Camera Path Calculation using IMU sensors

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1 Abstract

Modern mobile phones are equipped with accelerometers and gyroscopes. Data obtained from the accelerometer can be used to estimate the position of the camera between frames of a video while the orientation can be determined from the gyroscope. An approximation of the camera path can be calculated from the combination of these data. However, the output of this process can be fairly inaccurate. To improve the approximation we use the IMU data as the input of a Bundle Adjustment. The Bundle Adjustment gives an improved position and orientation data of the camera for each frame which in turn gives a better camera path estimation.

2 Methodology

The first step in our project is to obtain the IMU data required for the Bundle Adjustment. We use a recording app [1] to obtain the data by ourselves. We then detect the keypoints and compute their descriptors in each video frame using ORB. Keypoint matching is also performed in this step to identify the unique keypoints. The accelerometer provides us with the acceleration of the camera. We calculate the velocity and position of the camera from this data. The gyroscope, on the other hand, gives us the angular velocity which is used to calculate the orientation of the camera. The values obtained from the first two video frames are used to initialize the local Bundle Adjustment process. For each of the subsequent frames, the Bundle Adjustment outputs a corrected position and orientation value of the camera (see [1, 2]). These values are then used as the input for the Bundle Adjustment of the next frame. Performing this process over all the video frames gives us na approximation of the camera path which is fairly accurate. An overview of the entire process is illustrated in figure 1.

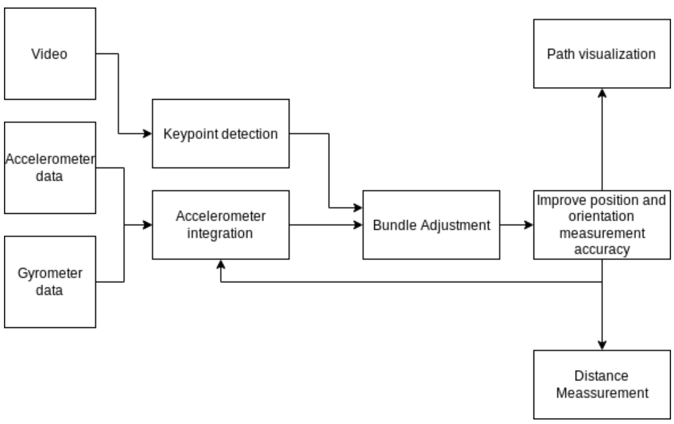

Figure 1: Pipeline

[1] See `https://github.com/e-lab/VideoSensors`

3 Problems and Possible Errors

We encountered multiple problems during the project that finally resulted in the output to not be usable. Firstly, recording synchronized IMU data and video is difficult. Our recording app has not been updated in 5 years and its output is not exactly synchronized. Especially when short and fast rotations are recorded, a difference of one second between IMU data and video results in significant discrepancies between the bundle adjustment and the IMU data. Secondly, the IMU sensors in smartphones are very inaccurate because of noise and its units of measurement are not specified because we did not calibrate the IMU. This also results in gravity correction to be difficult. Finally, the quality of our key-point matching is not ideal, which leads to large outliers in the bundle adjustment results. We try to solve this problem by discarding bundle adjustment results that differ too much from the IMU data and only using the result for 10% of the final position, but this leads to the results close to the IMU data without much improvement. The usage of an uncalibrated camera also increased the complexity of the problem.

4 Experiments and Results

We applied our algorithm to a number of recordings:

Distance measurement We moved the camera from one specified position to another at a known distance, while doing some other movement in between. We hoped to be able to measure the accuracy of the distance between the start and end positions. However, the uncalibrated IMU causes an undefined scale. The top-left image in figure 2 shows the setup used while the bottom-left image shows the measurement result.

Stationary We kept the camera stationary during the entire recording. This was done to determine the accuracy of the IMU and the bundle adjustment algorithm. You can see the result in the top-right image in figure 2. As we do not have any scaling which causes the gravity removal difficult. You can see that the position moved downward over time though the camera is stationary. The bundle adjustment sometimes corrected the error.

Staircase We recorded the path in a staircase moving down by two floors. Our hope was to evaluate the alignment between sdifferent floors. The bottom-right image in figure 2 shows the results. Unfortunately, the results were inconclusive. We also tried to correct the velocity of the IMU-Integration using the results from the bundle adjustments (green dots). However, this did not result in an improvement.

