



A Review: “Analysis of the Meter of Acoustic Musical Signals”

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Types of levels

- **Tatum**

- Atomic pulse level

- **Tactus**

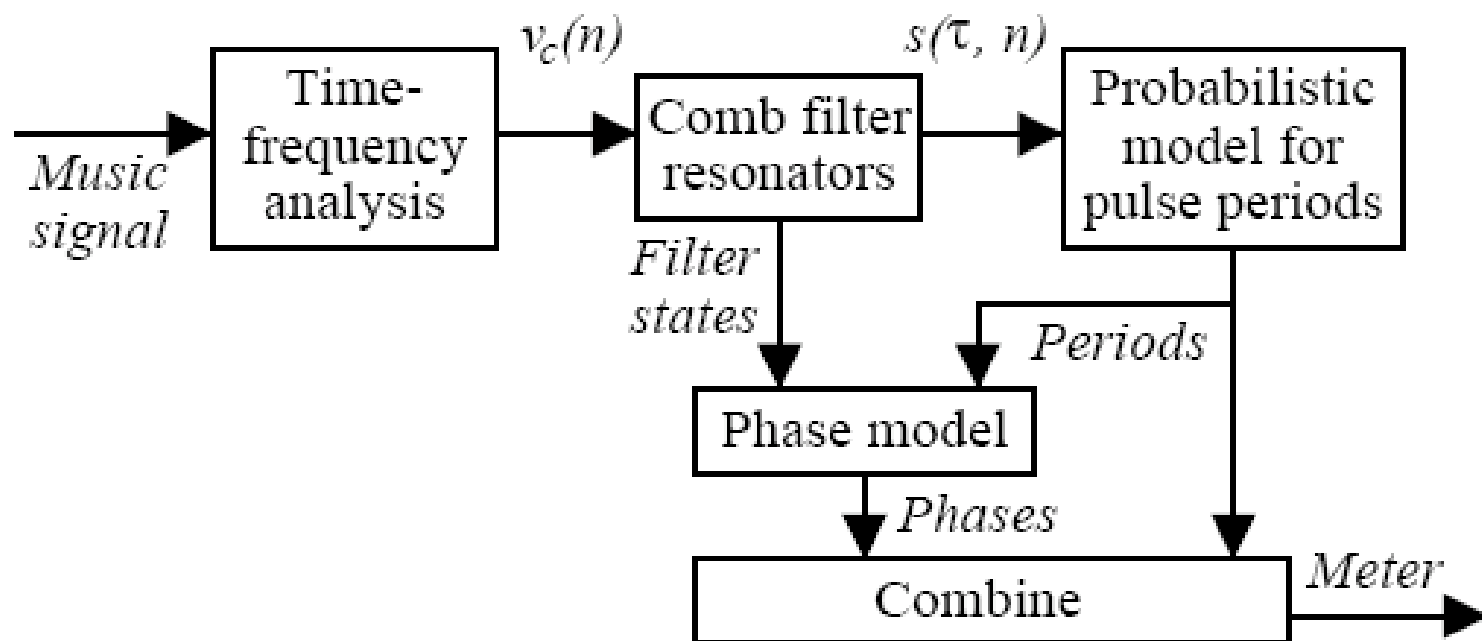
- Pulse level corresponding to the tempo

