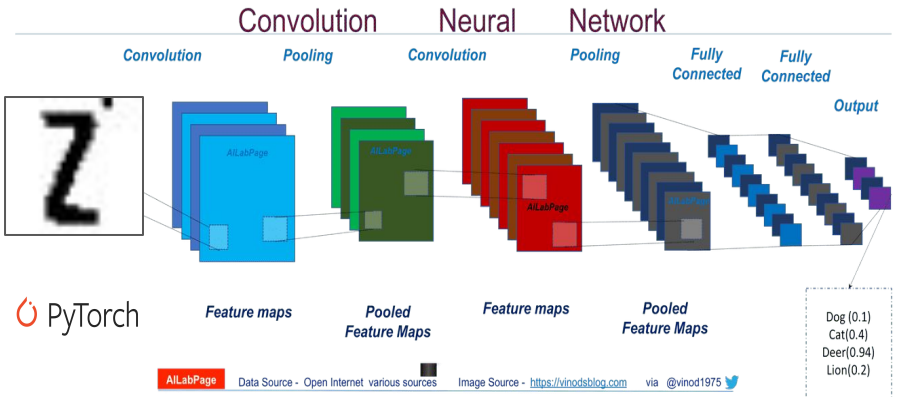
```
#ifndef PLATE_SEGMENTATION_H
#define PLATE_SEGMENTATION_H

#include <opencv2/core.hpp>
#include <opencv2/imgproc.hpp>

#include "graphics.h"
#include "PossibleChar.h"
#include "CharDetection.h"
#include "Clustering.h"


using namespace std;
using namespace cv;

const int ADAPTIVE_THRESH_BLOCK_SIZE1 = 19;
const int ADAPTIVE_THRESH_WEIGHT1 = 10;

Mat preprocessPlate(Mat & plateImg);

vector<Mat> cropROIs(Mat & plateImg, vector<PossibleChar> & charsAlligned);

void recognizePlate(Mat & originalImg, Rect & roi);

Mat GetSquareImage( Mat& img);

Mat padImage(Mat & src);

#endif
```

TECHNICAL ASPECTS - C++ CODE - 9/9

```
for (size_t i = 0; i < charImgs.size(); i++)
{
        //showIm(charImgs[i],"Character resized");
        ostringstream name;
        name << "ImChar" << i << ".png";
        imwrite(name.str(), charImgs[i]);

        string command;
        command = "python -c 'from CNN_PredictChar import predict; predict(\""+ name.str()+ "\")' >> result.txt";
        cout << "Command executed: " << command << endl;
        const char *command2 = command.c_str();
        system(command2);
}
```

function predict in CNN_PredictChar.py

TECHNICAL ASPECTS - PYTHON CODE - 1/3




```python
def createLossAndOptimizer(net, learning_rate=0.001):

    #Loss function
    loss = torch.nn.CrossEntropyLoss()

    #Optimizer
    optimizer = optim.Adam(net.parameters(), lr=learning_rate)

    return(loss, optimizer)
```

```python
class Net(nn.Module):

    def __init__(self):
        super(Net, self).__init__()
        # 1 input image channel, 6 output channels, 3x3 square convolution
        # kernel
        self.conv1 = nn.Conv2d(1, 6, kernel_size = 3, stride = 1, padding = 1 )
        self.pool1 = nn.MaxPool2d(kernel_size=2, stride=2, padding=0)
        self.conv2 = nn.Conv2d(6, 12, kernel_size = 3, stride = 1, padding = 1 )
        self.pool2 = nn.MaxPool2d(kernel_size=2, stride=2, padding=0)
        # an affine operation: y = Wx + b
        self.fc1 = nn.Linear(12 * 8 * 8, 256)  # 8*8 from image dimension
        self.fc2 = nn.Linear(256, 64)
        self.fc3 = nn.Linear(64, 36)

    def forward(self, x):
        x = F.relu(self.conv1(x))
        x = self.pool1(x)

        x = F.relu(self.conv2(x))
        x = self.pool2(x)

        x = x.view(-1, self.num_flat_features(x))

        x = F.relu(self.fc1(x))
        x = F.relu(self.fc2(x))
        x = self.fc3(x)
        return x

    def num_flat_features(self, x):
        size = x.size()[1:]  # all dimensions except the batch dimension
        num_features = 1
        for s in size:
            num_features *= s
        return num_features
```

