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HOW TO QUANTIFY GROUPS OF OBJECTS ?

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INTRODUCTION

In histometry, as well as in many other areas, objects of interest, e.g. cell nuclei, are locally distributed. Their overall resemblance or arrangement respectively, as well as their properties are the base of any diagnosis or qualification[9 10 11]. The estimation of quantitative properties of cellular objects is called *cytometry*, the quantification of *arrangement* properties of cells in histological sections *histometry*.

For the latter a program has been developed which on the base of a certain *graph arithmetic*[2 3] allows the following operations: *i)* the definition of object groups via neighborhoods, *ii)* the processing of the latter or more general of relational operations, *iii)* the gathering of object groups in hierarchy levels[1 2 4], *iv)* the computation of quantitative features at each hierarchy level and *v)* the display of graphs. The program is used to analyse histological sections of different origin[1].

A complete tissue section evaluation consists of *i)* the segmentation of the objects of interest, *ii)* the evaluation of object specific quantitative features (*cytometrical approach*), *iii)* the estimation of a base relation e.g. a local neighborhood, *iv)* the definition of objects at certain hierarchy levels and *v)* the evaluation of level specific quantitative object features (*histometrical approach*)[1 7].

DEFINITION OF HIERARCHIES

A hierarchical representation of structures is a widely used method[6]. In Fig.1 a hierarchical concept of tissue is displayed, as it is used for the qualitative and quantitative analysis of sections. The construction of a hierarchy depends on the modelling concept[13]. The latter may reflect e.g. how the structural elements are originated, their function or their degree of local disorder. Each model results in another hierarchy.

A hierarchy consists of levels and each level of objects with level-specific interrelationships. Each object in any hierarchy level is constructed from lower level objects (Fig. 1). Every relation has to be defined following the modelling concept. In image processing one may define the digitized picture elements (pixels) as the objects of the lowest hierarchy level.

The relationships used can be locally based, e.g. derived from zone of influence[12], Delaunay triangulation or Voronoi diagram[14], in combination with other non-locally based relations as being in a certain size class (*small, medium, big*), displaying a certain object type (*mitotic, undifferentiated*) or being not too far away from certain other objects (*near the basal layer, at the surface*). Of course some of the terms in brackets have to be defined as objects at certain hierarchy levels. In general this leads to some sort of small-scale expert system, since this is an accepted way of knowledge representation.

DEFINITIONS OF GRAPHS

Starting from any hierarchy level, a graph representation of the objects as *nodes* and the relationship as *edges* allows a formal processing as well as an easy display. Mathematical morphology[12] has been proven

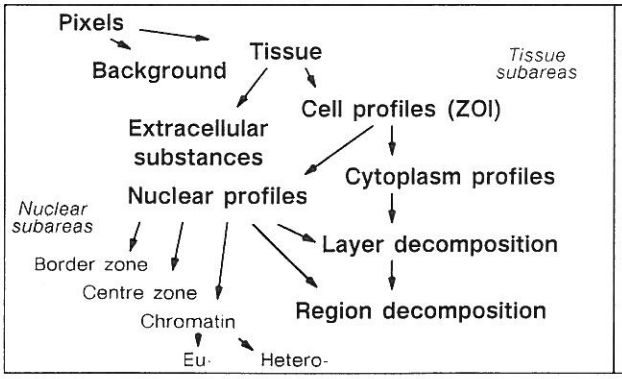

Fig. 1. Illustration of a hierarchical concept of a tissue section

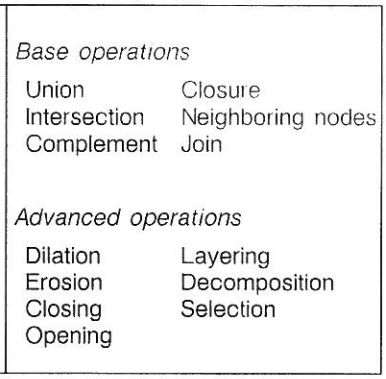

Fig. 2. Graph operations

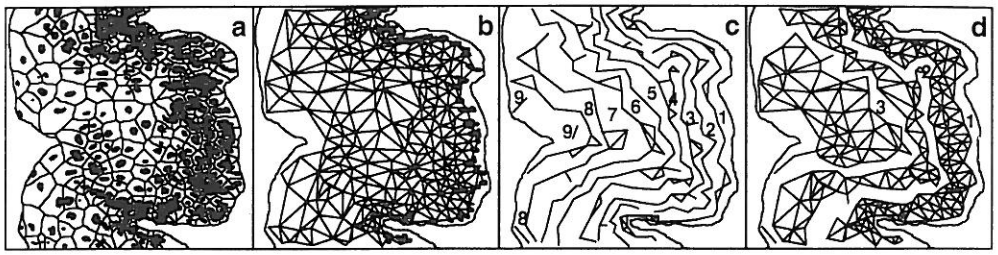

Fig. 3. Analysis of a tissue section (see text)
as a valuable tool. Graph operations are defined according some concepts of mathematical morphology (Fig. 2)[11].

EXAMPLES OF OBJECTS IN HISTOLOGY

For a tissue example the objects, nuclear profiles (black), are shown in Fig. 3a. The base relation is derived from zones of influences (Fig. 3a, thin lines) as shown in Fig. 3b (thin lines). Two different hierarchy levels are shown, growth layers in epithelial tissue (Fig. 3c) and tissue regions (Fig. 3d) starting from the cells of the basal layer marked in Fig. 3b (black) with objects numbered.

FEATURING OF OBJECTS

The features of objects are derived from the features of the lower level objects. The lowest level objects, the pixels, carry the features *pixel value* and *coordinates*. The features of objects of higher levels, e.g. nuclear profiles may be statistical parameters of the pixel value distributions like area as the number of pixels or the mean optical density as the mean of the corresponding pixel values and so on.

So for example objects of the next higher hierarchy level, lets say tissue regions, may be described by the mean distance of nuclear profiles in the region . Another more complicated feature may be the maximum free path length inside of an object.

SUMMARY

A method and a concept is shown to describe *objects* in a *hierarchical system*. This is, in principal, the usual way defining objects, however it is rarely consequently performed. For an example from pathology the methods are illustrated. Starting from the concepts of mathematical morphology for the description of shapes, this approach can be used to describe arrangements or architectures of objects. This might lead to a concept of shape in a more abstract but formal way.

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