Data Processing of 3D Laser Scanning on Structural Deformation

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Key words 3D Laser Scanning, Data Processing, Structure Safety.

SUMMARY

There are many problems when we evaluate the structure safety , such as structural uncertain factors, material behavior, excessive forces ,etc. To evaluate the structure safety, deformation measurement is one of the most important methods, and it is easiest to be measured by using 3D laser scanning. There are many advantages of the 3D laser scanning, including non-contact measurement, massive and precise digital data, and operation without limitation of light and weather.

This study aims to develop a high efficient data processing program of 3D laser scanning on structure safety. First, a 3D laser scanner was used to scan a two- story school building during the structural test. Second, a computer program is designed to process the scanning data according to different colors. As a result, different kinds of useful data, such as degree of deformation and width of cracks, are able to be acquired easily. Furthermore, a post-processed program is developed to evaluate the structure safety of buildings by applying the deformation results.

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1. INTRODUCTION

Both elastic and non-elastic structural deflections can be detected. The non-elastic deflection which results in a permanent distortion of the structure, can be used as a realistic design criterion. However, the structure deflections are generally elastic, and the structures would return to their original position after the loads are removed.

3D Laser scanning system can generate millions of 3D points within a short time when scanning an object. On the scanning object surface, the high density points would form a "point cloud". This point cloud can be digitally measured, sliced, and it would be used for distance measurement, volume calculations, solid modeling, etc.
The applications of 3D Laser scanning includes:

- 3D Point Cloud
- Architecture: as-builts
- CAD “Solid” models
- CBD streetscapes
- Fly-through visualizations
- Civil and structural engineering
- Deformation analysis
- Archaeology
- Line drawings
- Disaster documentation
- Volume calculations
- Ship-building/modification
- Sections/2D drawings
- Geo-technical slope monitoring
- Time based progress records
- Construction QC

2. EQUIPMENT and TEST ARRANGEMENT

2.1 Characteristic of Mensi GS100 3D Scanner

Metrology method . . . . Time of flight
User interface . . . . Trimble Recon, Notebook PC
Data interface . . . . Network TCP/IP, Wireless WiFi (optional)
SYSTEM PERFORMANCE
Standard range . . . . 100 m
Scanning speed . . . . up to 5000 points per second
Standard deviation

Range (m)	5	25	50	100
Typical values2 (mm)	1.4	1.4	1.4	2.5

Minimum resolution . . . . 3 mm @ 100 m (32 µrad)
Field of view
Horizontal . . . . .360°
Vertical . . . . 60° (angle included)
Laser type . . . . pulsed
Laser color . . . . .green
Safety . . . . Class 2 (21 CFR §1041.10) / Class 3R (IEC 60825-1)
Laser beam diameter . . . . 3 mm @ 50 m
Point capture modes . . . . X Y Z
X Y Z, point orientation
X Y Z, returned intensity (8 bits – 256 grayscale)
X Y Z, RGB true color (8 bits per channel)
X Y Z, orientation, returned intensity, RGB true color

2.2 IN-SITU TEST

In 2005, National Center for Research on Earthquake Engineering (www.ncree.gov.tw) conducted in-site push over tests and seismic assessment on school buildings. Our specimen located in Kouhu Taiwan, was a two-story concrete building with brick wall partition. In order to evaluate the structure performance, the structure displacement was controlled by the horizontal jackets as well as earthquake force simulation. The specimen was pushed step-by-step upon the story drift ratio (horizontal displacement / story height) until completely collapsed. Within each step, the structure sustained 10 minutes to observe the crack propagations. Simultaneously, the laser scanner also acquired the structure deformation data and kept these correspondent records for the further post process.

There were five scan data records: (1)the initial stage (unforced), (2) 0.25% drift ratio, (3) 0.5% drift ratio, (4) 0.75% drift ratio, and (5)1% drift ratio as shown on the figures 1~5. For analysis reference purpose, the object surface was marked the black grids.

