# AUTOMATIC MODELLING METHOD FOR STEEL STRUCTURES USING PHOTOGRAMMETRY

S. H. Jung[a], J. H. Yu[a*], J. K. Lee[b], L. Ge[a]

[a] School of Surveying and Spatial Information Systems, University of New South Wales, Sydney, NSW, Australia - jung.yu@student.unsw.edu.au
[b] Department of Civil engineering, Chungbuk National University, Cheongju, Republic of Korea

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**ABSTRACT:**

Industrial Photogrammetry which has advantages of high accuracy and fast measurement time is widely used in the manufacture measurement application. Especially, industrial photogrammetry has more powerful capability of quickness in the 3 dimensional coordinate measurement then comparing with optical measurement system like total station, laser tracker and laser scanner. The purpose of this paper is to improve product quality and shorten working term by 3D precise measurement of steel box girder shape using industrial photogrammetry method. This method is expected replacement to the pre-assemble step which is test fabrication with each box girder before shipment. In addition, the proposed target calibration technique use template data which has correction data of each coded target thickness and relationship between coded target and hole adapter. Moreover, length and corner point of members and bolt hole position are defined using corrected coded targets. In the result, this research technique expects that calibrated target can be used to decrease the number of target, auto-modelling procedure can decrease the overall processing time, and the automatic procedure time is approximately 50% decreased than normal manual procedure in the steel box girder measurement.

## 1. INTRODUCTION

Recently, photogrammetry is used in high precision measurement with a few micrometers accuracy. It has higher accuracy and fast measurement for huge measurement points in special shape, such as corner of members and bolt hole by comparing to other high precision equipments which are Total station, laser tracker and laser scanner. This research focuses on target field calibration of target thickness and gradient value, storage of each calibrated data to template file and auto-correction using calibrated target data when object measurement for improve the accuracy of photogrammetry.

The principal procedures of industrial photogrammetry for steel box girder have four steps. First step is to set the coded and/or reflect target on the members. Second step is to take photo using metric camera or well-calibrated semi metric camera. Third step is target recognition using the digital image processing methods. Final step is object modelling using recognized points coordinates of third step (Yu, 2006). In these steps, target setting and object modelling take more time and have more difficulties depending on the complexity of the members and numbers of points. Modelling procedure needs to be done manually so that it takes more time comparing to the processing steps. In the accuracy part of modelling, precision measurement equipment like a micrometer measures target thickness and gradient value for correction of target external shape errors after data processing (Jung, 2005). If the object shape is simple feature and has fixed curvature, this post procedure spends less time. However, if the shape of object is more complex shape and curvature, a post procedure needs more time depending on its complex level. The types of coded target used in industrial photogrammetry are varied depending on solution. Coded target uses light sensitive reflector and we measure the centre of circle reflector in coded target. Special pattern around the circle establishes the peculiar number for distinguishing each target. Each coded target have different thickness and even in the same target, corner thickness is different. INCA3 camera is used for

taking the photo and image is processed in orientation and simultaneous bundle adjustment.

For auto-modelling, calibrated target is set according to a working rule and the coordinate of the centre and the nugget at the measured target matching with template data. Lines and points are defined using surface information which is included in the template data. In summary, line is defined using crossing on the surface and point is generated using defined line. Proposed technique enforces 3D measurement of steel box girder. The 3D modelling procedure is automatically processed using calibrated target and auto modelling system (Karara, 1989; Mikhail, 2001; Wolf, 2000).

## 2. SYSTEM AND TARGET VERIFICATION

### 2.1 System Accuracy Verification



Figure 1. INCA3 digital camera

Before the main study, industrial photogrammetric system which is used INCA3 digital camera experiment accuracy verification in the laboratory. Control points are set up total 13 points on the two planes; 8 points in the first plane and 5 points

in the second plane. There are measured by trigonometric levelling using 1 second theodolite (Wild T-2). INCA3 digital camera take images in the same condition and these images are processed in the V-STARS system (Brown, 1998; Edmundson, 1998). Figure 1 is shown camera shape.

