APPLICATION-SPECIFIC DIGITAL FILTER SYNTHESIS USING FINE-GRAIN DATA-FLOW GRAPHS

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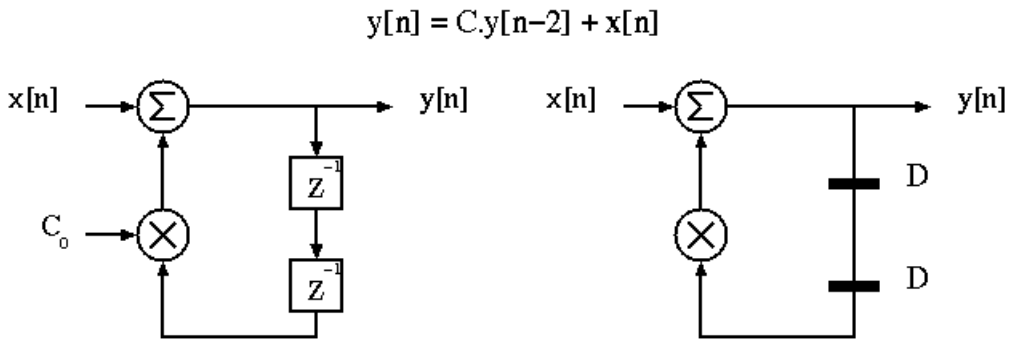
GOAL: provide a convenient framework for architecturally transforming a digital filter, in order to fit certain data-rate and hardware complexity constraints.

- digital filters can be represented as homogeneous SDF
- recursive and adaptive filters contain feedback loops
- loops impose a lower bound on iteration period
- this bound is referred to as the loop iteration bound
- iteration bound is tied with a particular DFG description
- not possible to achieve a period less than iteration bound
- the critical path in a DFG has the longest computation time among all paths that contain zero delays

FIGURE 1. Dataflow representation of a simple recursive filter



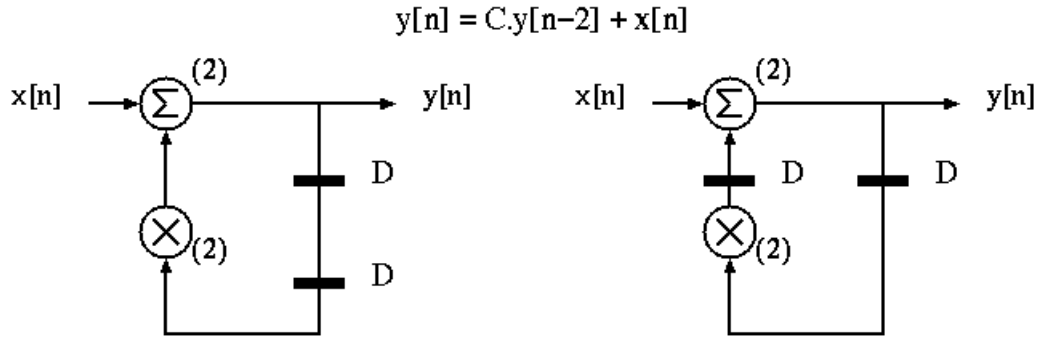
RETIMING

- reduce clock period
- reduce hardware complexity
- reduce power consumption

BASIC IDEA

- relocate delay elements without changing I/O function
- the number of delays in a cycle remains unchanged
- iteration bound remains unchanged
- redistribute portions of the critical path delay across other paths -> reduction in critical path -> higher clock rate
- move delays from multiple to single paths -> reduction in the number of delay elements