Fig.1 3D Laser scanning

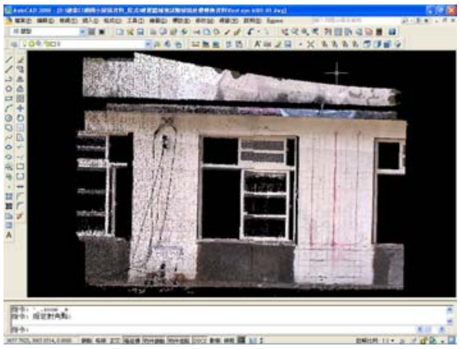

Fig.2 the primary stage

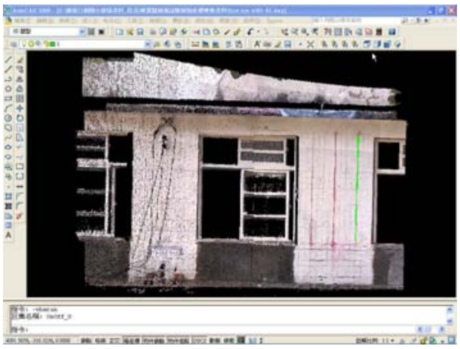

Fig.3 Drift ratio 0.25%

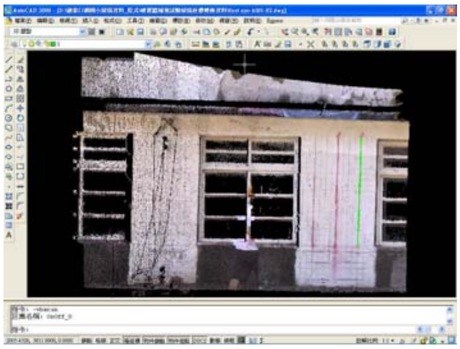

Fig.4 Drift ratio 0.5%

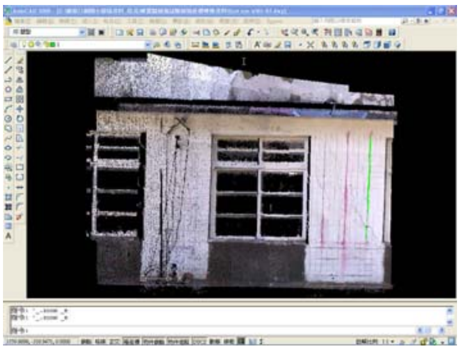

Fig.5 Drift ratio 0.75%

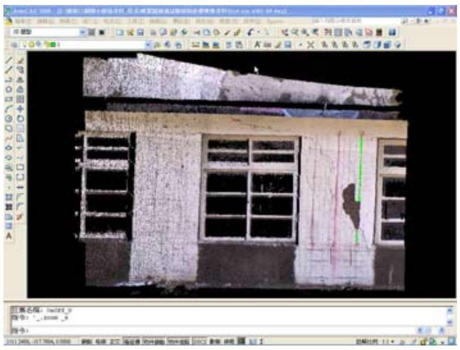

Fig.6 Drift ratio 1.0%

3. DATA PROCESS

3.1 3D Point Cloud Properties

By the 3D laser scanner acquisition results, the point contains three main information_ XYZ coordination, light returned intensity and RGB true color. Along the structure member boundary line, all the points own the geometric characteristic_ value discontinuity and orientation alteration. In order to observe the structure deformation, our data process would focus on the point coordination information. Besides, the variation of RGB colors and light intensity would be used to diagnose the potential crack location.

3.2 Procedures of Data Process Filtering

Referring Figure 1, three red lines marked the center of column (middle) and both side wing walls, and we aim the right one to study its behavior. The procedures of data process filtering as follows:

(1). Input the scanned point cloud data into AutoCAD.
(2). Screen the target area from the picture(see figure. 7).
(3). VBA program acquires the point color properties (see figure. 8).
(4). User Interface filters the proper points by varying RGB values(see figure. 9).
(5). Generate a green color layer for the extracted points and map with the original picture.

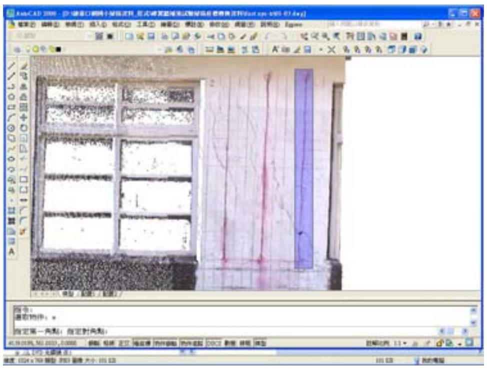

Fig.7 Screen area in AutoCAD

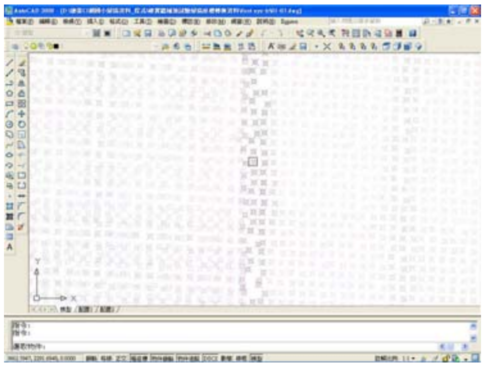

Fig.8 Point Zoom

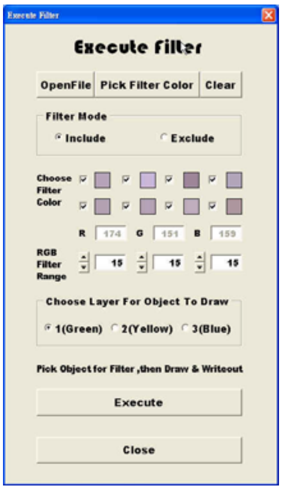

Fig.9 User Interface

4. Structure Deformation Analysis

4.1 Principle of Structure Deformation

After the data filtering, the scale of points would reduce to the accessible quantity. However, all these individual points are unable to interpret the entire structure behavior. In order to reconstruct the structure deformation as a continuous function, the points must be aggregated. By the statistic regression method, the extract points would generate a high order polynomial to present the structure deformation

