■ OBJECT AND MATERIAL EIGENFUNCTIONS – Cont'd.

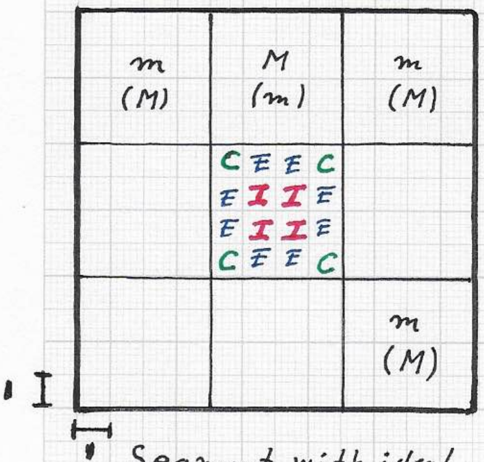
• Laplacian eigenfunctions: ... Additional derived data for a segment are:

$n_C = (t+1)^2$ number of texel corners (shared corners only counted once)

$n_E = 2(t^2+t)$ number of texel edges (shared edges only counted once)

$l = p$ Length of texel edge

$L = n_E\, l$ total length of all texel edges



Segment with ideal "checkerboard" texels with alternating types, m-type and M-type

Example: $m=1, M=2$

$f_i \in \{1,2\}$

$n = 144$

$M_T = \begin{cases} 224 \text{ or } 208 \\ \text{(4m- and 5M-texels or 5m- and 4M-texels)} \end{cases}$

$A = 144$

$nC = 36$
$nE = 72$
$nI = 36$

$p = 4$
$t = 3$

$T_m = 4$ or 5
$T_M = 5$ or 4

$a = 16$

$n_c = 16$
$n_E = 24$

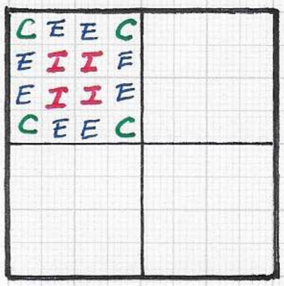
$l = 4$
$L = 96$

The specific values of all these segment features are provided here (left) for the ideal 3×3 texel "checkerboard" segment sketched on the previous and this page. This example demonstrates that one can a multitude of features for this ideal segment purely based on the classification of pixels as **C**, **E** or **I**. (Recall that this classification of pixels as **C**, **E** or **I** pixels is achieved by applying the eigenfunction-based convolution to local 5-pixel neighborhoods.)

...

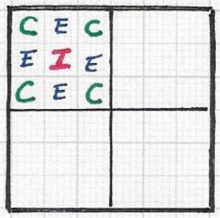
■ OBJECT AND MATERIAL EIGENFUNCTIONS - Cont'd.

• Laplacian eigenfunctions: ... In a more general setting, one can use and generalize the approach to derive and calculate a multitude of features for a segment - once a classification of all its pixels has been done; pixels are of corner (C), edge (E) or interior (I) types. Considering a priori knowledge that one has (or does not have) and assumptions one can make (or cannot make) about a segment to be analyzed and classified, the following list of features can be used as a guide:



First fragment: 4 texels, 16 pixels per texel

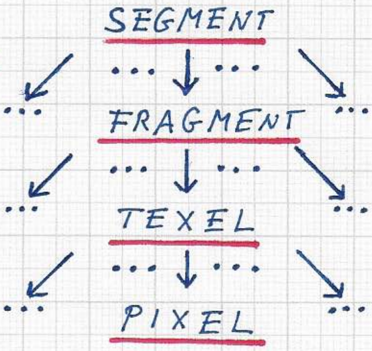
Second fragment:



4 texels, 9 pixels per texel

Sketch of a segment consisting multiple (2) fragments (not connected)

⇒ Scale-specific features possible!



"Object hierarchy" of a segment: A segment consists of fragments (not connected); a fragment consists of texels; a texel consists of pixels. The classification of pixels as C-, E- or I-pixels makes it possible to derive and compute multiple features of the "object hierarchy."

