Immersive positioning and measuring method in complex and narrow space

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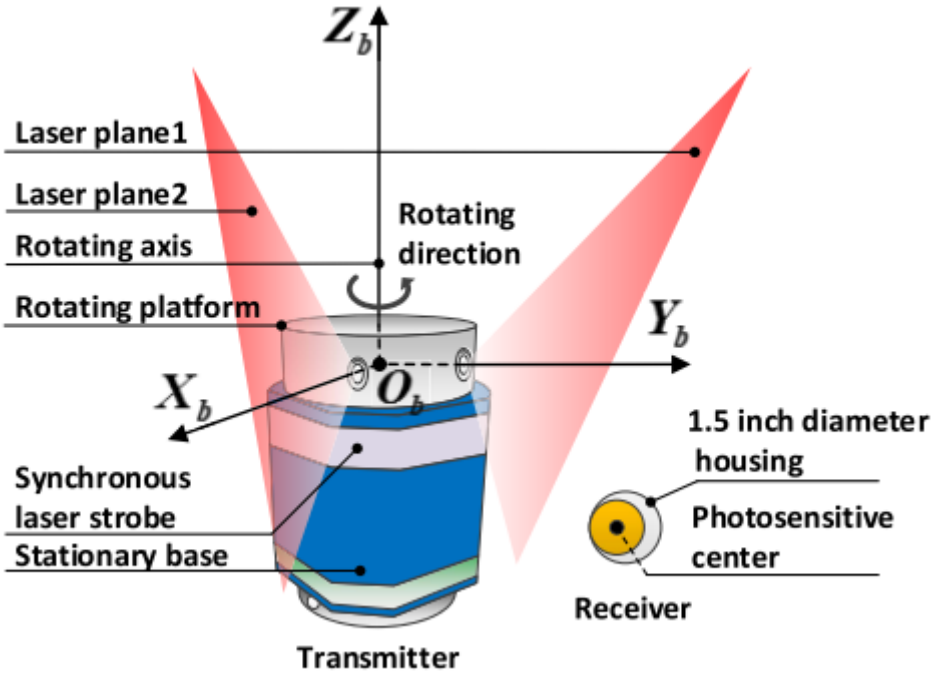
Laser and Optoelectronics Measurement Technology Research Group

Vision Measurement Systems

workshop Measurement Positioning System

workshop Measurement Positioning System



Working range	3-40m
Accuracy of angle measurement	±2″
Measurement frequency	30Hz

Outline

- Backgrounds
- Immersive measurement
- Global positioning
- System calibration
- Experiment
- Summary and outlook

