Parameterized Filters and Wavelet Packets Howto

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1 Parameterized Filters

1.1 Command line options

1.1.1 Encoder

```
-Ffilters_random [<tile-component idx>] <id> [ [<tile-component idx>]
    <id> ...]
  Specifies the options for the random generator to be used for specified
  tile-component as a byte sequence. The random generator is used for
  generating the sequence of random parameters specified by w9x7pr.
   s seed
   d denormalize function (0=linear [default], 1=square)
   p use positive range (0=no, 1=yes[default])
   i number of bins (default is 255)<tile-component idx>: see general
  note
-Ffilters [<tile-component idx>] <id> [ [<tile-component idx>] <id> ...]
  Specifies which filters to use for specified tile-component.
  <tile-component idx>: see general note
  <id>: ',' separates horizontal and vertical filters, ':' separates
  decomposition levels filters.
```

1.1.2 Decoder

```
-Ffilters_random [<tile-component idx>] <id> [ [<tile-component idx>]
    <id> ...]
  Specifies the options for the random generator to be used for specified
  tile-component as a byte sequence. The random generator is used for
  generating the sequence of random parameters specified by w9x7pr.
   s seed
   d denormalize function (0=linear [default], 1=square)
   p use positive range (0=no, 1=yes[default])
   i number of bins (default is 255)<tile-component idx>: see general
  note

  This option can be used if the used filters have not been written to
  the final bitstream. It can also be used to override the Filters
  specified in the bitstream (e.g. if an attack is simulated)
-Ffilters [<tile-component idx>] <id> [ [<tile-component idx>] <id> ...]
```

```
Specifies which filters to use for specified tile-component.
<tile-component idx>: see general note
<id>: ',' separates horizontal and vertical filters, ':' separates
decomposition levels filters.
This option can be used if the used filters have not been written to
the final bitstream. It can also be used to override the Filters
specified in the bitstream (e.g. if an attack is simulated)
```

1.2 Specifying a parameterized filter

The available paramterization takes one parameter α. You can specify α directly by using the filter String `w9x7p`*`P`*, where *`P`* should be replaced with the desired value of α.

You can also use a random value for α by using the filter string `w9x7pr`. Note that this option requires you to specify other command line options for the random number generator and the discretization technique.

Examples:

`w9x7p-1.6`	Create a filter with $\alpha = -1.6$
`w9x7p-2.1`	Create a filter with $\alpha = -2.1$
`w9x7pr`	Create a filter with random α

1.3 Specifying the filters

You can specify which filter to use for the wavelet decomposition by using the parameter `-Ffilters`. To use the same filter for all levels and directions of the wavelet transform just use `-Ffilters w9x7p`*`P`*, where *`P`* should be replaced with the desired value of α. You can specify different filters for each wavelet decomposition and each direction of the wavelet decomposition by separating the filter specifications with `,` for horizontal and vertical filters and `:` for the decomposition levels.

Examples:

`-Ffilters w9x7p-1.6:w9x7p-1.2` uses a filter with $\alpha = -1.6$ for the lowest resolution and $\alpha = -1.2$ for all other resolutions (this corresponds to 4 levels of decomposition with $\alpha = -1.2$ and the last decomposition with $\alpha = -1.6$).
`-Ffilters w9x7p-1.6,w9x7p-1.2` uses $\alpha = -1.6$ for the horizontal decomposition on all decomposition levels and $\alpha = -1.2$ for the vertical decomopsition on all decomposition levels
`-Ffilters w9x7p-1.6:w9x7p-1.20:w9x7p-4,w9x7p2.1:w9x7p4` uses for the first resolution $\alpha = -1.6$ for horizontal decomposition and $\alpha = 2.1$ for vertical decomposition. For the next resolution $\alpha = -1.2$ is used horizontally, and $\alpha = 4.0$ vertically. For the remaining resolutions $\alpha = -4.0$ is used horizontally and $\alpha = 4.0$ is used vertically.

Note that in any case only one value for α is written to the bitstream. If you use a combination of values, you need to specify them to the Decoder (also by using `-Ffilters`. (You can also use this Decoder option to override the single value that has been written to the bitstream, e.g. if you are simulating an attack).

