FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG
FACULTY OF ENGINEERING

Abstract:
Efficient Epipolar Consistency

André Aichert
Pattern Recognition Lab (CS 5)
Friedrich-Alexander University of Erlangen-Nürnberg
Bildverarbeitung für die Medizin, March 13th 2018

Agenda

Efficient Epipolar Consistency
André Aichert, Katharina Breininger, Thomas Köhler and Andreas K. Maier
CT-Meeting 2016

- Epipolar Geometry
- Epipolar Consistency of two X-ray Images
- Tracking an Unknown Object in Fluoroscopy
- Virtual Subtraction Angiography and Consistency

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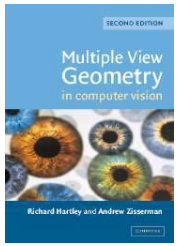
Epipolar Geometry

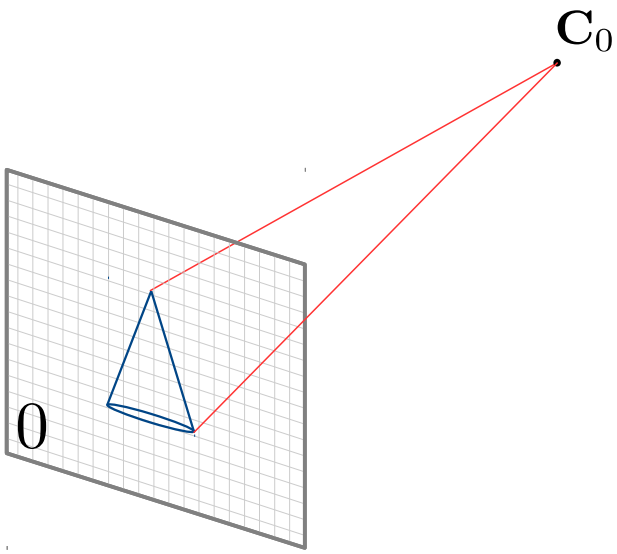
Constraint on Points in two Images



Multiple View Geometry in Computer Vision
Richard Hartley and Andrew Zisserman
Cambridge University Press, March 2004.

Central Projection

(e.g. photograph, X-ray image ...)



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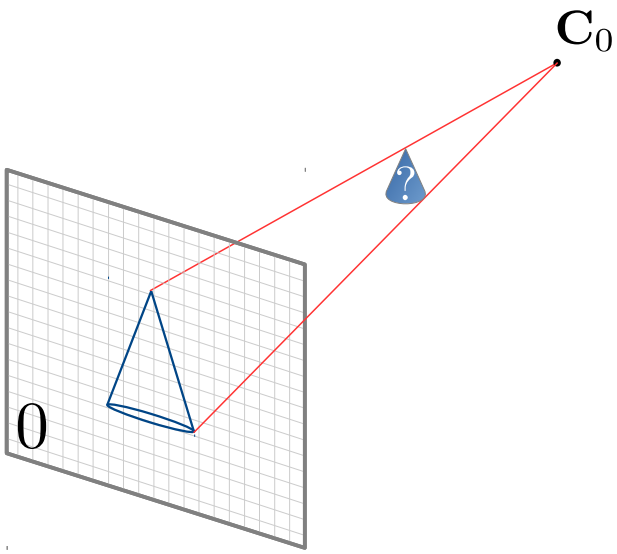
(e.g. photograph, X-ray image ...)



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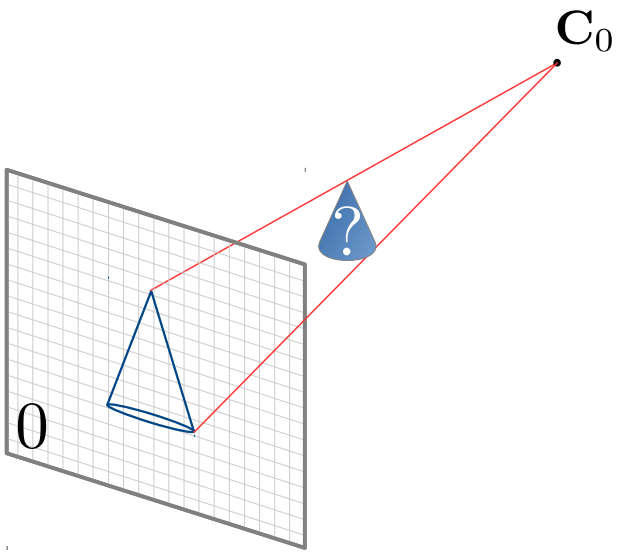

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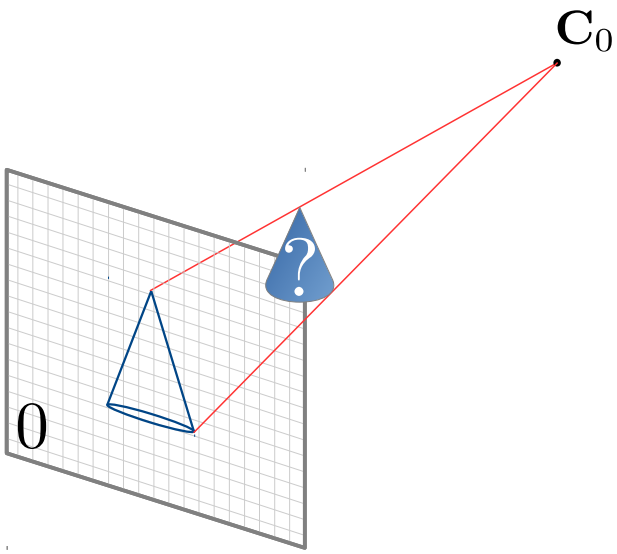

Central Projection

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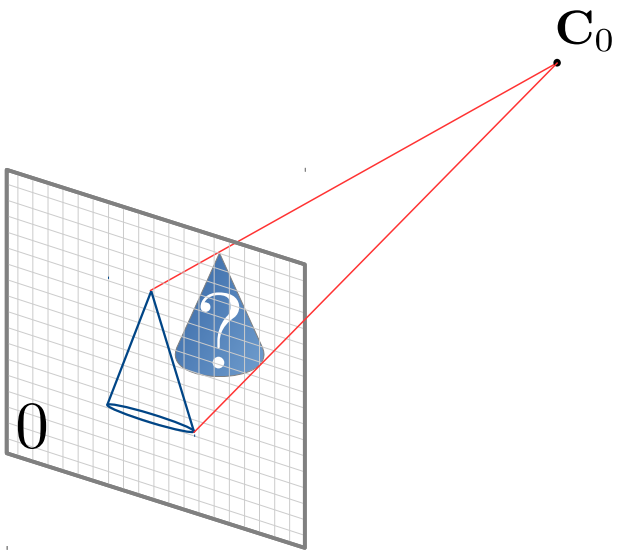
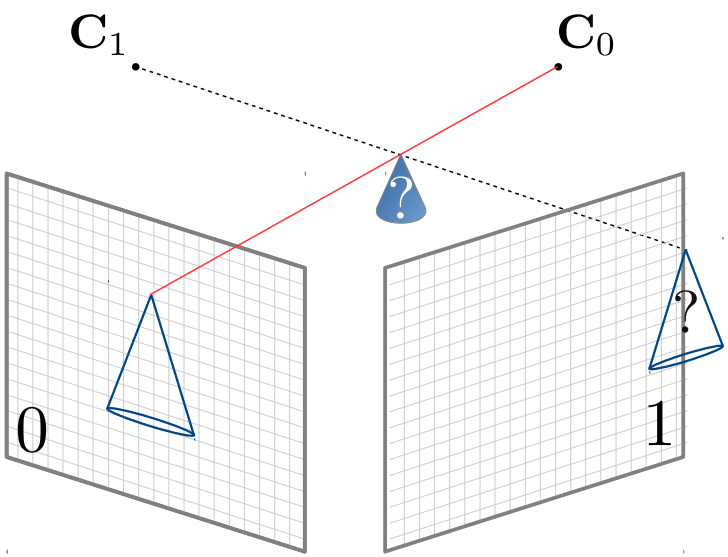


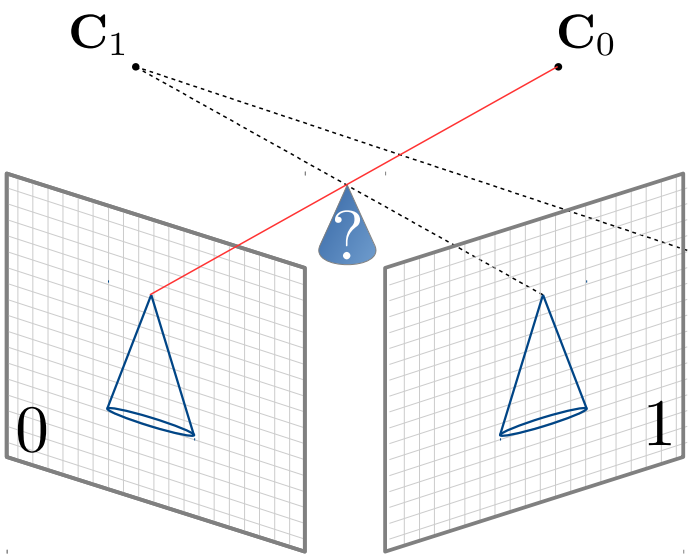
Epipolar Geometry

Constraints on points in two central projections?



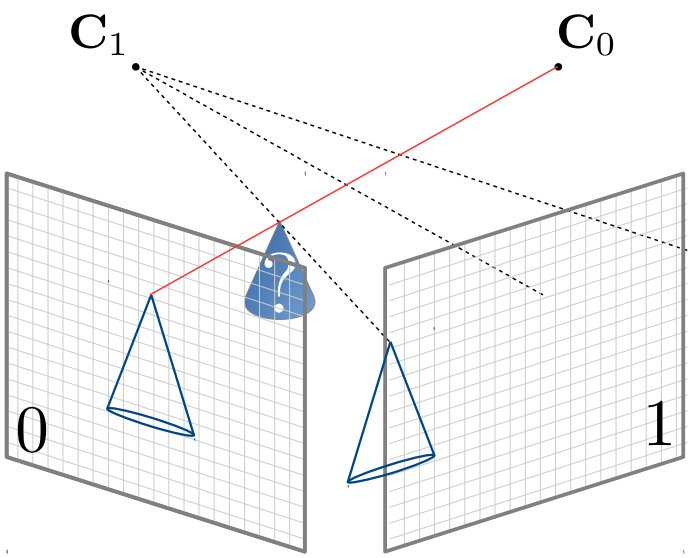
Epipolar Geometry

Constraints on points in two central projections?



Epipolar Geometry

Constraints on points in two central projections?



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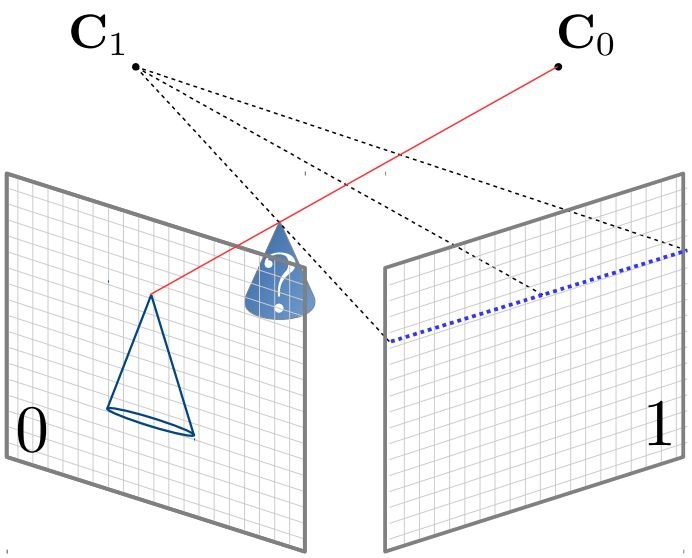
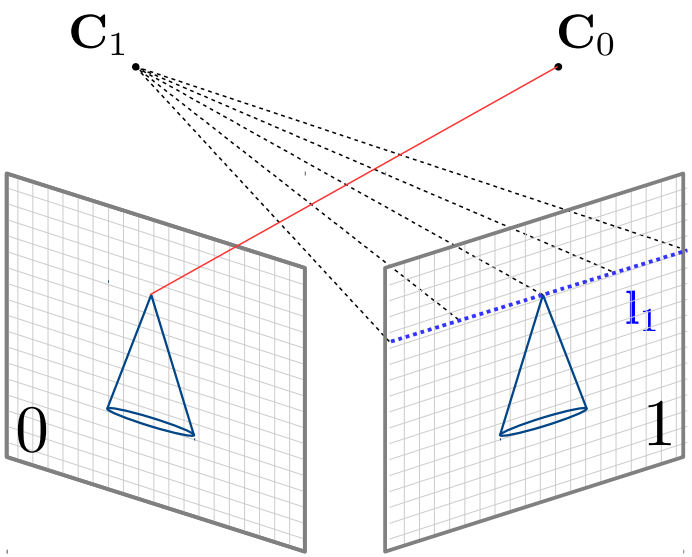


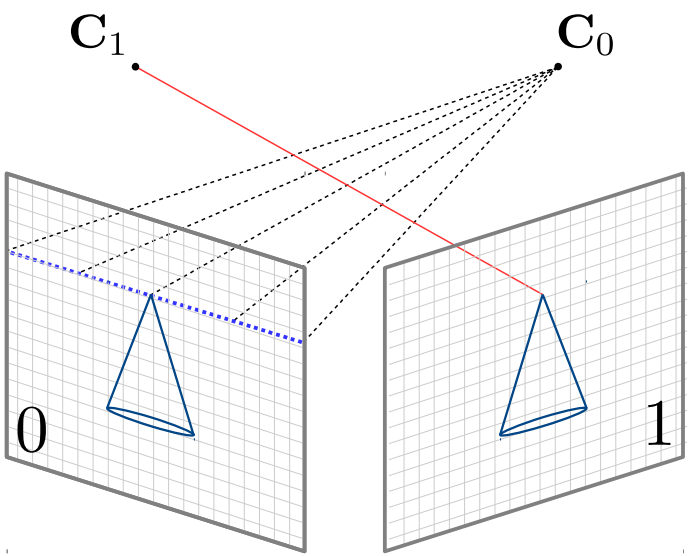
Epipolar Geometry

Constraints on points in two central projections?



Epipolar Geometry

Construction is symmetric.



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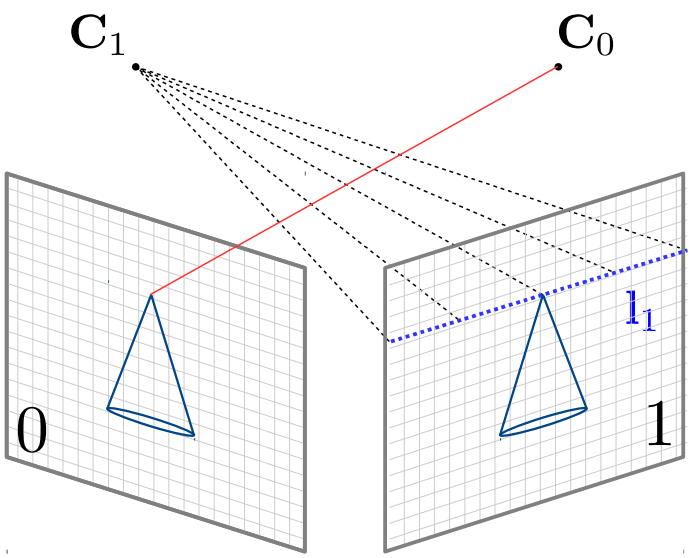
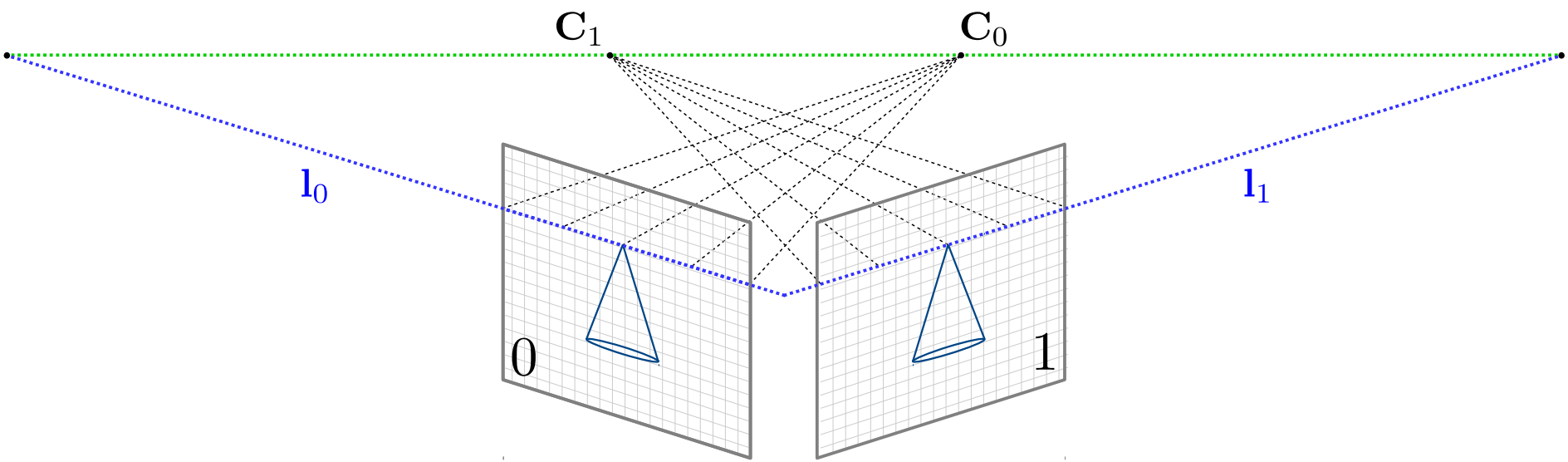