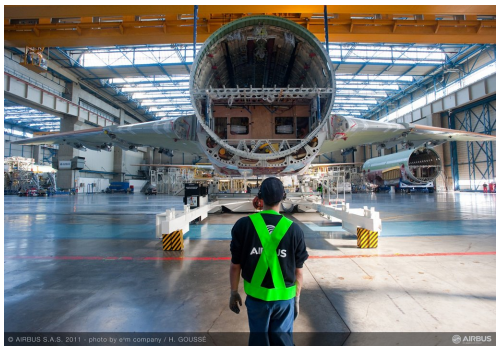
Backgrounds

Flexibility and portability for narrow space in manufacturing

Car

Train

Ship block

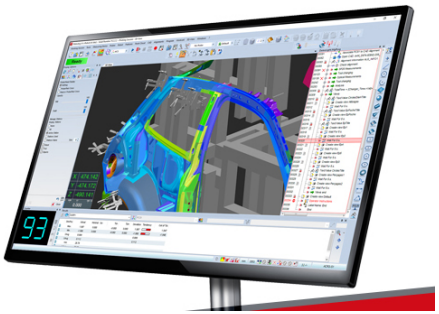


Airplane

Backgrounds

Inconvenience for present display mode

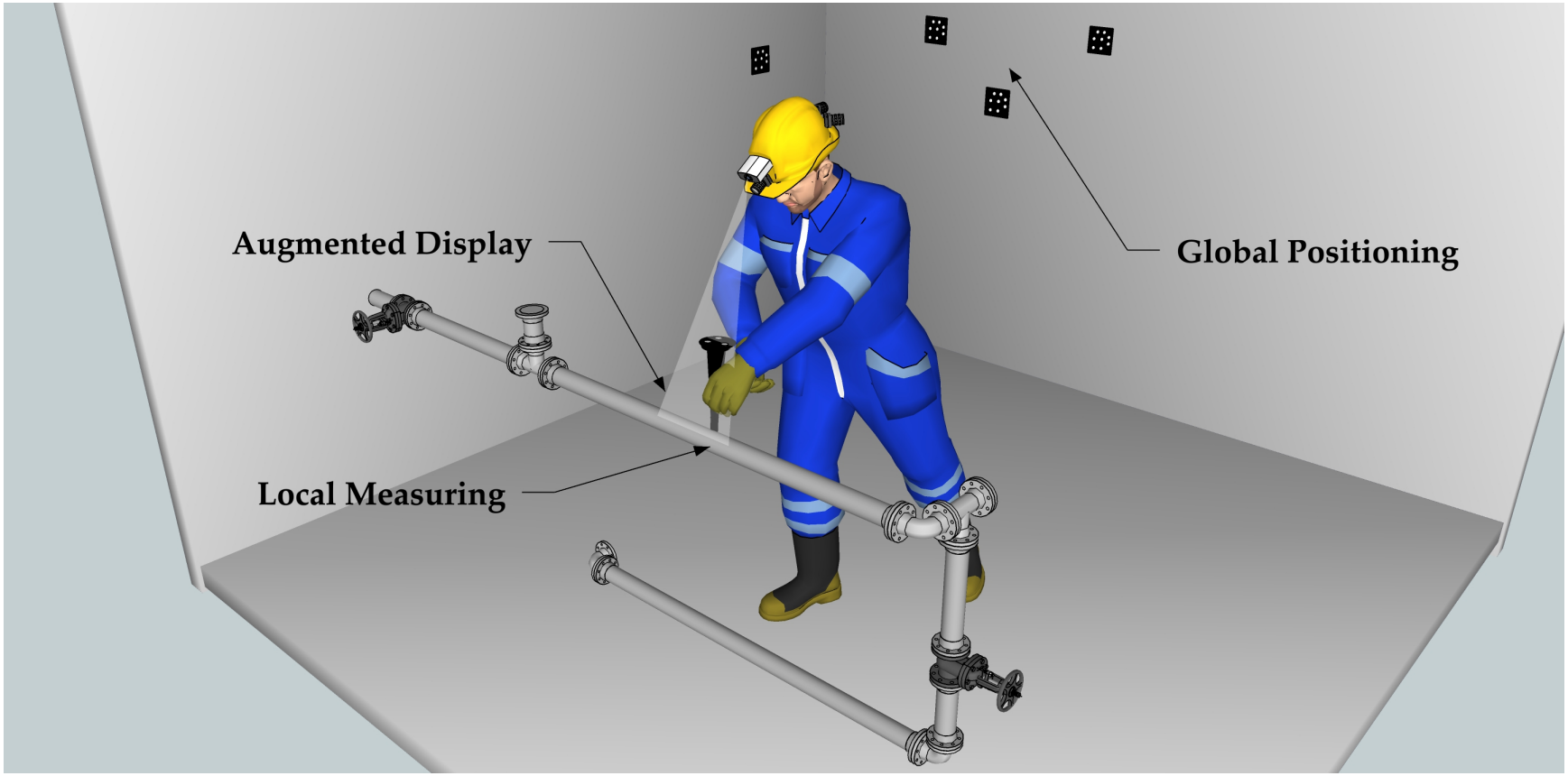
Computer



Augmented reality

