

An Implementation: Laplacian Coordinates for Image Segmentation Method

Software engineering

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Introduction

Problem statement

Problem Statement:

- ▶ Image segmentation
- ▶ Seeded segmentation
- ▶ Why Laplacian Coordinates method?

Objective:

- ▶ “Given a color image and some manually annotated pixels, provide a segmentation of the image in 2 regions using the Laplacian Coordinates for Seeded Image Segmentation algorithm”

Introduction

Background

Basic concepts:

- ▶ Energy equation:

$$E(x) = k_1 \sum_{i \in B} \|x_i - x_B\|_2^2 + k_2 \sum_{i \in F} \|x_i - x_F\|_2^2 + k_3 \sum_{i \in V} \|d_i x_i - \sum_{j \in N(i)} w_{ij} x_{ij}\|_2^2 \quad (1)$$

- ▶ Weight equation:

$$w_{ij} = e^{-\frac{\beta \|l_i - l_j\|_\infty^2}{\sigma}} \quad (2)$$

- ▶ Valency equation:

$$d_i = \sum_{j \in N_i} w_{ij} \quad (3)$$

- ▶ Linear system:

$$(I_s + L^2)x = b \quad (4)$$

Introduction

Implementation approach



(a) Qt.



(b) Eigen & OpenCV



googletest
Google C++ Testing Framework

(c) Gtest



(d) CMake



(e) Doxygen

Figure: Tools used for the implementation.

Project management

Gantt chart

At the very beginning and taking advantage of the preliminary study of the paper, we programmed a schedule in order to achieve the completeness of the project

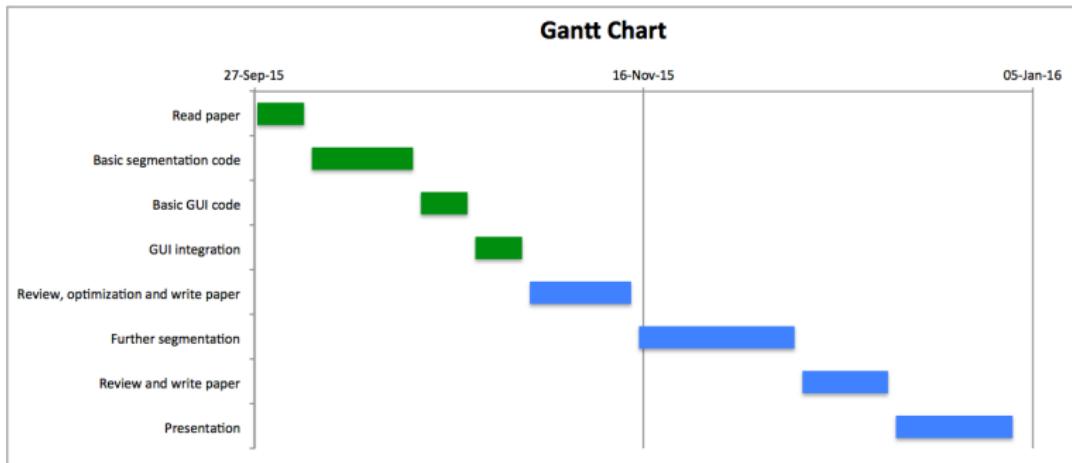


Figure: Gantt chart.

Project management

Tasks table

Table: Expected timing for the realization of the project.

Task name	Start	End	Duration (days)
Read paper	28/09/15	04/10/15	7
Basic segmentation code	05/10/15	18/10/15	14
Basic GUI code	19/10/15	25/10/15	7
GUI integration	26/11/15	01/11/15	7
Review, optimization and write paper	02/11/15	15/11/15	14
Further segmentation	16/11/15	06/12/15	21
Review and write paper	07/12/15	18/12/15	12
Presentation	19/12/15	03/01/16	16

Table: Final scheduling of the project.

Task name	Start	End	Duration (days)
Read paper	28/09/15	08/10/15	11
Basic segmentation code	09/10/15	18/10/15	10
Basic GUI code	19/10/15	25/10/15	7
GUI integration	26/11/15	03/11/15	9
Review, optimization and write paper	04/11/15	10/11/15	7
Further segmentation	11/11/15	27/12/15	47
Review and write paper	28/12/15	10/01/16	14
Presentation	28/01/16	10/01/16	14

Project management Tools

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(a) Github



(b) Trello



(c) Overleaf

Figure: Tools used for the project management.