Epipolar Geometry

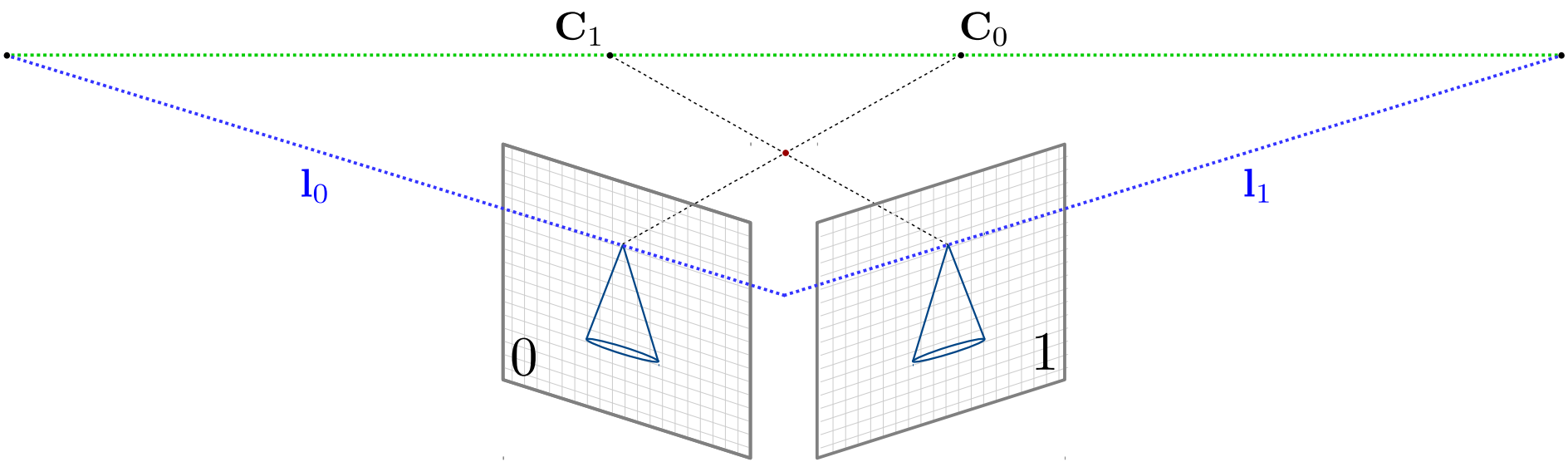
Plane through both source positions

and its intersection line with both detectors



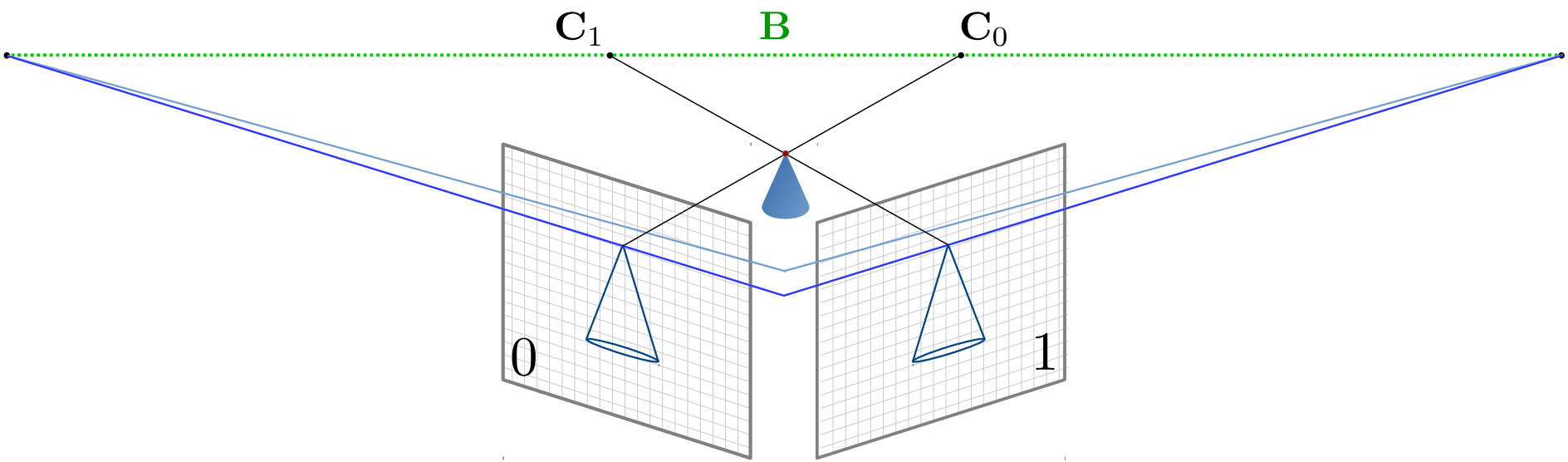
Epipolar Geometry

Observe: $\mathbf{l}_0$ and $\mathbf{l}_1$ are **corresponding epipolar lines**.



Epipolar Geometry

There exists a pencil of epipolar lines!



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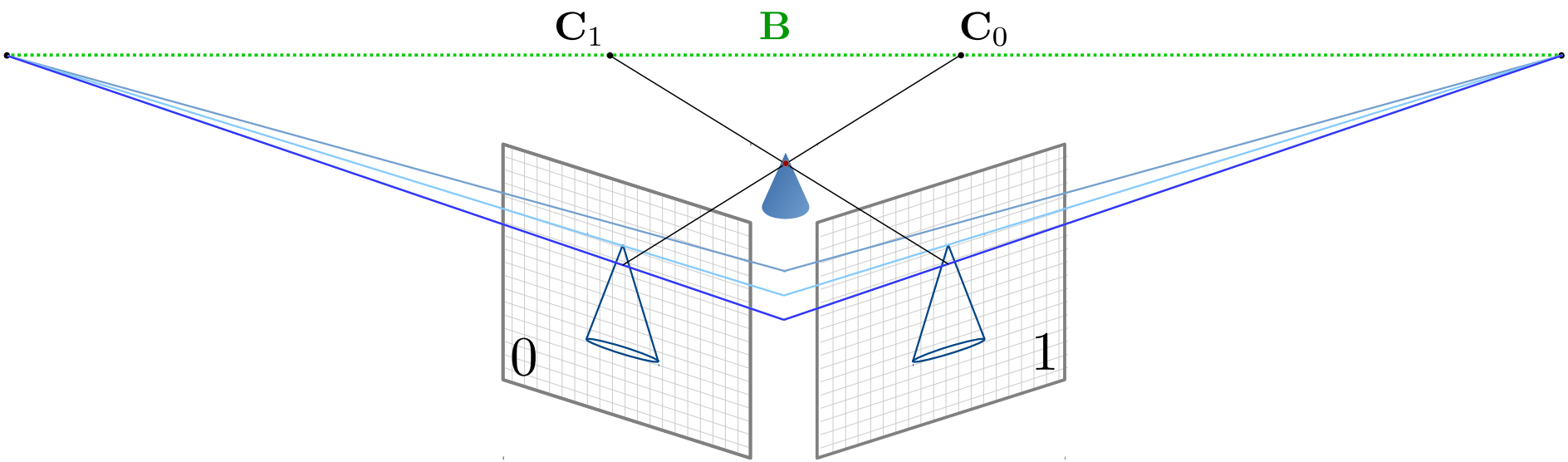

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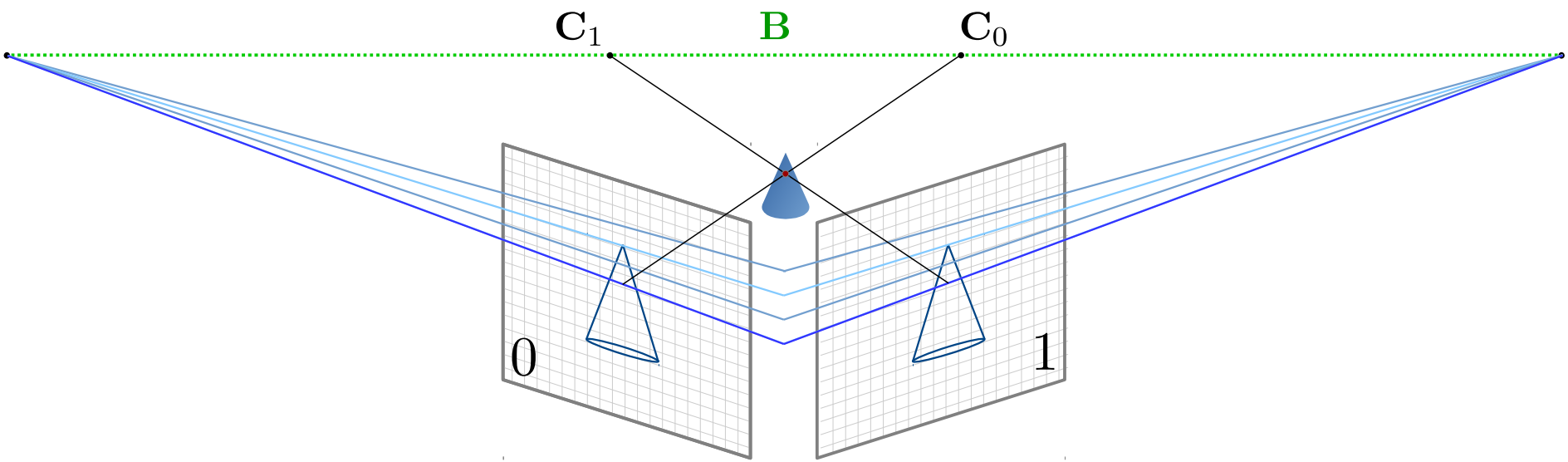

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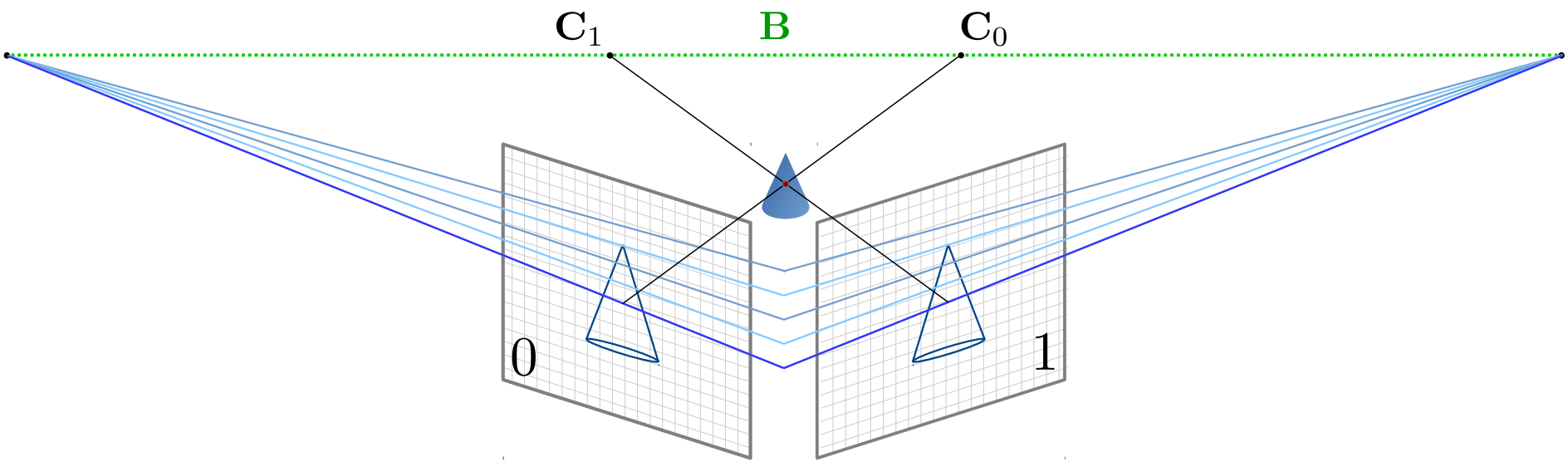

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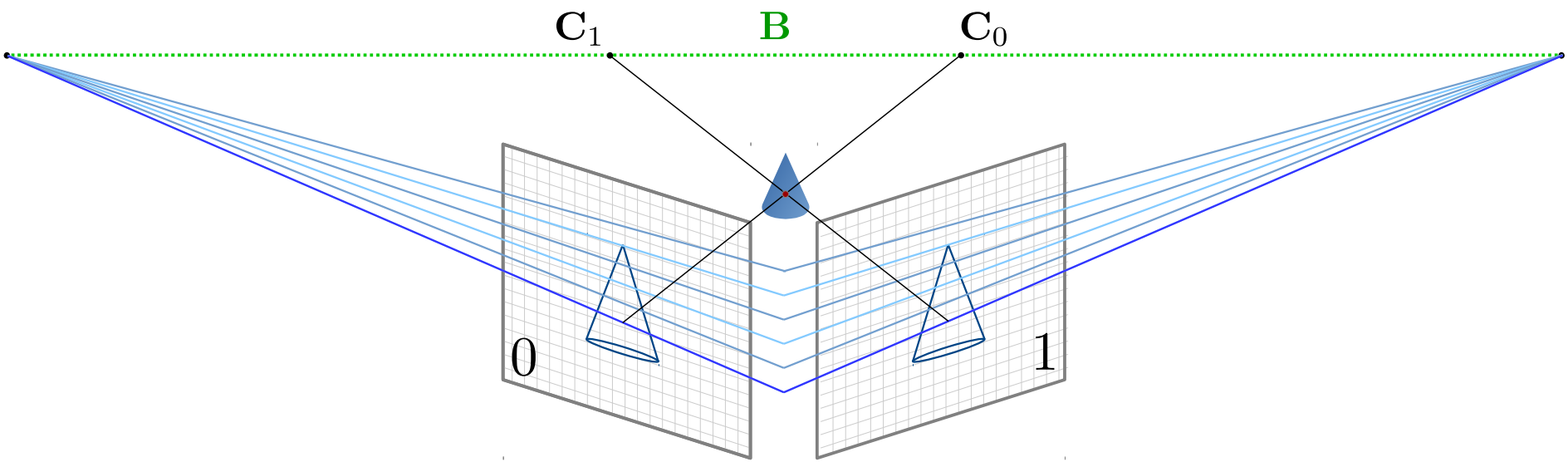

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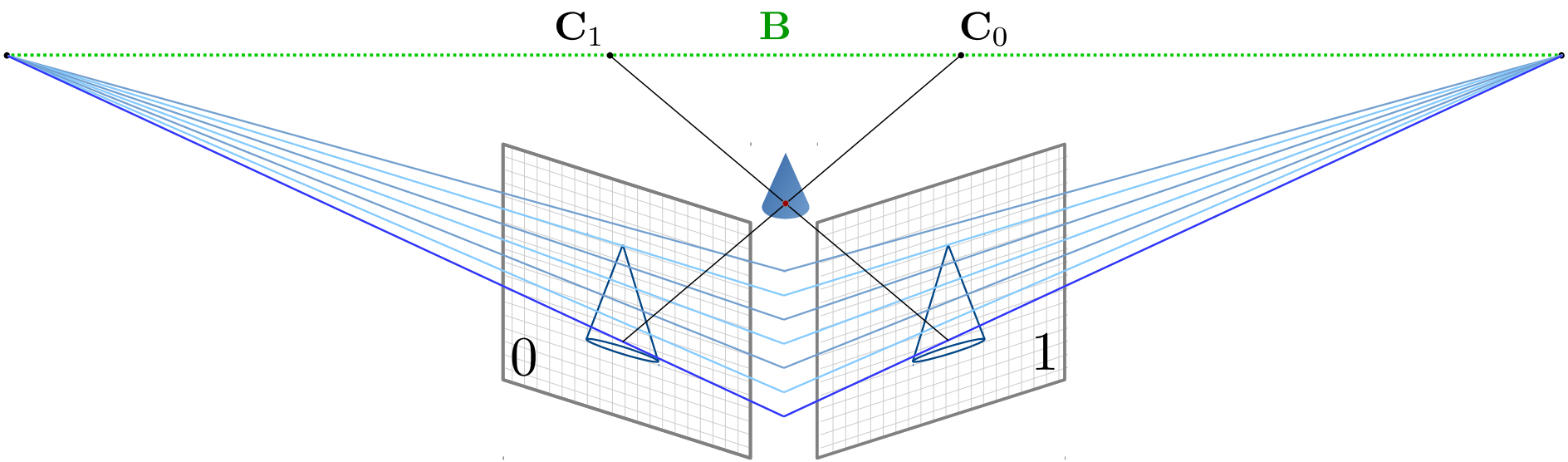

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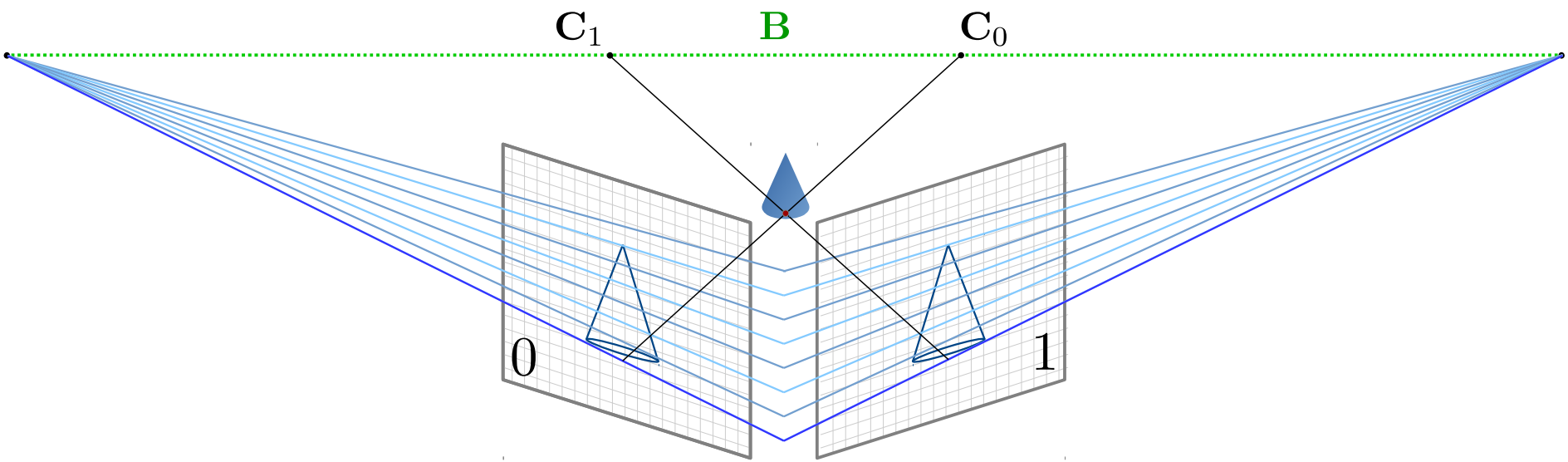

