

Lossless Video Compression Technique Using Bayesian Network and Entropy Coding

Rochan Avlur Venkat¹ Dr. Chandrashekhar Vidhanathan²

¹Department of Computer Science and Engineering
Mahindra Ècole Centrale, Hyderabad

²Founder Director
Anveshna Pvt. Ltd., Bengaluru

IEEE TENSYMP, 2019

Outline

1 Motivation

2 Methodology

3 Experiments

4 Analysis

Current & Future Landscape

- Global Internet Protocol video traffic will grow four-folds from 2017 to 2022¹
- UHD (or 4K) video will account for 22 percent of global IP Video traffic by 2022¹
- IP video traffic will account for 82 percent of traffic by 2022¹
- **High Fidelity** video data is playing an *increasingly* important role in *medicine, science, education, and entertainment*
- **Lossless** video compression algorithms are used in applications ranging from *archival of video records* to the *field of medicine*

¹Cisco Visual Networking Index: *Forecast and Trends, 2017–2022*, Updated: February 27, 2019

Pattern Recognition & Pattern Classification

- Spatial Correlation - Intra frame
- Temporal Correlation - Inter frame
- Encoding Schemes

Bayesian Network (BN)

- Model and Update beliefs about states of certain variables when some other variables were observed
- BNs aim to **model conditional dependence** between variable states
- Given a BN, the **Joint Probability** distribution over all variables x_1, \dots, x_n is then calculated as:

$$P(x_1, \dots, x_n) = \prod_{i=0}^n P(x_i | \prod x_i) \quad (1)$$

BN Structure Learning

- Given a dataset of values, motivation is to discover a BN structure that best represents the data

Algorithm 1 Structure Learning

```
function GreedyHillClimbing(initial structure,  $N_{init}$ ,  
dataset  $D$ , scoring function  $s$ , stopping criteria  $C$ )  
     $N^* \leftarrow N_{init}$ ,  $N' \leftarrow N^*$ ,  $tabu \leftarrow N^*$   
    while  $C$  is not satisfied do  
         $N'' \leftarrow argmax_{N \in neighborhood(N')} \text{and } N \notin tabu} s(N)$   
        if  $s(N') > s(N'')$  then // Check local optimum  
             $N' \leftarrow random(N')$  // Random operators  
        end if  
        if  $s(N'') > s(N^*)$  then // Check new best  
             $N^* \leftarrow N''$   
        end if  
         $tabu \leftarrow tabu \cup N'$   
         $N' \leftarrow N''$  // Move to neighbor  
    end while  
    return  $N^*$   
end function
```

Problem Statement

Bayesian Networks for Video Compression ?!

From Pixels to Binary Codes

- Color Space Conversion

$$Y = \frac{77}{256}R + \frac{150}{256}G + \frac{29}{256}B$$

$$C_b = -\frac{44}{256}R - \frac{87}{256}G + \frac{131}{256}B + 128$$

$$C_r = \frac{131}{256}R - \frac{110}{256}G - \frac{21}{256}B + 128$$



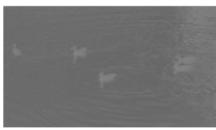
(a) Original



(b) Luma



(c) CB



(d) CR

- Difference Coding



(a) Difference

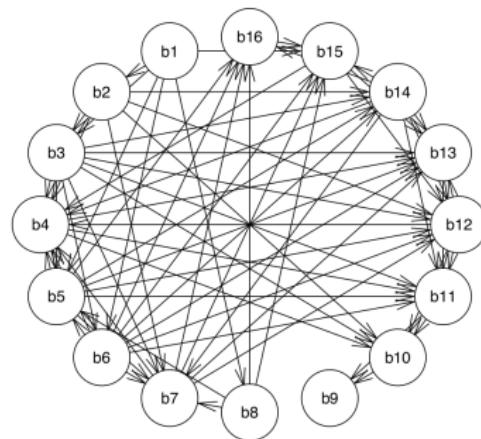
- Binary Code



(a) Binary Codes

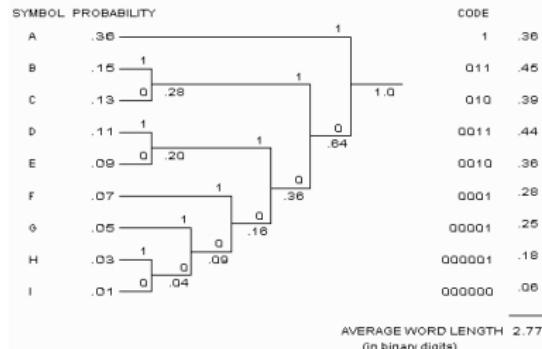
Learning a Bayesian Network

- Model conditional dependencies between individual binary variables by learning a BN structure
- Choose the network with least Bayesian Information Criterion (BIC) score either by hill-climbing (HC) or a Tabu search (TABU) greedy search



