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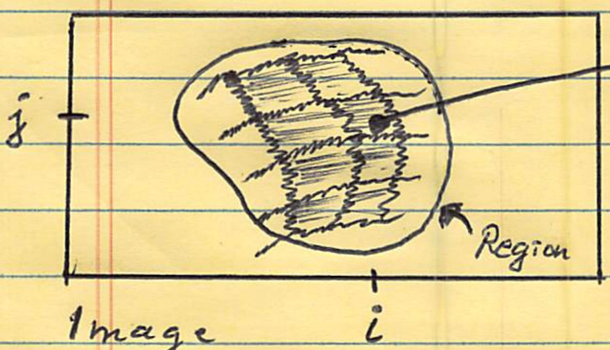
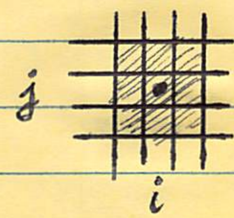
▪ THOUGHTS ON CLASSIFICATION

1) Designate a region(s) in an image as being of a certain "type"/"class" – then determine local "descriptors"/ "feature vectors" for each pixel in the region(s):



Local neighborhood around pixel (i,j):



– Compute local polynomial function $F_{i,j}$

2) The local (relatively low-degree) polynomial for each pixel (i,j) is of the form:

$$f(x,y) = c_{00} + c_{10}x + c_{20}x^2 + c_{01}y + c_{02}y^2 + c_{11}xy + c_{21}x^2y + c_{12}xy^2 + c_{22}x^2y^2$$

/* 3×3 neighborhood */

3) (Combinations of properties of) $f(x,y)$ can be used to define local characteristics, e.g.:

(i) $f(i,j)$

(ii) $\|\nabla f(i,j)\| = \|(f_x(i,j), f_y(i,j), f_z(i,j))\|$

(iii) $H(i,j) = \begin{pmatrix} f_{xx}(i,j) & f_{xy}(i,j) \\ f_{yx}(i,j) & f_{yy}(i,j) \end{pmatrix}$ "Hessian matrix" (*eigenvalues)

4) <u>THUS:</u> • Each function $f(x,y)$, i.e., a specific combination of its properties, defines a <u>multi-dimensional "feature vector" / "feature point"</u>.

- The set of all <u>pixels belonging to the same region(s)</u> therefore defines a <u>corresponding set of feature vectors/points</u>.

- This set of corresponding <u>feature vectors/points</u> is characterized by a specific <u>DISTRIBUTION</u> of vectors/points in the embedding multi-dimensional space.

! • <u>BUT</u>: This DISTRIBUTION "type" cannot be viewed or processed like a standard histogram.
<u>THUS</u>: The <u>DISTRIBUTION</u> in the embedding multi-dim. space must be considered and used like a <u>discrete POINT DISTRIBUTION in multi-dim. space</u>. This discrete point distribution can be used to <u>define a continuous DENSITY FUNCTION</u> over the embedding space.

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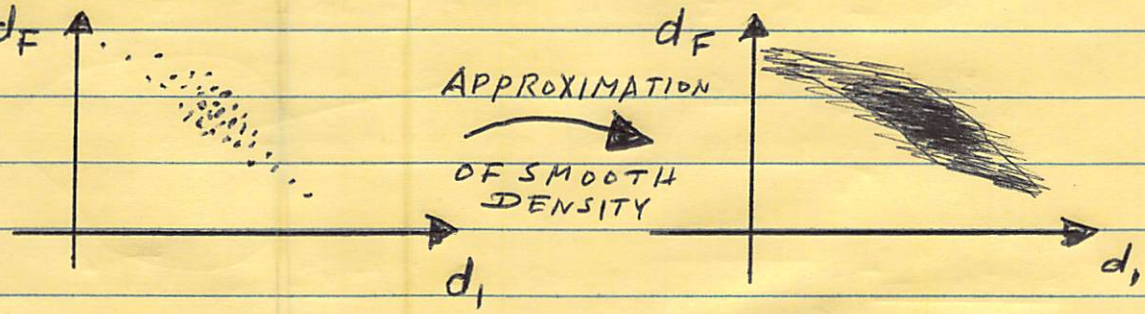
5) From a "<u>discrete feature point cloud</u>" in multi-dim. space to a "<u>continuous feature density function</u>":

<u>Ex</u>: multi-dim feature space with dimensions $d_1, \ldots, d_F$



DISCRETE DENSITY

<u>CONTINUOUS DENSITY</u> !

