Unidade Curricular

“Informação e Codificação”

António José Ribeiro Neves

an@ua.pt

https://www.ua.pt/pt/uc/15264

Outline

- Quizz
- Guiding questions
- Predictive Coding
- Audio and image predictors

Guiding questions

What is predictive coding, and how does it work?
Why do we encode only the prediction residuals instead of the actual data?
How does predictive coding help in audio compression?
How is predictive coding applied in image compression?
How is predictive coding used in video compression (intra- vs. inter-frame prediction)?
What are some challenges in predictive coding?
How does quantization affect predictive coding in lossy compression?
What types of predictive coding models are common in standards (e.g., JPEG, H.264, FLAC)?

Predictive coding

- Let $x^n = x_1 x_2 \dots x_n$ be the sequence of values (scalars or vectors) produced by an information source until time n.
- Predictive coding is based on encoding sequence $r^n = r_1 r_2 \dots r_n$, instead of the original sequence x^n, where

$$r_n = x_n - \hat{x}_n$$

and

$$\hat{x}_n = p(x^{n-1}) = p(x_1 x_2 \dots x_{n-1})$$

- The $\hat{x}_n$ are the estimates and the values of the sequence r^n are the residuals.
- Function $p()$ is the estimator or predictor.
- The aim of predictive coding is to have $H(r^n) < H(x^n)$.

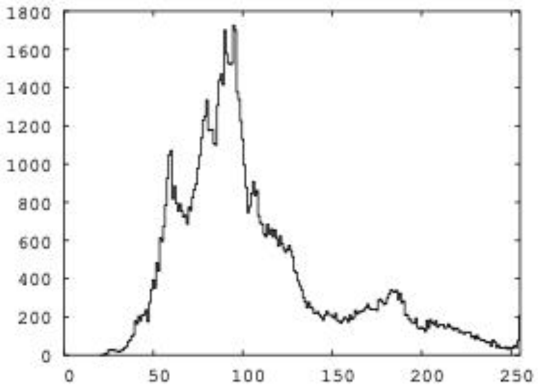
Examples

- Simple polynomial predictors used in some audio encoders:

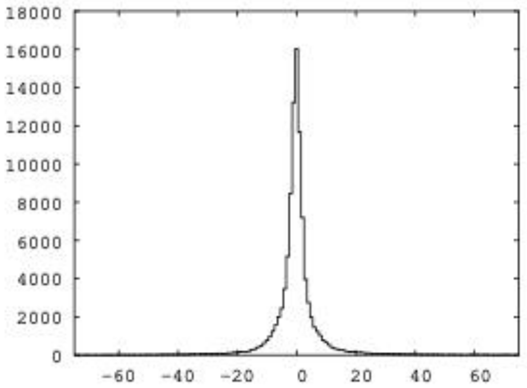
$$\begin{cases} \hat{x}_n^{(0)} = 0 \\ \hat{x}_n^{(1)} = x_{n-1} \\ \hat{x}_n^{(2)} = 2x_{n-1} - x_{n-2} \\ \hat{x}_n^{(3)} = 3x_{n-1} - 3x_{n-2} + x_{n-3} \end{cases}$$

and the corresponding residuals, computed efficiently:

$$\begin{cases} \hat{r}_n^{(0)} = x_n \\ \hat{r}_n^{(1)} = r_n^{(0)} - r_{n-1}^{(0)} \\ \hat{r}_n^{(2)} = r_n^{(1)} - r_{n-1}^{(1)} \\ \hat{r}_n^{(3)} = r_n^{(2)} - r_{n-1}^{(2)} \end{cases}$$



Original
$H = 7.26$ bits/symbol



Predictor 1 JPEG
$H = 4.49$ bits/symbol

Predictive coding

- Good predictors are fundamental in predictive coding.
- For efficient encoding, the estimated values should be as close as possible to the real values, i.e., the r_k values should be small.
- The decoder must be able to generate the same sequence, $\hat{x}^n$, of estimated values.
- In other words, the predictor cannot introduce any error during encoding / decoding.
- Therefore, the predictor must be causal, and, in lossy coding, the predictor at the encoder must use the reconstructed values, $\tilde{x}^{n-1}$, instead of the original values, x^{n-1}.

Predictive coding

- One of the main advantages of predictive coding is allowing a simple design of lossless encoders.

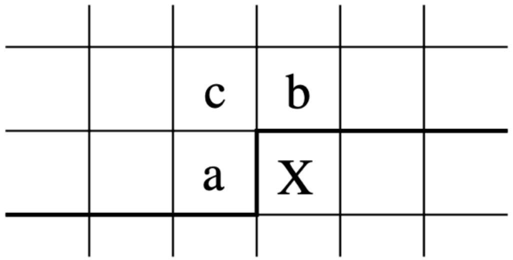
- In fact, most of the lossless encoders for audio and image rely on predictive coding techniques.

