# An Implementation: Laplacian Coordinates for Image Segmentation Method

## Software engineering

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# Content

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"

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:

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

- Valency equation:

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

- Linear system:

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


(a) Qt. (b) Eigen & OpenCV


(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

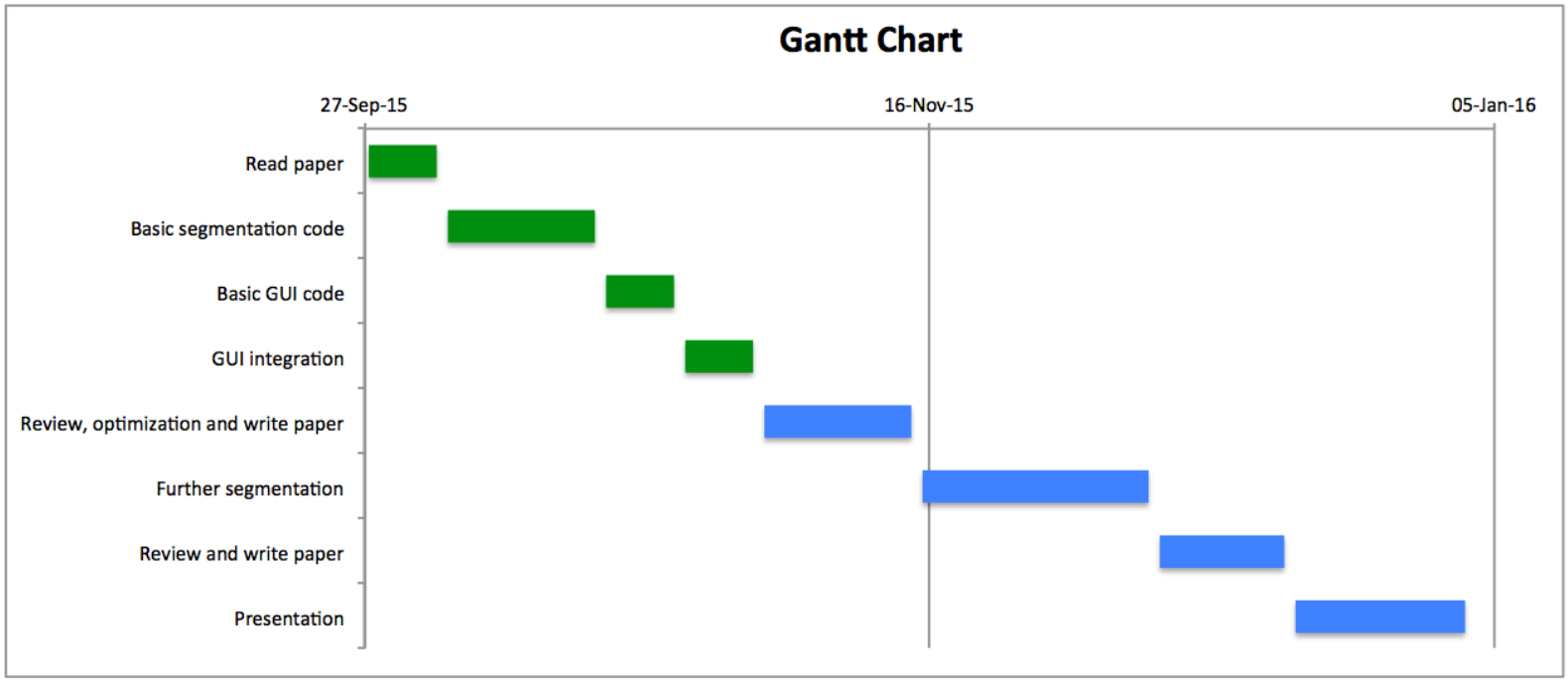



Figure: Gantt chart.

# 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 |


(a) Github (b) Trello (c) Overleaf

Figure: Tools used for the project management.