References

[1] Gaurav Gupta, Nishant Kejriwal, Prasun Pallav, Ehtesham Hassan, Swagat Kumar, and Ramya Hebbalaguppe. Indoor Localisation and Navigation on Augmented Reality Devices. In *2016 IEEE International Symposium on Mixed and Augmented Reality (ISMAR-Adjunct)*, pages 107–112. IEEE, sep 2016.

[2] E. Mouragnon, M. Lhuillier, M. Dhome, F. Dekeyser, and P. Sayd. Generic and real-time structure from motion using local bundle adjustment. *Image and Vision Computing*, 27(8):1178–1193, jul 2009.

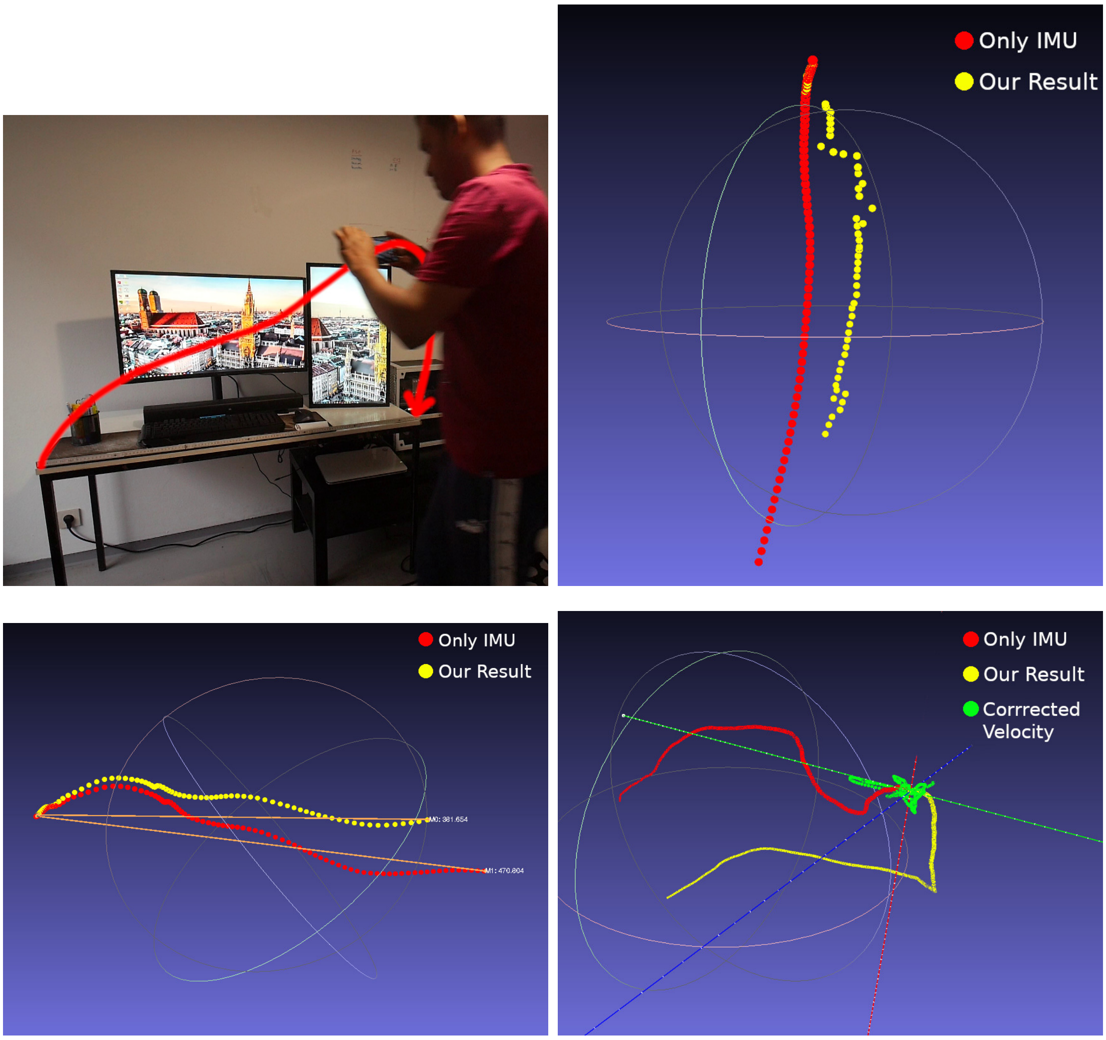

Figure 2: Our Experiments and Results. **Top-Left:** Distance measurement setup; **Botton-Left:** Distance measurement result; **Top-Right:** Stationary measurement result; **Botton-Right:** Staircase measurement result