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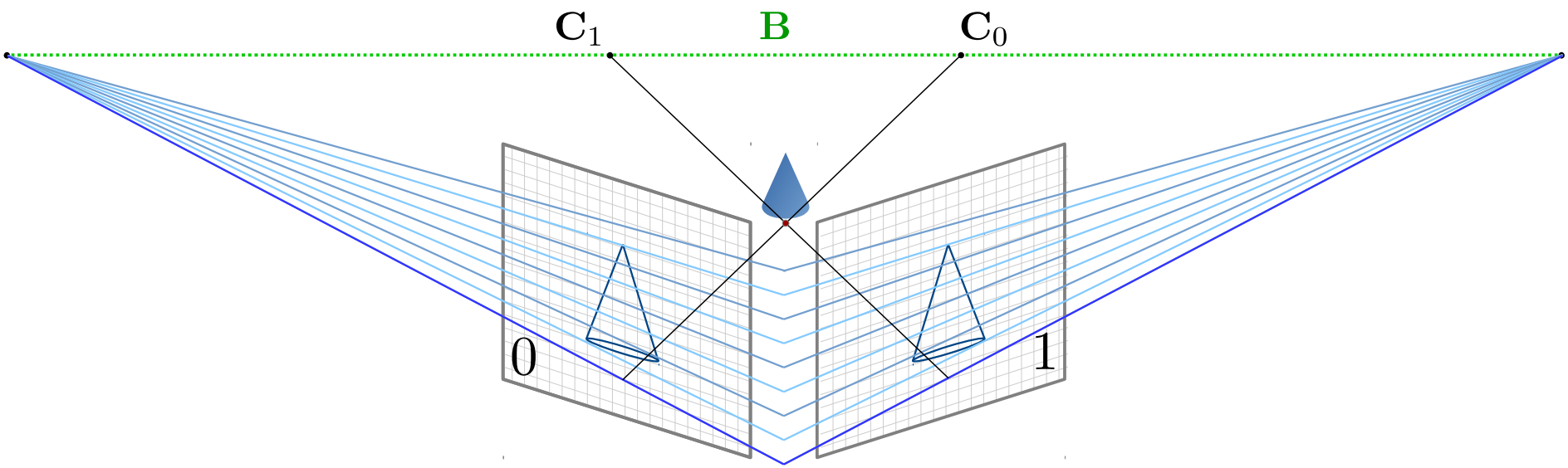
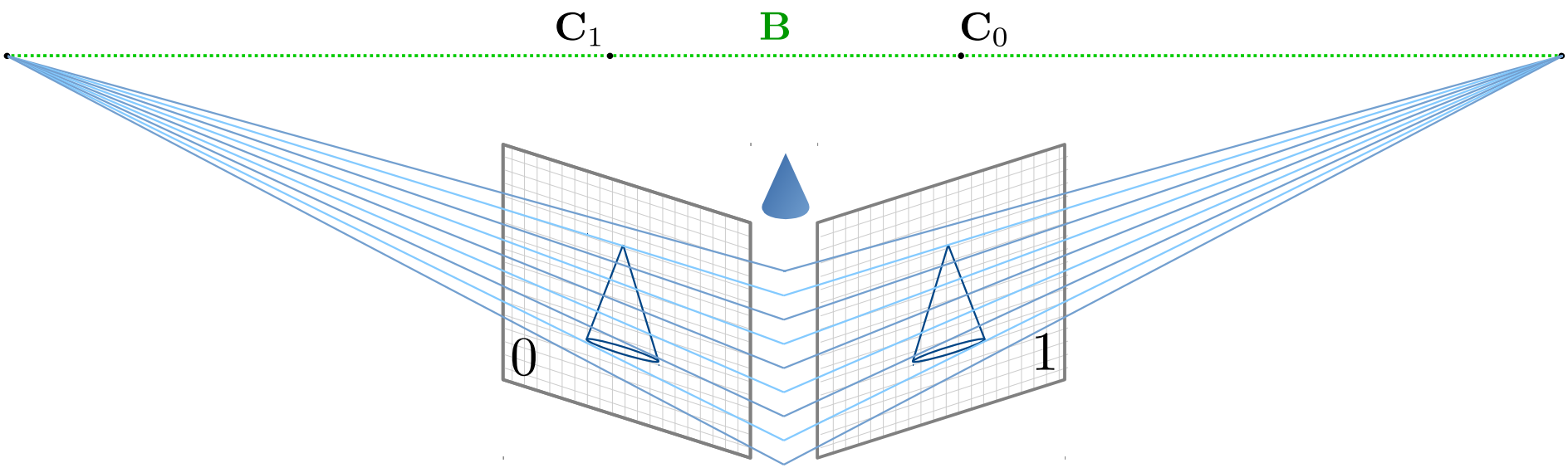


Epipolar Geometry

Observe: All epipolar planes contain the baseline $\mathbf{B}$.



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Consistency Conditions on Epipolar Lines

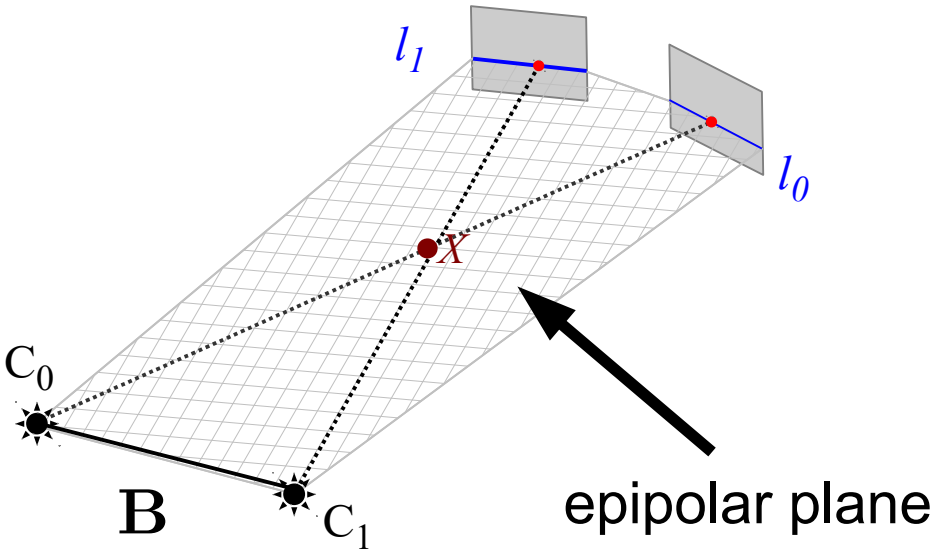
Stereo Rectification for X-ray Data Consistency Conditions

André Aichert, Jérôme Lesaint, Tobias Würfl, Rolf Clackdoyle, Laurent Desbat and Andreas K. Maier

CT-Meeting 2018, to appear

Epipolar Consistency

Consider a single epipolar plane:



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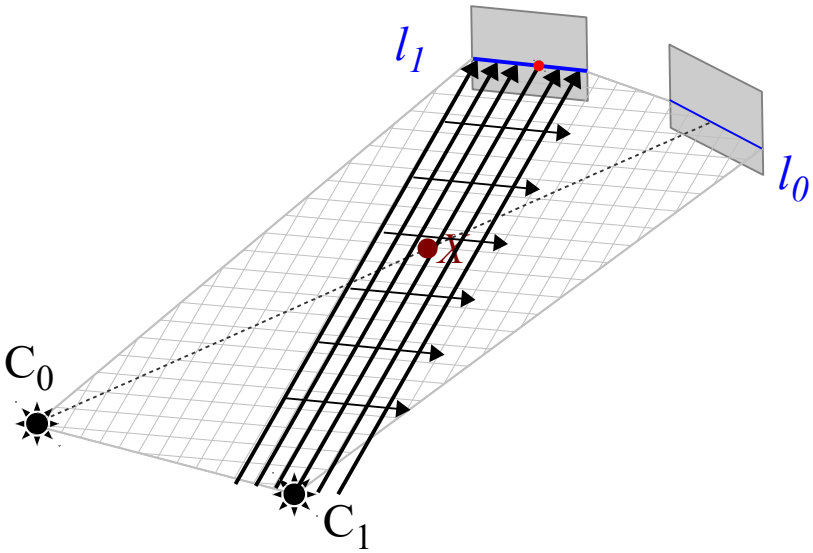

- Assume rays are approximately parallel
- Then: **plane integral = line integral!**

Epipolar Consistency

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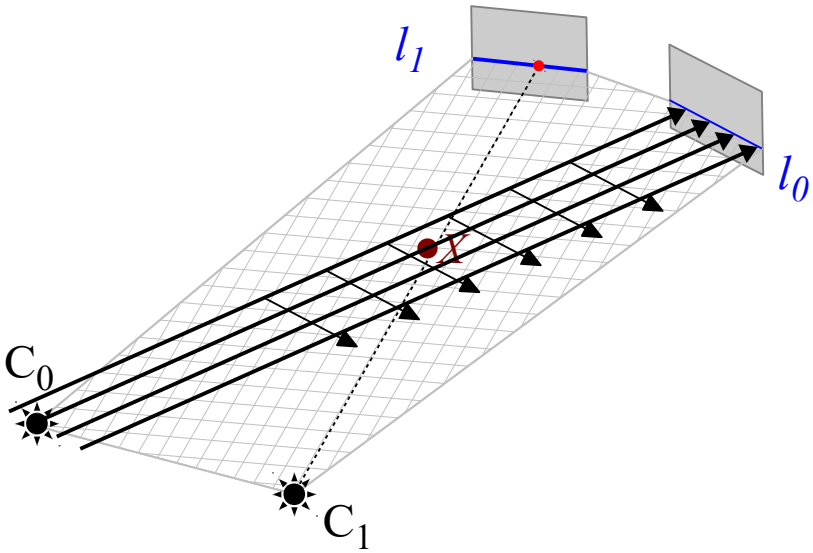

- Assume rays are approximately parallel
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- Symmetry: two ways of computing the same plane integral via lines 0 and 1

Epipolar Consistency

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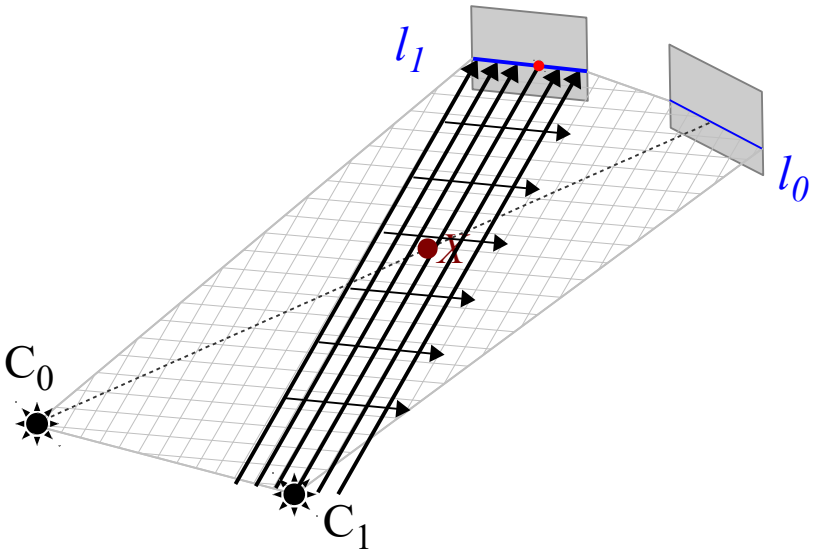

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Epipolar Consistency

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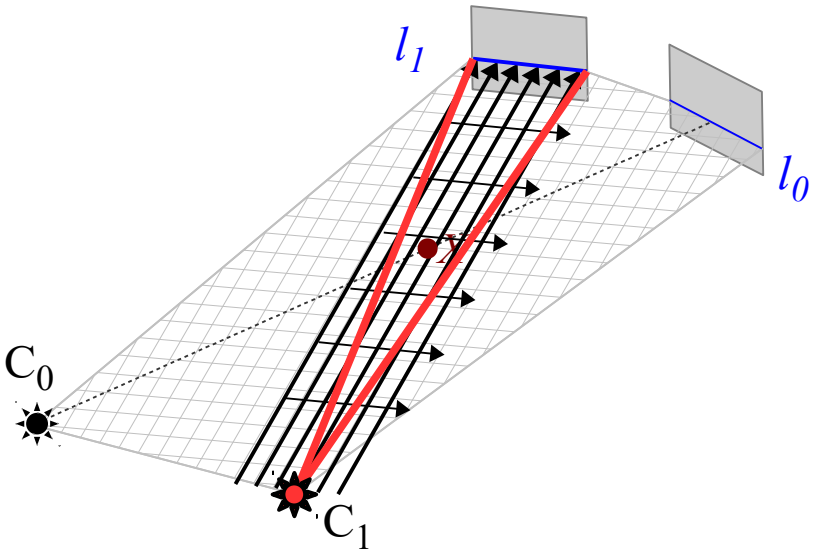
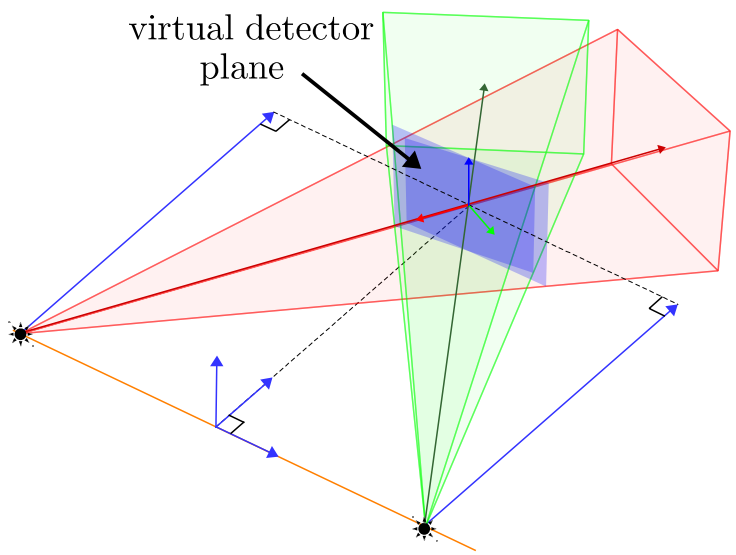


- Assume rays are approximately parallel
- Then: **plane integral = line integral!**
- Symmetry: two ways of computing the same plane integral via lines 0 and 1

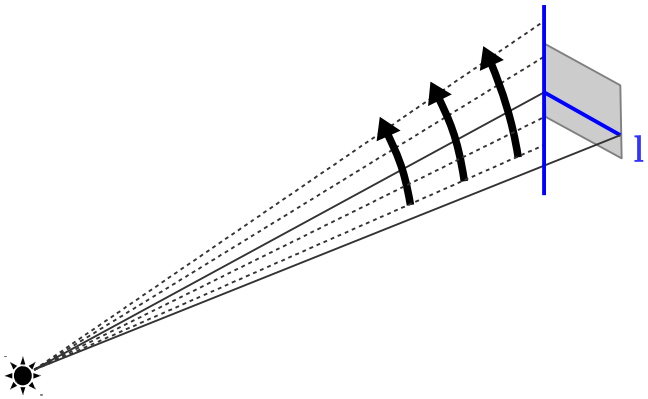
Epipolar Consistency

Two ways to handle general cone-beam projections:

