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Development of a monocular vision system for robotic drilling

Key words: Vision system, Robotic drilling, Error measurement, Elliptical contour extraction, Hand-eye calibration

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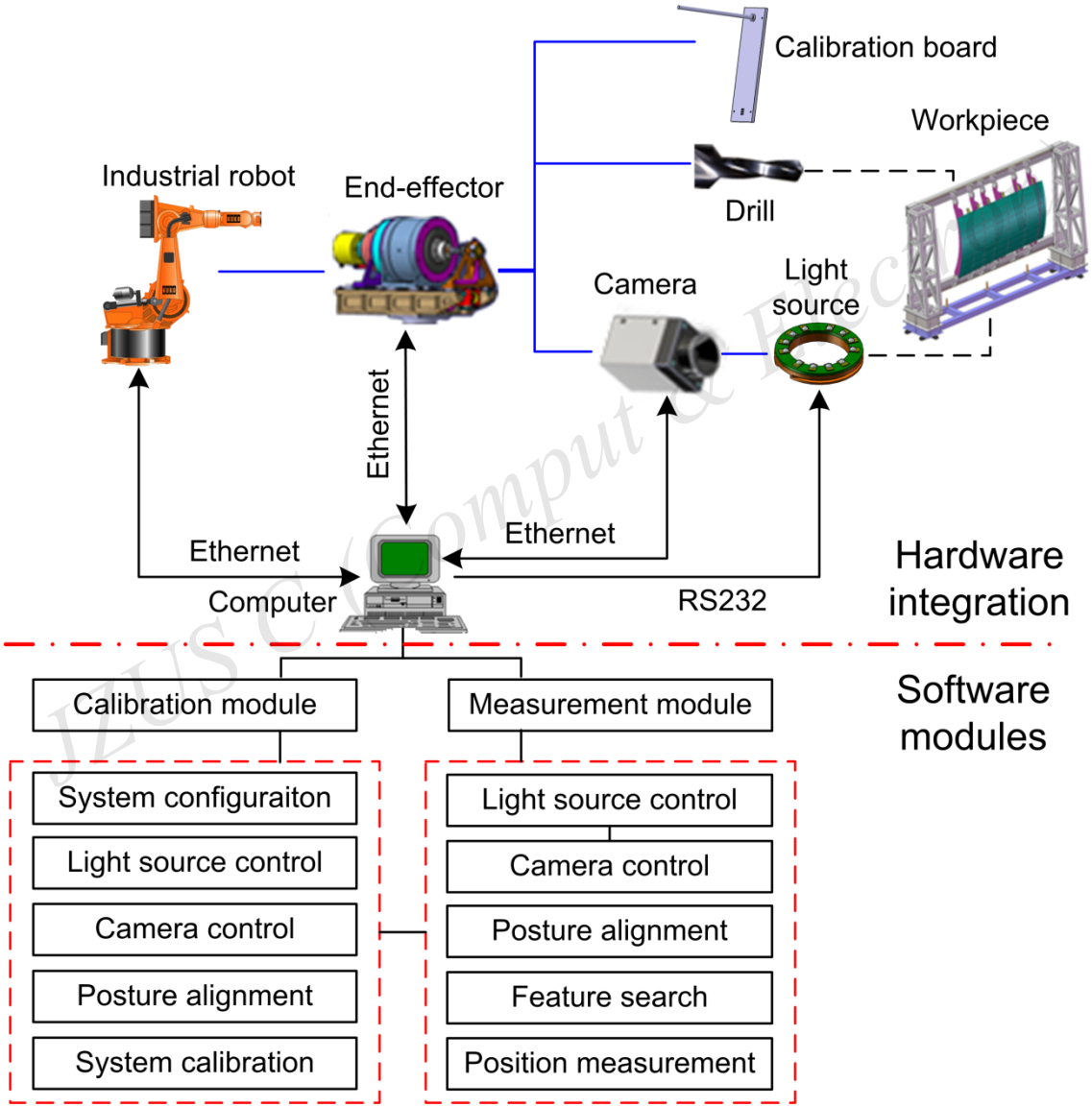
Motivation

- Develop a low cost and high-accuracy monocular vision system to measure relative errors between the drill TCP and the workpiece, so as to achieve higher positioning accuracy of the robot in robotic drilling for aeronautical structures.
- Disadvantages of existing research:
  - The cost of existing vision systems is relatively high.
  - The measurement accuracy of the developed vision systems in the literature needs to be improved.
  - An accurate explanation of the working principle of vision systems has been omitted in the literature.