| | X | Y | Z |
|---|---|---|---|
| RMSE | 0.04mm | 0.03mm | 0.05mm |

Table 1. Accuracy result of system

**2.2 Target Field Calibration**

Recently, many types of coded target are used for industrial photogrammetry depend on the solution of software. In this study, we used photogrammetric coded target which are produced by HUBBS MACHINE & MANUFACTURING. Normally, coded target is measured about centre position of circle which is located in middle of target and is made by light sensitive reflection material. The peculiar designed pattern; called 'nugget' around of circle orders individual numbers to each target. Coded target using the test have approximately 0.125mm thickness. However, there are attached different types of shape material and/or plastic adapter depend on the goal of usage. Attached coded targets have different thickness of four corners in same target furthermore, each target has different thickness. For highly accurate surveying like a few micrometer accuracy, targets have to have thickness correction (Ganci, 2000).

Figure 2. Target setting for calibration

32 pieces of coded targets which use in the field were established on the steel standard wall for target calibration. The circle targets which have 0.125mm thickness were spread around the coded target for measuring the standard wall. In addition, auto-bar was used for coordinate system and two scale bars (1,096mm, 596mm) were used for accurate measurement. INCA3 digital camera had taken 19 images. Centre coordinates of coded targets, circle targets, and nugget were measured from images using auto target processing and orientation and bundle adjustment. Then, circle targets were offset 0.125mm for project correction of real object. Template surface were produced using four circle targets around coded target. In addition, one coded target (centre point, nugget point) and four circle targets (point, surface) were stored to template file. Calibrated coded targets

and template files are used for auto correction of surveying data and auto modelling in the field.
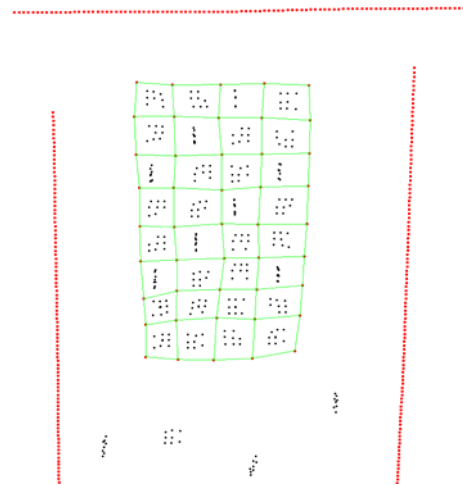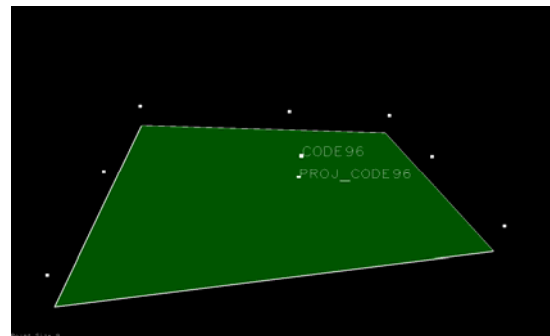
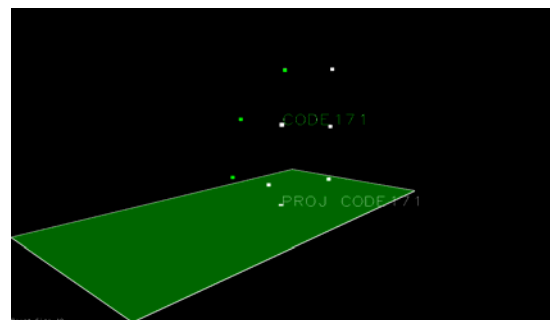Figure 3. Target points of each target

Figure 4. Plate-type Coded target

Figure 5. L-type target

**2.3 Bolt Hole Target Calibration**

Bolt hole measurement at the large object have difficulty by photogrammetry and other surveying systems. Normally, to hole measuring using photogrammetry, over three edge targets are used around the hole. And centre of hole is calculated by these edge target points.