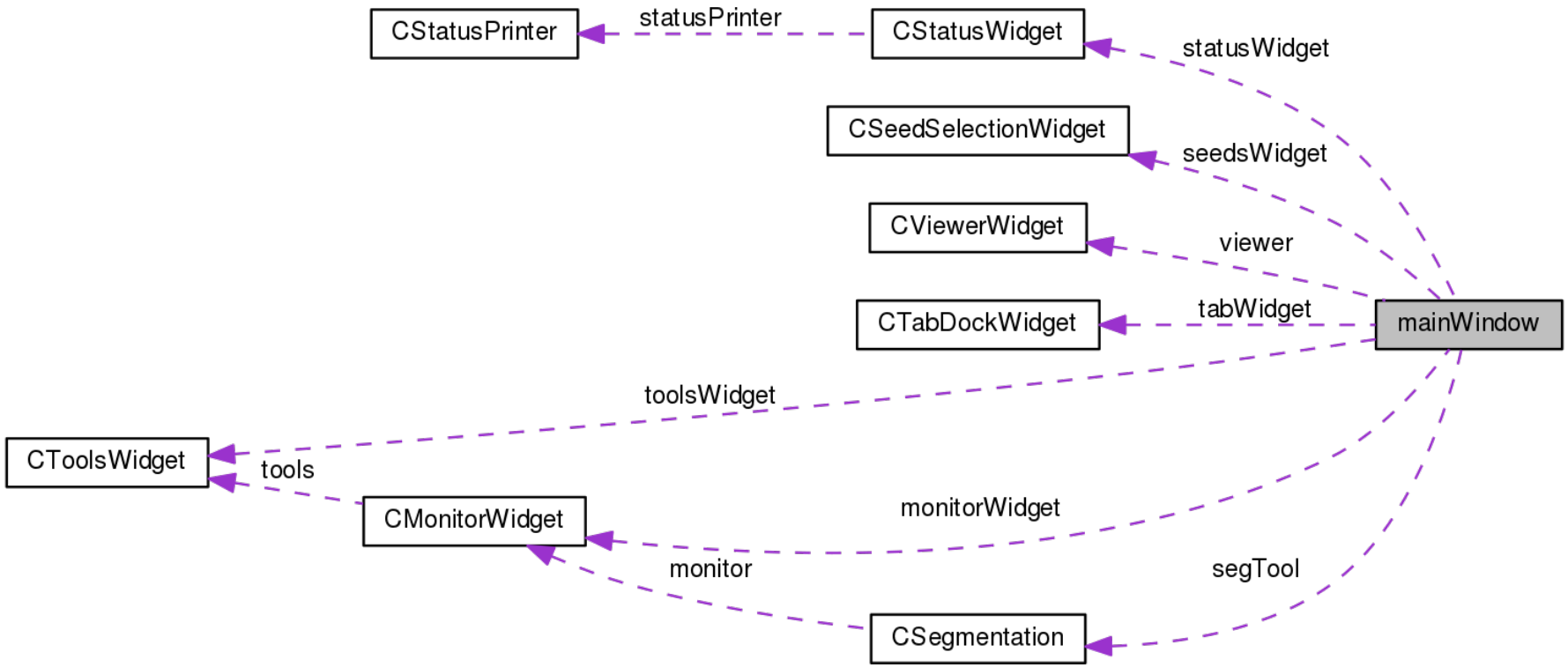



Figure: System diagram

# 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

Usage of the equations described in Casaca et al.

For implementation purposes:

- $\sigma$ is set to 0.1 by the authors recommendation.
- The tuning value of $\beta$ 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

