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Training school 5: “Light Field Data Representation, Interpretation, and Compression”

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Author: Mårten Sjöström

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Abstract:

Report on the fifth Training School of the Network, “Light Field Data Representation, Interpretation, and Compression”, organized at Mid Sweden University, Sundsvall, Sweden, 28<sup>th</sup> of May – 1<sup>st</sup> of June 2018. The training school was co-organized as an IEEE SPS Summer school.



Participants of the Training School 5 at Mid Sweden University, Sundsvall, Sweden.

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## Summary

The fifth ETN-FPI network training school on “Light Field Data Representation, Interpretation, and Compression”, was organized by Mid Sweden University in Sundsvall Sweden on 28<sup>th</sup> of May – 1<sup>st</sup> of June 2018. The training school was co-organized as an IEEE Signal Processing Society Summer School in order to attract further PhD students to learn the research area, learn about the ETN-FPI, and to extend the researcher network for the ESRs. The school was announced externally through IEEE web pages, Post on LinkedIn, and distribution through email lists.

The training school was attended by all fifteen ETN-FPI Early Stage Researchers (ESRs) and an additional 12 participants (11 PhD students and 1 Post-doc) because of openly inviting students to the IEEE SPS Summer School. Further participants were 1 research supervisor from ETN-FPI 1 Associate Partner, 8 speakers of which 4 were invited from outside the ETN-FPI, and 1 representative of IEEE during the first day, 1 intern, and 1 administrator. In total, the training school was attended by 40 persons.

The aim of the training school was to give an introduction to, and a deeper knowledge of, the theory and practice of representations and sparsification, compression, processing and rendering of Light Field (i.e. data for full parallax imaging). Lectures and exercises introduced the participants to fundamental theories and application of those theories.

The training school programme had lectures in the morning sessions, hands-on exercises in the afternoon sessions. On Thursday afternoon, a poster session was organized, at which participants were given the opportunity to present and discuss their own research. Each poster presenter gave a one-minute “teaser” accompanied by 1-2 slides, and then presented their posters as the lecturers walk around the posters. Two best poster awards were given based on the presentations. The school further had a social programme in order to encourage further networking between the participants: Welcome reception, Student Picnic, School Dinner Cruise on the Baltic Sea, and a Lecturer dinner. As the event was also financially funded by the IEEE Signal Processing Society Seasonal School programme, the chair of IEEE Sweden Section came and presented the organisation.

The training school renders formal recognition for those interested (e.g. PhD students). Four (4) university credits could be obtained for students that follow lectures, participate in exercises and discussions, present a poster of his/her own research and write a report of 3-4 pages on a specific subject related to the knowledge obtained at the training school.

All ESRs, supervisors and lecturers were hosted in the same hotel. Other participant were given different options depending on their budget.

All information about the training school is available at the school web page [www.full-parallax-imaging.eu/TS5](http://www.full-parallax-imaging.eu/TS5). Lecture notes are made available to the participants.

## Lecturers

The training school had invited a number of excellent researchers to present the subjects of the training school. Four of them came from outside the ETN-FPI, four were recruited among the supervisors in the network.



Dr. Donald G. Dansereau is a postdoctoral scholar at the Stanford Computational Imaging Lab. His research is focused on computational imaging for robotic vision, and he is the author of the Light Field Toolbox for Matlab. In 2004, he completed an MSc at the University Calgary, receiving the Governor General's Gold Medal for his pioneering work in light field processing. In 2014, he completed a PhD on underwater robotic vision at the Australian Centre for Field Robotics, University of Sydney. Donald's industry experience includes physics engines for video games, computer vision for microchip packaging, and FPGA design for automatic test equipment. His fieldwork includes marine archaeology on a Bronze Age city in Greece, hydrothermal vent mapping in the Sea of Crete, habitat monitoring off the coast of Tasmania, and wreck exploration in Lake Geneva.