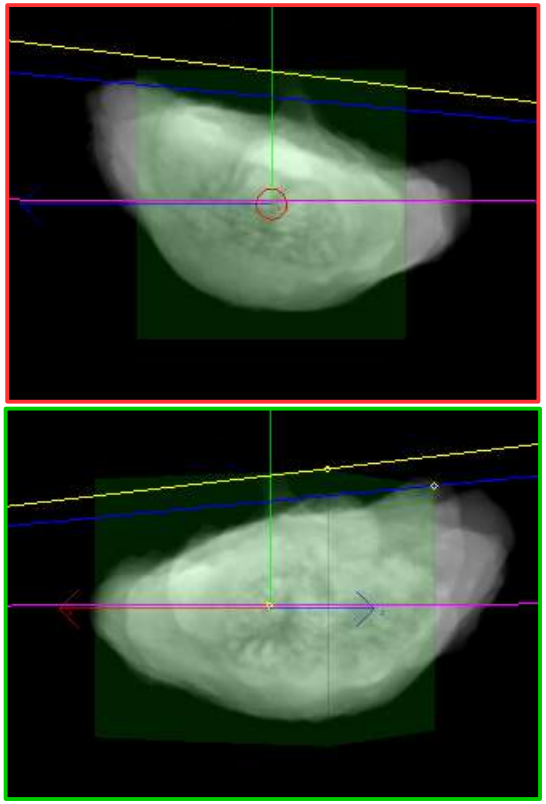
Rectification

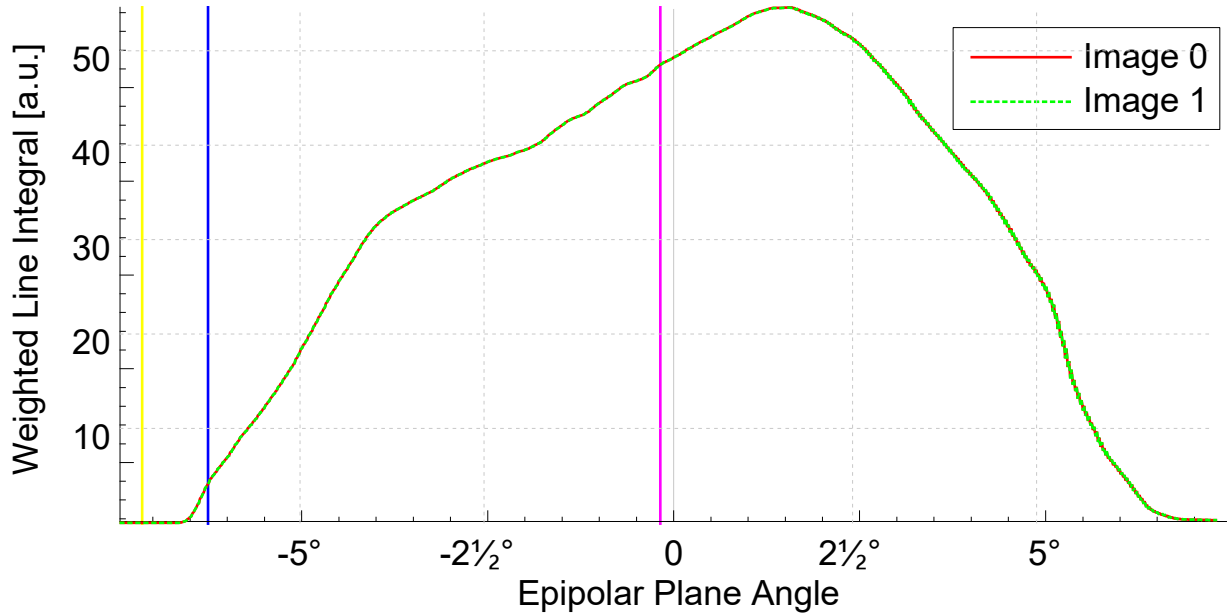


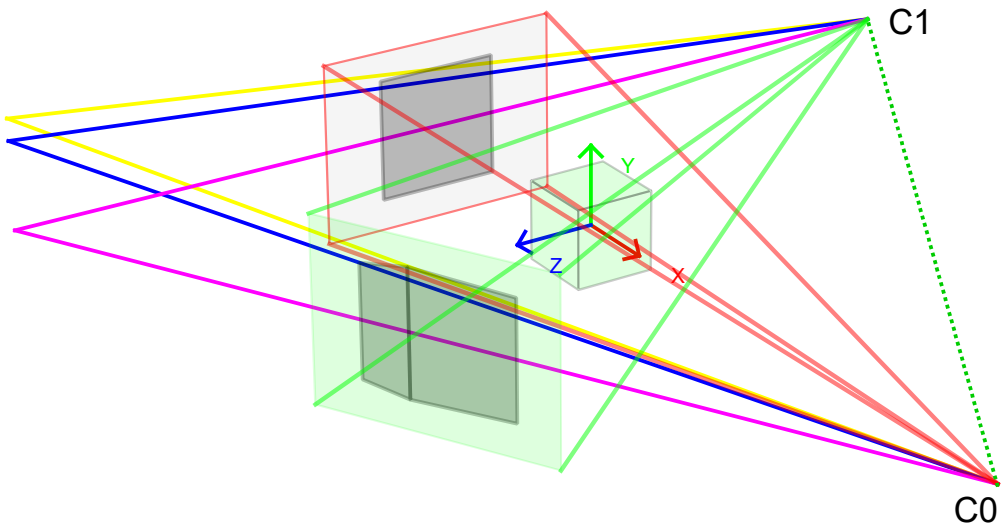
Orthogonal Derivative



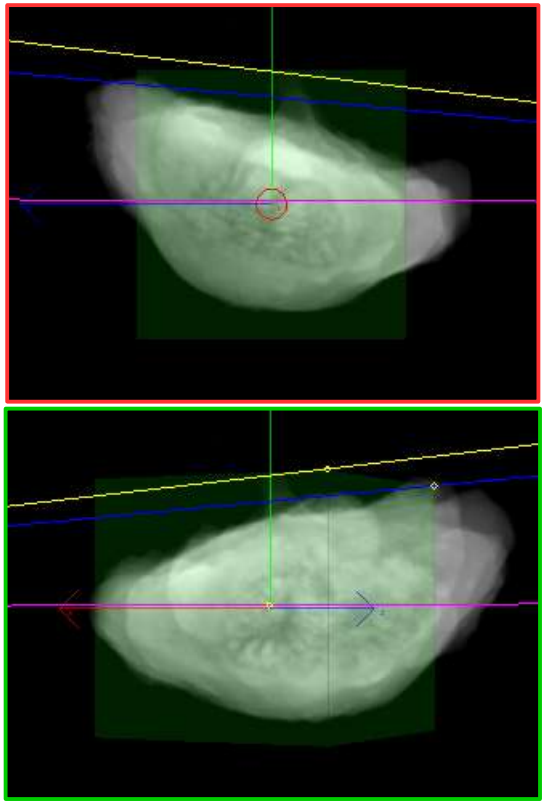
Fan-Beam Consistency

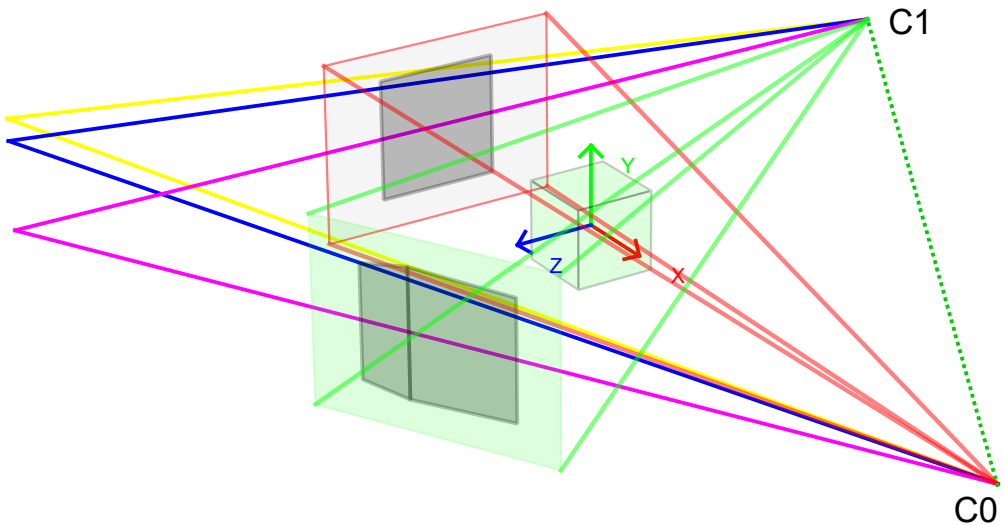


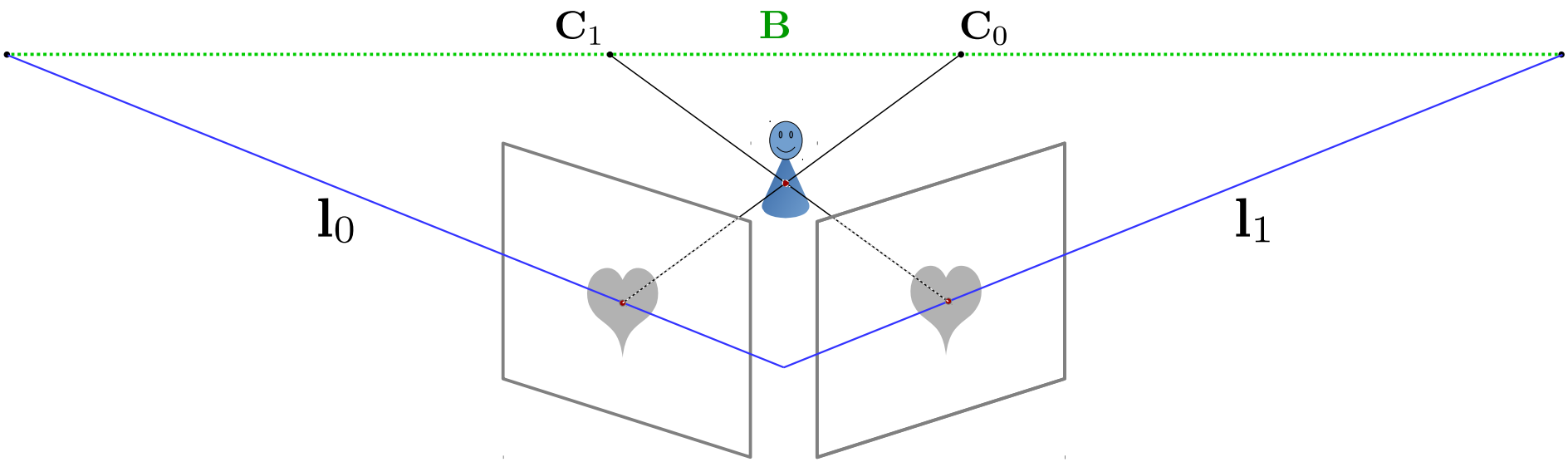




Cone-Beam Consistency





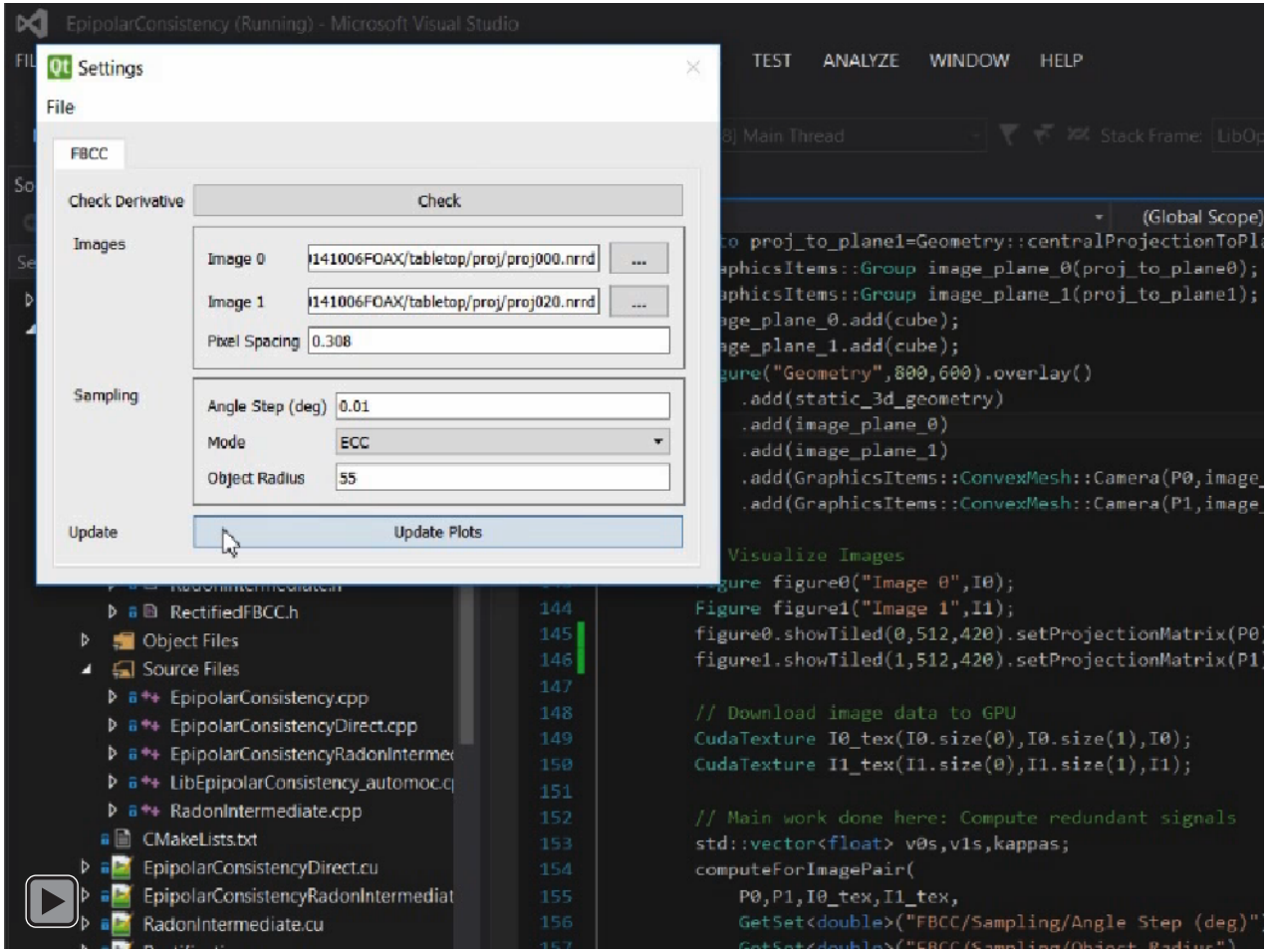


Demo, Video & Source Code

www5.cs.fau.de/research/software

Efficient Epipolar Consistency
Andre Aichert, Katharina Breininger, Thomas Köhler and Andreas K. Maier
CT-Meeting 2016

Open-Source Demo



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Tracking an unknown Object under Fluoroscopy

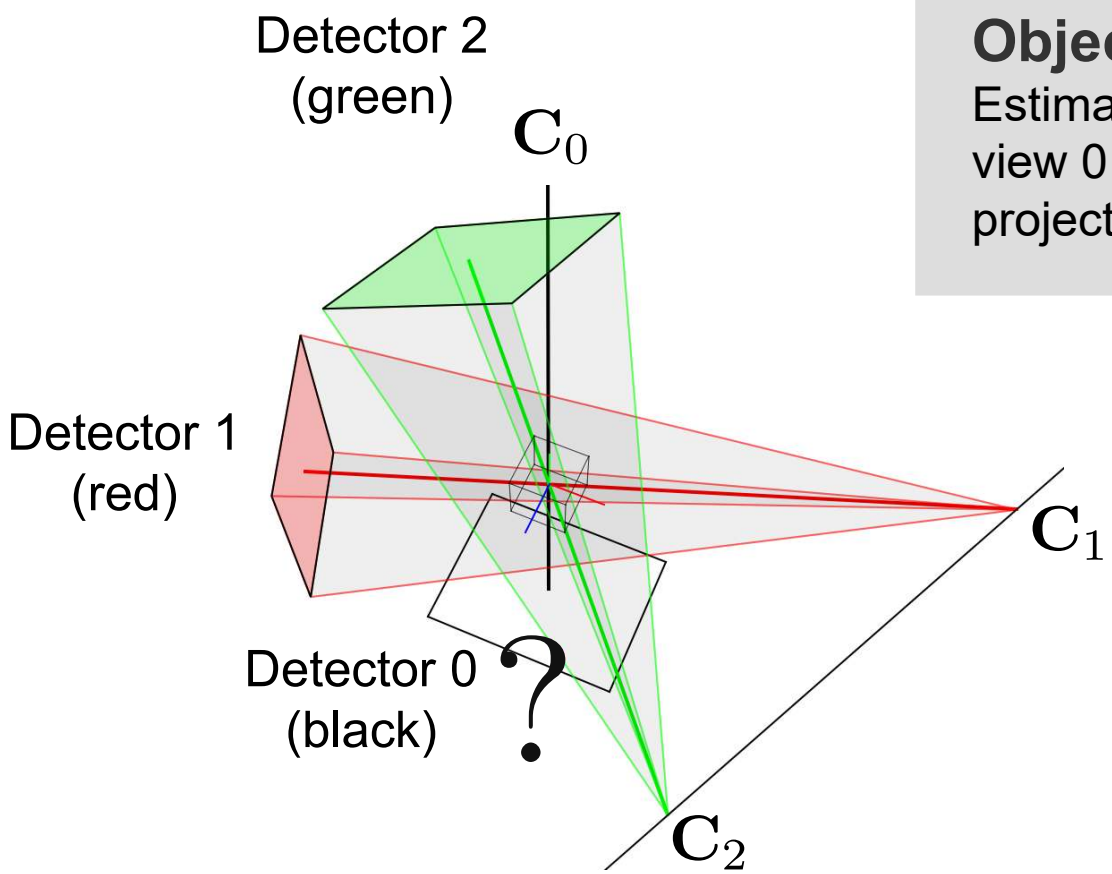
Epipolar Consistency in Fluoroscopy for Image-Based Tracking

Epipolar Consistency in Fluoroscopy for Image-Based Tracking

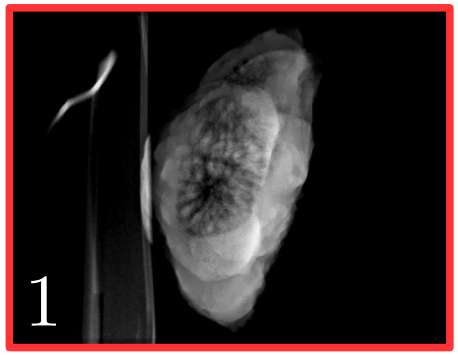
André Aichert, Jian Wang, Roman Schaffert, Arnd Dörfler, Joachim Hornegger and Andreas K. Maier

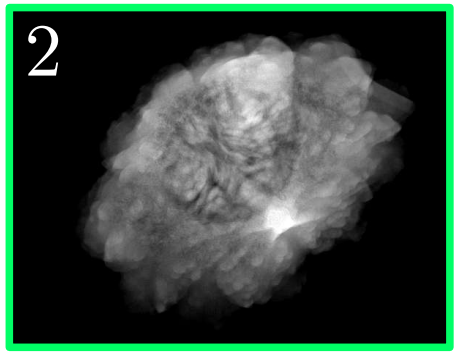
26th British Machine Vision Conference (BMVC) 2015

Experiment: Three views of an unknown object

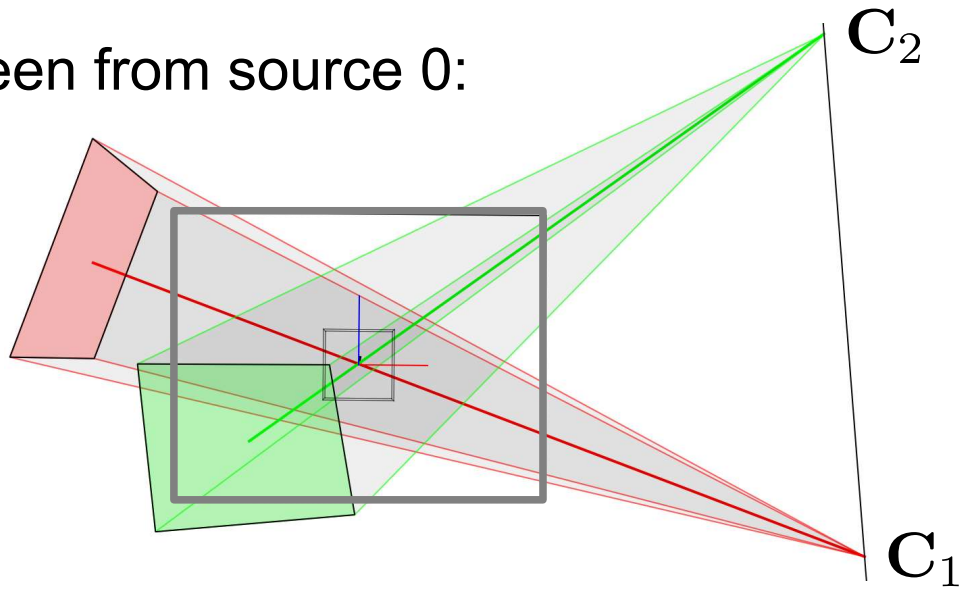


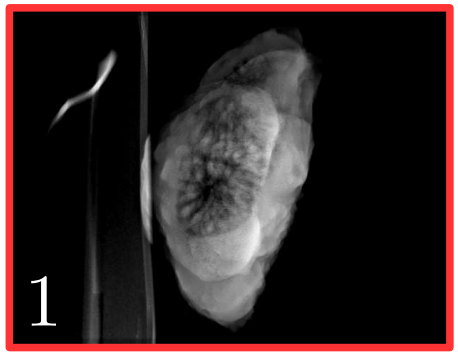
Objective:
Estimate pose of object in view 0 relative to known projections 1 and 2.