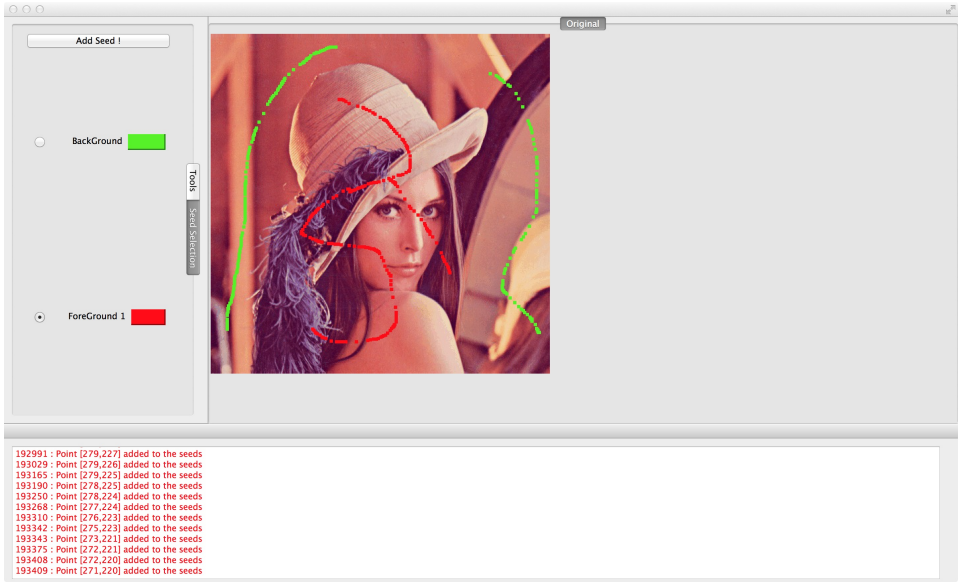



Figure: GUI layout.

GTest:

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

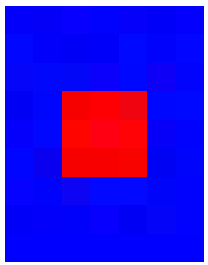


Figure: Test image for GTest ($9 \times 7$ pixels).

CMake:

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

# Additional features
## Speed vs accuracy

- Linear system proposed in Casaca et al.:

