Multiple View Geometry in Computer Vision

Information Meeting

15 Dec 2009

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Content of the Meeting

1. Motivation & Objectives
2. What the course will be about (Stefan)
3. Content of the book & preliminary choice of chapters
4. Course structure:
   - Meetings
   - Requirments, credits
   - Dates

 **Interrupt me with questions**

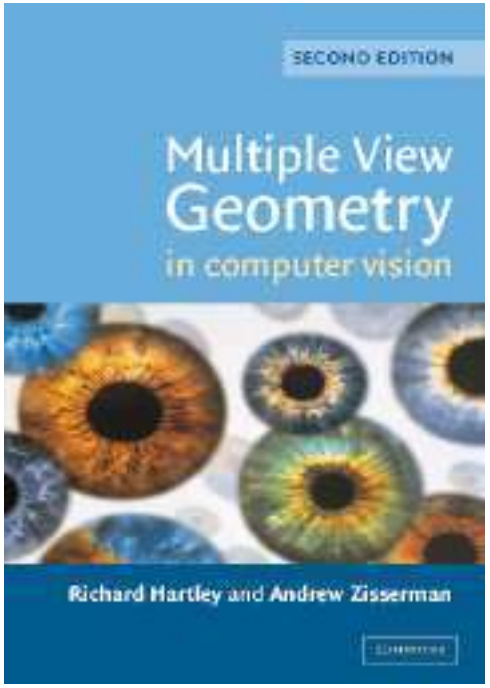
Motivation

- What the course is to be about?
  - Problem of reconstructing of a real world scens given several images
  - Techniques for solving this problem originating from geometry
- Motivation:
  - Interest in the topic of the geometric computing
  - Need to extend our knowlage
- Course:
  - PhD Course: more advanced topics, self-studing
  - Extention of the Stefan's course in **Geometric Computing and Visualization (geom'09; DD2428)**

Objectives

- To understand the geometric relations between multiple views of scenes
- To understand the general principles of parameter estimation
- To be able to compute scene and camera properties from real world images using state-of-the-art algorithms

Literature



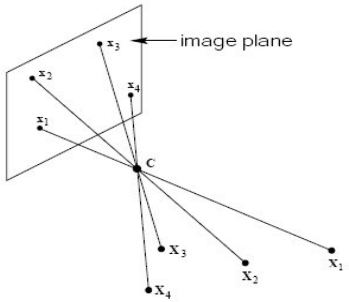
- Richard Hartley and Andrew Zisserman ”Multiple View Geometry in Computer Vision”. Second Edition, Cambridge University Press, March 2004.
- Book webpage: www.robots.ox.ac.uk/~vgg/hzbook/
  - Sample chapters: Content, Introduction
  - Corrections and Errata
  - Matlab code
- Related papers...

Book

- Reconstructing of a real world scens given several images
- Content of the book - 5 main parts:
  - PART 0: Background: projective geometry, transformations and estimation
  - PART 1: Camera Geometry and Single View Geometry
  - PART 2: Two-view Geometry
  - PART 3: Three-view Geometry
  - PART 4: N-view Geometry

Part 0: Background

- PART 0 - Projective geometry, transformations and estimation (theory!)
  - Chapter 2 – Projective Geometry and Transformations of **2D**:
    - Projective transformations of 2D space (when a plane is imaged by a perspective camera);
    - Hierarchy of transformations: projective, affine, euclidian;





    - Recovery of affine properties (e.g. parallel lines) or metric properties (e.g. angles between lines) from a prospective image.
  - Chapter 3 - Projective Geometry and Transformations of **3D**:
    - Extra properties arising from the additional dimention;
    - Plane at infinity and the absolut canonic.

Part 0: Background

- PART 0:
  - Chapter 4 – Estimation – 2D Projective Transformation:
    - Estimation of geometry (= computation of some transformation e.g. 2D homography, 3D to 2D camera projection, F matrix) from image measurments;
    - Answer the question – what should be minimized as a cost function;
  - Chapter 5 – Algorithm Evaluation and Error Analysis:
    - How the results of estimation algorithms may be evaluated.

