Experimental Evaluation of Causal Relationships Detection

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This document is a supplementary report to the ICCV2015 paper: Exploring Causal Relationships in Visual Object Tracking [1]. It brings detailed experimental evaluation of the proposed technique for detecting causal relationships on synthetic data.

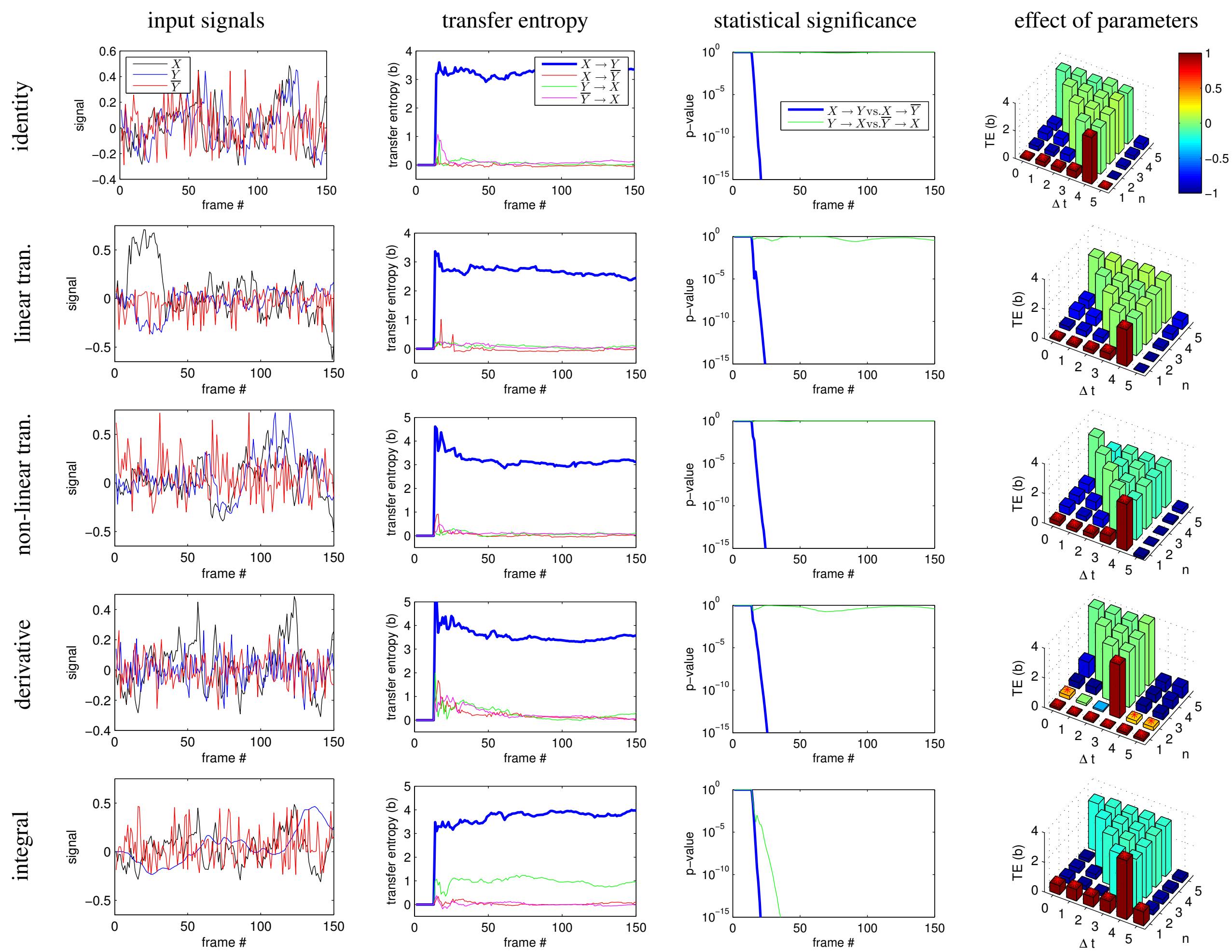

Figure 1. Results on synthetic data. A ground truth delay of 5 frames ($\Delta t = 4$ for $n = 1$) is used. In all cases, TE of the correct signal is consistently significantly higher then of the other signals, and is the only one which gains non-negligible statistical significance. The results for the derivative signal are different, since at least two frames are needed for its estimation (and therefore $\Delta t^* = 3$ and $n^* = 2$). Since the integral transformation uses information from a longer time interval (in fact from the whole history), there is a noticeable transport of information even in the reversed direction. The legend is the same as in Figure 4 of [1] (the colours indicate the relative improvement f and the red stars mark $f > \theta_f$).

For the purpose of validation on synthetic data, a 1D *stationary autoregressive process* (a random walk with exponential fading) was generated as an input signal X. The dependent signal Y was created by delaying X, applying a transformation (ranging from an identity to complex non-linear transformations) and adding Gaussian noise. We firstly compare the transfer entropy between the real signals (with $n = 4$ and $\Delta t = 4$), a random signal $\bar{Y}$ and the real signal with cause and effect reversed. Then the significance analysis is performed, and finally the optimal parameters for prediction are found. See Figure 1 for results.

The results clearly show, that transfer entropy is an excellent approach for analysing time series with complex relationships. While transfer entropy of the correct signal gains statistical significance after only a small number of frames, the significance of the reversed causal relationship stays low for the duration of the sequences. Performance under even highly non-linear transformations shows the value of the information-theoretic approach.

References

[1] K. Lebeda, S. Hadfield, and R. Bowden. Exploring causal relationships in visual object tracking. In *Proceedings of the International Conference on Computer Vision*, 2015. 1