Module:	Artificial Intelligence for Autonomous Systems
Academic Year:	2023-2024
Lecturers:	Dr. I. Petrunin
Title:	**Image Segmentation for Scene Learning**
Date issued:	09 January 2024
Submission date:	*To be notified on Canvas*.
Estimated time required:	50 hours

The assignment should be submitted electronically as a pdf, in the form of a brief individual report (2500 words limit applies) explaining the methods and giving a clear statement of the principal results. Students should highlight the physical basis for any assumptions made wherever possible.

The final completed assignment should be submitted to Turnitin following the standard procedure on or before the submission date.

You are reminded that in the absence of exceptional circumstances (supported by written evidence) late submissions will be penalised.

Aim

The aim of this study is to select, apply and study segmentation algorithms on the example of the proposed image dataset.

Problem Definition

Segmentation is one of the common applications of machine learning that allows for simplified and meaningful partitioning of image into multiple groups.

Practical applications of image segmentation include various areas of imaging, e.g. for surveillance, medical applications, visualization in the systems of augmented reality, optimization of communication requirements (as a part of the compression scheme) or as a pre-processing step for numerous detection and recognition tasks.

Segmentation can be implemented by using either supervised or unsupervised learning methods or their combination, resulting in a different set of requirements, outputs, challenges in implementation and performance.

In this case you're proposed to apply segmentation routine for a basic task of finding areas in the image, consisting of similar pixels that can be used as a pre-processing stage for the object detection and tracking. One of the requirements here is to preserve semantic context of the image as much as possible, while reducing dimensionality of the input to the following stages of processing.

The objectives of this works are as follows:

1. To discuss and select an appropriate segmentation method
2. Implement selected technique for segmentation images in the supplied image database
3. Assess and discuss the performance of the implemented segmentation technique.

Data

The dataset is presented by BSDS 500 image database [1] : (https://www2.eecs.berkeley.edu/Research/Projects/CS/vision/grouping/resources.html)

that contains 500 images of various objects both man-made and from nature. Archive with all images and ground truth segmentations can be downloaded separately from here: https://1drv.ms/u/s!AvThcPpjCs6KjGl2JR_OY-_-a_n1?e=u7hTzN.

[1] P. **Arbelaez, M. Maire, C. Fowlkes and J. Malik. Contour Detection and Hierarchical Image Segmentation, IEEE TPAMI, Vol. 33, No. 5, pp. 898-916, May 2011.**

The database is split into training, validation and testing sets in proportion 2:1:2. For all images the ground truth is supplied in the form of MATLAB data files containing both segments and their boundaries (boundaries are usually not required for segmentation validation). Thus, the data set can be used for multitude of methods, both supervised and unsupervised.

Please note that if an unsupervised segmentation is selected it doesn't need to be applied to the training and validation datasets – only to the test set of images.

An example of the images from the database and corresponding ground truth segmentations are shown in Figure below.

