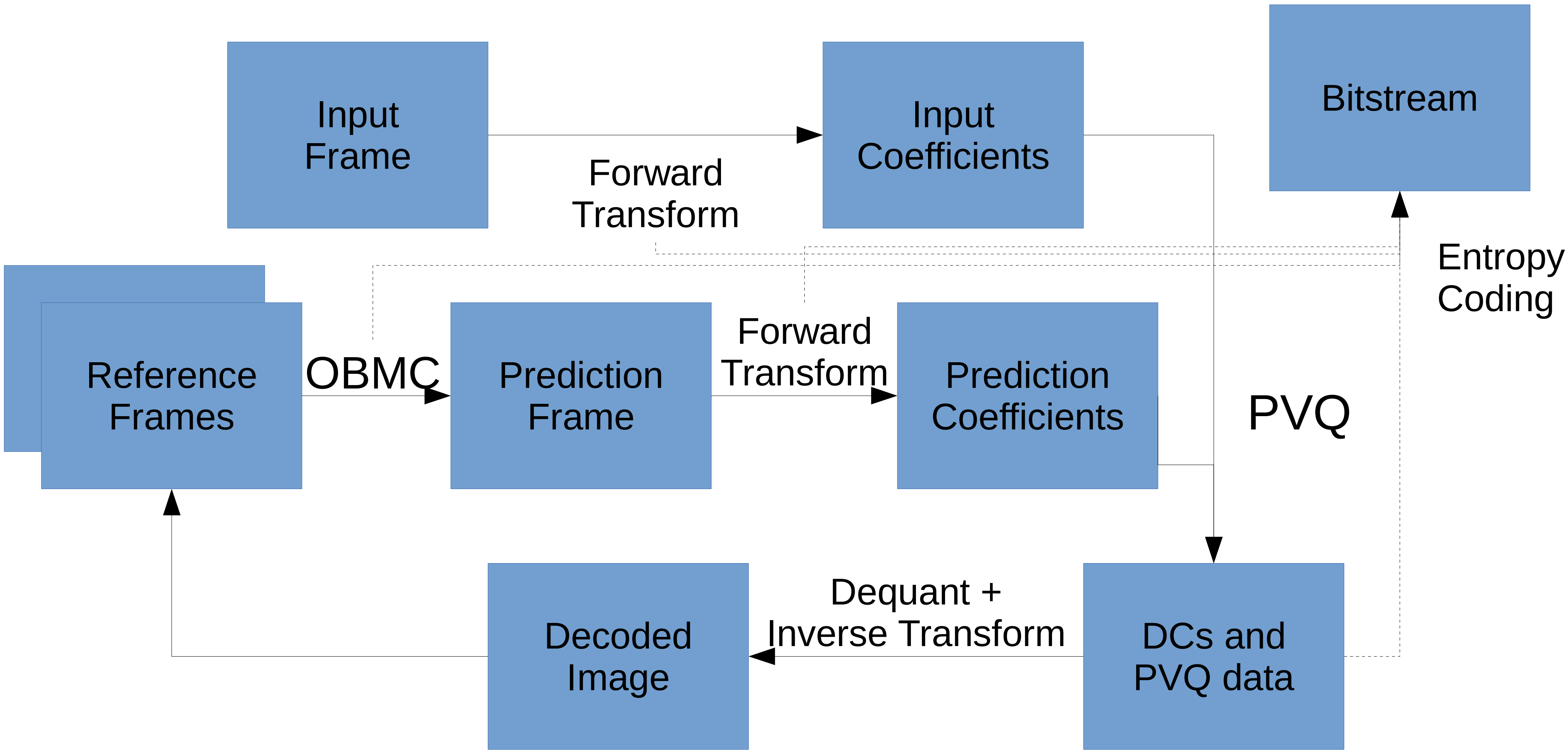
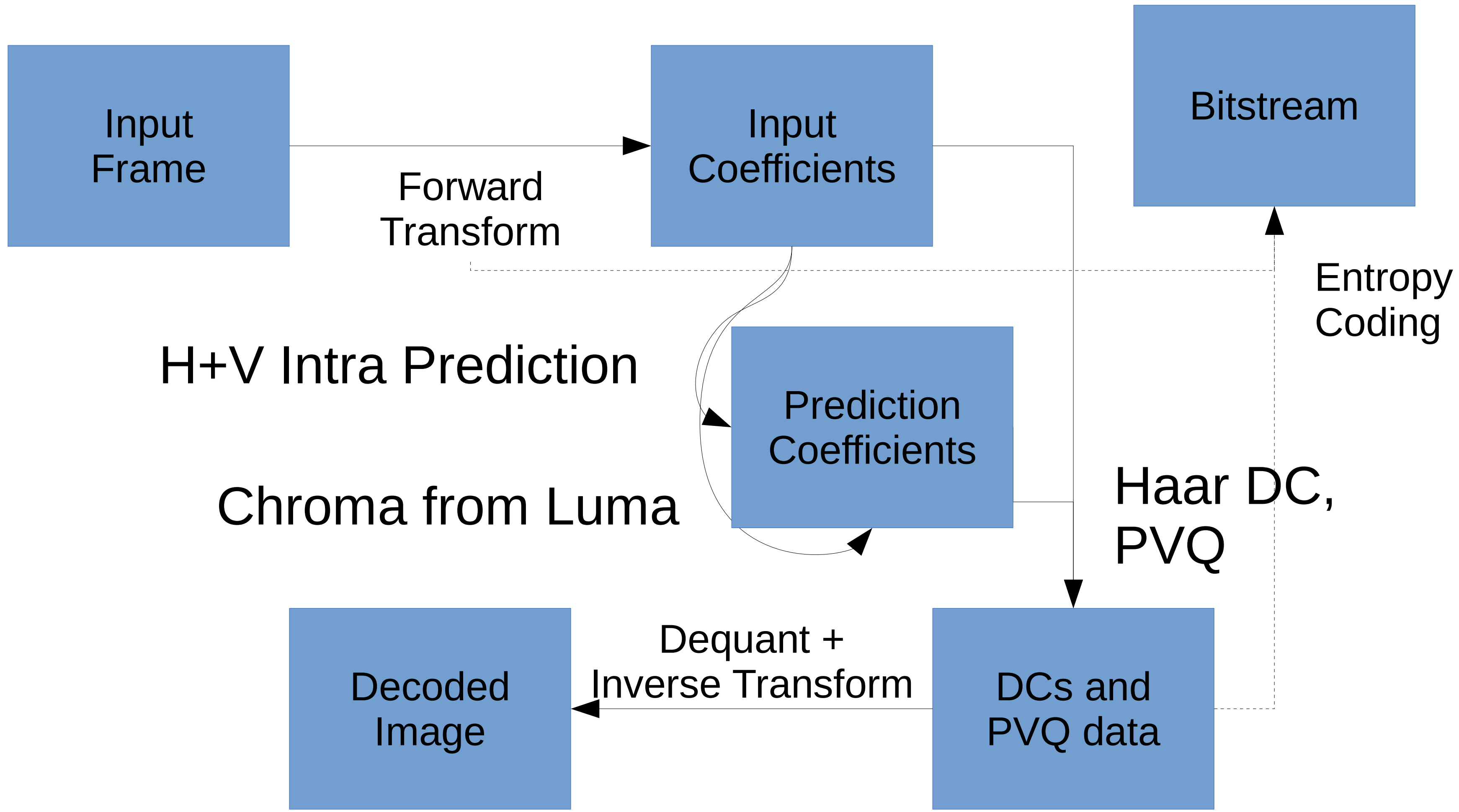
Daala: Tools and Techniques
IETF 93 (Prague)

