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MODIFIED CLOUD ANALYSIS: NON-LINEAR DYNAMIC ANALYSIS WITH UN-SCALED RECORDS

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One of the most efficient non-linear dynamic analysis procedures for analytic fragility evaluation is based on simple regression of structural response versus seismic intensity for a set of registered records. This procedure, also known as the Cloud Method (Jalayer, 2003), has many advantages such as simplicity, use of un-scaled records, and relatively small computational effort. This method suffers draw-backs such as modeling of record-to-record variability with constant standard deviation. Nevertheless, the simplicity of the formulation makes it a quick and efficient analysis procedure for fragility assessment or safety-checking in the context of the SAC-FEMA formulation (Cornell et al., 2002). Record selection is quite critical for Cloud Analysis as the results are often sensitive to the suite of ground motion records selected. The criteria for record selection for use in Cloud Analysis can be summarized as (Jalayer et al., 2015 and 2017):

1. The records should span a wide range of the intensity measure (in order to reduce the error in the estimation of the regression slope)
2. A significant proportion of the records should lead to the exceedance of the limit state (in order to avoid extrapolation in the zone of interest)
3. The number of ground motion records from the same event should be limited (in order to avoid data set with high correlation)
4. The soil type and the predominant focal mechanism (s) for the site should be kept in mind.

Respecting these criteria for the ultimate limit states (e.g., life safety, collapse prevention) might lead to cases of structural collapse (loss of load-bearing capacity), global dynamic instability (very large deformations) or cases of numerical non-convergence, which are referred to generically as “collapse” cases. Clearly, the original Cloud Analysis based on simple regression cannot be applied directly to the “collapse”-inducing ground motion records.

The Modified Cloud Analysis (MCA) is proposed as an alternative to the original Cloud Analysis for handling the collapse-inducing records. Based on the Total Probability Theorem, “collapse” and non-“collapse” can be treated as mutually exclusive and collectively exhaustive events. This way the original cloud analysis can be applied to the non-collapse portion of the records. The probability of collapse can be estimated, in the simplest case, as the ratio of the number of collapse-inducing records to the total number of records. The estimation of the collapse probability can be improved through using a generalized regression model (logistic regression). Comparisons with multiple-stripe analysis with variable set of conditional spectrum-compatible records indicates a very good agreement for the range of intensities, which matters for the sake of seismic risk assessment (Jalayer et al., 2017).

The modified Cloud Analysis leads to a 4 to 5 parameter fragility model (based on how the collapse probability is estimated) for application in seismic risk analysis. This fragility model can be used as an underlying probability model for estimating the relative sufficiency of various intensity measure candidates based on information theory (Jalayer et al., 2011; Ebrahimian et al., 2015). MCA is particularly efficient for estimating state-dependent fragility curves for aftershock risk assessment (Jalayer and Ebrahimian, 2017, known as "sequential Cloud Analysis"). Moreover, the method is very efficient for the propagation of epistemic uncertainties (Jalayer and Ebrahimian, 2019; Miano et al., 2017). Last but not least, MCA provides very efficient means for probabilistic seismic loss assessment (e.g., Ebrahimian et al., 2015).

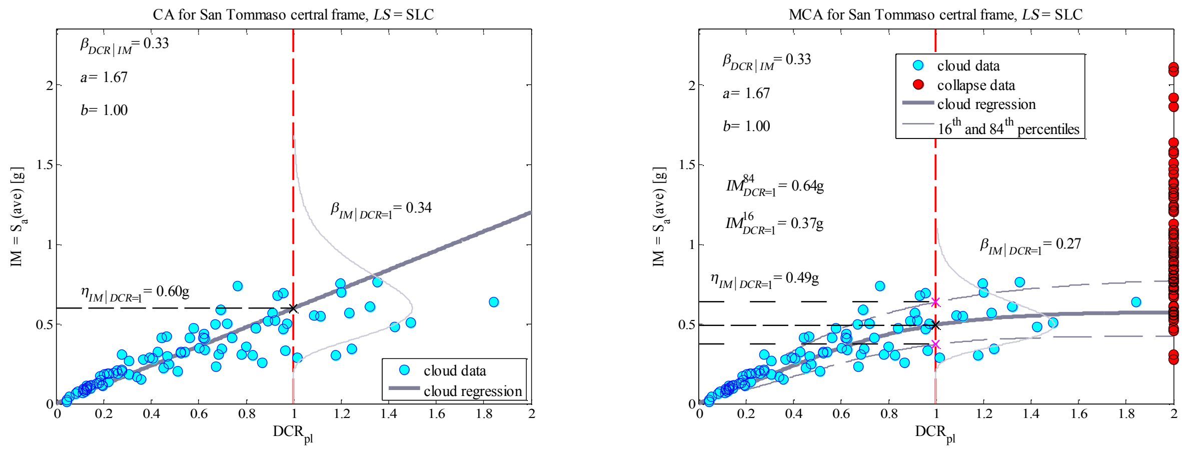

Figure 1. Cloud Analysis for an existing RC building based on 160 Ground Motion Records for limits state of near-collapse: (left) original Cloud Analysis for the non-collapse portion of data; (right) MCA for the whole dataset.

The application of the Modified Cloud Analysis for efficient fragility assessment is demonstrated for a shear-critical existing RC frame designed only for gravity-loading.

REFERENCES

Cornell, C.A., Jalayer, F., Hamburger, R.O., and Foutch, D.A. (2002). The probabilistic basis for the 2000 SAC/FEMA steel moment frame guidelines. *ASCE Journal of Structural Engineering*.

Jalayer, F., De Risi, R., and Manfredi, G. (2015). Bayesian Cloud Analysis: efficient structural fragility assessment using linear regression. *Bulletin of Earthquake Engineering*, *13*(4), 1183-1203.

Jalayer, F., Ebrahimian, H., Miano, A., Manfredi, G., and Sezen, H. (2017). Analytical fragility assessment using unscaled ground motion records. *Earthquake Engineering & Structural Dynamics*, *46*(15), 2639-2663.

Jalayer, F., Beck, J.L., and Zareian, F. (2011). Analyzing the sufficiency of alternative scalar and vector intensity measures of ground shaking based on information theory. *Journal of Engineering Mechanics*, *138*(3), 307-316.

Ebrahimian, H., Jalayer, F., Lucchini, A., Mollaioli, F., and Manfredi, G. (2015). Preliminary ranking of alternative scalar and vector intensity measures of ground shaking. *Bulletin of Earthquake Engineering*, *13*(10), 2805-2840.

Jalayer, F. and Ebrahimian, H. (2017). Seismic risk assessment considering cumulative damage due to aftershocks. *Earthquake Engineering & Structural Dynamics*, *46*(3), 369-389.

Jalayer, F. and Ebrahimian, H. (2019). Updated robust reliability: considering record-to-record variability and uncertainty in modelling parameters. *Proceedings of ICASP13*, Seoul.

Miano, A., Jalayer, F., and Prota, A. (2017). Considering structural modeling uncertainties using Bayesian cloud analysis. *Proceedings of the 6th ECCOMAS Thematic Conference on Computational Methods in Structural Dynamics and Earthquake Engineering (COMPDYN 2017)*.

Ebrahimian, H., Jalayer, F., and Manfredi, G. (2015). Seismic retrofit decision-making of bridges based on life-cycle cost criteria. *Proceedings of the 5th ECCOMAS Thematic Conference on Computational Methods in Structural Dynamics and Earthquake Engineering (COMPDYN 2015)* (25-27), Crete Island, Greece.