

# Time-frequency Analysis and Convolutional Neural Network Based Fuze Jamming Signal Recognition

Jikai Yang<sup>1</sup>, Zhiquan Bai<sup>1,\*</sup>, Jiacheng Hu<sup>1</sup>, Yingchao Yang<sup>1</sup>, Zhaoxia Xian<sup>1</sup>, Xinhong Hao<sup>2</sup>,  
KyungSup Kwak<sup>3</sup>

<sup>1</sup> Shandong Provincial Key Lab. of Wireless Communication Technologies, School of Information Science and Engineering, Shandong University, Qingdao 266237, Shandong, China

<sup>2</sup> School of Mechatronical Engineering, Beijing Institute of Technology, Beijing 100081, China

<sup>3</sup> Graduate School of Information Technology and Telecommunications, INHA University, Incheon 22212, Korea  
yjk1425@163.com, zqbai@sdu.edu.cn\*, 906603100@qq.com, yangyingchao1991@hotmail.com,  
xianzhaoxia2000@163.com, haoxinhong@bit.edu.cn, kskwak@inha.ac.kr

**Abstract**—Fuze jamming signal recognition plays a critical role in the battlefield environment. To improve the performance of fuze jamming signals detection, we propose a fuze jamming signal detector based on time-frequency analysis (TFA) and convolutional neural network (CNN), called TFA-CNN, in this paper. The detailed recognition process of the proposed TFA-CNN detector is provided, where the short-time Fourier transform (STFT) is first employed to convert the original jammed fuze signals into the time-frequency images and then the TFA-CNN detector is built to train the recognition model. Simulation results verify that the TFA-CNN detector outperforms the typical existing recognition detectors, such as LeNet, time-frequency images and convolutional neural network (TFI-CNN) and deep neural network (DNN), in the detection performance with a slightly higher time complexity. Specially, the average recognition accuracy of the proposed detector achieves 99.8% even at a low signal-to-interference-plus-noise ratio (SINR).

**Keyword**—fuze, CNN, STFT, image, accuracy



**Jikai Yang** is currently pursuing the M.S. degree in Electronic Information at the School of Information Science and Engineering, Shandong University, Qingdao, China. His research interests include deep learning, signal processing and signal recognition.



**Zhiquan Bai** received the M.Eng. degree in communication and information system from Shandong University, Jinan, China, in 2003, and the Ph.D. degree (Hons.) from INHA University, Incheon, South Korea, in 2007, under the Grant of Korean Government IT Scholarship. He held a postdoctoral position with INHA University, and was a Visiting Professor with The University of British Columbia, Canada. He is currently a Professor with the School of Information Science and Engineering, Shandong University. His research interests include cooperative technology and spatial modulation, orthogonal time frequency space modulation, MIMO technology, resource allocation and optimization, and deep-learningbased 5G wireless communications. He is a member of the editorial board of Journal of Systems Engineering and Electronics and also an associate editor of the International Journal of Communication Systems.



**Jiacheng Hu** received the B.S. degree from the School of Physical Science and Technology of Jinan University in Jinan, China. He is currently pursuing the M.S. degree in Electronic Information at the School of Information Science and Engineering, Shandong University, Qingdao, China. His research interests include OTFS, channel estimation, and deep learning.



**Yingchao Yang** is currently pursuing the Ph.D. degree in communication and information system from the School of Information Science and Engineering, Shandong University, Qingdao, China. His research interests include MIMO technology, spatial modulation, orthogonal time frequency space modulation, and cooperative communication.



**Zhaoxia Xian** received the B.S. degree from the School of Physical and Electronic Sciences at Shandong Normal University in Jinan, China. She is currently pursuing the M.S. degree in Electronic Information at the School of Information Science and Engineering, Shandong University, Qingdao, China. Her research interests include signal processing, signal recognition and deep learning.



**Xinhong Hao** received the B.S., M.S., and Ph.D. degrees in technical and electrical engineering from Beijing Institute of Technology University, Beijing, China, in 1996, 1999, and 2007, respectively. She is currently an Associate Professor with the Department of Technical and Electrical, Beijing Institute of Technology University. Her research interests include intelligent detection and control, radio target detection and signal processing, and information perception and confrontation.



**Kyung Sup Kwak** received his BS degree from the Inha University, Incheon, Korea, in 1977 and his MS degree from the University of Southern California in 1981 and his PhD degree from the University of California at San Diego in 1988, under the Inha University Fellowship and the Korea Electric Association Abroad Scholarship Grants, respectively. From 1988 to 1989, he was with Hughes Network Systems, San Diego, California. From 1989 to 1990, he was with the IBM Network Analysis Center, North Carolina. Since then, he has been with the School of Information and Communication Engineering, Inha University, Korea, as a professor. He is the director of UWB Wireless Communications Research Center (UWB-ITRC). Since 1994, he served as a member of the board of directors and the vice president and the president of Korean Institute of Communication Sciences (KICS) in 2006 and the president of Korea Institute of Intelligent Transport Systems (KITS) in 2009. He received many research awards, such as the award of research achievements in UWB radio from the Ministry of Information & Communication and Prime Ministry of Korea in 2005 and 2006, respectively. In 2008, he is elected as Inha Fellow Professor (IFP). In 2010, he received the Korean President official commendation for his contribution to ICT innovation and industrial promotion. He published more than 100 SCI journal papers, 300 conference/domestic papers, obtained 20 registered patents and 35 pending patents, and proposed 21 technical proposals on IEEE 802.15 (WPAN) PHY/MAC. He is one of the members of the IEEE, IEICE, KICS, and KIEE. His research interests include multiple access communication systems, cognitive radio, UWB radio systems and WBAN, WPAN, and sensor networks.