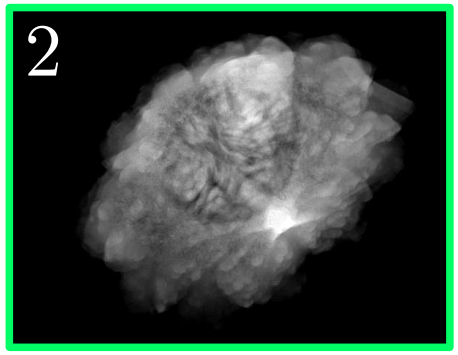




As seen from source 0:







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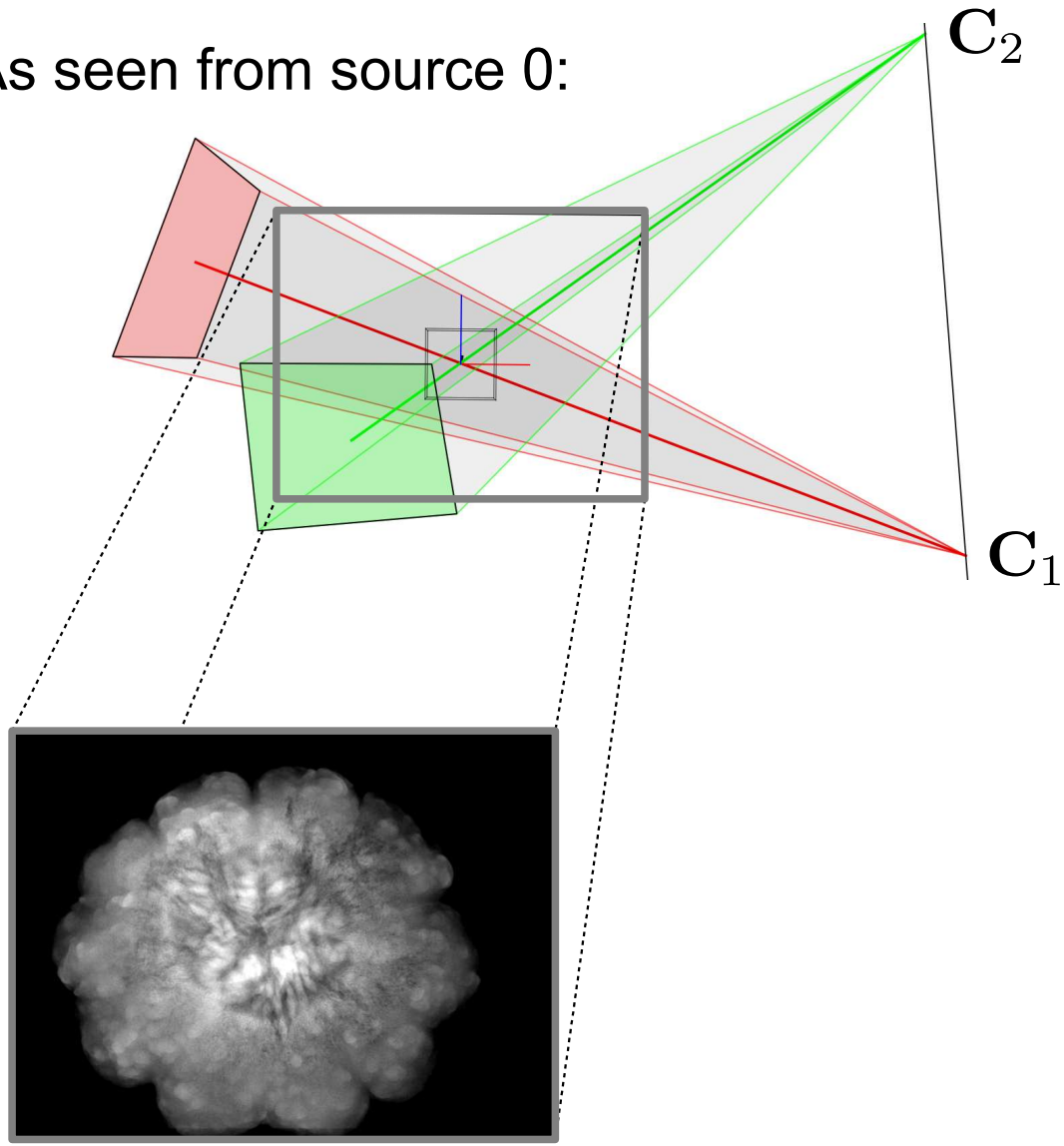
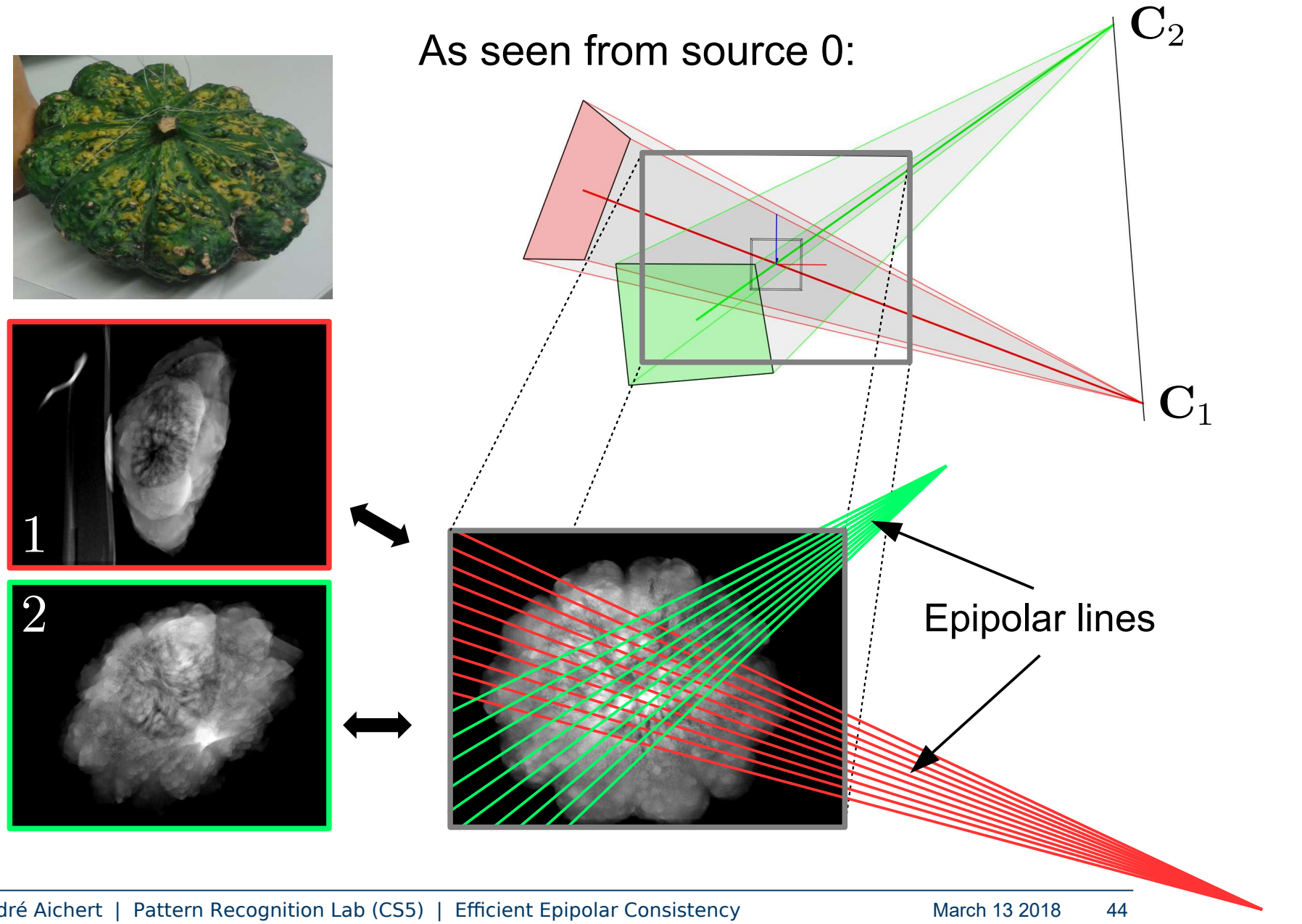
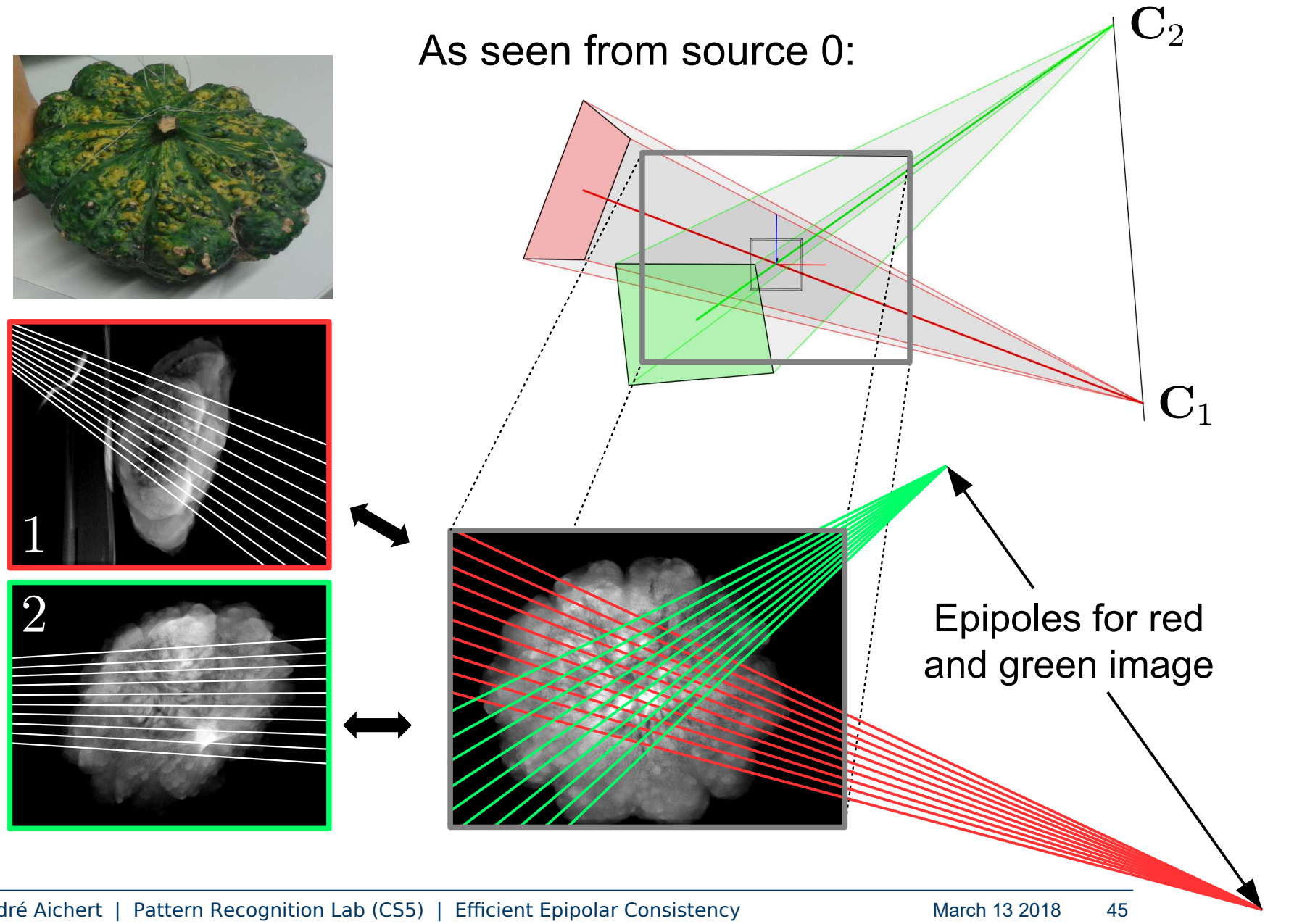
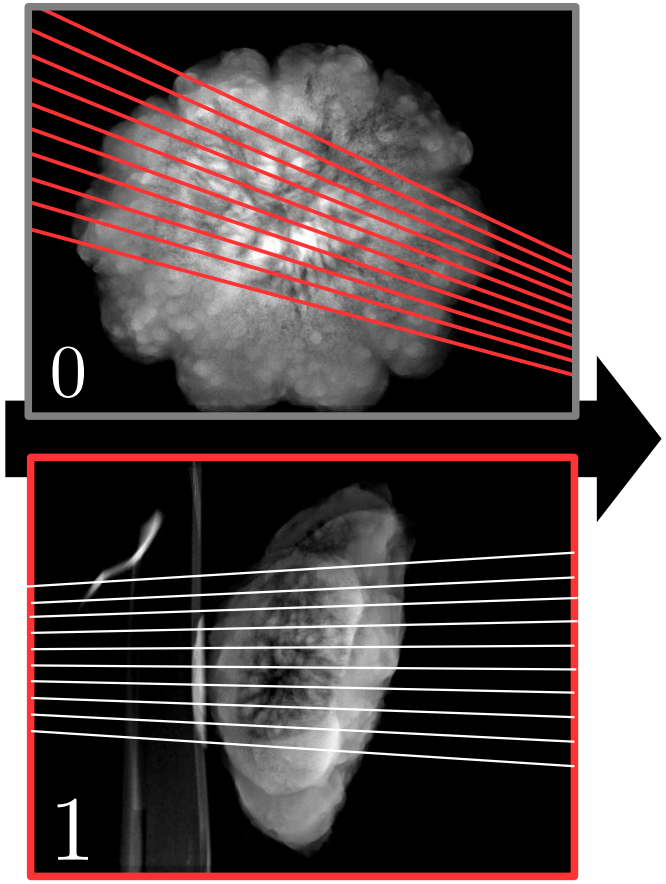
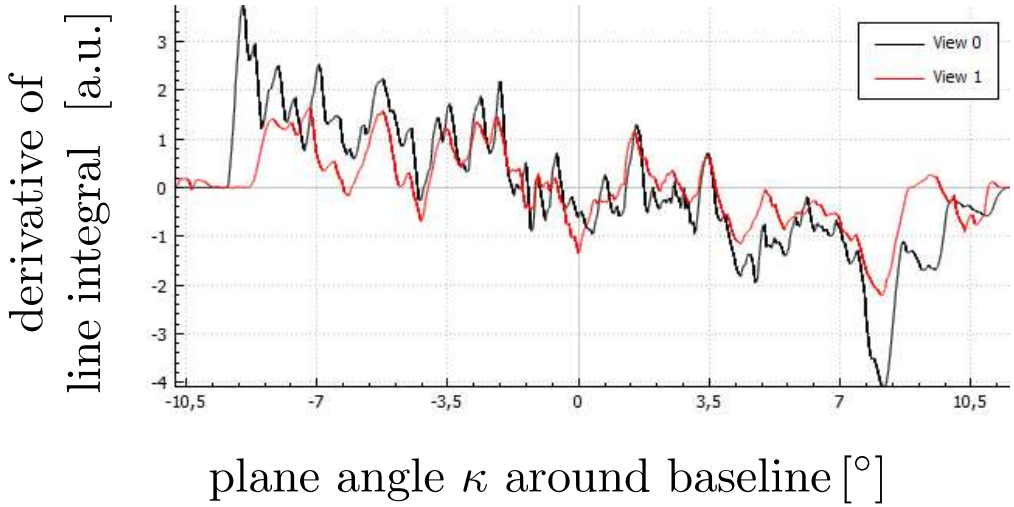



