

2.LK光流

2.1 光流文献综述

1. 光流可以分为哪几类？

forward additive algorithm

forward compositional algorithm

inverse additive algorithm

inverse compositional algorithm

2. 在compositional中，为什么有时候需要做原始图像的wrap？该wrap有何物理意义？

The incremental update to the wrap $W(x; \Delta p)$ must be composed with the current estimate for the wrap $W(x; p)$ in the compositional algorithm.

3. forward和inverse有何差别？

As a number of authors have pointed out, there is a huge computational cost in re-evaluating the Hessian in every iteration of the LK algorithm. If the Hessian were constant it could be precomputed and then re-used.

2.2 forward-addtive Gauss-Newton光流的实现

1. 从最小二乘角度来看，每个像素的误差怎么定义？

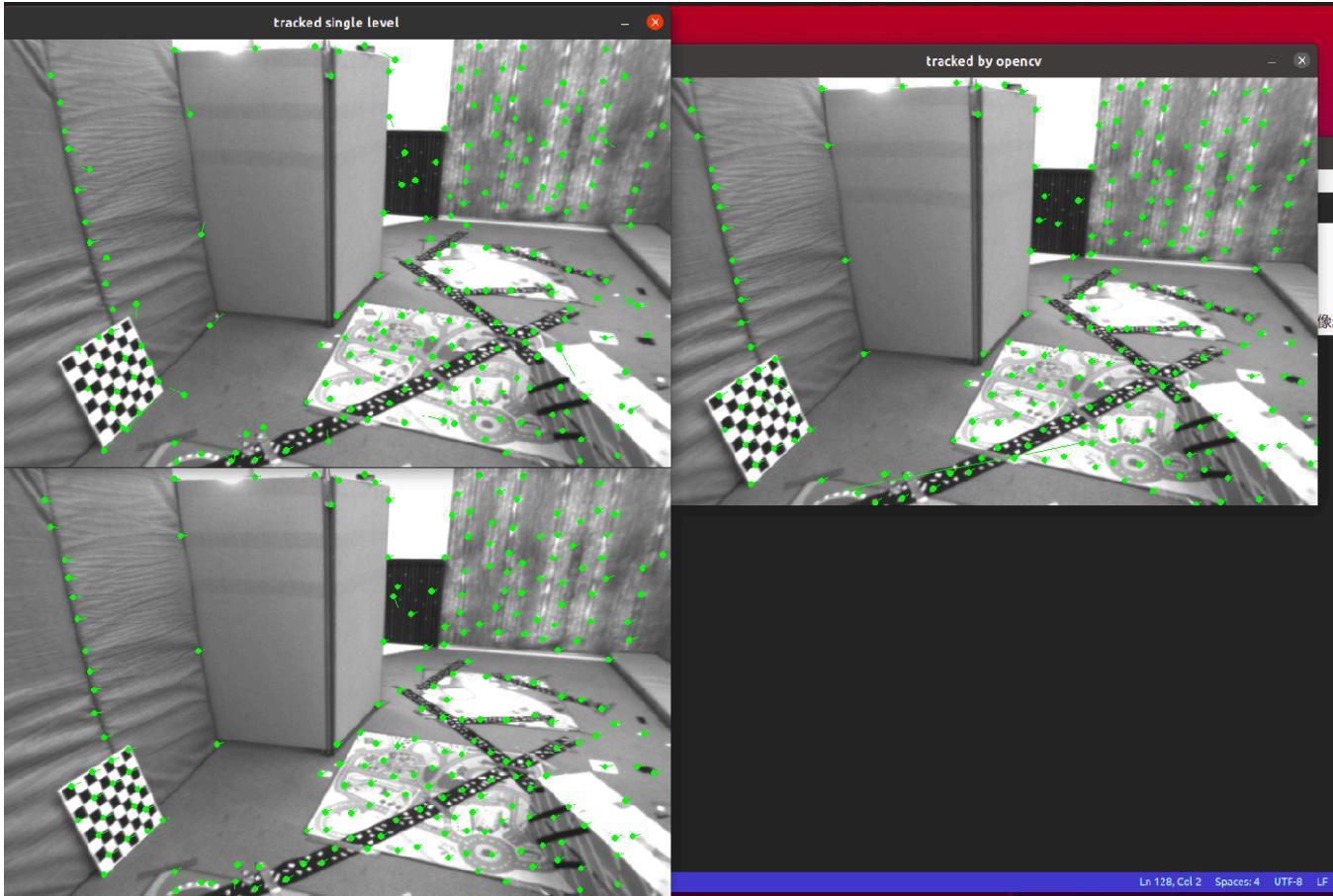
第一张图像在特征点 (x, y) 的像素值减去第二张图像在 $(x + dx, y + dy)$ 处的像素值

