**Supplementary Material to:**

**Direct Sparse Visual-Inertial Odometry with Stereo Cameras**

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# Chapter1 Visual-inertial Preliminaries

In our main paper [Ⅳ], The term  is the right Jacobian of  can be calculated by (1.1) and (1.2) .

Homogeneous camera calibration matrices are denoted by  as (1.3). and homogeneous 2D image coordinate point  is represented by its image coordinate and inverse depth as (1.3) relative to its host keyframe . Corresponding homogeneous 3D camera coordinate point  is denoted as (1.3).  are used to denote camera projection functions. The jacobian of ,  is denoted as (1.3)



# Chapter2 IMU Error Factors

## 2.1 Time-closest measurements selection strategy

Because of asynchronous but same frequency for accelerometer and gyroscope data, there will be different quantity samples of these two sensors between two consecutive keyframes. We select time-closest gyroscope measurement for one accelerometer measurement accordind to (Alg.1)

## 2.2 Errors and covariance calculation pseudo code

In our main paper [Fig. 2], we can get gyroscope, accelerometer data lists whose size is . We have 8 error items to define:

 are pure rotation values and aren’t related to accelerometer data.

 are rotation “plus” translation values and are related to both gyroscope and accelerometer data.

We calculate these error items by recursion. As an example, the recurrence of are presented here in (2.1), (2.2).



Furthermore, in order to calculate conveniently, we introduce a  to store all pure rotation values. All error items can be seen in (Alg.2).

## 2.3 Jacobian derivation

 The derivation of the Jacobians of  likes (2.3), (2.4), (2.5).

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# Chapter3 Photo Error Factors

## 3.1 Construction residual errors

Fig.1

Here, we take [Fig.1] as factor graph to illustrate photometric error optimaztion. According to our main paper [V.B], The parameters we want to optimize are enclosed in (3.1).



In this example, there are 7 dynamic residuals and 3 static residuals, Factor graph of the residuals function is in (3.2)

We first note that  do not appear in the expression of , hence the corresponding Jacobians are zero, we omit them for writing simplely. The remaining Jacobians can be computed as follows (3.3):

Iteration  can be calculated by (3.4):



## 3.2 Jacobian derivation

### 3.2.1 Dynamic Parameter

Firstly, if  is neither observed by frame ,  nor hosted by , , corresponding jacobians are zero as (3.6):

Otherwise, assuming the hostframe of 2D image coordinate point  is , and corresponding homogeneous 3D camera coordinate point is  in (3.7), body coordinate is . We transform  from frame  to  by , then transform  to camera coordinate point . At last,  is projected to 2D image coordinate point with .

#### 3.2.1.1 Jacobian of Affine Brightness Parameters

It is convenient to give jacobian of affine brightness parameters in (3.8).

#### 3.2.1.2 Right Jacobian of Pose

We can use the chain rule to get jacobian of  in (3.9):

The jacobian of  is enclosed in (3.10):

#### 3.2.1.3 Jacobian of inverse Depth

The inverse depth of  is  in 3D camera coordinate of . The jacobian of  is enclosed in (3.11):

### 3.2.2 Static Parameter

Firstly,  do not appear in the expression of  as (3.12), the corresponding jacobians are zero.

Secondly, we can follow chapter 3.2.1.3 to calculate jacobians of inverse depth. But some strategies can be used to reduce computation. For a pair of stereo frame : inverse depth , and  is only related to baseline of stereo cameras. Left frame  pixel  is projected to right frame  with  as (3.13) :

At last, we give jacobian of affine brightness parameters in (3.14).