As seen from source 0:
C_2
C_1
1
2
Epipolar lines

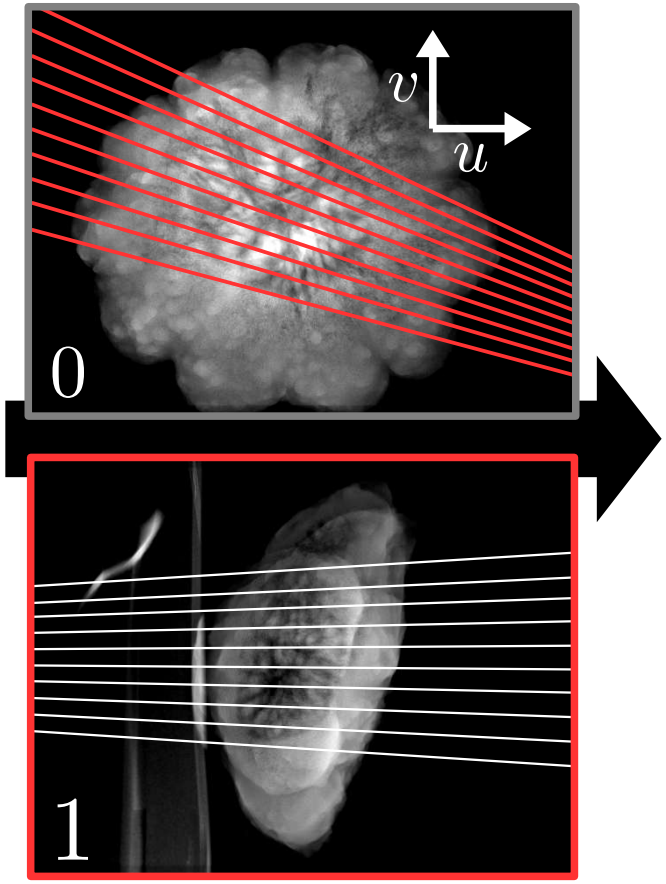

As seen from source 0:
C_2
C_1
1
2
Epipoles for red and green image

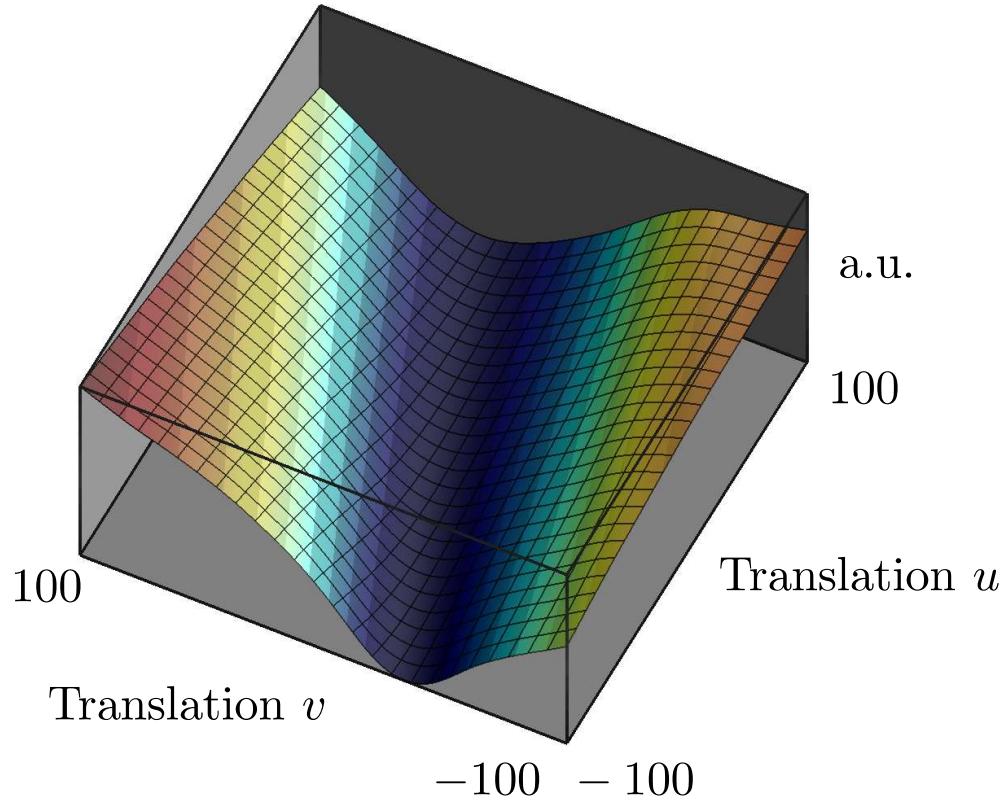
Redundant information in view 0 & 1



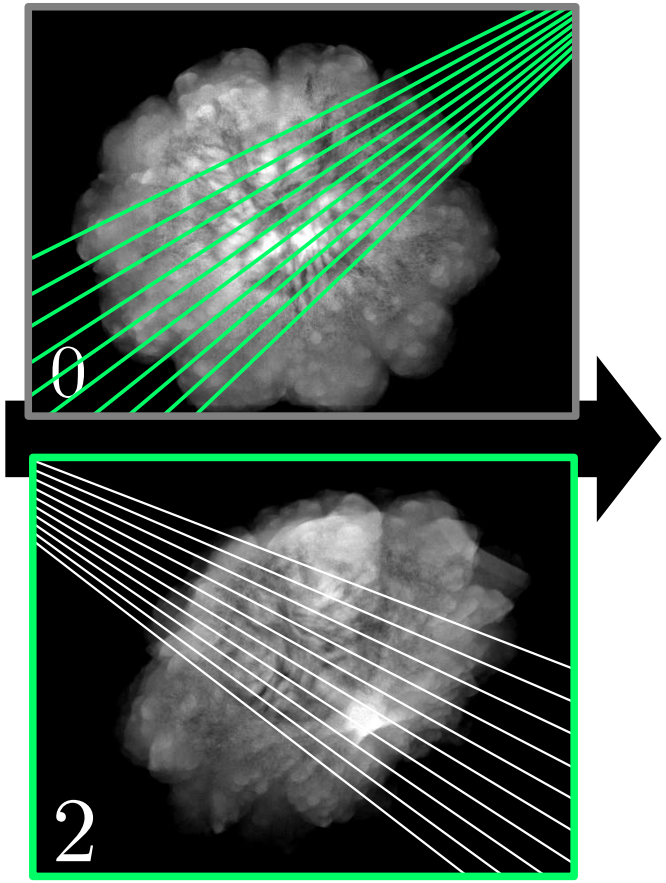


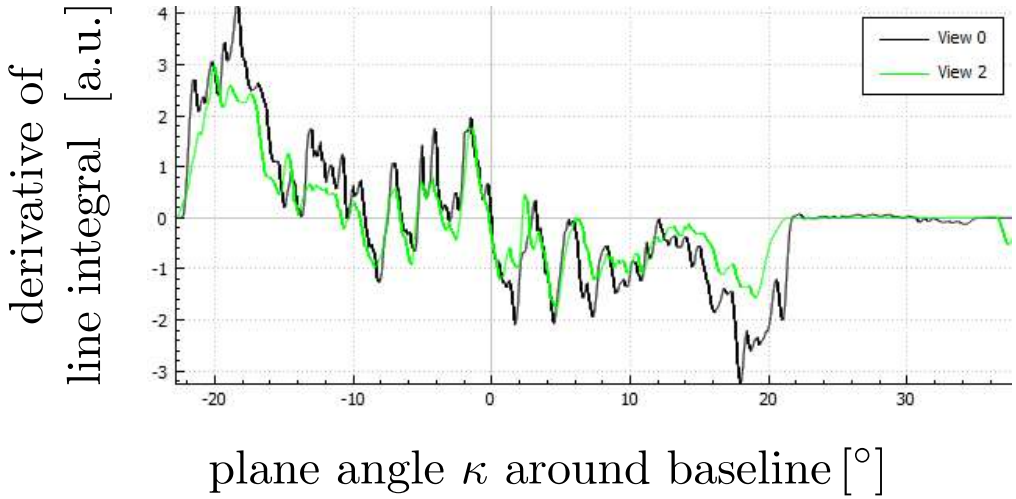
Consistency of view 0 & 1 for detector shifts in view 0



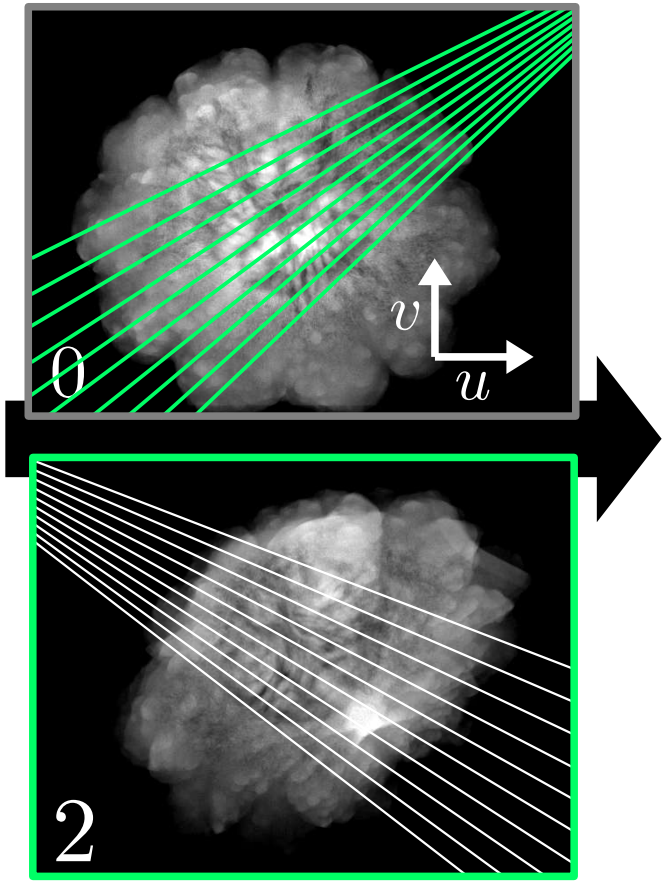


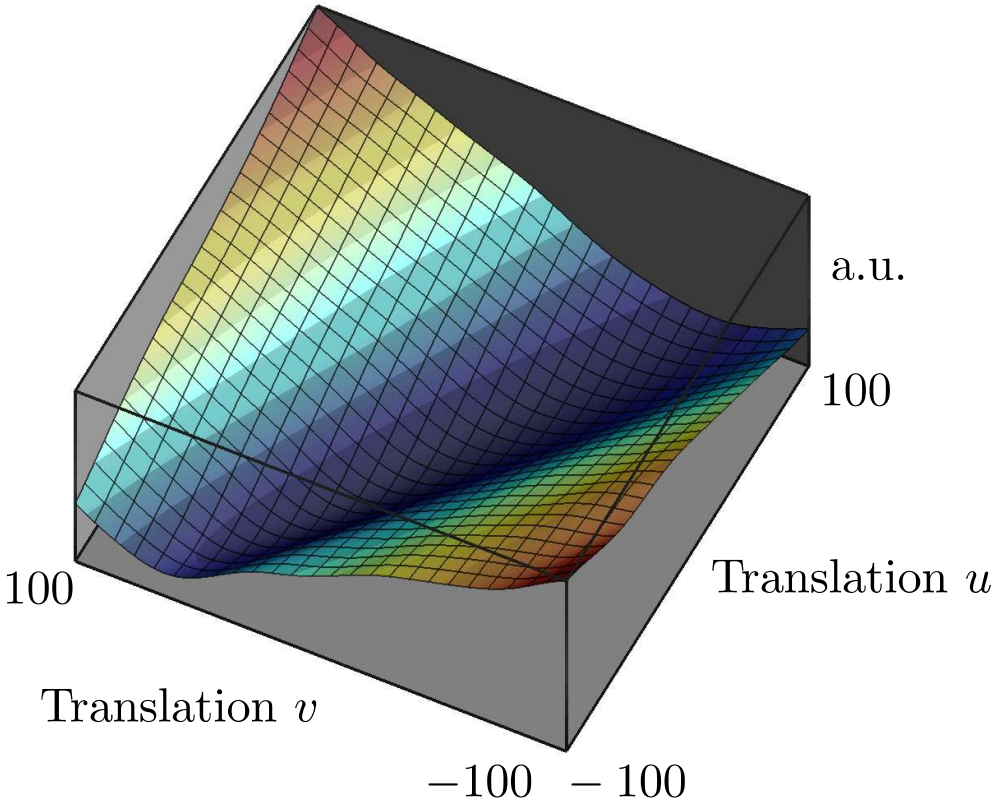
Redundant information in view 0 & 2



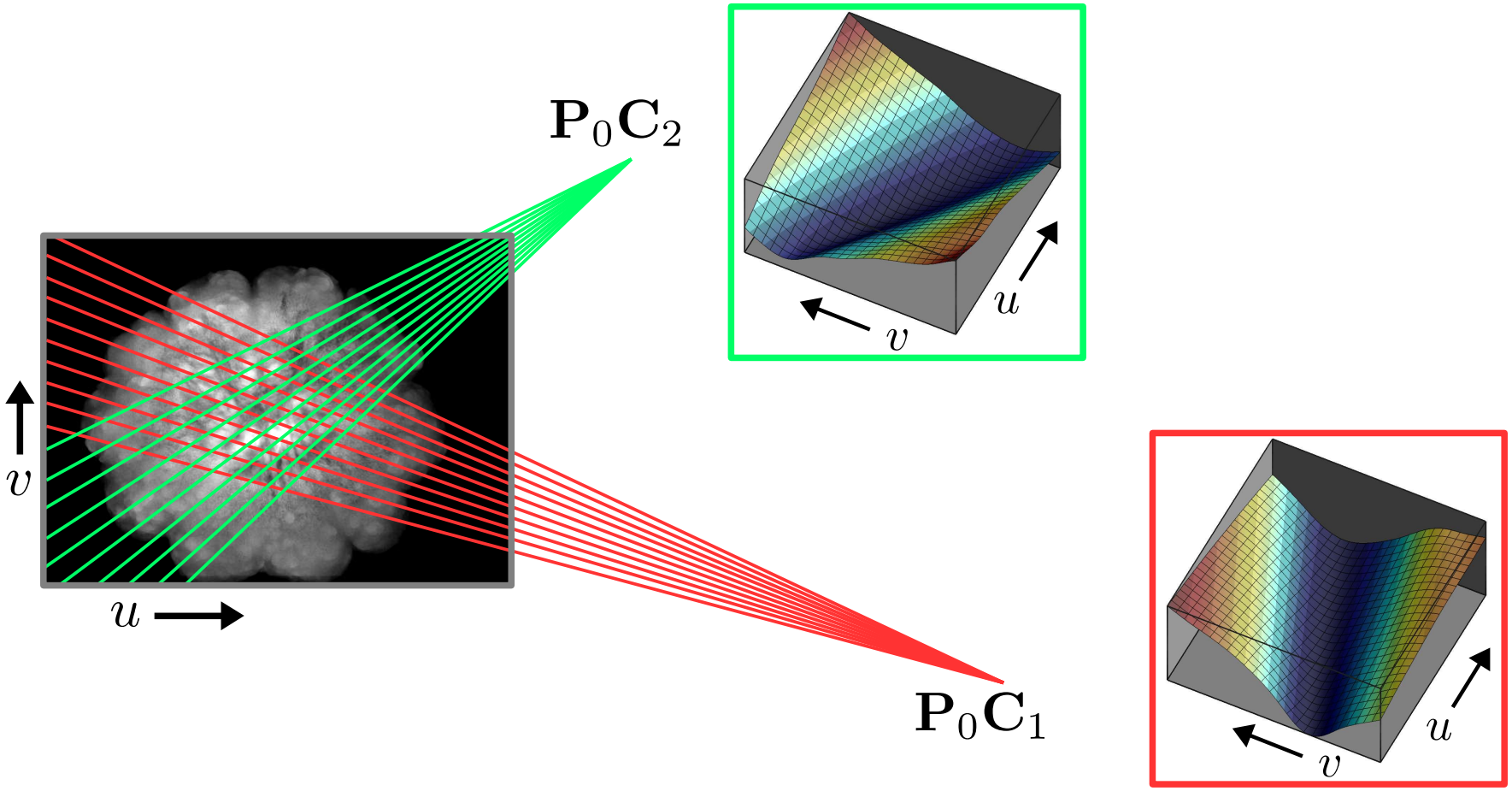


Consistency of view 0 & 2 for detector shifts in view 0

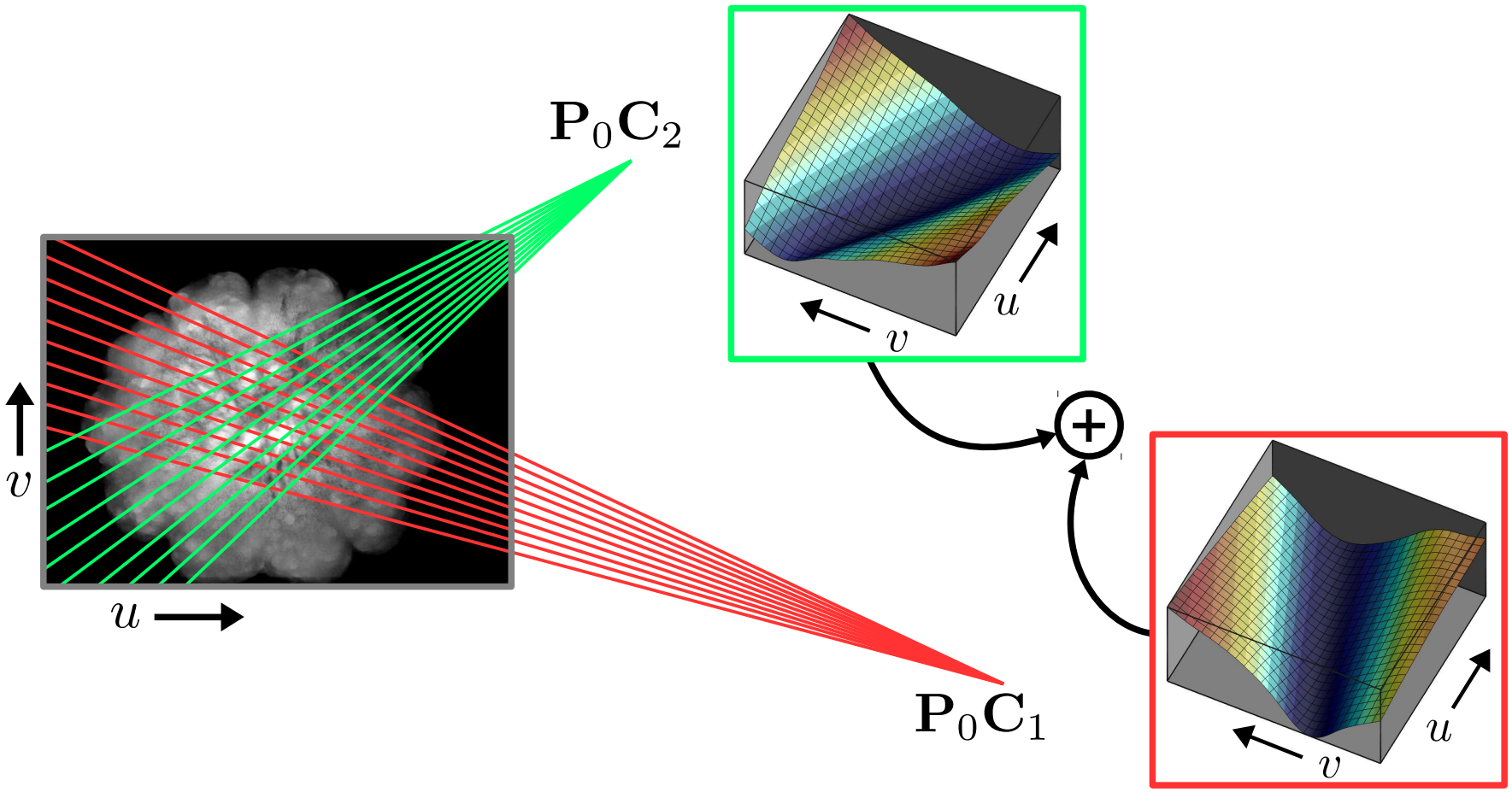




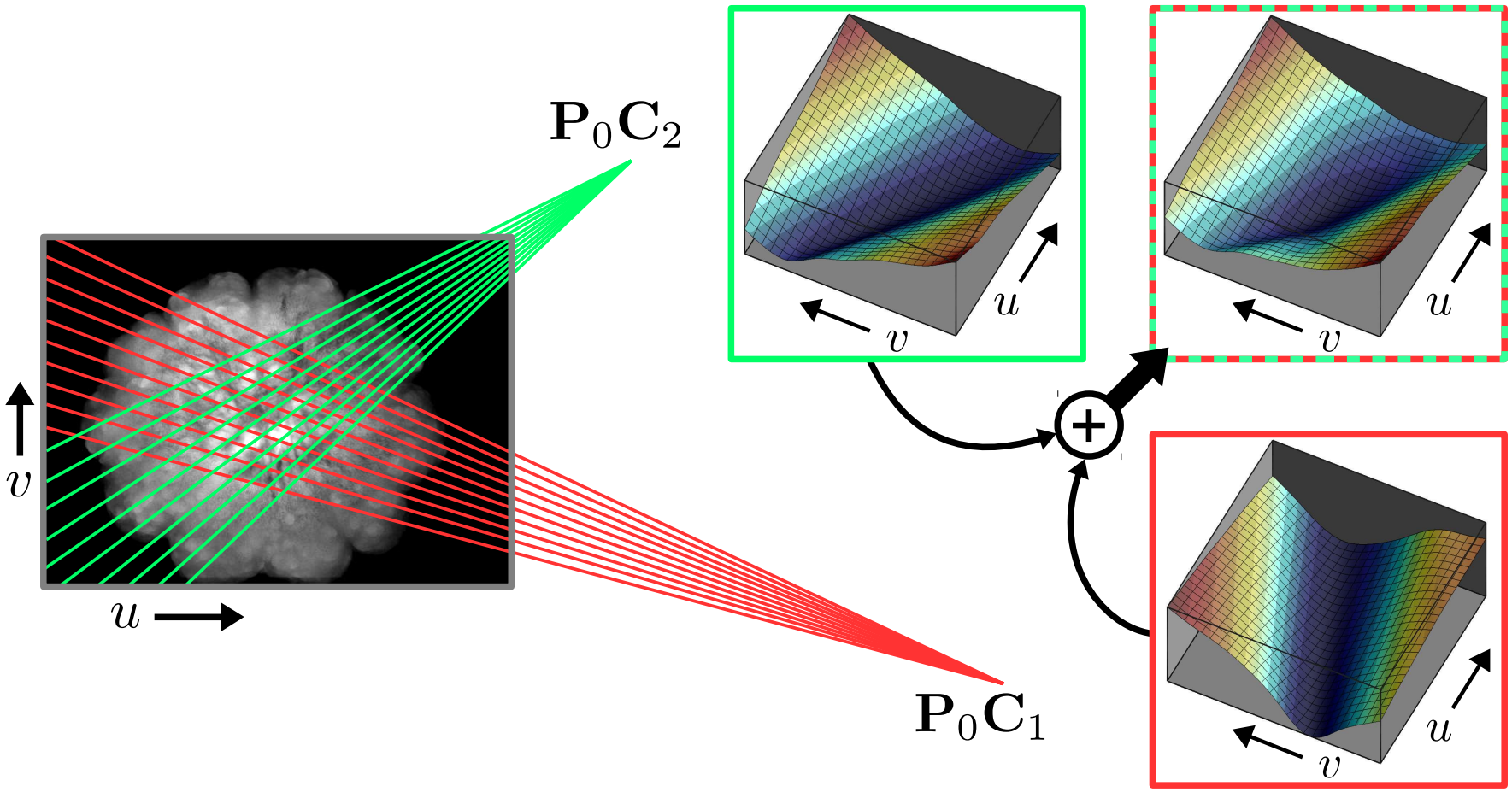
Shape of cost function depends on location of epipoles



