Adaptive Variational Nonlinear Chirp Mode Decomposition

icassp 2022 Singapore

Hao Liang[1,3], Xinghao Ding[1,3], Andreas Jakobsson[2], Xiaotong Tu[1,3,*], Yue Huang[1,3]

[1]School of Informatics, Xiamen University, China

[2]Div. of Mathematical Statistics, Lund University, Sweden

[3]Institute of Artificial Intelligent, Xiamen University, China

Paper #5736

Motivation

- Most methods are **unsuitable for wide-band signals**.
- The performance of many methods **relies heavily on the setting of the user-selected parameters**.

Contributions

- We propose **an adaptive implementation** from a Bayesian perspective.
- The proposed method can **adaptively estimate the instantaneous amplitudes and frequencies**, and form the dictionary in a **data-driven manner.**
- **A full posterior density function** is inferred, which may then be used to give a sense of confidence.

Proposed Method

- **Estimating the Nonlinear Chirp Signal**

$$\min_{\boldsymbol{w}} \ \alpha||\boldsymbol{y}-\boldsymbol{\Phi w}||_2^2+||\boldsymbol{w}||_2^2$$

- **Bayesian Strategy**

$$\mathrm{p}(\boldsymbol{y} \mid \boldsymbol{w}, \gamma_0)=\mathcal{N}\left(\boldsymbol{y} \mid \boldsymbol{\Phi w}, \gamma_0^{-1}\boldsymbol{I}\right)$$

$$\mathrm{p}(\boldsymbol{w} \mid \boldsymbol{\gamma})=\prod_{j=1}^{m}\mathcal{N}\left(w_j \mid 0, \gamma_j^{-1}\right)$$

$$\mathrm{p}(\boldsymbol{w} \mid \boldsymbol{y}, \gamma_0, \boldsymbol{\gamma})=\mathcal{N}\left(\boldsymbol{w} \mid \boldsymbol{\mu}, \boldsymbol{\Sigma}\right)$$

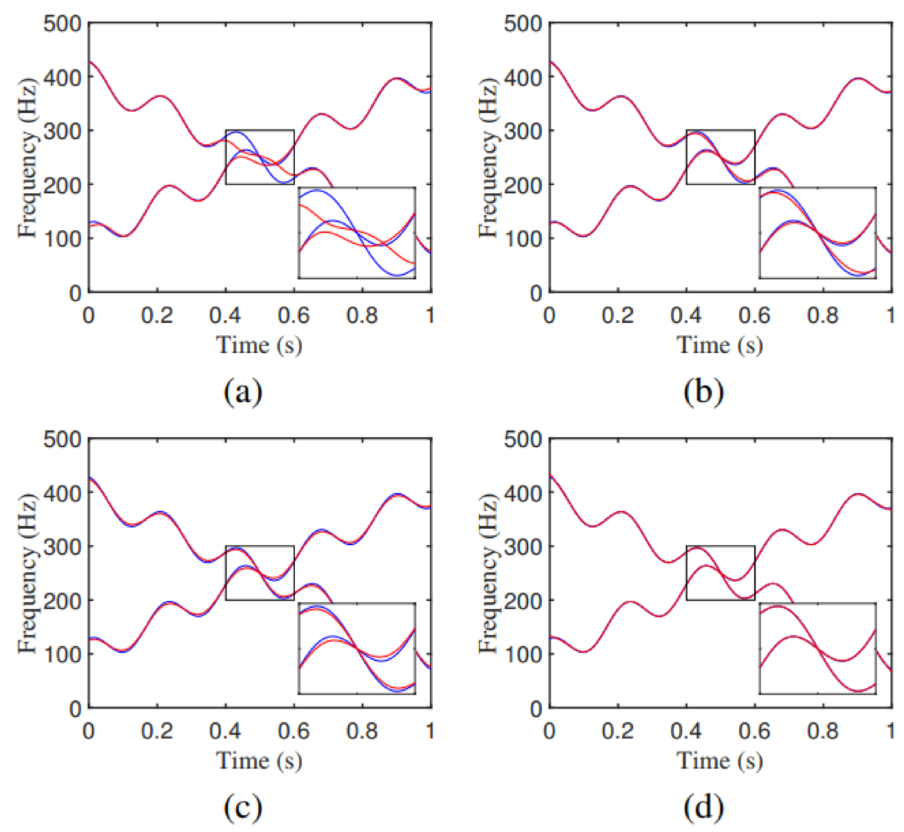
- **Data-driven Implementation**

$$\Delta f_k^{(i)}(t)=-\frac{1}{2\pi}\frac{d}{dt}\arctan\left(\frac{v_k^{(i)}(t)}{u_k^{(i)}(t)}\right)$$

