45 Analysis of Irregular and Hierarchical Visual Objects

Markus Peura

45.1 Introduction

Visual appearance of many natural objects is highly irregular and indefinite. The objects studied for example in biology, medical sciences, meteorology, and geomorphology have been challenges for computer vision. Examples of such objects are shown in Fig. 97. Dynamical behaviour and complex spatial hierachy are often additional difficulties in designing automated recognition schemes.

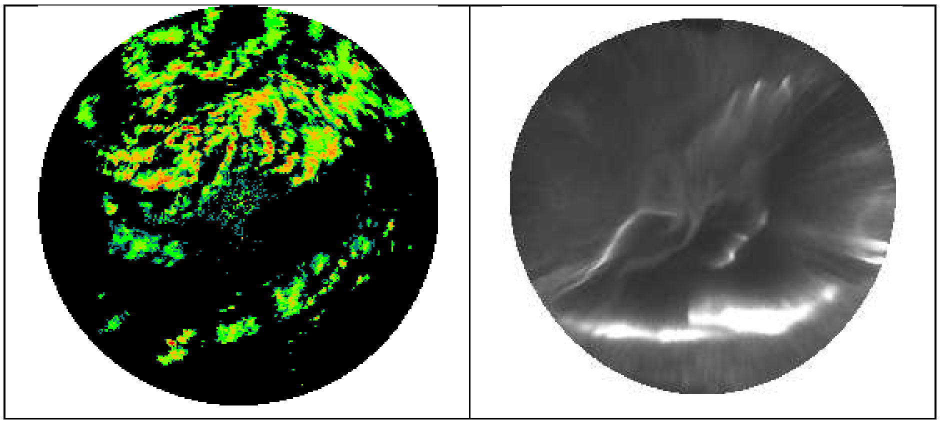

Figure 97: Examples of irregular natural images: precipitative clouds detected by a weather radar (left) and Northern lights captured by an all-sky camera (right).

45.2 Shape descriptors

A *shape descriptor* is an index, providing numerical information of a contour of an object [1]. Some descriptors are shown in Fig. 98. These descriptors were studied initially within the running paper project (Sec. 44). Convexity is a description the smoothness of an object, attaching penalty to every concavity (inlet) on its contour. Elongation is defined as the ratio of principal axes; the principal axes are the eigenvectors of the covariance matrix of a contour. Compactness is the ratio of a squared perimeter and an area. Variance and elliptic variance measure the shape difference from a circe and an ellipse, respectively.

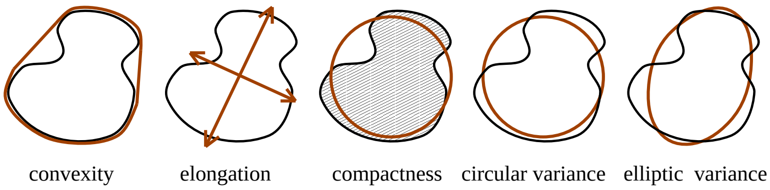

Figure 98: Shape descriptors.

45.3 Spatial hierarchy

As far as topology is considered, a natural way to perceive it is to regard intensities as altitude analogously to terrain elevation on a topographical map (Fig. 99 a and b). Finally, an attribute tree is obtained by attaching segment information (size, intensity, shape descriptions, etc.) to the obtained structure [2],[3].

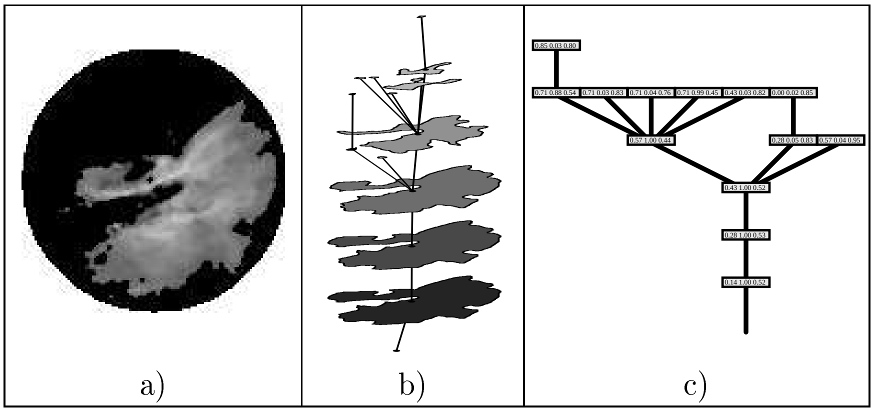

Figure 99: Original image (a), its topology (b) and attribute tree (c).