Shape of cost function depends on location of epipoles



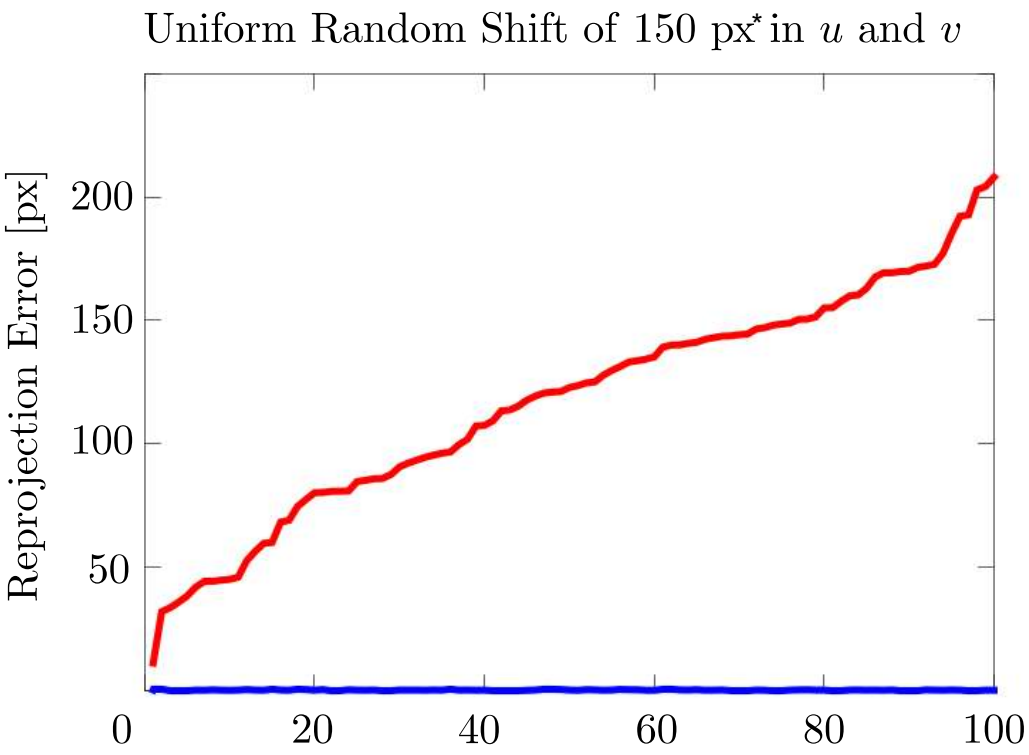
Shape of cost function depends on location of epipoles



Optimization of Consistency

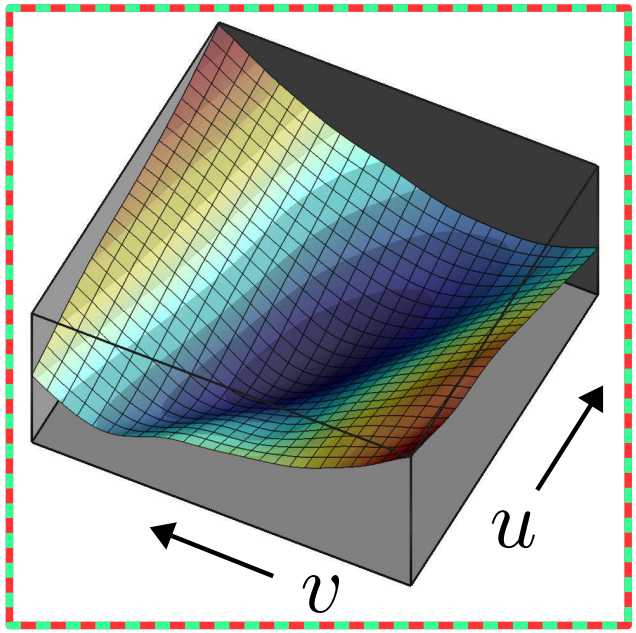
Motion model: detector shifts

Random study (sorted by initial offset)

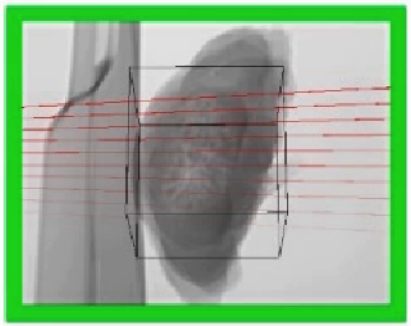


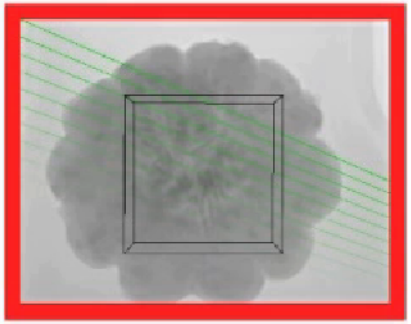
* Image size: 2480 x 1920

Cost function



Pumpkin Phantom Experiment





Two Reference Images

Mostly Translations

FRIEDRICH-ALEXANDER
UNIVERSITÄT
ERLANGEN-NÜRNBERG

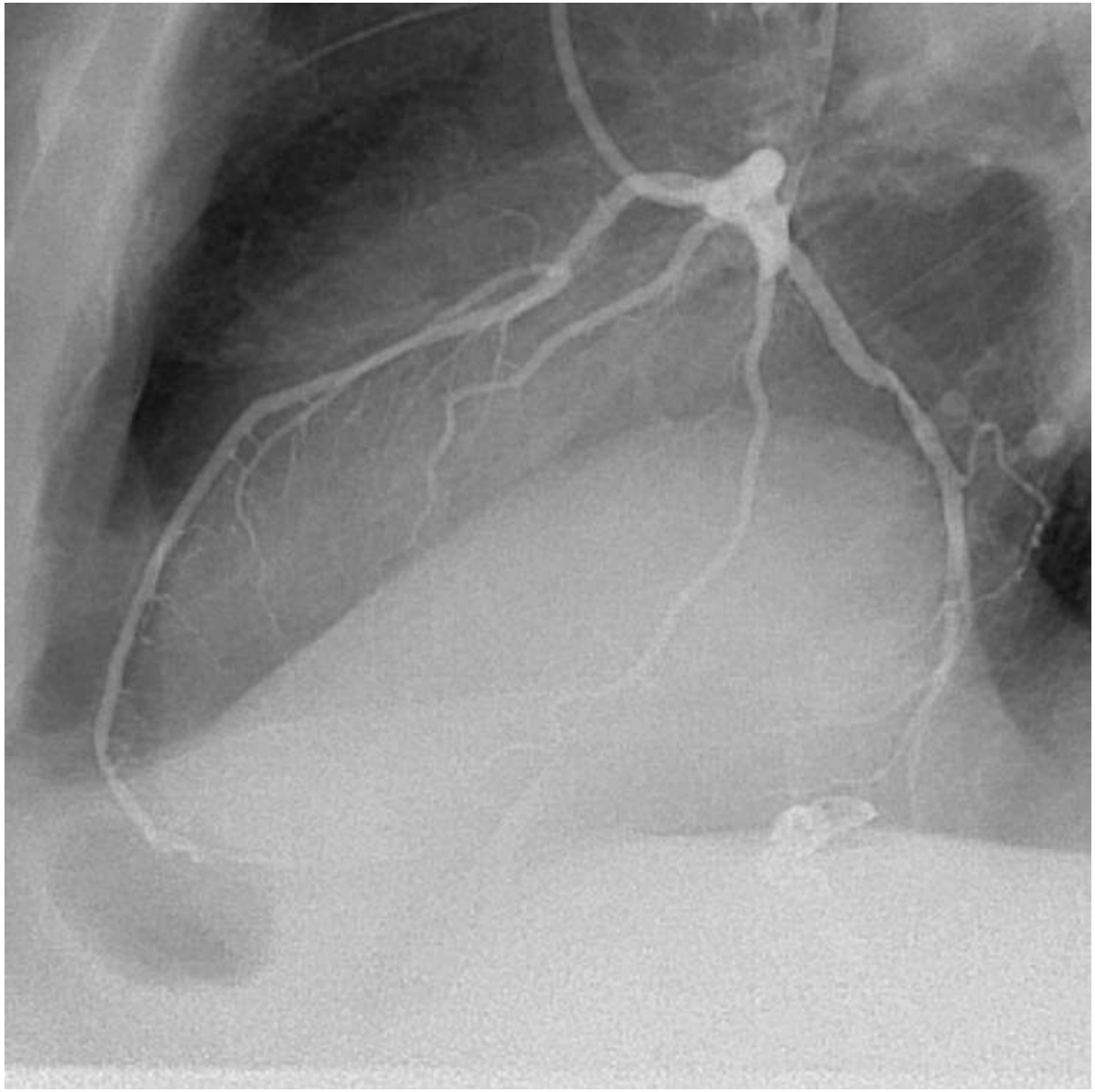
FACULTY OF ENGINEERING

Virtual Subtraction Angiography

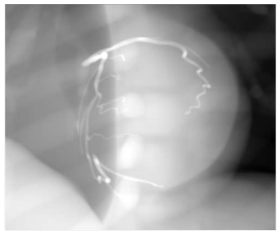
for Epipolar Consistency in case of Truncation

Virtual Single-frame Subtraction Imaging
Mathias Unberath, Andre Aichert, Stephan Achenbach, and Andreas K. Maier
CT-Meeting 2016