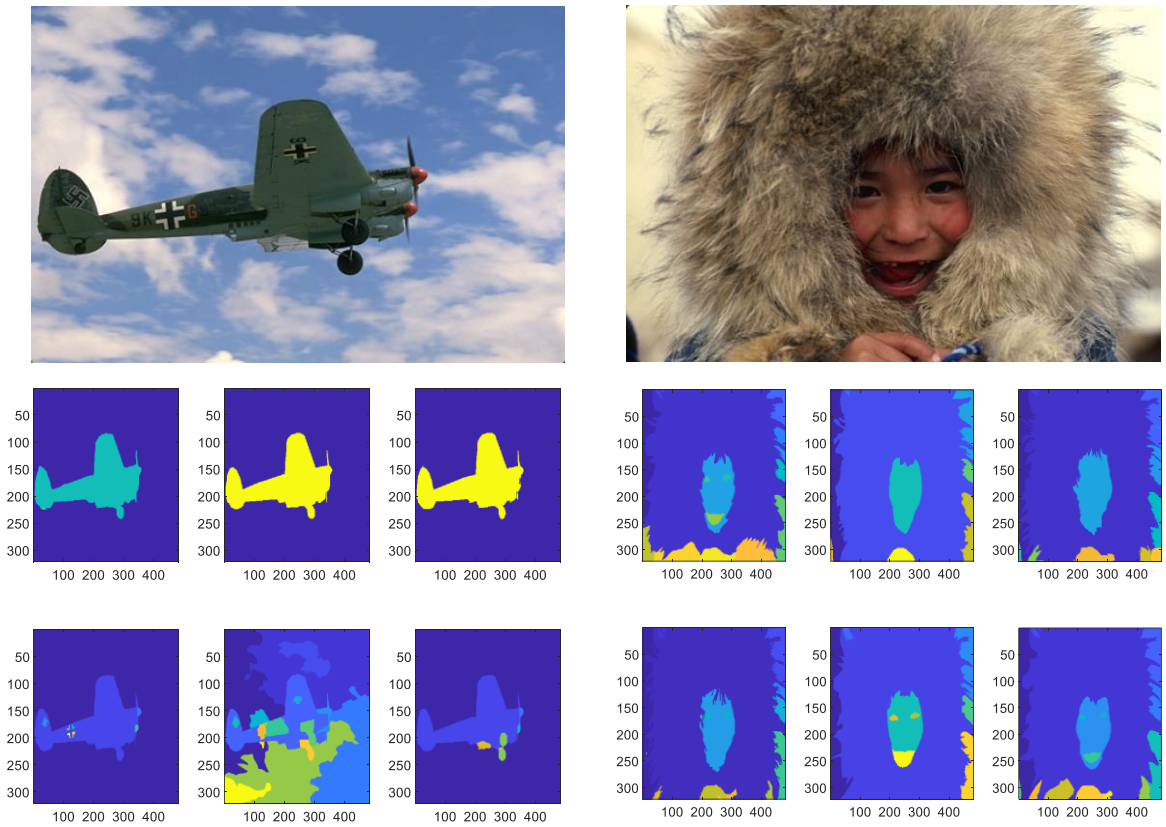

Figure 1 Examples of images from the test set of the database with alternative versions of segmentation ground truth.

You can see that a single image is assigned with multiple ground truth segmentations representing the variety of the task requirements one can face in practical applications[2].

Methodology

[2] D. Martin, C. Fowlkes, D. Tal, and J. Malik, "A Database of Human Segmented Natural Images and Its Application to Evaluating Segmentation Algorithms and Measuring Ecological Statistics,"Proc. Int'l Conf. Computer Vision, 2001.

To achieve the objectives of this work you need to select the segmentation method, justifying pros and cons in comparison with other methods (500 words max).

It is anticipated that one of the methods from the scope of the materials taught in the module will be implemented for segmentation purposes, following the generic selection process.

The method should be implemented to the test images of the proposed dataset (200 images). If necessary, training and validation parts of the data set can be used (i.e. in case of using supervised learning method).

Any analysis tools are permitted – there is no requirement to use MATLAB/Python/Tensorflow or any other tool, but it is recommended to include the code in the report to enable markers to see possible reasons for the problems with the results (if this happens) to be accounted for during the marking process.

The results should be analysed and discussed using performance metrics, such as precision and recall. You may wish to utilise more than one ground truth (examples are in Figure 1) while tuning the technique and discussing your results. Extra performance metrics, which do not involve ground truth, can bring additional marks (10 max).

The word count for the report is low (2500 words, excluding references), therefore, results and discussion should be predominantly presented in the graphical or tabulated way. Reproduction of the problem statement and data description will not be included in the word count.

Assignment report should be prepared using the supplied template and may consist, for example, of sections as follows: Selection of the segmentation technique, Segmentation results, Analysis and discussion, Conclusions.

