2015/2016

Optimization and inference techniques for CV

Code: 43086

Credits: 6

Type: OB/OT/TFM Course: 1 Semester: 1

Contact

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Lecturers

Coloma Ballester (Module coordinator)
Juan Francisco Garamendi (Project coordinator)
Joan Serrat
Oriol Ramos

Use of languages

Principal working language: English

Prerequisites

Degree in Engineering, Maths, Physics or similar

Objectives and contextualisation

The aim of this module is to learn about numerical optimization algorithms that are behind many tasks in computer vision. Main concepts will include energy minimization, numerical techniques for variational problems, convex optimization and graphical models. These techniques will be applied in the project in the context of image segmentation and restoration (denoising and inpainting).

Skills and learning outcomes

E01 - Identify concepts and apply the most appropriate fundamental techniques for solving basic problems in computer vision.

01 - Identify the basic optimisation techniques and their associated algorithms.

02 - Identify the basic concepts of graphical models and inference algorithms.

E02 - Conceptualise alternatives to complex solutions for vision problems and create prototypes to show the validity of the system proposed.

03 - Identify the best representations that can be defined for solving both optimisation and inference problems with graphical models.

E03 - Choose the most suitable software tools and training sets for developing solutions to problems in computer vision.

04 - Choose optimisation and inference techniques and train them to resolve a particular project.

E04 - Plan, develop, evaluate and manage solutions for projects in the different areas of computer vision.

05 - Use optimisation and inference techniques to plan, develop, evaluate and manage a solution to a particular problem.

B06 - Use acquired knowledge as a basis for originality in the application of ideas, often in a research context.

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B07 - Solve problems in new or little-known situations within broader (or multidisciplinary) contexts related to the field of study.

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B10 - Continue the learning process, to a large extent autonomously

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T02 - Understand, analyse and synthesise advanced knowledge in the area, and put forward innovative ideas.

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T03 - Accept responsibilities for information and knowledge management.

10 - Accept responsibilities for information and knowledge management.

T04 - Work in multidisciplinary teams.

11 - Work in multidisciplinary teams.

Content

1. Introduction to energy minimization methods. Overview of varational formulation. Examples.
2. Review of numerical linear algebra (I)
3. Review of numerical linear algebra (II): minimum squares, regression, singular value decomposition, Gauss Seidel, applications (face recognition, Poisson editing)
4. Numerical techniques for variational problems (I)
5. Numerical techniques for variational problems (II); Euler-Lagrange equation, gradient descent, conjugate gradient, Newton's method, Gauss-Newton. Applications (variational image restoration, optical flow computation, bundle adjustment...)
6. Convex optimization (I). Constrained and unconstrained optimization. Primal, dual, and primal dual methods. Convex relaxation. Applications: Total Variation restoration, disparity computation, optical flow computation, SVM, minimization of non-local functionals.
7. Convex optimization (II): Vectorial Total Variation. Applications: Total Variation Restoration and inpainting for color images
8. Segmentation with variational models. The Mumford and Shah Functional. Explicit and implicit Shape Representations: Mimimum paths for segmentation. Level sets Formulation. Applications to image and video segmentation.
9. Bayesian networks and MRFs. Inference types. Example: stereo, denoising.
10. Inference algorithms 1: belief propagation (sum-product and max-sum) and generalizations. Examples: bob tracking, video synchronization
11. Inference algorithms 2: Graph cuts, linear programming relaxation. Examples: co-segmentation
12. Learning of graphical models. Structured SVMs
13. GM for computer vision and implementation: a guided problems

Methodology

Supervised sessions:

- **Lecture Sessions**, where the lecturers will explain general contents about the topics. Some of them will be used to solve the problems.

Directed sessions:

- **Project Sessions**, where the problems and goals of the projects will be presented and discussed, students will interact with the project coordinator about problems and ideas on solving the project (approx. 1 hour/week)
- **Presentation Session**, where the students give an oral presentation about how they have solved the project and a demo of the results.
- **Exam Session**, where the students are evaluated individually. Knowledge achievements and problem-solving skills

Autonomous work:

- Student will autonomously study and work with the materials derived from the lectures.
- Student will work in **groups** to solve the problems of the projects with deliverables:
    - Code
    - Reports
    - Oral presentations

Activities

TYPE	ACTIVITY	HOURS	LEARNING OUTCOMES
Supervised			
	Project, Presentation and Exam Sessions	10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

Directed

Lecture Sessions	20	1, 2, 3

Autonomous

Homework	120	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

Evaluation

The **final marks** for this module will be computed with the **following formula**:

Final Mark = 0.4 x **Exam** + 0.55 x **Project**+ 0.05 x **Attendance**

where,

Exam: is the mark obtained in the Module Exam (must be >= 3)
Attendance: is the mark derived from the control of attendance at lectures (minimum 70%)
Projects: is the mark provided by the project coordinator based on the weekly follow-up of the project and deliverables. All accordingly with specific criteria such as:

- Participation in discussion sessions and in team work (inter-member evaluations)
- Delivery of mandatory and optional exercises.
- Code development (style, comments, etc.)
- Report (justification of the decisions in your project development)
- Presentation (Talk and demonstrations on your project)

Evaluation activities

TITLE	HOURS	WEIGHTING	LEARNING OUTCOMES
Exam	3	0,4	1, 2, 3, 6, 7, 8, 9, 10
Project	7	0,55	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

Bibliography

Journal articles:

1. S.P. Boyd, L. Vandenberghe, "*Convex optimization*", Cambridge University Press, 2004.
2. Xavier Bresson and Tony F. Chan. "*Fast Dual Minimization of the Vectorial Total Variation Norm and Applications to Color Image Processing. Inverse Problems and Imaging*". American Institue of Mathematical Sciences. Vol 2, No. 4, pp 455-484 2008.
3. Chan, T. F., & Vese, L. a. "*Active contours without edges*". IEEE Transactions on Image Processing : A Publication of the IEEE Signal Processing Society, *10*(2), pp 266–77, 2001.
4. Daphne Koller and Nir Friedman, "*Probablistic Graphical Models. Principles and techniques*", 2009.
5. Patrick Pérez, Michel Gangnet, and Andrew Blake. "*Poisson image editing*". In ACM SIGGRAPH 2003 Papers (SIGGRAPH '03). ACM, New York, NY, USA, 313-318 2003.
6. L.I. Rudin, S. Osher, and E. Fatemi. "*Nonlinear Total Variation based Noise Removal Algorithms*". Physical D Nonlinear Phenomena, 60, pp 259-268, November 1992.

Book:

1. Tony F. Chan and Jianhong Shen. "*Image Processing and Analysis: Variational, PDE, Wavelet and Stochastic Methods*". Society for Industrial and Applied Mathematics, 2005.
2. Aubert Gilles, Pierre Kornprobst. "*Mathematical Problems in Image Processing: Partial Differential Equations and the Calculus of Variations*". Springer-Verlag New York.
3. Joe D. Hoffman. "*Numerical Methods for Engineers and Scientists*"
4. Daphne Koller and Nir Friedman, "*Probablistic Graphical Models. Principles and techniques*", 2009.
5. Sebastian Nowozin and Christoph H. Lampert, "*Structured Learning and Prediction in Computer Vision*", Foundations and Trends in Computer Graphics and Vision: Vol. 6: No. 3-4, pp 185-365, 2011.
6. C. Pozrikidis. "*Numerical Computation in Science and Engineering*".