TECHNICAL ASPECTS - PYTHON CODE - 2/3

Training dataset: chars74K
http://www.ee.surrey.ac.uk/CVSSP/demos/chars74k/

Preprocessing and training in Jupyter Notebook

Weights of the trained net saved and ready to be reloaded

```
# Save model
torch.save(CNN.state_dict(), 'saved_model.pth')
```

```
import skimage
from os import walk

common_path = '0-9_and_A-Z/Sample'
images = []
labels = []

for n in range(1,37):
    f = []
    x = "%03.0f"%n
    mypath = '0-9_and_A-Z/Sample'+x
    for (dirpath, dirnames, filenames) in walk(mypath):
        f.extend(filenames)
        break
    print("Number of files in "+mypath+" : ", len(f), '\n')

    for i in range(len(f)):
        f[i] = mypath+'/'+f[i]

    template_imgs = skimage.io.imread_collection(f) # loads all the images

    rescaled_template_imgs = []
    #skimage.io.imshow(template_imgs[0])

    for i in range(len(template_imgs)):
        image_rescaled = skimage.transform.rescale(template_imgs[i], 1.0 / 4.0, anti_aliasing=False)
        rescaled_template_imgs.append(image_rescaled)

    rescaled_template_imgs = np.array(rescaled_template_imgs)
    filtered_imgs = rescaled_template_imgs[mask]
    hotEncodedLabel = np.array([i==n-1 for i in range(36)], dtype=int) # one hot encoding
    class_labels = np.full((len(filtered_imgs),len(hotEncodedLabel)), hotEncodedLabel)

    #skimage.io.imshow(rescaled_template_imgs[0])
    images.append(filtered_imgs)
    labels.append(class_labels)
    #print(template_imgs.shape)
```

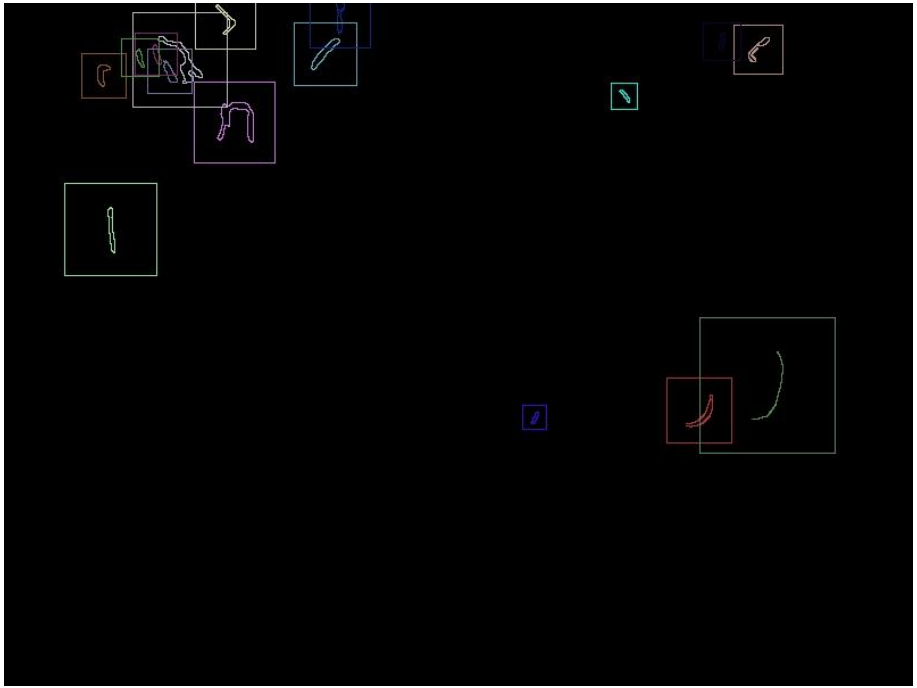
TECHNICAL ASPECTS - PYTHON CODE - 3/3

```python
import ConvolutionalNN as myCNN
import torch
import string
import skimage
import numpy as np

def predict(image_path):
    """
    Image_path can be local (if found in the same folder of the script) or complete
    Image must be of a number 0-9 or a capital letter A-Z.
    Only resolution accepted: 32x32.
    """

    CNN = myCNN.Net().double()
    state_dict = torch.load('saved_model.pth')
    CNN.load_state_dict(state_dict)

    #IncompatibleKeys(missing_keys=[], unexpected_keys=[]) means "no error"

    img = skimage.io.imread(image_path, as_gray=True)
    #skimage.io.imshow(img)
    img = np.array(img).reshape((1,1,32,32)) #vector of a single element with 1 channel of 32x32 pixels
    img = img/img.max() # in case it wasn't normalized
    img = torch.from_numpy(img)

    my_dict = define_dict()

    outputs = CNN(img)
    _, predicted = torch.max(outputs.data, 1)
    predicted = predicted.numpy()
    char = my_dict[predicted[0]]
    print(char)
```