Bolt hole target is produced to reduce the target setting time and auto-processing. Bolt hole target is composed L-type coded target and hole adapter.
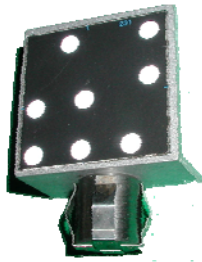
Figure 6. Bolt hole target

Bolt hole target calibration has 7 steps; (1) Target setting around the steel plate for calibration (coded target, auto-bar, and 596mm scale bar 2ea) (2) Edge target setting in the hole and edge of steel plate (3) Centre position calculation using edge target (4) Bolt hole target setting at same position (5) Target identification and plane definition about bolt hole target (6) Position matching with centre of hole and bolt hole target (7) template data definition. The target plane is calculated by nugget in the coded target. The template data has relationship between hole centre and code target plane and each code target information and composition. Target calibration is repeated three times according to the above steps. Measurement error is 0.05~0.1mm.



Figure 7. Conventional hole measurement



Figure 8. target setting by conventional hole measurement



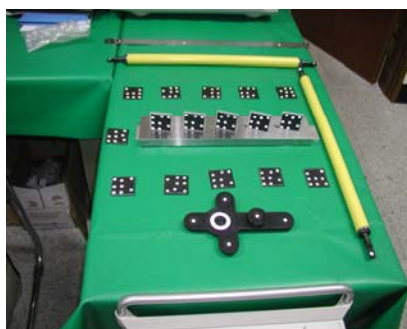Figure 9. 3D result from Conventional hole measurement
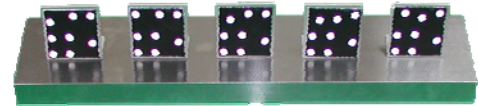


Figure 10. Proposed hole measurement



Figure 11. Target setting by proposed hole measurement



Figure 12. 3D result from proposed hole measurement

## 3. FIELD TEST

### 3.1 Accurate Measurement Using Calibrated Coded Target

In the industrial photogrammetry, typically, structure modelling briefly has two parts; (1) establish targets on the object (2) supervised processing using measured target position. These methods are taken long time for set up the targets, needed many targets and reduced the modelling accuracy. Figure 13 is shown conventional target setting and composition. However, utilization of calibration data of target is reducing the number of targets and improving modelling accuracy and auto-modelling process. Like table 2 and table 3, Calibrated targets were set up according to a working rule and target centre point and nugget coordinates were adjusted with template data. In this step, lines and points were determined using surface information which is included in the template data. In summary, line is defined using crossing on the surface and point is generated using defined line. In this study, one set of calibrated coded target is consisting of two pieces of plane coded targets and one piece of L type target. Figure 14 is shown target setting and composition using the proposed field calibrated target.

One intersection point between three planes is defined as CORN1. Furthermore, according to the same principle, each intersection points are defined as CORN2, CORN3, … . It is defined merge condition for automatic line connection using defined CORN# point.
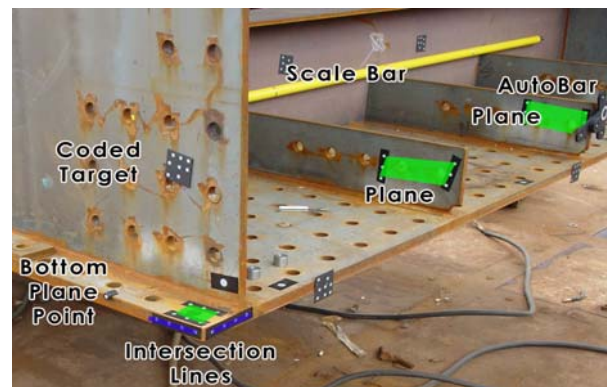


Figure 13. Target setting for corner point measurement using conventional method

Figure 14. Target setting for corner point measurement using field calibrated target
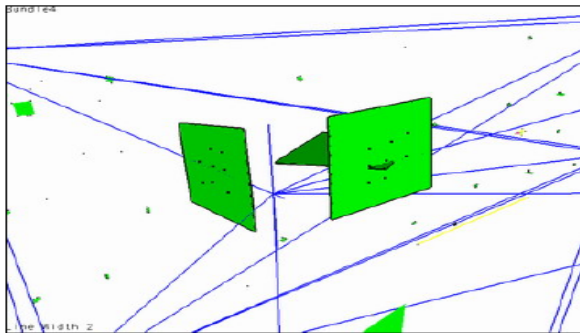


