TEXTURE COMPRESSION USING SMOOTH PROFILE FUNCTIONS

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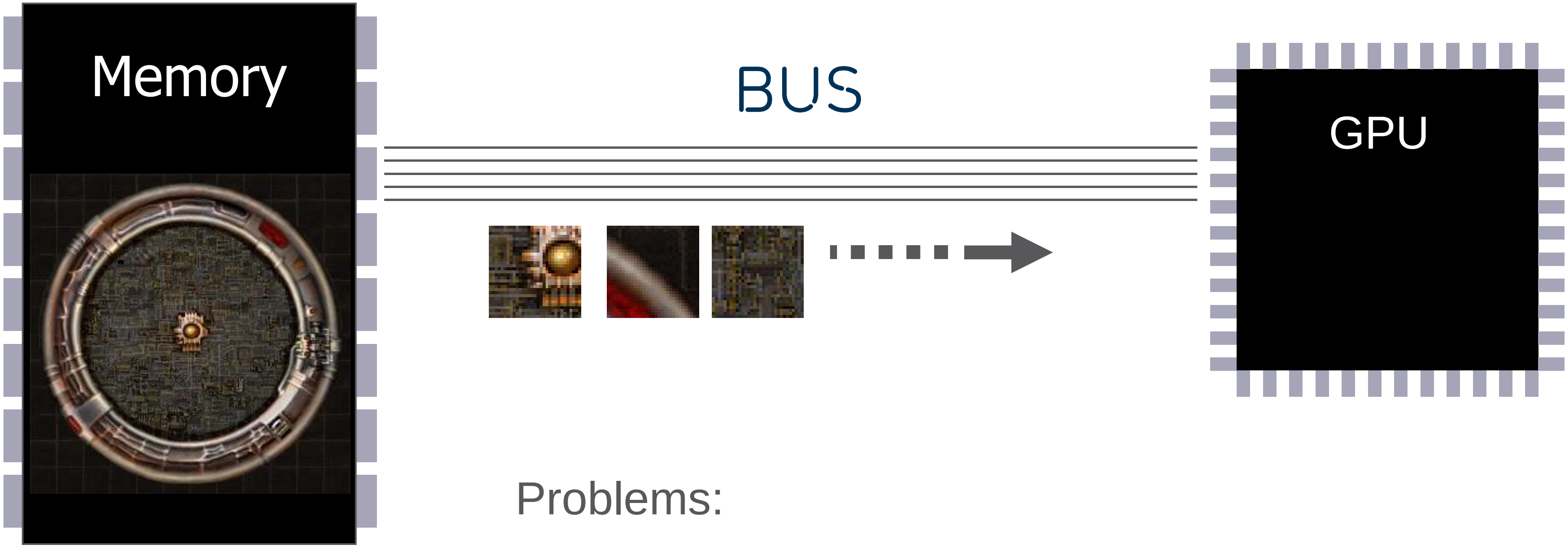
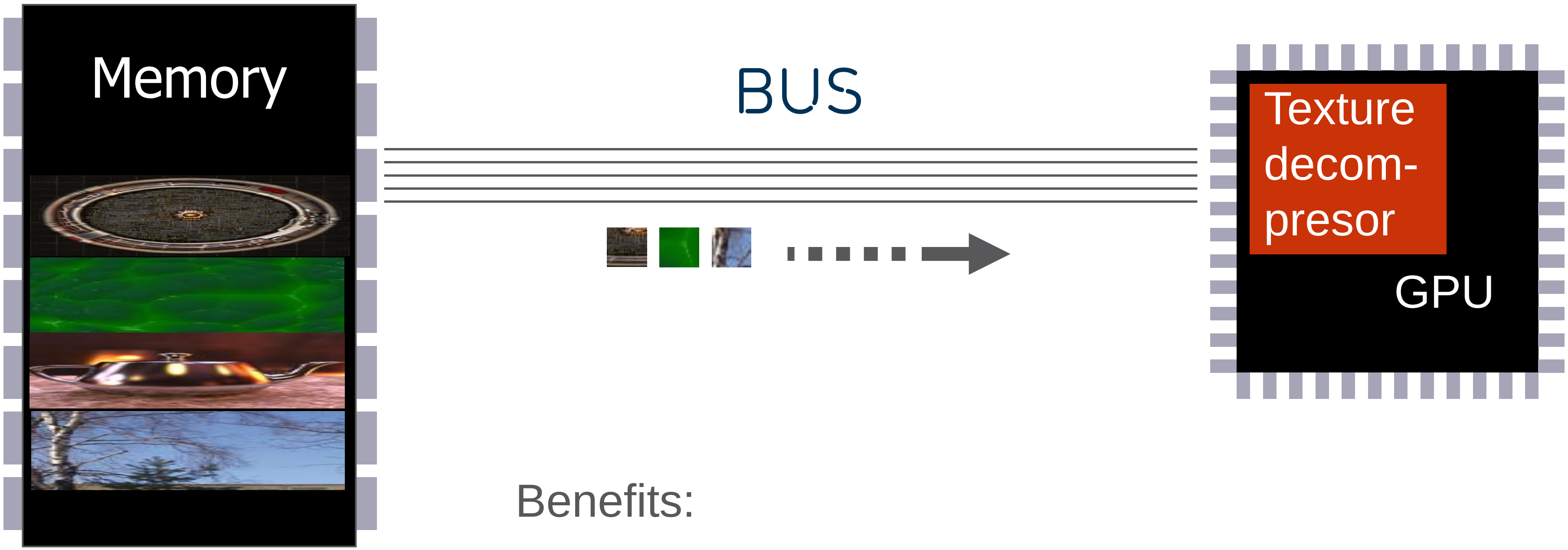
TEXTURING
AND THE BUS



Problems:

- Memory can get full
- Bus can get full (performance bottleneck)

TEXTURE COMPRESSION HELPS



Benefits:

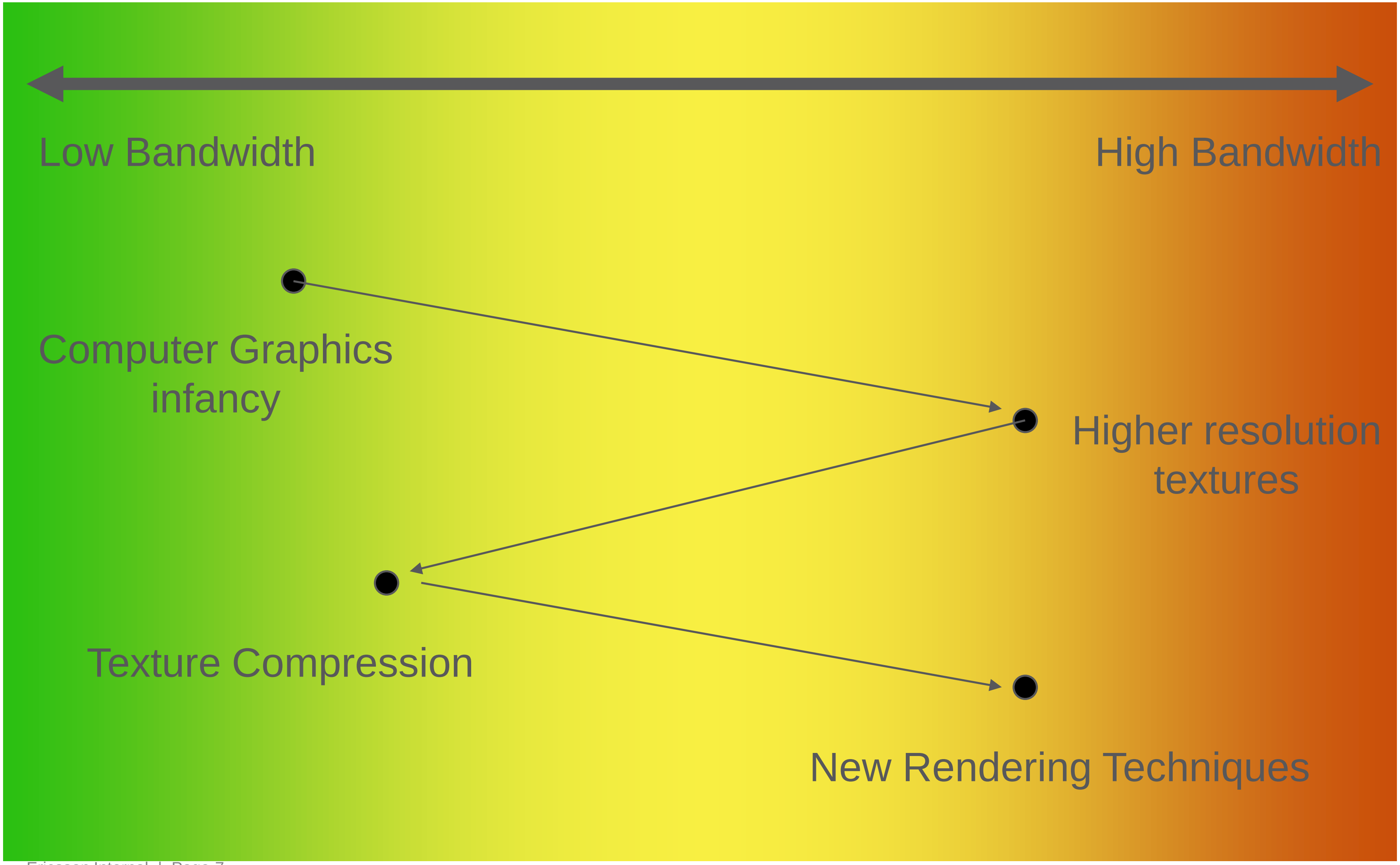
- More textures fit in memory
- Less traffic on bus = higher performance
- Less traffic on bus = lower power consumption

POWER SAVINGS

› Especially good for mobile devices

... unless you want to carry an extra battery.

NICER RENDERING WORKS AGAINST US



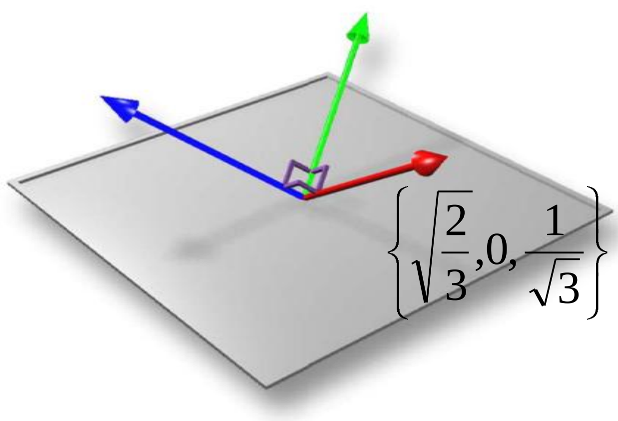
RADIOSITY NORMAL MAPPING

- Improves lighting realism in 3D games.
  - Catches light interactions between images: light bouncing, soft shadows, color bleed
- First used by Valve in Half-Life 2
- Other examples include Mirrors Edge from DICE, EA.
- Can be thought of as “directional light maps”.

image courtesy of DICE EA

RADIOSITY NORMAL MAPPING

- Sample the light in three directions in every pixel.

