MATLAB Code for Optimal Quincunx Filter Bank Design

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1 Introduction

This file introduces the MATLAB code that implements the two algorithms (i.e., Algorithms 1 and 2 in [1], or Algorithms 4.1 and 4.2 in [2]) used for the construction of quincunx filter banks with perfect reconstruction, linear phase, high coding gain, certain vanishing moments properties, and good frequency selectivity. The code can be used to design quincunx filter banks with two, three, or four lifting steps. The SeDuMi Matlab toolbox [3] is used to solve the second-order cone programming subproblems in the two algorithms, and must be installed in order for this code to work. The SeDuMi toolbox can be obtained from its official website at http://sedumi.mcmaster.ca/.

2 Code for Algorithm 1

Algorithm 1 is used to design quincunx filter banks with two lifting filters.

2.1 L2n.m

Purpose	Optimal design of quincunx filter banks with two lifting steps.
Usage	[p, u] = L2n(s_size, Np, Nu, level, model, ini_point, x00, sf, dm, ws, wp, outname)
Description	Input: **s_size**: the support sizes of the two lifting filters, a 1×4 vector with each element being even and less than 8 **Np**: number of dual vanishing moments. Np is an even integer and is ≤ 6. **Nu**: number of primal vanishing moments. Nu is an even integer and is $\leq N_p$ **level**: number of decomposition levels, usually ≤ 6 **model**: model for input images, 0 (isotropic) or 1 (separable) **ini_point**: type of initial point, 0 (KS filter banks proposed in [4]), 1 (random initial point), or 2 (fixed initial point given by x00) **x00**: the fixed initial point when ini_point = 2

sf: scaling factor d for the upper bound of the error function e_h, as given in (40) in [1].
dm: quincunx sampling matrix, 0 $\left(\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}\right)$ or 1 $\left(\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}\right)$
ws: weight for the stopband, a nonnegative real number
wp: weight for the passband, a nonnegative real number
outname: name of the output data
Output:
p: coefficients of the first lifting filter
u: coefficients of the second lifting filter
All of the intermediate and final results are saved in the Matlab workspace named 'outname'.

Algorithm: Algorithm 1 in [1], or Algorithm 4.1 in [2].

Examples:
[p, u] = L2n([4 4 4 4], 2, 2, 4, 0, 0, [], 2, 0, 1, 1, 'data/test');
[p, u] = L2n([6 6 6 6], 4, 4, 4, 0, 1, [], 1, 0, 1, 0, 'data/test');

3 Code for Algorithm 2

Algorithm 2 is used to design filter banks with more than two lifting filters.

3.1 L3n2.m

Purpose: Optimal design of quincunx filter banks with three lifting steps, where the first lifting filter adds the first channel to the zeroth one.

Usage: [A1, A2, A3] = L3n2(s_size, level, model, ini_point, x00, sf, Np, Nd, dm, ws, wp, outname)

Description: Input:
s_size: support sizes of the three lifting filters, a 1×6 vector where each element is even and ≤ 6
level: number of decomposition levels, usually ≤ 6
model: model for input images, 0 (isotropic) or 1 (separable)
ini_point: initial point, 0 (KS filter banks in [4]), 1 (random initial point), or 2 (fixed initial point given by x00)
x00: the fixed initial point when ini_point = 2
sf: scaling factor d for the upper bound of the error function e_h
Np: number of primal vanishing moments (2 or 4)
Nd: number of dual vanishing moments (2 or 4)
dm: quincunx sampling matrix, 0 $\left(\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}\right)$ or 1 $\left(\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}\right)$
ws: weight for the stopband, a nonnegative real number
wp: weight for the passband, a nonnegative real number
outname: name of the output data
Output:
A1, A2, A3: lifting filter coefficients

	All of the intermediate and final data are stored in the Matlab workspace named 'outname'.
Algorithm	Algorithm 2 in [1], or Algorithm 4.2 in [2].
Examples	[A1, A2, A3] = L3n2(4*ones(1,6), 4, 0, 1, [], 1, 2, 2, 0, 1, 1, 'data/test'); [A1, A2, A3] = L3n2([4 4 4 4 2 2], 4, 0, 0, [], 2, 4, 4, 0, 1, 0, 'data/test');