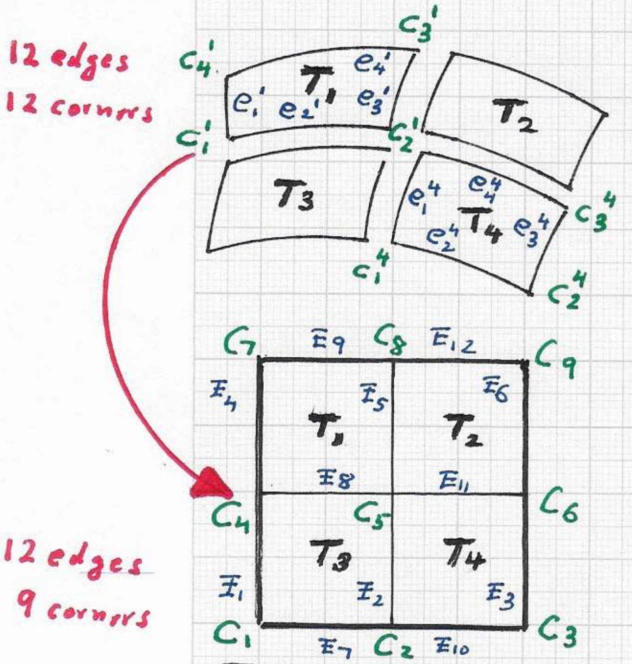
1) GEOMETRY

- PIXEL AREA (e.g., uniform 1×1 unit area)
- TEXEL AREAS (→ histogram of areas)
- FRAGMENT AREAS (→ histogram)
- SEGMENT AREA (total area)
- TEXEL EDGE LENGTHS (→ e.g., histogram of length values in entire segment)
- TOTAL TEXEL EDGE LENGTH (→ e.g., sum of all length values of all distinct edges in entire segment)

...

■ OBJECT AND MATERIAL EIGENFUNCTIONS – Cont'd.

• Laplacian eigenfunctions: ... List of potential features:



Fragment with 4 texels. Top: "Texel-centric view" where each texel is viewed individually and has 4 edges; bottom: "Fragment-centric view" where the fragments consists of 4 texels that share an edge or a corner. These two views can be used to compute the quantities under "3) Numbers, Counts" in different ways.

• The convolution mask applied to all pixels determines whether a pixel "is in a corner region," "is in an edge region" or "is in the interior" of a texel.

2) MASS

- PIXEL MASSES (e.g., values from a known finite set of values $\{m_i\}_{i=1}^{N_m}$; histogram of mass values)
- TEXEL MASSES (→ histogram)
- FRAGMENT MASSES (→ histogram)
- TOTAL SEGMENT MASS

3) NUMBERS, COUNTS

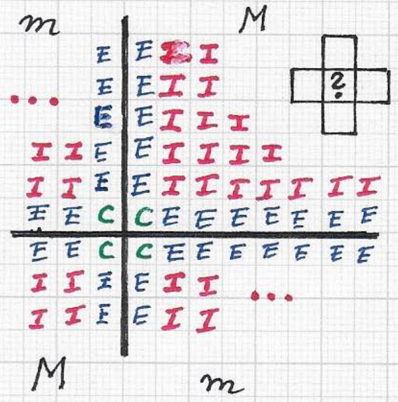
- NUMBERS OF PIXELS CLASSIFIED AS PIXELS IN CORNER REGION (C), EDGE REGION (E) OR INTERIOR (I) (nC, nE, nI)
- NUMBERS OF DISTINCT "CORNER," "EDGE" AND "INTERIOR REGIONS" (for segment; per fragment, per texel [→ histogram])
- NUMBERS OF PIXELS FOR SEGMENT, FRAGMENTS, TEXELS (→ histogram)
- NUMBERS OF TEXELS IN SEGMENT AND FRAGMENTS (→ histogram)

It is not necessary to calculate/estimate the values of all these variables – since they depend on each other. Values of those variables should be computed that can be calculated simply and that are "most relevant" for classification.

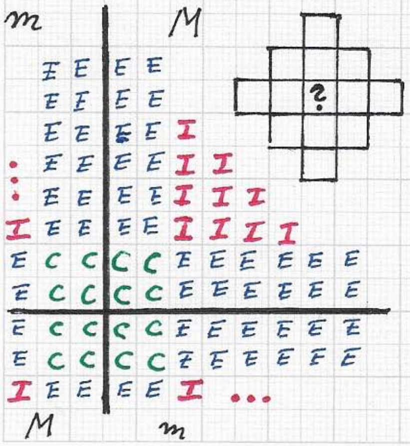
~ BH

■ OBJECT AND MATERIAL EIGENFUNCTIONS – Cont'd.

• Laplacian eigenfunctions: The discussed segment analysis and classification approach DOES NOT compute or store edges/boundaries/interfaces "shared" by texels or corners where multiple texels "come together." Instead, pixels classified as C-pixels, E-pixels or I-pixels are used to deduce, compute and represent segment information similar to shared-edge and shared-corner information. The convolution mask used to establish C-type, E-type or I-type of a pixel performs as follows: (i) pixels in a "texel corner region become C-pixels; (ii) pixels not in a "texel corner region" but in a "texel edge region" become E-pixels; (iii) pixels not in a "texel corner region" and not in a "texel edge region" become I-pixels. The two figures (left) show the "typical" and desirable (or undesirable!) effect of the size/resolution of a convolution mask when applied to a local pixel neighborhood to determine the pixel-type of the mask's center pixel. The size of a mask should be determined based on its (positive) impact on segment feature quality and classification performance. ...