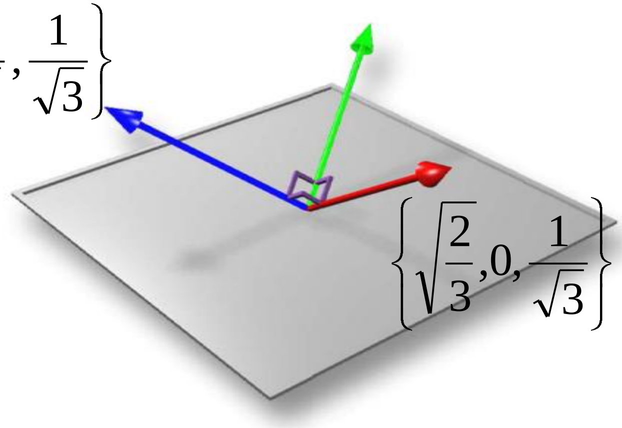


images courtesy of Valve

RADIOSITY NORMAL MAPPING

› Sample the light in three directions in every pixel.

$$\left\{-\frac{1}{\sqrt{6}},-\frac{1}{\sqrt{2}},\frac{1}{\sqrt{3}}\right\}$$

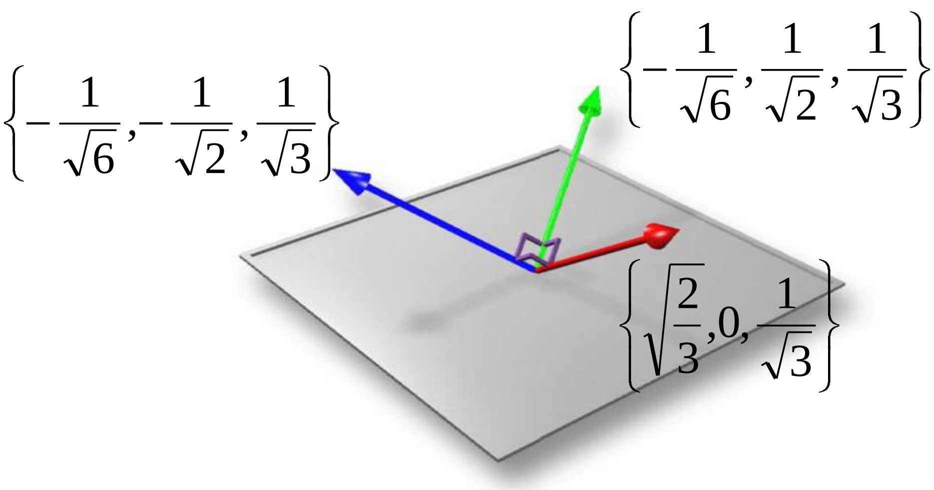


$$\left\{\sqrt{\frac{2}{3}},0,\frac{1}{\sqrt{3}}\right\}$$

images courtesy of Valve

RADIOSITY NORMAL MAPPING

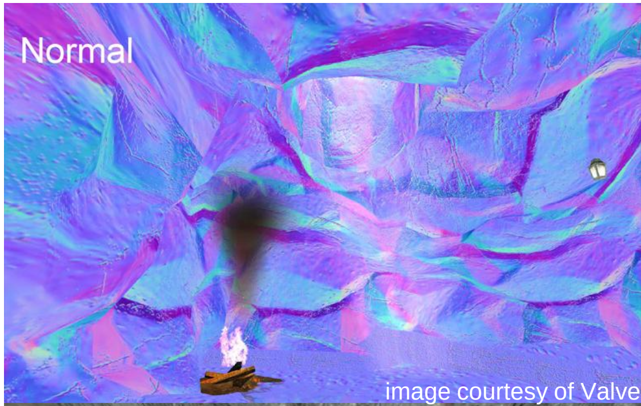
- Sample the light in three directions in every pixel.
- We will refer to these components as "radiosity light maps".

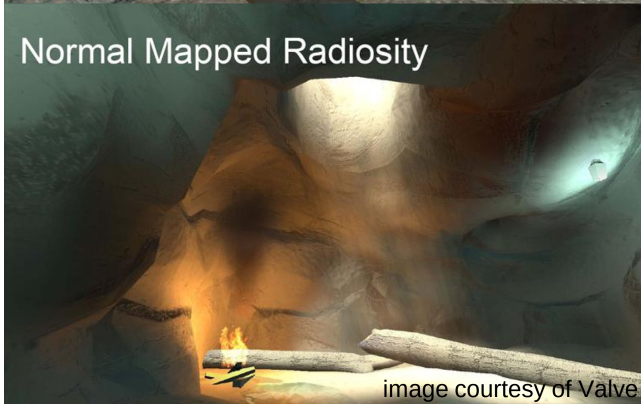


images courtesy of Valve

RADIOSITY NORMAL MAPPING

- A normal map is used to decide how much of every radiosity light map should be used.
- Together with the albedo this gives the final image.
- The normal map and the albedo can often be repeated/reused. The radiosity lightmaps are unique to each surface.
- A lot of data! Mirror's Edge has 3GB of compressed data.



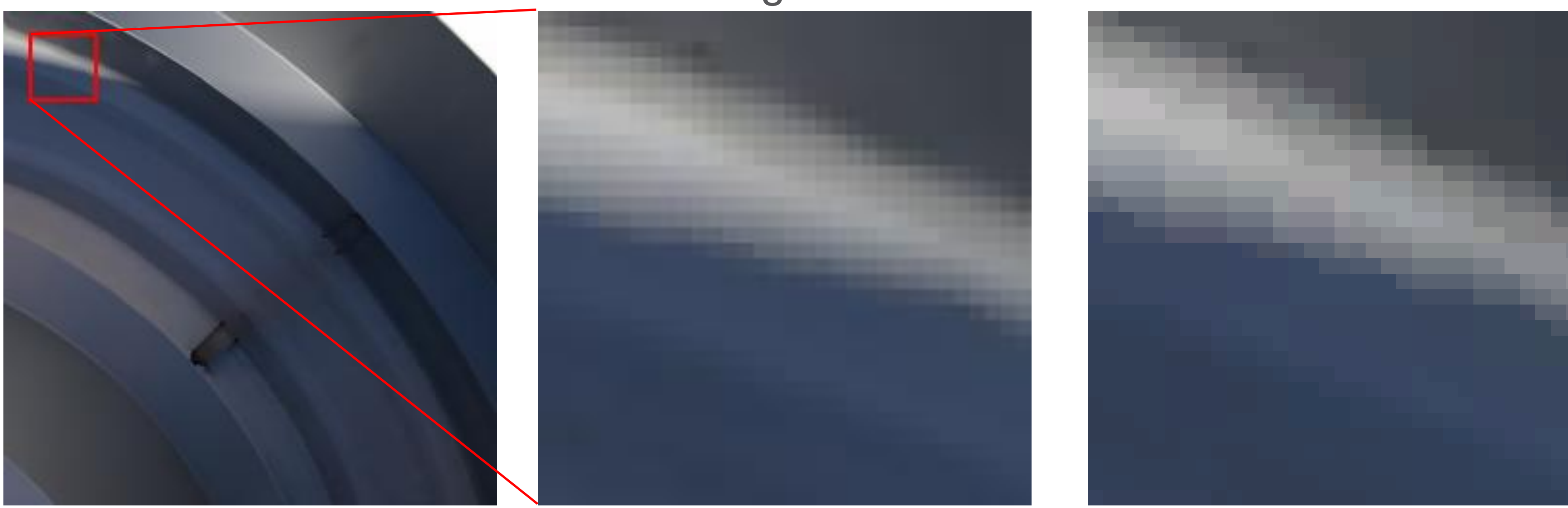


images courtesy of Valve

OLD CODECS NOT IDEAL

- Radiosity light maps contain a lot of smooth transitions.
- Traditional texture codecs not good at smooth transitions.
- DXT1 can only handle four colors per block

original DXT1



Radiosity Light Map from Mirror’s Edge, Image courtesy of DICE, EA

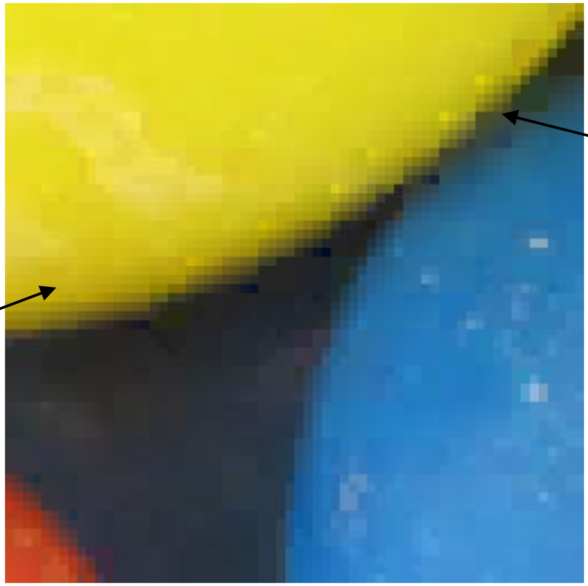
OLD CODECS NOT IDEAL (CONT.)

› ETC2 has a planar mode that can handle linear gradients, but not faster changes.

original

linear model works well

ETC2



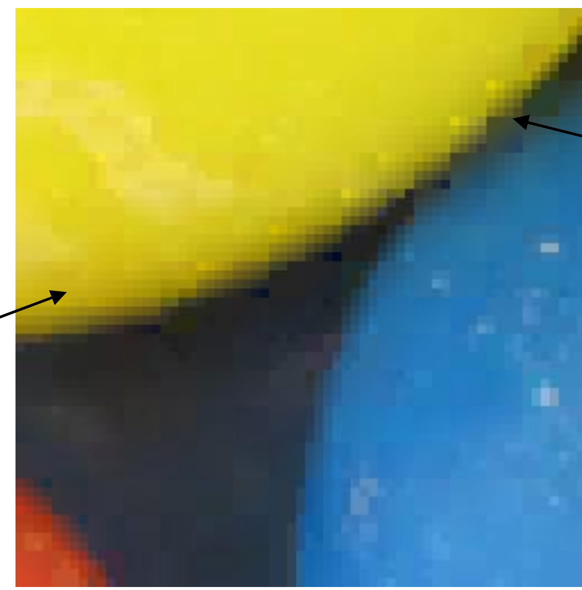
linear model breaks down

OLD CODECS NOT IDEAL (CONT.)

- ETC2 has a planar mode that can handle linear gradients, but not faster changes.
- Higher quality codecs exist (e.g. Microsoft's BC7) but comes at a penalty of doubling the bit rate.

