

Discrete Hartley transform

A **discrete Hartley transform (DHT)** is a Fourier-related transform of discrete, periodic data similar to the discrete Fourier transform (DFT), with analogous applications in signal processing and related fields. Its main distinction from the DFT is that it transforms real inputs to real outputs, with no intrinsic involvement of complex numbers. Just as the DFT is the discrete analogue of the continuous Fourier transform (FT), the DHT is the discrete analogue of the continuous Hartley transform (HT), introduced by Ralph V. L. Hartley in 1942.^[1]

Because there are fast algorithms for the DHT analogous to the fast Fourier transform (FFT), the DHT was originally proposed by Ronald N. Bracewell in 1983^[2] as a more efficient computational tool in the common case where the data are purely real. It was subsequently argued, however, that specialized FFT algorithms for real inputs or outputs can ordinarily be found with slightly fewer operations than any corresponding algorithm for the DHT.

Definition

Formally, the discrete Hartley transform is a linear, invertible function $H: \mathbf{R}^N \rightarrow \mathbf{R}^N$ (where \mathbf{R} denotes the set of real numbers). The N real numbers x_0, \dots, x_{N-1} are transformed into the N real numbers H_0, \dots, H_{N-1} according to the formula

$$H_k = \sum_{n=0}^{N-1} x_n \operatorname{cas}\left(\frac{2\pi}{N}nk\right) = \sum_{n=0}^{N-1} x_n \left[\cos\left(\frac{2\pi}{N}nk\right) + \sin\left(\frac{2\pi}{N}nk\right) \right] \quad k = 0, \dots, N-1.$$

The combination $\cos(x) + \sin(x) = \sqrt{2} \cos\left(x - \frac{\pi}{4}\right)$ is sometimes denoted **cas**(*x*), and should not be confused with **cis**(*x*) = $e^{ix} = \cos(x) + i \sin(x)$, or $e^{-ix} = \operatorname{cis}(-x)$ which appears in the DFT definition (where *i* is the imaginary unit).

As with the DFT, the overall scale factor in front of the transform and the sign of the sine term are a matter of convention. Although these conventions occasionally vary between authors, they do not affect the essential properties of the transform.

Properties

The transform can be interpreted as the multiplication of the vector (x_0, \dots, x_{N-1}) by an N -by- N matrix; therefore, the discrete Hartley transform is a linear operator. The matrix is invertible; the inverse transformation, which allows one to recover the x_n from the H_k , is simply the DHT of H_k multiplied by $1/N$. That is, the DHT is its own inverse (involutory), up to an overall scale factor.

The DHT can be used to compute the DFT, and vice versa. For real inputs x_n , the DFT output X_k has a real part $(H_k + H_{N-k})/2$ and an imaginary part $(H_{N-k} - H_k)/2$. Conversely, the DHT is equivalent to computing the DFT of x_n multiplied by $1 + i$, then taking the real part of the result.

Hartley Transforms

Scott C. Dulebohn



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