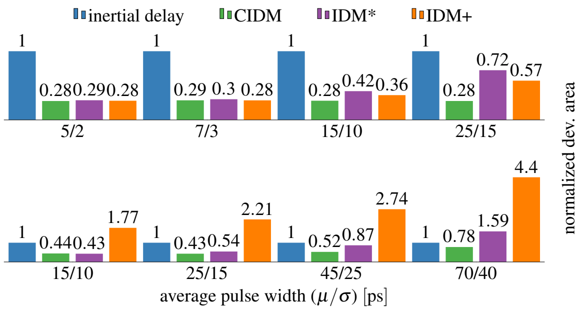

Figure 7: Accuracy, expressed as the normalized total deviation area of the digital predictions, relative to SPICE for the standard inverter chain (top) and high/low threshold inverter chain (bottom). Lower bars indicate better results.

trace obtained with a digital delay model. Summing up the area (without considering the sign), we obtain a metric that can be used to compare the similarity of two traces. Since the absolute values of the area are inexpressive, we normalize the results and use the inertial delay model as baseline.

For short pulses, IDM*, IDM+ and CIDM perform similarly. We conjecture that this is a consequence of the narrow range for V_{th}^{out*} and V_{th}^{in*} ([0.39156, 0.4] V), and therefore the induced error due to non-perfect matchings in IDM+ is negligible. For broader pulses, we observe a reduced accuracy of IDM* and IDM+, which is primarily an artifact of the imperfect approximation of the real delay function by the ones supported by the Involution Tool. We even observed settings, where CIDM does not even beat the inertial delay model, which can also be traced to this cause.

For our custom inverter chain [Fig. 7 (bottom)], CIDM outperforms, as expected, the other models considerably, whereas IDM+ occasionally delivers poor results, even compared to inertial delays. This is a consequence of the non-matching threshold values and the accumulating error. IDM* achieves much better predictions, but still falls short compared to CIDM. For broader pulses, CIDM and the inertial delay model perform similar, since they use the same maximum delay $\delta_\uparrow(\infty)$ and $\delta_\downarrow(\infty)$. The degradation of IDM* is once again a result of the imperfect delay function approximations.

Finally, analog simulations shown in Fig. 8 reveal, that subthreshold pulses at some stage $S1$ can recover at the subsequent stage ($S2$) and even later in the chain ($S4$). Note that such a behavior is only faithfully modeled by CIDM, since IDM cannot propagate canceled transitions on signal $S1$ (dashed lines).

To summarize the results of our experiments, we highlight that the characterization procedure for IDM either requires high effort (IDM*) or may lead to modeling inaccuracies (IDM+). The CIDM clearly outperforms all other models w.r.t. modeling accuracy for our custom inverter chain, and is also the only model that can faithfully predict the "de-cancellation" of sub-threshold pulses.

8 CONCLUSIONS

We presented the Composable Involution Delay Model (CIDM), a generalization of the Involution Delay Model (IDM) that retains its faithful glitch-propagation properties. Its distinguishing properties

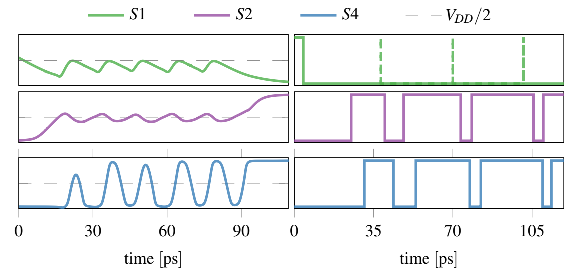

Figure 8: Recovering sub-threshold waveforms in an inverter chain using the CIDM.

are wider applicability, composability, easier characterization of the delay functions, and exposure of canceled pulse trains at interconnecting wires. Despite this considerable step forward towards a faithful delay model, there is still some room for improvement, in particular, for accurately modeling the delay of multi-input gates.

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