# ON THE APPLICATION OF CMOS IMAGE SENSOR TO DIGITAL PHOTOGRAMMETRY

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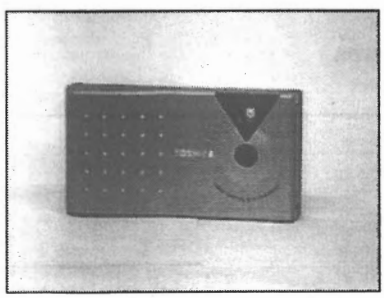
## ABSTRACT

The change in photogrammetry from analog to digital means a change from film to CCD sensor, and real-time imaging became possible. There are many kinds of digital still cameras on the market and a digital camera is generally utilizing in digital photogrammetric fields as a convenient equipment of data acquisition.
In these circumstances, digital camera is expected to become a useful tool in various real-time imaging fields, e.g. industry metrology, machine and robot vision, medical and sports science, archaeology, construction management and so on.
However, a CMOS sensor has recently received more attention from the point of view of the low price and low power consumption. Due to low power consumption, miniaturization can be achieved and if a CMOS sensor can be utilized instead of a CCD sensor, a CMOS sensor will become more useful instrument in close-range photogrammetry such as Robot Vision and so on.
With this objective, the application of a CMOS camera to digital photogrammetry was discussed in this paper.

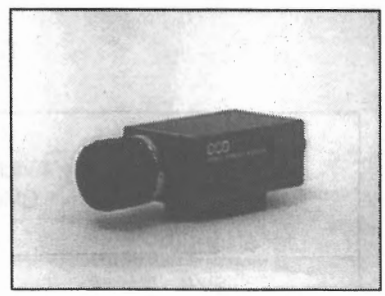
## 1. INTRODUCTION

There are many kinds of digital still cameras on the market and a digital camera is generally utilizing in digital photogrammetric fields as a convenient equipment of data acquisition due to its ability for real-time imaging. However, miniaturization and reducing the price are expected. These issues can be resolved using a CMOS (Complementary Metal Oxide Semiconductor) sensor since a CMOS sensor has ability to reduce consuming electric power. With this motive, a CMOS sensor has recently received more attention and a new type digital still camera used a CMOS sensor, Allegretto appeared on the market in August, 1997.
In order to estimate accuracy of the CMOS Camera (Allegretto), experiments using the CMOS Camera, the Digital camera (DC-3) and the CCD Camera (XC-75) were performed and accuracy were estimated in this paper.



(a) Allegretto

(b) DC-3



(c) XC-75

Figure 1 Digital camera

## 2. CMOS SENSOR

A CMOS sensor is semiconductor which is used as a CPU or memory chip of a Personal Computer and there are following abilities,

+ a CMOS sensor can be easily mass-produced by existing semiconductor factory and manufacturing process.
+ a CMOS sensor can be cheaply produced than a CCD sensor in case of the same pixel numbers.
+ making a singe-chip can be performed by integrating peripheral circuits because a CMOS sensor and peripheral circuit is semiconductor which is produced with the same technology.
+ miniaturization can be achieved by making a single-ship.
+ structure of a CMOS sensor became simple and consuming electric power became one-tenth compared with a CCD sensor because a CMOS sensor consist of combination of photodiode and a CMOS transistor.

On the contrary, a CMOS sensor have following week points,

- sensor area became smaller than a CCD sensor because many wiring printed on a sensor.
-it is difficult to get clear contrast image due to above reason.

Nevertheless, a CMOS sensor are expected to miniaturize and to develop a smart sensor.

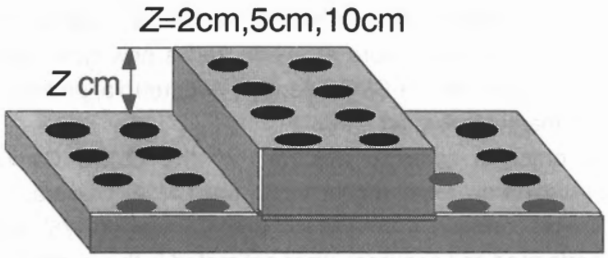



Figure 2 Test model

## 3. EXPERIMENT

In order to investigate on the application of a CMOS image sensor to digital photogrammetry, experiments were performed using the CMOS camera (Allegretto), Digital camera (DC-3) and the CCD camera (XC-75). Figure 1 shows these three digital cameras and major components for these cameras are shown in Table1. Figure 2 shows the test site and the three test models (Z=20mm, 50mm and 100mm) were used in this paper. Figure 3 shows the control points and check points. The squared points are control points and another 33 black circle points are check points for checking accuracy. Figure 4 shows the stereo image for one of the test site which was taken by the CMOS camera and Table 2 shows the altitude, base line and base-height ratios for experiments.