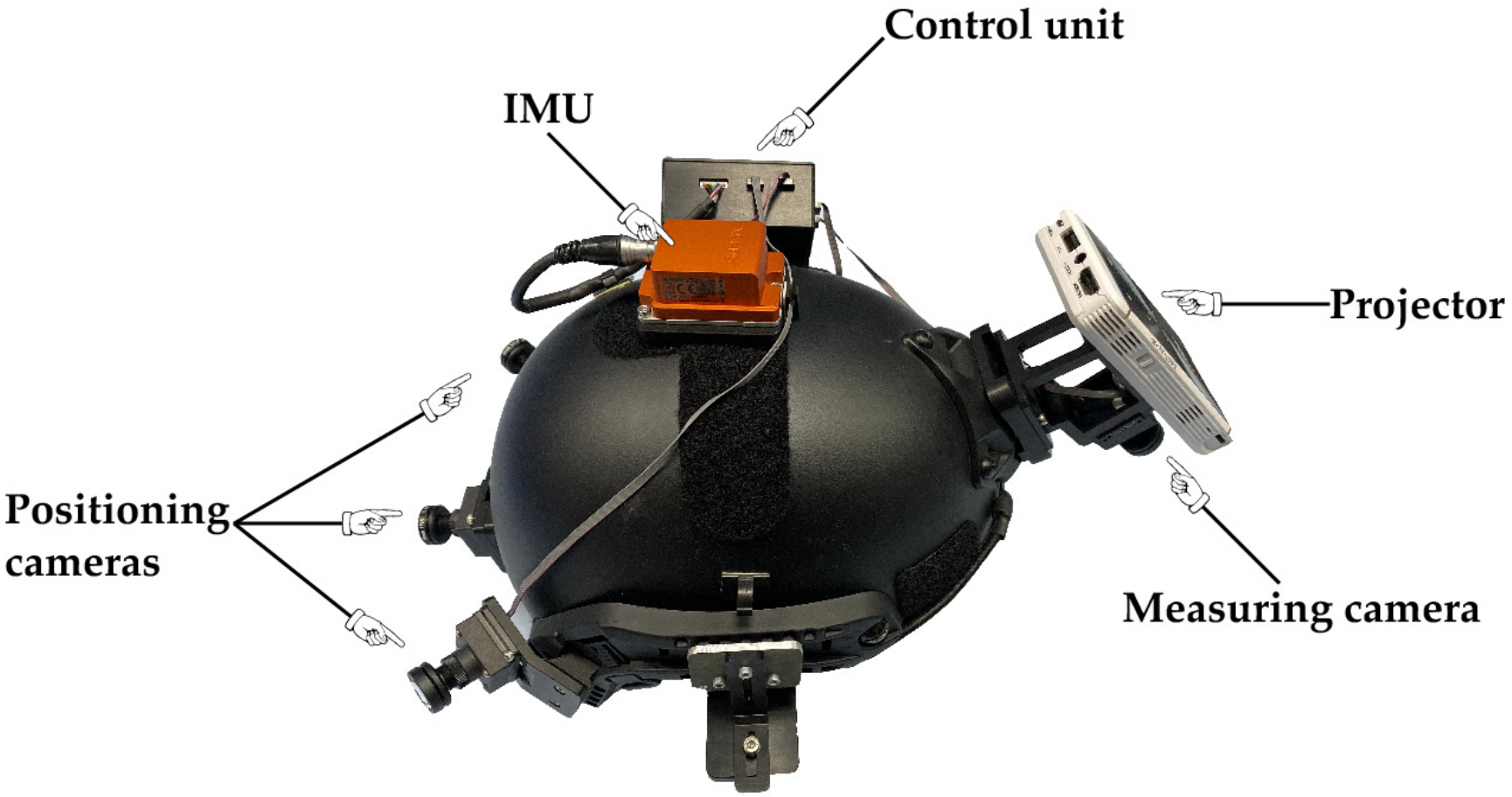
Screen

Immersive measurement



Immersive positioning and measuring method

Immersive measurement



Immersive positioning and measuring helmet

Immersive measurement

Infrared LED marker

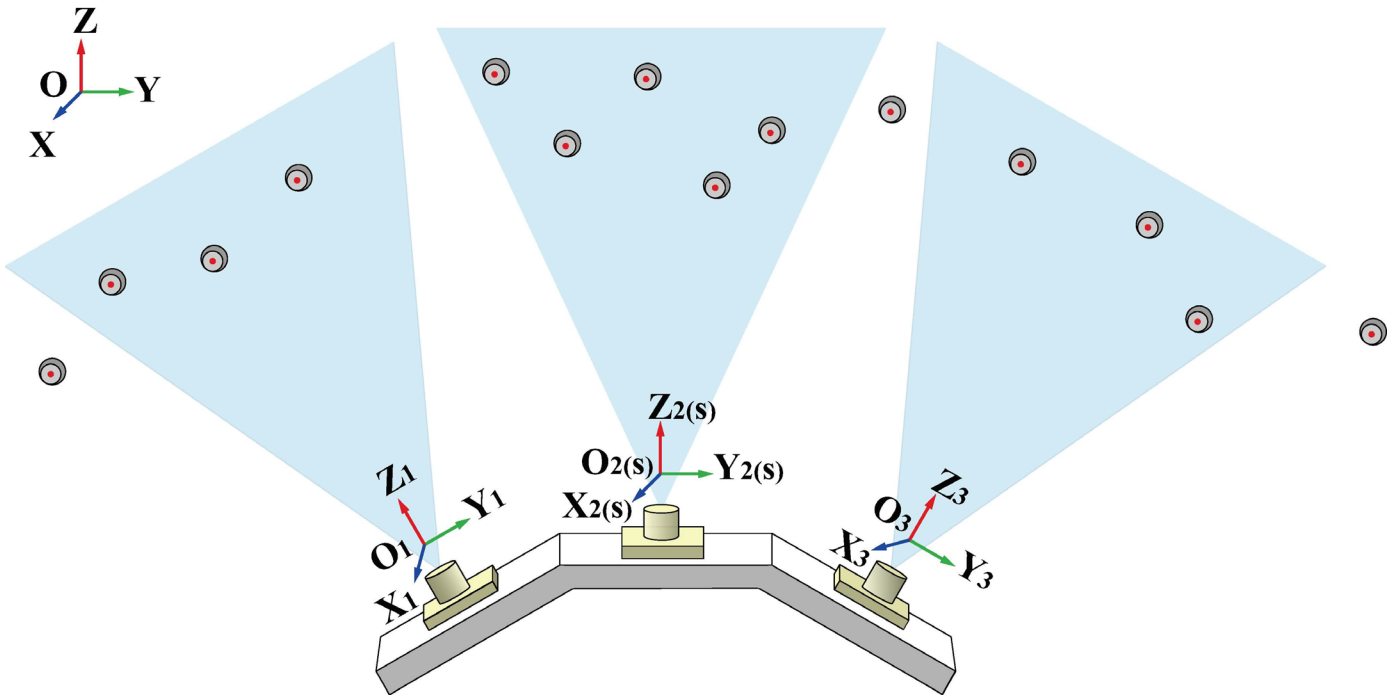
Coordinate transformation using

- ✓ **photogrammetry systems,**