Figure 15. 3D result from corner point measurement using field calibrated target

| Lable | Object 1 | Object 2 | Type |
|---|---|---|---|
| C1_C2 | CORN1 | CORN2 | Line |
| C1_C3 | CORN1 | CORN3 | Line |
| C1_C4 | CORN1 | CORN4 | Line |
| C1_C5 | CORN1 | CORN5 | Line |
| C1_C6 | CORN1 | CORN6 | Line |
| C1_C7 | CORN1 | CORN7 | Line |
| C1_C8 | CORN1 | CORN8 | Line |
| C2_C3 | CORN2 | CORN3 | Line |
| C2_C4 | CORN2 | CORN4 | Line |
| C2_C5 | CORN2 | CORN5 | Line |
| C2_C6 | CORN2 | CORN6 | Line |
| C2_C7 | CORN2 | CORN7 | Line |
| C2_C8 | CORN2 | CORN8 | Line |
| C3_C4 | CORN3 | CORN4 | Line |
| C3_C5 | CORN3 | CORN5 | Line |
| C3_C6 | CORN3 | CORN6 | Line |
| C3_C7 | CORN3 | CORN7 | Line |
| C3_C8 | CORN3 | CORN8 | Line |
| C4_C5 | CORN4 | CORN5 | Line |
| C4_C6 | CORN4 | CORN6 | Line |
| C4_C7 | CORN4 | CORN7 | Line |
| C4_C8 | CORN4 | CORN8 | Line |
| C5_C6 | CORN5 | CORN6 | Line |
| C5_C7 | CORN5 | CORN7 | Line |
| C5_C8 | CORN5 | CORN8 | Line |
| C6_C7 | CORN6 | CORN7 | Line |
| C6_C8 | CORN6 | CORN8 | Line |
| C7_C8 | CORN7 | CORN8 | Line |

Table 2. Automatic modelling line condition

| Label | Object1 | Object2 | Object3 | Object4 | Type |
|---|---|---|---|---|---|
| P1 | CORN1 | CORN2 | CORN3 | CORN4 | Plane |
| P2 | CORN5 | CORN6 | CORN7 | CORN8 | Plane |
| P3 | CORN2 | CORN4 | CORN6 | CORN7 | Plane |
| P4 | CORN1 | CORN4 | CORN5 | CORN6 | Plane |
| P5 | CORN1 | CORN3 | CORN5 | CORN8 | Plane |
| P6 | CORN2 | CORN3 | CORN7 | CORN8 | Plane |

Table 3. Automatic modelling plane condition

## 3.2 Object Measurement

The research object is approximately 10.00×2.60×1.80m bridge steel box girder. For precise measurement of object, coded target, tape target, and bolt hole target were attached around the object. Proposed bolt hole target was specially produced for position measuring of bolt hole. In addition, auto-bar which defines the coordinate system and scale bar (±0.002mm) which defines standard length was set up on the object. Process step is shown in figure 16.

| |
|---|
| Project definition |
| Project name |

↓

| |
|---|
| Camera and Target |
| Calibration data and template data |

↓

| |
|---|
| Import the image into the project |
| Setting the image path |

↓

| |
|---|
| Auto measurement |
| Identify coded target, auto-bar and scale bar |

↓

| |
|---|
| Bundle adjustment |
| 3D coordinate evaluation |

↓

| |
|---|
| Scaling measurement |
| Adding scale bar, applying scale |

↓

| |
|---|
| Automatic modelling of 3D object |
| Vector distance, points calculation |