System implementation

Basis

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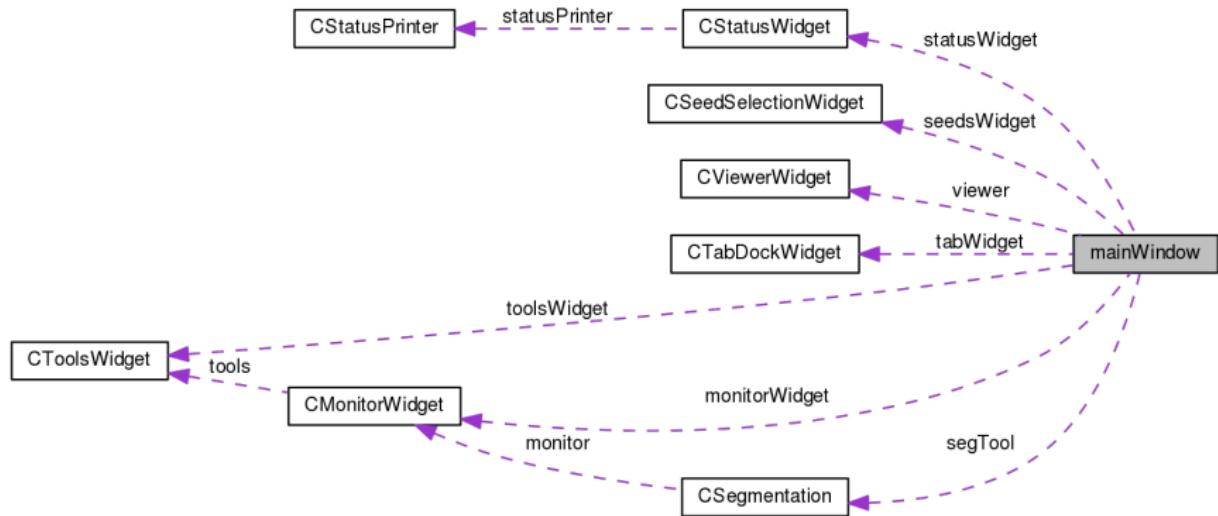


Figure: System diagram

System implementation

Basis



The previously explained algorithm is implemented in two parts:

- ▶ Segmentation code
- ▶ Graphical User Interface (GUI)

Using the following methods in implementation:

- ▶ Multi-threading
- ▶ Data serialization
- ▶ Hash value calculation

System implementation

Segmentation code

Usage of the equations described in Casaca et al.

For implementation purposes:

- ▶ σ is set to 0.1 by the authors recommendation.
- ▶ The tuning value of β can be chosen by the user through the user's interface.

System implementation

GUI

Features:

- ▶ Tab generation
- ▶ Beta slider
- ▶ Size of coloring
- ▶ Seed selection
- ▶ Browsing image button
- ▶ Execute segmentation

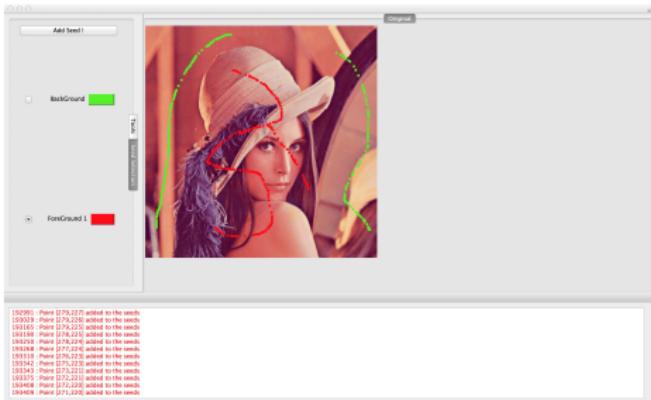


Figure: GUI layout.

GTest:

- ▶ Google Test is an unit testing library. It is available in some languages. We used it for the C++ programming language

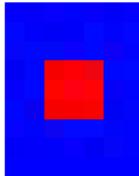


Figure: Test image for GTest (9×7 pixels).

CMake:

- ▶ CMake is a cross platform that allows the building of a directory tree outside the source tree

Additional features

Speed vs accuracy

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- Linear system proposed in Casaca et al.:

$$(I_s + L^2)x = b \quad (5)$$

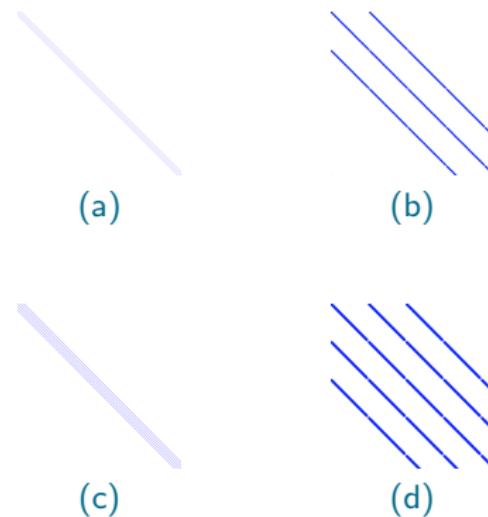


Figure: First row: sparsity of L . Second row: sparsity of L^2 .

