Online extrinsics calibration for VIO

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Extrinsics include:

- The relative pose between camera and IMU.

$$ {}_wT_b = {}_wT_c \cdot {}_cT_b $$

$$ \begin{bmatrix} {}_wR_b & {}_wt_b \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} {}_wR_c & {}_wt_c \\ 0 & 1 \end{bmatrix} \begin{bmatrix} {}_cR_b & {}_ct_b \\ 0 & 1 \end{bmatrix} $$

$$ \Rightarrow \begin{cases} {}_wR_b = {}_wR_c \cdot {}_cR_b \\ {}_wt_b = {}_wR_c \cdot {}_ct_b + {}_wt_c \end{cases} $$

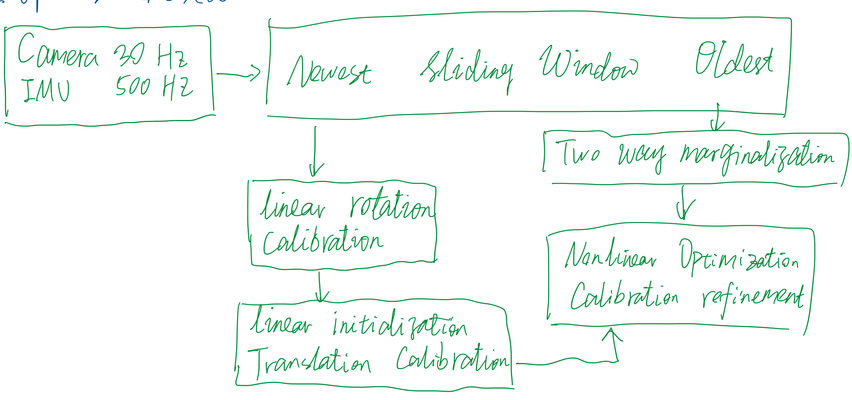
- The time shift between image and IMU.

$$ t_{IMU} = t_{cam} + t_d $$

This delay is different for each run, so we need to calibrate it online.

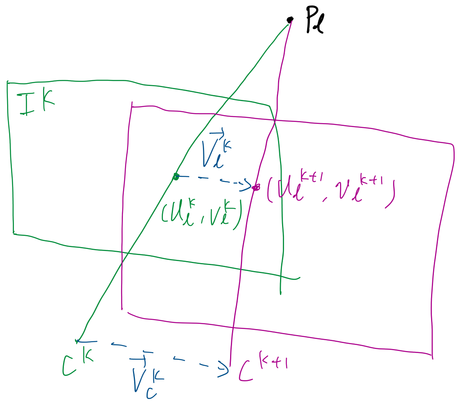
Methods for online calibration from VINS

- Extrinsics calibration
  1. Calibrate the ${}_cR_b$
  2. Calibrate ${}_ct_b$.
  3. Optimize ${}_cR_b$, ${}_ct_b$.



- Time delay calibration

Camera moves from C^k to C^{k+1} in a short time.
The feature also moves from $[u_l^k, v_l^k]$ to $[u_l^{k+1}, v_l^{k+1}]$ on the image.
And its constant velocity is V_l^k.



We can then add time in the optimization of reprojection error:

$$ l_l^k = z_l^k(t_d) - \pi\left({}_wR_{c_k}^{\top}(P_l - {}_wt_{c_k})\right) $$

$$ z_l^k(t_d) = [u_l^k, v_l^k]^{\top} + t_d V_l^k $$

Summary:

	Method	Accuracy	Used when:
Extrinsics Calibration	VINS	1°/0.02m	1. Nonlinear optimization based VIO. 2. extrinsics change slowly with time.
	VI-ORB-SLAM	0.6°/0.05m	1. Nonlinear optimization, and the extrinsics do not change wrt time 2. more efficient, suitable for limited computation device.
Time shift	Pixels move with constant velocity.	0.68 ms	1. nonlinear optimization. 2. simple and less accurate.
	Add time in preintegration.	<0.68 ms	1. nonlinear optimization. 2. more accurate, faster convergence.