Daala Inter Encoder

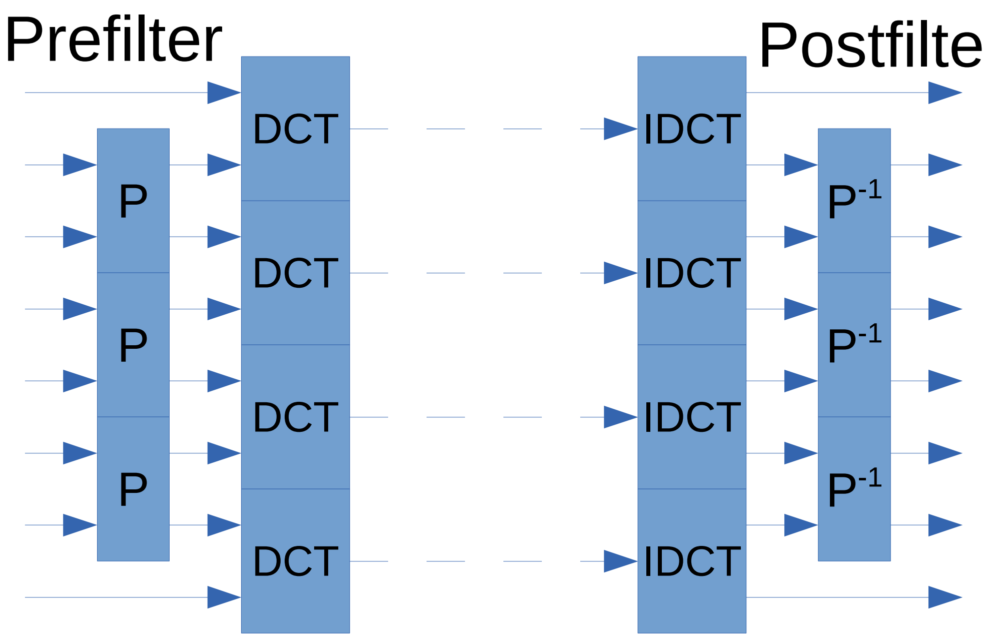


Daala Intra Encoder



Transform

- Lapped transform
  - N-point *pre-filter* removes correlation between blocks
  - N-point DCT within blocks
  - Decoder applies inverse (non-adaptive *post-filter*)



Transforms

- draft-egge-netvc-tdlt-00
- Sizes: 4x4, 8x8, 16x16, 32x32 (64x64 in progress)
- Reversible
  - iLT(fLT(x)) == x for all x
- Biorthogonal (not orthogonal)
  - Not all basis functions have the same magnitude
  - Slight correlation between coefficients

Overlapped Block Motion Compensation

- draft-terriberry-netvc-obmc
- Goal: MC prediction with no blocking artifacts
- Variable block size (unrelated to transform size)
  - Unlike Dirac, larger blocks use larger blend window
  - Currently restricted so adjacent blocks differ by at most one size to maintain continuity
    - Possible to remove this restriction
- Subpel: separable 6-tap filters
  - Windowed sinc
  - 7-bit coefficients, no truncation/rounding between horizontal/vertical stages

OBMC → Prediction

- OBMC produces a *prediction image* for the whole frame
  - PVQ requires a prediction in the frequency domain
  - Just apply forward transforms to the prediction image
- Currently no explicit intra mode
  - PVQ can choose to discard the prediction (noref)
  - Our encoder still spends bits trying to improve it during motion search

Displaced Frame Difference

- Motion Compensation
  - Copy blocks from an already encoded frame (offset by a motion vector)
  - Subtract from the current frame
  - Code the residual

Input

⊖

Reference frame

=

Residual

Displa… Frame D…ference

- Motio… ompensation
  - Co… blocks from an already enc… … fra… (offset by … motion vector)
  - S… tract from the curre… … ame
  - C… e the residual