original

ETC2

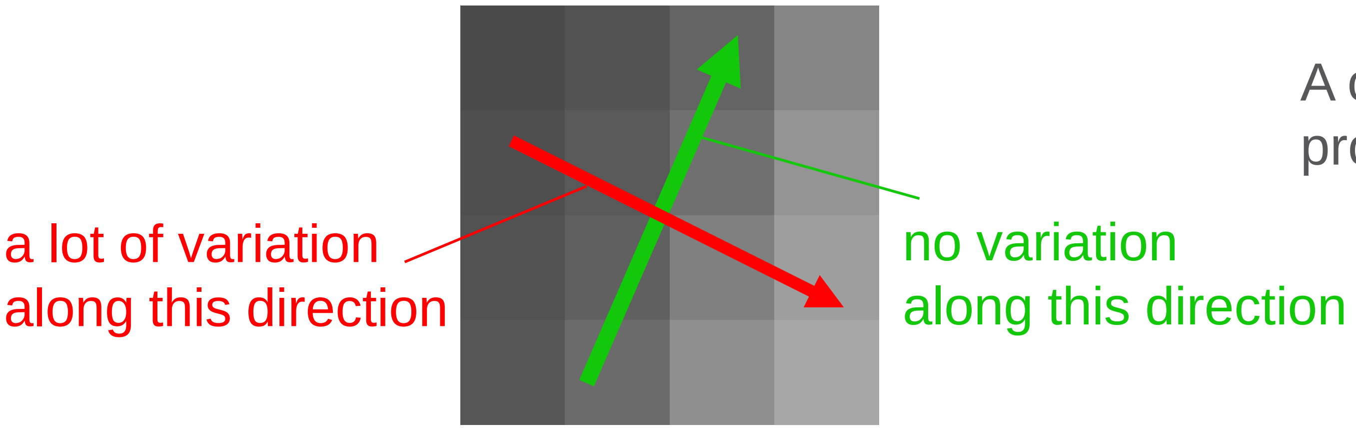


linear model works well

linear model breaks down

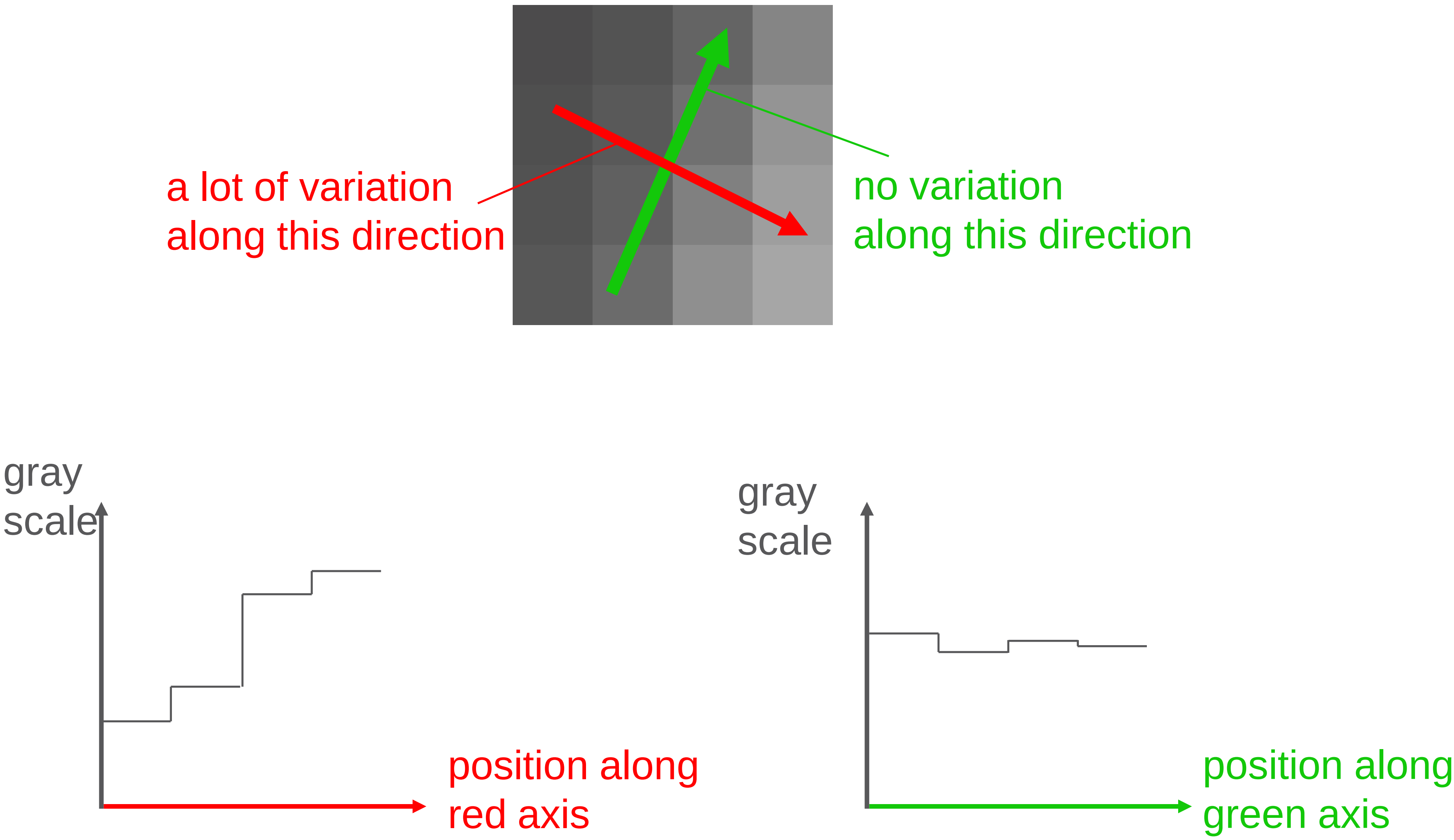
TRAIN OF THOUGHTS

- Problem:
  - How to compress radiosity lightmaps well?
- Inspiration:
  - Smooth blocks contain very little information. Should compress well!
  - ETC2 planar mode was built on this notion.
- Observation:
  - Most smooth blocks vary only in one direction.



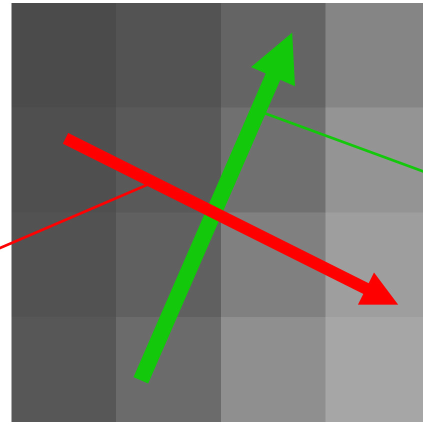
A one-dimensional problem!

GRAY SCALE EXAMPLE



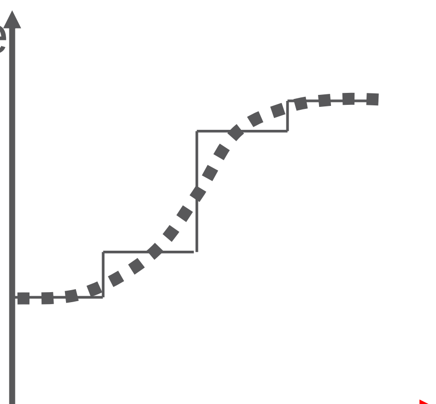
GRAY SCALE EXAMPLE

a lot of variation
along this direction



no variation
along this direction

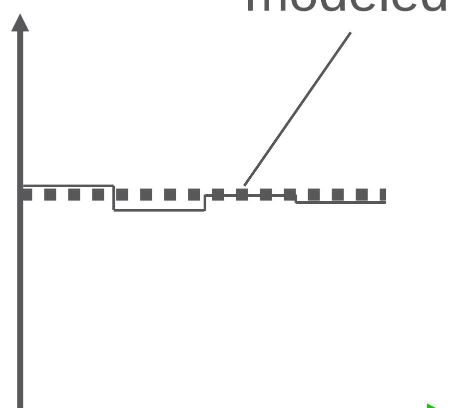
gray
scale



position along
red axis

gray
scale

modeled as constant

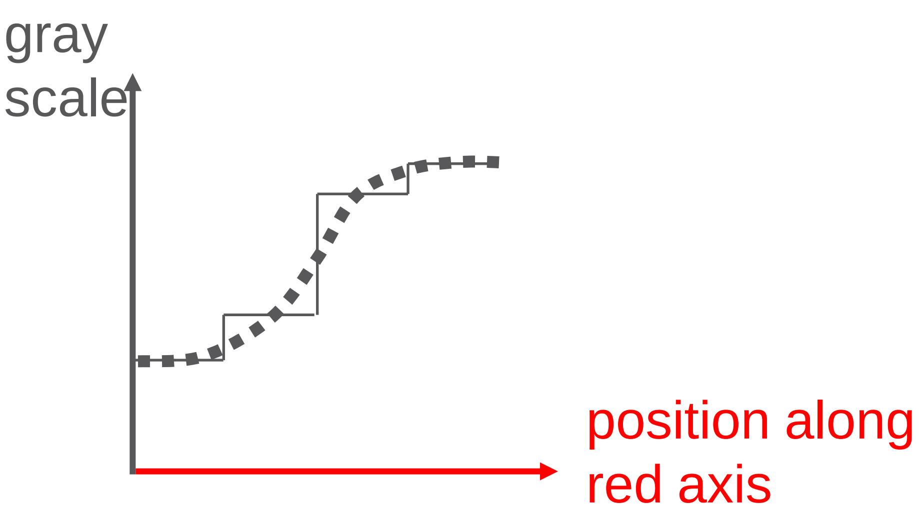


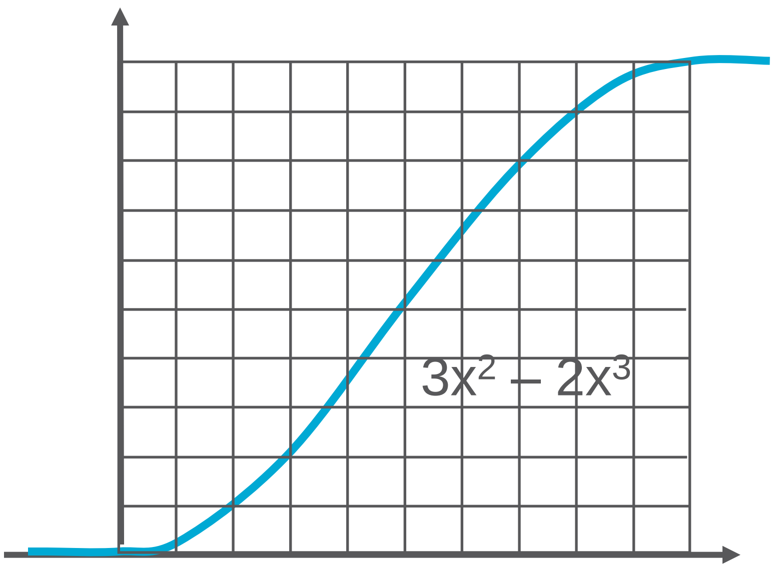
position along
green axis

GRAY SCALE EXAMPLE

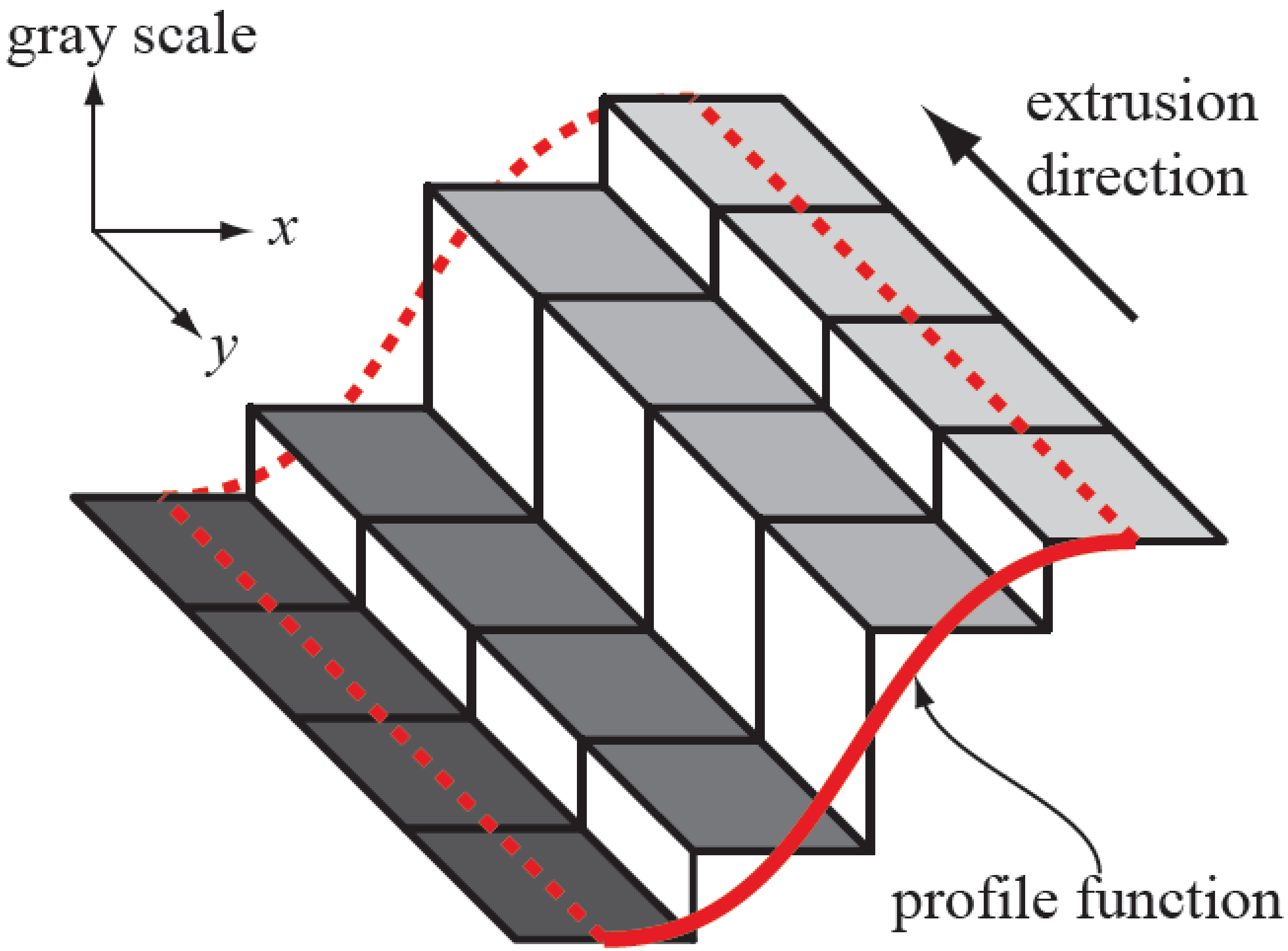
- We approximate this with a simple non-linear function that we call “profile function”.