$$(I_s + L^2)x = b \tag{5}$$

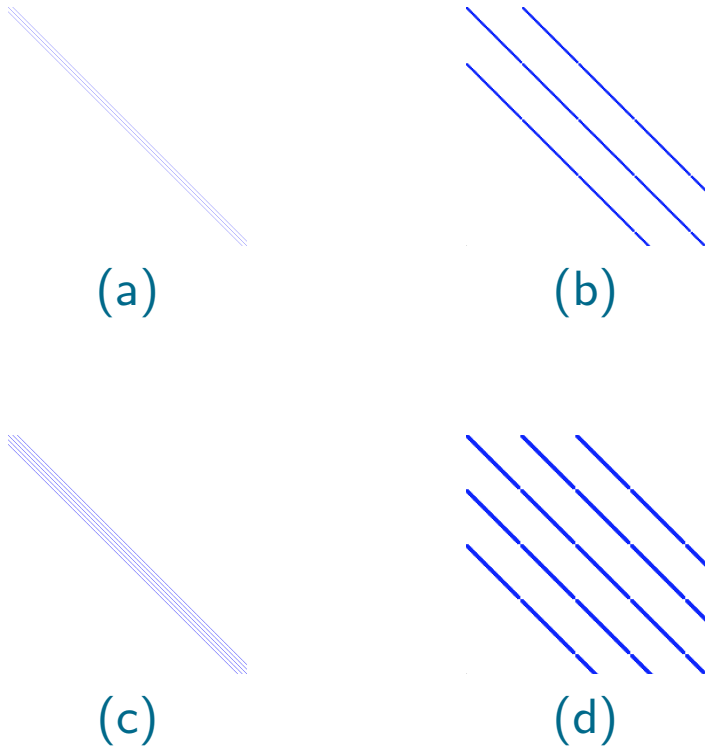


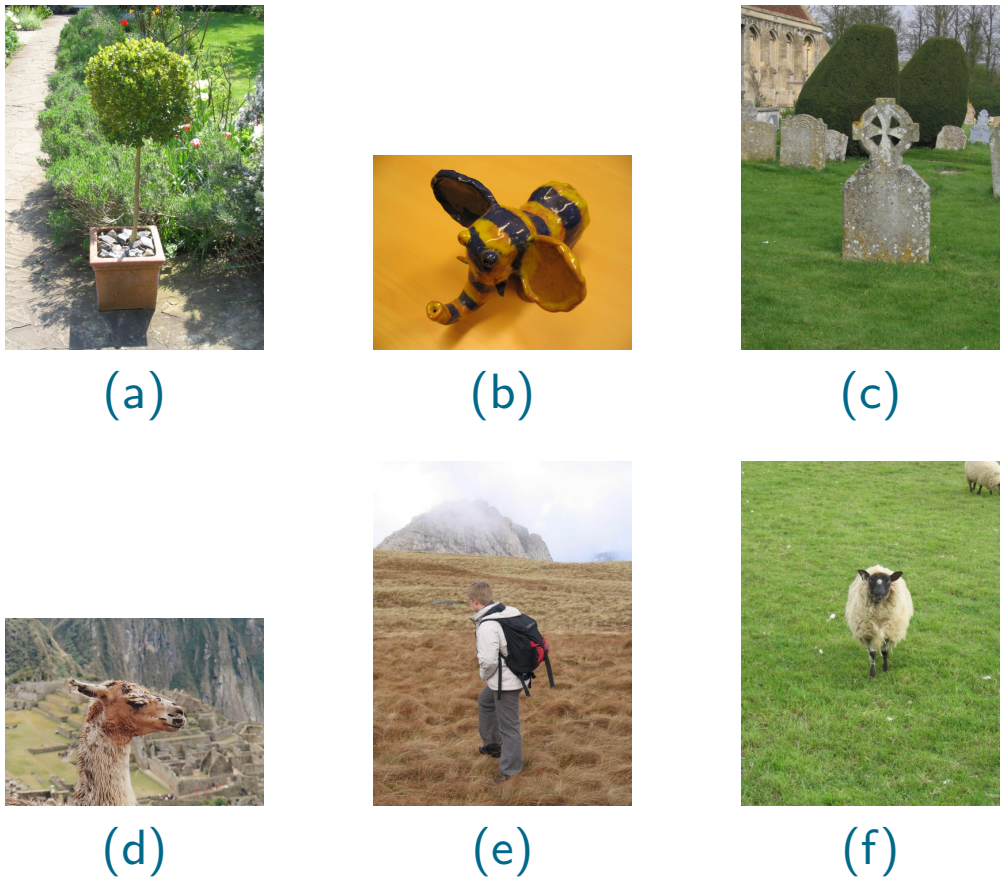

Figure: First row: sparsity of $L$. Second row: sparsity of $L^2$.

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

