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FUZZY NOISE-INDUCED CODIMENSION TWO BIFURCATIONS BY FUZZY GENERALIZED CELL MAPPING WITH ADAPTIVE INTERPOLATION

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ABSTRACT

Fuzzy Generalized Cell Mapping with Adaptive Interpolation (FGCM-AI) is developed to investigate codimension-two bifurcations in nonlinear dynamical systems with fuzzy noise. An adaptive interpolation is introduced in a set-valued fuzzy parameter space to compute the one-step transition membership matrix of the FGCM. For each of initial points in the state space, a coarse database is constructed at first, and then interpolation nodes are inserted into the database iteratively each time errors are examined with the explicit formula of interpolation error until a maximal error is just under an error bound. With such an adaptively expanded database on hand, interpolating calculations assure the required accuracy with maximum efficiency gains. The new method is termed as Fuzzy Generalized Cell Mapping with Adaptive Interpolation (FGCM-AI). Global changes in fuzzy dynamics are dominated by the underlying deterministic counterparts, and fuzzy attractor expands along the unstable manifold leading to a collision with a saddle when a bifurcation occurs. Two symmetrically related fuzzy attractors grow and merge as the intensity of the fuzzy noise is increased. By introducing a small symmetry-breaking parameter to break the symmetry, the merging explosion bifurcation unfolds to a pattern with two different kinds of catastrophic and explosive bifurcations. Considering both the intensity of the fuzzy noise and the symmetry-breaking parameter together as controls, a vertex in a two-parameter space is found where a co-dimension two bifurcation of fuzzy attractors occurs. Such a codimension two bifurcation is fuzzy noise-induced and cannot be seen in deterministic systems. At the vertices of the codimension-two bifurcations, the dynamics of the system becomes extremely unpredictable and sensitive to control parameters as well as intensity of fuzzy noise. This means fuzzy noise not only reshapes attractors but also increase unpredictability in global dynamics even under any small noise perturbation.

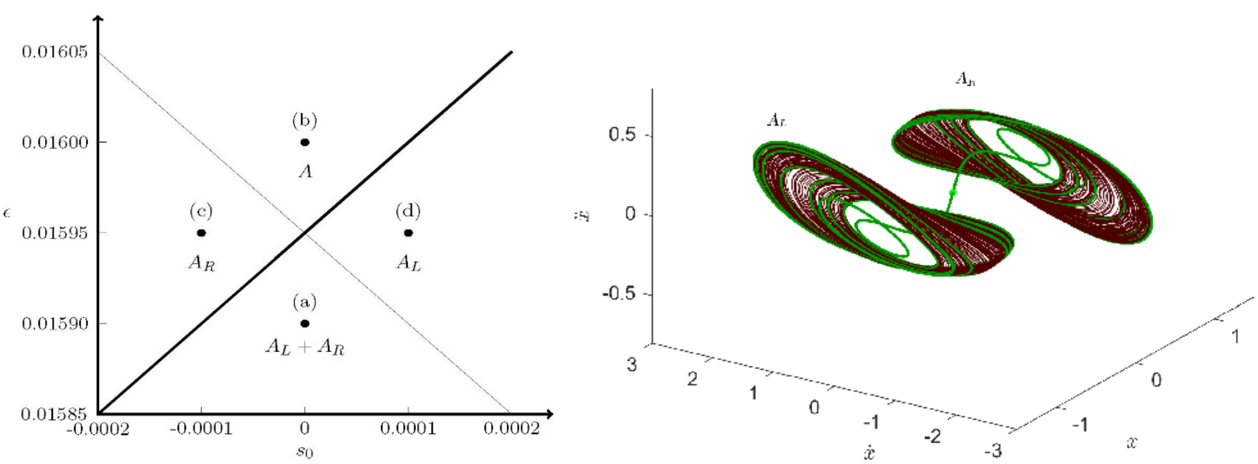

Figure 1: Codimension-two bifurcation induced by fuzzy noise

Keywords: Generalized cell mapping, Adaptive interpolation, Fuzzy noise, Codimension-two bifurcation

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ON THE NONHOLONOMIC CONSTRAINTS AND MOTION CONTROL OF WHEELED MOBILE STRUCTURES