Rotational Angiography

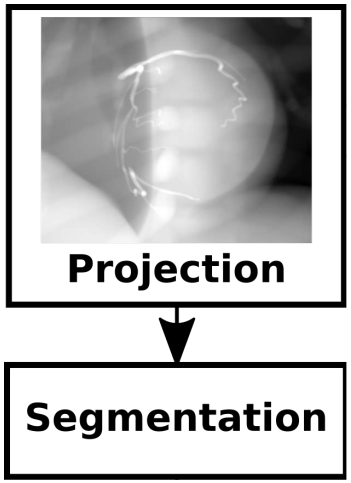


Single-frame Subtraction Pipeline

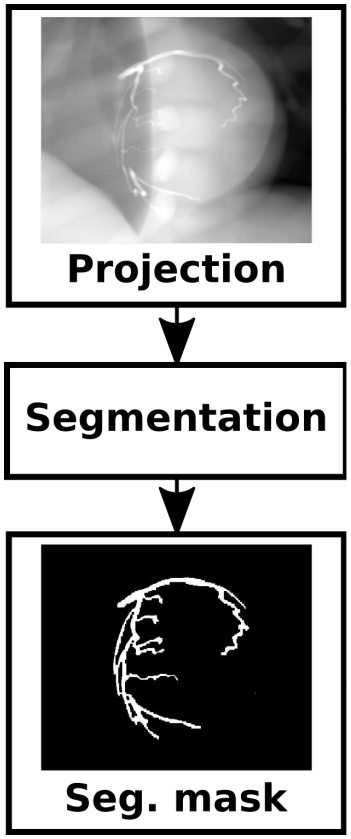


Projection

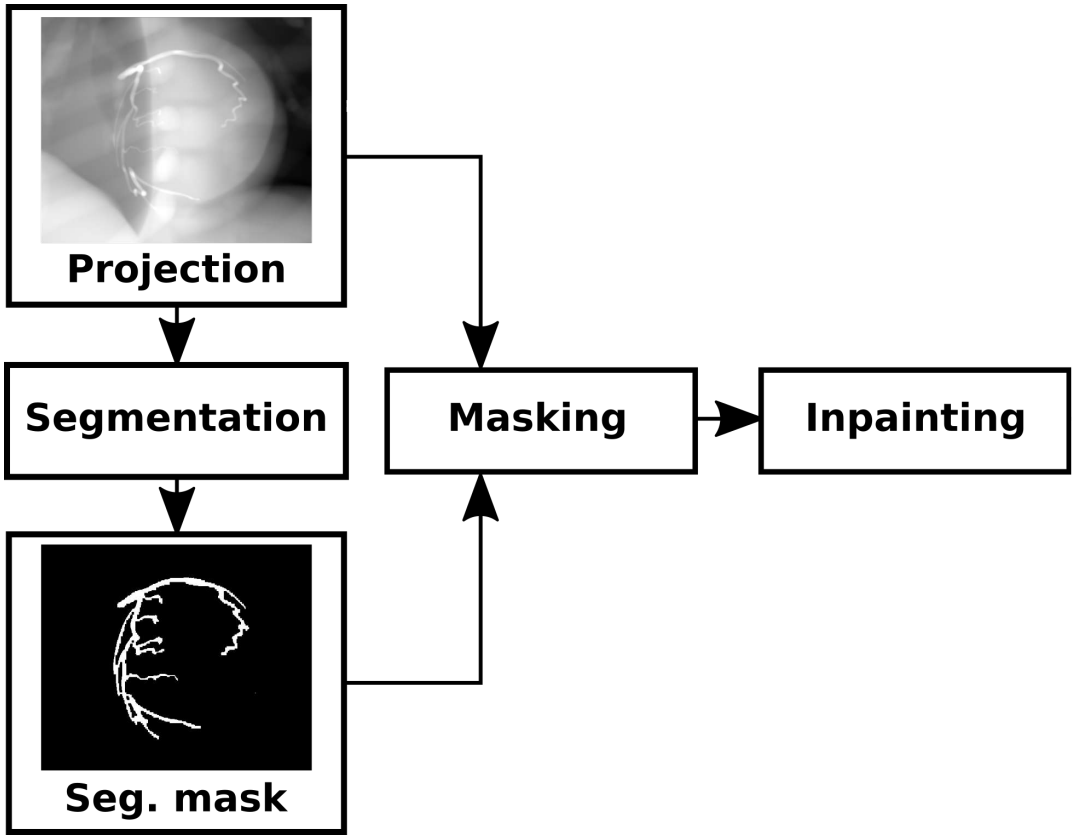
Single-frame Subtraction Pipeline



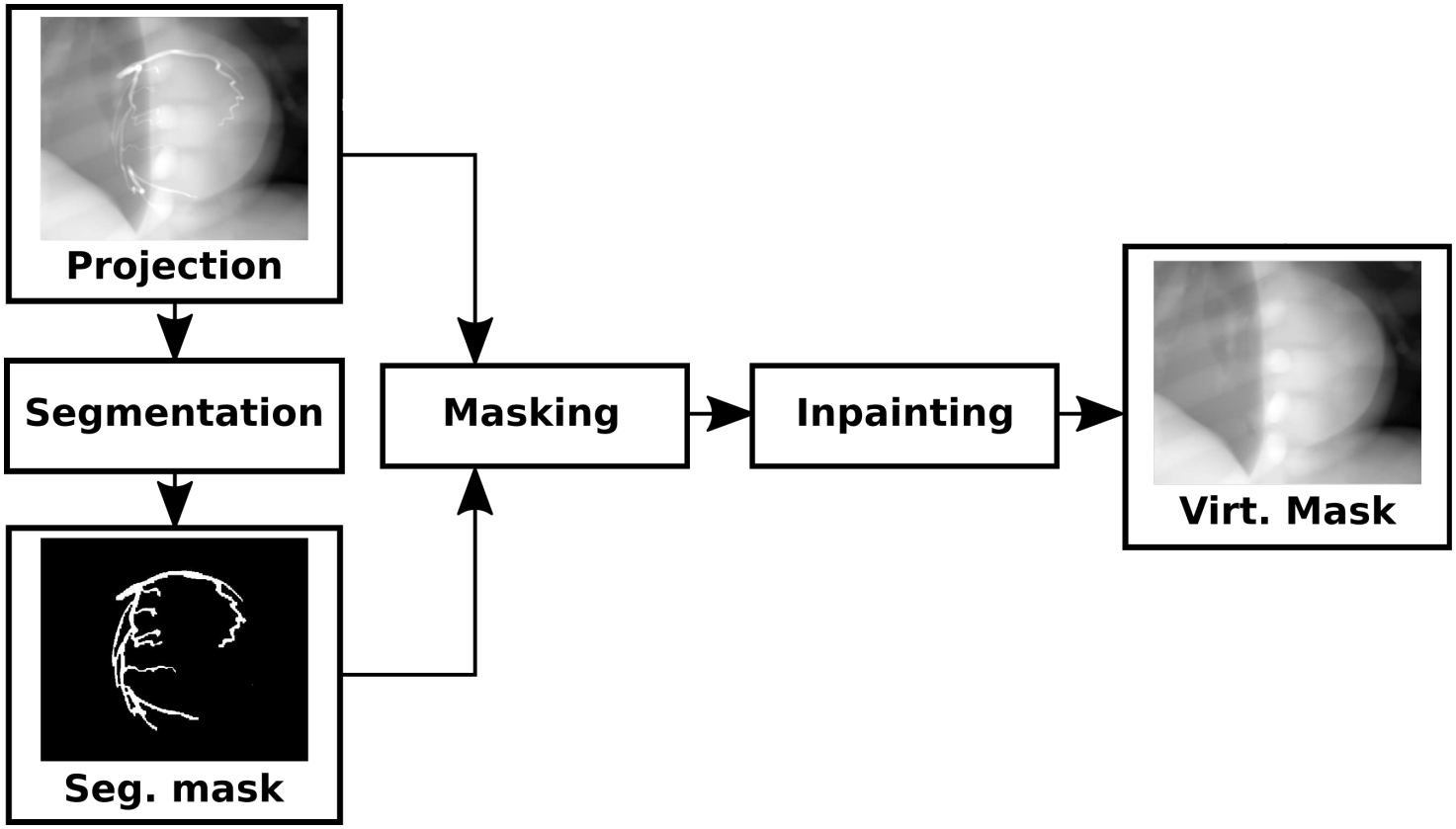
Single-frame Subtraction Pipeline



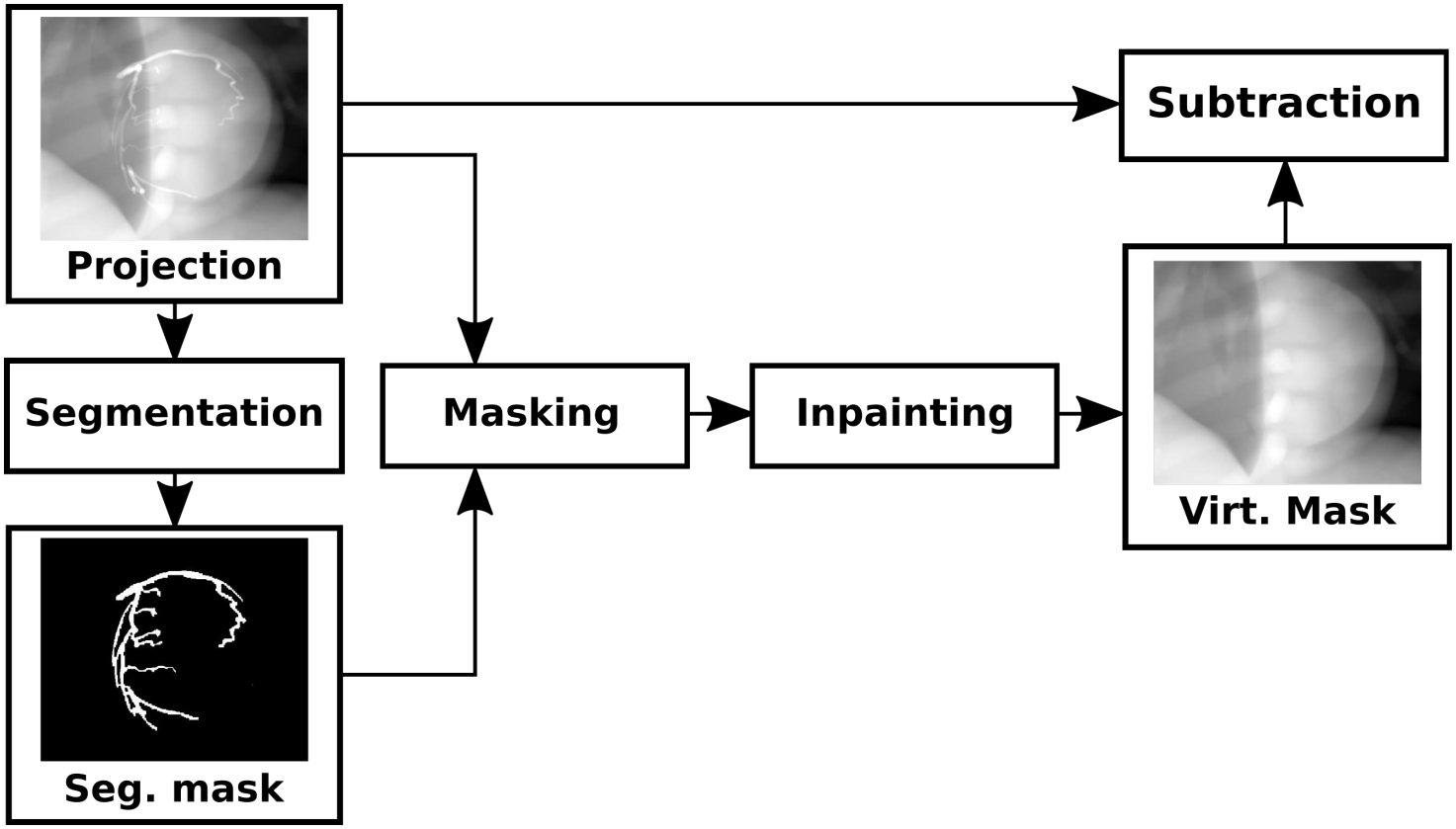
Single-frame Subtraction Pipeline



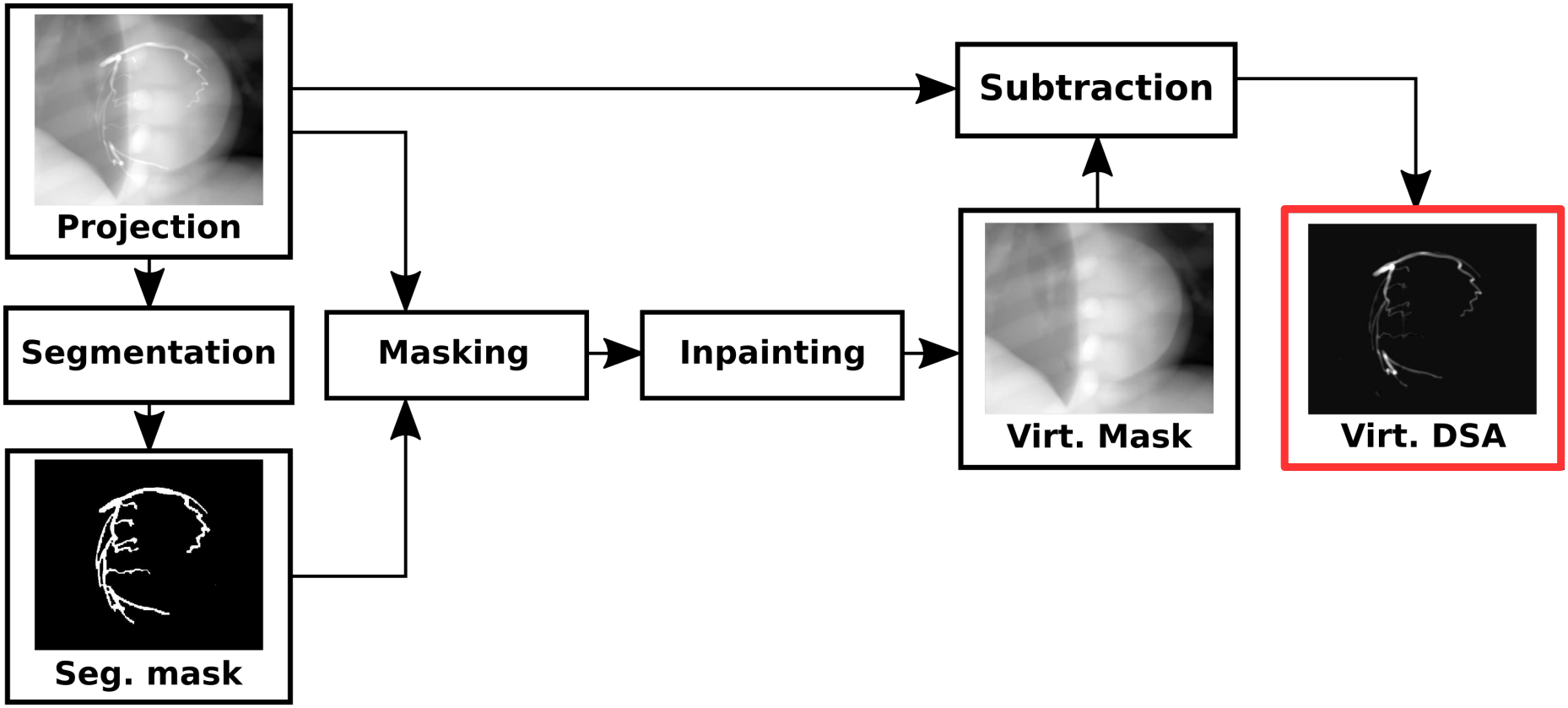
Single-frame Subtraction Pipeline



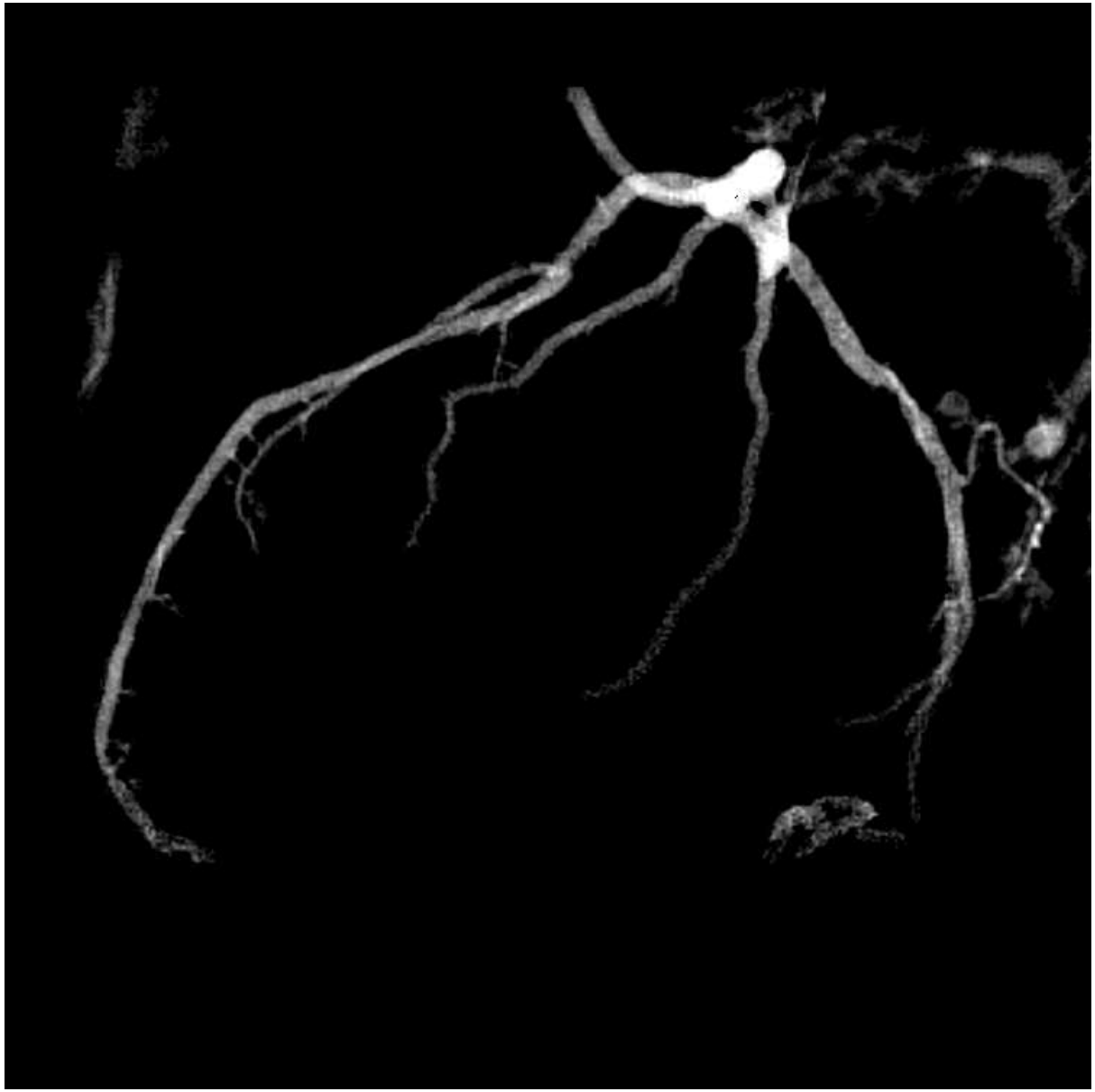
Single-frame Subtraction Pipeline



Single-frame Subtraction Pipeline



Virtual Subtraction Angiography



Virtual Subtraction Angiography (Phantom)

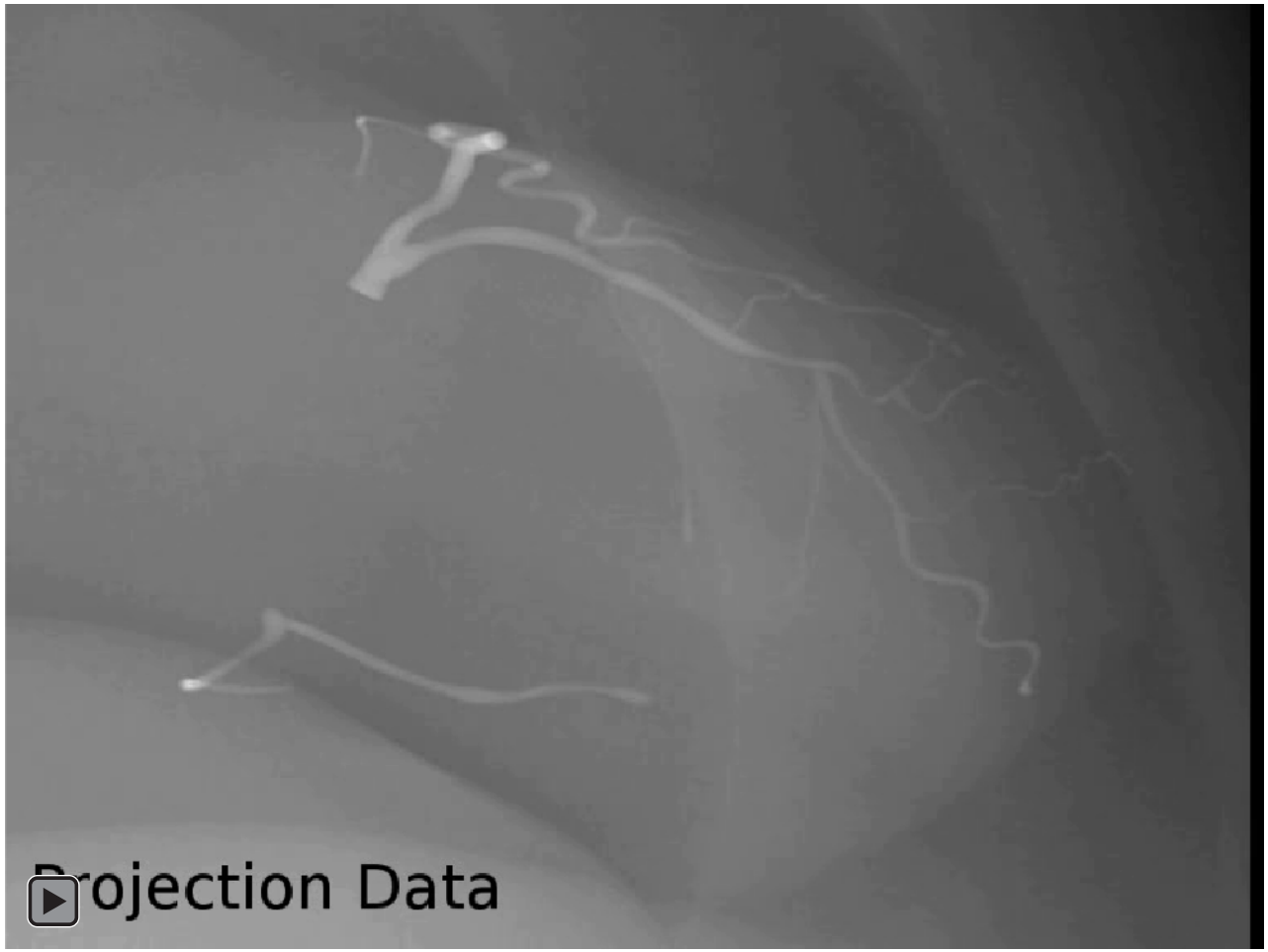
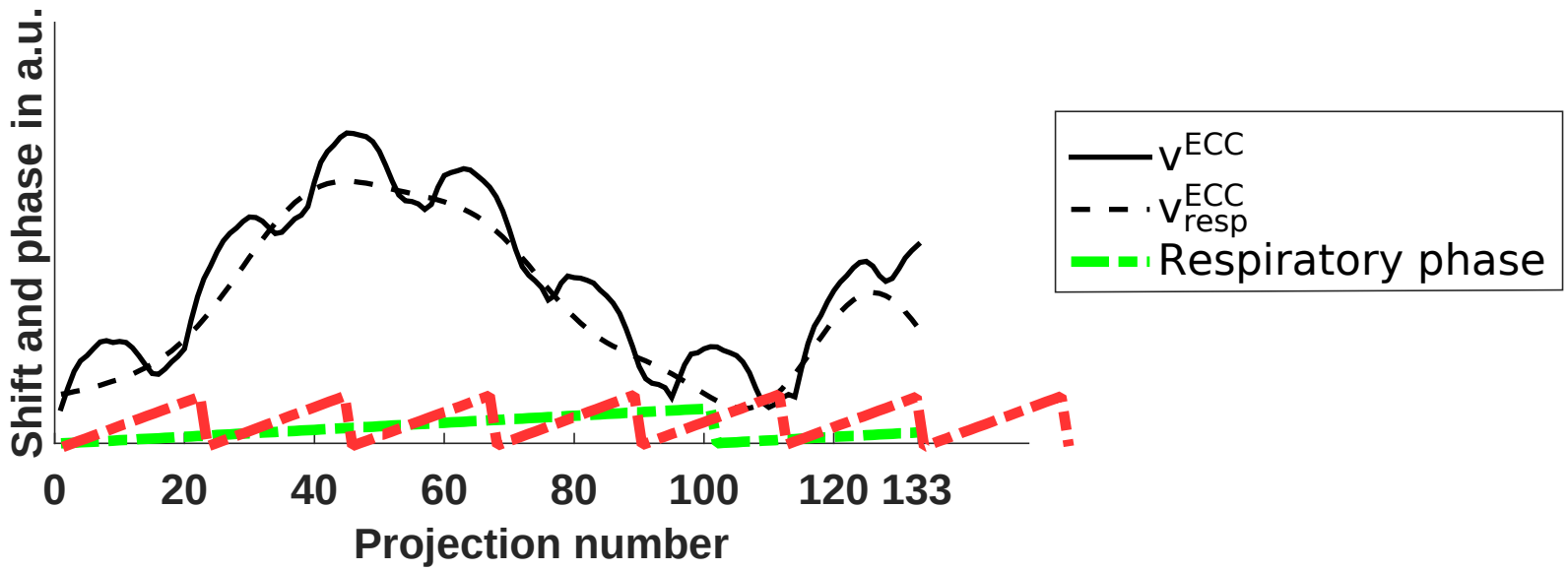


Image-based Gating in Rotational Angiography

Separate high and low frequency parts

→ Separate heart beat from breathing motion



Conclusion

Efficient Epipolar Consistency
André Aichert, Katharina Breininger, Thomas Köhler and Andreas K. Maier
CT-Meeting 2016

- Open-source implementation of Epipolar Consistency
- Applicable to any two X-ray images (e.g. flat panel CT)

- Issue #1: Motion in direction of epipolar lines
- Issue #2: Truncation along epipolar lines

Publications Partially Covered by this Talk

Geometrical jitter correction in computed tomography
Nicole Maass, Frank Dennerlein, André Aichert, Andreas K. Maier
CT-Meeting 2014

Epipolar Consistency in Transmission Imaging
André Aichert, Martin Berger, Jian Wang, Nicole Maass, Yu Deuerling-Zheng, Arnd Doerfler, Joachim Hornegger, Andreas K. Maier
IEEE Transactions on Medical Imaging 34 (11), 2205-2219, 2015

Geometric Adjustment of X-ray Tomosynthesis
Tobias Grulich, Wolfgang Holub, André Aichert, Andreas K. Maier
Fully 3D 2015

Epipolar Consistency in Fluoroscopy for Image-Based Tracking
André Aichert, Jian Wang, Roman Schaffert, Arnd Dörfler, Joachim Hornegger, Andreas K. Maier
26th British Machine Vision Conference (BMVC) 2015

Virtual Single-frame Subtraction Imaging
Mathias Unberath, André Aichert, Stephan Achenbach, and Andreas K. Maier
CT-Meeting 2016

Stereo Rectification for X-ray Data Consistency Conditions
André Aichert, Jérôme Lesaint, Tobias Würfl, Rolf Clackdoyle, Laurent Desbat and Andreas K. Maier
CT-Meeting 2018, to appear

Demo, Video & Source Code

www5.cs.fau.de/research/software

Efficient Epipolar Consistency
Andre Aichert, Katharina Breininger, Thomas Köhler and Andreas K. Maier
CT-Meeting 2016