Base on the elastic structure theorem, the member forces such as moment and shear, are derived from the deformation function. The slope, moment, shear and load can construct their relationships to the displacement function by differentiation, as

Slope vs. the first differentiation
Moment vs. the second differentiation
Shear vs. the third differentiation
Load vs. the fourth differentiation

To meet the continuity, the target function order should be not less than 3. Therefore, the displacement is adopted 3-order-polynomial and governed by the regression result.

4.2 Data Regression Result

The building displacement magnitude in the X coordination was controlled within the push over test. For each drift ration, the extracted points and the regressed deformation function is plotted in Fig. 10. In term of x as the displacement and y as the vertical position, the detail of 3-order-polynomial is

Drift Ratio = 0.25%

$$X = 9.232637984+0.0080993325Y+3.523210259E\text{-}5Y^2-1.44559201E\text{-}8Y^3 \quad (1)$$

Drift Ratio = 0.50%

$$X = 24.68450149+0.0203727699Y+2.45194839E\text{-}5Y^2-1.024178051E\text{-}8Y^3 \quad (2)$$

Drift Ratio = 0.75%

$$X = 6.103391095+0.0417109682Y+1.698996738E\text{-}5Y^2-9.78823491E\text{-}9Y^3 \quad (3)$$

Drift Ratio = 1.00%

$$X = 18.00573769+0.0639420276Y+1.448785106E\text{-}6Y^2-6.531292778E\text{-}9Y^3 \quad (4)$$

