Variation Based Dense 3D Reconstruction Using Photometric Invariants from Monocular Mini-Laparoscopic Sequences

Additional Material: Figures

Sven Painer
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Chapter 1

Introduction

Figure 1.1: Two examples of mini-laparoscopic images. (a) shows a scarred liver surface and (b) shows a liver surface with severe cirrhosis. These images are taken from real mini-laparoscopic sequences by courtesy of Universitätsklinikum Hamburg-Eppendorf (UKE).
Chapter 2

Theoretical Background

![Diagram](image)

*Figure 2.1:* Overview of the sparse reconstruction. The necessary steps for the Structure from Motion approach are shown.

![Diagram](image)

*Figure 2.2:* Overview of the epipolar geometry. The camera centers are located at \( C \) and \( C' \) and the epipoles are denoted by \( e \) and \( e' \). The 3D point \( \X \) is projected into both images onto the points \( \x \) and \( \x' \), respectively. These could be shifted to \( x \) and \( x' \) due to noise. In both image planes the epipolar lines are given by a dashed line.
Figure 2.3: Illustration of the procedure to compute the cost volume. All pixels of the reference frame $v_r$ are backprojected into the 3D space for all depth samples $d$ between $\xi_{\text{min}}$ and $\xi_{\text{max}}$. In this example, there are three depth samples. This voxel volume is then projected into another frame $v_m$. The values of the pixel in the reference frame and the pixel in the other frame are then taken to compute the cost volume. This figure is taken from [1].

Figure 2.4: Inverse depth map constructed from cost volume. (a) shows an inverse depth map constructed only by the cost volume. For each pixel, the inverse depth value with the minimum costs is taken. (b) shows the error function for the pixel $u$ that is marked in (a).
Chapter 3

Implementation

Figure 3.1: Class diagram of the class Configuration.
Figure 3.2: Class diagram of the dense reconstruction. Only the public interface of the class *Dtam* is shown.
Chapter 4

Evaluation

Figure 4.1: Estimation of dense reconstruction parameters. The dense reconstruction is executed with different parameter values. The crosses indicate these measurements. The line shows a parabola that is estimated to fit the data. The circle marks the minimum of this parabola that is also taken as the parameter value.
Figure 4.2: Example of a reconstructed frame. (a) shows the reference frame. (b) shows the ground truth inverse depth map and (c) shows the reconstructed inverse depth map. The error for each pixel in millimeters is illustrated in (d).
Appendix A

Class Diagrams of CUDA Framework

Figure A.1: Class diagram of the class CudaException.

Figure A.2: Class diagram of the class CudaStream.
Figure A.3: Class diagram of the class HostPinnedMemory.

Figure A.4: Class diagram of the class DeviceMemory.
Figure A.5: Class diagram of the class `DeviceMemory2D`.

```
DeviceMemory2D
- ptr: T*
- pitch: size_t
- width: unsigned int
- height: unsigned int
- isCopy: bool

+ «constructor» DeviceMemory2D()
+ «constructor» DeviceMemory2D(pWidth:unsigned int, pHeight:unsigned int)
+ «constructor» DeviceMemory2D(other:const DeviceMemory2D<T>&)
+ operator=(other:const DeviceMemory2D<T>&): const DeviceMemory2D&
+ «destructor» ~DeviceMemory2D()
+ allocate(pWidth:unsigned int, pHeight:unsigned int)
+ free()
+ getWidth(): unsigned int const
+ getHeight(): unsigned int const
+ getPitch(): size_t const
+ data(): T*
+ data(): const T* const
+ operator[](index:unsigned int): T*
+ operator[](index:unsigned int): const T* const
```
Appendix B

Class Diagrams of Sparse Reconstruction
Figure B.1: Overview of the classes used in the sparse reconstruction. The reconstruction steps are implemented by using the strategy pattern. Only the base classes of the strategies are shown.
Figure B.2: Class diagram of the classes SfM and Trajectory. Only the public interface is shown.
Figure B.3: Class diagram of the classes belonging to the tracking strategy. Only the public interface of the class Tracking is shown.