Prof. Paolo Favaro, University of Bern, Switzerland is the director of the Computer Vision Group. His research interests include computer vision, computational photography, machine learning, signal and image processing, estimation theory, inverse problems, and variational techniques. He is a member of the IEEE. The main topic of Prof. Favaro's lecture will be on Light field processing, especially depth estimation, extended depth of field, super-resolution, reflection separation and motion de-blurring.



Dr. Christine Guillemot, INRIA, France, heads a research team dedicated to the design of algorithms for the image and video processing chain, with a focus on analysis, representation, compression, and editing, including for emerging modalities such as high dynamic range imaging and light fields. Dr. Guillemot has long experience from research at France Telecom, and Bellcore. Christine Guillemot is an IEEE fellow, and is a 2017 IEEE Distinguished Lecturer. The main topic of Dr. Guillemot's lecture will be on Light Fields Processing, especially sparsity and dimensionality reduction for compression and super-resolution.



Prof. Ioan Tabus, Tampere University of Technology, Finland is a professor in Signal Processing and heads the research group on Signal Interpretation and Compression. His research interests include 3D image processing, audio, image and data compression, and genomic signal processing. He is a senior member of the IEEE. The main topic of Prof Tabus' lecture will be on Light field compression, especially model-based and predictive lossless light field coding.



Prof. Atanas Gotchev, Tampere University of Technology, Finland is a professor in Signal Processing and heads the research group on 3D Media. His recent work concentrates on algorithms for multisensor 3-D scene capture, transform-domain light-field reconstruction, and Fourier analysis of 3D displays. The main topic of Prof. Gotchev's lecture will be on Light field sparsification and restoration of dense light field, especially compressive sensing, image dictionaries, and shearlets.



Attila Barsi, Lead Software Developer at Holografika Ltd. Attila Barsi received the M.Sc. degree in computer science from Budapest University of Technology, Budapest, Hungary, in 2004. From 2005 to 2006, he was a Software Engineer with DSS Hungary. Since 2006, he has been a Software Engineer, and then, a Lead Software Engineer with Holografika, Budapest. He is the author or co-author of several conference and journal papers. His



research interests include light fields, real-time rendering, ray tracing, global illumination, and GPU computing.



Dr Roger Olsson, Mid Sweden University, Sundsvall, Sweden, is a Senior Researcher (PhD) in Telecommunications. Co-founder of research group Realistic 3D. Co-supervisor of PhD students. Research interests in Computational Photography; 3D rendering, Multi-view and Light field video compression. Member of the IEEE.



Prof. Mårten Sjöström, Mid Sweden University, Sundsvall, Sweden, is Professor in Signal Processing. Senior member of IEEE. Head of research group Realistic 3D at Mid Sweden University, with focus on Multidimensional signal processing and imaging (3D and Light field video capture, processing, compression, rendering and quality assessment). Previously chair (main organizer) of EU COST Training School on Plenoptic Capture, Processing and Reconstruction 2013, Co-applicant and WP-leader of European Training

Network for Full Parallax Imaging, publication chair and tutorial chair at 3DTV-conference at different occasions.

## Programme

### Day 1 Introduction to Light Field

On the first day, 28 May 2018, the school was opened by the school chair Mårten Sjöström and the dean at the Faculty of Science, technology and Media, Prof. Hans-Erik Nilsson. Teaching was on introduction to light field, its representation and some fundamental processing for computational imaging.



#### Lecture 1a

Lecturer: Donald Dansereau

Contents:

- Light field – Plenoptic function, two-plane parameterization
- 2-Camera geometry, Camera sampling, calibration and sampled light fields
- A simple interpolating renderer: 4D light field to 2D view

#### Lecture 1b (45 min)

Lecturer : Donald Dansereau

Contents:

- Epipolar plane images, homographies
- Spatial-domain refocusing and super-resolution
- Simple depth estimation from gradients
- 



#### Lecture 1c (45 min)

Lecturer : Donald Dansereau

Contents:

- Fourier Slice Theorem, frequency-domain refocusing
- Introduction to the Light Field Toolbox for Matlab

#### Exercise 1 (30 + 90 min)

Instructor: Donald Dansereau

Contents:

- Hands-on use of the Light Field Toolbox for Matlab: loading, visualizing, linear filters, writing an interpolating light field renderer

## Day 2 Data Representation and Sparsification

On the second day, 29 May 2018, teaching was on fundamentals of sparsification, shearlets, low rank matrix completion, and diffusion.