1.4 Using Random Filters

If you want to use a random sequence of filters use the `w9x7pr` specification in -Ffilters. It can be combined with filters with fixed value, e.g. `-Ffilters w9x7p-1.6,w9x7pr` uses

$\alpha = -1.6$ for horizontal decomposition on all levels and a different random filter for the vertical decomposition on all levels.

In addition you have to use the option `-Ffilters_random` for initializing the random generator and specifying the discretization strategy. The parameter takes the form `-Ffilters_random s`*S*`d`*D*`p`*P*`i`*I*, where

- *S* Seed for the PRNG
- *D* denormalize function (0=linear [default], 1=square)
- *P* use positive range for α (0=no, 1=yes[default])
- *I* number of bins (default is 255).

Examples:

Encoder: `-i lena512.pgm -o out.j2k -Wwritewps off -debug -rate 0.25 -Wlev 5 -Ffilters w9x7pr -Ffilters_random s199d1p0i122`

Decoder: `-debug -i out.j2k -o reconstructed.pgm -Vcomp lena512.pgm -Ffilters w9x7pr -Ffilters_random s199d1p0i122 -GPFile results.gp -GPStyle ple`

2 Wavelet Packets

2.1 Command line options

2.1.1 Encoder

```
    -Wwps wavelet packet structure (default = )
      Specifices the customized wavelet packet decomposition tree
      Default is Hex Notation. Use initial ``b'' to use binary notation
-Wreadwpsfile (deafult = )
 Perform a wavelet packet decomposition with the decomposition
 structure given by this parameter.
    -WwpsRandom (default = )
      Specification string for pseudorandom wavelet packet structures
      Format: s<long>c<float>b<float>g<int>m<int>n<int> where
       s Seed for the PNRG
       c Change Value
       b Base Value
       g Maximum Global Decomposition Depth
       m Max. Approximation Subband Decomposition Depth
       n Min. Approximation Subband Decomposition Depth
    -Wwritewpsfile (default = structure.wps)
      Write wavelet packet structure to specified file (as a hex string).
    -Wwritewps (default = off)
      Write wavelet packet structure to bitstream. Turn this off to retain
      standard J2K bitstream compliance
```

2.1.2 Decoder

```
    -Wwps wavelet packet structure (default = )
      Specifices the customized wavelet packet structure (WPS)
      Use this if the WPS is not specified in the bitstream or if the WPS of
```

```
    the bitstream should be overridden.
    NOTE: this overrides anything obtained by the options Wreadwps and
    Wreadwpsfile
  -Wreadwpsfile (default = structure.wps)
    Attempt to read wavelet packet structure from the specified file.
  -Wreadwps (default = off)
    Attempt to read wavelet packet structure from bitstream. Turn this off
    to retain standard J2K bitstream compliance
```

2.2 How to create randomized wavelet packets

Use the `-WwpsRandom` option with the approriate initialization string. You have to decide where to write the wavelet packet decomposition structure. Your options are

- write structure to Bitstream (this costs some bytes in the final bitstreams as the representation so far is not very sophisticated). Use option `-Wwritewps on` for the Encoder and option `-Wreadwps on` for the Decoder.
- write structrue to separate file. Use `-Wwritewpsfile` *<filename>* for the Encoder and `-Wreadwpsfile` *<filename>* for the Decoder.
- or just output the structure to the screen. In this case the Decoder has to be passed the decomposition string with `-Wwps` *<struct_string>*).

  Note that the random decomposition generation might change your resolution level.

You will always find a visual representation of the decomposition structure in the file `tree.eps`. There is also some code to do a dot-graph of your wavelet decomposition – it's not really finished yet, if you want to use it, write me an e-mail.