- ✓ **total station**
- ✓ **laser tracker**

Hand-held probe

Global positioning

Multiple cameras with non-overlapping views

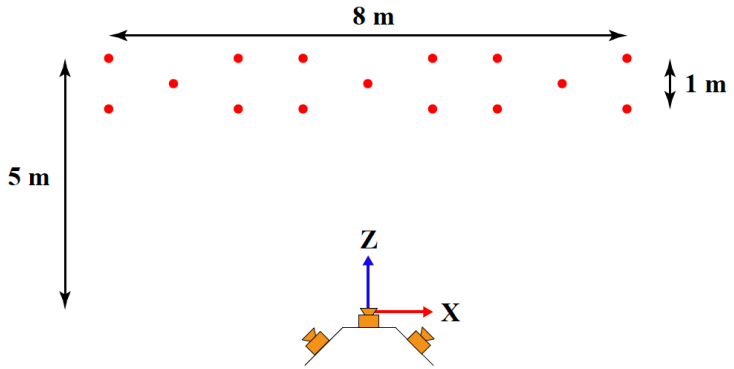


$$\begin{cases} \boldsymbol{X_1} = \boldsymbol{R_{21}X_2} + \boldsymbol{T_{21}} \\ \boldsymbol{X_3} = \boldsymbol{R_{23}X_2} + \boldsymbol{T_{23}} \end{cases}$$