- **Measure**

- Musical measure level



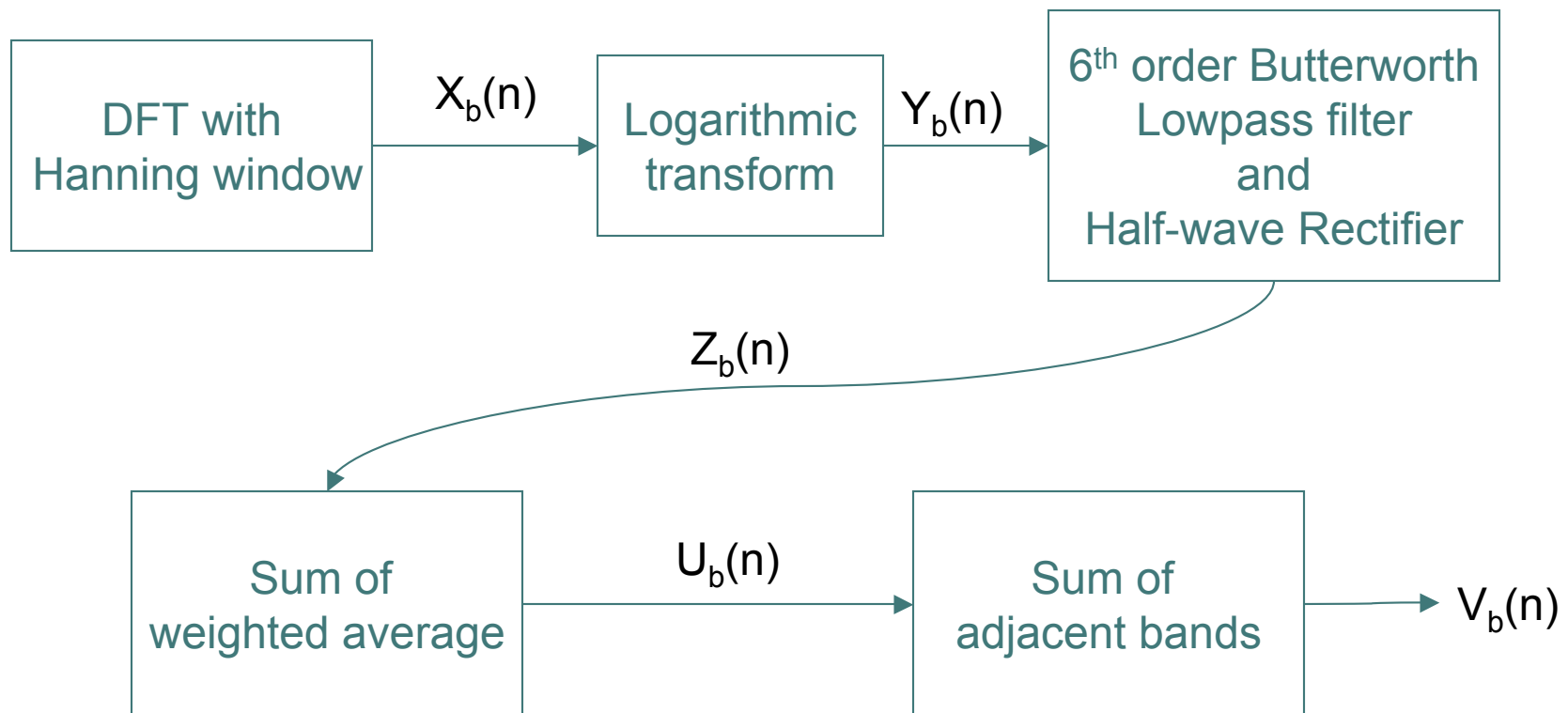
Meter Estimation Method





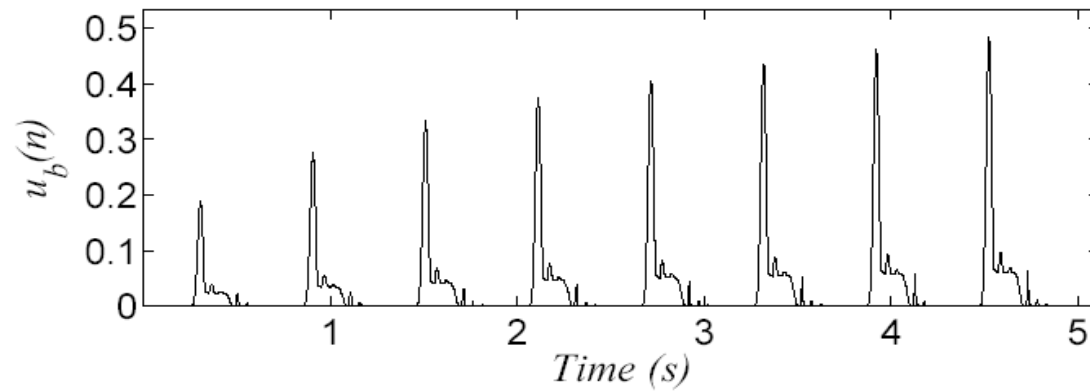
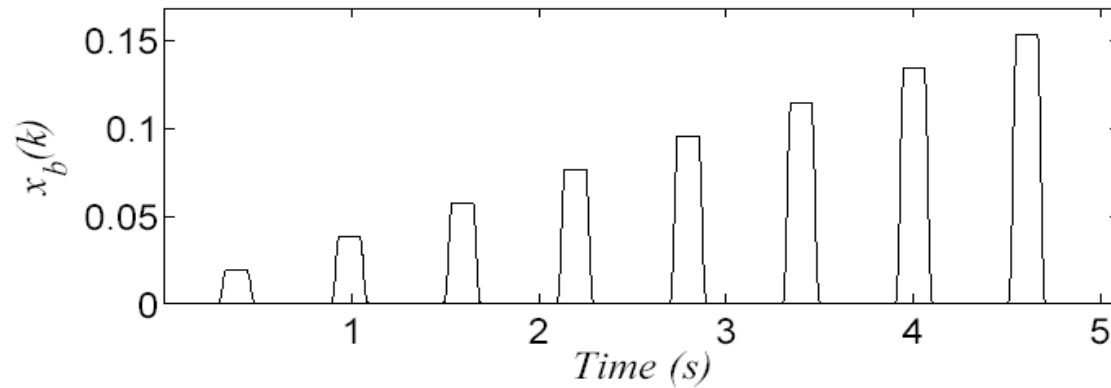
Time-Frequency Analysis

