Spectrum anomaly detection using filtering Stockwell transform and Siamese Network

Xiao Yan Wang(1), Jing Jing Yang* (1), Ming Huang(1)*, Zhi Gang Chen(2), and Ji Da Wu(2)
(1) School of Information Science and Engineering of Yunnan University Kunming, 650091, PR China
(2) Radio Monitoring Center of Yunnan Province, Kunming 650228, China
* yangjingjing@ynu.edu.cn; huangming@ynu.edu.cn

A large number of wireless devices are applied to emerging applications to accommodate the massive traffic volume, leading to various high levels of interference behaviors such as spectrum congestion and transmission of non-stationary and malicious signals [1]. Higher order statistics features are extracted to identify abnormal patterns such as Fourier transform (FT), short time Fourier transform (STFT) and discrete wavelet transform (DWT). However, the above methods have some fatal disadvantages. The spectral parameters based on FT does not exhibit any time-domain characteristics, STFT using the filters of the fixed bandwidth for signal decomposition at all frequencies does not yield a multiresolution analysis of the signals, DWT cannot analyze non-stationary signal. Stockwell transform (ST) has high popularity for the analysis of nonstationary and nonlinear signals [2], but it is yet to be adequately explored in the radio monitoring domain.
Motivated by the excellent performance of ST, higher-order features are extracted from Stockwell images to detect and locate anomalies of abrupt and interfered radio signal in this article, what we focus on is whether an abnormal behavior occurs rather than normal behavior occurs in real environment, but redundant information from normal behavior often messes up our judgment and leads to wrong detection results. In order to eliminate such anomalies and avoid wrong detection results, we propose a filtered Stockwell transform (FST) that filters out redundant information while improving the detection probability, and its superiority over ST is confirmed in simulation experiments. Results show that the proposed method is superior to STFT in describing mutation signals and superior to ST in performing anomaly feature extraction. This work presents an effective anomaly detection method AnoSCNN, which combines the improved Stockwell transform and Siamese convolutional neural network (SCNN). In the experiment, the detection performance of the proposed method is improved by 13.18% and 29.52% compared with STFT and ST, respectively.

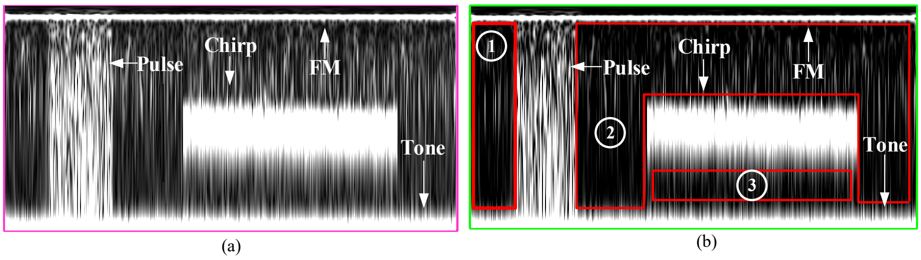

Figure 1. Example Stockwell images. (a) Image from ST. (b) Image form FST.

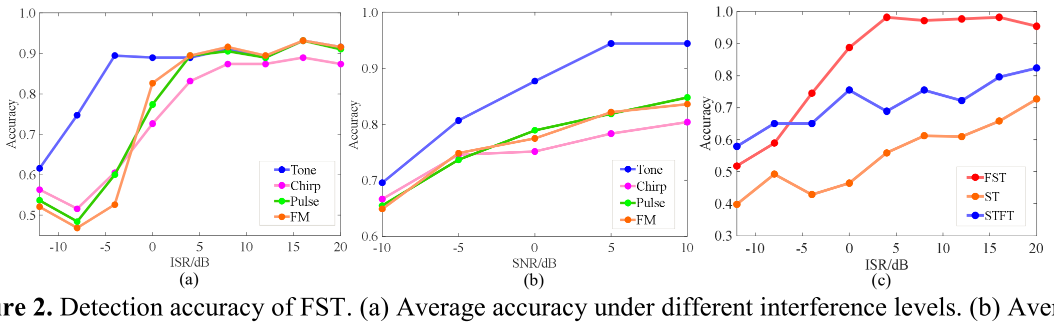

Figure 2. Detection accuracy of FST. (a) Average accuracy under different interference levels. (b) Average accuracy under different channel conditions. (c) The average accuracy of FST, ST and STFT with SNR=5dB.

1. Q. N. Lu, J. J. Yang, Z. Y. Jin, D. Z. Chen, and M. Huang, "State of the Art and Challenges of Radio Spectrum Monitoring in China," Radio Science, **52**, 10, September 2017, pp. 1-7, doi: 10.1002/2017RS006409.

2. R. G. Stockwell, L. Mansinha and R. P. Lowe, "Localization of the complex spectrum: the S transform," in IEEE Transactions on Signal Processing, vol. 44, no. 4, pp. 998-1001, April 1996, doi: 10.1109/78.492555.