The AV1 Constrained Directional Enhancement Filter (CDEF)

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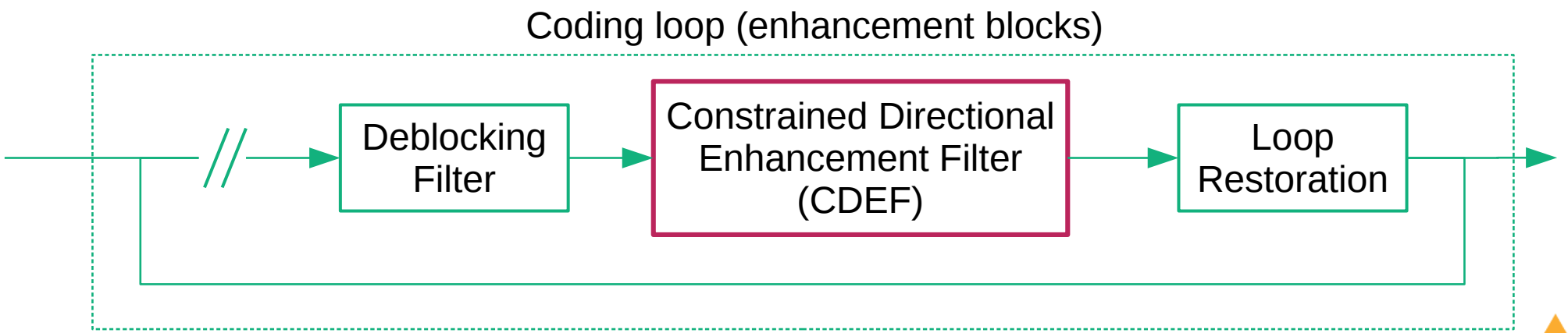
ALLIANCE FOR OPEN MEDIA

The AV1 Video Codec

- Royalty-free licensing
- Created by the Alliance for Open Media
- Officially released March 28th 2018
- Based on VP9 (Google) with technology from Thor (Cisco) and Daala (Mozilla)



CDEF Overview

- Applied after deblocking filter, in coding loop
- Reduces ringing (and other) artifacts
- Low hardware and software complexity
- Main ideas
  - Non-linear filter
  - Direction search
  - Direction-adaptive taps
  - Applied to both luma and chroma

Non-Linear Filter

- Blurs ringing while preserving edges
  - Behaves like an FIR at low contrast
  - Ignores large contrasts (edges)
- Fully vectorizable, no division

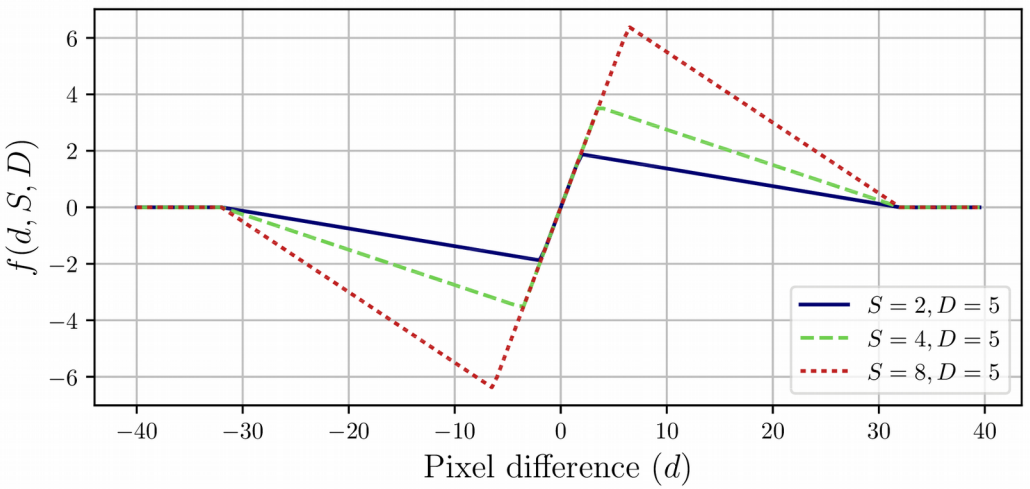
$$y(i) = x(i) + \sum_m w_k f\left(x(i+m) - x(i), S, D\right)$$

