# Distortion Measurement of Large Crane Arms in Loading Test Based on Series-Parallel Cameras Net Videometrics

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Large crane arms have complex structure, large working range and large lifting weight. In working state, the distortion and stress of such crane arms was complex. To keep safety in lifting work and estimate the real working radius, it was necessary to test and analyze the arm's distortion and stress parameters in working states with different arm length, working radius and lifting weight etc. To measure lots of key positions' distortion precisely was the basic work for stress analysis.

Videometrics was an important and effective method to measure the large structure's distortion and movement in large field. We designed a series-parallel cameras net videometrics system made up of a group of series cameras and parallel cameras, to measure the large crane arms' distortion parameters in chosen working states precisely. For the crane arms of nearly one hundred meters length, the distortion measurement precision was several centimeters.

The videometrics method of series relay cameras was a new theory proposed by the group of the authors. It was successfully applied to measure multi-positions' distortion of large and sightless structures. Figure 1 showed the theory of this method. Cameras, cooperative symbols, or their combinations were installed on the reference position and the measurement positions of the large structure to form the series cameras measurement system's relay stations. Every relay station's camera was used to observe the next station's cooperative symbols. So every two neighboring stations relative pose could be calculated. Then we transferred and syncretized these stations' measurement results to reach every station's pose relative to the reference station. So the measurement positions' distortion parameters could be reached. The series cameras were constructed on the crane arm as shown in figure 2. From the underpan to the ends of the main arm and the vice-arm, lots of positions' distortion relative to the underpan could be calculated by such transfer calculation.

Cameras of the parallel net were distributed on the ground around the crane. Some of the cameras' view field covered with whole of the crane arm and the vehicle as shown in figure 3. Other cameras' view field covered with parts of the crane arm or the vehicle separately as shown in figure 4. On the crane arm and the vehicle, lots of cooperative symbols were disposed. All of the cameras were controlled to shot synchronously. Then the cooperative symbols including those in the above relay stations were extracted in the images. The cooperative symbols extraction results and the cameras' parameters were used together to reach the crane arms precise distortion results by bundle adjustment.

Parameters of the cameras were calibrated before the loading tests. The series cameras' intrinsic parameters (focal lengths and distortion coefficients) and the extrinsic parameters relative to the fixed cooperative symbols were calibrated in the laboratory. After calibration, the relay stations with changeless states were installed on the crane arm. The parallel cameras intrinsic and extrinsic parameters were both calibrated in field. Such calibration needed some control points with precisely known coordinates in space. Before the loading test, we took the cooperative symbols on the crane arms in some stations as control points. These control points' coordinates in space were measured by using a total station.

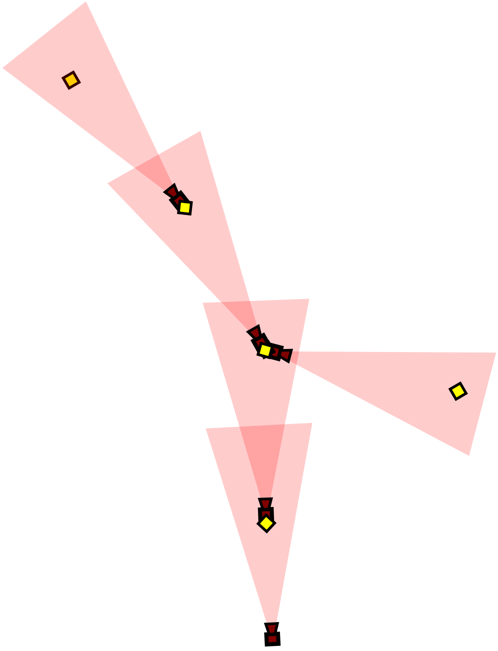

Fig. 1 A sketch map of the theory of series cameras measurement, where the baby pink field was the cameras view field, and the yellow diamonds were the cooperative symbols.