3.2 L3n.m

Purpose	Optimal design of quincunx filter banks with three lifting steps, where the first lifting filter adds the zeroth channel to the first one.
Usage	[A1, A2, A3] = L3n(s_size, level, model, ini_point, x00, sf, Np, Nd, dm, ws, wp, outname)
Description	Input: **s_size**: support sizes of the three lifting filters, a 1×6 vector where each element is even and ≤ 6 **level**: number of decomposition levels, usually ≤ 6 **model**: model for input images, 0 (isotropic) or 1 (separable) **ini_point**: initial point, 0 (KS filter banks in [4]), 1 (random initial point), or 2 (fixed initial point given by x00) **x00**: the fixed initial point when ini_point = 2 **sf**: scaling factor d for the upper bound of the error function e_h **Np**: number of primal vanishing moments (2 or 4) **Nd**: number of dual vanishing moments (2 or 4) **dm**: quincunx sampling matrix, 0 $\left(\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}\right)$ or 1 $\left(\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}\right)$ **ws**: weight for the stopband, a nonnegative real number **wp**: weight for the passband, a nonnegative real number **outname**: name of the output data Output: **A1, A2, A3**: lifting filter coefficients All of the intermediate and final results are saved in the Matlab workspace named 'outname'.
Algorithm	Algorithm 2 in [1], or Algorithm 4.2 in [2].
Examples	[A1, A2, A3] = L3n(4*ones(1,6), 4, 0, 0, [], 2, 2, 2, 0, 1, 1, 'data/test'); [A1, A2, A3] = L3n([4 4 4 4 2 2], 4, 0, 1, [], 1, 2, 4, 0, 1, 0, 'data/test');

3.3 L4n.m

Purpose	Optimal design of quincunx filter banks with four lifting steps, where the first lifting filter adds the zeroth channel to the first one.
Usage	[A1, A2, A3, A4] = L4n(s_size, level, model, ini_point, x00, sf, Np, Nd, dm, ws, wp, outname)
Description	Input:

	s_size: support sizes of the three lifting filters, a 1×8 vector with each element being even and ≤ 6 **level**: number of decomposition levels, usually ≤ 6 **model**: model for input images, 0 (isotropic) or 1 (separable) **ini_point**: initial point, 0 (KS filter banks in [4]), 1 (random initial point), or 2 (fixed initial point given by x00) **x00**: the fixed initial point when ini_point = 2 **sf**: scaling factor d for the upper bound of the error function e_h **Np**: number of primal vanishing moments (2 or 4) **Nd**: number of dual vanishing moments (2 or 4) **dm**: quincunx sampling matrix, 0 $\left(\begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}\right)$ or 1 $\left(\begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}\right)$ **ws**: weight for the stopband, a nonnegative real number **wp**: weight for the passband, a nonnegative real number **outname**: name of the output data Output: **A1, A2, A3, A4**: lifting filter coefficients All of the intermediate and final results are saved in the Matlab workspace named ‘outname’.
Algorithm	Algorithm 2 in [1], or Algorithm 4.2 in [2].
Examples	[A1, A2, A3, A4] = L4n(4*ones(1,8), 4, 0, 0, [], 2, 4, 4, 0, 1, 1, ‘data/test’); [A1, A2, A3, A4] = L4n([2 2 2 2 4 4 4 4], 4, 0, 2, [-0.25 -0.25 0.125 0.125 zeros(1, 16)], 1, 2, 2, 0, 1, 1, ‘data/test’);

References

[1] Y. Chen, M. D. Adams, and W.-S. Lu, “Design of optimal quincunx filter banks for image coding,” Accepted for publication in *EURASIP Journal on Applied Signal Processing*, July 2006.

[2] Y. Chen, “Design and application of quincunx filter banks,” M.A.Sc. thesis, Dept. of Electrical and Computing Engineering, University of Victoria, Victoria, BC, Canada, 2006. Available from http://www.ece.uvic/˜mdadams.

[3] J.F. Sturm, “Using SeDuMi 1.02, a MATLAB toolbox for optimization over symmetric cones,” *Optimization Methods and Software*, vol. 11–12, pp. 625–653, 1999.

[4] J. Kovacevic and W. Sweldens, “Wavelet families of increasing order in arbitrary dimensions,” *IEEE Trans. on Image Processing*, vol. 9, no. 3, pp. 480–496, Mar. 2000.