Input Residual

Perceptual Vector Quantization

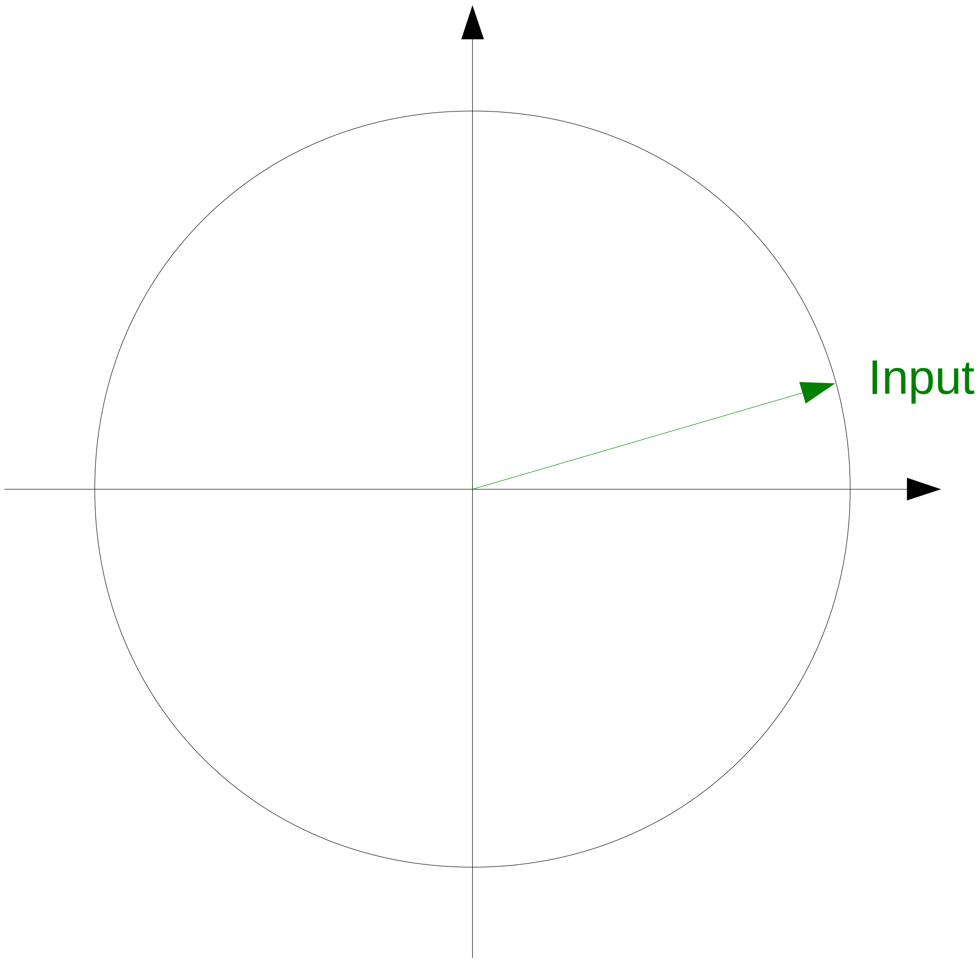
- Separate “gain” (contrast) from “shape” (spectrum)
  - Vector = Magnitude × Unit Vector (point on sphere)
- Potential advantages
  - Better contrast preservation
  - Better representation of coefficients
  - Free “activity masking”
    - Can throw away more information in regions of high contrast (*relative* error is smaller)
    - The “gain” is what we need to know to do this!

PVQ with a Prediction

- Subtracting and coding a residual loses energy preservation
  - The “gain” no longer represents the contrast
- But we still want to use predictors
  - They do a *really* good job of reducing what we need to code
  - Hard to use prediction on the shape (on the surface of a hyper-sphere)
- Solution: transform the space to make it easier