### Lecture 2a (45 min)

Lecturer: Atanas Gotchev

Contents:

- Fundamentals of Sparsification
- Densely sample light field

### Lecture 2b (45 min)

Lecturer: Atanas Gotchev

Contents:

- Sparsification in shearlet domain

### Lecture 3a (45 min)

Lecturer: Christine Guillemot

Contents:

- Fundamentals of Low Rank matrix Completion, examples in EPI

### Lecture 3b (45 min)

Lecturer: Christine Guillemot

Contents:

- Diffusion in EPI, Angular super-resolution

### Exercise 2 (90 min)

Instructor: Atanas Gotchev

Contents:

- Exercises on sparsification in shearlet domain

### Exercise 3 (90 min)

Instructor: Christine Guillemot

Contents:

- Exercises on low rank completion



## Day 3 – Compression

On the third day, 30 May 2018, teaching was on fundamentals of compression and on Light Field Compression, assessment of Light Field, and ongoing standardization.

### Lecture 4a (45 min)

Lecturer: Märten Sjöström

Contents:

- Introduction to image and video coding

Lecture 4b (45 min)

Lecturer: Ioan Tabus

Contents:

- Introduction to Light Field compression

Lecture 4c (35 min)

Lecturer: Ioan Tabus

Contents:

- Standardisation work for Light Field compression

Lecture 4d (55 min)

Lecturer: Roger Olsson

Contents:

- Different approaches to LF Compressions and quality assessment

Exercise 4 (90 min)

Instructor: Ioan Tabus

Contents:

- Exercises on Light Field Compression using scripts

Lecture 5a (45 min)

Lecturer: Christine Guillemot

Contents:

- Light Field Segmentation, super rays processing, super resolution

Day 4 – Processing

On the fourth day, 31 May 2018, teaching was on different processing methods for light field, such as computation models, depth estimations, and super-resolution. The day ended with a poster sessions, at which participants were given the opportunity to present their research and discuss it with each other.

Lecture 5b (45 min)

Lecturer: Paolo Favaro

Contents:

- Computational Models for Light Field Imaging: Plenoptic point spread functions, light field images and phase space interpretation

Lecture 5c (45 min)

Lecturer: Paolo Favaro

Contents:

- Depth estimation: stereo, multiview stereo, relations between point spread functions and depth

Lecture 5d (45 min)

Lecturer: Paolo Favaro

Contents:

- Super-resolution (Extended depth of field) and motion de-blurring with Light Field cameras



Exercise 5 (30 + 90 min)

Instructor: Paolo Favaro

Contents:

- Exercises on light field imaging, depth estimation, motion de-blurring

Poster Session (3 hours)

Instructor: Mårten Sjöström

Contents:

- Students presented a one-minute teaser accompanied by 1-2 slides.
- Students presented their work for the lecturers in front of their posters; lecturers posing questions.
- Students studied and discussed each other's works.



Day 5 – Rendering

On the fifth and last day of the training school, 1 June 2018, teaching was on rendering methods for light fields on Graphics Processing Units (GPUs), especially on rasterized rendering and ray tracing.

Lecture 6a (45 min)

Lecturer: Attila Barsi

Contents:

- Rasterized rendering on GPUs.
  - Definition of virtual scenes, scene graphs, etc.
  - Geometry, lights, cameras, shaders, materials, local illumination model, basics of shading, etc.

