An Analysis of Co-Occurrence and Gabor Texture Classification in 2D and 3D

Carl Philips[1]*, Daniel Li[2], Jacob Furst Ph.D.[1], Daniela Raicu Ph.D.[1]
[1] DePaul University, 1 E. Jackson, Chicago, IL, USA
[2] Johns Hopkins University, 3400 N. Charles St. Baltimore, MD. USA
*CPhilips@students.depaul.edu

Purpose:

Due to advances in technology radiologists often have to analyze several hundred images looking for tumours that could be only a few millimetres in diameter. To solve this problem Computer Aided Diagnosis systems (CAD) are being developed; a vital step of which is organ classification, for which texture is often used.

Technological advances have allowed for the creation of nearly isotropic voxels. Due to this advance in technology 3D texture algorithms were created, however, there has been little research to find if these 3D algorithms are better than their 2D counterparts. In this paper we compare multi-dimensional versions of two texture extraction algorithms (Co-Occurrence matrices and Gabor filters), to see if the 3D versions outperform the 2D versions.

Methods:

To do this we first extracted 20^3 voxel cubes from 20 patients. These cubes were identified as being completely liver or completely non-liver. Two different test setups were used, differentiated by how the training and testing sets were selected. In the Pooled setup The cubes were divided into training and testing groups through a 2/3 (training) 1/3 (testing) division of all cubes (Pooled). For the Separated setup 2/3 of the patients were designated as training and the rest as testing.

Once the cubes had been divided into training and testing sets they were analyzed using two Co-Occurrence algorithms (2D and 3D) and seven Gabor filters (four 2D and three 3D); the average runtime for each algorithm was also saved as it was suspected that the 3D algorithms were significantly slower than their 2D counterparts.

The normal Co-Occurrence algorithm analyzes pixel relationships in four directions. To make 3D Co-Occurrence matrices one simply analyzes pixel relationships in nine additional directions. This is seen in Figure i below. Directions 1-4 are used in the standard Co-Occurrence algorithm and directions 5-13 are added to make it a 3D algorithm.

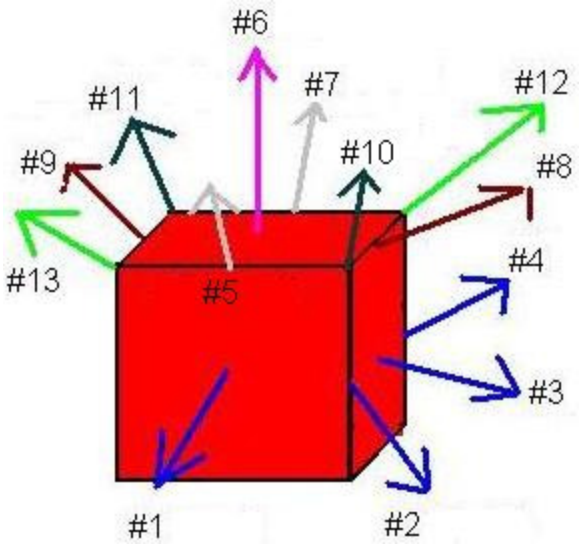

Figure i: All thirteen directions.

Gabor filters are essentially the product of a Sinusoid and a Gaussian distribution. Thus two 2D algorithms are a one dimensional sinusoid multiplied by a two dimensional distribution and a two dimensional sinusoid multiplied by a two dimensional distribution. These two algorithms were used twice, once applied axially and then applied axially, sagittally, and coronnaly. The three 3D algorithms are simply the product of a three dimensional distribution and a one, two, or three dimensional sinusoid.

Using these results the cubes were classified using decision trees (Matlab R2007a Classification & Regression tree [C&RT]). A range of parameters were used and for each test the parameter with the highest test score was selected.

Results:

Below we see a summary of the best testing accuracies using either test setup, Pooled or Separated.

Table i: Best Testing Accuracies.

	Pooled		Separated	
	Co-Occurrence	Gabor	Co-Occurrence	Gabor
2D	87.6%	95.0%	87.6%	81.2%
3D	87.3%	88.0%	88.7%	85.3%

Conclusion:

From Table i we see that Co-Occurrence matrices were largely unaffected by the test setup or even the dimensionality. This is good as it indicates that Co-Occurrence matrices are a stable, producing consistent results. We also learned that to date, 3D Co-Occurrence algorithms are pointless, they have a significantly longer runtime than their 2D counterparts (.8412 seconds per cube versus the 2D's .3284 s/cube) with no positive influence on accuracy.

From the same table we learn that the above is not true for Gabor filters. The two test setups had vastly different accuracies, as did the dimensionality. When using the pooled setup compared to the 2D algorithm the 3D algorithm had a 7% loss in accuracy with a significant increase in runtime (each cube took over 300 times longer). Conversely, with the separated setup the 3D algorithm saw a 4.1% increase in accuracy but took over 100 times longer per cube. Based upon these results we recommend using a 2D algorithm in all cases. If one is analyzing a returning patient then the Gabor filters are ideal, however if one is analyzing a completely new patient then Co-Occurrence Matrices would be ideal.