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Alternative predictors in chaotic time series

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ABSTRACT

In the scheme of reconstruction, non-polynomial predictors improve the forecast from chaotic time series. The algebraic manipulation in the Maple environment is the basis for obtaining of accurate predictors. Beyond the different times of prediction, the optional arguments of the computational routines optimize the running and the analysis of global mappings.

New version program summary

Program Title: LinMapTS

Program Files doi: http://dx.doi.org/10.17632/pnhy9zymrp.1

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Programming language: Maple17

Journal reference of previous version: Comput. Phys. Comm. 207 (2016) 325

Does the new version supersede the previous version?: Yes

Nature of problem: Time series analysis and improving forecast capability.

Solution method: The method of solution is published in [1].

Restrictions: The routines employ the global variables $\{a_i, b, X_i\}$; If more than 2000 vectors are employed in the global mapping the normality test is not applicable.

Unusual features: The algebraic manipulation of the predictors improves the global forecast.

Reasons for the new version:

In the reconstruction's scheme [2], the predictor in the *global approach* has a standard form [3]. From a time series $\{X(0\Delta t), X(1\Delta t)\cdots, X((S-1)\Delta t)\}$ with S scalar quantities $X(t)$ and a time interval Δt, a state vector in the N-dimensional reconstructed phase space is

$$|x(t)\rangle \doteq \begin{bmatrix} X((N-1)T\Delta t) \\ \vdots \\ X(T\Delta t) \\ X(0) \end{bmatrix}. \tag{1}$$

The time delay T is a parameter for the choice of the observables $X((N-k)T\Delta t)$ (k is an integer) that are available in the time series [4].
The predictors $\mathcal{P}(|x_r\rangle)$ in the routine LinGfiTS of the package LinMapTS are linear combinations of the adjustment parameters.

$$\mathcal{P}(|x\rangle) = \sum_{i=1}^{m} a_i\,\varphi_i(|x\rangle). \tag{2}$$

Because this restricted form, the m-dimensional vector of parameters $|a\rangle$ is a computational solution of a matrix equation. So the computational procedure requires small runtimes for the least squares minimization [1].

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The routine generates only polynomial global maps, i.e. the functions $\varphi(|x\rangle)$ can assume forms – in a reconstructed phase space with variables (X_1, X_2, X_3) – like $\varphi_1 = X_1{}^2$, $\varphi_2 = X_1{}^3X_2{}^2X_3$ and so on. The predictors do not admit terms such as $\sin(X_1X_2X_3)$ or $\ln\left(1+\frac{1}{X_1X_2X_3}\right)$.
A prediction – denoted by X_{1P} – is the result of the application of the global map

$$X_{1P} = \mathcal{P}\left(|x_{P-1}\rangle\right), \tag{3}$$

where P is the order of the last known observable in the time series.

The principal focus in this new version is to extend the permissible functional forms for the global mappings. If non-polynomial terms take part in the predictors, the accuracy of the forecast can be improved. Here, the purpose is to offer the researcher best features when he intends to increase the predictions' power from a *chaotic time series*.
Another desired extension refers to the time of prediction. With the integer parameter τ, the future instant is given by $t + \tau\Delta t$. We have been presented this idea in the new version of the package `TimeS` [5]. But the runtime for generating polynomial maps is greater than the computational procedure `LinGfiTS` [1]. In this work, we apply $1 \to \tau$ in Eq. (3). Then it is rewritten as

$$X_{1P} = \mathcal{P}\left(|x_{P-\tau}\rangle\right). \tag{4}$$

Summary of revisions:
New optional arguments enable the selection of functional forms with different prediction times in the method of forecasting;
Instructions to use the LinMapTS package (README.pdf), computational routines (LinMapTS.txt) and test file (LinMapTS.mw).

In order to optimize the running of the programs `LinGfiTS` and `ConfiTS`, the arguments have now been rearranged. The current routines own optional arguments. Some of them are indispensable in the previous version.
Nowadays, the command `LinGfiTS` requires only two arguments. The first is a list of reconstructed vectors – assigned as V – and the second is the order of the last vector present in the global mapping – assigned as *final*.
The input necessary for the running of the procedure `ConfiTS` must have, in the following order: the global map – assigned as *map* –, the list V and the integer *final*.
Below, we describe all arguments that take part in the new version of the package `LinMapTS`.

- `[> LinGfiTS(V, final, optional arguments);`
- Required arguments:
  - List of reconstructed vectors—assigned as V in this paper.
  - The vector that has, as its first component, the last known value of the time series—assigned as *final* in this paper.
- Optional arguments:
  - `Degree = <integer>`. This argument specifies the degree of the polynomial predictor. The default is 2.
  - `Func = <expression>`. This argument specifies the predictor for the global mapping.
  - `Level <integer>`. This argument selects the interval of the time series for the global mapping. The default is 5.
  - `PT = <integer>`. This argument specifies the value of the parameter τ. The default is 1.
  - `Analysis = 1`. This argument is the necessary input for a graphical analysis of the global fitting.
- `[> ConfiTS(map,V,final, optional arguments);`
- Required arguments:
  - The global map—assigned as *map* in this paper.
  - List of reconstructed vectors—assigned as V in this paper.
  - The vector that has, as its first component, the last known value of the time series—assigned as *final* in this paper.
- Optional arguments:
  - `Level <integer>`. This argument selects the interval of the time series for the global mapping. The default is 5.
  - `PT = <integer>`. This argument specifies the value of the parameter τ. The default is 1.
  - `Analysis = 1`. This argument is the necessary input for a graphical analysis of the residuals' distribution and the applying of the normality test.

$$\sigma_\tau = \sqrt{\frac{\sum_{j=1}^{M}\left(X_{1j} - \sum_{i=1}^{m} a_i\varphi_i\left(|x_{j-\tau}\rangle\right)\right)^2}{M-1}}. \tag{5}$$

The outputs remain unchanged from the original programs [1]. The routine `LinGfiTS` makes available a global map, whereas the procedure `ConfiTS` returns the expected deviation σ_τ in the forecast.
However, this statistical quantity now incorporates the parameter τ. Its formula (5) employs the M reconstructed vectors which take part in global fitting.
As a first example of using the commands, the time parameter selected is $\tau = 2$. So it is necessary to include the optional argument PT=2 in the Maple prompt.