

Bidimensional empirical mode decomposition method for image processing in sensing system[☆]

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ABSTRACT

Recent developments in image processing play a significant role in processing the images clearly. Undoubtedly, identifying the target against clutter is another challenging task in Ground Penetrating Radar (GPR) image processing. To successfully distinguish targets from surrounding clutter, a novel Bidimensional Empirical Mode Decomposition (BEMD) system is proposed. The overall process can be broken down into four steps. First, images are decomposed using BEMD arithmetic to extract the Intrinsic Mode Functions (IMFs). Then, these IMFs could be examined using gradual single frequency signals to bring out and highlight the physical meaning of instantaneous amplitudes and instantaneous frequencies. To find the best-fitting hyperbolas, the object position of the vertex is estimated using maximum point estimation method and velocity is estimated using a minimum entropy method. Finally, the location of reflection hyperbolas can be extracted clearly. The simulation and experimental images show the effectiveness of this method in identifying targets.

1. Introduction

Recently, developments in image processing play a significant role in processing the images clearly. But, identifying the target against the clutter is another challenging task in image processing. Some images like Ground Penetrating Radar (GPR) B-Scan image is used to locate anomalies below the surface of the Earth, like mines, pipes, and many other buried objects. To determine the exact position of the object, a proper and effective method for identifying the target against the clutter is essential.

Previous works have addressed automatic detection of buried objects from GPR images. Delbo et al. proposed that hyperbolic signatures of buried objects might be extracted using wavelet method to reduce noise, and they have also used a clutter suppression approach to identify hyperbolas [1]. This facilitates estimation of the positions of these objects. Gamba et al. [2] and Capineri et al. [3] used preprocessing steps to render the signatures of buried targets clearer, and then used artificial neural networks to interpret the images automatically. Al-Nuaimy [4] used an artificial neural network classifier to pre-identify areas likely to contain targets and Hough transformation to locate hyperbolic patterns.

Huang et al. developed a method of adaptive signal processing called Empirical Mode Decomposition (EMD) [5]. This can be used to introduce and process nonstationary and nonlinear signals. Unlike other decomposition methods, EMD is adaptive, empirical, and direct but does not require any pre-determined basis conditions. This method's decomposition process is based on local timescale

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data. Many applications involve using EMD to process geophysical signals. Battista used EMD to remove cable strum noise from seismic data [6]. Bekara eliminated the first EMD component from the f - x domain [7]. Narayanan used EMD method to mitigate both coherent and random noise in wall radar human detection [8]. Wu et al. proposed Ensemble Empirical Mode Decomposition (EEMD) to overcome these problems [9]. EEMD involves evaluating the signal through Gaussian white noise.

Li et al. attempted to improve signal resolution and provide better details regarding human life signal characteristics [10]. They did some research into through-wall UWB radar to detect the presence of people using EEMD. However, EEMD requires raw data with a high Signal to Noise Ratio (SNR). Han performed an accurate reconstruction of the original signal using Complete EEMD (CEEMD) and the results show better spectral separation of modes [11].

All these methods are effective, but the preciseness still needs to be improved. And these methods involve one-dimensional signal decomposition to process radar data. In this paper, a novel Bidimensional Empirical Mode Decomposition (BEMD) approach of target location by GPR two-dimensional images (B-Scan) is proposed. BEMD method was originally proposed by Nunes [12]. We use it to deal with GPR images. Simulation and experiment data indicate the effectiveness of BEMD method in clutter suppression and high preciseness of targets extraction.

The remainder of this paper is organized as follows. Section 2 introduces BEMD algorithm framework, including BEMD preprocessing method, region of interest (ROI) extraction method, and position of vertex and velocity estimation method. Section 3 presents the simulation results and experiment results, which show the effectiveness and high performance of the proposed BEMD method. Finally, in Section 4, concluding remarks summarizing the overall study are provided.

2. Algorithm framework

BEMD method can reduce clutter signals by Intrinsic Mode Functions (IMFs). Then, the IMFs can be treated as gradual single frequency signals, which makes the physical meaning of instantaneous anomalies and instantaneous frequencies clearer. After decomposition, whatever IMF component is provided, most of the target information is selected for further detection of hyperbolas. At this point, it is possible to remove most of the background clutter without distorting the target signal. To identify the best-fitting hyperbolas, the position of the vertex object is estimated with maximum point estimation. Velocity is estimated using the minimum entropy. This is done to locate the reflection hyperbolas.

The object detection algorithm can be divided into four steps: (1) Using BEMD to decompose image into IMFs; (2) Extracting the ROI; (3) Estimating the position of vertex by computing slope; (4) Estimating the velocity based on minimum entropy; and (5) Detecting hyperbolic patterns after estimating the parameters. A flowchart of this proposed strategy is given in Fig. 1.

Raw images are first decomposed using BEMD to extract intrinsic mode functions. This not only removes clutter from the ground surface echo but also increases the visibility of targets' reflections. The object position of the vertex is estimated by computing the slope of each point, and velocity is estimated using the minimum entropy method. The location of reflection hyperbolas can be extracted using the estimated parameter [13].

2.1. Bidimensional empirical mode decomposition preprocessing

EMD is an adaptive signal processing method suitable for preliminary processing of nonlinear and non stationary signals. The

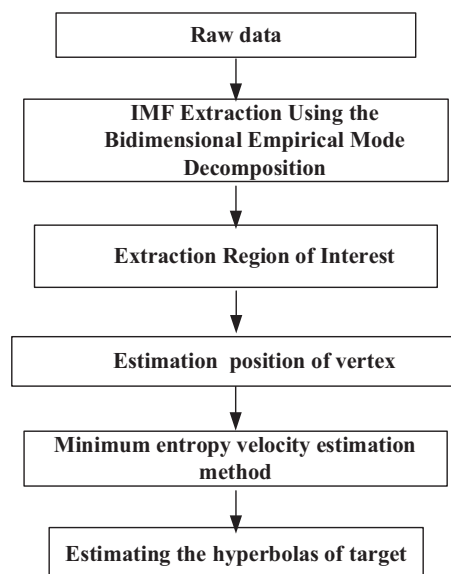


Fig. 1. Detection algorithm.

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