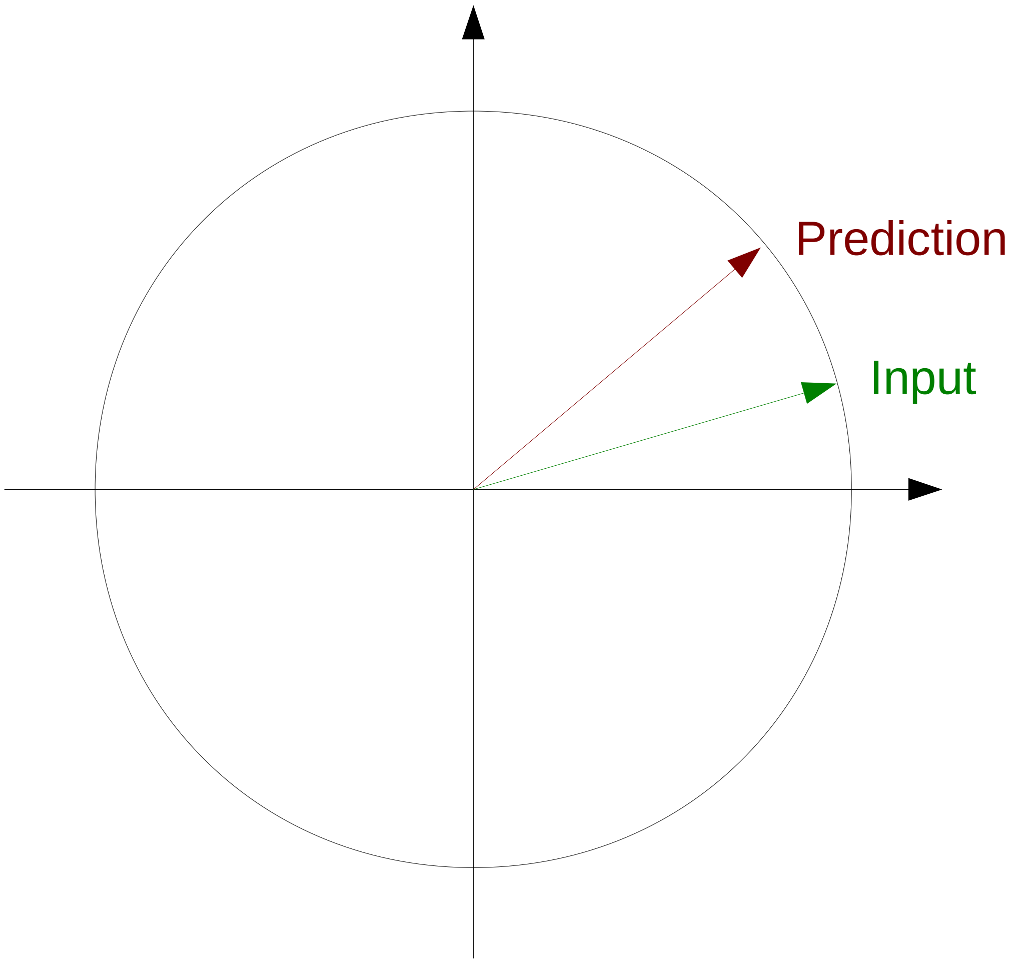
2-D Projection Example

- Input



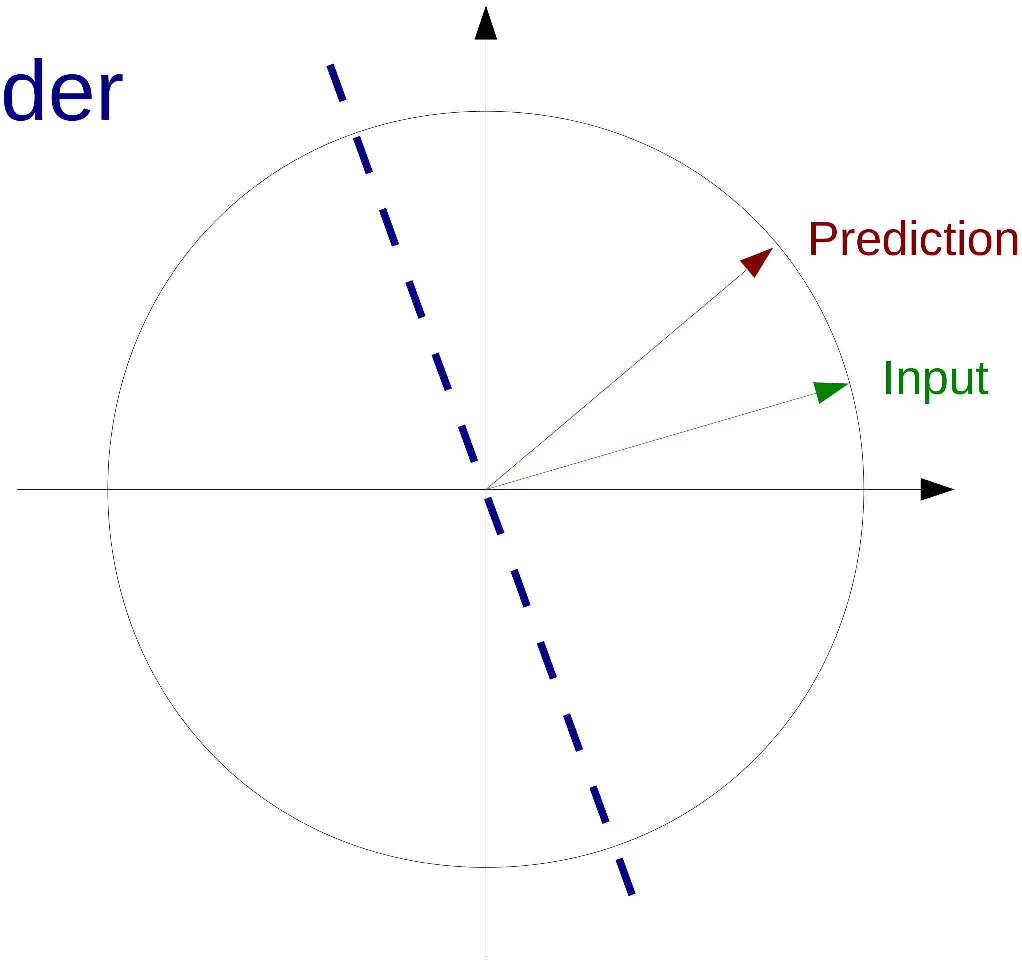
2-D Projection Example

- Input + Prediction



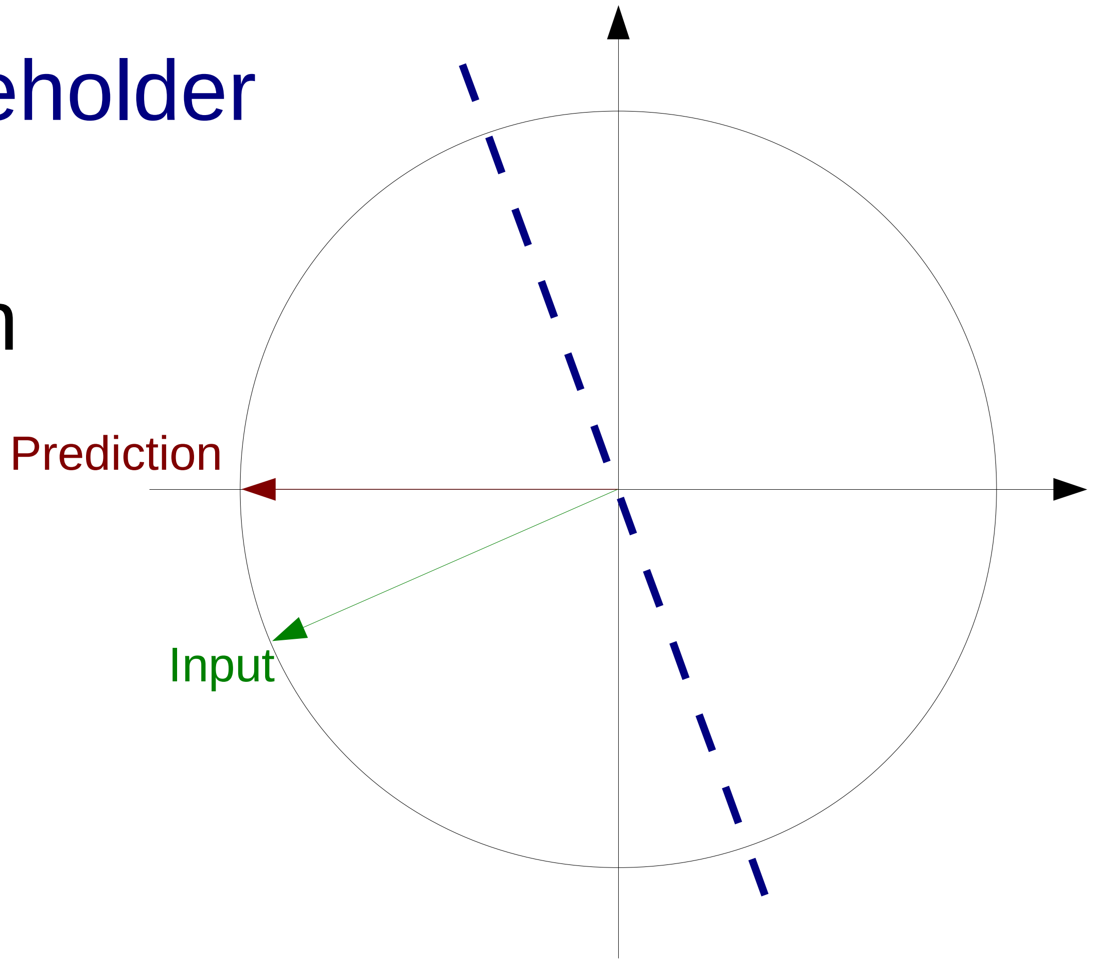
2-D Projection Example

- Input + Prediction
- Compute Householder Reflection



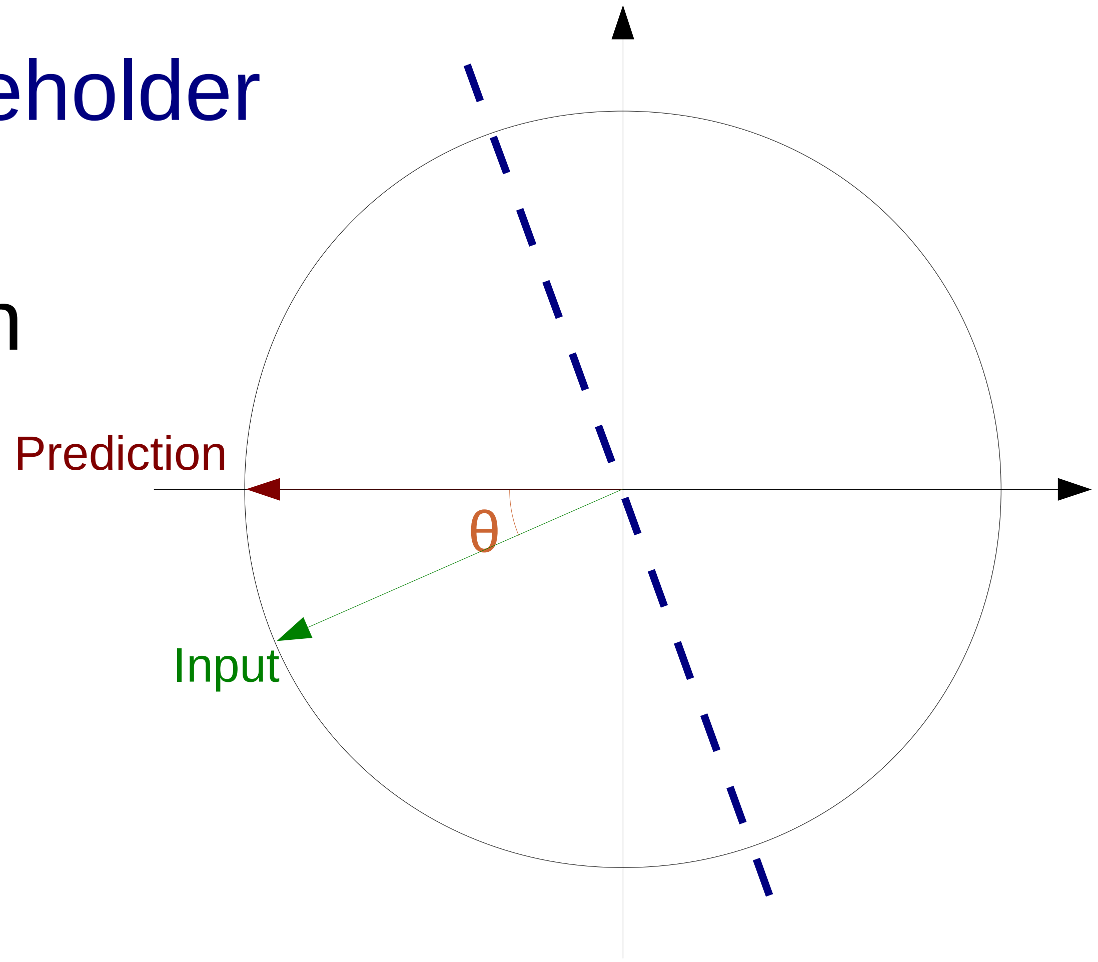
2-D Projection Example

- Input + Prediction