$$f(x) = \begin{cases} 1 & x>=1 \\ 3x^2 - 2x^{3,} & 0<x<1 \\ 0 & x<=0 \end{cases}$$

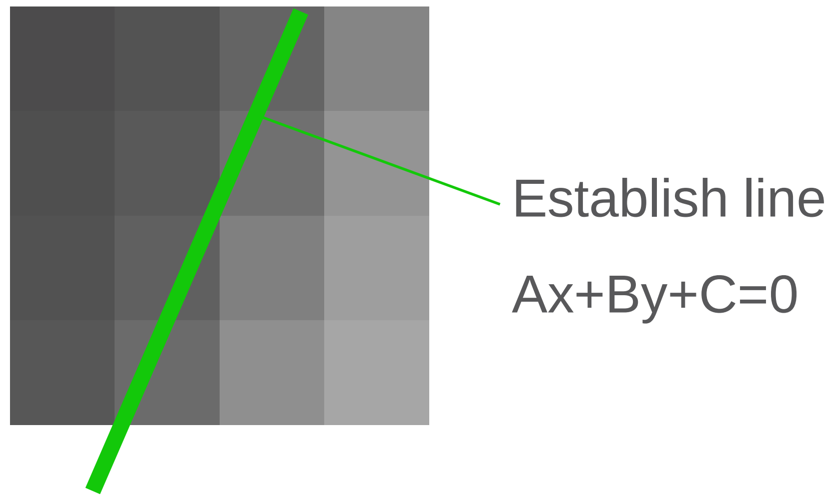


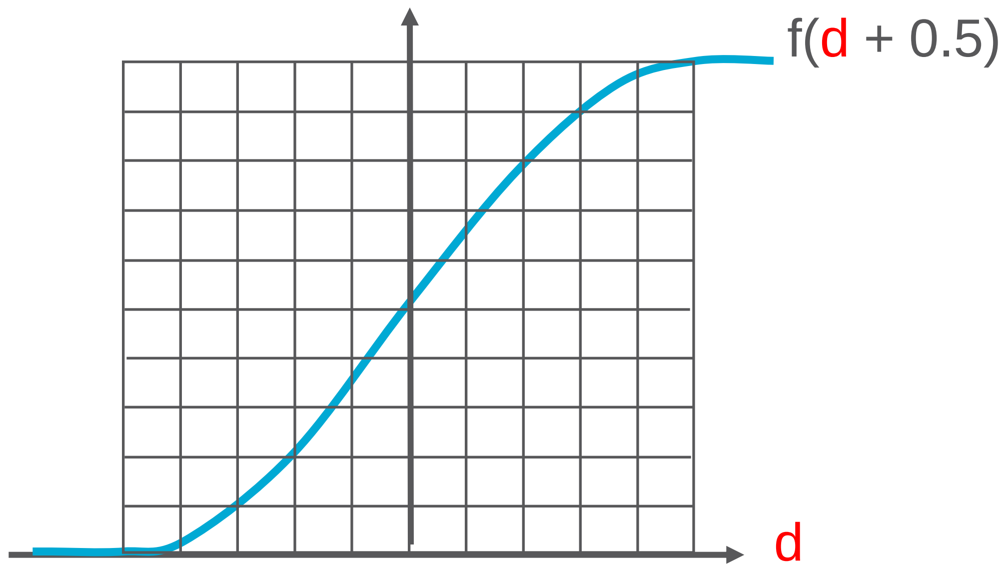


PROFILE FUNCTIONS



GRAY SCALE EXAMPLE

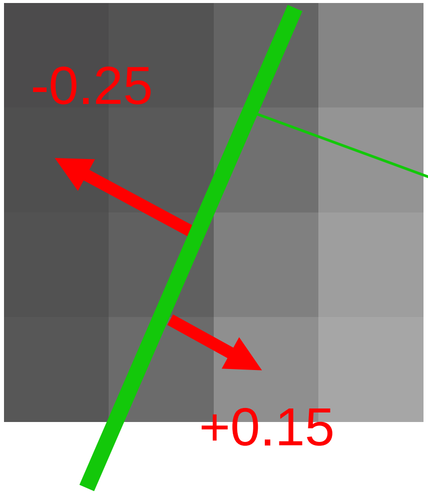




GRAY SCALE EXAMPLE

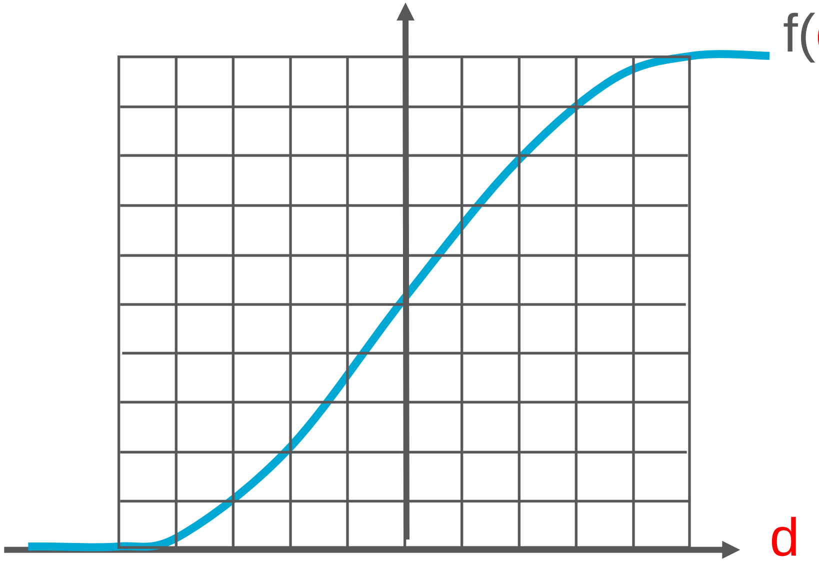
calculate signed

distance *d* to this line



Establish line

Ax+By+C=0



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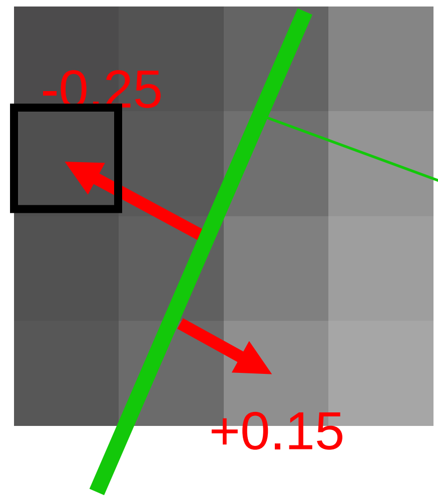
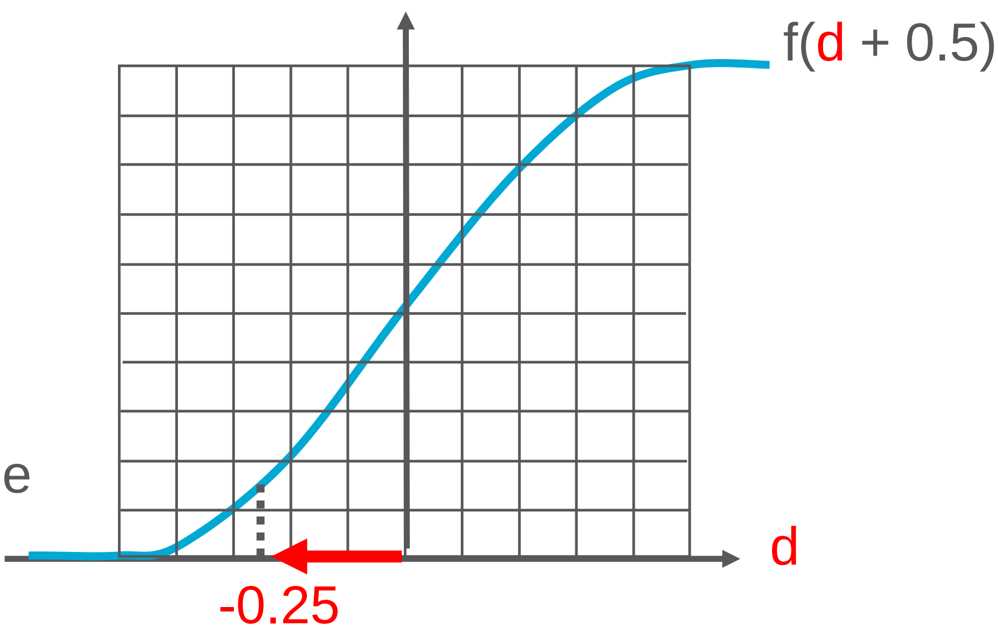