Output value — Center value — Weight — Non-linear function — Pixel difference — Filter parameters

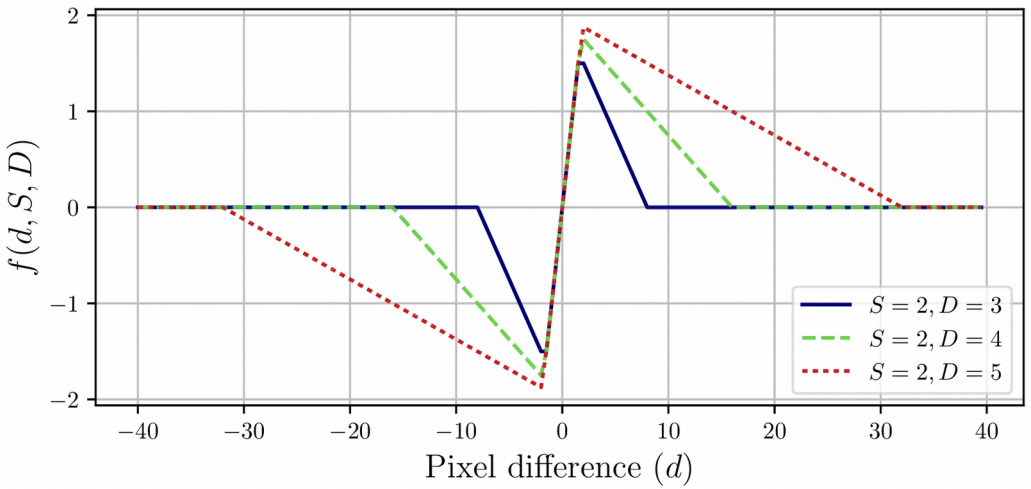
Constraint Function

- Parameterized by strength and damping
  - Trade-off between ringing removal and blurring
  - Typically use higher strength at lower bitrate

