A Simple and General Model for Mobile Video Workload Generation

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Slides of this presentation are available at:

http://www.cse.wustl.edu/~jain/wimax/video89.htm

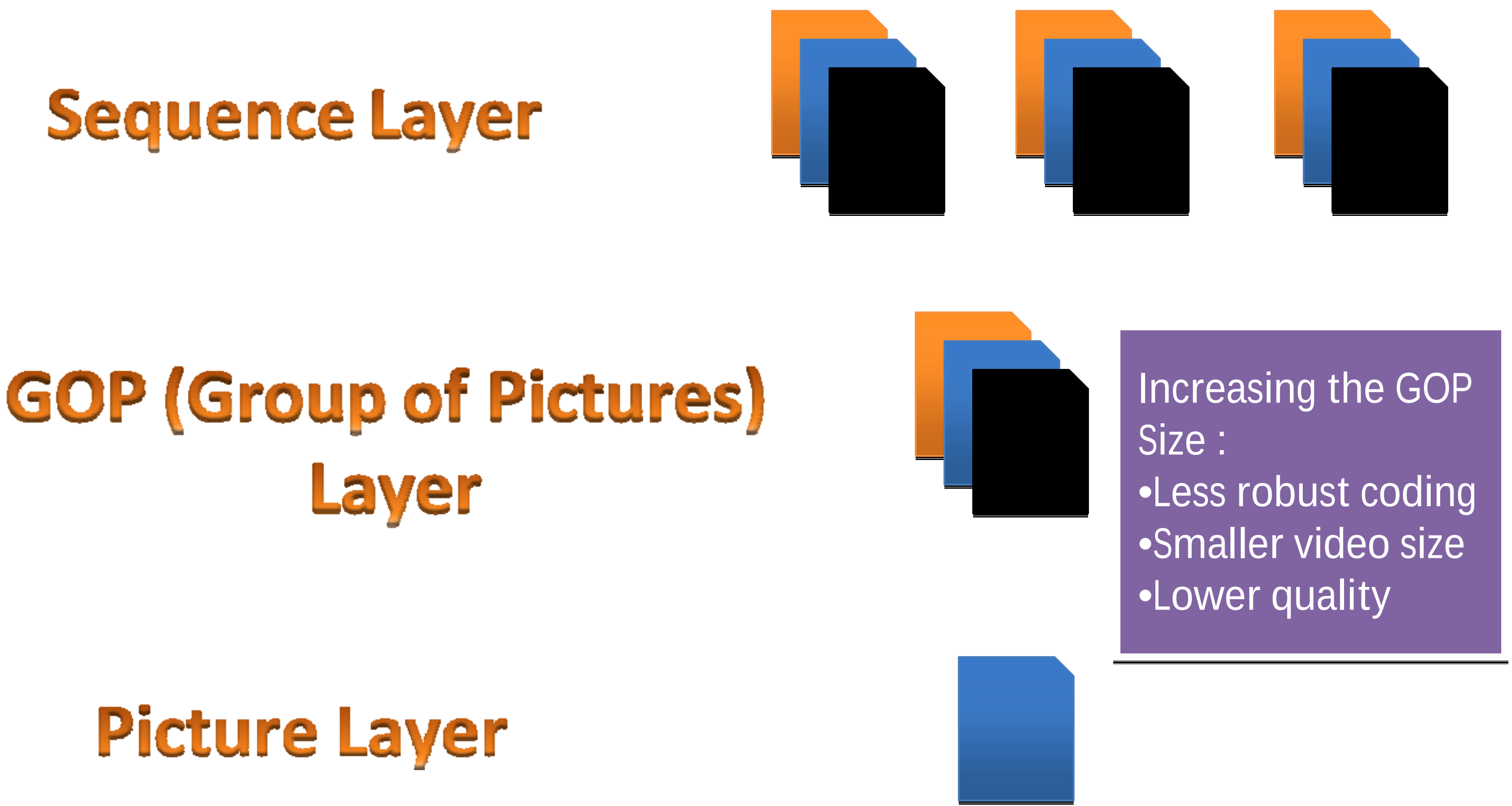
- Motivation
- MPEG Encoding
- Related Work
- Seasonal ARIMA
- SAM : Results
- Conclusion

Motivation

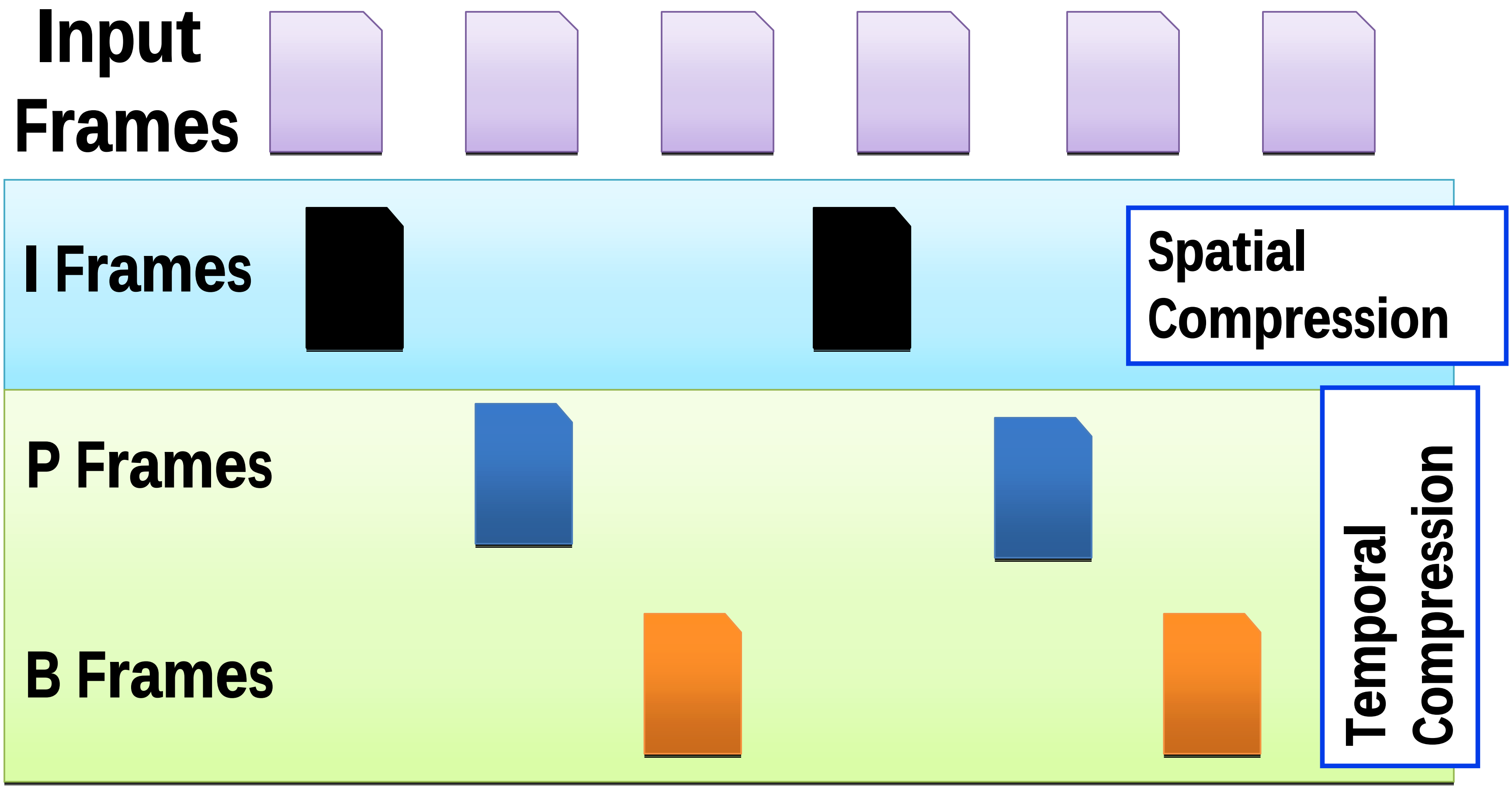
- Video streaming is one of the fastest growing applications on the web
- 75 percent of the U.S. Internet users spend 3 – 3.5 hours/month watching streaming videos
  - [29% increase from last year]
- Advertisement revenues reached 1.37 billion dollars [1]
- Accurate video model to understand constraints of the network environment and its impact on video performance especially for time sensitive contents