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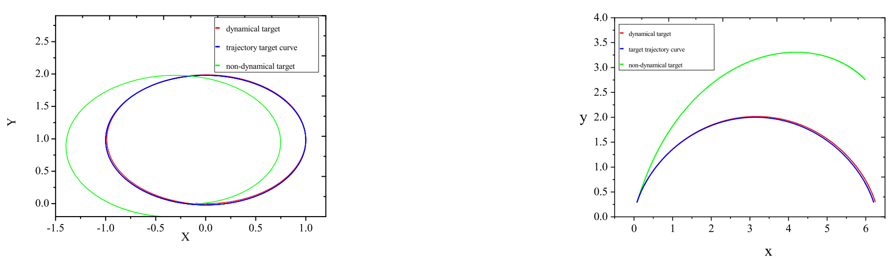
ABSTRACT

When the wheels of wheeled mobile structures run under the conditions of pure rolling and nonslipping, one has

$$-\dot{x}\sin\theta + \dot{y}\cos\theta = 0. \tag{1}$$

Eq.(1) is a common nonholonomic constraint discribing the motion characteristic of the center point, which means that the lateral velocity of the center point should be zero. In fact, if the lateral velocity is not zero at a moment, there will be a sharp point in the trajectory curve of the center point. Another significant nonholonomic constraint discribing the relationship between the yaw motion of center point and the steering angle of front wheels is $\dot{\theta} = \frac{v\tan\varphi}{a}$. Usually, the dynamics equations of wheeled structures merely describe the relationships between the torques and motion speeds. However, an actual task is usual to control the wheeled structure to track a given smooth curve precisely. Based on Eq.(1), the curve target can be transformed into the form of speed target with curvature $k(s)$

$$\begin{cases} \dot{x} = v\cos\theta \\ \dot{y} = v\sin\theta \end{cases} \Rightarrow \begin{cases} v = \sqrt{\dot{x}^2 + \dot{y}^2}, \\ \dot{\theta} = \dfrac{\dot{x}\ddot{y} - \ddot{x}\dot{y}}{\dot{x}^2 + \dot{y}^2} = k(s(t))v \end{cases} \Rightarrow \begin{cases} \hat{v} = \dot{\phi}(t), \\ \dot{\hat{\theta}} = k(s)v(t), s(t) = \displaystyle\int_0^t v(\tau)d\tau. \end{cases} \tag{2}$$



(a)The actual motion trajectory of the TWIP (b) The actual motion trajectory of the single-wheel

Figure 1: The actual motion trajectories of the two-wheeled inverted pendulum and the single-wheel

As shown in Figure 1, wheeled structures can move accurately along a given curve by using the dynamical tracking target (2) even though the forward speed error is unstable. Actually, the idea of dynamical trajectory tracking can be widely used in tracking a given curve precisely on various mechanical structures. One of its main advantages is that the speed error would not be accumulated, and the location error will not become larger and larger. Secondly, the forward speed target $\hat{v}$ can be chosen freely for better control effect. Especially, the accumulative location error caused by the initial speed error can be reduced dramatically by using an appropriate function $\phi(t)$. **Keywords:** Nonholomic constraint, Wheeled mobile structure, Curvature tracking, Dynamical tracking target.

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VIBRATION ENERGY TRANSFER BETWEEN OSCILLATORS COUPLED WITH A NONLINEAR JOINT

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ABSTRACT

This paper investigates the vibration transmission, in particular, the vibration energy transfer within nonlinear systems comprising two substructures coupled via a nonlinear joint. Such systems are frequently encountered in engineering structures in which substructures are interfaced through a nonlinear element [1]. For instance, bolted joints with flanges may have the characteristics that the compressional stiffness is much higher than the tensional stiffness [2]. To improve the dynamic performance of engineering structures, it is of importance to understand to influence of nonlinear interfacial elements on the vibration transmission. It is also necessary to propose novel designs of structural joints with superior vibration attenuation performance.