Strength: end of linear region

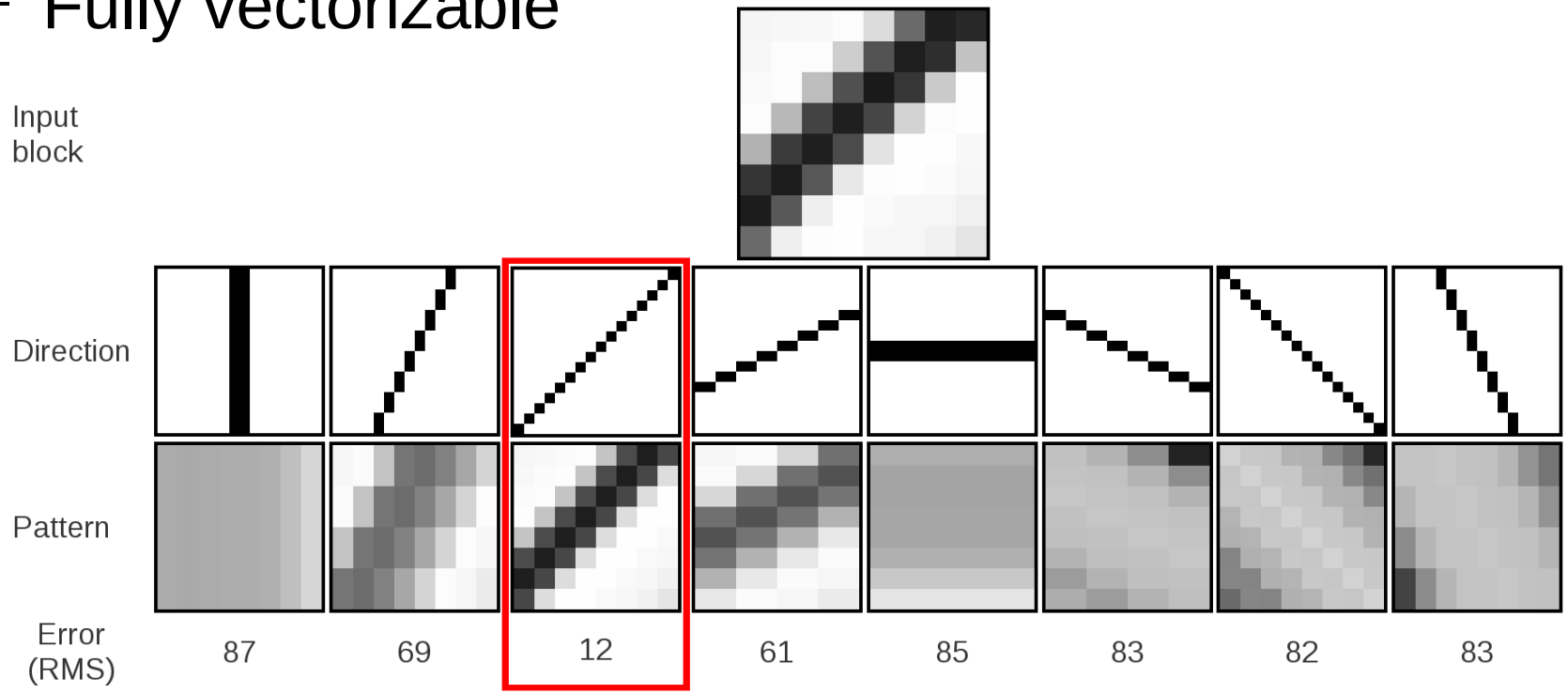


Damping: point of zero output



Direction Estimation

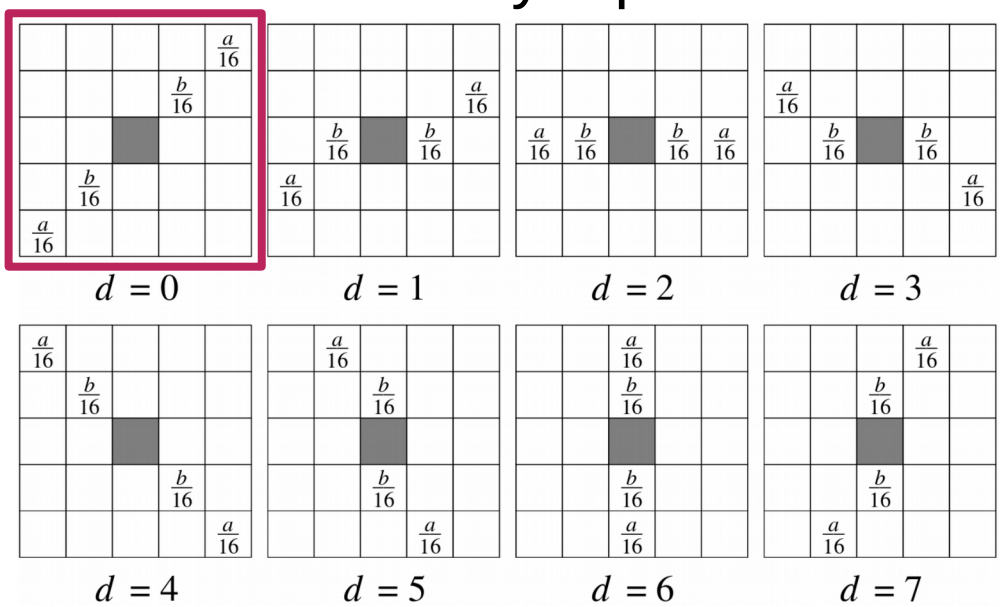
- Runs on 8x8 **decoded** blocks (no signaling)
  - Small enough for tracking curves
  - Large enough to reliably estimate direction
- Find direction that minimizes “prediction” error
  - Fully vectorizable



