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FAST SUPER-RESOLUTION-BASED PULSE PHASE ESTIMATION METHOD FOR XNAV

Abstract

XNAV (X-ray pulsar-based navigation), which employs the high periodic stability of pulsars, is a novel autonomous navigation method for space vehicle. After first introduced in 1980s, the past four decades have witnessed a significant growth in XNAV, including the pulse phase estimation and the navigation algorithm. Besides, some flight experiments were performed, such as SEXTANT (Station Explorer for X-ray Timing and Navigation Technology), the TG-2 (Tiangong-2) spacelab and the Insight-HXMT (Insight-Hard X-ray Modulation Telescope) Satellite. The pulsar signal is extremely weak, an orbiting space vehicle can only record a series of photon TOAs (times of arrival) rather than a continuous pulsed signal. Moreover, the orbit motion of a space vehicle introduces an unknown Doppler frequency into the pulse signal. In the flight experiments on XNAV performed by SEXTANT, the pulse phase and Doppler frequency are estimated together by a two-dimensional grid search which is of high computational cost. The two-dimensional grid search method can be viewed as sampling the objective function on the nodes of grid and finding the node corresponding to the maximin of objective function. Therefore, the resolution of grid, which depends on the interval size between the nodes, is one of the main factors impact the computational complexity and the estimation accuracy of the grid search method. If the resolution of grid is high, the estimation accuracy and the computational cost of the grid search method are also high. In order to balance the estimation accuracy and computational cost, this paper introduces image super-resolution reconstruction method into pulse phase and Doppler frequency estimation. In the proposed method, we first obtained a LR (low resolution) frequency-phase spectrum by sampling the objective function on a sparse grid, and then reconstruct HR (high resolution) frequency-phase spectrum by interpolation. The pulse phase and Doppler frequency estimation result is obtained by finding the nodes of the reconstructed HR frequency-phase spectrum corresponding to the maximin of objective function. The performance of proposed method is verified by the simulation data and the real data from NICER (Neutron Star Internal Composition Detector). Simulation results show that the proposed method can reduce the computational cost while ensuring the accuracy of pulse phase and Doppler frequency estimation.