ABSTRACT

Sensors such as accelerometers and displacement transducers are generally used in earthquake-simulated shake table testing to measure the induced motions. In particular, the Anti-seismic Structure Laboratory at the Pontificia Universidad Católica del Perú (PUCP) uses LVDT (linear variable differential transformer) sensors, which can achieve accurate measurements. However, there are limitations in the number of measuring points; moreover, the required instrumentation is demanding and destructive tests can not be measured with such devices.

We present the preliminary results of an optical motion tracking system to measure the induced motions for shake table testing at the PUCP's Anti-seismic Structure Laboratory.

1. INTRODUCTION

Shake table tests are used to assess how a model or a full-size building responds to the vibrations of a simulated earthquake. The accuracy of the induced motion's measurements are paramount to appraise the behavior and the structural health of the construction during the tests, and their analysis may also be used to propose design enhancements.

Particularly, the PUCP's Anti-seismic Structure Laboratory uses LVDT (linear variable differential transformer), a type of displacement transducers to measure the earthquake induced motions. The tests are carried out on a Shake Table (4.40 x 4.40 m) with one degree of freedom. The maximum displacement and acceleration of the Shake Table are 130 mm for each sense and 10 respectively. Usually each test lasts about 30 seconds.

In the context of this work, tracking is the problem of generating an estimate of the motion of an object given a sequence of images. The object(s) for an optical motion tracking system may be:

- particular features of the scene (image-based systems).
- artificial markers (marker-based systems).

Image Based Systems

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Drawbacks:
- Need robust feature detection techniques.
- Need of artificial illumination.

Table 1: Optical Motion Tracking Systems in Earthquake Engineering

2. TRACKING AM-FM MARKERS

2.1 AM-FM Demodulation

The AM-FM representation of images allows modeling non-stationary image content in terms of amplitude and phase functions using

\[ \hat{f}(x,y) = A(x,y) \cdot \cos(\phi(x,y)) \]

where \(A(x,y)\) and \(\phi(x,y)\) are the instantaneous amplitude and phase functions at \((x,y)\). The term AM-FM demodulation implies the computation of:
- instantaneous frequency (IF) vector functions \(\omega(x,y) = -\partial \phi(x,y) / \partial x\).
- instantaneous phase (IP) functions \(\phi(x,y)

We use the robust AM-FM demodulation algorithm proposed in [7] (see also [8] and [9] for further details). The AM-FM dominant component analysis (DCA), [8], is used to model the scene image as

\[ \hat{f}(x,y) = A(x,y) \cdot \cos(\phi(x,y)) \]

where \(\omega(x,y)\) is stationary (see Figure 2). AM-FM markers are shown in (a).

Figure 1: System configuration for the two types of tests carried out in the PUCP’s Anti-seismic Structure Laboratory.

In this work we adopt a marker-based optical motion tracking system to measure the (simulated) earthquake induced motions, where one of our main contributions is the use of AM-FM (amplitude modulated, frequency modulated) opaque markers. The segmentation process for such markers is robust to changing levels of illumination. They also embed spatial resolution information used to simplify the measurement of the induced motions.

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2.2 AM-FM Markers: description, segmentation and tracking

The AM-FM opaque markers are shown in Figure 2(a). They embed spatial information and are usually printed in a A4 laser printer.

Segmentation procedure

- Compute the DCA AM-FM demodulation.
- Compute histograms for the 2D datasets \(\omega(x,y)\) and \(\phi(x,y)\).

Figure 2: AM-FM markers are shown in (a). (b) depicts a typical video frame. In (c) and (d) we display the 2D datasets \(\omega(x,y)\) and \(\phi(x,y)\) as images. \(\omega(x,y)\) and \(\phi(x,y)\) are the dominant Instantaneous Frequency (IF) of 2Db in the vertical and horizontal direction respectively (see 32). Note the high contrast of (c), where the vertical AM-FM markers are placed.

4. CONCLUSIONS

- The AM-FM markers provide a robust segmentation scheme.
- The induced movements are consistently tracked.
- The system has an accuracy comparable to the LVDT sensors' accuracy (in the order of millimeters).
- The use of the markers dramatically decreases the instrumentation time: from up to two days down to less than 30 minutes.

ON-GOING WORK

- Estimation of the cameras' intrinsic/extrinsic parameters.
- Acquire the uncompressed video via an HDMI frame-grabber.
- Off-line (real-time) analysis.

ACKNOWLEDGMENT

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REFERENCES