[1] Comscore Press Center

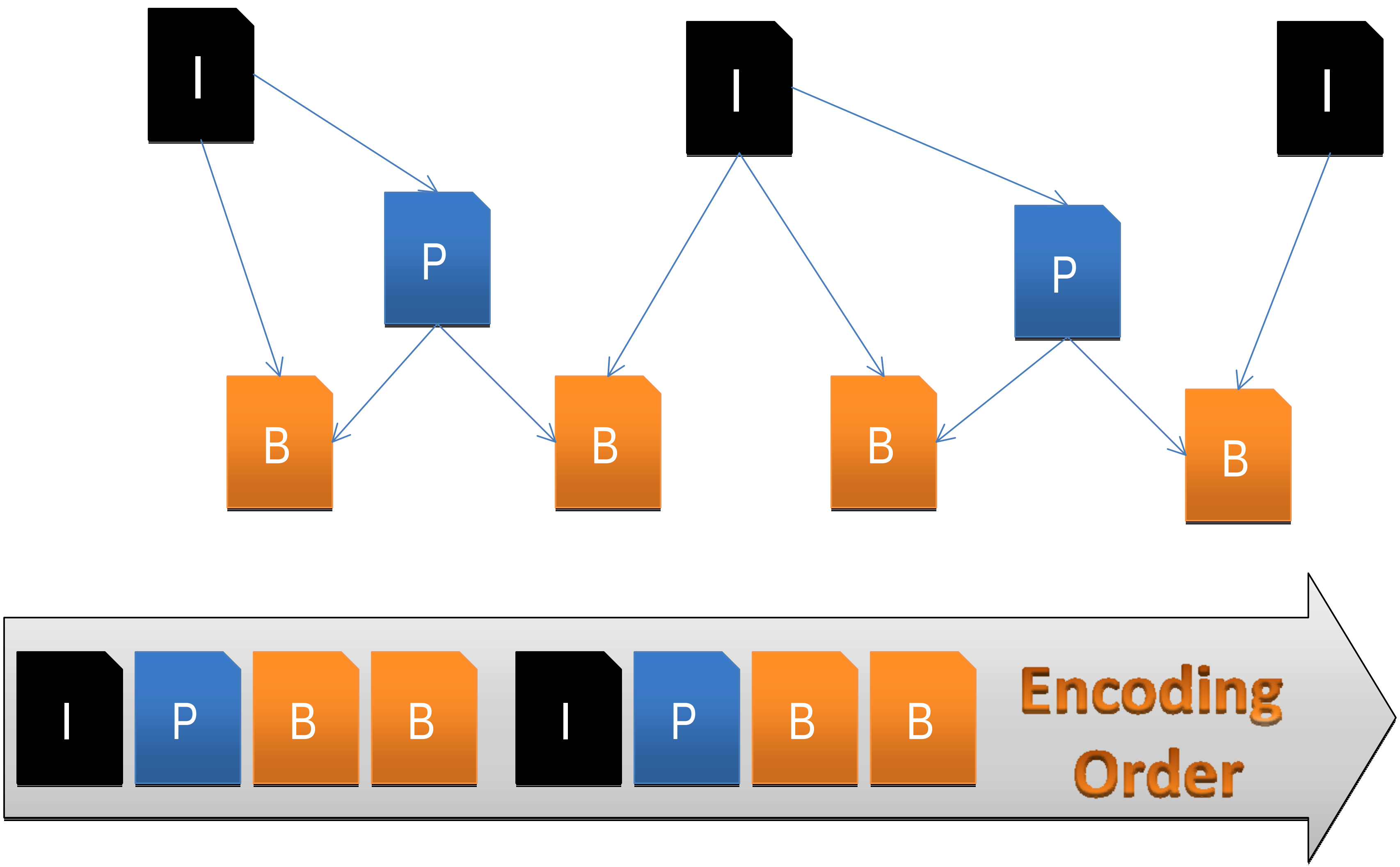
MPEG Layer Hierarchy



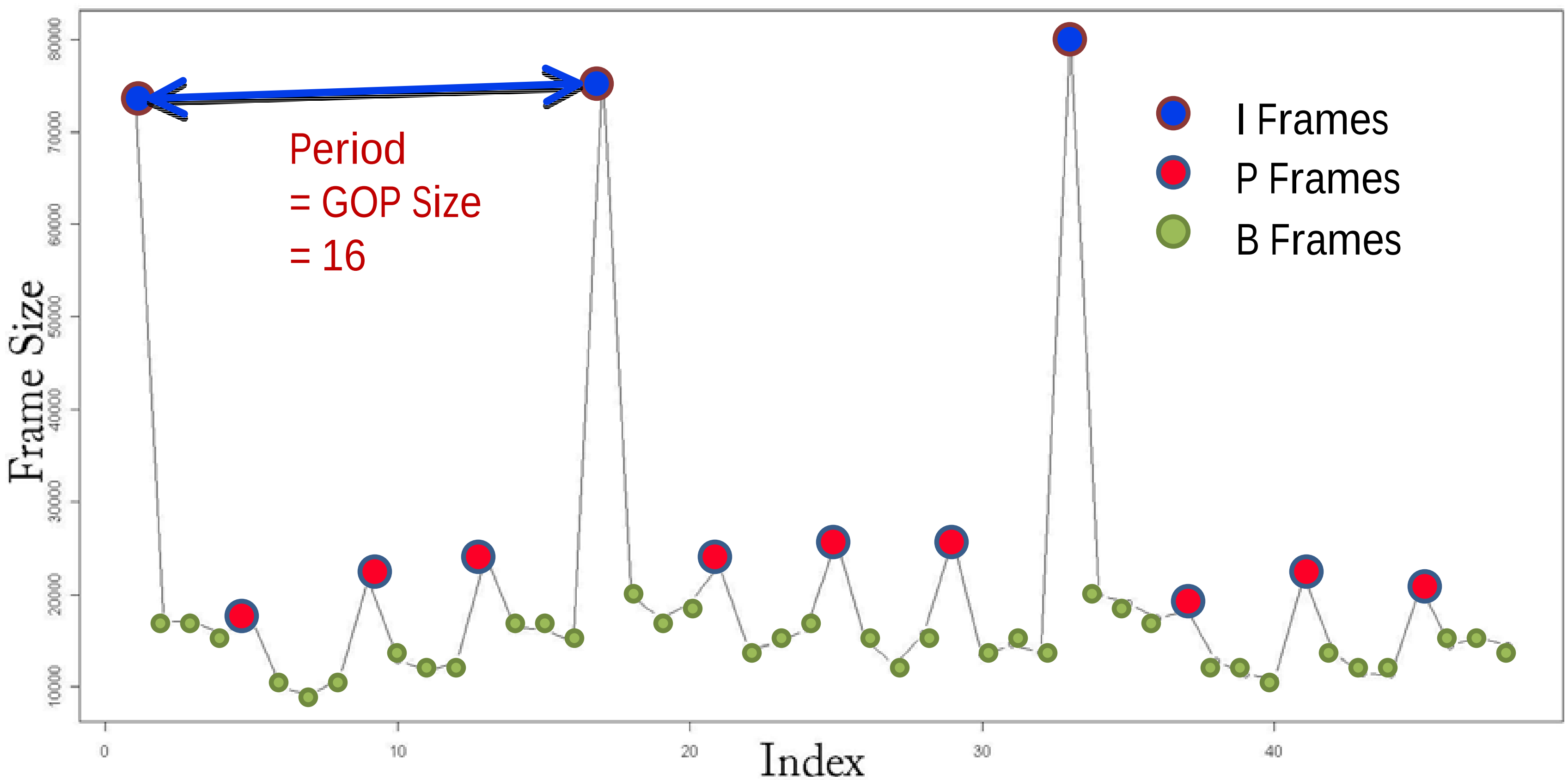
MPEG Encoding



Encoding and Transmission Order



Seasonality in MPEG Encoding



Previous and Related Work

- Markov chain models
- Separate models for I, P and B frames
- Considering "Epoch": Group of scenes
- Time series models
- Wavelet models

Other considerations

- Solutions are movie specific
  - Require distribution history
  - Parameters tweaked for each individual movie
- "simple" approaches may require up to 9 parameters
- Most approaches are scene specific
- Complexity in the approach to reach satisfying results

Time Series Models

- Auto-regressive Models : AR

AR(1) Model:

$$y(t) = a_1\, y(t-1) + w(t)$$

AR(p) Model:

$$y(t) = a_1\, y(t-1) + a_2 y(t-2) + \ldots + a_p y(t-p) + w(t)$$

The current value depends on the previous values

- Moving Average Models : MA

MA(1) Model:

$$y(t) = w(t) + b_{(}\, w(t-1)$$

MA(q) Model:

$$y(t) = w(t) + b_1\, w(t-1) + b_2 w(t-2) + \ldots + b_q w(t-q)$$

The current value depends on the previous forecasting errors

Time Series Models (Cont)

- Autoregressive Moving Average Model: ARMA(p,q)

$$y(t) - a_1 y(t-1) - \ldots - a_p y(t-p)$$
$$=$$
$$w(t) + b_1 w(t-1) + \ldots + b_q w(t-1) + \ldots + b_q w(t-q)$$

ARMA combines Autoregressive and Moving Average components

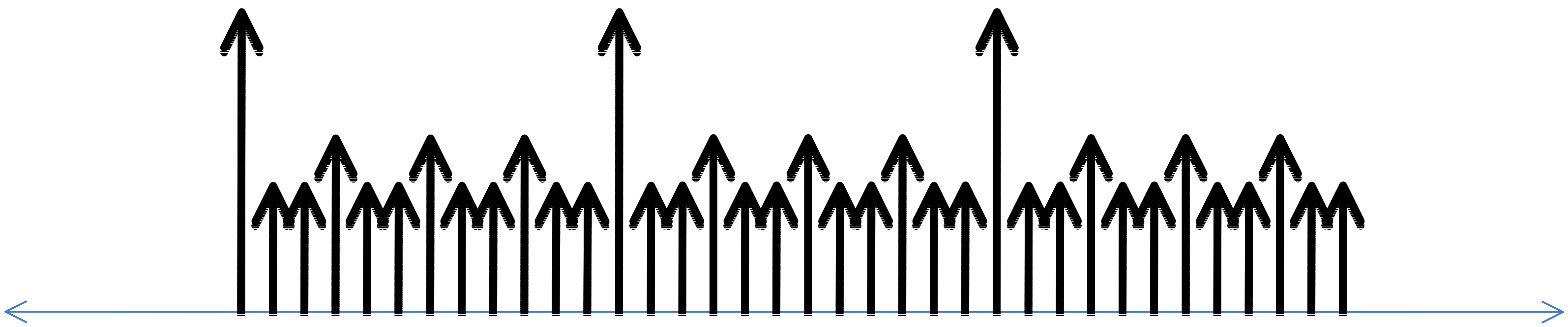
- Autoregressive Integrated Moving Average Model : ARIMA (p,d,q)
  - ARIMA adds the differencing component with order d to obtain stationarity, here is the expression

$$y(t) - y(t-1) = w(t) + a_1[y(t-1) - y(t-2)] - b_1 w(t-1)$$

Seasonal ARIMA

- Seasonal ARIMA models are used for data series that exhibit periodic behavior
- Seasonal ARIMA is described as:
  - ARIMA (p, d, q) × (P, D, Q)s
  - P, D, Q are the same and operates across multiples of lag s (the number of periods in a season)