$$I_1(x_i, y_i) - I_2(x_i + \Delta x_i, y_i + \Delta y_i)$$

2. 误差相对于自变量的导数如何定义？

自变量为 $[\Delta x, \Delta y]^T$ ，用中值差分表示图像梯度，导数则为：

$$\begin{bmatrix} -\frac{dI_2}{d\Delta x} \\ -\frac{dI_2}{d\Delta y} \end{bmatrix} = \begin{bmatrix} -\frac{I_2(x + \Delta x + 1, y + \Delta y) - I_2(x + \Delta x - 1, y + \Delta y)}{2} \\ -\frac{I_2(x + \Delta x, y + \Delta y + 1) - I_2(x + \Delta x, y + \Delta y - 1)}{2} \end{bmatrix}$$



2.4 推广至金字塔

1. 所谓 *coarse-to-fine* 是指怎样的过程？

光流法中通过对图像缩放不同倍率，计算光流时先从最顶层图像开始计算，然后把上一层计算结果作为下一层计算的初始值，是一个由粗到精的过程。使用该方法后，图像实际运动太大时，图像缩小后运动的像素比较小，也能较好的追踪到。

2. 光流法中的金字塔用途和特征点法中的金字塔有何差别？

特征点法金字塔用于在图像缩放不同尺度下对比特征点，保证特征点的尺度不变性，不论相机是向前运动还是向后运动，同一特征点都能在像素平面上匹配上。

2.6 讨论

1. 我们优化两个图像块的灰度之差真的合理吗？哪些时候不够合理？你有解决办法吗？

LK光流有三个假设：亮度恒定，相邻帧运动幅度小，空间（局部）一致。在满足上述条件的情况下是合理的，但是当相邻图像整体灰度值变化较大，相机运动过快，特征点局部领域内灰度值不一致时不合理。

尽量保证相机曝光恒定（把曝光时间作为待估计变量），对图像块减去均值计算相对亮度信息，图像金字塔的方法可以改善上述情况。

2. 图像块大小是否有明显差异？取 16×16 和 8×8 的图像块会让结果发生变化吗？

实际测试发现，图像块大效果更好，但窗口较大时，受野值影响小，结果更加鲁棒，但是窗口较小时，光流的计算更加精确。

3. 金字塔层数对结果有怎样的影响？缩放倍率呢？

金字塔层数一般越多效果越好，但层数太高后顶层图像太小，特征点太紧密容易错误跟踪。放大倍率小，金字塔的层数相对更多，计算效果更好，但是增加了计算量。

3. 直接法

The screenshot shows the Visual Studio Code interface with the following details:

- Explorer:** Shows a project structure with files like optical_flow.cpp, direct_method.cpp, calc_disparity.cpp, and CMakeLists.txt.
- Editor:** The direct_method.cpp file is open, showing code related to estimating pose using optical flow. It includes Eigen::Vector2d and Sophus::SE3d types.
- Terminal:** A terminal window at the bottom shows command-line output from running the program. The output includes cost values and good projection counts for each layer.
- Code Editor:** A preview window on the right displays a document titled "Preview hw6.md" containing notes about pyramid layers and direct methods.