$$F = \sum_{i}^{m}\sum_{j}^{n}\left(e_{ijx}^2 + e_{ijy}^2\right) = \min$$

Global positioning

Comparison between the multi-camera rig with the single camera

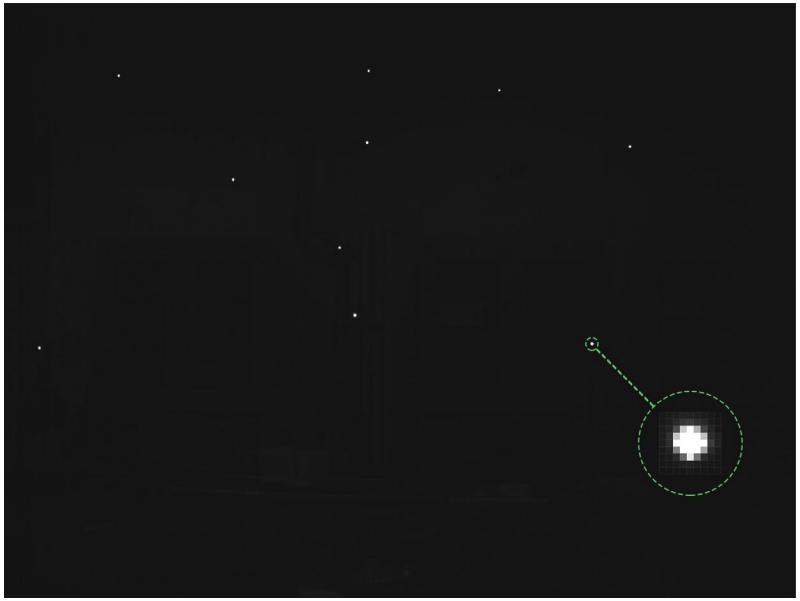


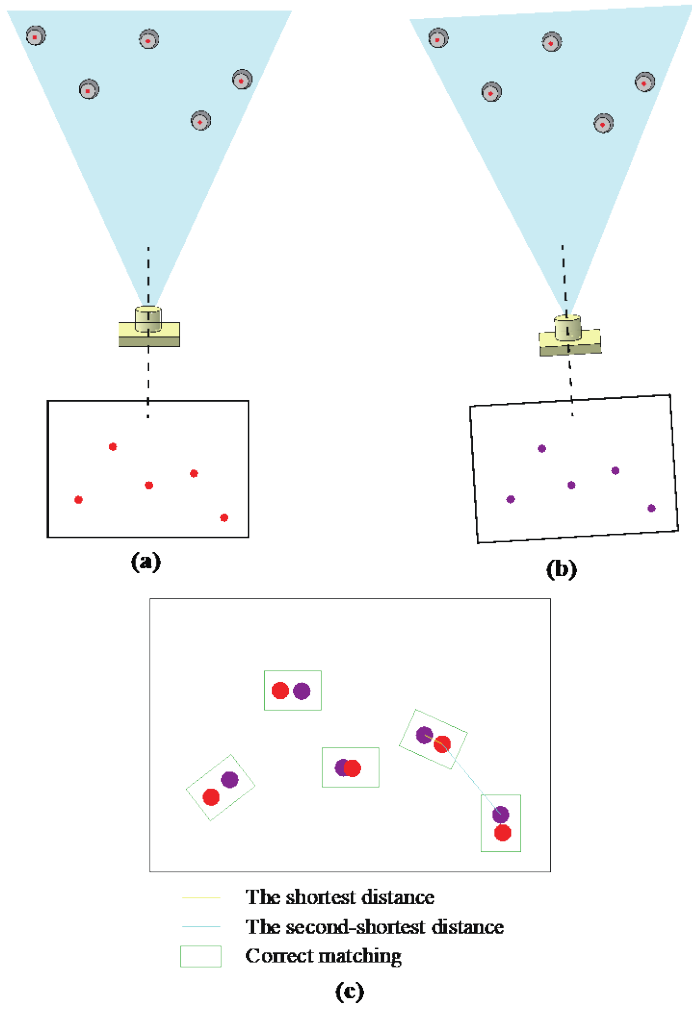
6DOF parameter	The single camera	The multi-camera rig
θ_s (°)	0.0147	0.0087
φ_s (°)	0.0067	0.0084
κ_s (°)	0.0038	0.0065
X_s (mm)	0.715	0.629
Y_s (mm)	1.191	0.754
Z_s (mm)	0.292	0.528