- Compute Householder Reflection
- Apply Reflection



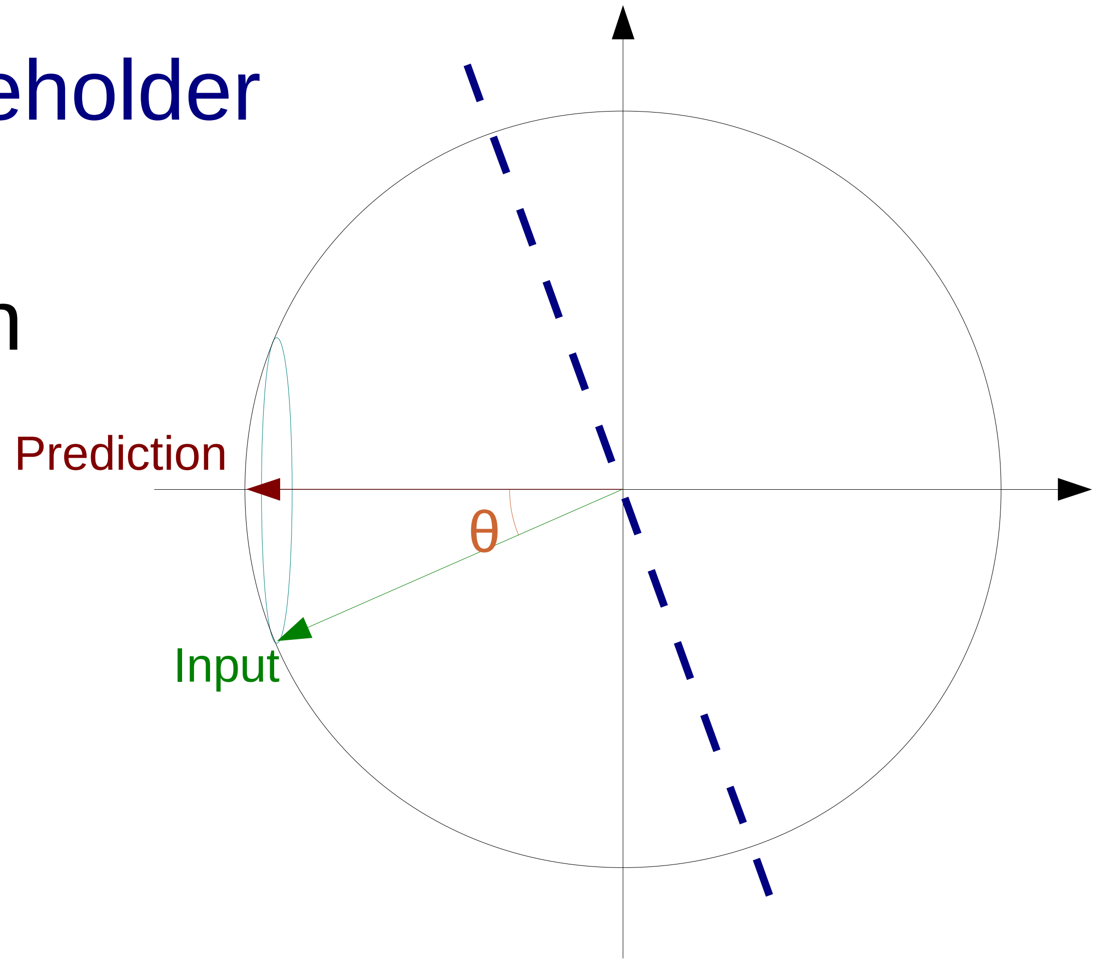
2-D Projection Example

- Input + Prediction
- Compute Householder Reflection
- Apply Reflection
- Compute & code angle



2-D Projection Example

- Input + Prediction
- Compute Householder Reflection
- Apply Reflection
- Compute & code angle
- Code other dimensions