Establish line

Ax+By+C=0

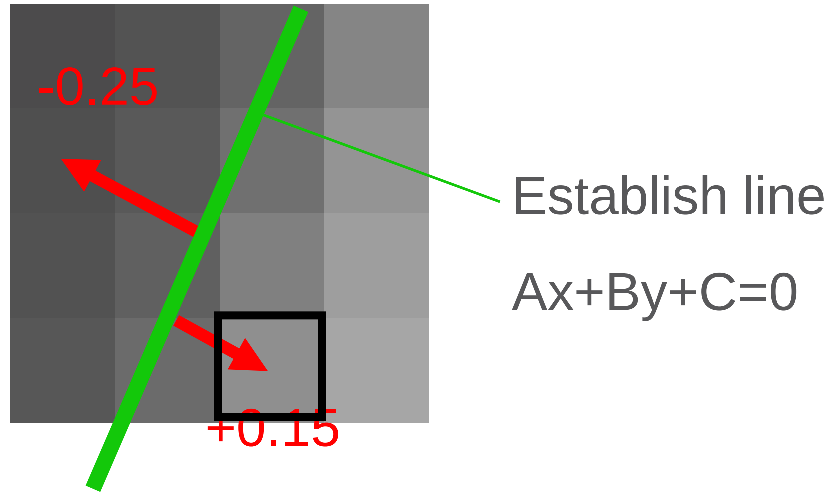


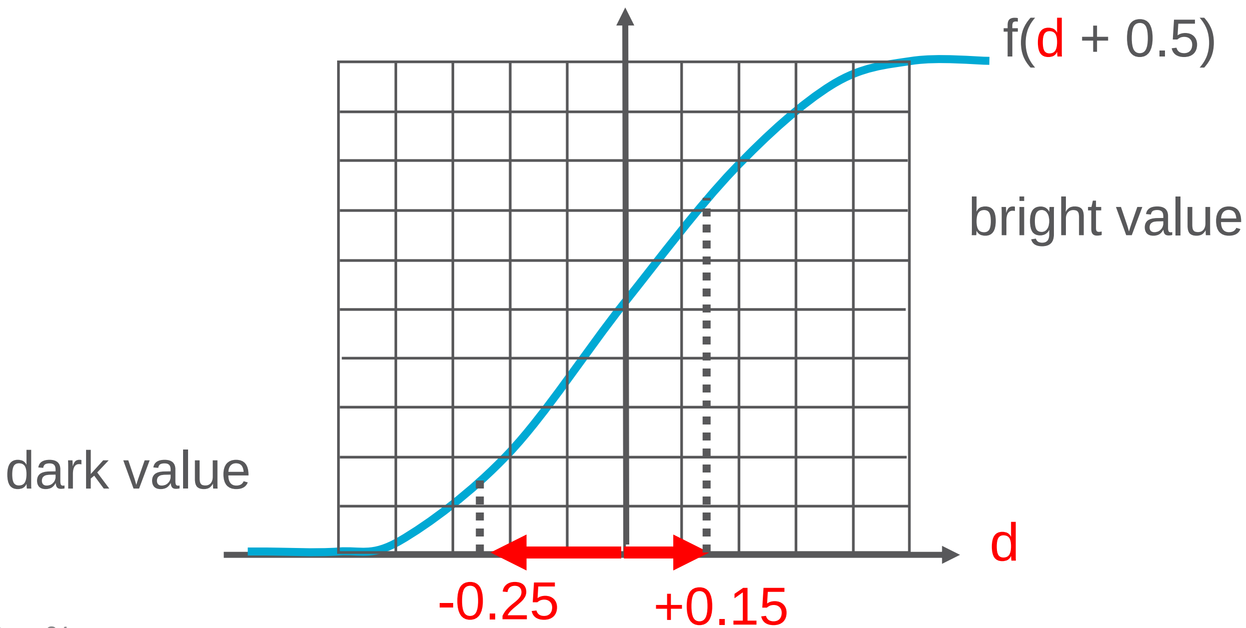
dark value

GRAY SCALE EXAMPLE

calculate signed

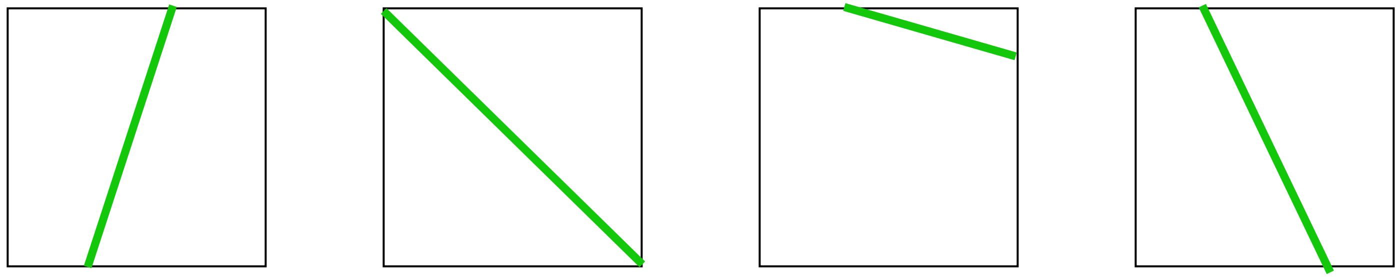
distance *d* to this line





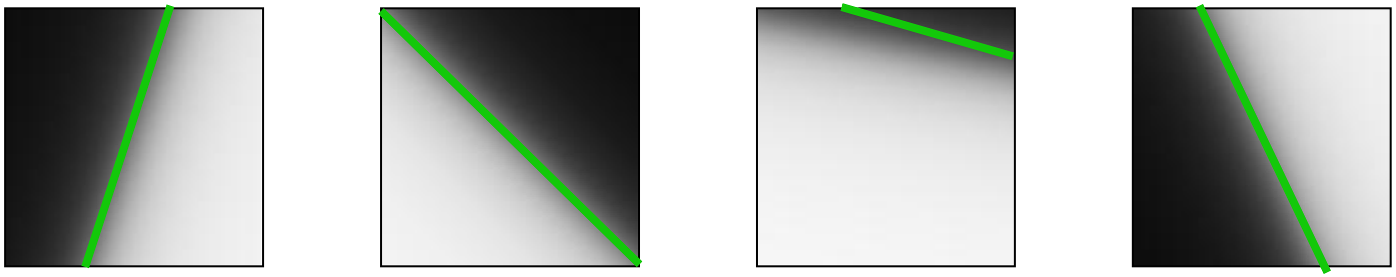
GRAY SCALE EXAMPLE

- With just the parameters A, B and C in Ax+By+C=0, it is possible to describe a rather large set of blocks:



GRAY SCALE EXAMPLE

› With just the parameters A, B and C in $Ax+By+C=0$, it is possible to describe a rather large set of blocks:



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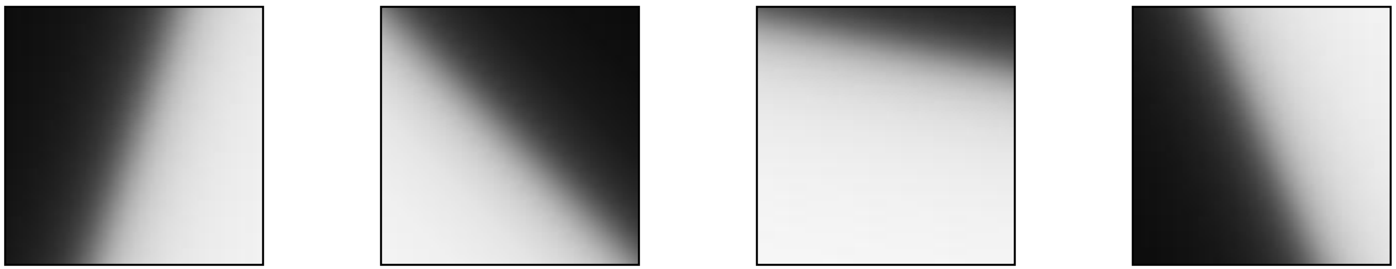

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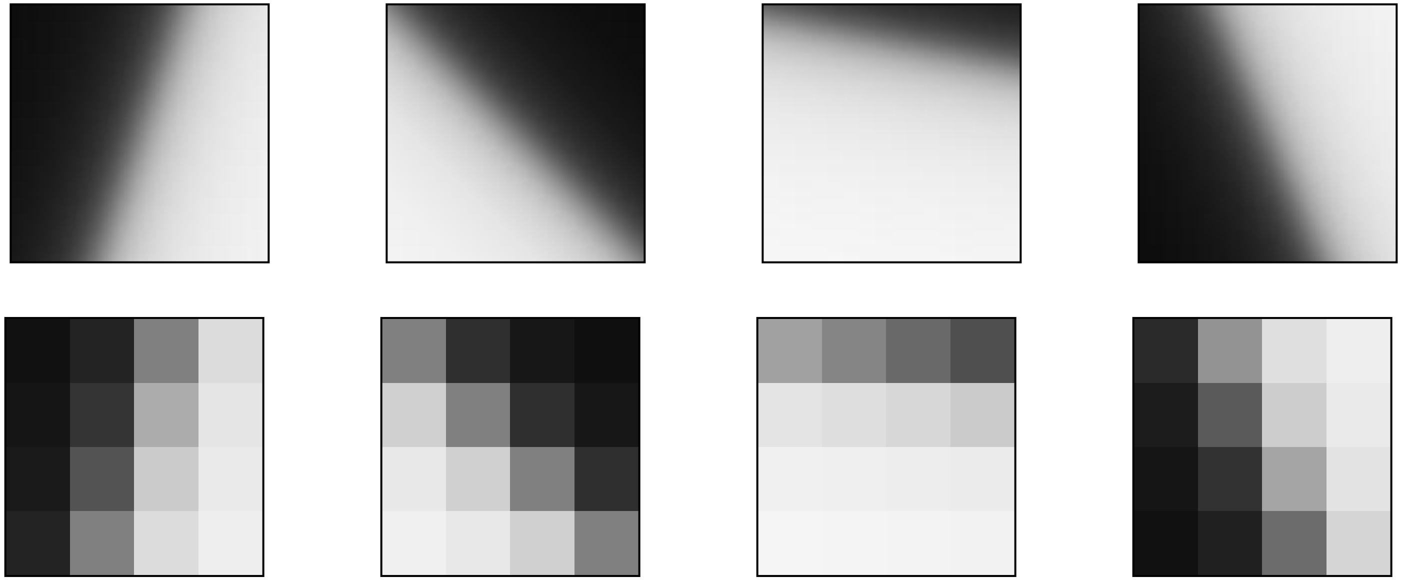

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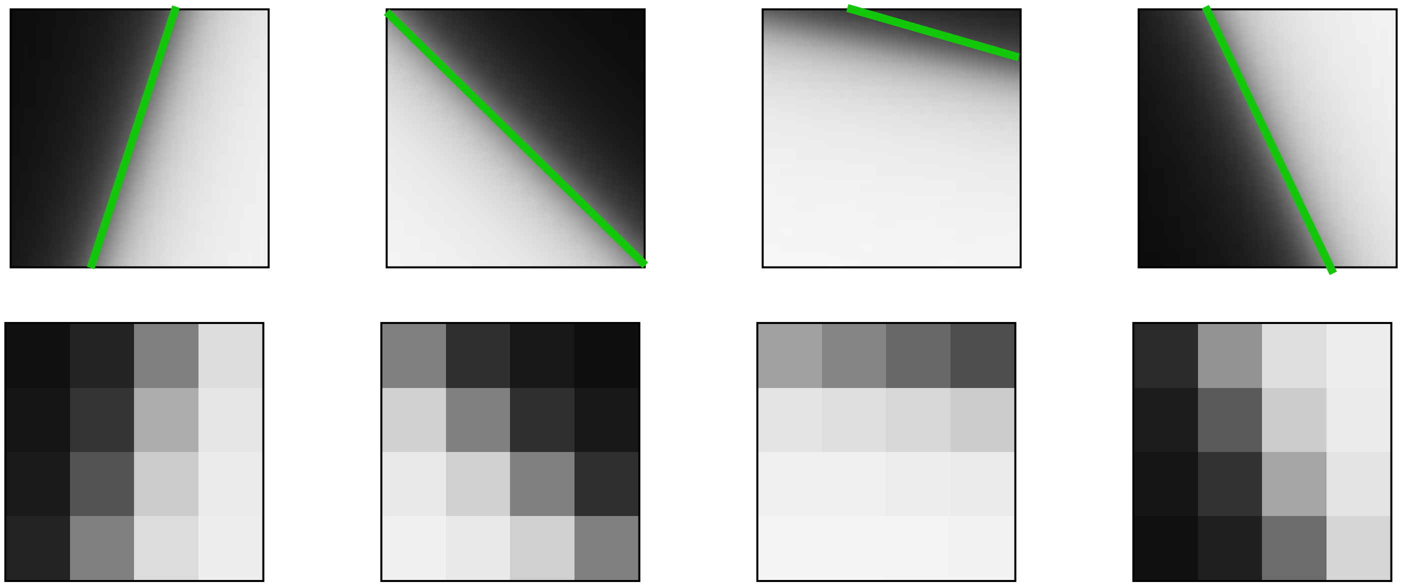


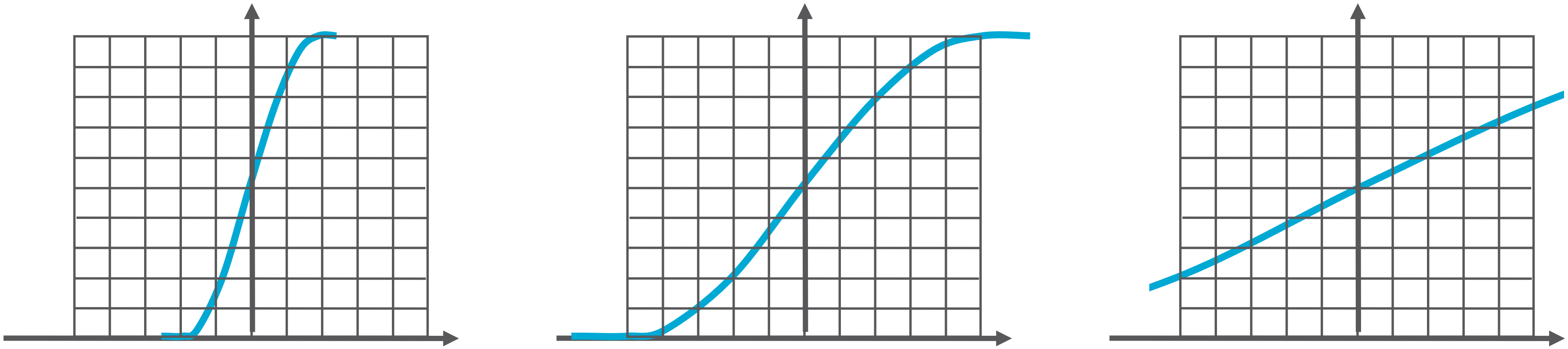
- Since A and B only represents a rotation, one can instead store θ, and use A=cos(θ), B=sin(θ).