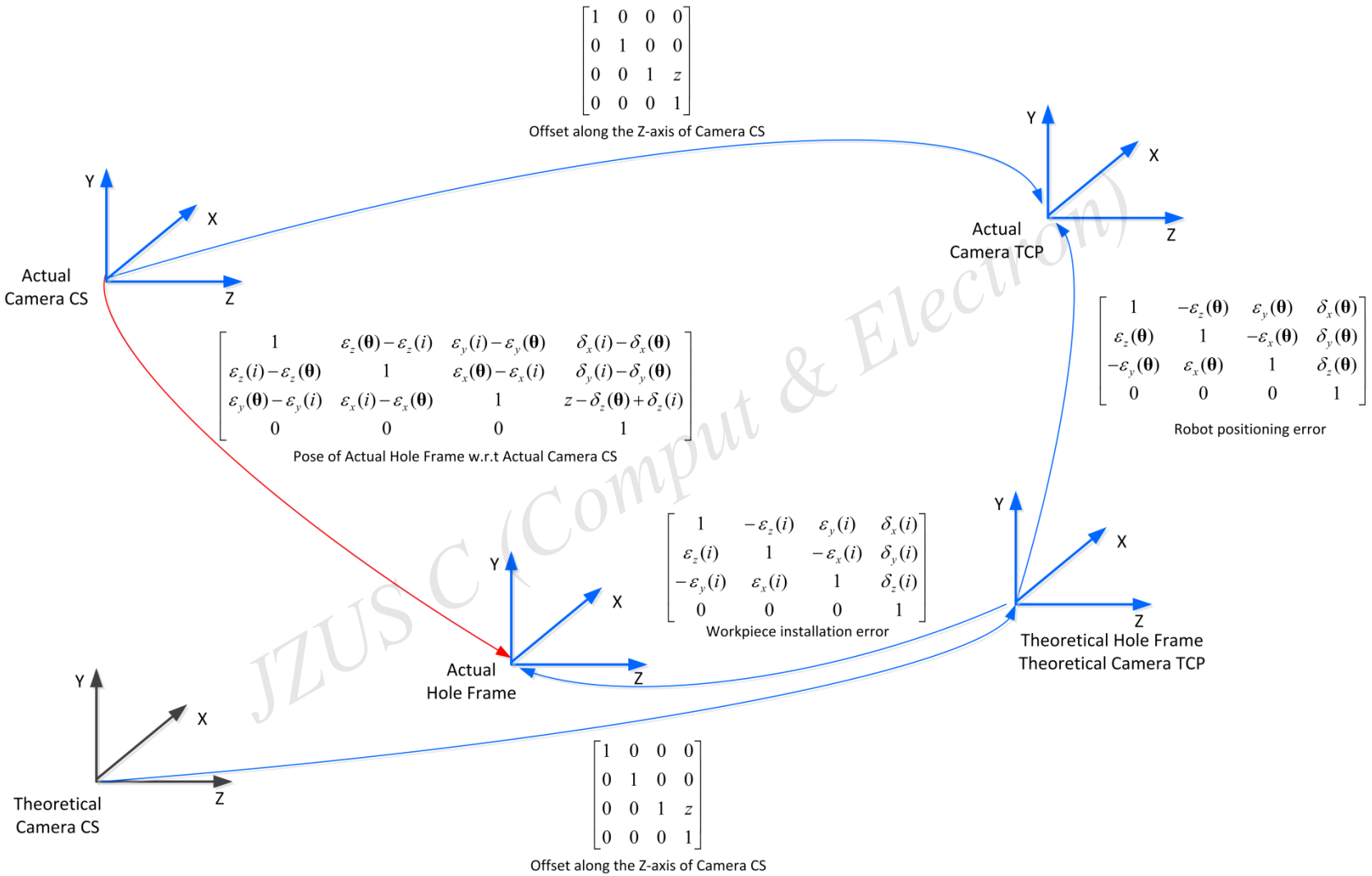
Architecture of the vision system



Features

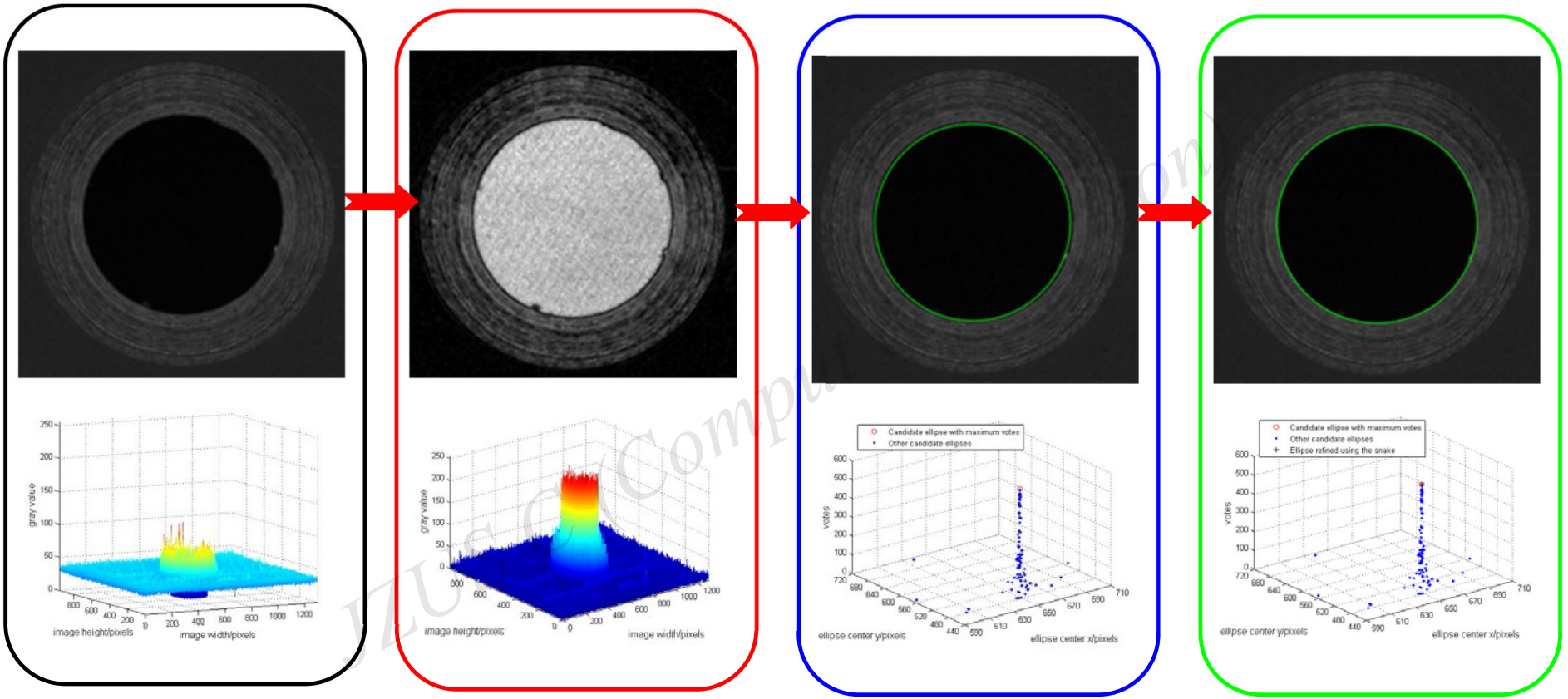
- A deeper understanding of the working principle of the vision system
- A novel elliptical contour extraction algorithm for accurate and robust reference hole detection
- Simultaneous calibration of camera internal parameters and hand-eye relationship

(I) Relative error measurement



No Abbe error is introduced in the relative error measurement of the monocular vision system when the camera TCP is defined as an offset of the camera CS along its *Z*-axis by object distance.

