Development of real-time extensometer based on image processing

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Abstract. An extensometer system was developed by using high definition web camera as main sensor to track object position. The developed system applied digital image processing techniques. The image processing was used to measure the change of object position. The position measurement was done in real-time so that the system can directly showed the actual position in both x and y-axis. In this research, the relation between pixel and object position changes had been characterized. The system was tested by moving the target in a range of 20 cm in interval of 1 mm. To verify the long run performance, the stability and linearity of continuous measurements on both x and y-axis, this measurement had been conducted for 83 hours. The results show that this image processing-based extensometer had both good stability and linearity.

1. Introduction

Extensometer is a device used to measure the displacement of an object [1]. The device is made using various types of sensors, either electrical or optical. The electrical and optical extensometers that are still being developed in Research Center for Physics, Indonesian Institute of Sciences, for example, are fiber-based, potentiometer-based and encoder-based extensometer [2]. Those devices are now in the testing process to be used in ground movement monitoring system [3]. The devices were tested for their sensitivity, resolution, linearity, stability and reliability.

The three extensometers have some advantages and disadvantages over each other, e.g. optical fiber extensometer has high resolution and sensitivity, but its range of measurement is shorter than the others. On the other hand, electrical extensometer that uses a potentiometer has a fairly high linearity, but its reliability is easily influenced by environmental factors such as humidity and temperature. Meanwhile, extensometer using encoder has advantages in stability, linearity, and resolution, but it is more expensive than the others.

In addition, there are other factors to be considered in developing an extensometer that is safe for measurement device. In general, devices that use optical and electrical materials will need a sling tied between the object and the device. The device detects the movement of the sling in order to measure the displacement of the object. However, this measurement method may cause the device to be attracted by the sling. This drawback can be solved by using another technique such as wireless system extensometer.

One of the techniques proposed is webcam-based extensometer. It uses image processing technique on motion-based tracking. This extensometer uses a web camera to detect the movement of the object...
periodically. The data consists of object positions and the displacement in each interval can be calculated.

2. Methods
To establish webcam-based extensometer system, there were some instruments used. The system employed a web camera with 1080 pixels (full-HD) as a main device, a computer or PC, a servo motor, and a target. This target was designed as a black circle with a diameter of 3 cm [4]. The target was installed in front of a web camera with a distance of 1 meter as shown in figure 1.

![Figure 1. The target object in a circle shape was installed on motion part.](image)

This target can be moved in x and y-axis using a motion part controlled by servo motor controller. This motion part can be moved in a 1 mm resolution using PC interface. In every 1 mm of movement, an image was captured by the web camera at a given position of x and y-axis. Specially developed software was used to control the motion part or servo motor and image capturing by a web camera.

Calibration of the camera's pixel to the actual position was then conducted by performing a stability test. The stability test was used as a parameter to detect the stability of the camera's pixel in capturing the object in 127 Lux of light intensity and 1 meter distance between a web camera and the object for 307830 seconds or approximately 83 hours. The result of the stability test showed the linearity value of camera's pixel and a counter time to find out the capabilities of this system.

![Figure 2. Flowchart of web camera-based extensometer program.](image)
In this system, the sampling time was 10 seconds using a stream mode acquisition. In every 10 seconds, the system calculated the average position of the target to give the accurate value. In order to get the displacement, the system was programmed to calculate the difference of the position from \( X_t \) to \( X_{t_f} \) then the displacement value can be calculated using subtraction [5, 6]. Another part of the system was the software, which was developed to get and extract the images then determine the position. The diagram of the software is shown in figure 2.

The arrangement of all parts in this system, which consisted of a PC, a web camera and a motion part, is shown in figure 3. This system measured the position of target in every 10 seconds and it gave a displacement value when the object moved to another point. The displacement measurement was conducted in one single axis, which is x-axis, in ±10 cm range.

![Diagram](image)

**Figure 3.** Set up of webcam-based extensometer.

### 3. Results and discussion

The webcam-based extensometer system was tested in the Research Center for Physics. The test was conducted in two parts. The first test was a stability test and the second was a linearity test. The stability test was conducted by measuring the target for 307830 seconds or approximately 83 hours. This test was done in an indoor area which had a light intensity of 127 Lux and temperature of 28 °C. The result of this test is shown in figure 4.

![Graph](image)

**Figure 4.** The results of stability test in an indoor area.

Figure 4 shows the results of position stability test in x-axis (blue line) and y-axis (red line). The x-axis of the graph is time counter and the y-axis is camera’s pixel. The average position of target in x-axis was 1074 with a least square equation of \( y = -1\times10^{-5}x + 1074.2 \). This means that the equation remained constant. In y-axis, it can be seen that the position of target is at 659 with a least square equation of \( y = -0.0001x + 661.02 \). This also means that the gradient was close to 0 and it can be concluded that the position still remained constant.

Another test was linearity test using servo motor to move the target along x-axis while the position of the target was measured by web camera-based extensometer. This test required a motor servo...
controlled by PC to move from the zero point (origin) to 10 cm in the right direction and from zero point (origin) to 10 cm in the left direction. The result can be seen in figure 5.

In figure 5, it can be seen that the x-axis is displacement in mm unit and the y-axis is position in pixel plane of the chart. The displacement referred to the origin in the x-axis of motion part. The target was moved by motor servo to the right direction until it reaches the limiting distance. The limiting distance was 10 cm from the origin.

![Figure 5](image.png)

**Figure 5.** The result of linearity test in positive direction.

To analyze the correlation between displacement and position in the chart area, a least square method was applied. It was used to calculate the linearity of this extensometer. The least square method gave an equation of \( y = 0.884x + 1053.7 \). The value of 0.884 was also known as the sensitivity and the 1053.7 was the offset. This equation can be used to get the displacement value by inverting the equation. If \( x \) is displacement and \( y \) is a position in the chart area then it can be converted into \( \frac{y - 1053.7}{0.884} \).

To complete the test, a measurement was also conducted by moving the target to the left until it reach the limiting distance. The limiting distance was also the same with that in previous test, which was 10 cm to the left from the origin. The result is shown in the figure 6.

![Figure 6](image.png)

**Figure 6.** The result of stability test in negative direction.
From the figure 6, it can be seen that there was a correlation between the displacement and the position in the chart shown. This correlation was linear and had a least square formula of \( y = 0.88935x + 1067.7 \). The displacement can be known by calculation using this formula. If the pixel position can be measured by the webcam-based extensometer, then the displacement of the target can be calculated. The formula for the displacement will be \( x = y - 1057.7/0.88935 \).

This system was able to give the value of target displacement whenever the target was moved to another position. A web camera captured the image and the software calculated it into a displacement value.

4. Conclusions
A web camera-based extensometer system has been tested to observe its stability and linearity. This system gave a good linearity and stability. Therefore, it can be used to monitor the displacement of object in the lateral area of an object. As a consequence, the web camera also had to be positioned in the lateral area. This system was still able to detect the movement of an object for every 1 mm in 1 meter distance.

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