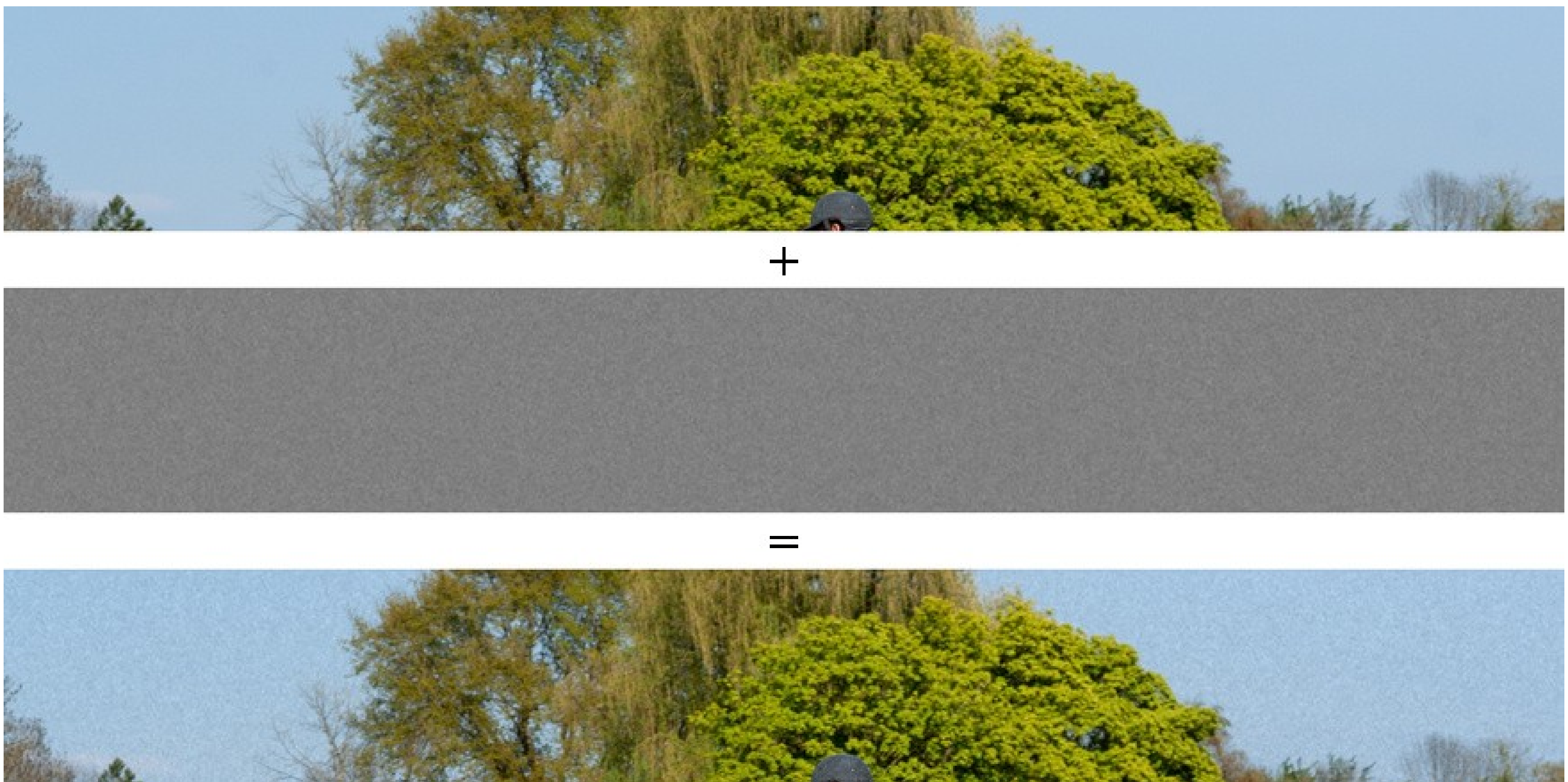


What does this accomplish?

- Creates another “intuitive” parameter, θ
  - “How much like the predictor are we?”
  - $\theta = 0 \rightarrow$ use predictor exactly
- Remaining N-1 dimensions are coded with VQ
  - We know their magnitude is gain*sin(θ)
- Instead of subtraction (translation), we’re scaling and reflecting