Seasonal ARIMA Example



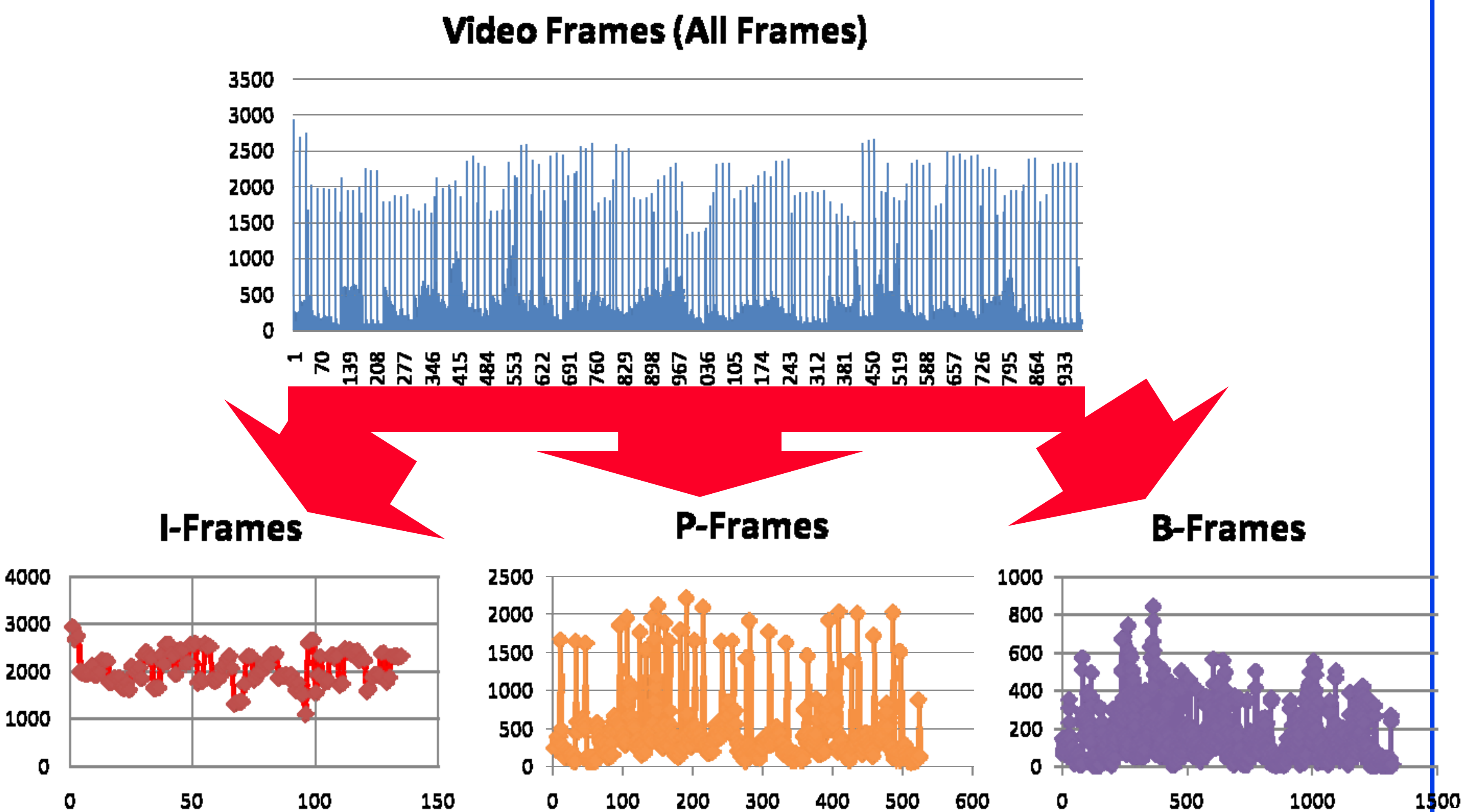
ARIMA $(1,2,1)x(1,2,1)_{12}$

- Example :
  - ARIMA$(1,2,1)$ x $(1,0,1)_{12}$
  - Represents a series of period of 12

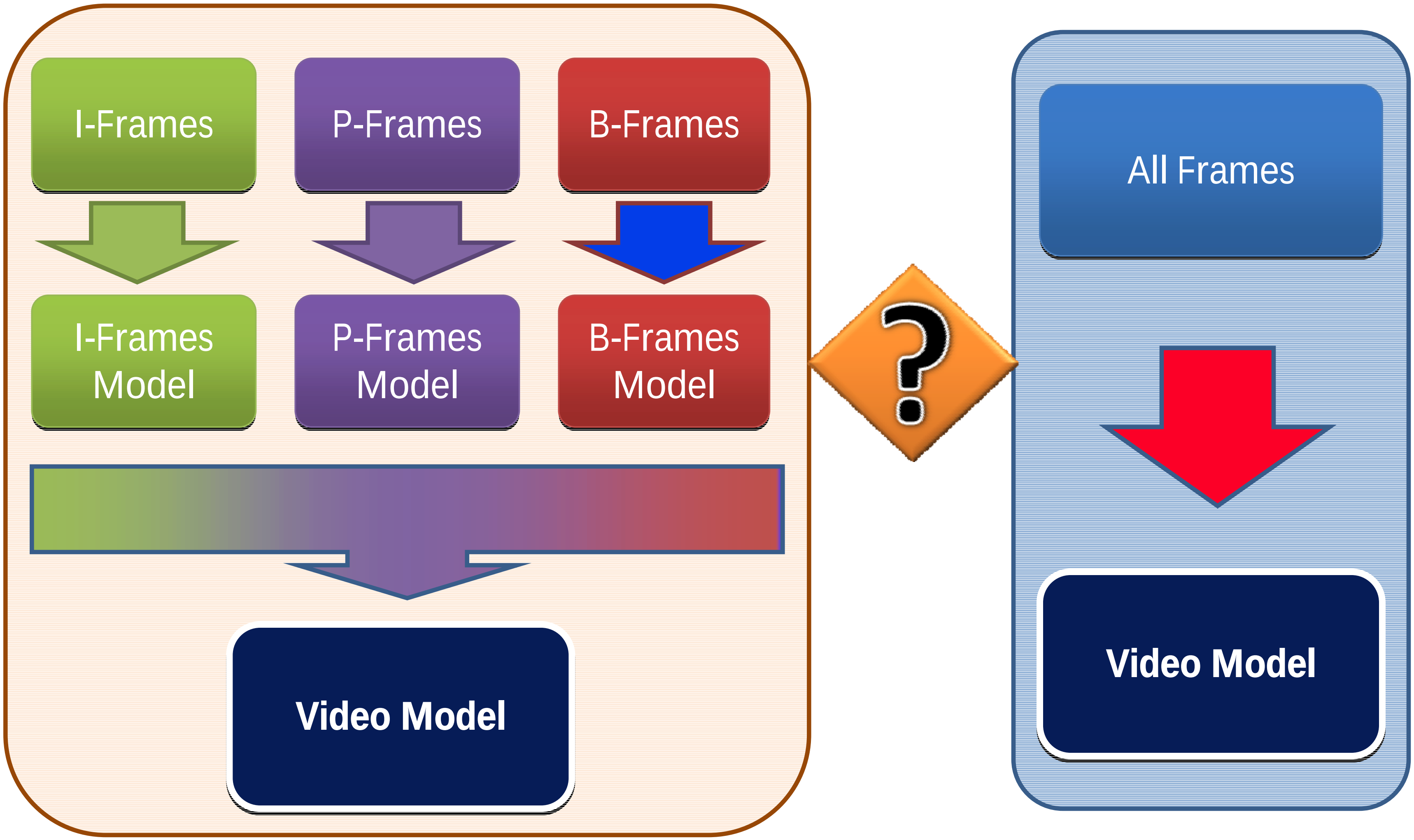
Preliminary Analysis: Short Scenes

- Simple TV ads
- Suitable video encoding
  - MPEG-4 Part 2
  - Advanced Simple Profile (ASP):
  - CIF (Common Intermediate Format)size
    - (352 × 288)
  - Frames rate 25fps
- Short scenes (6000 frames)

Video Frame Analysis



Separate Model Vs. Single Model



Results

Movie		All-Frames	Composite model (I-Frames), (P-Frames), (B-Frames)
Matrix I	Model	$(3, 0, 1)\times(1, 1, 1)^{12}$	(0, 1, 3), (1, 1, 1), (3, 1, 6)
	AIC (Akaike Info. Criterion)	**120369.3**	**119775.3**
LOTR I	Model	$(1, 0, 1)\times(1, 1, 1)^{12}$	(0, 1, 5), (0, 1, 1), (2, 1, 2)
	AIC (Akaike Info. Criterion)	**125689.7**	**125270.9**
LOTR II	Model	$(3, 0, 3)\times(1, 1, 1)^{12}$	(0, 1, 3), (0, 1, 1), (1, 1, 2)
	AIC (Akaike Info. Criterion)	**127488.4**	**125278.9**