Assessment

Assignment marking will be focused on the ability discuss the appropriateness of the techniques with the following selection and quality of the results assessment. A part of the marks will be allocated for implementation efforts and results obtained.

Use of the programming languages or tools is not assessed, i.e. type of the tool used or length of the code will not affect marks. Problem statement and data description (in case they are included in the report) will not be assessed too.

It is expected that in order to pass *one technique should be selected, implemented and discussed for segmentation of the images from the "test" set of BSDS 500 database*.

The marks for the assignment will be distributed as follows:

1. Discussion and selection of the techniques for segmentation that include concise pros and cons discussion [10 marks for supervised and 10 marks for unsupervised techniques] (500 words max)

[20 Marks]

2. Work carried out, efforts and results that include implementation of technique(s) (including parameter tuning) [10 marks], completeness of results (all images to be processed and included into analysis) [10 marks], (qualitative) correctness of results [10 marks]

[Total: 30 Marks]

3. Analysis, discussion and conclusions that include selection and application of metrics for analysis [10 marks for effective comparison with ground truth + 5 per additional suitable metric with appropriate reasoning, up to10 max], performance considerations [5 marks], comparison with other known techniques (as applicable) [5 marks] and concluding remarks related to issues and challenges with the implemented technique [5 marks]

[Total: 35 Marks]

4. Style and presentation that include presence of logical structure, appropriate citation style (if references used), quality of graphical material (labels, legends, titles and captions as appropriate), readability of the text material, clarity of results presentation in the text.

a) Structure [5 marks],
b) Clarity [10 marks].

[Total: 15 Marks]

Marking rubric

	Fail (0-49%)	**Pass/Satisfactory (50-59%)**	**Good (60-69%)**	**Excellent (70-100%)**
Content	Demonstrates inadequate knowledge of the subject	Demonstrates sufficient knowledge to address ILOs	Demonstration of knowledge meets all and exceeds some ILOs	Demonstration of knowledge exceeds many ILOs
Argument	Absence of critique of the subject matter	Some critique of the subject matter	Good capacity for critical evaluation	High capacity for critical evaluation
Presentation	A poorly structured and communicated piece of work.	Simple structure with adequate communication skills	Well-structured work with good communication skills	Well-structured work with excellent communication skills

	A large number of spelling or grammar errors; references incorrectly cited; Poor or no use of titles, subtitles, figures or tables; Lack of legends and labelling.	Most spelling and grammar is correct; other presentational aspects generally correctly applied	Minor errors	No mistakes in spelling or grammar; references correctly and consistently cited; appropriate use of titles and subtitles; creative use of figures and tables to complement the text and are correctly labelled and referred to

Appendix 1. Code for accessing images in the database

```
%% Description
% This is an example code for reading multiple images and accessing the
% corresponding ground truth information

%% path to the data set
path = 'C:\Assignment data\data';
cd (path)
imgDir = '\images\test\';
gtDir = '\groundTruth\test\';

D= dir(fullfile([path imgDir],'*.jpg'));

%% importing and displaying images
tic;
% here we use only a few images for demonstration
for i =1:3 %numel(D)
    IMG = imread ([path imgDir D(i).name(1:end-4) '.jpg']);
    figure, imshow(IMG);
    title([D(i).name(1:end-4) '.jpg'])
end
toc;

%% displaying ground truth
tic;
% again, we use only a few images for demonstration
for i =1:3 %numel(D)
    GT = load([path gtDir D(i).name(1:end-4) '.mat']);
    % plotting preparations, assuming max 6 segmentations, frequently there
    % are 5
    figure ('name', ['Ground truth for ' D(i).name(1:end-4) '.jpg'])
    for k=1:length(GT.groundTruth)
        segments = double(GT.groundTruth{k}.Segmentation);
        subplot(2,3,k)
        imagesc(segments)
        title(num2str(k))
    end
end
toc;
```