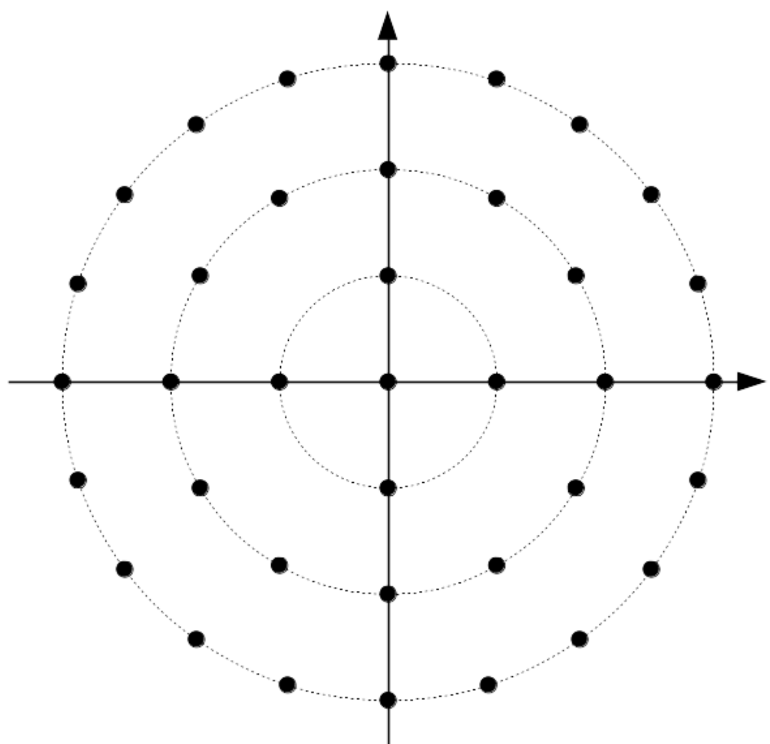
Activity Masking

- Noise is more visible in low contrast areas
  - Sensitivity $\propto g^{\alpha}$