- Though composite model is better, All Frames or single model is pretty close.
- Composite model requires more analysis work, and multiplexing
- AIC = goodness = accuracy and the number of the parameters

Simplified Seasonal ARIMA Model

Movie		All-Frames	Composite model (I-Frames), (P-Frames), (B-Frames)	General model
Matrix I	Model	$(3, 0, 1)\times(1, 1, 1)^{12}$	(0, 1, 3), (1, 1, 1), (3, 1, 6)	$(1, 0, 1)\times(1, 1, 1)^{12}$
	AIC (Akaike Info. Criterion)	**120369.3**	**119775.3**	**120378.1**
LOTR I	Model	$(1, 0, 1)\times(1, 1, 1)^{12}$	(0, 1, 5), (0, 1, 1), (2, 1, 2)	$(1, 0, 1)\times(1, 1, 1)^{12}$
	AIC (Akaike Info. Criterion)	**125689.7**	**125270.9**	**125689.7**
LOTR II	Model	$(3, 0, 3)\times(1, 1, 1)^{12}$	(0, 1, 3), (0, 1, 1), (1, 1, 2)	$(1, 0, 1)\times(1, 1, 1)^{12}$
	AIC (Akaike Info. Criterion)	**127488.4**	**125278.9**	**127597**

- **Conclusion: ARIMA(1,0,1)(1,1,1)^{G} represents most of the movies that we have analyzed.**

Full Movie Analysis

- Full movie traces
- Matrix trilogy :
  - Each around 188 thousand frames
- LOTR (Lord of The Rings) trilogy :
  - Each around 266 thousand frames

Frame Size Statistics

Movie	Standard Deviation	Mean
LOTR 1	9594.778	9342.26
LOTR 2	11178.38	11481.00
LOTR 3	10794.25	11145.63
Matrix 1	**7946.338**	**7348.922**
Matrix 2	10687.00	9508.467
Matrix 3	**12701.56**	**10522.08**

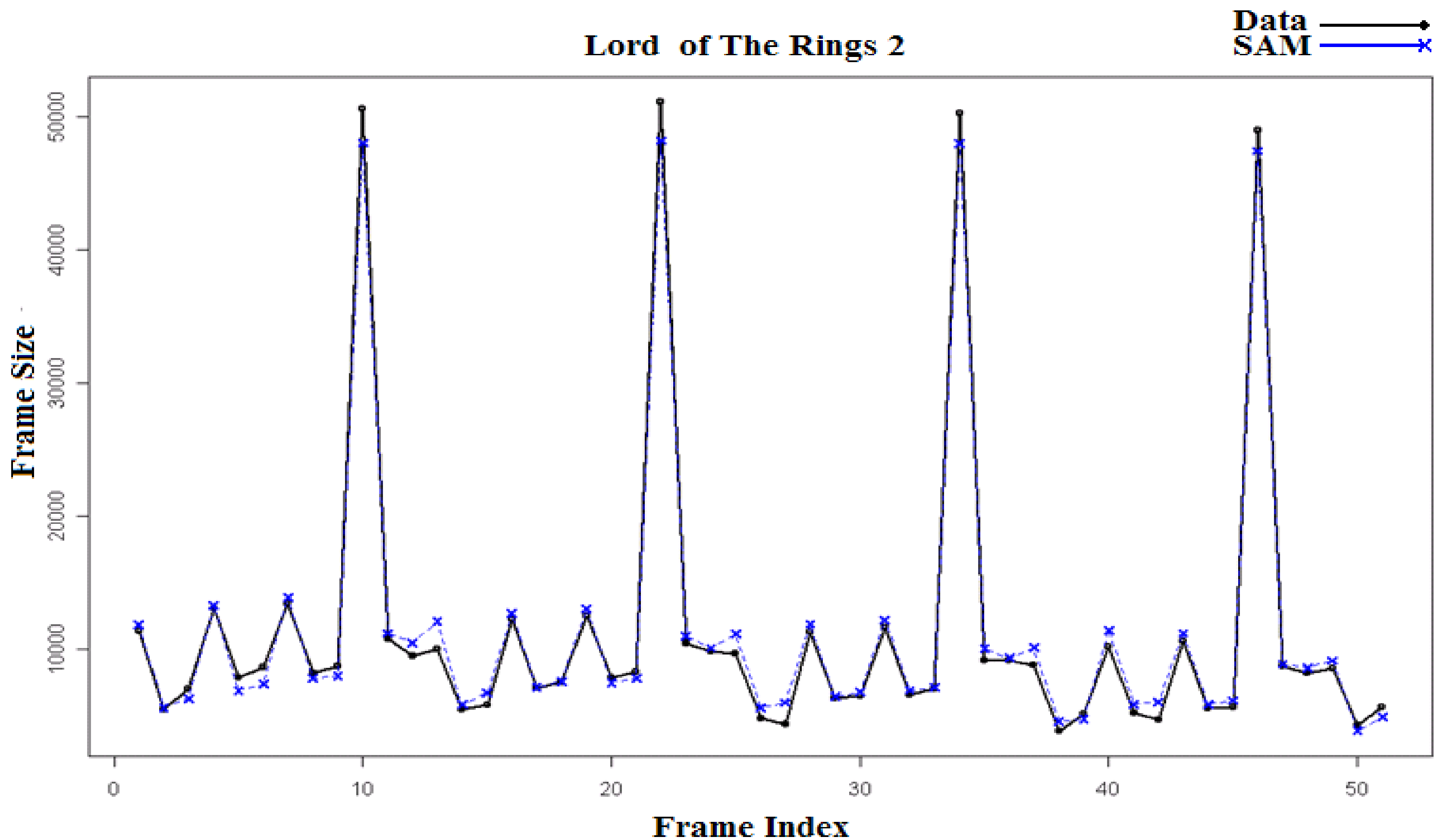
- Observation: Mean and Standard deviation vary significantly.