6) <u>UTILIZATION</u> of continuous density function for material / texture comparison / recognition / classification:

<u>GIVEN</u>:
- Stored <u>continuous density functions</u> (of specified types of materials / textures)
- Extracted (set of) <u>region(s) R in an image</u>

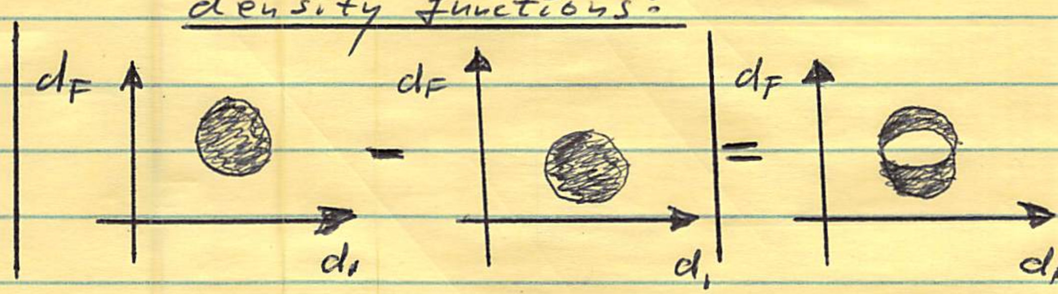
<u>ALGO</u>:
- Compute the <u>continuous density for R</u>;
- <u>USING A "PROPER" DISTANCE MEASURE</u>, <u>compute the differences between all stored density functions and the density of R</u>;
- Determine the material/texture type for R; ∎

7) **ISSUES** (non-trivial...):

- **Step 3)**: The computed and stored characteristics of $f(x,y)$ should – in certain/most cases – be INVARIANT to, e.g.,
  - "allowable variation" of the f-value,
  - scaling (of a certain type) of the "texture" in the image,
  - rotation of the texture in the image.

  ⇒ MUST ENSURE the desired type(s) of INVARIANCE when defining f's local characteristics!

- **Step 6)**: Need for a proper DISTANCE MEASURE for two continuous density functions:



DENSITY 1   DENSITY 2   DIFFERENCE (ABS. VALUE)

AND: How small must the (absolute) difference be for 2 densities to be viewed as "the same"?

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8) ALTERNATIVE:

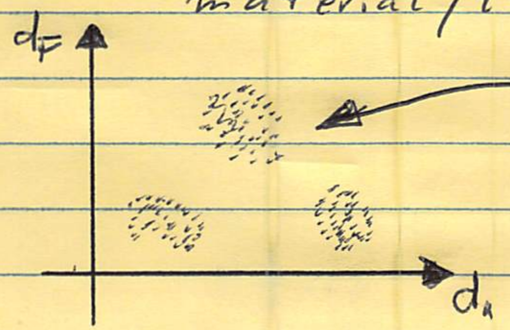
- Do NOT establish/use a material/texture class database
- Do NOT perform segmentation in a given image

INSTEAD:

i) Compute the local characteristics for each pixel (i, j) based on its associated local polynomial f(x,y).

ii) Compute the discrete density / feature point distribution in the multi-dim. space used to represent each pixel's associated characteristics

iii) "Automatically analyze" this discrete density – and determine K "meaningful" material/texture types; subsequently, label each pixel with the corresponding material/texture index/label.



Here: 3 feature point "clusters" in multi-dim. feature space ⇒ 3 TYPES

→ Consider K-means clustering. ∎ BH