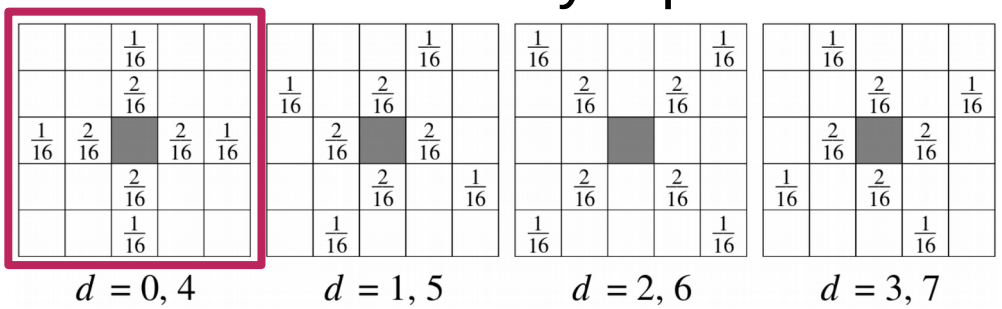
Directional Filter

- Sum of two direction-dependent sets of taps
  - Primary taps along direction (higher strength)
  - Secondary taps off direction (lower strength)

Primary taps

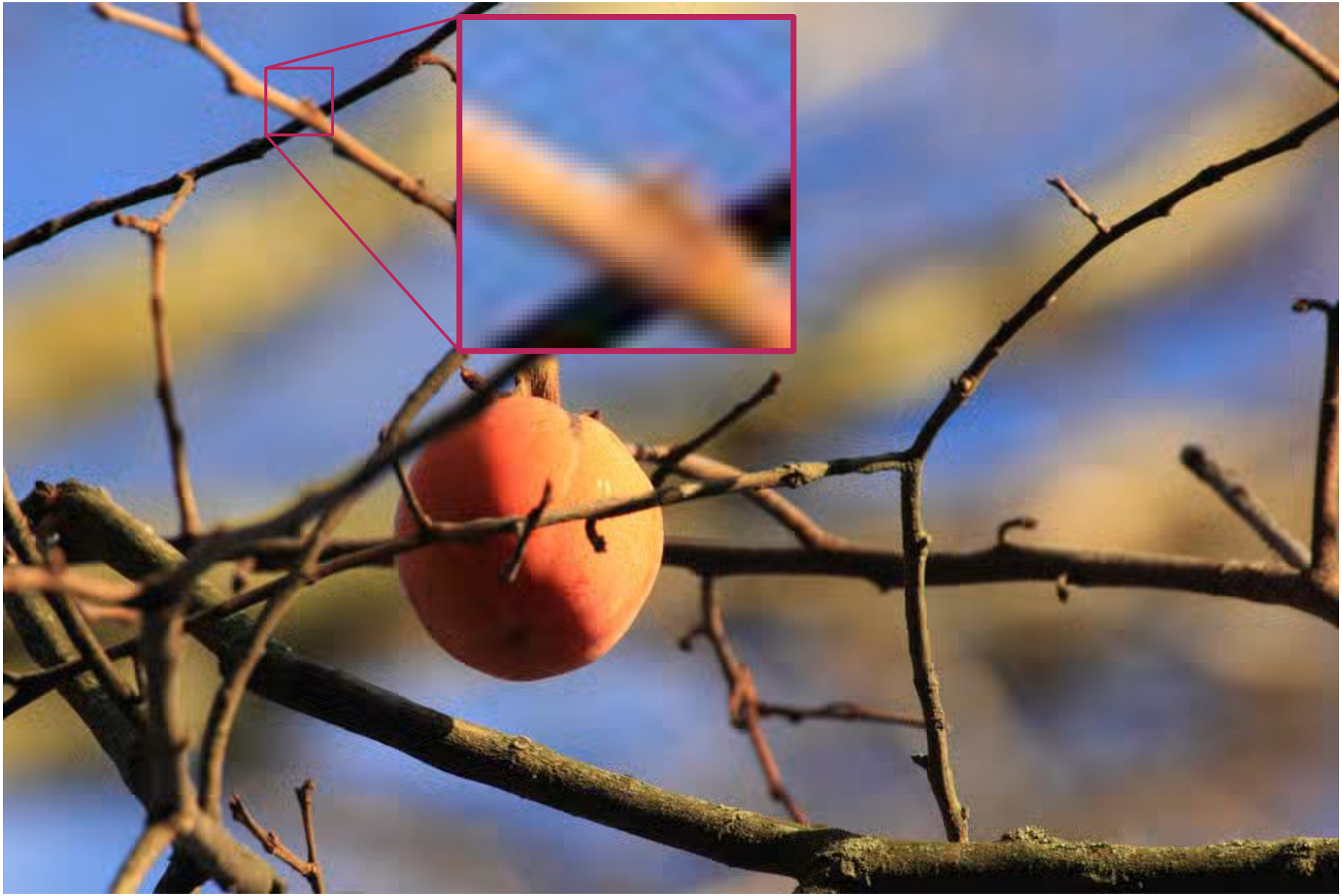


Secondary taps

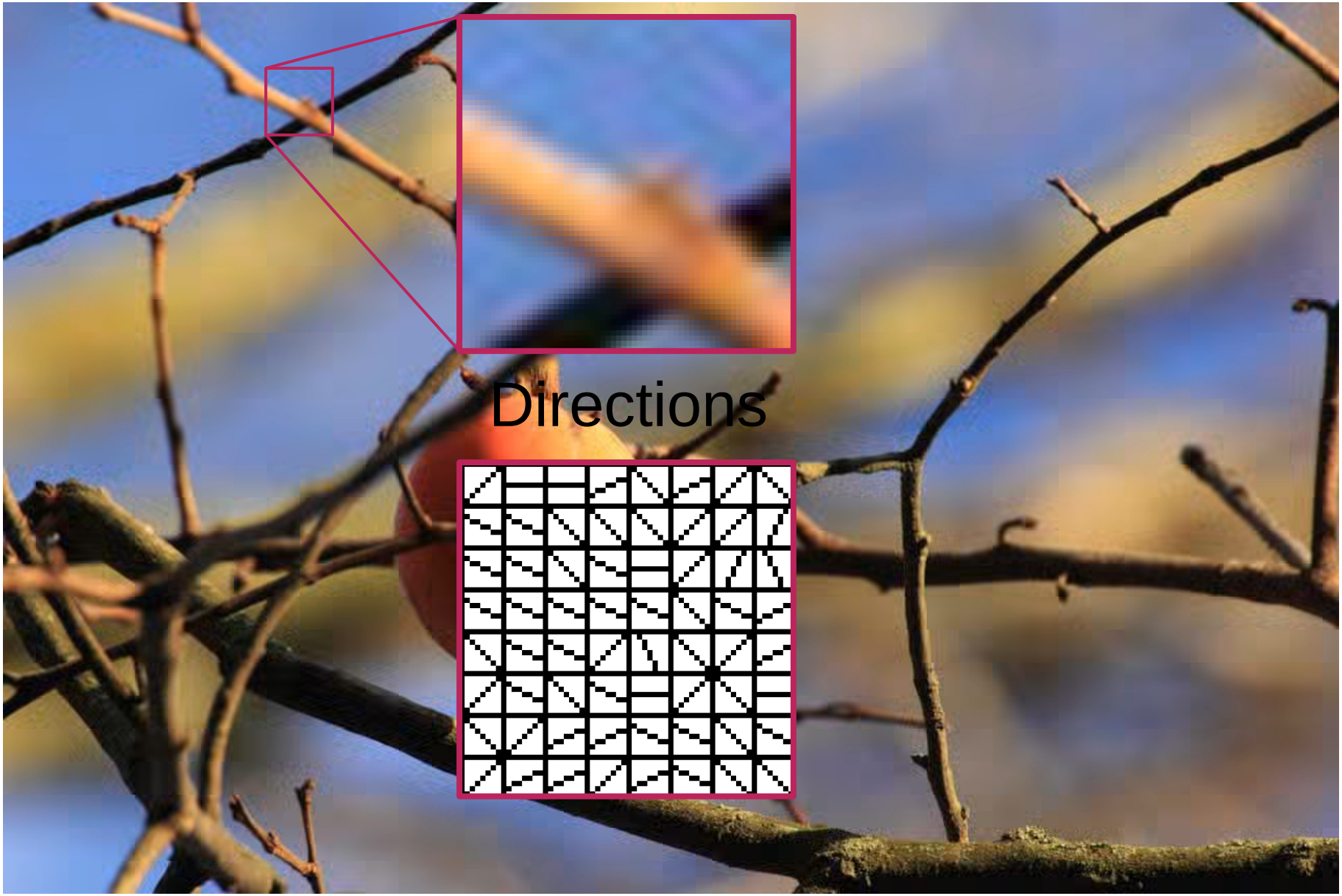


Example

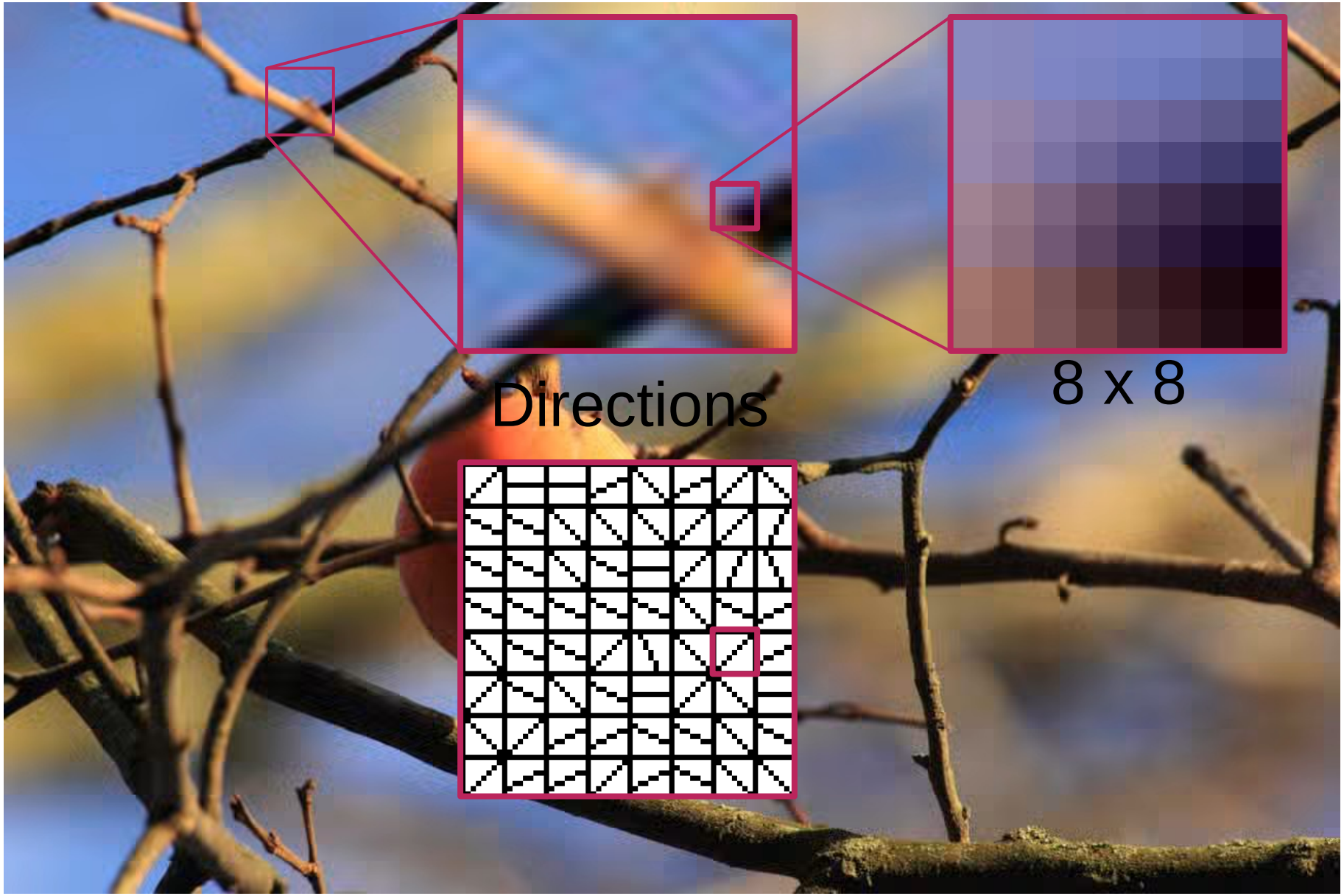