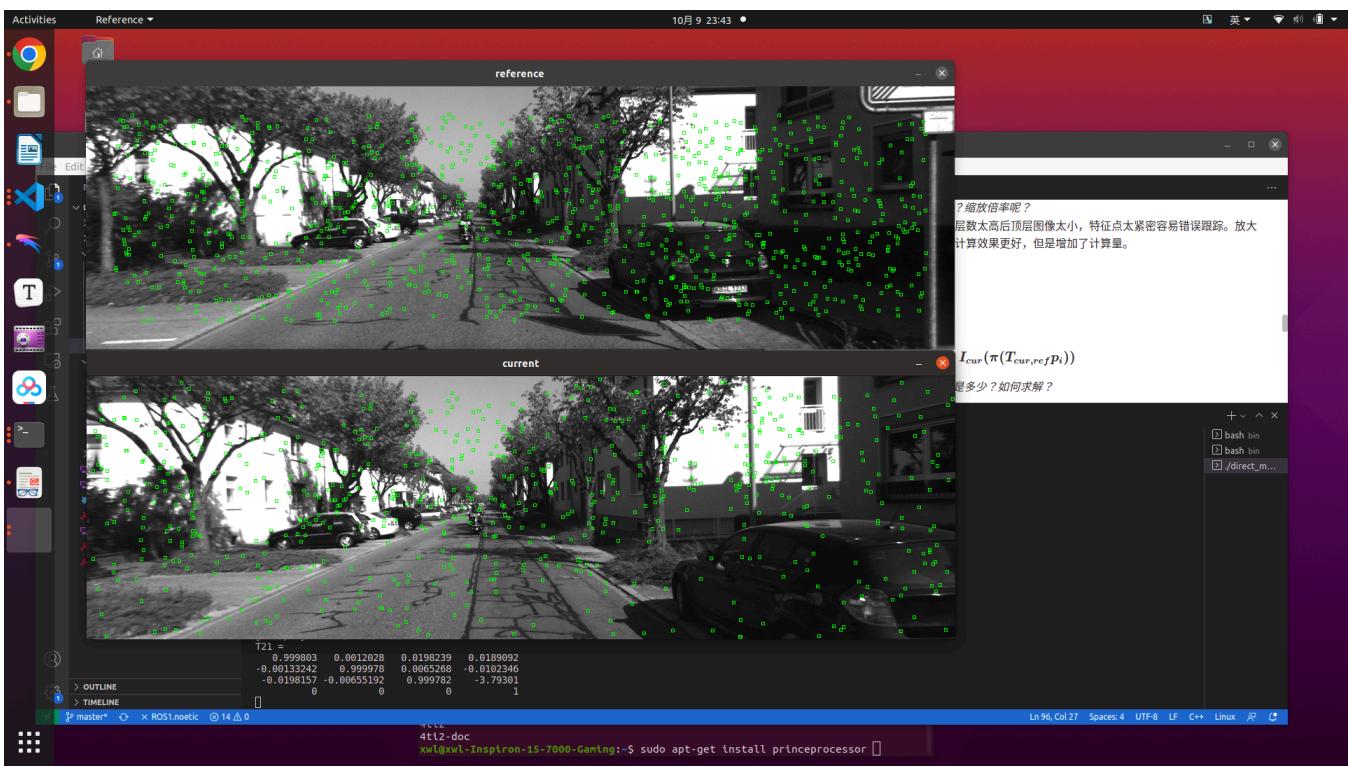
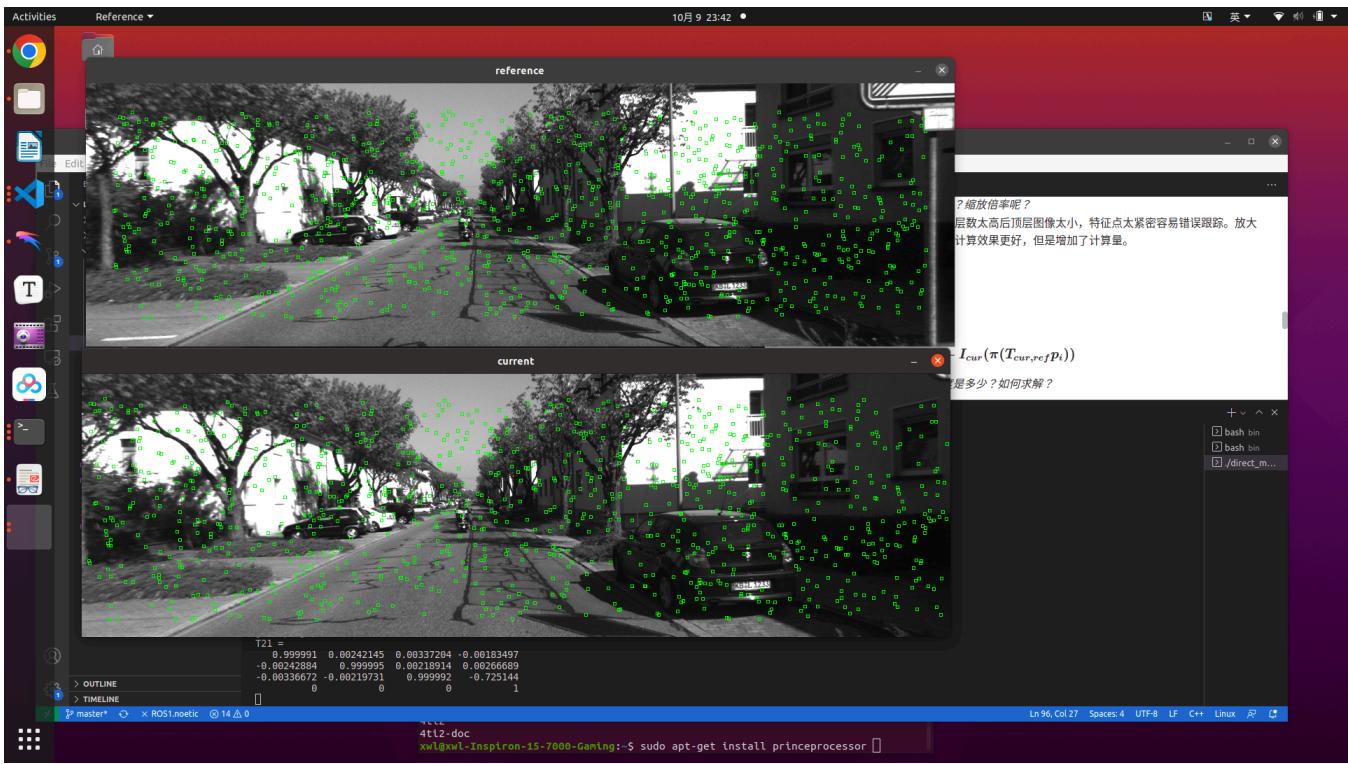
```
cost = 9496.62, good = 978
cost = 9429.66, good = 978
cost increased: 9639.69, 9421.97
good projection: 978
current - reference - 15363e-06
00249382
0.731695
1
xwl@xwl-Inspiron-15-7000-Gaming:~/Documents/L6/direct_method/bin$ ./direct_method
cost = 9496.62, good = 980
cost = 9429.66, good = 980
cost = 10273.4, good = 951
cost = 8079.18, good = 937
cost = 8067.71, good = 936
cost increased: 8869.25, 8867.71
good projection: 936
121 =
0.999993 0.00231187 0.00286123 0.0108526
-0.00231817 0.999995 0.00220222 0.00707574
-0.00285612 -0.00220884 0.999993 -0.716537
0 0 0 0
xwl@xwl-Inspiron-15-7000-Gaming:~$ sudo apt-get install princeprocessor
```