Models for Mobile Video

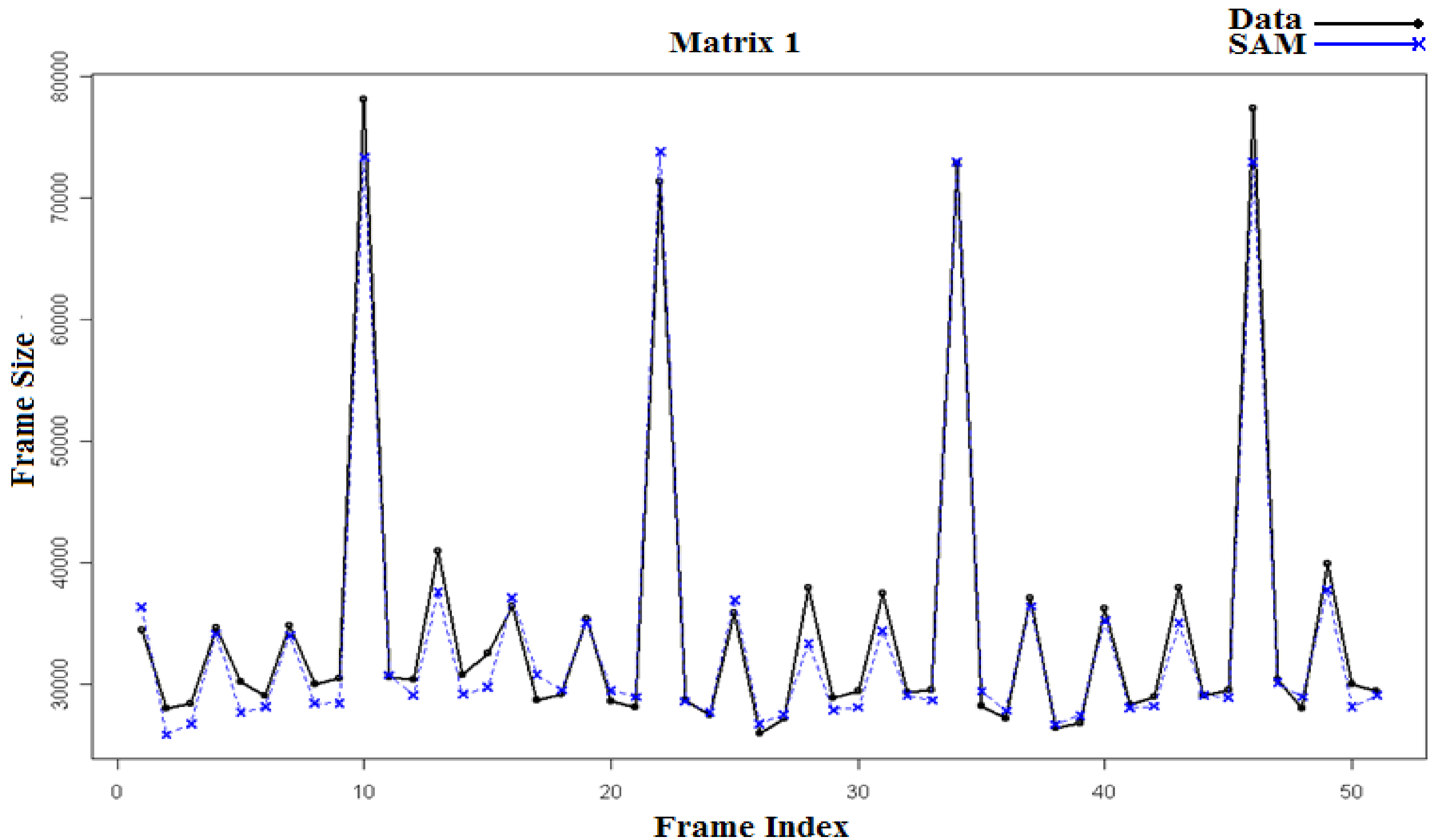
Movie	AIC (Optimal)	AIC (SAM)	Difference% ([S-O]/O)
LOTR 1	15209108	15214697	**0.036%**
LOTR 2	18195617	18220707	**0.137%**
LOTR 3	16495282	16515722	**0.123%**
Matrix 1	11222747	11227109	**0.038%**
Matrix 2	20321203	20361456	**0.198%**
Matrix 3	34489730	34764677	**0.797%**