Lecture 6b (45 min)

Lecturer: Attila Barsi

Contents:

- Ray tracing on CPUs and GPUs: path tracing, whitted ray tracer

Exercise 6 (45 + 45 min)

Instructor: Attila Barsi

Contents:

- Exercises on Rasterization and Ray tracing

Best Poster Award

A jury selected two best poster awards among the posters presented at the training school. The jury consisted of Dr. Donald G. Dansereau, Prof. Paolo Favaro, Dr. Christine Guillemot, Prof. Ioan Tabus, Dr Roger Olsson,



and Prof. Mårten Sjöström. The decision has been based on One-minute Presentation, Slides, Poster layout, Oral presentation, Responses to questions, and Research idea. The two awardees were

- Light field Microscopy for neurobehavioral analysis in freely swimming fish by Anca Stefanoui, Technical University of Munich, Germany
- Shearlet-Based LF Reconstruction of Scenes with Non-Lambertian Properties by Sergio Moreschini, Tampere University of Technology, Finland



## Social Events

The training school had a number of social events in order to encourage interaction and discussions between the participants. Particular for this training school was that an additional 13 participants came from outside the ETN-FPI, which gave a possibility for the ESRs to extend their professional network.

### Welcome reception

A welcome reception was held on 28<sup>th</sup> of May at “Grönborg”, which is Sundsvall’s newest creative centre. It is a gathering place for the whole region where business, academy and society meet. Grönborg is located on Campus Sundsvall, Mid Sweden University.



### Student Picnic

A picnic was arranged by local participants (PhD students) from Mid Sweden University on the 29<sup>th</sup> of May. The school participants gathered outside the lecture hall and walk up the North Hill to the open-air museum. Grilling and conversation was mixed with joyful local games. The evening was particularly pleasant thanks to the wonderful weather, and participants had to be reminded of the late hours and next day’s lectures because the sun did not set until 22.17 yet leaving daylight for the whole night.

### School dinner

On the 20<sup>th</sup> of May, a school dinner took place on the boat “MS Medvind”. The trip took the participants on a trip around Alnö, one of the islands near Sundsvall. On the boat, a buffet with Swedish delicacies was served. Departing at 18.00 and returning three hours later, the trip gave the participants a magnificent view of the beautiful archipelago in the best possible summer weather.



## Feedback

Feedback was given by the ESRs, who filled in a form rating the event, the lectures and the exercises. Other participants are not included in this feedback report. The used scale rated each item from 1 to 5: 1 = Poor, 2 = Below average, 3 = Average, 4 = Good, 5 = Excellent.

The overall outcome of lectures and exercises suggest that participants have found the training school technical program interesting since the average score for contents and presentation was reported around 4.

### General questions related to the arrangement

The feedback scores show a very satisfactory response with a mean above 4.2 from the ESRs related to the organization of the training school. The venue was ranked as high as 4.8 and the social programme was highly appreciated among the ESRs, in particular the student picnic. It can be noted that the training school was beneficial for many, but not for all because the school subjects may only be broadening their competence. Best paper award got many high ranked responses, whereas certain low scores may depend on the session being rather long.

	Questions	Mean	STD
1	Rate the title of school	4.5	0.78
2	Rate the composition of lecture topics	4.2	0.73
3	Rate the benefit from the school for you	3.6	1.26
4	Rate the best poster award	3.7	1.56
5	Rate the venue	4.8	0.62
6	Rate the social program overall	4.5	0.52
7	Welcome reception (Monday)	4.4	0.65
8	Student picnic (Tuesday)	4.8	0.44
9	School Dinner (cruise)(Wednesday)	4.2	1.01
10	Rate the web site	4.2	0.9
11	Rate the information exchange and responsiveness	4.2	1.07

### Lectures contents and presentation

The feedback shows that the ESRs found the lecture contents of good quality with average rates above 4. Only three lectures had an average rate just below 4 (i.e. 3.9). The ESRs especially found the lecture contents by Donald Dansereau of good quality, which reached an average rank of 4.9. Quality of presentations was

also ranked very high with average rank above 4. Three of the presenters were given an average rank below 4 for their quality of presentation, yet clearly above averaged rank 3.

#### Exercises contents and presentation

In general, the feedback indicates that the ESRs appreciated the exercises. Both quality of contents and quality of presentations for the exercises follow very much the same trend as for the lectures; most instructors were given an average rank of 4. In particular, the ESRs showed keen interest in the exercises prepared by Donald Dansereau with an averaged rank of 4.8 for the quality of contents.