The differences of an altitude were caused by lens type, i.e. wide angle lens was equipped with the CMOS and Digital camera, and standard lens was equipped with the CCD camera.

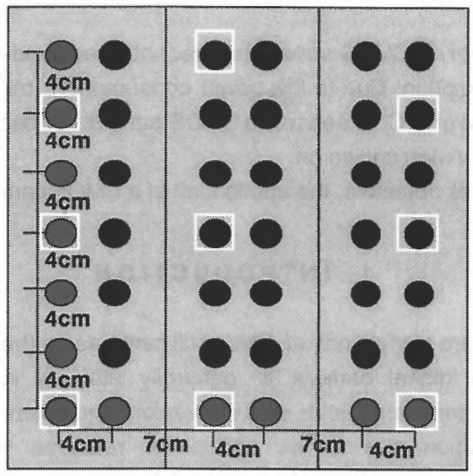
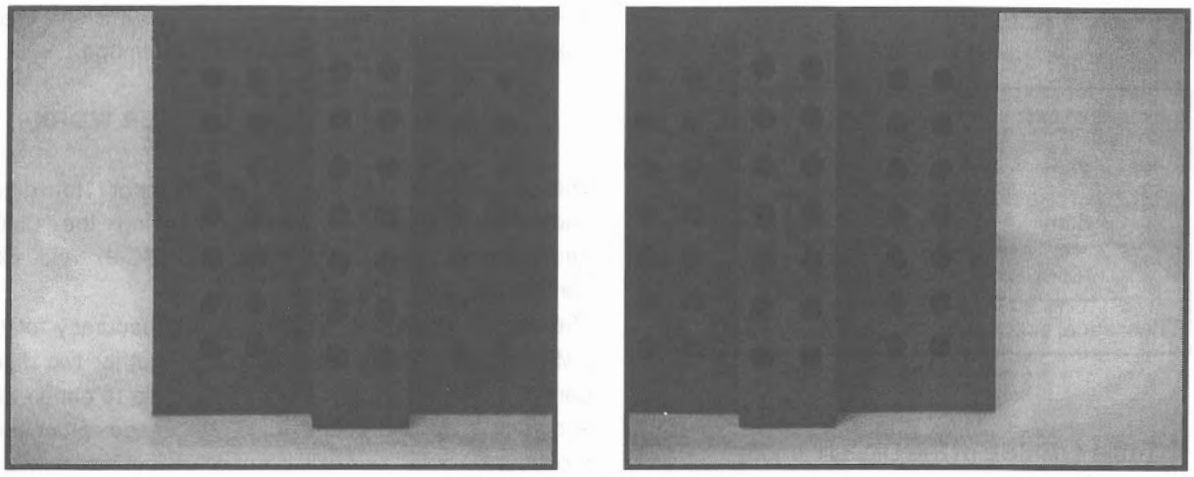



Figure 3 Control points and check points

Table 1 Major components for three digital cameras

| | CMOS camera | Digital camera | CCD camera |
|---|---|---|---|
| Image sensor | 1/4 inch 330K-Squarepixle CMOS image sensor | 1/4 inch 350K-Squarepixle CCD image sensor | 1/2 inch 380K-pixle CCD image sensor |
| focal length | 4.9mm | 4mm | 16mm |
| cell size | 5.6x5.6$\mu$m | 5.6x5.6$\mu$m | 8.4x9.8$\mu$m |
| power consumption | 30mW | | 1.6W |
| weight | 130g | 234g | 198g |
| product name | Allegretto(TOSHIBA) | DC-3(RICOH) | XC-75(SONY) |



(a) Left image (b) Right image

Figure 4 Stereo image by the CMOS camera

Table 2 Altitude, base line and base-height ratios

| | H(m) | B(m) | B/H |
|---|---|---|---|
| CMOS camera | 0.730 | 0.160 | 0.219 |
| Digital camera | 0.675 | 0.160 | 0.237 |
| CCD camera | 1.427 | 0.145 | 0.102 |