Global positioning

Feature points correspondence

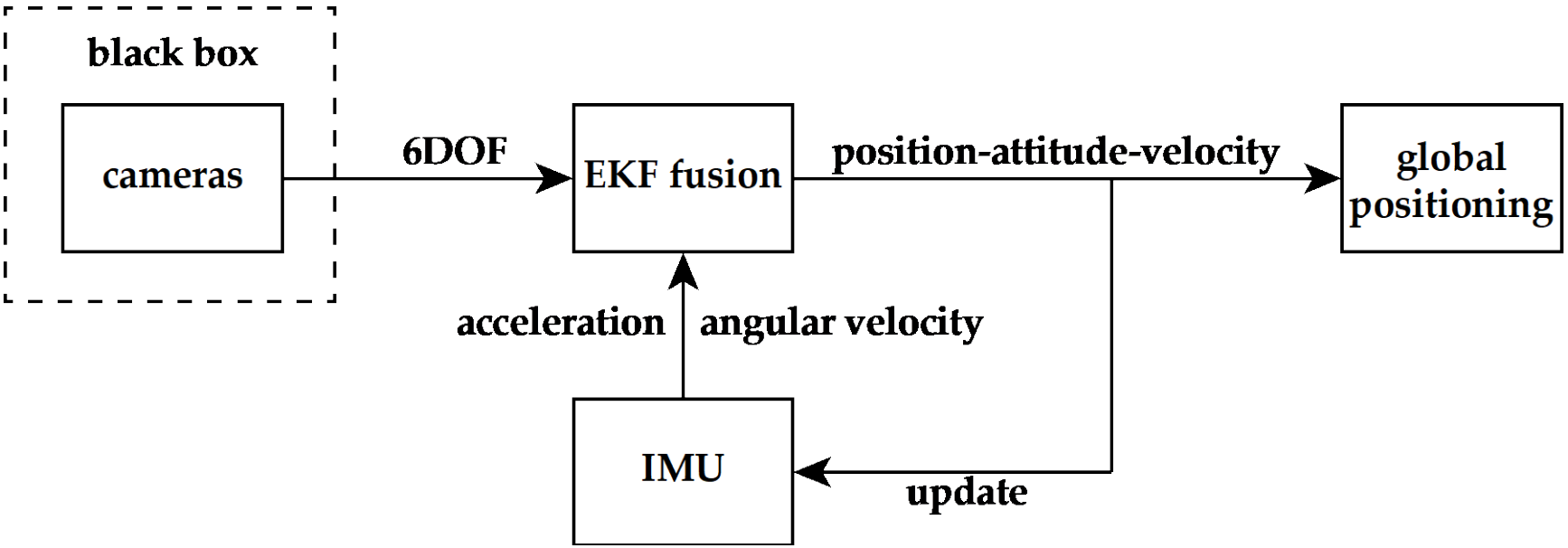
Nearest Neighbor method with reciprocity check





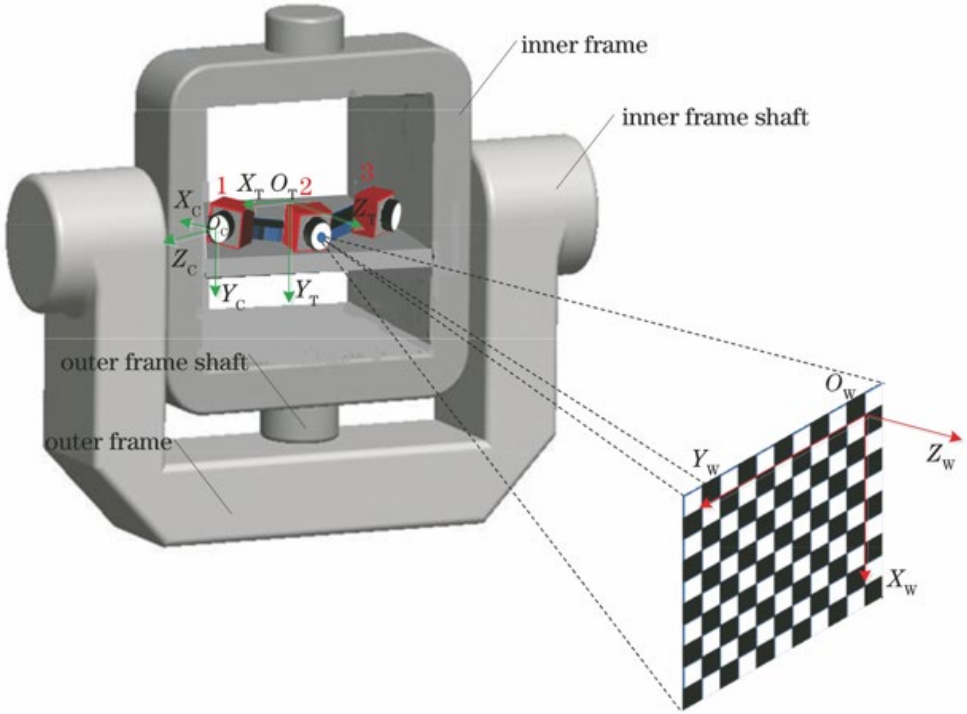
Global positioning

Visual-inertial fusion based on extended Kalman filter



error state vector $\tilde{x} = \left\{ \Delta p_w^{i\,\mathrm{T}} \quad \Delta v_w^{i\,\mathrm{T}} \quad \Delta \theta_w^{i\,\mathrm{T}} \quad \Delta b_w^{\mathrm{T}} \quad \Delta b_a^{\mathrm{T}} \right\}$