GRAY SCALE EXAMPLE

› By introducing a division by *w* before using the function, the width of the function can be varied.

gray scale = f((*d* + 0.5)/*w*)

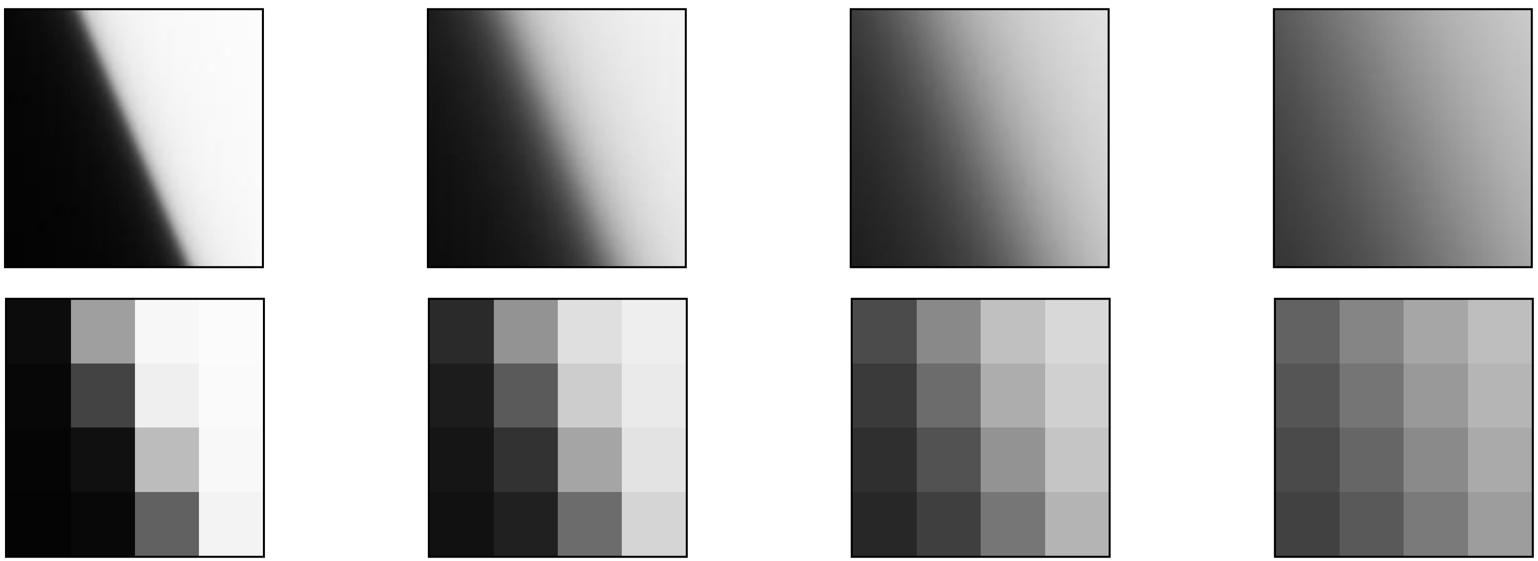
small *w* = small width   medium width   large *w* = large width



GRAY SCALE EXAMPLE

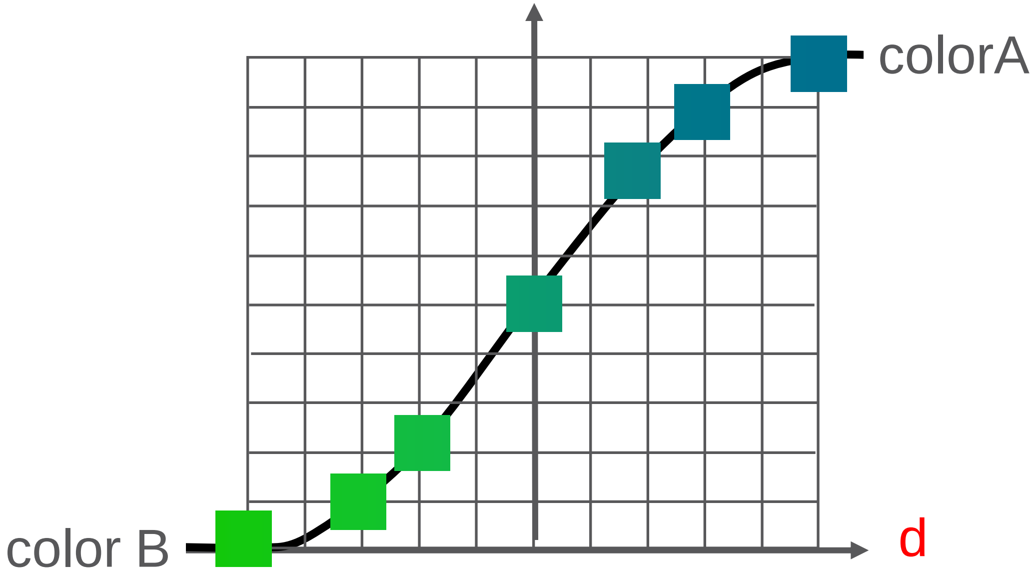
› With the extra parameter *width*, more blocks are possible:

← sharp edges smooth transitions →



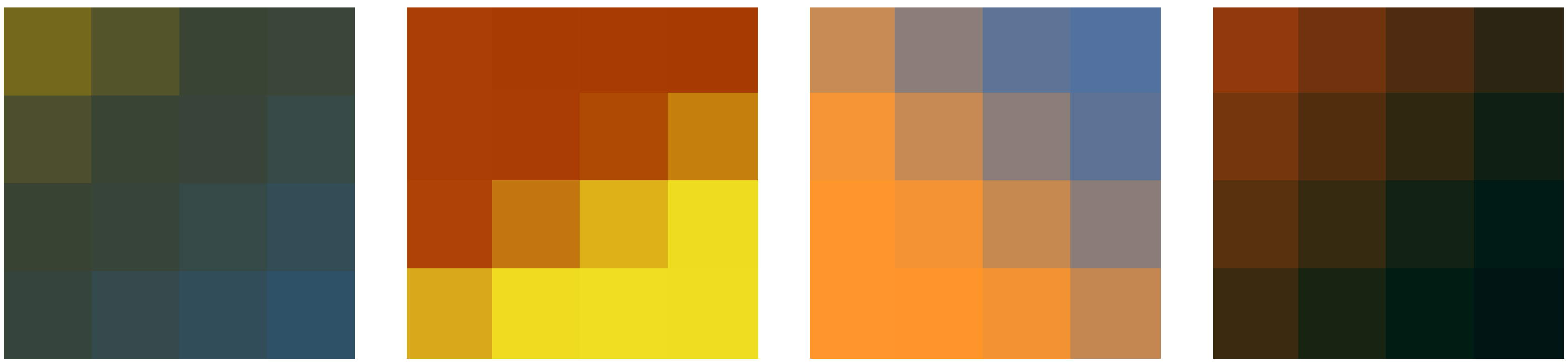
EXTENSION TO COLOR

- Instead of using the output from the function f( ) directly as a gray scale value, it is used for interpolation between two colors:
- i = f((d+0.5)/w)
- color = (1-i)*colorA + i*colorB



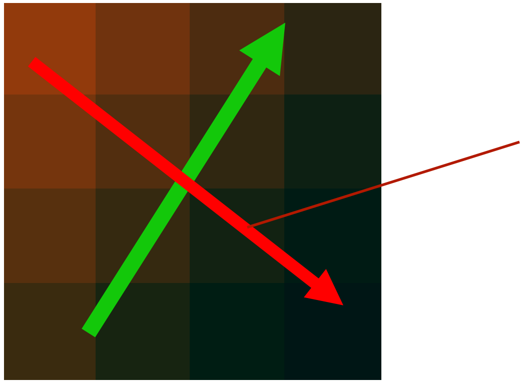
EXTENSION TO COLOR

- Thus by storing colorA and colorB, in addition to θ, C and width, many blocks can be represented.
- Unique color in ever pixel possible!



THE OTHER DIRECTION

- Typically, the block is not completely constant in the other direction -> block artifacts.
- To mitigate these artifacts, we linearly compensate the intensity in the other direction.



first direction –most of the variability

nonlinear model

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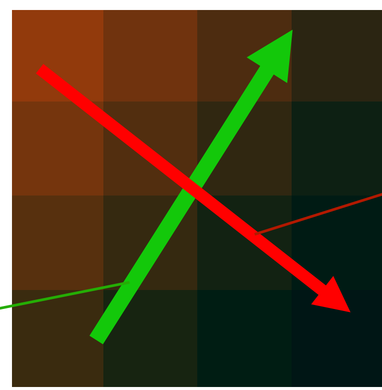


first direction –most of the variability

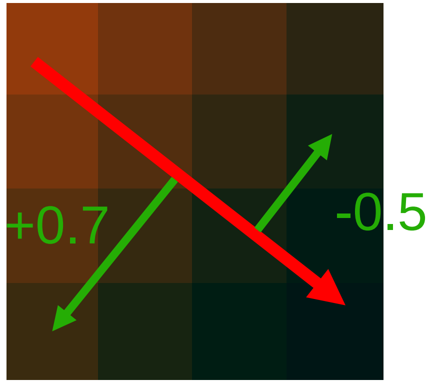
nonlinear model

second direction – still some variability

linear model

THE OTHER DIRECTION

- Typically, the block is not completely constant in the other direction -> block artifacts.
- To mitigate these artifacts, we linearly compensate the intensity in the other direction.
- We calculate the signed difference d_2 from the dominant direction, and add $d_2 * \gamma$ to each color component.



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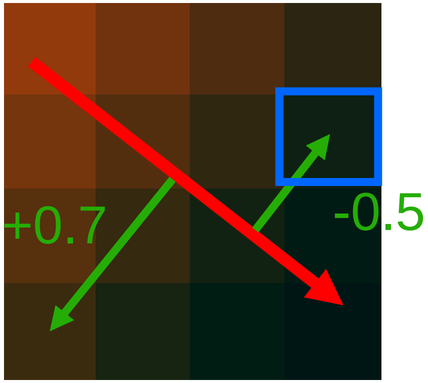

add -0.5γ(1,1,1)
to color in this pixel

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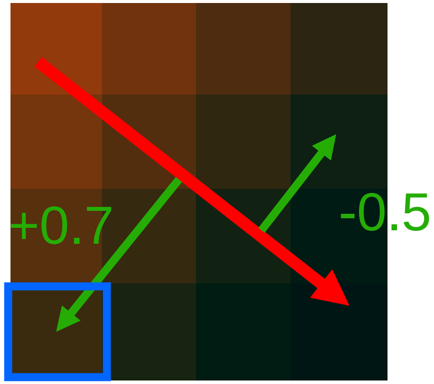
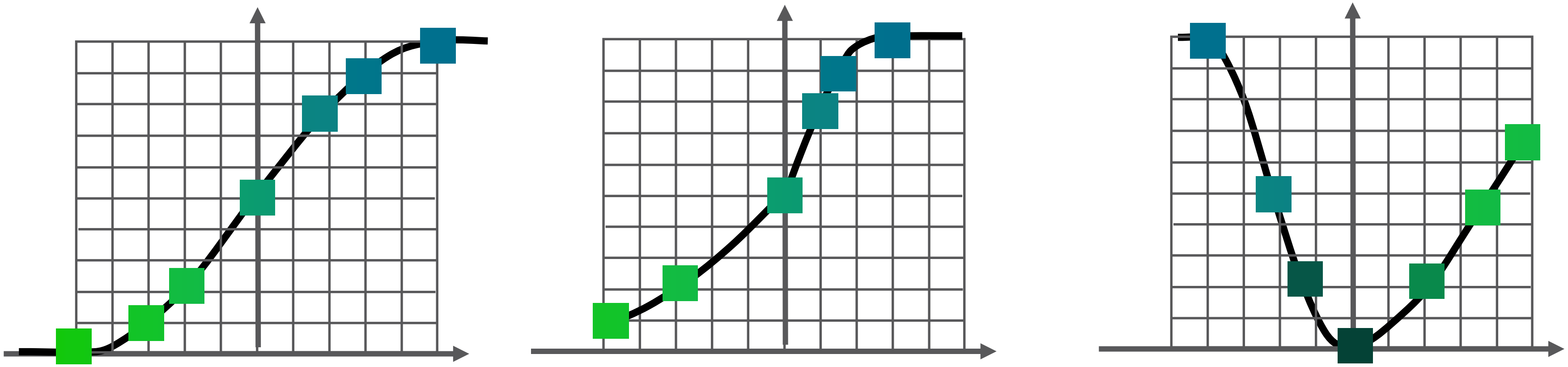