↓

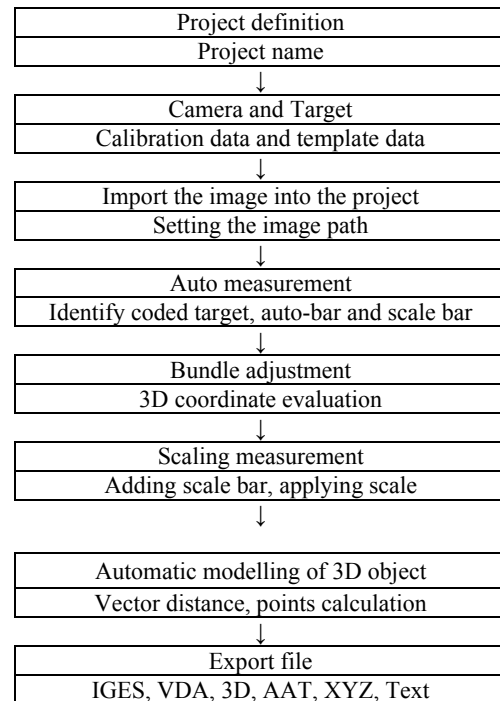| |
|---|
| Export file |
| IGES, VDA, 3D, AAT, XYZ, Text |

Figure 16. Flowchart of processing using photogrammetry

INCA3 digital camera was taken 141 images around the object. Image process was used V-STARS system. Camera position and points position are shown in figure 17.

Measuring data have identification and X, Y, Z coordination. 1195 points were measured in the test. Figure 18 is shown bolt hole position, each label, and template plane targets.
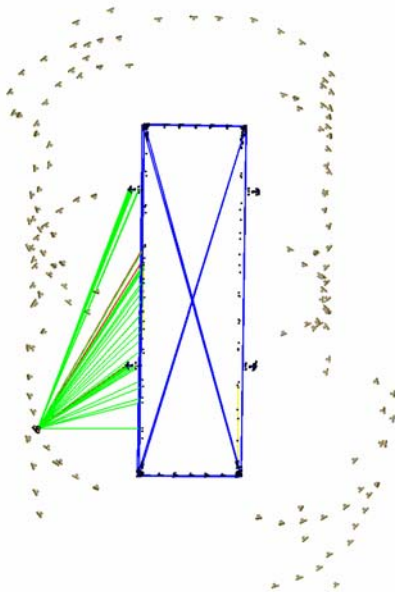
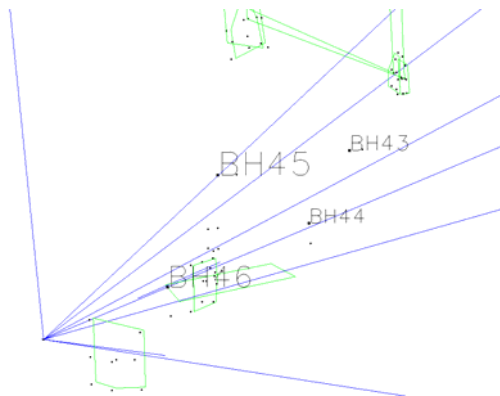Figure 17. Camera position around the object



Figure 18. Bolt hole position and lable

## 4. RESULTS AND DISCUSSION

Member's size is calculated from measured points data, figure 19 shows line generation between each points and figure 20 shows surface generation using line frame and point ID. Table 4 is members length data.
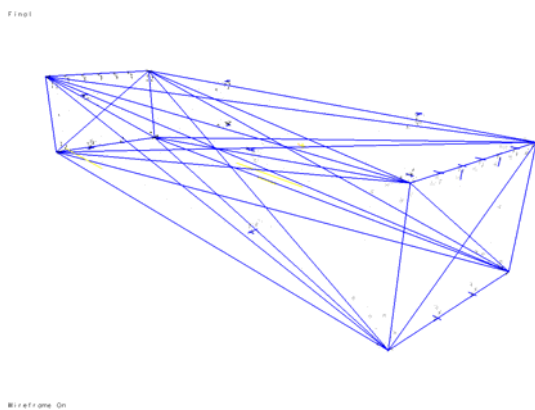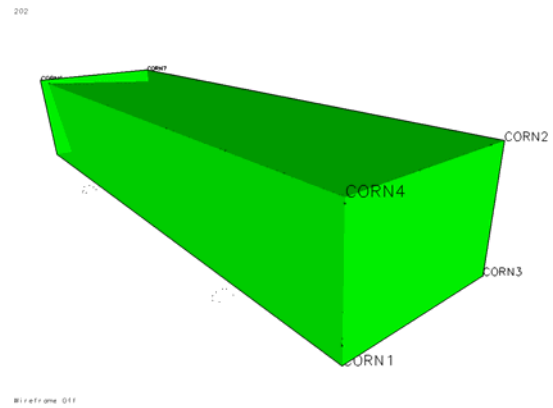