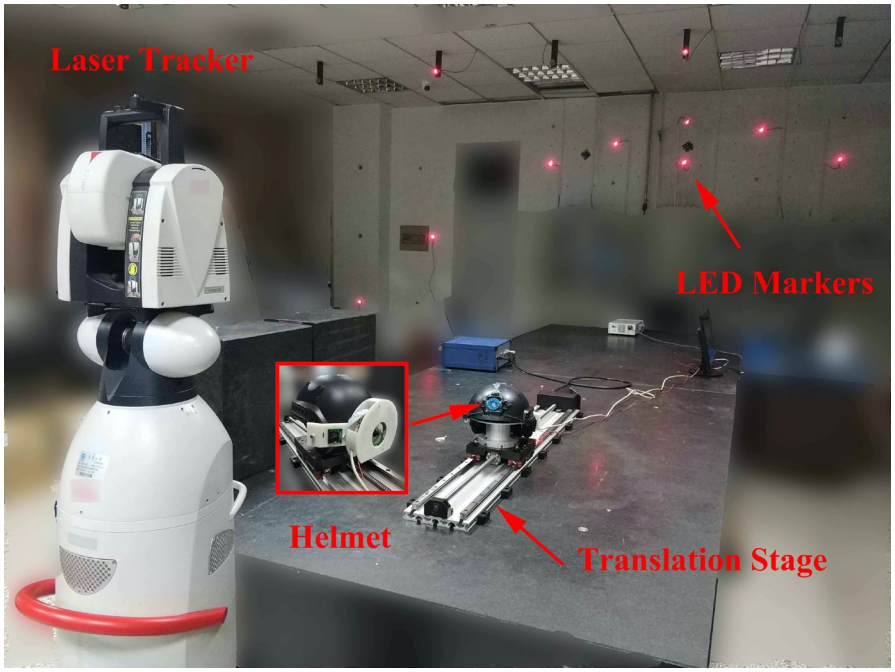
System calibration



$$Z_{Ck}\begin{bmatrix} u_k \\ v_k \\ 1 \end{bmatrix} = \begin{bmatrix} 1/d_x & 0 & u_0 \\ 0 & 1/d_y & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} R_{CT} & T_{CT} \\ 0 & 1 \end{bmatrix}^{-1} \begin{bmatrix} R_{Tk} & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} R_{CT} & T_{CT} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} R_1 & T_1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} X_W \\ Y_W \\ Z_W \\ 1 \end{bmatrix}$$