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

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

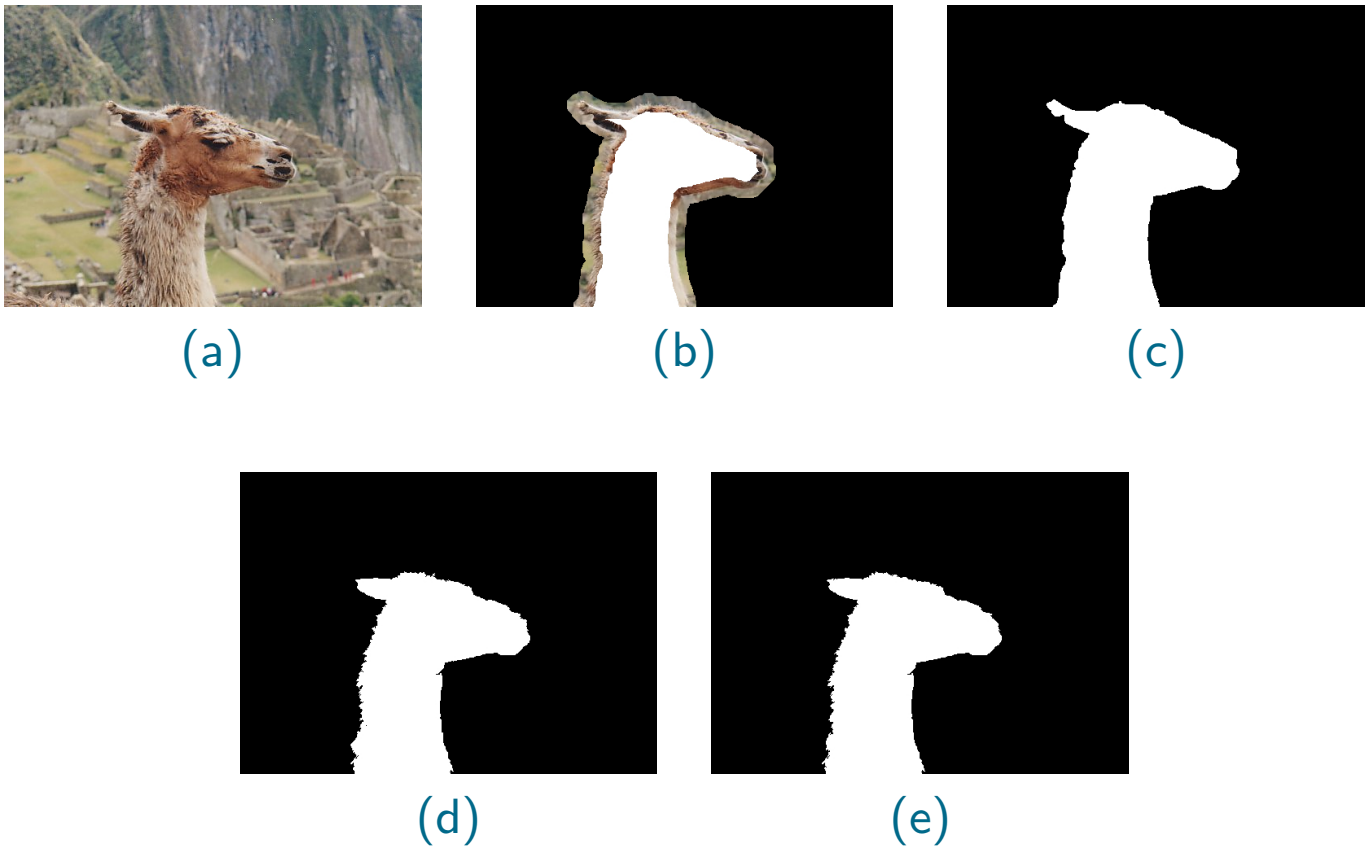
- Grabcut database
- Berkeley Image Segmentation Benchmark Database