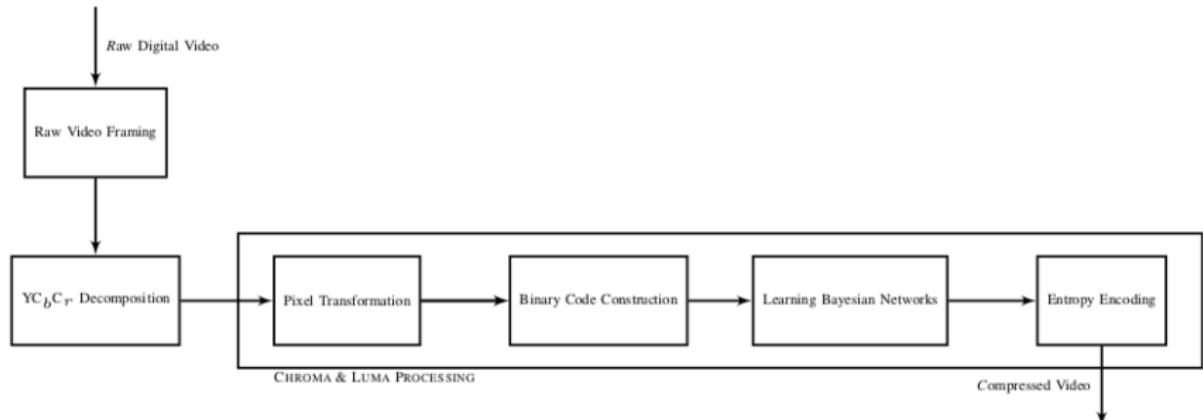
(a) Bayesian Network

Huffman Encoding



- Compute JP from Conditional Probability (CP) Table
- Construct a Huffman Encoding tree
- Look-up table will be based on CP rather than JP or frequency

Putting it all together...



Experimental Setup

- Raw uncompressed video files selected from SVT High Definition Multi-Format Test Set
- Compared the proposed technique *BayesianCompress* with *Gzip*, *FFV1*, *H.264* or *MPEG-4 Part 10*, *Dirac* and *JPEG2000*
- Pixel Transformation and Entropy Coding implemented in C programming language, compiled using the GNU C Compiler (GCC)
- Structure Learning of the Bayesian Network was implemented using *bnlearn* and *gRain* packages in R programming language

Results

Parameter	blue_sky	rush_hour	station	tractor	Avg.	Ratio(25 fps)	crowd_run	into_tree	old_town	Avg.	Ratio (50 fps)
Frame Rate (fps)	25	25	25	25	-	-	50	50	50	-	-
# of Frames	217	500	313	690	-	-	500	500	500	-	-
Codec	Compression Ratio										
Gzip	1.85	2.03	1.90	1.67	1.86	1.25	1.57	1.54	1.54	1.45	
FFV1	2.74	3.19	2.69	2.74	2.84	1.88	2.04	1.97	1.97	1.96	
H.264	2.68	3.04	2.69	2.65	2.77	2.03	2.26	2.03	2.03	2.11	
Dirac	2.67	2.90	2.68	2.56	2.70	1.90	2.18	2.01	2.01	2.03	
JPEG2000	2.62	3.20	2.69	2.73	2.81	1.84	2.03	1.95	1.95	1.94	
BayesianCompress	2.69	3.13	2.80	2.88	2.87	1.95	2.13	2.01	2.01	2.03	

Summary

- Correlation and Conditional Dependencies of Pixels in independent Color Axis of a video stream can be exploited using Bayesian Networks for Video Compression
- Performed on average better than state-of-the-art techniques @ 25 fps, slightly behind H.264 @ 50 fps
- Exploring the use of Arithmetic Coding
- Custom Bayesian Network learning algorithm specifically for the proposed video compression technique to improve its overall accuracy and improve performance

References I

-  Brendan J. Frey. *Bayesian Networks for Pattern Classification, Data Compression and Channel Coding*. Ph.D. Thesis, Univ. Toronto, Toronto, ON, Canada, 1997
-  S. Davies and A. Moore. *Bayesian networks for lossless dataset compression*. In Conference on Knowledge Discovery in Databases (KDD), 1999
-  S. Davies. *Fast Factored Density Estimation and Compression With Bayesian Networks*. Ph.D. Thesis, School of Computer Science, Carnegie Mellon University, 2002.
-  D. Grossman, P. Domingos. *Learning Bayesian Network Classifiers by Maximizing Conditional Likelihood*. In International Conference on Machine Learning. ACM, 2004.
-  R.E. Neapolitan. *Learning Bayesian Networks*. Pearson Prentice Hall, Upper Saddle River, NJ, 2004.
-  Differential Pulse Code Modulation (DPCM), <http://einstein.informatik.uni-oldenburg.de/rechnernetze/dpcm.htm>
-  Rongkai Zhao et.al. Fast Near-Lossless or Lossless Compression of Large 3D Neuro-Anatomical Images
-  Tony Robinson, SHORTEN: Simple lossless and near lossless waveform compression
-  Artificial Intelligence: A Modern Approach. Pg. 461-565
-  John Skilling. *Nested Sampling for General Bayesian Computation*
-  SVT High Definition Multi Format Test Set, ftp://vqeg.its.bldrdoc.gov/HDTV/SVT_MultiFormat/SVT_MultiFormat_v10.pdf

Q&A
Thank You!