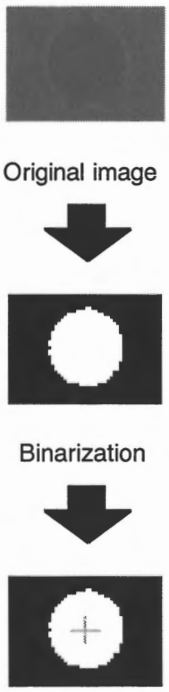



Figure 5 Image processing procedure

Camera calibrations were performed by the bundle adjustment using 9 control points. Calibration accuracy depend on the pointing accuracy of image coordinate. Therefore, following image processing procedure was applied and the basic steps of this image processing procedure are shown in Figure 5. An Image coordinate for each point was calculated following equation as a center of gravity.

$$u_c = \frac{\sum_{i=1}^{n} w_i u_i}{\sum_{i=1}^{n} w_i}$$
$$v_c = \frac{\sum_{i=1}^{n} w_i v_i}{\sum_{i=1}^{n} w_i} \quad (1)$$

where, $(u_c, v_c)$: the center of gravity,
$(u_i, v_i)$: image coordinate, $w_i$: weight

## 4. EXPERIMENT RESULTS

Table 3, 4, 5 show the R.M.S.E. for check points and the theoretical accuracy which were calculated following equation.

$$\sigma_{xy} = \left(\frac{H}{f}\right)\sigma_p$$
$$\sigma_z = \left(\frac{H}{f}\right)\left(\frac{H}{B}\right)\sigma_p \quad (2)$$

where, $H$; altitude of camera, $B/H$; base-height ratio, $f$; focal length, $\sigma_p$; pointing accuracy

Table 3 RMSE of the CMOS camera

| Height of test site | X,Y(mm) | Z(mm) |
|---|---|---|
| 2cm | 0.207 | 1.650 |
| 5cm | 0.193 | 1.853 |
| 10cm | 0.121 | 1.597 |
| Theoretical accuracy | 0.167 | 0.761 |

Table 4 RMSE of the Digital camera

| Height of test site | X,Y(mm) | Z(mm) |
|---|---|---|
| 2cm | 0.132 | 0.739 |
| 5cm | 0.13 | 0.812 |
| 10cm | 0.134 | 0.535 |
| Theoretical accuracy | 0.189 | 0.797 |

Table 5 RMSE of the CCD camera

| Height of test site | X,Y(mm) | Z(mm) |
|---|---|---|
| 2cm | 0.183 | 1.667 |
| 5cm | 0.116 | 0.852 |
| 10cm | 0.158 | 1.311 |
| Theoretical accuracy | 0.173 | 1.705 |

0.2 pixel ( $\fallingdotseq$ 0.002mm) were obtained from experiments and with regard to pointing accuracy for each camera, $1.1 \times 10^{-3}$(mm) for the CMOS and Digital camera, $1.9 \times 10^{-3}$(mm) for the CCD digital camera were calculated using scale factor of each camera.

It may be seen from the results of this experiment that,

1) with regard to the 2D accuracy for the Digital camera and the CCD camera are almost equal or high values compare with the theoretical accuracy.

2) similarly, accuracy for the Z-coordinate with regard to the Digital camera and the CCD camera are the same results.

3) with regard to the CMOS camera, accuracy for the 2D and the Z-coordinate are low values than the theoretical accuracy.

These results, probably due to the insufficient image quality which was caused by low contrast image.

## 5. CONCLUSION AND FURTHER WORK

The application of the CMOS sensor to digital photogrammetry was investigated using the CMOS camera (Allegretto), Digital camera (DC-3) and CCD camera (XC-75) in this paper.

The simple experiment result show that accuracy for the CMOS camera is low value than the another two digital camera. However, it will become possible to obtain high accuracy by improvement of an image processing procedure.

Furthermore, considering a low price CMOS sensor with 1.3 million pixels appeared on the market and a smart camera utilized a CMOS sensor is now rapid diffusing. It is concluded that utilization of a CMOS sensor is expected to become useful tool in various real-time photogrammetric fields in the near future.

## References

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