Example



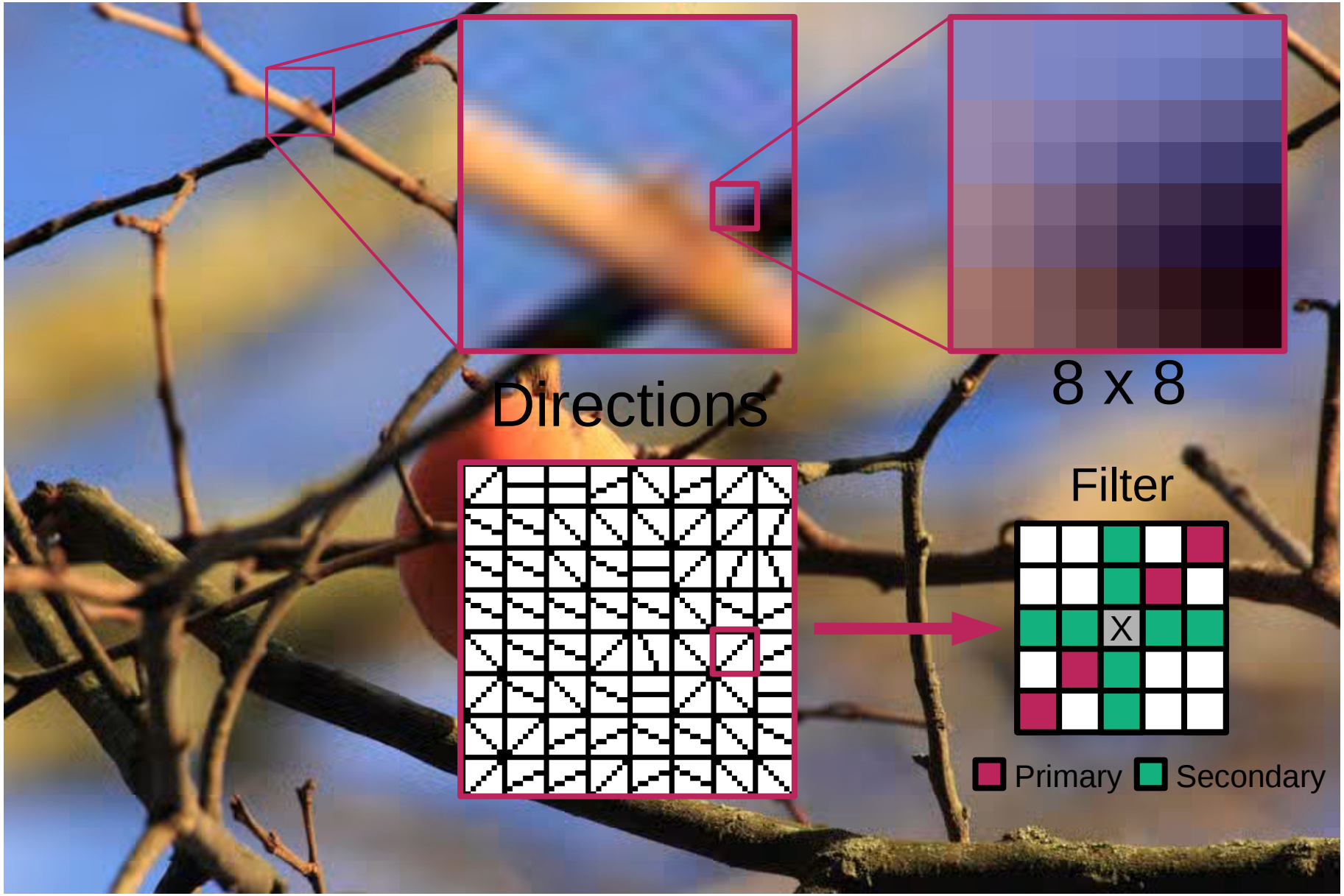
Example



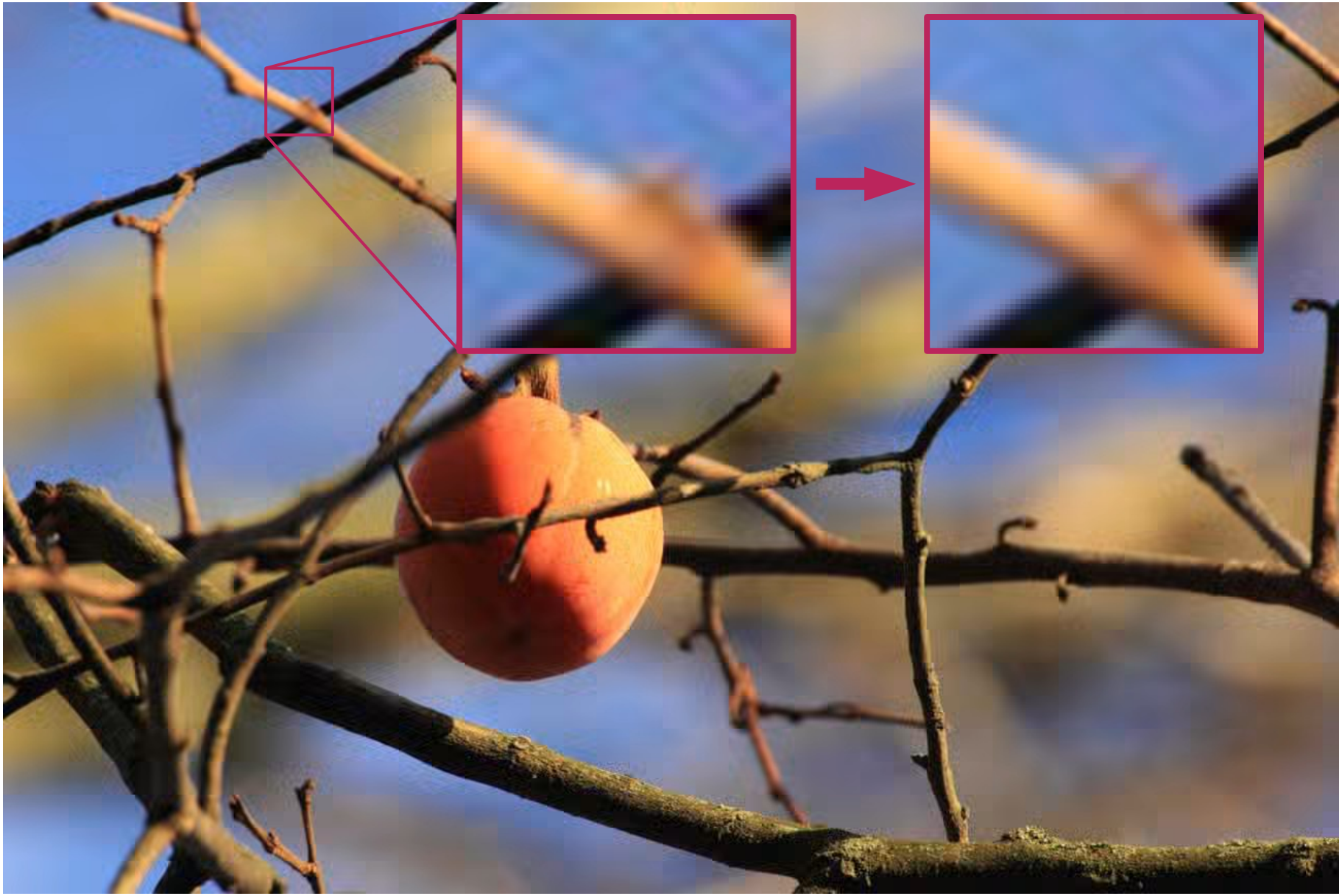
Example



Example



Example



Example (Before)

Example (After)

Signaling

- Limited side information
- Two levels of signaling
  - Frame-level list of 1-8 presets
  - Preset selection at 64x64 level (0-3 bits)
- No 8x8 signaling, no direction signaling
- No signaling when 64x64 filter block is skipped

Results

- PSNR BD-rate improvement
  - 1.1% for high-latency, 3.7% for low-latency
- Significant **subjective** improvement (HL)