add $0.7\gamma(1,1,1)$
to color in this pixel

FURTHER REFINEMENTS

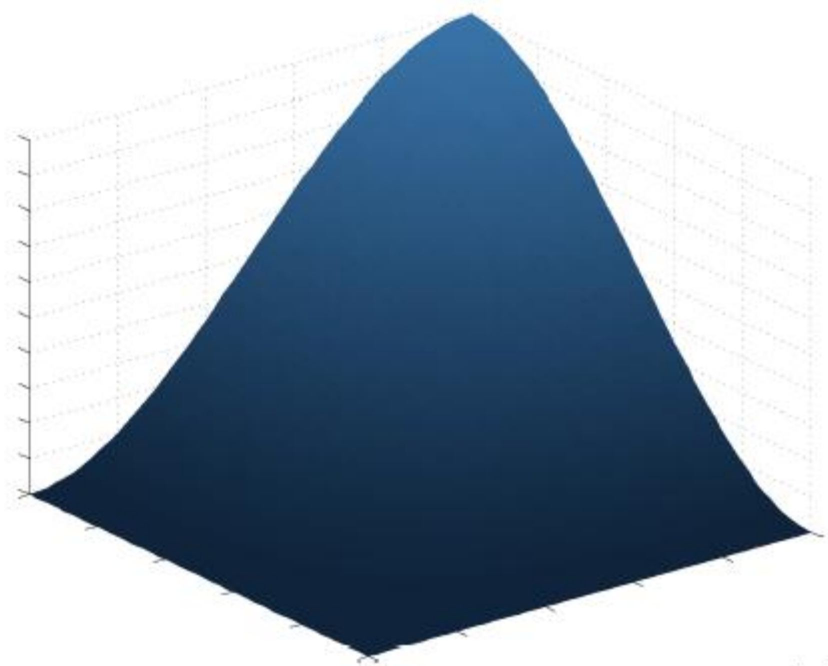
- Sometimes, the profile function $3x^2-2x^3$ is not ideal. We therefore have two other profile functions.
  - assymetric single: different widths on each side
  - assymetric double: middle color, different widths



“symmetric single” “asymmetric single” “asymmetric double”

FURTHER REFINEMENT

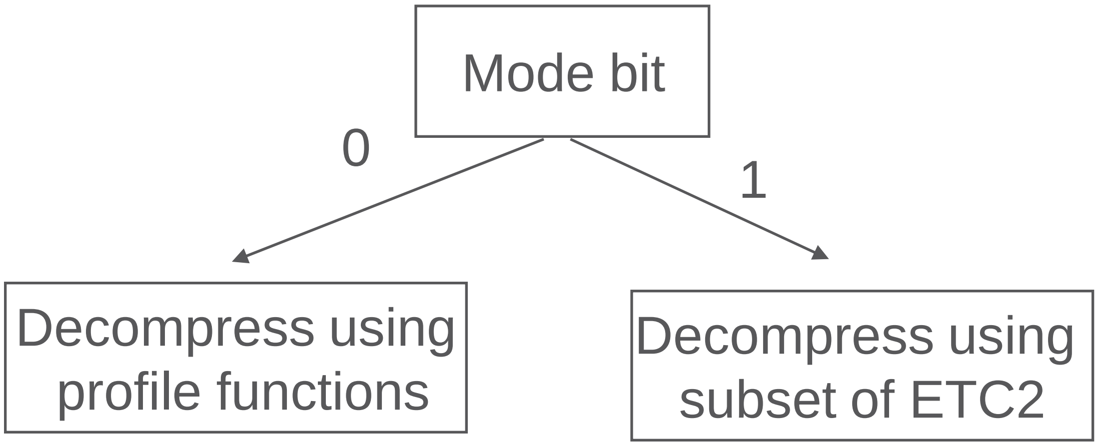
- Some blocks have significant variability in both directions
- The fourth function “corner” can sometimes help – two functions multiplied by each other.



(d)

FALLBACK

- Some blocks are far too irregular to be represented using smoothfunctions. Noisy blocks, high-frequency blocks.
- Use a subset of ETC2 as a fallback.



BIT DISTRIBUTION

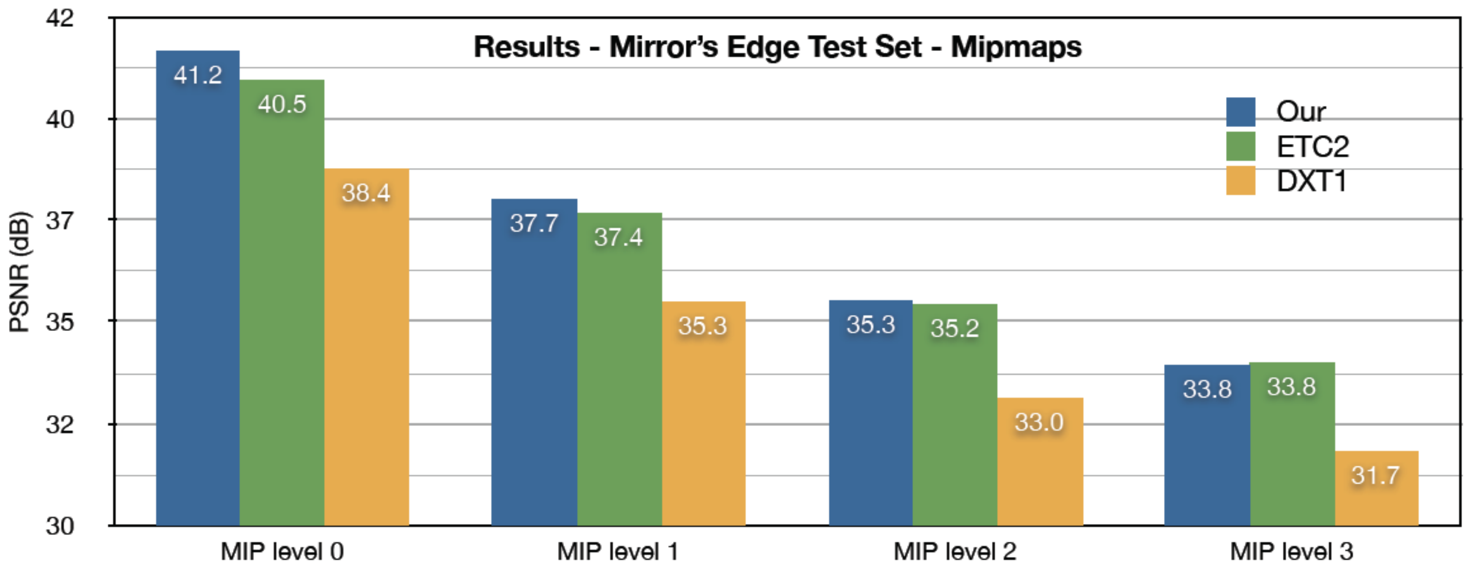
colorA RGB666	18 bits
colorB RGB666	18 bits
width	5 bits
rotation	7 bits
translation	7 bits
second direction tilt (γ)	6 bits
function selector	2 bits
ETC2 fallback	1 bit
Total	64 bits

RESULTS

- We have tested our algorithm against DXT1 and ETC2
- Same bitrate, quality measured using Peak Signal to Noise Ratio (PSNR)
- Four different data sets:
  - Radiosity Lightmaps from the game “Mirror’s Edge” by DICE/EA
  - Radiosity Lightmaps from the game “Medal of Honor” by DICE/EA
  - 64 “regular textures”, both game textures and photos
  - 24 “Kodak images”, photos only

RESULTS MIRROR'S EDGE

- › Proposed scheme 41.2 dB
  - ETC2: 40.5 dB (-0.7 dB)
  - DXT1: 38.4 dB (-2.8 dB)
- › Greatest improvement on large resolution mipmaps



MEDAL OF HONOR TEST SET

- Proposed 37.06 dB
  - ETC2 37.01 dB (-0.05 dB)
  - DXT1 34.15 dB (-2.91 dB)
- Test set contained many small lightmaps of size 16x16 pixels and less
- Excluding these increased the advantage
  - ETC2 -0.53 dB
  - DXT1 -3.05 dB

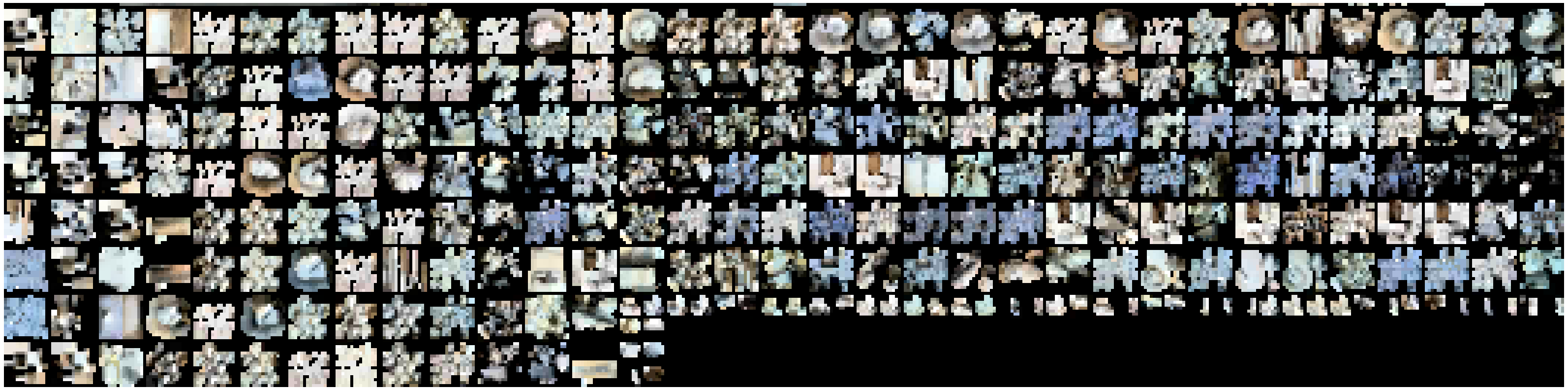


Image courtesy of DICE/EA

REGULAR TEXTURES

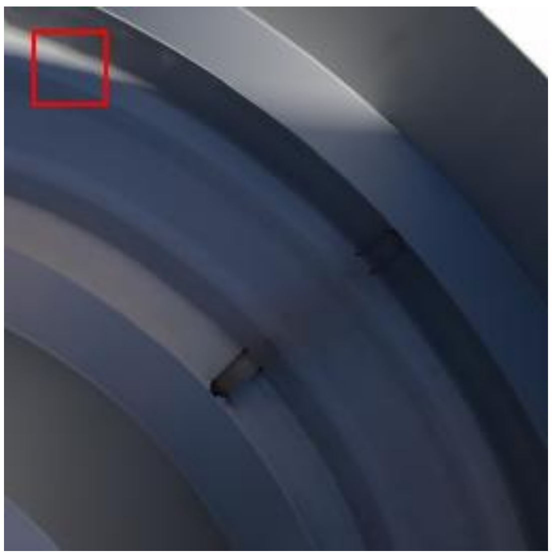
- Works for radiosity lightmaps – what about regular textures?
- Works for these too!
- 64 images (photos and game textures)
- Proposed scheme 34.38 dB
  - ETC2 34.04 dB (-0.34 dB)
  - DXT1 33.13 dB (-1.25 dB)