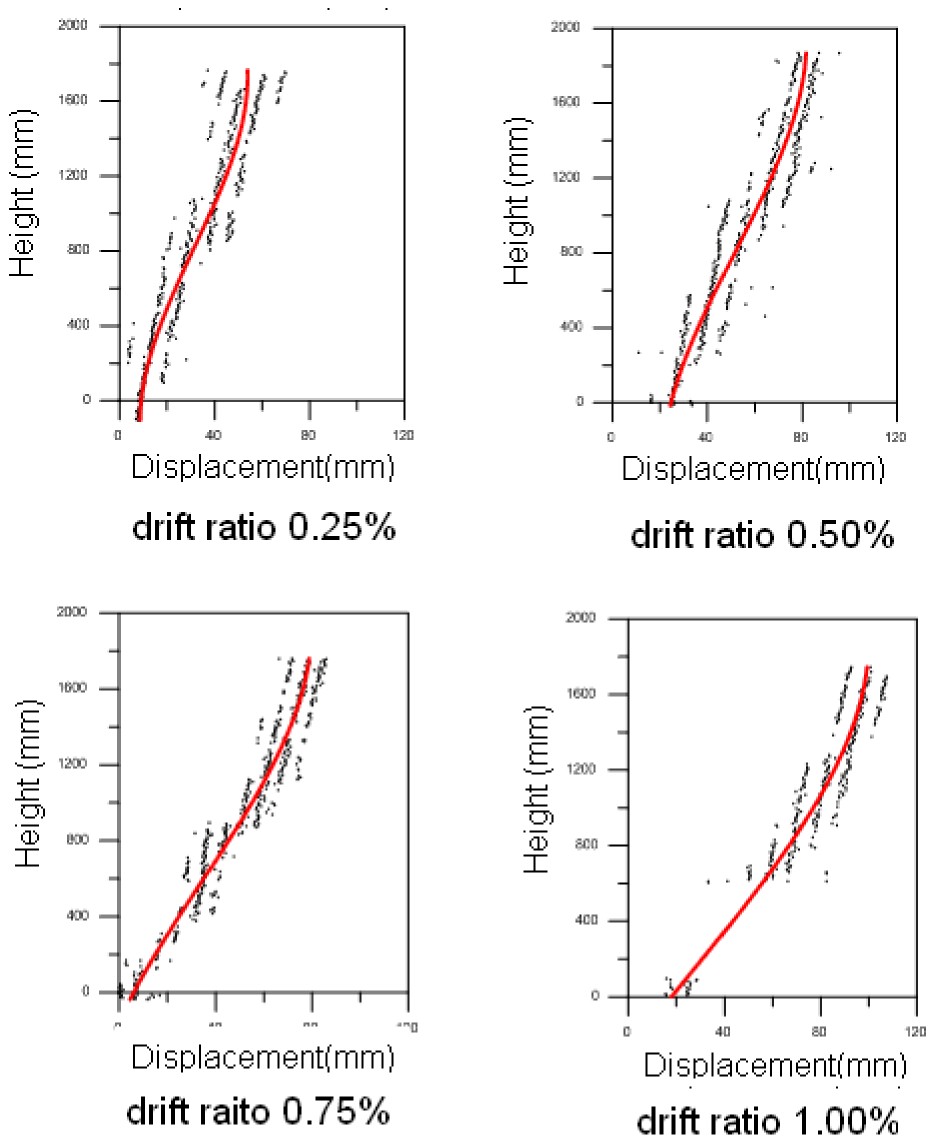

Fig.10 Member deformation shape by data regression

The traditional measurement only survey the point displacement in single direction, comparatively, the point cloud would precisely demonstrate the structure distortion in three dimensional as shown in Fig. 11.

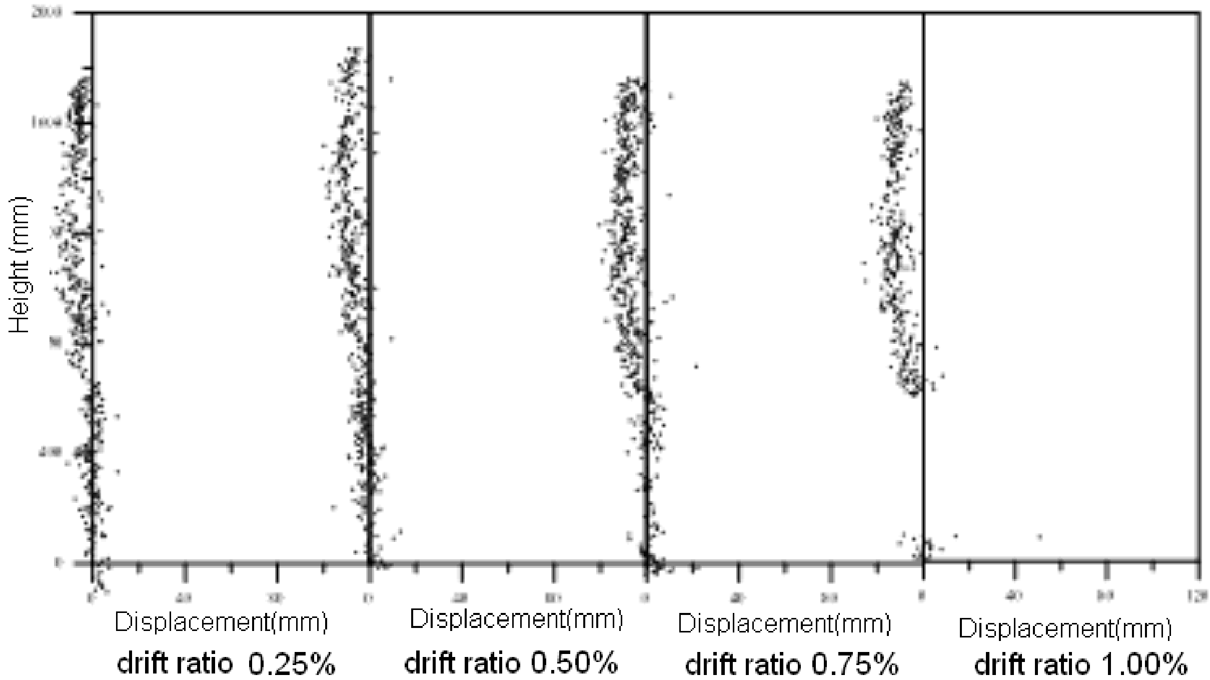

Figure11 Point distribution verse different drift ratio

5. CONCLUSION

The laser scanner not only performs the wide range, speedy operation and data accuracy acquisition, but also provides the point digital information including three dimensions, returned light intensity and RGB colors.

In this paper, the 3D laser scanner application in the structure deformation is demonstrated, and the detail deforming behavior would be closely monitored by the color filtering. The result of our study can be summarized as:

(1) The point cloud data can be effectively extracted by the color property.
(2) The deformation function can be determined by the statistic regression.
(3) The deformation behavior can be available to observe by the polynomial function.
(4) The deformation monitoring by 3D scanner is more integral than the traditional survey.

To extend our study, the 3D scanned result would develop its application on the building safety evaluation. From the deformation polynomial, the structure safety evaluation would be checked to the building code requirement. The availability of the scanned information such as intensity and color values , would make a further study to measure the crack propagation and detect the potential structure weakness.

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