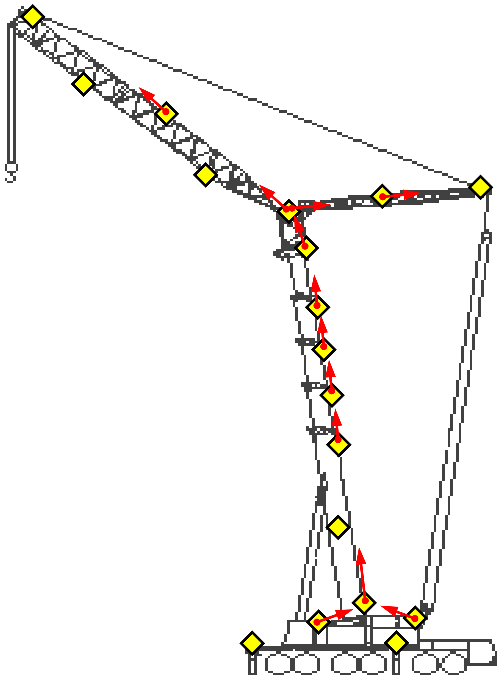

Fig. 2 A side view of series cameras net installed on the crane arm and the vehicle, where the red arrows were the cameras' observational direction, and the yellow diamonds were the cooperative symbols.

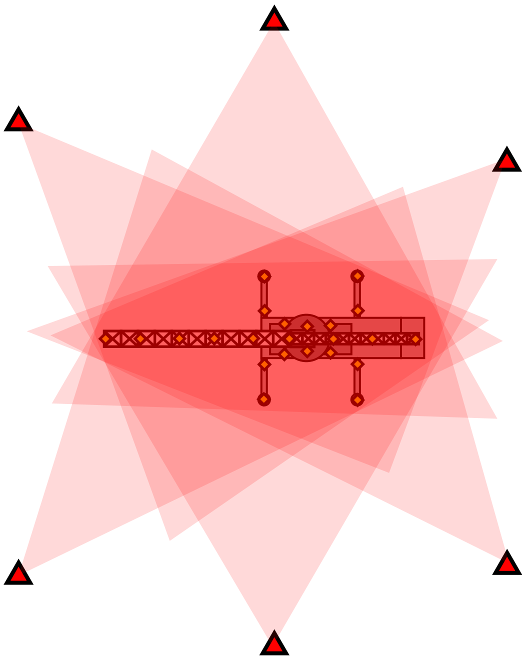

Fig. 3 A planform of the full field measurement parallel cameras distributed around the crane, where the red triangles were the cameras installed positions, the baby pink field was the cameras' view field, and the yellow diamonds were the cooperative symbols.

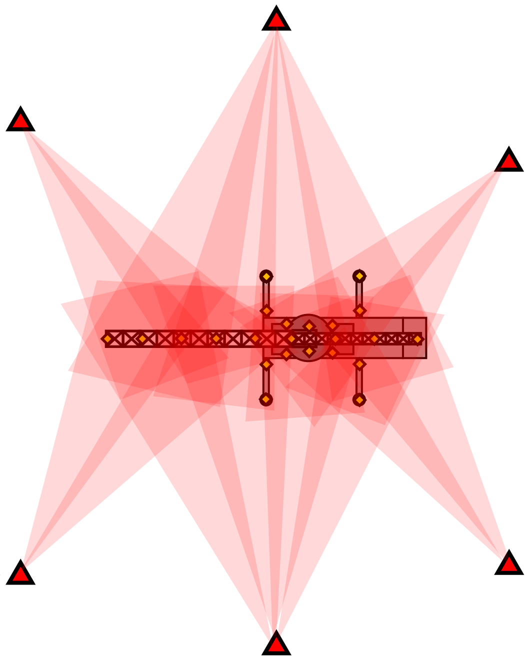

Fig. 4 A planform of the part field measurement parallel cameras distributed around the crane, where the red triangles were the cameras installed positions, the baby pink field was the cameras' view field, and the yellow diamonds were the cooperative symbols.