As illustrated by Figure 1, one of the substructures is subjected to external excitation. In many applications, it is desirable that the level of vibration transmission through the design of joint to be minimized to achieve vibration suppression. In this paper, nonlinear joints are proposed which are based on geometry nonlinearity of linkage mechanisms. The dynamic model of the overall system is firstly established. The governing equations are then solved by using a semi-analytical approach and also numerical integrations. Vibration energy transfer between the two substructures is then quantified using time-averaged power flow variables. The vibration power input, transmission and dissipation mechanisms are investigated. The effects of the nonlinear joint parameters on the level of vibration transmission between the two subsystems are examined and compared with those of the linear joint case. The findings provide some deeper understanding into the vibration transmission mechanisms and benefit enhanced design of structural joints for vibration mitigation purpose.

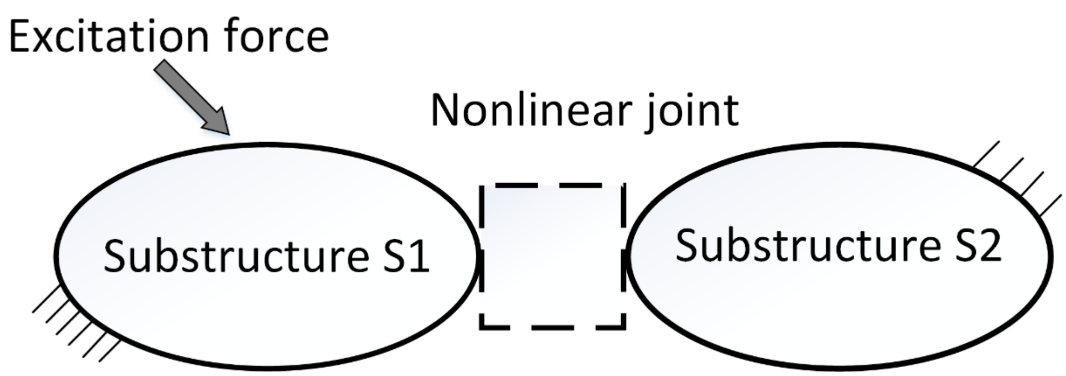

Figure 1: Coupled structures with a nonlinear joint.

Keywords: Vibration transmission, nonlinear joint, vibration energy transfer, power flow analysis

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NUMERICAL INVESTIGATION OF DYNAMIC BEHAVIOUR OF JEFFCOTT ROTOR SUPPORTED BY TILTING-PAD JOURNAL BEARINGS

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ABSTRACT

The tilting-pad journal bearings (TPJBs) are known [1] for providing high stability of rotating machines, low friction loss and low sensitivity to load direction. There are two main configurations of bearing design [1] – load between pads (LBP) and load on pad (LOP). Presented contribution focuses on general mathematical model development of the TPJB based on the decomposition of TPJB with n pads to n independent partial arc journal bearings in the moving coordinate systems.

Developed methods for modelling of rotors supported by TPJB were employed in an in-house software. Finite difference method [3] is used for solution of the Reynolds equation and evaluation of non-linear hydrodynamic force from calculated pressure field on each pad. Mutual interaction [2, 3] between the shaft and the tilting-pads is described by non-linear hydrodynamic force or linearized stiffness and damping coefficients of oil film.

Derived mathematical model of Jeffcott rotor supported by TPJB was chosen for numerical analyses and investigation of the system behaviour with respect to the system stability. Static and dynamic simulations were performed and several results are depicted in Fig. 1. Firstly, Fig. 1a shows the static equilibrium position (blue line) of the journal centre in the TPJB and the dynamic response (red line) of the rotor to the unbalance at constant rotor speed. Corresponding tilting angles of the pads during the static analyses are obvious from Fig. 1b. Pressure fields on the pads are depicted in Fig. 1c.