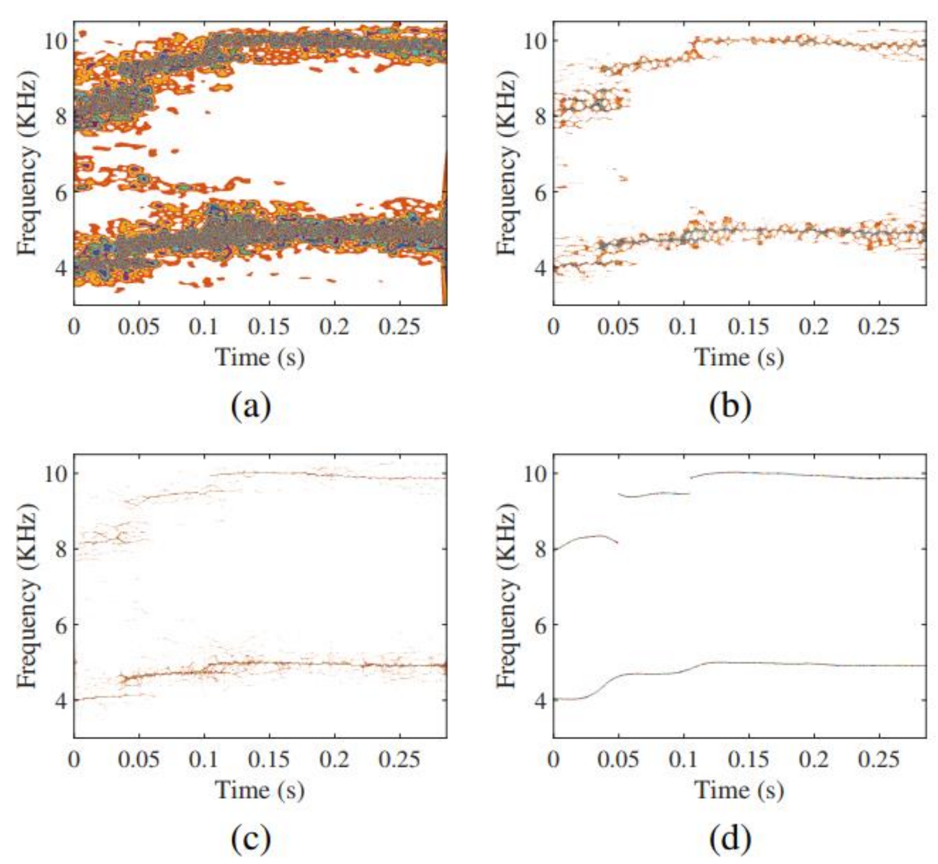
$$\Delta\tilde{\boldsymbol{f}}_k^{(i)}=\left(\boldsymbol{I}+\beta\boldsymbol{H}^T\boldsymbol{H}\right)^{-1}\Delta\boldsymbol{f}_k^{(i)}$$

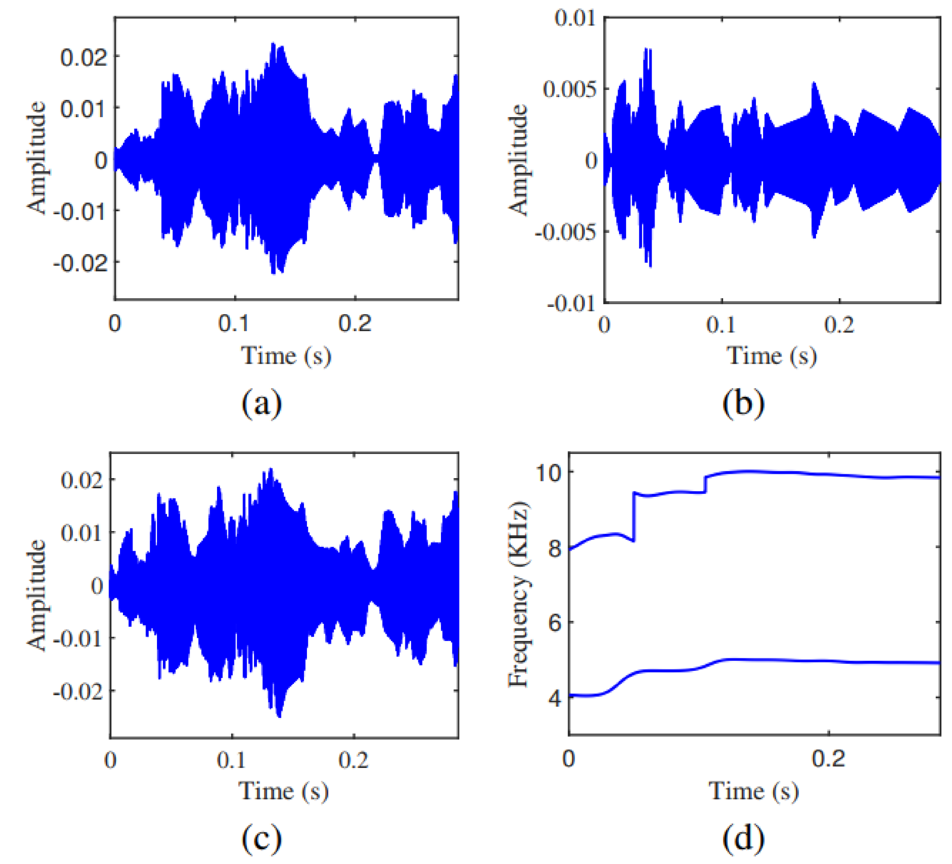
Visualized results

- **Simulated Signal**



- **Real-life Signal**





Numerical results

- The proposed algorithm provides **more accurate results with smaller relative errors**, clearly illustrating that the proposed method's **estimates well match the theoretical values**.
- Our method **yields a high-resolution time-frequency representation**, being capable of **representing the two modes and time-varying features** of the signal.
- The real-life example indicates the **potential** of the proposed method in **analyzing ocean signals**.

The codes are available at https://github.com/HauLiang/AVNCMD.