COMSATS Institute of Information Technology

ECI750 Multimedia Data Compression

Lecture 12

Lossless Image Compression

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Lossless Image Compression

- In this chapter we will look at:
  - The old lossless JPEG compression standard
  - Context Adaptive Lossless Image Compression (CALIC)
  - The new lossless JPEG compression standard (JPEG-LS)

Lossless Image Compression

- ***Example of Predictive Coding***

Lossless Image Compression

The old JPEG standard

- Provides eight different prediction schemes from which the user can select.

$$
\begin{aligned}
\mathbf{1} \quad & \hat{I}(i,j) = I(i-1,j) \\
\mathbf{2} \quad & \hat{I}(i,j) = I(i,j-1) \\
\mathbf{3} \quad & \hat{I}(i,j) = I(i-1,j-1) \\
\mathbf{4} \quad & \hat{I}(i,j) = I(i,j-1) + I(i-1,j) - I(i-1,j-1) \\
\mathbf{5} \quad & \hat{I}(i,j) = I(i,j-1) + (I(i-1,j) - I(i-1,j-1))/2 \\
\mathbf{6} \quad & \hat{I}(i,j) = I(i-1,j) + (I(i,j-1) - I(i-1,j-1))/2 \\
\mathbf{7} \quad & \hat{I}(i,j) = (I(i,j-1) + I(i-1,j))/2
\end{aligned}
$$

Lossless Image Compression

The old JPEG standard (2)

- All eights modes of prediction can be tried and the one that gives the most compression is used.

Lossless Image Compression

The old JPEG standard (3)

Image	JPEG 0	JPEG 1	JPEG 2	JPEG 3	JPEG 4	JPEG 5	JPEG 6	JPEG 7
Sena	53,431	37,220	31,559	38,261	31,055	**29,742**	33,063	32,179
Sensin	58,306	41,298	37,126	43,445	**32,429**	33,463	35,965	36,428
Earth	38,248	32,295	**32,137**	34,089	33,570	33,057	33,072	32,672
Omaha	56,061	**48,818**	51,283	53,909	53,771	53,520	52,542	52,189

Image	Best JPEG	GIF	PNG
Sena	31,055	51,085	31,577
Sensin	32,429	60,649	34,488
Earth	32,137	34,276	26,995
Omaha	48,818	61,341	50,185

Lossless Image Compression

CALIC

- Uses both context and prediction of the pixel values
- Two modes:
  - Grayscale images
  - Bi-level images
- Important factors
  - A given pixel generally has a value close to one of its neighbours
  - Which neighbour has the closest value depends on the local structure of the image.

Lossless Image Compression

CALIC (2)

- Pixel Neighbourhood

		NN	NNE
	NW	N	NE
WW	W	X	

- Calculation of vertical and horizontal distortion values

$$d_h = |W - WW| + |N - NW| + |NE - N|$$

$$d_v = |W - NW| + |N - NN| + |NE - NNE|$$

Lossless Image Compression

CALIC (3)

- Algorithm for initial prediction

if $d_h - d_v > 80$
  $\hat{X} \leftarrow N$
else if $d_v - d_h > 80$
  $\hat{X} \leftarrow W$
else
{
  $\hat{X} \leftarrow (N+W)/2 + (NE-NW)/4$
  if $d_h - d_v > 32$
    $\hat{X} \leftarrow (\hat{X}+N)/2$
  else if $d_v - d_h > 32$
    $\hat{X} \leftarrow (\hat{X}+W)/2$
  else if $d_h - d_v > 8$
    $\hat{X} \leftarrow (3\hat{X}+N)/4$
  else if $d_v - d_h > 8$
    $\hat{X} \leftarrow (3\hat{X}+W)/4$
}

Lossless Image Compression

CALIC (4)

- Refinement of initial prediction

$$[N, W, NW, NE, NN, WW, 2N - NN, 2W - WW]$$

- Compare each component of this vector with our initial prediction
- If the value of the component is less than the prediction, replace the value with a 1; otherwise replace it with 0.
- The result is an eight-component binary vector (with 256 possible vectors)
  - Because of the dependence of various components, 144 possible vectors.

Lossless Image Compression

CALIC (5)

$$\delta = d_h + d_v + 2\,|N - \hat{N}|$$

- The range of values of δ is divided into four intervals.
- The four possibilities along with 144 texture descriptors, create 144x4=576 contexts for X.
- Keep track of the prediction error in each context and offset the initial prediction by that amount.
- This results in the final prediction value.

Lossless Image Compression

JPEG-LS

- The initial prediction

$$
\begin{aligned}
&\text{if } NW \geq \max(W, N)\\
&\quad \hat{X} = \max(W, N)\\
&\text{else}\\
&\{\\
&\qquad \text{if } NW \leq \min(W, N)\\
&\qquad\quad \hat{X} = \min(W, N)\\
&\qquad \text{else}\\
&\qquad\quad \hat{X} = W + N - NW\\
&\}
\end{aligned}
$$

- The initial prediction is then refined using the average value of the prediction error in that particular context.

Lossless Image Compression

JPEG-LS

- Contexts
  - Calculate measures of differences

$$D_1 = NE - N$$

$$D_2 = N - NW$$

$$D_3 = NW - W.$$

  - Define a three-component context vector Q

Lossless Image Compression

JPEG-LS (2)

- Mappings of contexts

$$
\begin{aligned}
D_i \le -T_3 &\Rightarrow Q_i = -4 \\
-T_3 < D_i \le -T_2 &\Rightarrow Q_i = -3 \\
-T_2 < D_i \le -T_1 &\Rightarrow Q_i = -2 \\
-T_1 < D_i \le 0 &\Rightarrow Q_i = -1 \\
D_i = 0 &\Rightarrow Q_i = 0 \\
0 < D_i \le T_1 &\Rightarrow Q_i = 1 \\
T_1 < D_i \le T_2 &\Rightarrow Q_i = 2 \\
T_2 < D_i \le T_3 &\Rightarrow Q_i = 3 \\
T_3 < D_i &\Rightarrow Q_i = 4
\end{aligned}
$$

- T1, T2, T3 are positive coefficients that can be defined by the user.
- Given 9 possible values for each component, we can have 9x9x9=729 possible contexts.

Lossless Image Compression

JPEG-LS (3)

- Reducing the number of contexts

Lossless Image Compression

JPEG-LS (4)

- The prediction errors are encoded using Golomb codes.

Lossless Image Compression

JPEG-LS (5)

- Results

Image	Old JPEG	New JPEG	CALIC
Sena	31,055	27,339	26,433
Sensin	32,429	30,344	29,213
Earth	32,137	26,088	25,280
Omaha	48,818	50,765	48,249

- Outperforms the old standard by 6% to 18%