Activities Reference 10月 9 23:42 ● 英

direct_method.cpp - L6 - Visual Studio Code

```

    direct_method > direct_method.cpp s x calc_disparity.cpp s hw6.md
    83     pixels_ref.push_back(Eigen::Vector2d(x, y));
    84 }
    85 // estimates 01-05.png's pose using this information
    86 Sophus::SE3d T_cur_ref;
    87
    88 for (int i = 1; i < 6; i++)
    89 { // 1-10
    90     cv::Mat img = cv::imread(fmt_others % i).str();
    91     // first you need to test single layer
    92     // std::cout << "debug0" << std::endl;
    93
    94     cv::Mat current, reference;
    95     cv::cvtColor(img, current, cv::COLOR_BGR2GRAY);
    96     cv::cvtColor(reference, reference, cv::COLOR_BGR2GRAY);
    97
    98     cv::Sobel(current, current, CV_32F, 1, 0, 3);
    99     cv::Sobel(reference, reference, CV_32F, 1, 0, 3);
    100
    101     cv::normalize(current, current, 0, 1, cv::NORM_MINMAX);
    102     cv::normalize(reference, reference, 0, 1, cv::NORM_MINMAX);
    103
    104     cv::GoodFeaturesToTrack(current, corners, 100, 0.01, 10, 3);
    105
    106     cv::calcOpticalFlowPyrLK(current, reference, corners,
    107                               corners2, mask, 10, 20, 3, 3, 1.2, 0.01);
    108
    109     cv::warpPerspective(reference, reference, T21, reference.size());
    110
    111     cv::cvtColor(reference, reference, cv::COLOR_GRAY2BGR);
    112
    113     cv::circle(reference, corners, 2, cv::Scalar(0, 255, 0), -1);
    114     cv::circle(reference, corners2, 2, cv::Scalar(0, 255, 0), -1);
    115
    116     cv::putText(reference, "current", cv::Point(10, 10), cv::FONT_HERSHEY_SIMPLEX, 0.5, cv::Scalar(0, 0, 255));
    117     cv::putText(reference, "reference", cv::Point(10, 10), cv::FONT_HERSHEY_SIMPLEX, 0.5, cv::Scalar(0, 0, 255));
    118
    119     cv::imwrite("optical_flow.png", reference);
    120
    121     cv::destroyAllWindows();
    122
    123     cout << "cost = " << cost << endl;
    124     cout << "good = " << good << endl;
    125     cout << "cost increased: " << cost_increased << endl;
    126     cout << "good projection: " << good_projection << endl;
    127
    128     T21 = T21;
    129
    130     cout << "T21 = " << endl;
    131     cout << T21 << endl;
    132
    133     cout << "0.000001 0.00269516 0.00324939 6.95383e-09
    134     -0.00278241 0.00000000 0.00232272 0.00240382
    135     -0.00032095 0.00224103 0.00000000 -0.731695
    136     0 0 0 1
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3.1 单层直接法

1. 该问题中的误差项是什么？

光度误差： $e = I_{ref}(\pi(p_i)) - I_{cur}(\pi(T_{cur,ref}p_i))$

2. 误差相对于自变量的雅可比维度是多少？如何求解？

6x1维度

$$\frac{\partial(u)}{\partial\delta\xi} = \begin{bmatrix} \frac{f_x}{Z} & 0 & -\frac{f_x X}{Z^2} & -\frac{f_x X Y}{Z^2} & f_x + \frac{f_x X^2}{Z^2} & -\frac{f_x Y}{Z} \\ 0 & \frac{f_y}{Z} & -\frac{f_y Y}{Z^2} & -f_y - \frac{f_y Y^2}{Z^2} & \frac{f_y X Y}{Z^2} & \frac{f_y X}{Z} \end{bmatrix}$$

$$J^T = -\frac{\partial I_2}{\partial u} \frac{\partial u}{\partial \delta\xi}$$

3. 窗口可以取多大？是否可以取单个点？

可以取4x4或者6x6等大小，如果取单个点会降低鲁棒性。

3.4 延伸讨论

1. 直接法是否可以类似光流，提出*inverse, compositional*的概念？它们有意义吗？

可以。光流中优化的是 dx, dy ，*inverse*使用参考图片在 (x, y) 处的梯度可以减少计算量。

2. 请思考上面算法哪些地方可以缓存或者加速？

可以减小图像块的大小，使用*inverse*的方法可以免去梯度重复计算。

3. 在上述过程中，我们实际假设了哪两个patch不变？

对应点处patch灰度值、深度信息不变

4. 为什么可以随机取点？而不用取角点或者线上的点？那些不是角点的地方，投影算对了吗？

直接法是通过最小化光度误差对位姿进行优化，不是角点也可以

5. 请总结直接法相对于特征点法的异同与优缺点

4.*使用光流计算视差