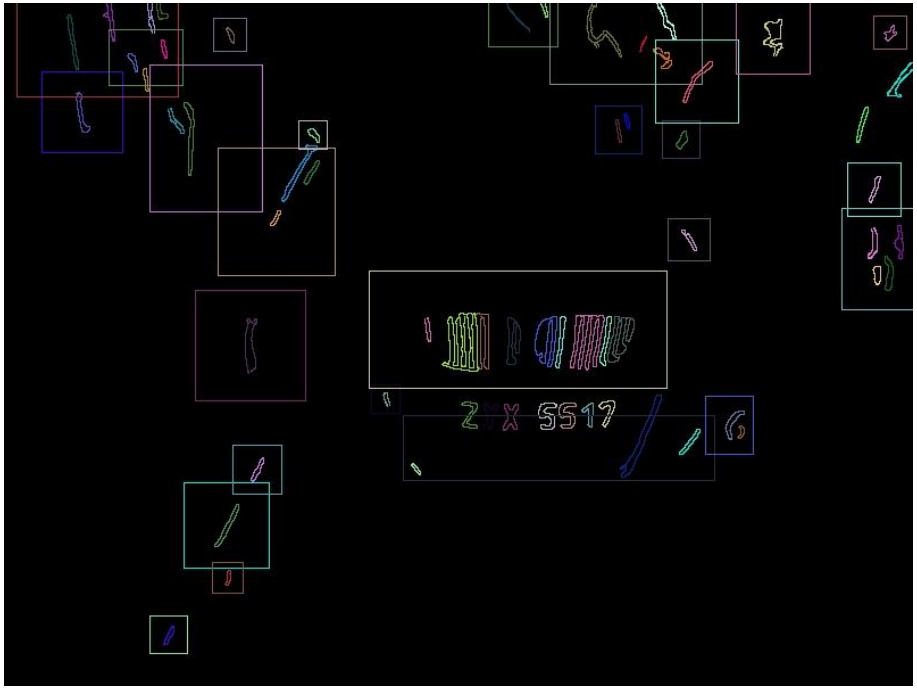
Common Issues

1. Plate detection
2. Characters detection
3. Characters recognition

COMMON ISSUES - PLATE DETECTION - 1/2



COMMON ISSUES - PLATE DETECTION - 2/2



COMMON ISSUES - CHAR. DETECTION

COMMON ISSUES - CHAR. RECOGNITION