Part 0: Background

- PART 0:
  - Chapter 4 – Estimation – 2D Projective Transformation:
    - Estimation of geometry (= computation of some transformation e.g. 2D homography, 3D to 2D camera projection, F matrix) from image measurments;
    - Answer the question – what should be minimized as a cost function;
  - Chapter 5 – Algorithm Evaluation and Error Analysis:
    - How the results of estimation algorithms may be evaluated.

PART	CHAPTER	TITLE	LENGTH	Geom'09	Recommended	Students / Units
0	2	Projective Geometry and Transformations of **2D**	40 pages	---	YES	2
	3	Projective Geometry and Transformations of **3D**	20 pages	---	YES	1
	4	Estimation – 2D Projective Transformation	60 pages *(LONG!)*	---	YES *(IMPORTANT!)*	3
	5	Algorithm Evaluation and Error Analysis	20 pages	---	NO	

Part 1: Single-View Geometry

- PART 1:
  - Chapter 6 – Camera Models:
    - Cameras models: finite camera (projective), cameras at infinity (affine camera);
    - Parallel and prospective projection, camera center, principle point, K matrix etc.
  - Chapter 7 – Computation of the Camera Matrix
    - 2 algorithms – accurate estimated world points, and 'inaccurate' estimated (lab 1 geom09);
  - Chapter 8 – More Single View Geometry
    - As far scen considerd as a set of point only. What will happen if we have lines, planes canonics and quadrics under projective transformation?
    - Camera calibration (computation of K matrix without computation of the camera matrix)

PART	CHAPTER	TITLE	LENGTH	Geom'09	Recommended	Students /Units
1	6	Camera Models	25 pages	70% in geom'09	YES (without 6.4)	1 •A few new concepts; • New notation;
	7	Computation of the Camera Matrix	15 pages	70% in geom'09 (lab 1)	YES	
	8	More Single View Geometry	40 pages	---	YES (without 8.5)	2

Part 2: Two-View Geometry

- PART 2:
  - Chapter 9 – Epipolar geometry and the Fundamental Matrix:
    - Epipolar geometry; essential (E) matrix ; fundamental (F) matrix;
  - Chapter 10 – 3D reconstruction of Cameras and Structures:
    - Reconstruction of both cameras and scene structure from image points coorespondance;
    - Direct method (in geom'09); Stratified reconstruction (affine, metric assumptions);
  - Chapter 11 – Computation of F matrix:
    - Different algorithms for computing F matrix (e.g. 8-points algorithm; RANSAC algorithm etc.); possibility to **implement** some algorithms;

PART	CHAPTER	TITLE	LENGTH	Geom'09	Recommended	Students/ Units
2	9	Epipolar geometry and the Fundamental Matrix	25 pages	90% in geom'09	YES	1
	10	Computation of the Camera Matrix	15 pages	50% in geom'09	YES	
	11	More Single View Geometry	30 pages	20% in geom'09 (lab 3)	YES Without (11.1, 11.2)	A few studens to imlement algorithms and present them

Rest of Part 2 & Part 3

- PART 2:
  - Chapters 12-14 – treat secondary problems;
    - Chapter 12 – algorithms for estimating a best solution for 'real' points in 3D space for triangluation;
    - Chapter 13 – two-view geometry of planes; what happen if points lie on the same plane;
    - Chapter 14 – two-view geometry for affine cameras. Easier methods in Chapter 18.

- PART 3 - Three-View Geometry
  - Chapters 15-17 – from historical reasons;
    - The same problems can be solved using tools developed for the multiple (N)-view geometry.