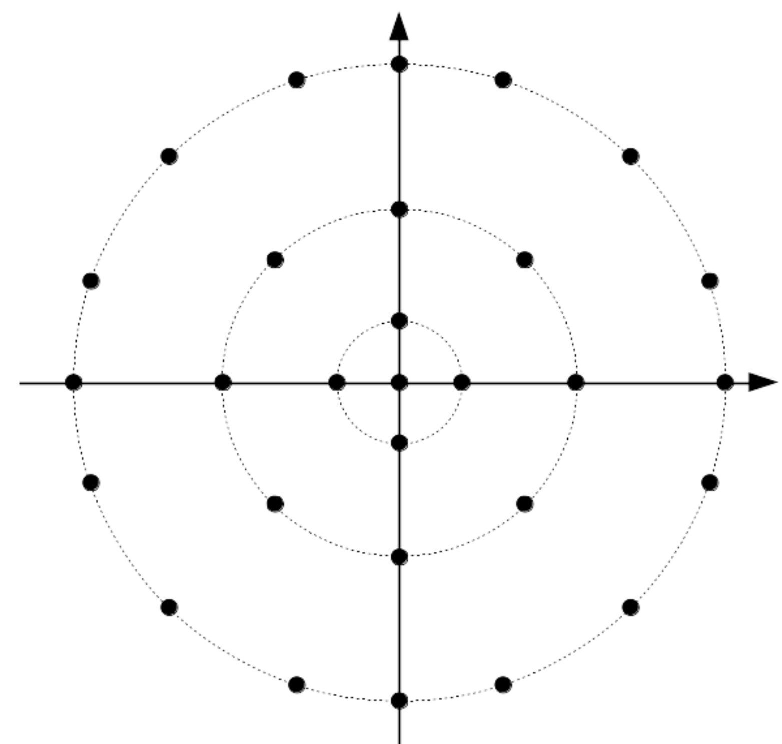


Activity Masking

- Better resolution in low-contrast (gain) areas
- Compand gain with exponent β



β=1

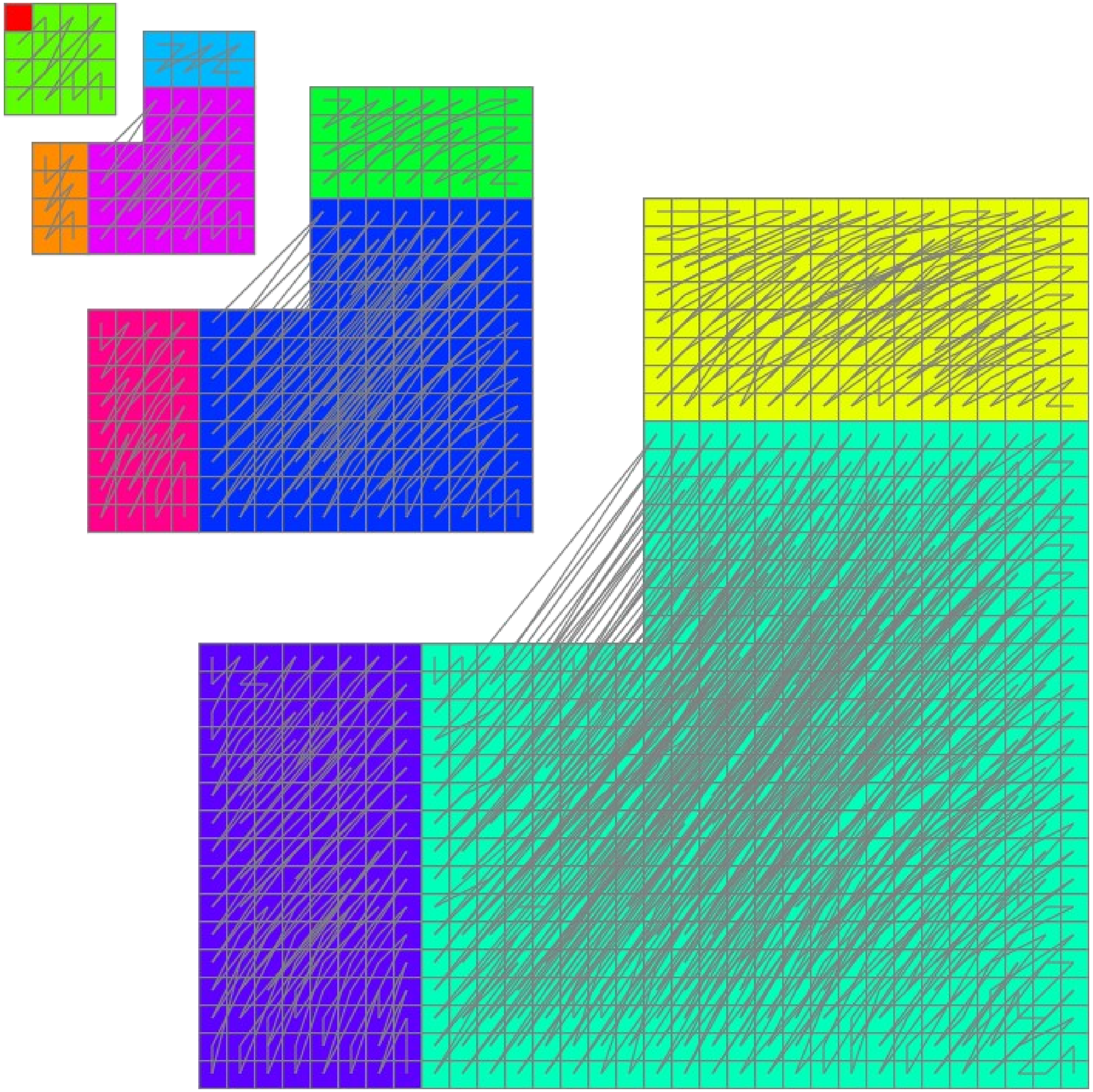


β=1.5

PVQ Bands

- DC coded separately with scalar quantization
  - Intra uses “Haar DC” to get better resolution over large areas
- AC coefficients grouped into bands
  - Gain, theta, etc., signaled separately for each band
  - Layout ad-hoc for now
- Scan order in each band optimized for decreasing variance

Band Structure



To Predict or Not to Predict

- $\theta > \pi/2 \rightarrow$ Prediction not helping
  - Could code large *θ’s*, but doesn’t seem that useful
  - Need to handle zero predictors anyway
- Current approach: code a “noref” flag
  - Jointly coded with small gain and theta values

H+V Intra Prediction (luma)

- Copy first row/column of neighbor to corresponding bands
  - Only if size of corresponding blocks match
- Use noref to decide whether to use that as a predictor
- For the first band (first 15 AC coeffs), have to choose (only one noref flag)
  - Copy from neighbor with highest energy
- No explicit intra mode signaled

Chroma from Luma

- Use luma coeffs. as PVQ predictor for chroma
  - For 4:2:0 4x4 chroma blocks, TF-merge 4x4 luma blocks and take the low quadrant
- No longer building a model from neighbors
  - PVQ gains signal scaling
  - noref flag can disable prediction
  - Additional “flip” flag can reverse the whole predictor (coded on first non-noref band)
- No longer predicting chroma DC from luma

Quantization

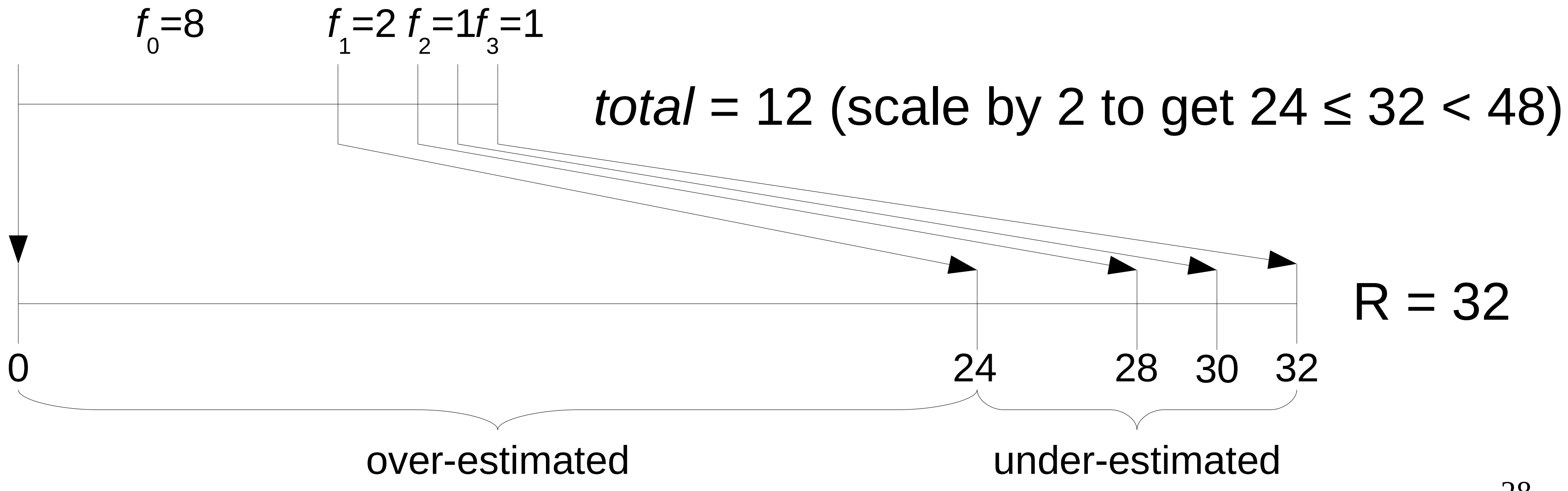
- Per-coefficient quantizers
  - Interpolated up/down from 8x8 matrix
  - Compensation for LT basis magnitudes in separate step
- Built-in activity masking
  - Goal: better resolution in flat areas
  - Low contrast → low energy (gain)
  - Compand gain, choose resolution for θ and K based on quantized gain

Entropy Coding

- draft-terriberry-netvc-codingtools
- Non-binary arithmetic coding
  - Theory: many overheads are *per-symbol*
  - Reducing the number of symbols improves throughput/cycle
- Much simpler than encoding multiple symbols in parallel
  - Decoder search in non-binary alphabet can still be parallelized (with SIMD or in hardware)

Entropy Coding

- Multiply-free partition function
  - Modified from Stuiver & Moffat 1998 design
  - $R \rightarrow c + \min(c, R - total)$
  - Requires $total \leq R < 2*total$ (shift up if not)



Entropy Coding: Properties

- 15-bit probabilities
- Alphabet sizes up to 16
  - Want to keep as close to this as possible for maximum efficiency
- Several different adaptation strategies
  - Traditional frequency counts
  - Laplace encoder parameterized by expected value
  - “Generic Coder” combines frequency counts at several scales with exponential “tails”

Entropy Coder: Raw bits

- Appended to the end of the frame
- Coded from back to front
  - Much simpler than CABAC bypass mode
  - Same technique used in Opus
- Encoder writes to separate buffer, merged during Dirac-style carry propagation step

TODO

- PVQ needs a fixed-point implementation
- No B-frames at all (in progress)
- Need 64x64 blocks for OBMC
- Need 64x64 transforms
- Lots of potential improvements in motion search
- Lots of ways to exploit PVQ we haven’t tried
- Generic coder should be replaced by more targeted probability modeling
- Deringing filter (have prototype, too slow)
- Etc.