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# Normalized proper orthogonal decomposition (NPOD) for building pressure data compression

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## Abstract

Proper orthogonal decomposition (POD) has been widely realized as a tool for compressing fluctuating building pressure data in wind-engineering area. Modes are determined by eigen decomposition of data covariance matrix, and then truncation is applied to retain only the modes with the highest energy. However, as observed by S. Kho, C. Baker, R. Hoxey [Pod/arma reconstruction of the surface pressure field around a low rise structure, J. Wind Eng. Ind. Aerodyn. (90) (2002) 1831–1842] and analyzed in the authors' previous paper D. Ruan, H. He, D. Smith, K.C. Mehta [A Semi-optimal Mode Selection Scheme for Pod Based Compression of Wind Field Data, Seoul, Korea, 2004], reconstruction performance varies a lot among individual taps. In D. Ruan, H. He, D. Smith, K.C. Mehta [A Semi-optimal Mode Selection Scheme for Pod Based Compression of Wind Field Data, Seoul, Korea, 2004], a semi-optimal mode choosing scheme was proposed in an integer programming (IP) framework and numerical experiments have shown sound results. Nevertheless, computation cost for solving IP optimization could be an issue as the total number of taps grows. In this paper, we address the problem with normalized proper orthogonal decomposition which is from a completely different perspective: we first normalize the data to force every tap to have similar contribution to the total energy; the standard POD is then applied to get a compact representation. During the reconstruction phase, normalized data is first restored and a scaling procedure which is exactly the inverse to the normalization is applied to finally reconstitute the data

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in its original form. Feasibility test with experimental data from Texas Tech University yields good results. Computation cost is almost the same as the standard POD method.


*Keywords:* Data compression; Proper orthogonal decomposition (POD); Principal component analysis (PCA); Eigendecomposition; Normalized cumulative fluctuation energy (NCFE); Integer programming (IP); Normalized proper orthogonal decomposition (NPOD)

## 1. Introduction

Principal component analysis (PCA) is a powerful tool in compact data representation/data compression. Beginning with a data set in a high-dimensional space, PCA tries to find a lower dimensional hyperplane that best represents the data points. In wind engineering field, it is generally recognized as proper orthogonal decomposition (POD) and is widely studied to describe fluctuating building surface pressure data [3–8]. Some authors have tried to fit autoregressive (AR) model to extracted POD modes [9,10] in order to achieve further compression. While some investigators [4,3] claimed that this decomposition helps in identifying the hidden systematic structure in the pressure fluctuation, other parties argued [11], that the most useful aspect of POD is its economy in describing the spatial/temporal variation of wind pressure field [12–14].

In traditional POD-based compression methods, the covariance matrix of the observation data is first eigendecomposed to get the set of eigenvectors (modes). The modes are then arranged in an energy non-increasing fashion and truncation is applied to retain only a subset of them. However, as Kho et al. [1] observed, the exclusion of higher (less energetic) modes leads to significant inaccuracy of reconstituted time series at some of the tapping points.

In the authors' previous work [2], contributions of each mode to the fluctuation energy at individual tapping points are analyzed, and an IP framework is proposed to choose a subset of the eigenvectors after eigendecomposition for reconstruction purpose. However, the solutions to IP optimization problems are not trivial and the computation cost grows with the number of taps included.

In this work, we take a completely different perspective by taking advantage of proper normalization. We avoid the unbalanced performance in the traditional POD-based methods by first normalizing the observation data to make each tap contribute similarly to the total energy. This results in a decomposition that assigns similar weight to each dimension of data (each tap). In the compression step, only the first few normalized modes are retained as in traditional POD. During the reconstitution process, normalized data are first restored according to the traditional POD approach, then a scaling procedure which plays the role of inverse normalization is applied and transforms the normalized data to its original space.

Feasibility test and verification is conducted using experimental data collected at wind engineering research field laboratory (WERFL) at Texas Tech University.

## 2. Proper orthogonal decomposition (POD)

POD, which is also known as PCA in statistics and signal processing is a well-established technique for dimension reduction. The most common way to look at POD is in terms of