Examples:
Encoder: `-i lena512.pgm -o lena.j2k -debug -rate 0.25 -Ffilters w9x7 -Wlev 5 -epic on -WwpsRandom s88901g5n5m5c0b1 -Wwritewps off -Wwritewpsfile struct.wps`
Decoder: `-debug -i lena.j2k -Ffilters w9x7 -Wreadwps off -Wreadwpsfile struct.wps -verbose on -o out/reconstructed.pgm -Vcomp lena512.pgm -Vessthreshold 12 -GPFile result.gp -GPStyle plevsd`

Encoder: `-i lena512.pgm -o lena.j2k -debug -rate 0.25 -Ffilters w9x7 -Wlev 4 -Wwps f0402c128024120d0200 -Wwritewps off`
Decoder: `-debug -i lena.j2k -Ffilters w9x7 -Wreadwps off -Wwps f0402c128024120d0200 -o reconstructed.pgm -Vcomp lena512.pgm -GPFile result.gp -GPStyle plevsd`

2.3 Best Basis Algorithm

These following paramters are relevant for Best Basis:

```
-Wbbacf additive costfunction: LogE, EIC, Norml, Norml2 (default = )
    Use this to turn on best basis for encoding. Specifies the (additive)
    costfunction to be used for the best basis algorithm
-Wbba_lldecompose [on|off] (default = on)
    Use this to specify if the global LL subband tree should always be
    decomposed in BBA, regardless of the cost
```

Turn on bestbasis by specifying a cost function with Wbbacf. With the default settings, you will find a visualization of the decomposition structure as "tree.eps" and a hex description of the decomposition structure as "structure.wps" (this file is also read by JJ2KDecoder).

Examples:

The following will do a best basis decomposition on Lena with costfunction LogE and save the resulting wavelet packet structure to "lena_logE.wps":

`JJ2KEncoder -i lena512.pgm -o lena512.j2k -Wbbacf LogE -Wwritewpsfile lena_logE.wps`

The corresponding parameters for the decoder are as follows:

`-i lena512.j2k -o reconstructed.pgm -Wreadwpsfile lena_logE.wps`

If you want to reuse the saved decomposition structure on another image without having to re-run the best-basis algorithm you can use the option `-Wreadwpsfile` also for the Encoder:

`-i lena512.pgm -o lena512.j2k -Wreadwpsfile lena_logE.wps`

You can also use the description in the .wps file to create an interface to another JPEG2000, e.g., Kakadu, but you will have to implement the conversion for the different WP-decompositions yourself.

Note that the BB-implementation can also be used with the `lossless`-Option:

`JJ2KEncoder -i lena512.pgm -o lena512.j2k -lossless on -Wbbacf LogE -Wwritewpsfile lena_logE.wps`

3 Combining Parameterized Filters + WP

Examples:

Encoder: `-i lena512.pgm -o lena.j2k -debug -rate 0.25 -Ffilters w9x7pr -Ffilters_random s3902 -Wlev 5 -epic on -WwpsRandom s88901g5n5m5c0b1 -Wwritewps off -Wwritewpsfile struct.wps`

Decoder: `-debug -i lena.j2k -Ffilters w9x7pr -Ffilters_random s3902 -Wreadwps off -Wreadwpsfile struct.wps -verbose on -o out/reconstructed.pgm -Vcomp lena512.pgm -Vessthreshold 12 -GPFile result.gp -GPStyle plev`

4 Output of Results

4.1 Encoder

Screen:

```
-epic [on|off] (default = off)
  Epic output (even more verbose)
-Wfreqanalysis [on|off] (default = on)
  Print information on the coefficient data after decomposition
```

Gnuplot file:

```
-GPStyle cor (default = cor)
  Specify which values are to be written to GPFile; valid options are
  cor  Correlation coefficient
```

```
-GPFile filename.gp
  Specify a file for result output
```

4.2 Decoder

```
-Vcomp filename.pgm
  Calculate PSNR and ESS/LSS compared to a pgm file
-GPStyle plesvd (default = ple)
  Specify which values are to be written to GPFile; valid options are
  p  PSNR
  l  Luminance Similarity Score  (LSS)
  e  Edge Similarity Score (ESS)
  v  Variance
  s  Wavelet Packet Decomposition Structure
  d  Actual maximum decomposition depth
-GPFile filename.gp
  Specify a file for Result output
```