FIGURE 2. Retiming Example

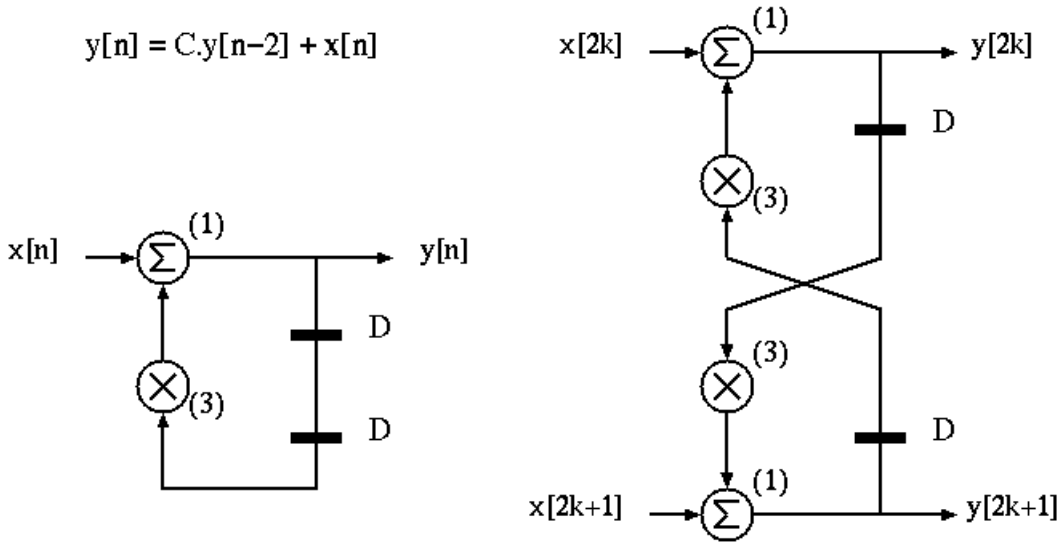


- initial DFG: iteration bound=2, critical path=4
- retimed DFG: iteration bound=2, critical path=2

UNFOLDING

- used to describe multiple iterations as a single iteration
- reveals any hidden concurrency -> smaller iteration period
- preserves precedence constraints of algorithm
- preserves the number of delays in the DFG
- there are cases where the iteration bound cannot be attained without unfolding
- if a node in the loop needs more computation time than the iteration bound itself (we cannot retime)
- we can retime this DFG, and still meet the iteration bound, if the granularity was finer

FIGURE 3. Unfolding Example (ITERATION BOUND = 2)



- initial DFG: critical path=4, throughput=1
- retimed DFG: critical path=3, throughput=1
- unfolded DFG: critical path=4, throughput=2

- trade-off between critical path reduction and register minimization is better answered at the bit-level, instead of the word-level.

FIGURE 4. Direct form FIR Filter

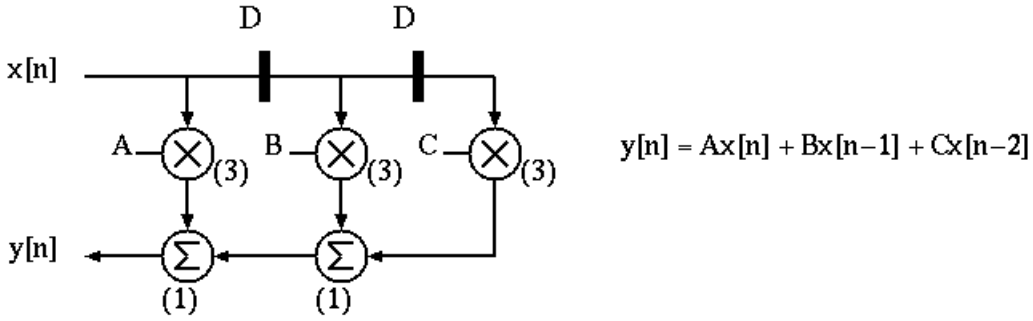


FIGURE 5. Transposed-form (retimed) FIR filter

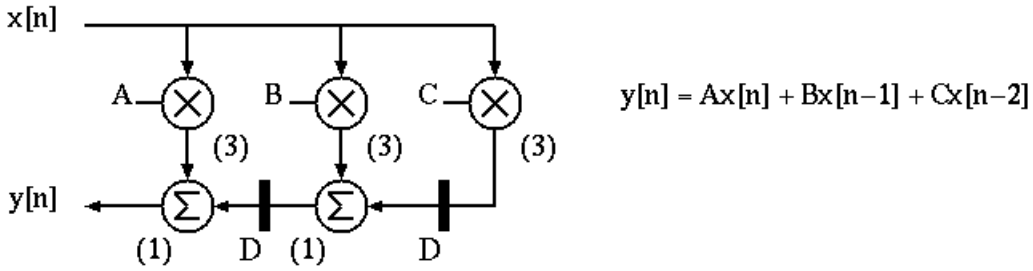


FIGURE 6. Fine-grain cutset retiming