Additional features

Multiple-regions segmentation

- ▶ On the research paper, in order to achieve multiple segmentation they treat the linear system equation as an extension of solving N linear systems.

$$(I_s + L^2)x^{(j)} = b^{(j)} \quad (6)$$

- ▶ No need to compute the matrices I_s and L for each iteration.
- ▶ The vector b has to be redefined for each segmentation j

Results and evaluation

Databases

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- ▶ Grabcut database
- ▶ Berkeley Image Segmentation Benchmark Database



(a)



(b)



(c)



(d)



(e)



(f)

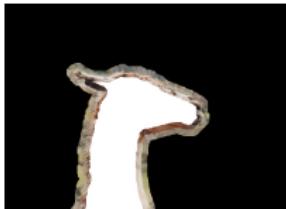
Figure: a) bunch. b) ceramic. c) grave. d) llama. e) person. f) sheep.

Results and evaluation

Results



(a)



(b)



(c)



(d)



(e)

Figure: a) original image. b) the tri-map seeds. c) ground-truth. d) obtained result considering L2. e) obtained result considering L.

Results and evaluation

Benchmarking

Table: Region quality metrics of the six studied images. Evaluation done considering the two studied approaches.

Image	Approach	RI	GCE	Vol
Bush	L^2	0.9441	0.0534	0.4010
	L	0.9310	0.0665	0.4662
Ceramic	L^2	0.9817	0.0117	0.1677
	L	0.9796	0.0137	0.1837
Grave	L^2	0.9840	0.0128	0.1432
	L	0.9820	0.0144	0.1558
Llama	L^2	0.9747	0.0240	0.1781
	L	0.9729	0.0255	0.1857
Person	L^2	0.9864	0.0097	0.1172
	L	0.9868	0.0094	0.1151
Sheep	L^2	0.9900	0.0072	0.0852
	L	0.9899	0.0073	0.0857

Results and evaluation

Accuracy vs speed

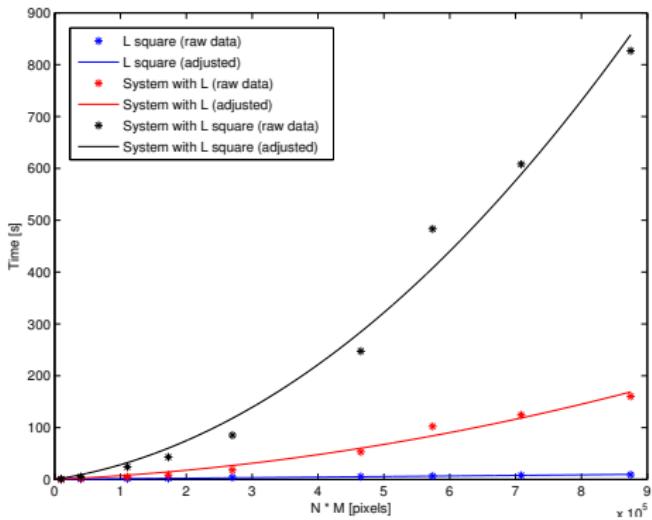


Figure: Time spent on computing L^2 , on solving the system with L and on solving the system with L^2 regarding the number of pixels in the image.

Results and evaluation

Multi-region segmentation



Figure: a) original image. b) manually selected seeds for multiple-region segmentation.

Results and evaluation

Multi-region segmentation



(a)



(b)



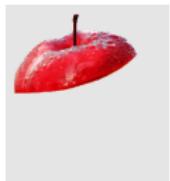
(c)



(d)



(e)



(f)



(g)



(h)



(i)



(j)

Figure: First row: computed masks. Second row: results after applying the masks.

DEMO



Final remarks and future works

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- ▶ Importance of project management
- ▶ Open source code
- ▶ Different method to be studied
- ▶ Further improvements: real time segmentation

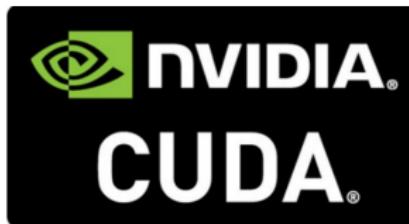


Figure: Nvidia - Cuda.

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