Three-dimensional truncated correlation photothermal coherence tomography image optimization using linear iso phase imaging

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This is a study of the effect thermal transient truncation in the Truncated Correlation Photothermal Coherence Tomography (TC-PCT) algorithm. A new phase channel is introduced which was coined the name Linear Iso Phase (LIOP). The channel improves the conventional TC-PCT phase by redevising its matched-filter sampling scheme and removing the effect of circular aliasing artifacts introduced in the frequency-domain-transformed cross-correlation (CC) calculations.

Background – Introduction. - A brief overview of the existing TC-PCT [1] and enhanced TC-PCT (eTC-PCT) [2] algorithms will be presented to better understand their signal processing differences, followed by a new phase imaging channel algorithm termed the Linear Iso Phase (TC-PCT LIOP) which uses an alternative sampling procedure and linear-cross correlations for improved volumetric reconstructions as opposed to the circular cross-correlations used by the TC-PCT phase channel. The algorithms are applied to imaging a multi-layered sample and comparisons are made between the volumetric reconstructions produced.

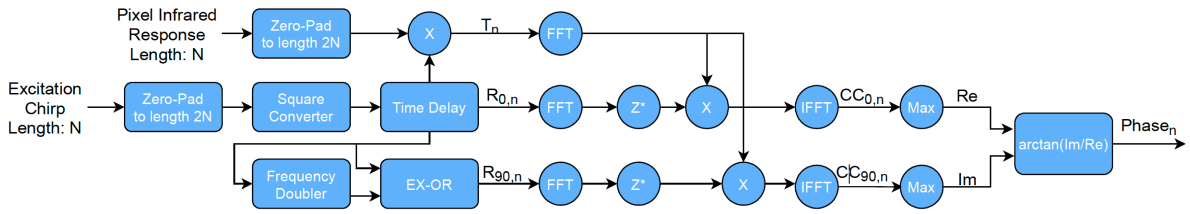

Fig. 1. Linear Iso-TCPCT Phase signal processing diagram.

Image processing – The new LIOP channel was introduced to reduce the sparsity-induced noise present in the TC-PCT phase while maintaining its strong thermal-wave localization character. This image reconstruction in the time-delay domain is that the infrared signal tends to decay in amplitude strength as the delay time increases. This results in three-dimensional reconstructions requiring large dynamic range which are difficult to display as the surface slice amplitude is generally much greater than its deeper (longer delay times) counterparts. This limits the visualization of small local features making it difficult to detect their presence and becomes more of an issue as the deposited pulse energy increases. For visualization purposes, the spatial correlation of features matters more than their signal intensities. Hence, the image intensities can be readjusted to improve feature visibility while preserving spatial coherence on a slice-by-slice method. To do so, it was found that by applying global histogram

equalization [3] to each tomographic slice, the contrast of the reconstructions, particularly for the amplitude channels, can be greatly improved.

Experimental and results. - To implement this algorithm, the Scikit Image [4] Python package was used and applied to the tomographic reconstructions on a slice-by-slice basis. In this method, each equalized slice is rescaled between (0,1), ensuring a lower volumetric dynamic range than the input volume resulting in enhanced slice contrast. The effectiveness of this algorithm in improving subtle feature visibility can be seen in Figs. 2 which are 3D image reconstructions of the marquetry art sample of Fig. 1 using multi-pulse excitation signals. The LIOP reconstruction (Fig. 2) shows clear separation between the sample's surface and hidden hole, with slowly developing wood grains, producing a more faithful reconstruction of deep inhomogeneities.

Fig. 1. (**A)** The irradiated mahogany veneer front layer of the marquetry sample. (**B)** The pine layer of the art sample with a 14-mm diameter drilled through-hole in the pine layer only.

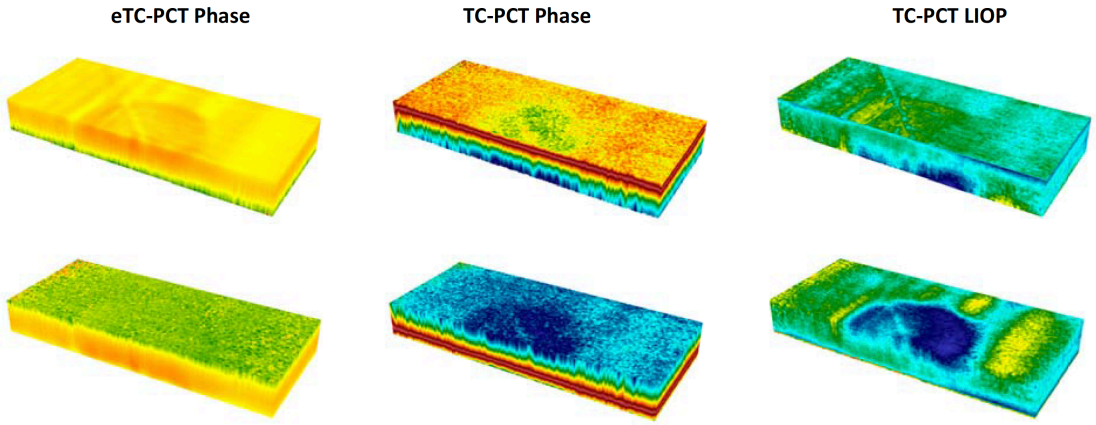

Fig. 2. Tomographic phase reconstructions of Fig. 1 derived from a 0.2-0.4-Hz, 17-s chirp with 5x pulses at 10-ms widths and 100-ms slice widths for all the reconstructions. The top row shows the irradiated surface facing upwards, and the bottom row shows the hidden backside facing upwards for the eTC-PCT Phase (left column), TC-PCT Phase (middle column) and TC-PCT LIOP (right column) algorithms. The blind hole and woodgrains are 0.7 mm below the irradiated surface.

Conclusions. - A new TC-PCT phase channel, termed "Linear Iso Phase" (LIOP) was introduced, which exhibits improved experimental phase reconstruction quality by removing the effects of circular aliasing resulting from frequency-domain-transformed cross-correlation operations, while enhancing subtle feature resolution even at very low thermal-wave modulation frequencies.

References

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