(a) (b) (c)

(d) (e) (f)

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



(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.

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



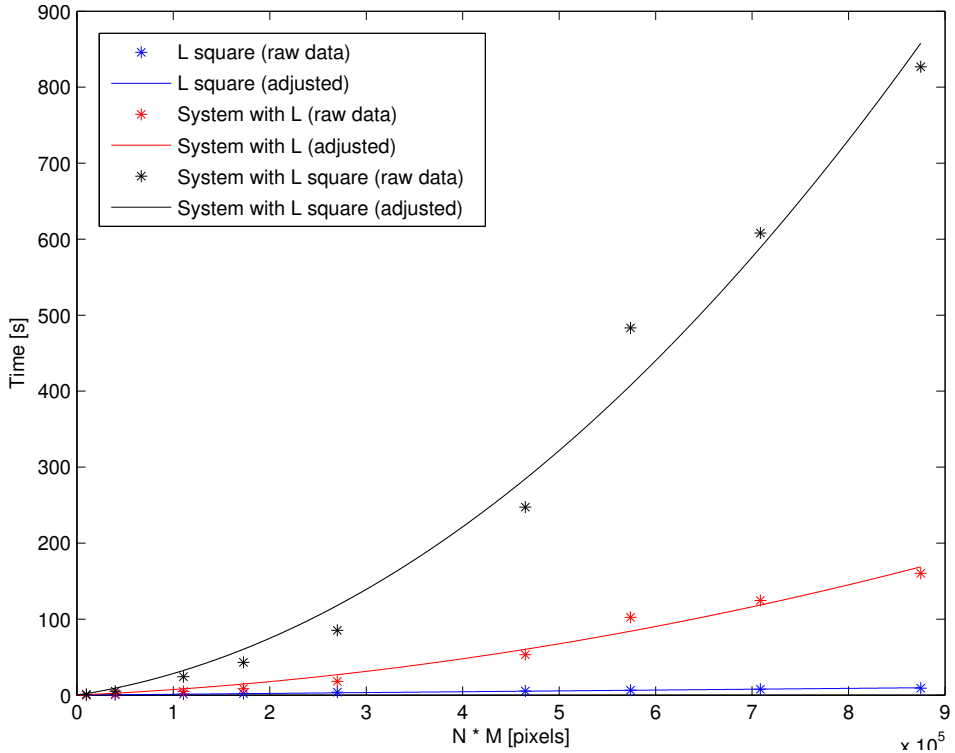


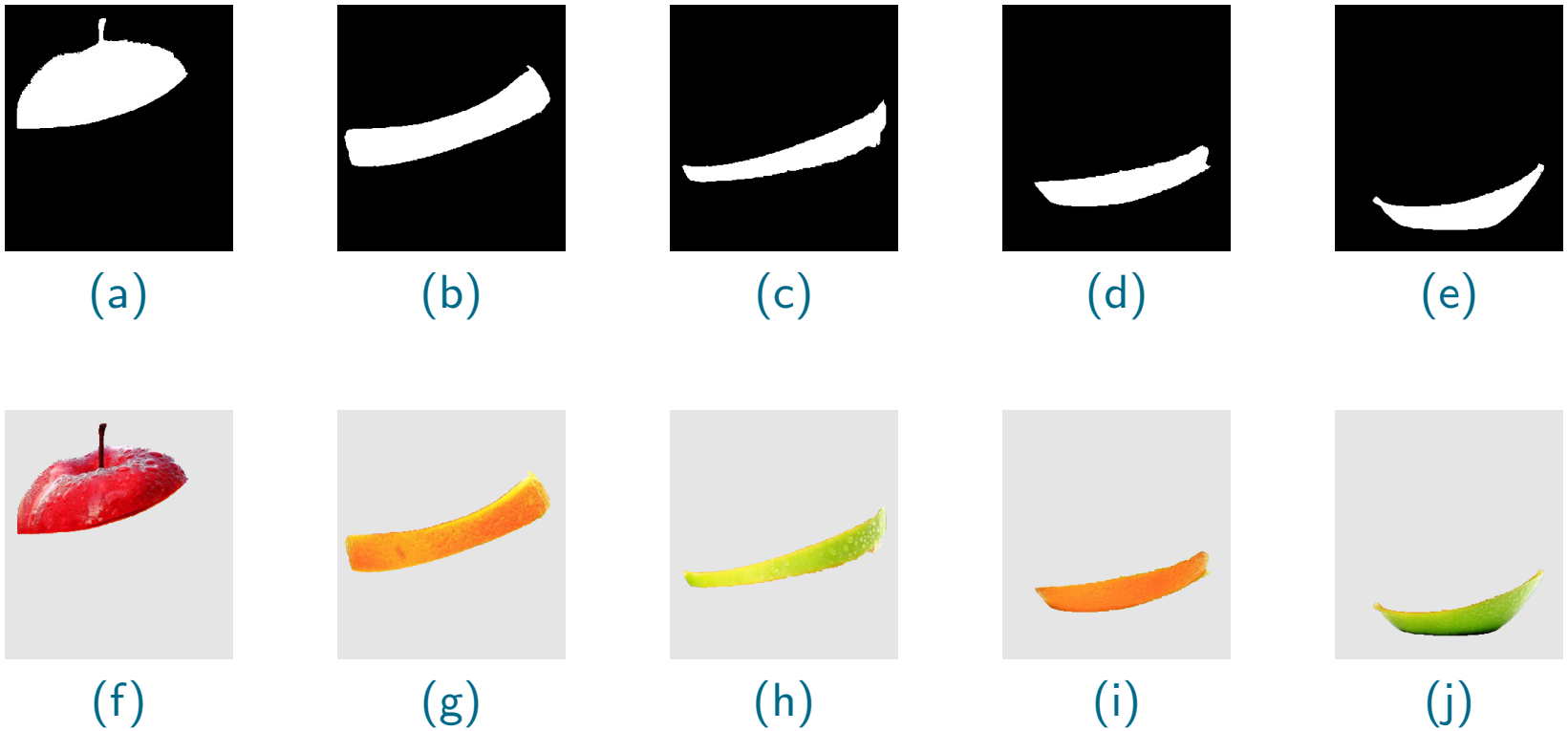

Figure: Time spent on computing $L^2$, on solving the system with L and on solving the system with $L^2$ regarding the number of pixels in the image.

(a) (b)

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



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

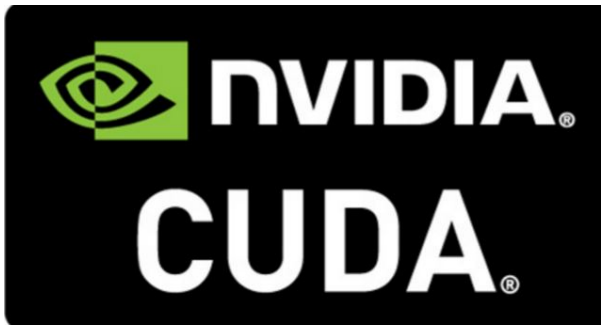



Figure: Nvidia - Cuda.

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