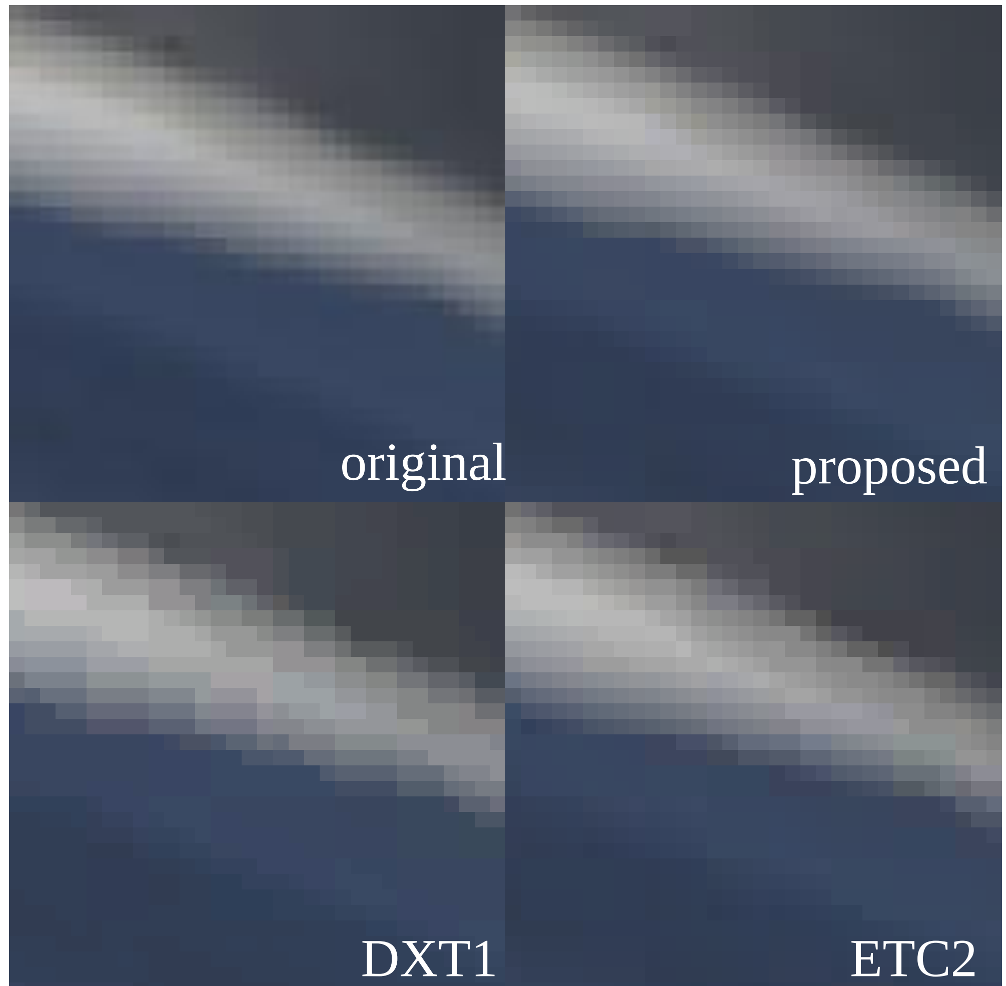
KODAK IMAGE DATABASE

- Contains only photos
- Publicly available
- Proposed scheme 37.67 dB
  - ETC2 37.44 dB (-0.23 dB)
  - DXT1 36.02 dB (-1.65 dB)

SOME EXAMPLES

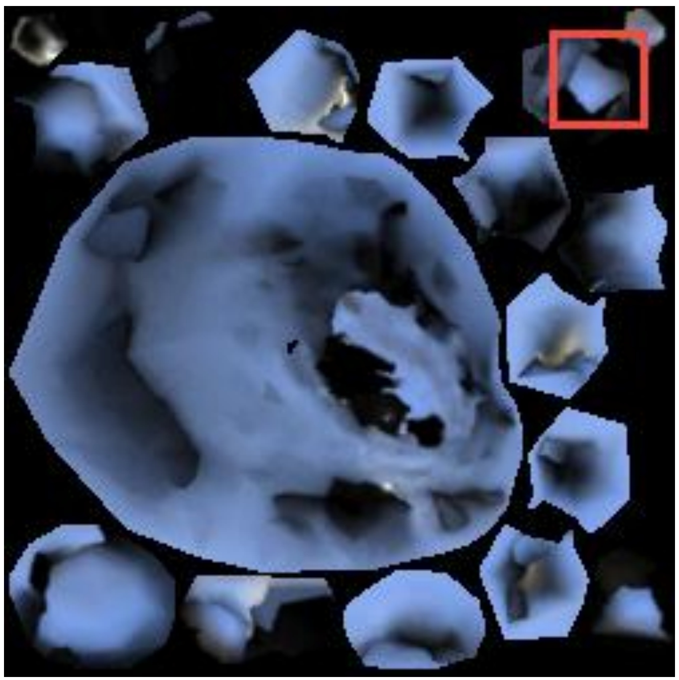
- Radiosity lightmap

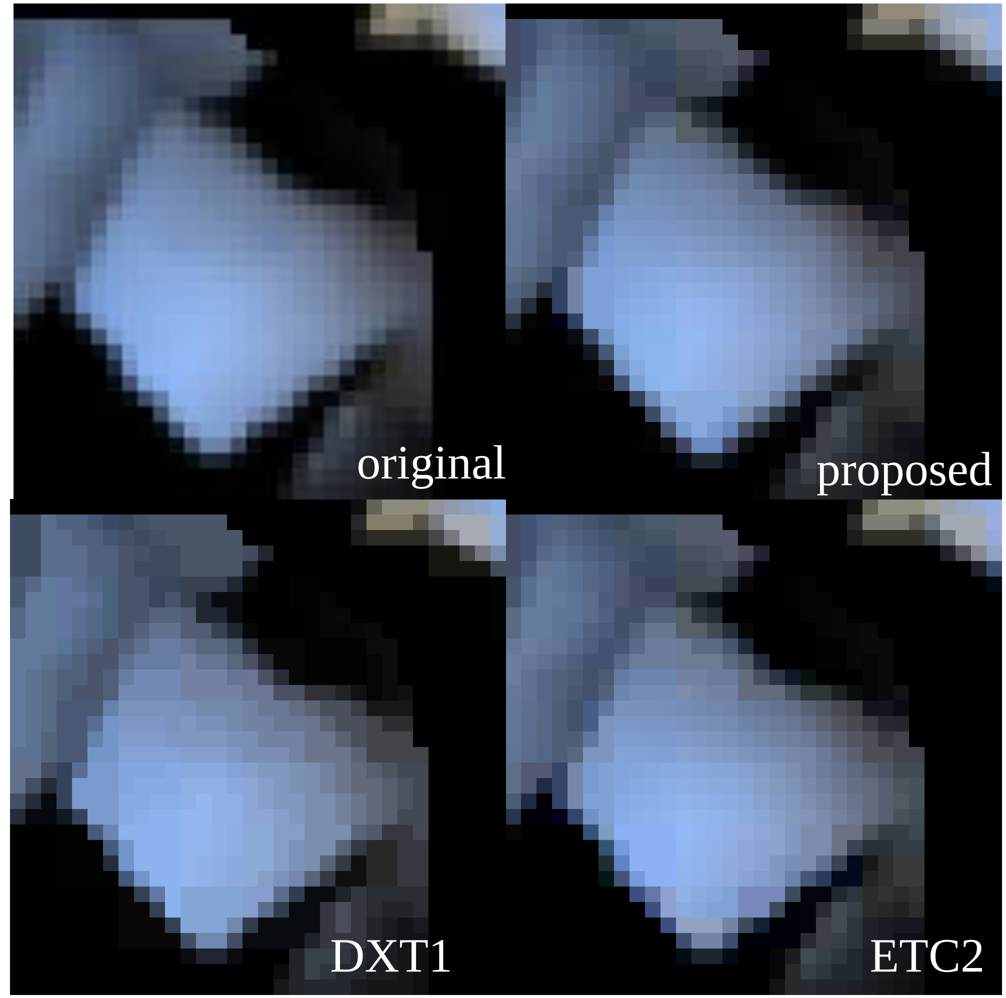




SOME EXAMPLES

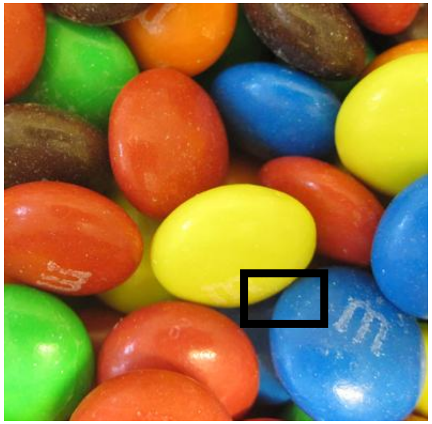
› Radiosity light map

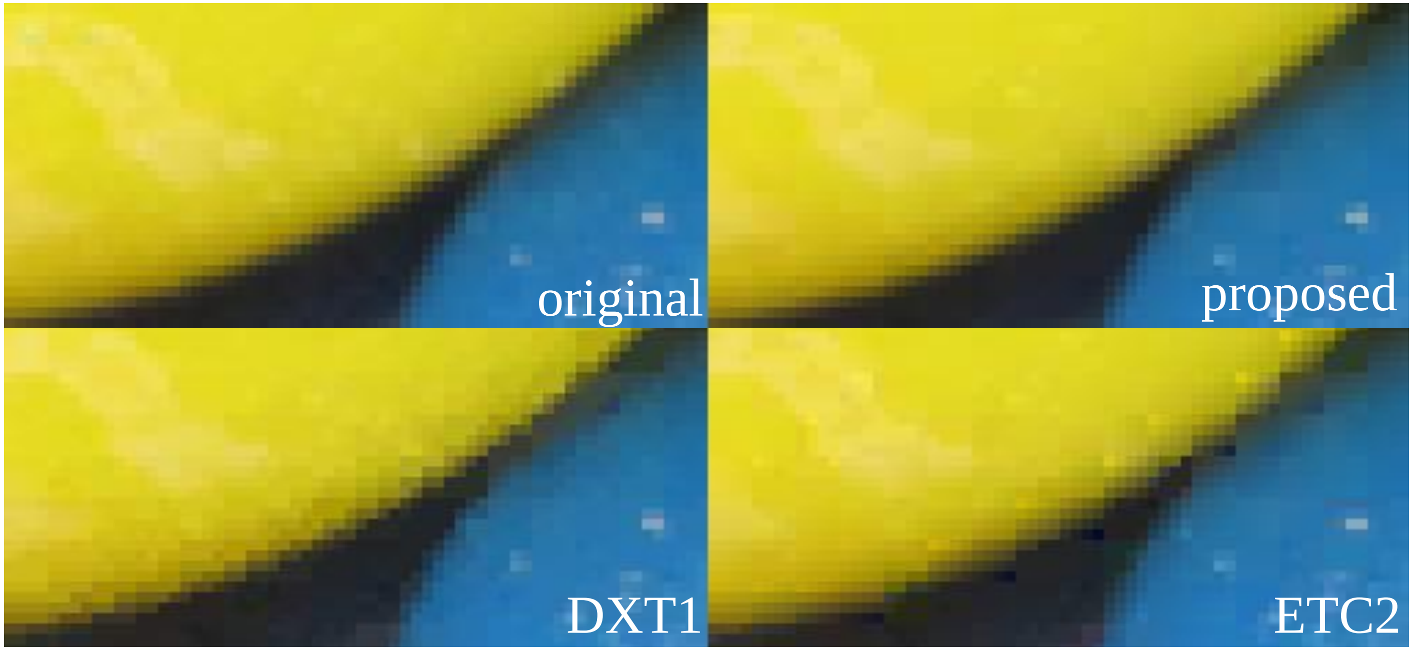




SOME EXAMPLES

- Natural image example





HARDWARE COMPLEXITY

- We have made a rough estimate of the complexity of the decoder for the proposed system
- Roughly 5 times the size of DXT1 hardware
- Roughly 4 times the size of ETC2 hardware

SUMMARY

- We have created a texture compression system targeted for slowly varying textures
- Main idea is to describe block in only one direction using profile functions
- Works well on radiosity lightmaps – up to 0.7 dB better than ETC2
- Bonus: Also works on regular textures – up to 0.34 dB better than ETC2

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