- Observation: **SAM is within 1% of the optimal model**

Observed vs Predicted Frame Sizes

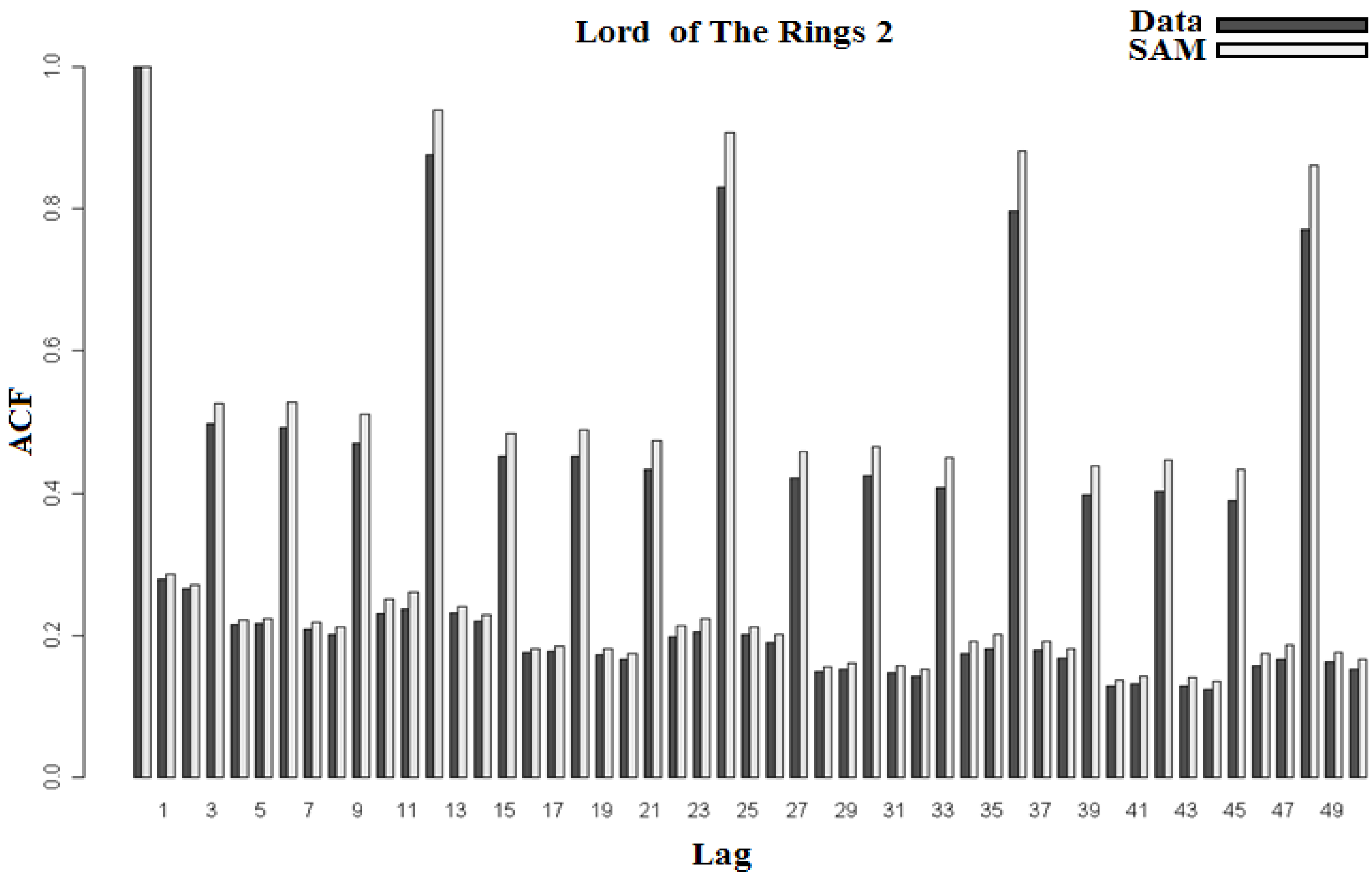


Observed vs Predicted Frame Sizes 2



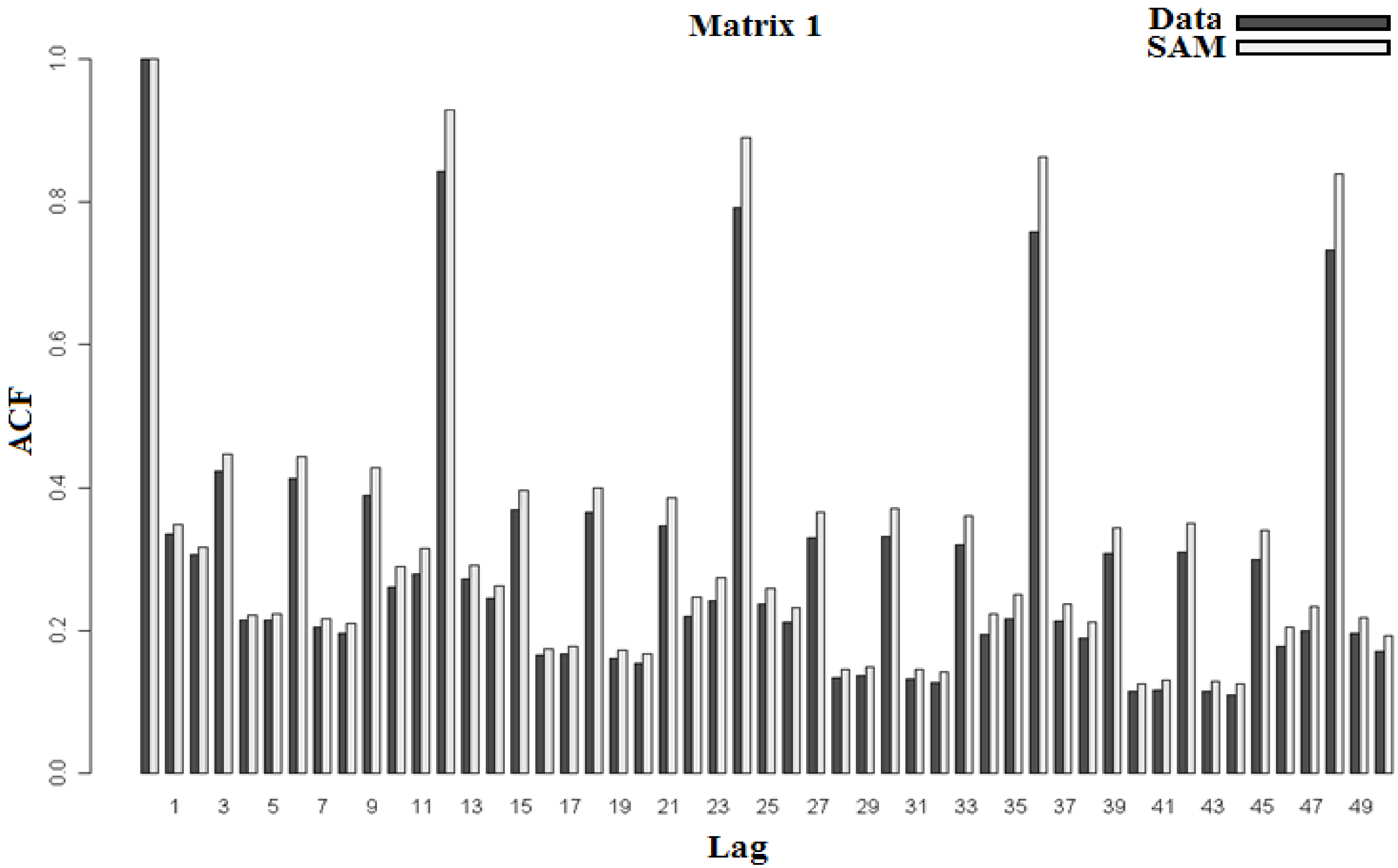
- Observation: Good fit

Observed vs Predictred ACF



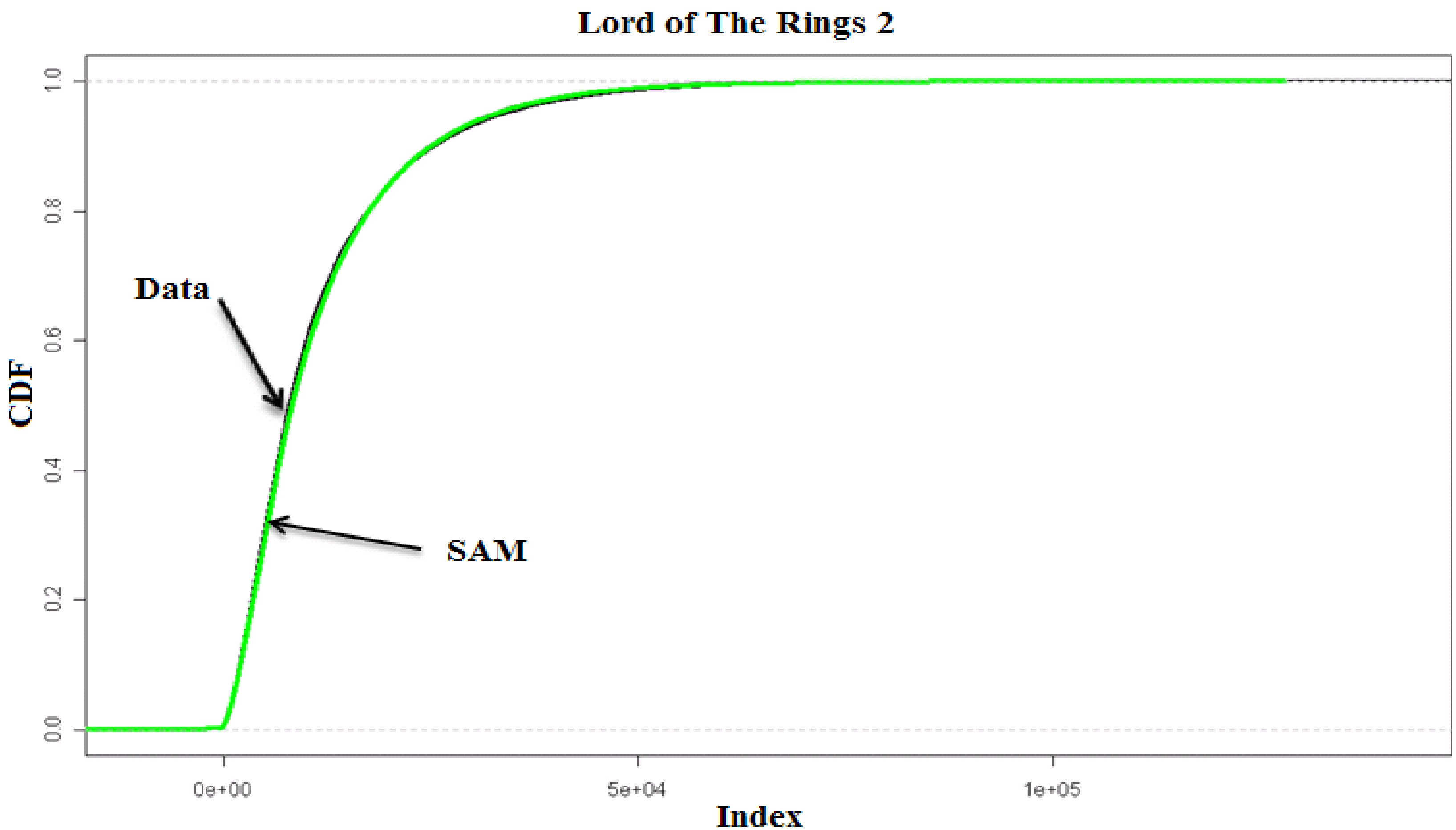
- Observation: Good fit

Observed vs Predictred ACF 2



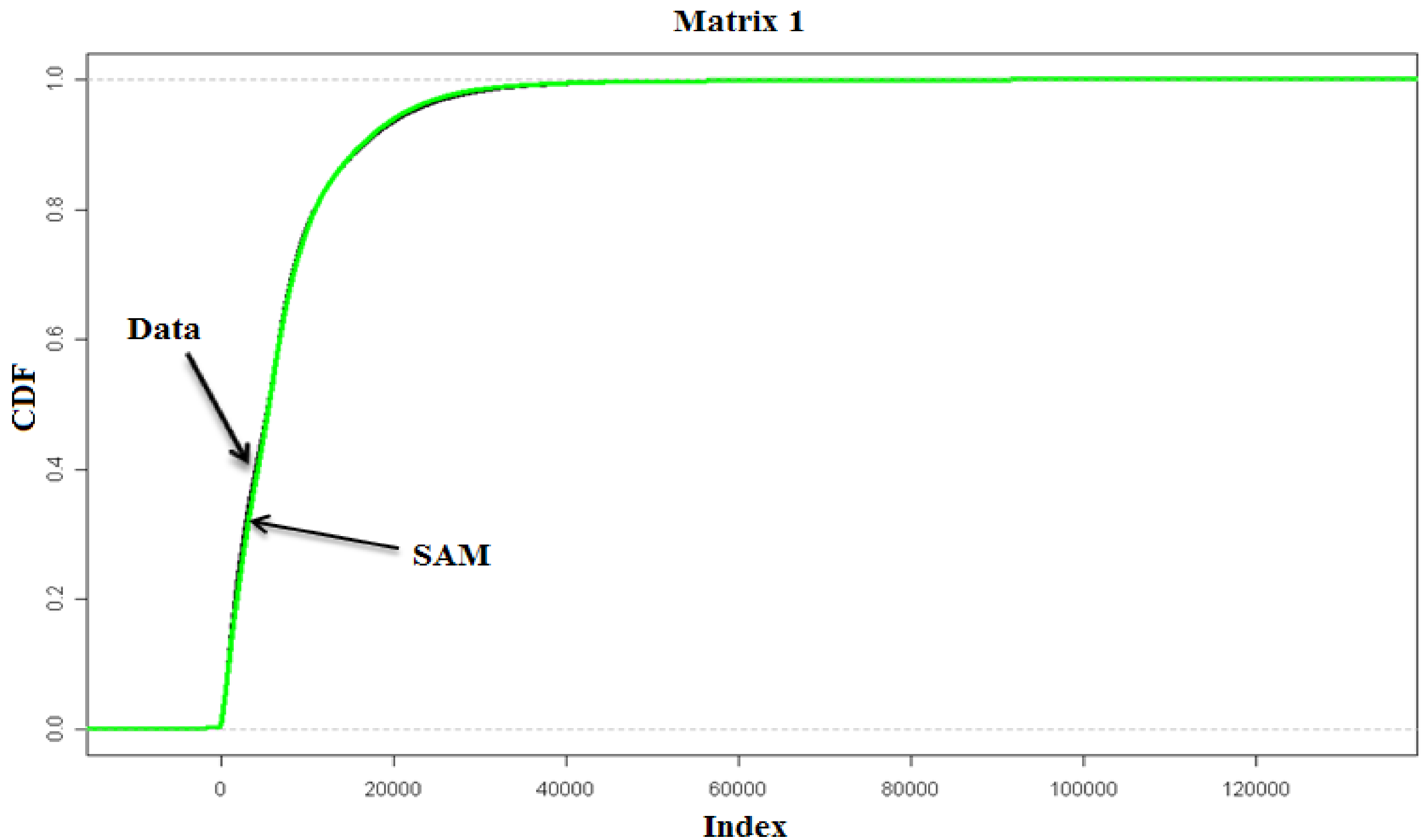
- Observation: Good fit

Observed vs Predictred CDF



- Observation: Good fit

Observed vs Predictred CDF 2



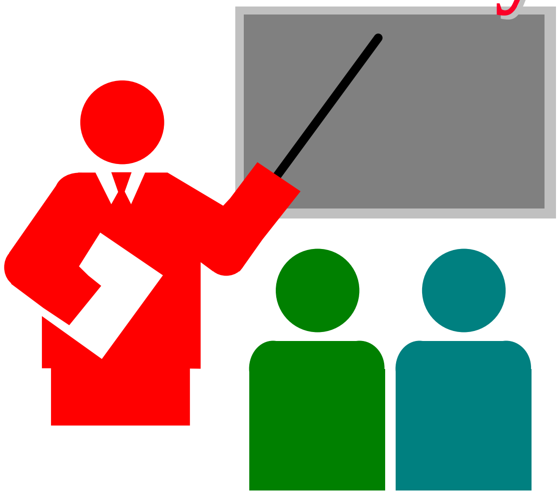
- Observation: Good fit
  Single model is good. What about model parameters?

Model Parameters

Movie	AR	MA	SAR	SMA
LOTR 1	0.9262	-0.6911	0.2411	-0.8638
LOTR 2	0.9306	-0.6770	0.2715	-0.8610
LOTR 3	0.9322	-0.6818	0.2683	-0.8440
Matrix 1	0.9241	-0.6561	0.1602	-0.8050
Matrix 2	0.9382	-0.6809	0.2336	-0.8760
Matrix 3	0.9327	-0.6372	0.1002	-0.8951
Mean	**0.93**	**-0.67**	**0.21**	**-0.86**
[Min, Max]	[0.924, 0.938]	[-0.691, -0.637]	[0.1, 0.271]	[-0.895, -0.805]

- Observation: There is very little variation in parameters.

Summary



- IPB or composite model is better than All-Frames or a single model however the difference is small
- SAM model is a simple seasonal ARIMA model that is capable of representing different movies
- Movies models coefficients are quite close to each other, which suggest a unified model
- Will this model work with all movies from different genres ? → Future work

Reference

- Abdel-Karim Al-Tamimi, Raj Jain, Chakchai So-In, "SAM: A Simplified Seasonal ARIMA Model for Mobile Video over Wireless Broadband Networks," Proc. IEEE International Symposium on Multimedia (ISM 2008), Berkeley, CA, December 15-17, 2008, http://www.cse.wustl.edu/~jain/papers/sam_ism.htm