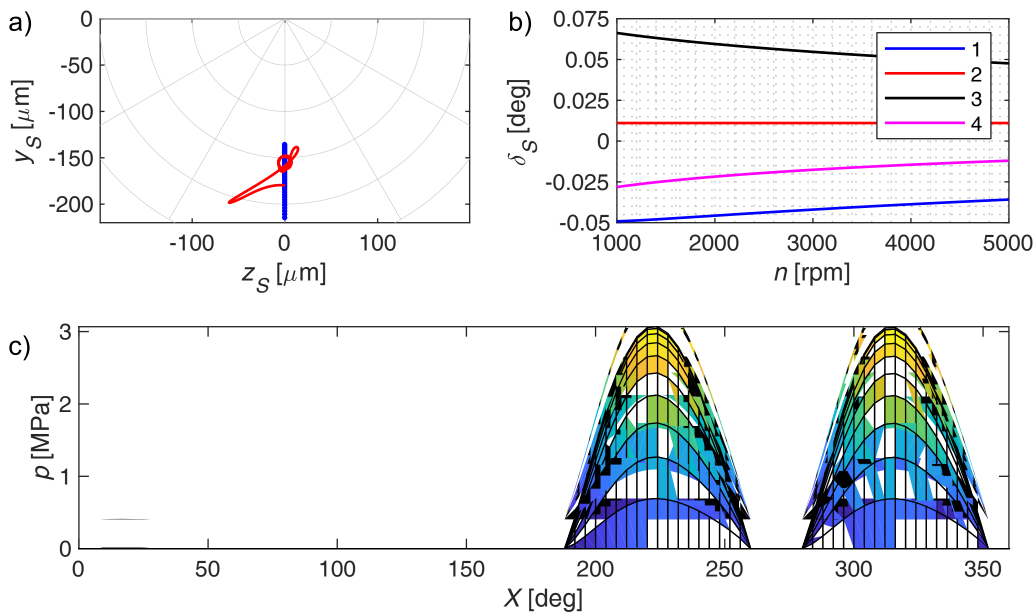

Figure 1: Chosen results of the static analyses and investigation of the system in the time domain

Keywords: tilting-pad journal bearing, rotordynamics, stability analysis, Jeffcott rotor

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THE SHORT AND LONG TERMED PREDICTIONS OF COVID-19 IN DIFFERENT COUNTRIES IN THE WORLD

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ABSTRACT

Now COVID-19 threaten the world seriously. The prediction of its development is important for the containment. In this paper, firstly we make the accurate short-termed predictions (i.e., one day predictions) of the numbers of accumulative confirmed patients (NACPs) for some countries such as USA, UK, Russia and Pakistan in the world by using hyperbolic tangent functions as basic functions for the fitting method. The relative errors can be less than 0.1%. Then, we make long-termed prediction for numbers of accumulative confirmed patients (NACPs) and numbers of accumulative death patients (NADPs) of COVID-19 in different countries and regions by fitting method. We use hyperbolic tangent functions as basic functions for the fitting method. The results indicate that it is possible to make the short- and long-termed prediction NACPs and NADPs of COVID-19 by using a small amount of data. And we can estimate the arrival times of the plateau phases of COVID-19 in some countries and regions. It shows that our method is simple (model-free) and very effective in long-termed prediction of NACPs and NADPs with small data.

Keywords: short- and long-termed prediction; NACP; NADP; COVID-19; plateau phase

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DISTANCE METRIC LEARNING FOR VIBRATION-BASED STRUCTURAL DAMAGE DETECTION

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ABSTRACT

It is unlikely that all possible damage scenarios are encountered during the operation of a structure. Therefore, if a supervised machine learning algorithm is used for a data-driven structural health monitoring (SHM) application, only a small subset of all possible damage scenarios is likely to be available for training. This may result in misclassification of novel damage scenarios that are encountered during the inspection of the structure. SHM methods are, therefore, mostly based on unsupervised algorithms, such as distance-based outlier analysis methods, especially for low-level applications where the aim is to detect rather than localize or assess the severity of damage. In these methods, only the undamaged state of the structure is characterized and any deviation from this characterization is considered to be an indication of damage. In this case, however, any information from the previously seen damage scenarios is lost. This work proposes an alternative SHM method, which is grounded on a distance-based outlier detection method but additionally utilizes the available damaged state data. The novelty is that the outlier detection method, specifically the one-class kNN classification method, is used in conjunction with a distance metric learning algorithm. Instead of a generic distance metric function, such as the Euclidean distance metric function, the distance metric learning algorithm uses the available damaged and undamaged state data to learn a distance metric function that is tailored specifically for the outlier detection problem at hand. The proposed method is applied to a laboratory scale experimental model of a top-tensioned offshore riser and its performance was compared with those of selected supervised and unsupervised methods. In the inspection phase, the proposed method performed as well as the reference supervised methods for damage scenarios seen in the training phase while it outperformed the reference unsupervised methods for damage scenarios unseen in the training phase.