PART	CHAPTER	TITLE	LENGTH	Geom'09	Recommended	Students
2	12-14		---	---	NO	
3, 4	15-17		---	---	NO	

Part 4: N-view Geometry

- PART 4:
  - Chapter 18 – N-View Computational Methods
    - State-of-the-art methods for estimating projective and affine reconstruction from a set of images; Factorization of cameras and 3D coordinates;
  - Chapter 19 – Auto-Calibration:
    - Algorithms for determining internal camera parameters directly from multiple images.

PART	CHAPTER	TITLE	LENGTH	Geom'09	Recommended	Students
4	18	N-View Computational Methods	25 pages	Just Intro	YES	1
	19	Auto-calibration	15 pages	---	YES (only 19.1-19.4)	1
	20-22				No	

Preliminary Plan of the Meetings

BOOK PART	CHAPTER	Problems	TITLE	# pages	Geom'09	Students/ Units	Meeting	Dates
0	2		Projective Geometry and Transformations of **2D**	40	---	2	**I**	
	3		Projective Geometry and Transformations of **3D**	20	---	1	**II**	
	4		Estimation – 2D Projective Transformation	60	---	3	**II and III**	
1	6 (without 6.4)		Camera Models	25	70%	1 • A few new concepts; • New notation;	**IV**	
	7		Computation of the Camera Matrix	15	70% (lab 1)			
	8 (without 8.5)		More Single View Geometry	40	---	2	**V**	
2	9		Epipolar geometry and the Fundamental Matrix	25	90%	1 • A few new concepts; • New notation;	**VI**	
	10		Computation of the Camera Matrix	15	50%			
	11 (without 11.1-11.2)		More Single View Geometry	30	20% (lab3)	? Implementation	**VII**	
4	18		N-View Computational Methods	25	---	1	**VIII**	
	19 (only 19.1-19.4)		Auto-calibration	15	---	1	**IX**	

Meetings + Learning Approach

- Meetings:
  - In total 9-10;
  - Every second week; When: mid Jan-May / Feb-mid Jun (?)
  - Presentation (50min) + Problem solving (50min)
- Learning approach:
  - Before meeting (ALL):
    - Reading a relevant part of the book (papers)
    - Solving specified problems
  - Meeting:
    - Assigned students present a relevant part of the book
    - Exercise session: solving problems, presenting implemented algorihms (ALL)
  - Working in pairs or individually? How we are going to share the work?

Sharing Work + Reward ☺

- Chapters - different length and difficulty
- ***Units:***
  - For each chapter – number of ***units (students)*** to be assigned to is specified;
  - 1 unit =~20pages, 25 min of presentation
  - For each meeting 40 pages to read, 2-4 problems to solve
  - 12 units to be presented; 2-4 to be implemented (present the results)
    - Each of us: 2 x present OR 1 present+1 implement and shortly discuss
- Credits: 7.5 ECTS (PhD credits)

BOOK PART	CHAPTER	Problems	TITLE	# pages	Geom'09	Students/ Units	Meeting	Dates
0	2		Projective Geometry and Transformations of **2D**	40	---	2	**I**	
	...							
	11 (without 11.1-11.2)		More Single View Geometry	30	20% (lab3)	? Implementation	**VII**	

Important:

- PRELIMINARY ”setup” for the course
  - If you feel that something is missing in the course:
    - Topics
    - If you would like to implement an algorithm...
  - If you feel that something is not fair (e.g. load of work for different chapters/units)
  - If you have better ideas to solve some issues...

Let me know – madry@kth.se

Useful Materials

- Stefan's lecture notes for **DD2428 course:** www.nada.kth.se/~stefanc/gc_lec_notes.pdf
- Presentations prepared by Marc Pollefeys: www.cs.unc.edu/~marc/mvg/slides.html
- Marc Pollefeys ”Visual 3D Modeling from Images - Tutorial Notes” www.cs.unc.edu/~marc/tutorial.pdf
  - A detailed and advanced description of 3D modeling with pictures from multiple cameras

Thanks for attention!