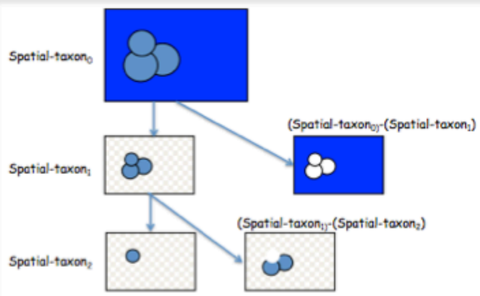
Image Segmentation Using Fuzzy-Spatial Taxon Cut

Lauren Barghout Ph.D.
Visiting Scholar, BISC Program, EECS, University of California at Berkeley

Computer vision is typically thought of as an open universe problem because every possible outcome is unknown. However, in this model, I start by framing image segmentation as a closed universe problem that assumes that scenes are organized according to a standardized natural-scene-taxonomy, comprised of spatial-taxons. Spatial-taxons are regions (pixel-sets) that are figure-like, in that they are perceived as having a contour, are either `thing-like', or a `group of things', that draw our attention. Defined in this way, the image segmentation problem can be operationalized into a series of iterative two-class fuzzy inferences.



Definition 1. Hierarchy of nested spatial-taxons:

Let X be the universe of discourse consisting of all pixels within the rectangular (or square) pixel array of an image, such that $X_{1,1}$ is located at the upper left corner, and pixel $X_{I,J}$ at the lower left corner. Let ST_0 be a non-empty set that contains all pixels in the universe of discourse (the image). ST_0 has two mutually exclusive children ST_1 and $ST_0 - ST_1$ such that $ST_1 \wedge (ST_0 - ST_1) = \emptyset$ and $ST_1 \vee (ST_0 - ST_1) = ST_0$ (the parent). We have now defined abstraction level 0 and level 1. The most abstract information granule is the whole image and the second most abstract level contains two mutually exclusive children subsets.

Let's next define the set ST_1 as having two children subsets: ST_2, $(ST_1 - ST_2)$. As before, these children are mutually exclusive, such that $ST_2 \wedge (ST_1 - ST_2) = \emptyset$ and $ST_1 \vee (ST_0 - ST_1) = ST_0$ (the parent). This is the third most abstract level in nested spatial-taxon hierarchy. [2]

Each spatial-taxon / background dichotomy is inferred by a fuzzy-logic inference engine which simulates low-level visual processes and a few rules of figure-ground perceptual organization. Allowed spatial-taxons must conform to a set of "meaningfulness" cues, as specified by a generic scene-type. The model determines the optimal spatial-taxon partition by optimizing a utility function used to score the posited spatial-taxon. The utility function, inspired by a study of pictorial object naming that found that objects were identified at an "entry point" level of abstraction (Jolicoeur, Gluck, Kosslyn, 1984), attempts to identify an analogous "entry point" spatial-taxon.

Earlier versions of this work are used commercially in background removal software. The specific model I'll present at this workshop, was tested on 70 real images composed of three "generic scene-types", each of which required a different combination of the perceptual organization rules built into our model. Five human subjects rated image-segmentation quality on a scale from 1 to 5 (5 being the best). The majority of generic-scene-type image segmentations received a score of 4 or 5 (very good, perfect). ROC plots show that this engine performs better than normalized-cut [Shi, J., Malik, J (2000), Berkeley Image Segmentation Database http://www.eecs.berkeley.edu/Research/Projects/CS/vision/bsds 2010 version]

In this workshop talk, I'll discuss the implementation details of the fuzzy logic model, the utility function and error calculation. I'll focus on how this model compares to other computer vision models, how it can be encapsulated within large-scale machine learning systems and how it can be used top-down model of human vision research.

Model details can be found in below references:

Barghout, Lauren (2015) Spatial-taxon Information Granules as Used in Iterative Fuzzy-Decision-Making for Image Segmentation. Chapter in Granular Computing and Decision-Making: Interactive and Iterative Approaches. Eds. Witold Pedrycz and Shyi-Ming Chen (in press) Springer-Verlag.

Barghout, Lauren. (2014) Visual Taxometric Approach to Image Segmentation Using Fuzzy-Spatial Taxon Cut Yields Contextually Relevant Regions. Information Processing and Management of Uncertainty in Knowledge-Based Systems. Springer International Publishing. 163{173

Barghout, Lauren. (2014) Vision: Global Perceptual Context Changes Local Contrast Processing Updated to include computer vision techniques. Scholars Press. ISBN-10: 3639709624 ISBN-13: 978-3639709629