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Construction of Graph Signal Modulations via Graph Fourier Transform and Its Applications

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Abstract : Classical window Fourier transform has been widely used in signal processing, image processing, machine learning and pattern recognition. The related Gabor transform is powerful enough to capture the texture information of any given dataset. Recently, in the emerging field of graph signal processing, researchers devoting themselves to develop a graph signal processing theory to handle the so-called graph signals. Among the new developing theory, windowed graph Fourier transform has been constructed to establish a time-frequency analysis framework of graph signals. The windowed graph Fourier transform is defined by using the translation and modulation operators of graph signals, following the similar calculations in classical windowed Fourier transform. Specifically, the translation and modulation operators of graph signals are defined by using the Laplacian eigenvectors as follows. For a given graph signal, its translation is defined by a similar manner as its definition in classical signal processing. Specifically, the translation operator can be defined by using the Fourier atoms; the graph signal translation is defined similarly by using the Laplacian eigenvectors. The modulation of the graph can also be established by using the Laplacian eigenvectors. The windowed graph Fourier transform based on these two operators has been applied to obtain time-frequency representations of graph signals. Fundamentally, the modulation operator is defined similarly to the classical modulation by multiplying a graph signal with the entries in each Fourier atom. However, a single Laplacian eigenvector entry cannot play a similar role as the Fourier atom. This definition ignored the relationship between the translation and modulation operators. In this paper, a new definition of the modulation operator is proposed and thus another time-frequency framework for graph signal is constructed. Specifically, the relationship between the translation and modulation operations can be established by the Fourier transform. Specifically, for any signal, the Fourier transform of its translation is the modulation of its Fourier transform. Thus, the modulation of any signal can be defined as the inverse Fourier transform of the translation of its Fourier transform. Therefore, similarly, the graph modulation of any graph signal can be defined as the inverse graph Fourier transform of the translation of its graph Fourier. The novel definition of the graph modulation operator established a relationship of the translation and modulation operations. The new modulation operation and the original translation operation are applied to construct a new framework of graph signal time-frequency analysis. Furthermore, a windowed graph Fourier frame theory is developed. Necessary and sufficient conditions for constructing windowed graph Fourier frames, tight frames and dual frames are presented in this paper. The novel graph signal time-frequency analysis framework is applied to signals defined on well-known graphs, e.g. Minnesota road graph and random graphs. Experimental results show that the novel framework captures new features of graph signals.

Keywords : graph signals, windowed graph Fourier transform, windowed graph Fourier frames, vertex frequency analysis
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