45.4 Indexing and matching attribute trees

As to recognizing and classifying obtained attribute trees, graph matching is a rigorous but rather elaborous technique. In this study, new fast techniques for indexing, matching, and generalizing unordered attribute trees have been developed. The proposed matching scheme is based on dividing the tree recursively into subtrees. The subtrees are matched according to indices, which have been calculated in advance using linear updating rules. In other words, exhaustive matching of subtrees is replaced by matching points in space. The overall computation time is linear.
The descriptors used in this study are height, node count, centroid, and branching variance, which have straightforward real-world analogies. The height of a tree is the length of the longest branch starting from the root. The descendant count can be thought as the mass of a tree. The centroid is an indicator of the vertical distribution of the mass. The branching variance measures structural irregularity. When matching attribute trees, these descriptors can be readily generalized to the attributes. One step of the matching scheme is illustrated in Fig. 100, where height and node count have been outlined as the height and width of the rectangles, respectively.

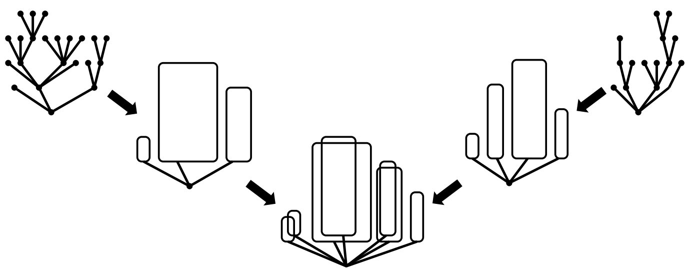

Figure 100: Illustration of the index-based heuristic matching.

45.5 The self-organizing map of attribute trees

After matching two trees, the resulting tree can be *weighted*. Weighted instatiations of the matched trees are essentially interpolations and imply direct applicability in learning systems involving prototype generation trough averaging. The *self-organizing map of trees* [4] is an extension of the standard self-organizing map (using vectors); the key issues is the revised definitions for a distance metric and adjusting. A map trained with 1115 weather radar images is shown in Fig. 101. The applied attribute vectors have three elements: intensity (red), are (green) and elongation (blue).

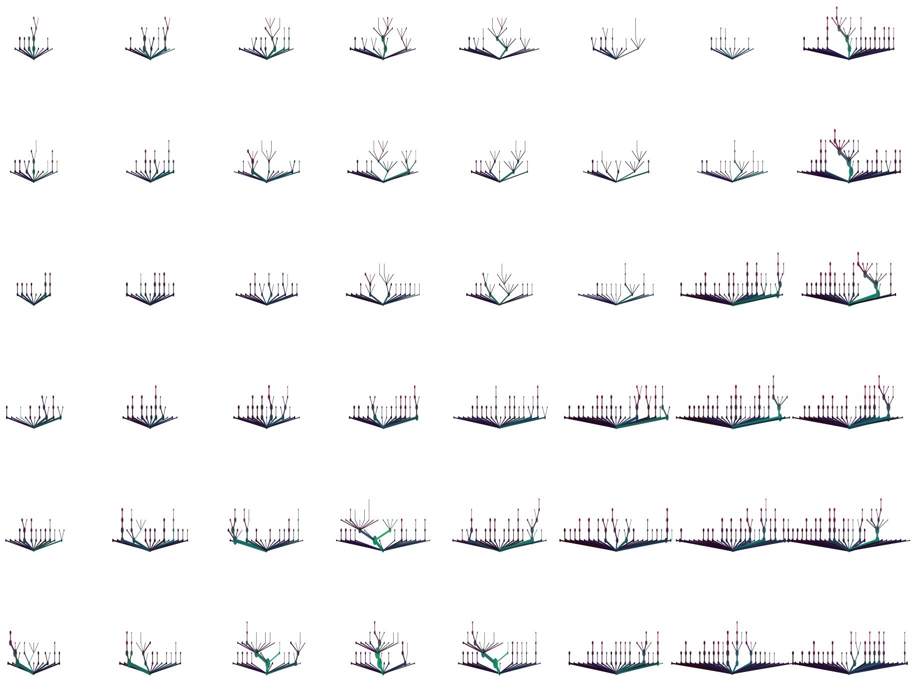

Figure 101: A self-organizing map of attribute trees.

References

[1] Iivarinen, J., Peura, M., Särelä, J. and Visa, A.: "Comparison of Combined Shape Descriptors for Irregular Objects". BMVC'97, 8th British Machine Vision Conference, Essex, Great Britain, September, 1997.

[2] Peura, M.: "A Statistical Classification Method for Hierarchical Irregular Objects". Image Analysis and Processing, Vol. 1, pp. 604-611, Alberto del Bimbo (Ed.), Lecture Notes in Computer Science, Springer Verlag, September 1997.

[3] Peura, M., Koistinen, J., and King, R.: "Visual modelling of radar images". COST-75 Advanced weather radar systems - International seminar, pp. 307-317. Locarno, Switzerland, March 1998. European Commission.

[4] Peura, M.: "The Self-Organizing Map of Trees". *Neural Processing Letters*, 8(2), pp. 155-162, October 1998. Kluwer Academic Press.