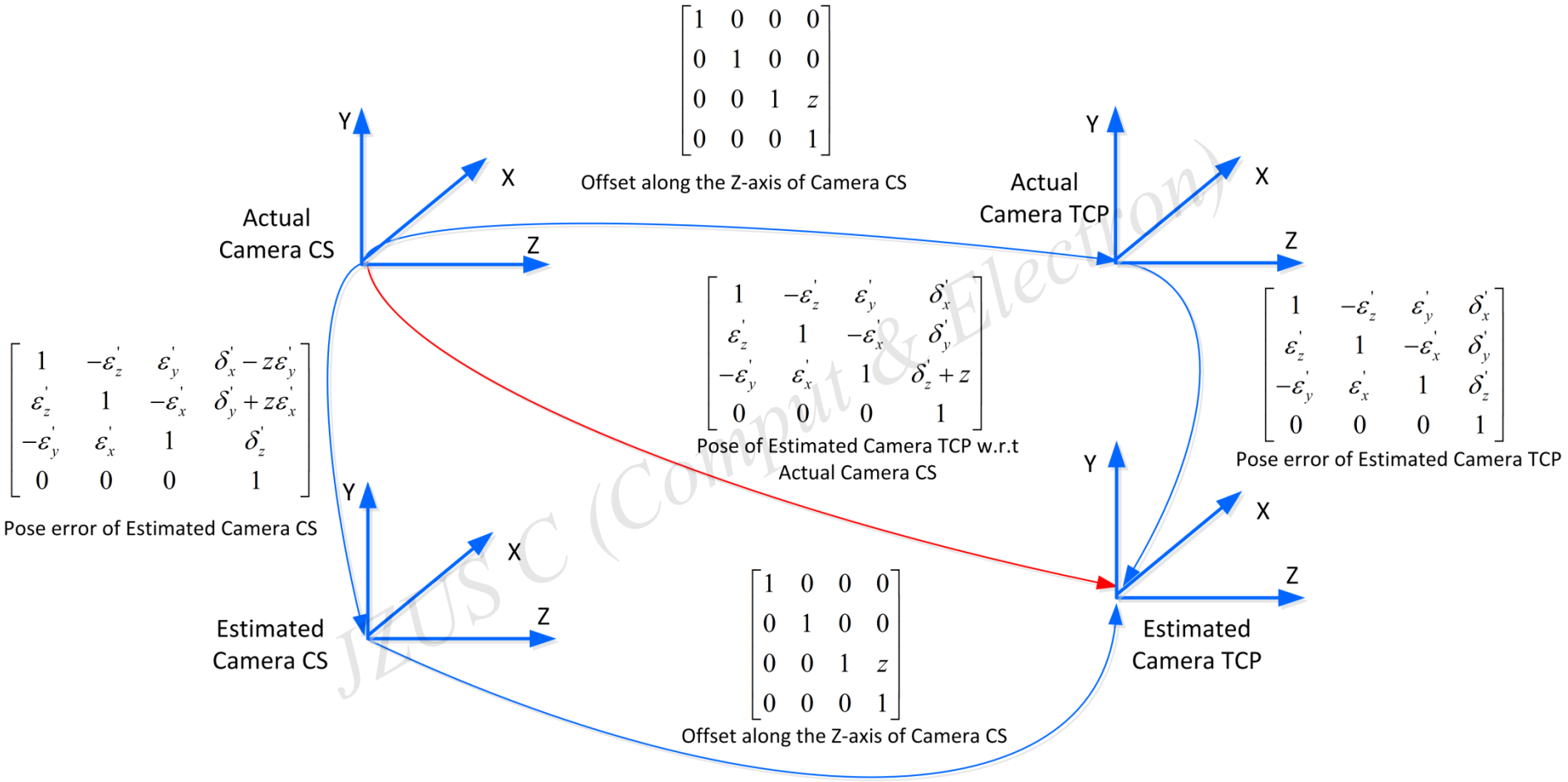
(II) Elliptical contour extraction



Original Image → **Salient region detection** → **Voting** → **Optimization with snake**

The robust elliptical contour extraction method comprises three stages:
(1) salient region detection; (2) voting; (3) optimization with the Snake model.

(III) Vision system calibration



Simultaneous calibration of camera internal parameters and hand-eye relationship is enabled using this practical and accurate calibration method with a dedicated calibration board.

Experimental results

We compute the distance between reference holes and the ball-shaped drill axis, which is pre-aligned with the center lines of the reference holes using the position coordinates of the reference holes obtained with the developed vision system. Results of experiments performed on a robotic drilling system are shown below:

Number	Center coordinates of the optical target	Parameters of the ball-shaped drill axis (direction vector of drill axis/one point on the axis)	Distance (mm)
Hole 1	−2366.422,1413.671,971.788	12.699,23.868,0.039/−2377.472,1393.026,971.694	0.084
Hole 2	−2432.467,1446.628,1038.065	12.699,23.868,0.039/−2377.472,1393.026,971.694	0.077
Hole 3	−2299.542,1379.751,970.621	12.699,23.868,0.039/−2377.472,1393.026,971.694	0.079
Hole 4	−2365.810,1412.536,1036.981	12.699,23.868,0.039/−2377.472,1393.026,971.694	0.108
Hole 5	−2433.221,1447.462,973.104	12.699,23.868,0.039/−2377.472,1393.026,971.694	0.115
Hole 6	−2499.462,1480.494,1039.459	12.699,23.868,0.039/−2377.472,1393.026,971.694	0.141