Figure B.4: Class diagram of the classes belonging to the pose estimation strategy. Only the public interface of the class PoseEstimation is shown.
**Triangulation**

+operator()\((E:\text{const Mat}&,P1:\text{const Mat}&,P2:\text{const Mat}&,
\text{pts1}:\text{const vector<Point2d}>&,\text{pts2}:\text{const vector<Point2d}>&,\text{result}:\text{vector<Point3d}>&):\text{int}
+\text{«destructor»} \sim \text{Triangulation}()

**TriangulationOpenCV**

*Figure B.5:* Class diagram of the classes belonging to the triangulation strategy. Only the public interface of the class \textit{Triangulation} is shown.

**BundleAdjustment**

+\text{«constructor»} \text{BundleAdjustment}(\text{intrinsics}:\text{const Mat}&,\text{pSfm}:\text{SfM}&)
+\text{«destructor»} \sim \text{BundleAdjustment}()
+\text{doBundleAdjustment}(\text{startFrame}:\text{unsigned int},\text{endFrame}:\text{unsigned int},\text{fixedFrames}:\text{int}=-1,\text{fixPoints3D}:\text{bool}=\text{false})

**Pba** \quad **Sba**

*Figure B.6:* Class diagram of the classes belonging to the bundle adjustment strategy. Only the public interface of the class \textit{BundleAdjustment} is shown.
Appendix C

Evaluation Results of Sparse Reconstruction
Figure C.1: Evaluation results of the sparse reconstruction of Phantom 1 Sequence 1.
C Evaluation Results of Sparse Reconstruction

Translational Error

Rotational Error
Figure C.2: Evaluation results of the sparse reconstruction of Phantom 1 Sequence 2.
Figure C.3: Evaluation results of the sparse reconstruction of Phantom 1 Sequence 3.
Figure C.4: Evaluation results of the sparse reconstruction of Phantom 1 Sequence 4.
C Evaluation Results of Sparse Reconstruction

Translational Error

Rotational Error
Figure C.5: Evaluation results of the sparse reconstruction of Phantom 1 Sequence 5.
C Evaluation Results of Sparse Reconstruction

Translational Error

Rotational Error
Figure C.6: Evaluation results of the sparse reconstruction of Phantom 2 Sequence 1.
Figure C.7: Evaluation results of the sparse reconstruction of Phantom 2 Sequence 2.
**Translational Error**

![Graph showing translational error over frame index](image)

**Rotational Error**

![Graph showing rotational error over frame index](image)
Figure C.8: Evaluation results of the sparse reconstruction of Phantom 2 Sequence 3.
Figure C.9: Evaluation results of the sparse reconstruction of Phantom 2 Sequence 4.
Figure C.10: Evaluation results of the sparse reconstruction of Phantom 2 Sequence 5.
C Evaluation Results of Sparse Reconstruction

Translational Error

Rotational Error

frame index

frame index
Figure C.11: Evaluation results of the sparse reconstruction of Phantom 3 Sequence 2.
C Evaluation Results of Sparse Reconstruction

Translational Error

Rotational Error
Figure C.12: Evaluation results of the sparse reconstruction of Phantom 3 Sequence 3.
Figure C.13: Evaluation results of the sparse reconstruction of Phantom 3 Sequence 4.
C Evaluation Results of Sparse Reconstruction

Translational Error

Rotational Error
Figure C.14: Evaluation results of the sparse reconstruction of Phantom 3 Sequence 5.
Bibliography

Variation Based Dense 3D Reconstruction
Application on Monocular Mini-Laparoscopic Sequences
Painer, S.
2016, XV, 78 p. 34 illus., Softcover
ISBN: 978-3-658-12697-1