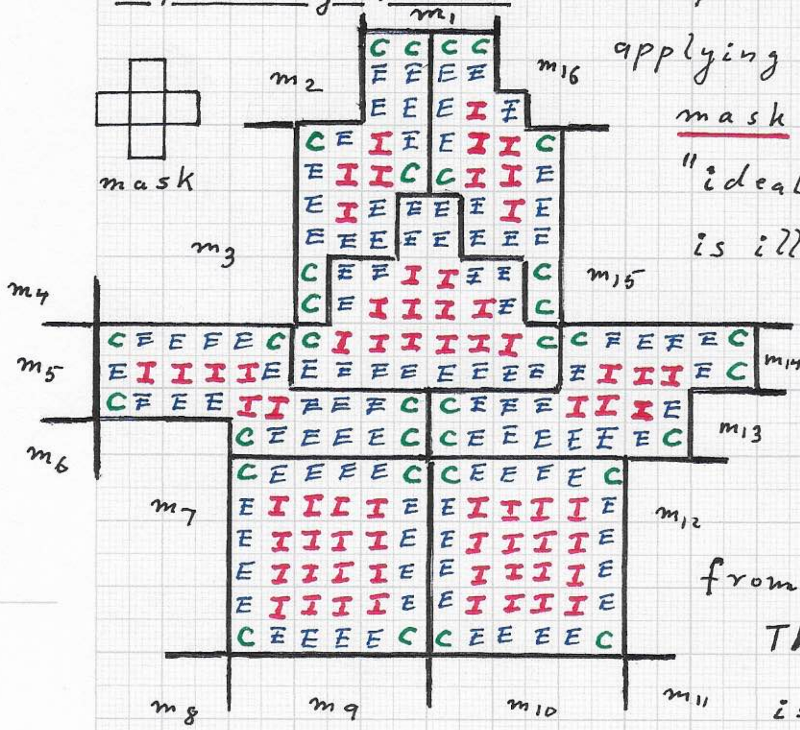
Neighborhood of 4 texels of alternating types m and M. The 5-pixel convolution mask classifies the center pixel "?" as a pixel of type C, E or I. Due to its 5-pixel domain, the mask produces "2-pixel-wide edge strips E" and "4-pixel corner regions C" – when the pixels of the mask lie partially in an m-type and partially in an M-type texel (⇒ E) or lie in more than 2 texels of different mass-type (⇒ C).



Example of a 13-pixel convolution mask producing wider "E-strips" and Larger "C-regions".

■ OBJECT AND MATERIAL EIGENFUNCTIONS – Cont'd.

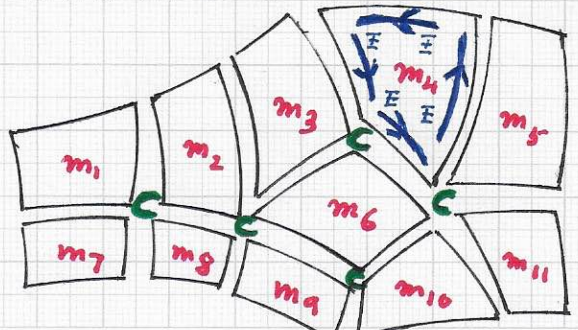
• Laplacian eigenfunctions: … The pixel classification principle of applying the 5-pixel convolution mask to a set of pixels with "ideal and distinct mass values m_i" is illustrated in the example (left).



"Texel boundaries" are drawn with bold black lines. (Texel boundaries are NOT explicitly known; they result from classifying pixels as C, E or I.)

Part of a fragment with texels of mass-type m_i. It is assumed that all the m_i-values are very different from each other. In this example, it is assumed that the 5-pixel convolution mask leads to an I when all 5 pixels have the same mass value; an E when there are 2 different mass values among the 5 mask values; and a C when there are more than 2 different values among the 5 mask values.

The example shown on this page is much more complicated than the ideal and simple checkerboard examples. The resulting C-type, E-type and I-type pixels in this more complicated example imply a much more general geometrical and topological/structural configuration. Nevertheless, many features describing the complex fragment texels can be computed from classified pixels. The sketch of a very general texel structure (Left, bottom) shows "curved" texel boundaries (edges E) and corners C of valence/degree 3, 4 and 5 that must be handled.



Abstract sketch of texels of type m_i that can arise in a general setting.

~BH