Experiment

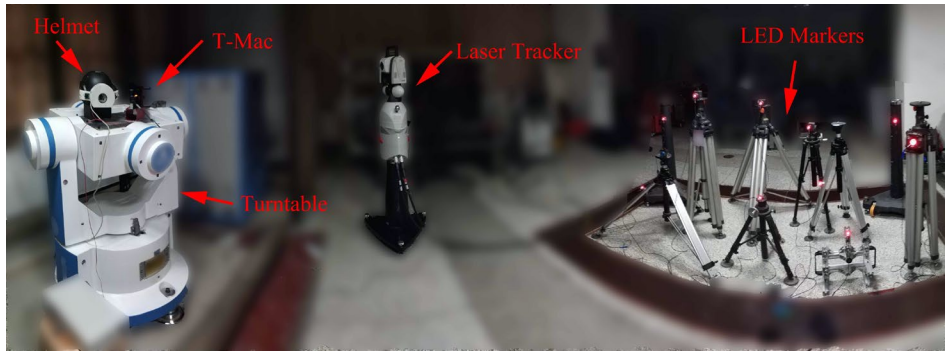
Distance measurement

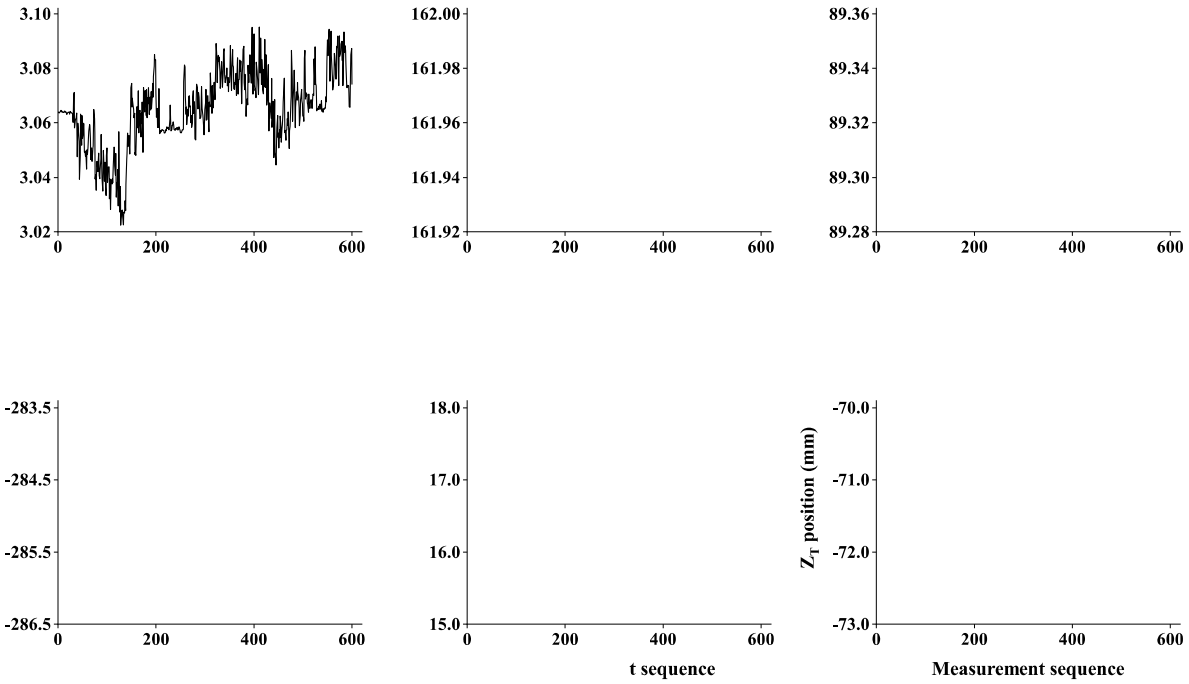


Position	Multi-camera rig	Laser tracker	Error
1	900.567	900.330	0.237
2	900.436	900.242	0.194
3	900.064	900.247	-0.183
4	899.970	900.381	-0.411
5	899.848	900.318	-0.470
6	899.594	900.207	-0.613
7	899.968	900.347	-0.379
8	900.588	900.185	0.403
9	900.863	900.342	0.521

RMS error = 0.383 mm

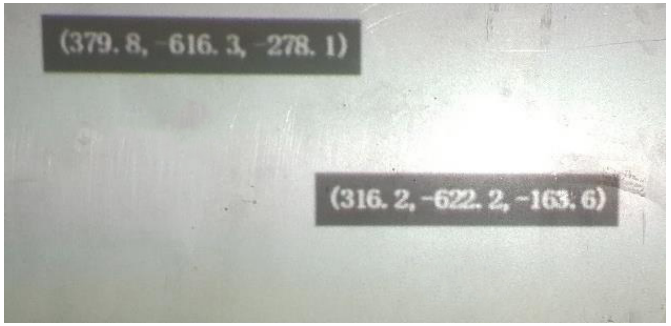
Experiment





Position error better than 0.8 mm

Experiment



Summary

1. An immersive positioning and measuring method is proposed, and the system architecture is elaborated.
2. The global positioning method using a non-overlapping multi-camera rig is introduced, and the visual-inertial fusion framework is built to realize robust 6DOF measurement.
3. The experiments demonstrate the feasibility of the measuring system and the result can be overlaid onto the object accurately.

Outlook

1. Improve the design of the helmet to make it easier and more convenient to use.
2. Conduct more tests in the real working scene to validate the performance of our system.

Thank you for listening!

Welcome to visit Tianjin University

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