```
the calculated disparity is 10.9200 and the ground_truth disparity is 11  
the calculated disparity is -1.76575 and the ground_truth disparity is 27  
the calculated disparity is 9.83838 and the ground_truth disparity is 26  
the calculated disparity is -10.0763 and the ground_truth disparity is 23  
the calculated disparity is 9.87018 and the ground_truth disparity is 10  
the calculated disparity is 21.8598 and the ground_truth disparity is 20  
the calculated disparity is 10.3151 and the ground_truth disparity is 10  
the calculated disparity is 16.7521 and the ground_truth disparity is 17  
the calculated disparity is 21.0757 and the ground_truth disparity is 19  
the calculated disparity is 23.5785 and the ground_truth disparity is 23  
the calculated disparity is 19.795 and the ground_truth disparity is 18  
the calculated disparity is 10.0251 and the ground_truth disparity is 9  
the calculated disparity is 2.02045 and the ground_truth disparity is 25  
the calculated disparity is 16.7381 and the ground_truth disparity is 17  
the calculated disparity is 4.60495 and the ground_truth disparity is 6  
the calculated disparity is 38.44 and the ground_truth disparity is 21  
the calculated disparity is 30.5611 and the ground_truth disparity is 29  
the calculated disparity is 5.22272 and the ground_truth disparity is 5  
the calculated disparity is 31.8062 and the ground_truth disparity is 32  
the calculated disparity is 2.02142 and the ground_truth disparity is 25  
the calculated disparity is 11.701 and the ground_truth disparity is 12  
the calculated disparity is 16.2327 and the ground_truth disparity is 16  
the calculated disparity is 15.2127 and the ground_truth disparity is 21  
the calculated disparity is 16.857 and the ground_truth disparity is 17  
the calculated disparity is 16.4348 and the ground_truth disparity is 17  
the calculated disparity is 3.00192 and the ground_truth disparity is 2  
the calculated disparity is 23.2293 and the ground_truth disparity is 22  
the calculated disparity is 16.8336 and the ground_truth disparity is 17  
the calculated disparity is 12.6601 and the ground_truth disparity is 12  
the calculated disparity is -23.6251 and the ground_truth disparity is 21  
the calculated disparity is -4.28964 and the ground_truth disparity is 17  
the average error is 6
```