Figure 19. Automatic line generation
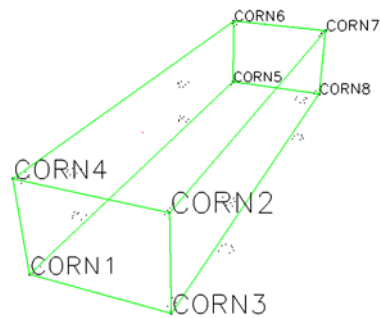


Figure 20. Automatic plane generation



Figure 21. Length inspection of members

| Line | measurement | Design |
|------|-------------|--------|
| CORN1-CORN2 | 3174.203 | - |
| CORN1-CORN3 | 2597.096 | 2600.000 |
| CORN1-CORN4 | 1797.242 | 1800.000 |
| CORN1-CORN5 | 10015.944 | 10000.000 |
| CORN1-CORN6 | 10179.851 | - |
| CORN1-CORN7 | 10488.936 | - |
| CORN1-CORN8 | 10323.805 | - |
| CORN2-CORN3 | 1797.646 | 1800.000 |
| CORN2-CORN4 | 2637.120 | 2600.000 |
| CORN2-CORN5 | 10483.638 | - |
| CORN2-CORN6 | 10336.743 | - |
| CORN2-CORN7 | 9972.568 | 10000.000 |
| CORN2-CORN8 | 10128.217 | - |
| CORN3-CORN4 | 3175.493 | - |
| CORN3-CORN5 | 10326.496 | - |
| CORN3-CORN6 | 10490.215 | - |
| CORN3-CORN7 | 10136.209 | - |
| CORN3-CORN8 | 9970.772 | 10000.000 |
| CORN4-CORN5 | 10173.711 | - |
| CORN4-CORN6 | 10017.392 | 10000.000 |
| CORN4-CORN7 | 10336.984 | - |
| CORN4-CORN8 | 10481.807 | - |
| CORN5-CORN6 | 1799.003 | 1800.000 |
| CORN5-CORN7 | 3174.825 | - |
| CORN5-CORN8 | 2595.992 | 2600.000 |
| CORN6-CORN7 | 2636.067 | 2600.000 |
| CORN6-CORN8 | 3172.836 | - |
| CORN7-CORN8 | 1795.435 | 1800.000 |

Table 4. Length of each member (Unit: mm)

Residual between design size and measured size is maximum 36.067mm and minimum 0.997mm. 3D modelling results which are generated from measured data are exported to IGS file. It is used to assembling simulation. In the summary, total processing time for target setting, photographing, data processing, and data analysis is reduced 80 minute to 40 minute in the box girder measurement using proposed photogrammetry method.

| Processing Steps | Time (min.) | |
|---|---|---|
| | convention | propose |
| Target setting | 30 | 10 |
| Photographing | 20 | 20 |
| Data processing and Drawing | 30 | 10 |
| Total | 80 | 40 |

Table 5. Total processing time

## 5. CONCLUSIONS

In this study, we focus on the time reduction of processing and automation of modelling for industrial photogrammetry using target field calibration and bolt hole target. Proposed technique enforces 3D measurement of steel box girder. The 3D modelling procedure is automatically processed using calibration target and auto modelling system. Measurement accuracy of Proposed industrial photogrammetric method is $\sigma_X$ =0.04mm, $\sigma_Y$ =0.03mm, $\sigma_Z$ =0.05mm. Total measuring points are 1,195. There are used to analysis of location, length, and angle relationship of each member and each hole. Accuracy of feature value is improved by automatic target thickness correction using proposed target field calibration method. In the result, this research technique expects that calibrated target and bolt hole target can be used to decrease the number of target, auto-modelling procedure can decrease the overall processing time, and the automatic procedure time is approximately 50% decreased than normal manual procedure in the steel box girder measurement. In addition, proposed method can use to comparison of final product and design data, deformation analysis of pre-/post-product of thermal deformation and load test.

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