- However, for lossless coding, there is an additional constraint regarding the predictor: the estimates generated must be platform independent.

- Generally, this constraint implies that the predictor can use only integer arithmetic.

Predictive coding

- The lossless mode of JPEG (ISO/IEC 10918-1, ITU-T T.81, 1992) provides seven linear predictors:

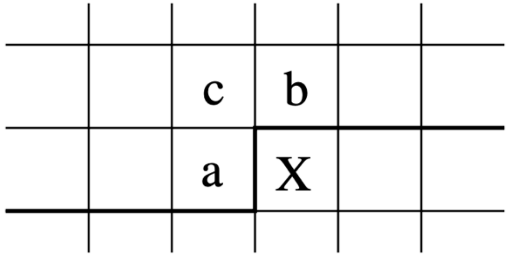


Mode	Predictor
1	a
2	b
3	c
4	$a+b-c$
5	$a+(b-c)/2$
6	$b+(a-c)/2$
7	$(a+b)/2$

- Generally, the performance of the several predictors may vary considerably from image to image.
- If encoding time is not a problem, then all of them can be tested and the one with the best compression rate chosen.

Predictive coding

- JPEG-LS (ISO/IEC 14495-1, ITU-T T.87, 1999) uses a predictor based on the same spatial configuration as that of JPEG:



- However, instead of a linear predictor, it uses the nonlinear predictor

$$\hat{x} = \begin{cases} \min(a, b) & \text{if} \quad c \geq \max(a, b) \\ \max(a, b) & \text{if} \quad c \leq \min(a, b) \\ a + b - c & \text{otherwise} \end{cases}$$

- Note that the linear part of this predictor ($a + b - c$) is the same as predictor number 4 of JPEG.

Predictive coding

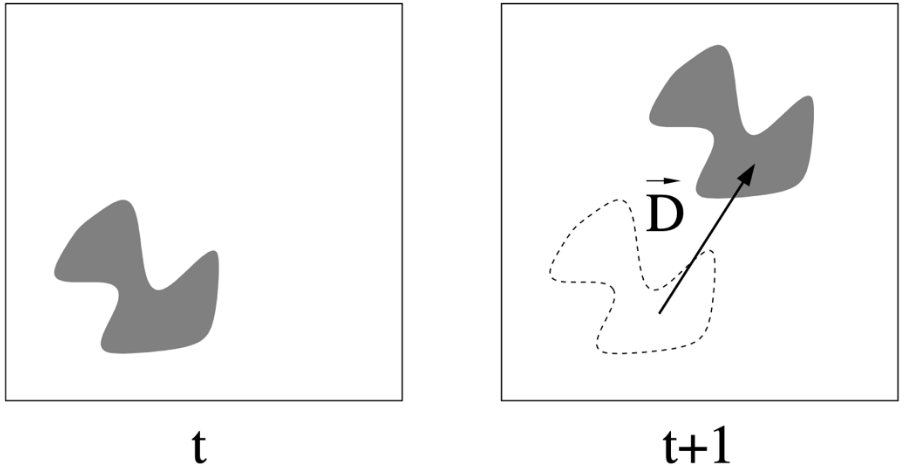
(a)

(b)

Predictor	1	2	3	4	5	6	7	JLS
Entropy (a)	4.49	4.21	4.74	4.18	4.16	4.04	4.10	**3.98**
Entropy (b)	5.60	5.05	5.82	5.19	5.23	4.97	5.15	**4.93**

Motion compensation

- Typically, the differences between one frame and the previous frame of a video sequence are due to the motion of the several elements of the scene.
- Exceptions occur when there are scene changes, zoom-in / zoom-out operations and camera translation.



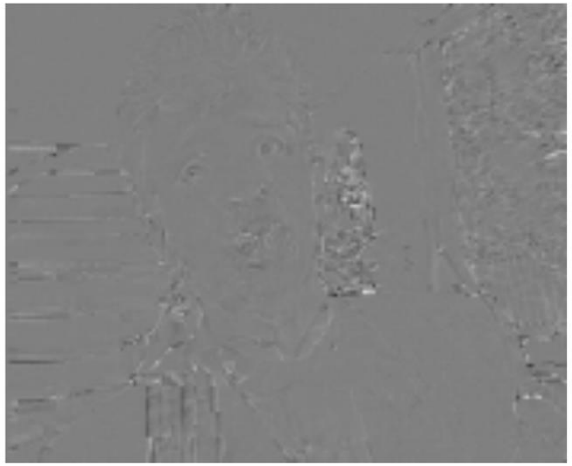
- To exploit this redundancy, it is frequent to use temporal prediction (interframe compression), which relies on motion compensation.

Example

Frame 200

Frame 201

Direct difference
$H = 5.23$ bpp



Motion compensation
$H = 4.38$ bpp