$$X_b(n) \rightarrow Y_b(n) \rightarrow Z_b(n) \rightarrow U_b(n) \rightarrow V_b(n)$$





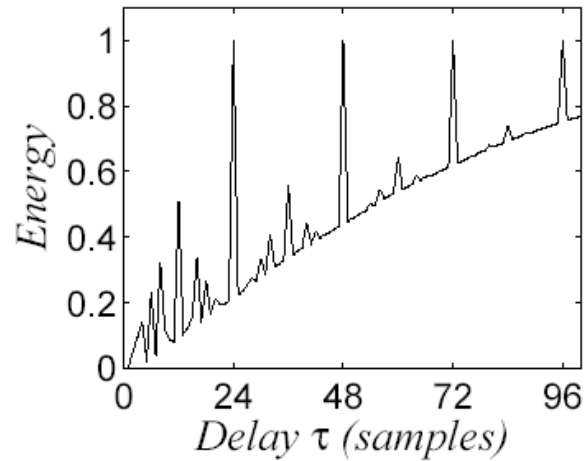
Time-Frequency Analysis



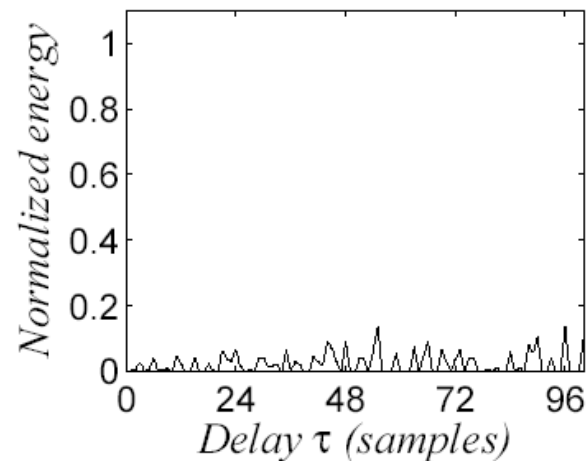
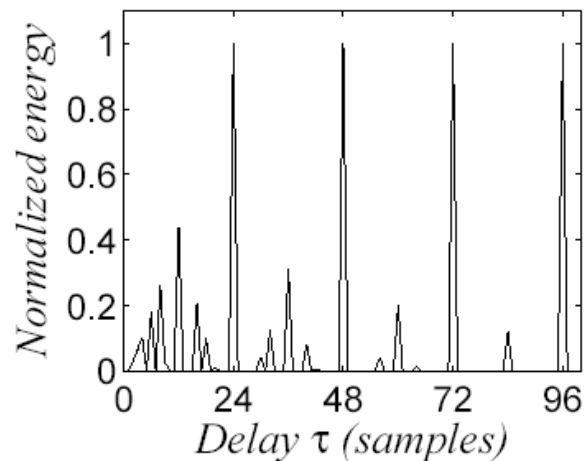
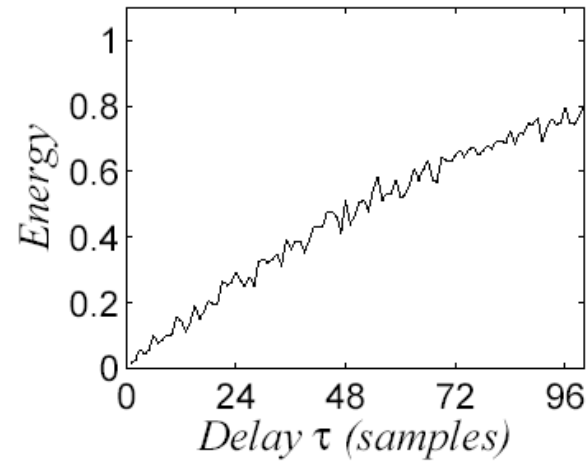


Comb Filter Resonators

Energy with Impulse Train

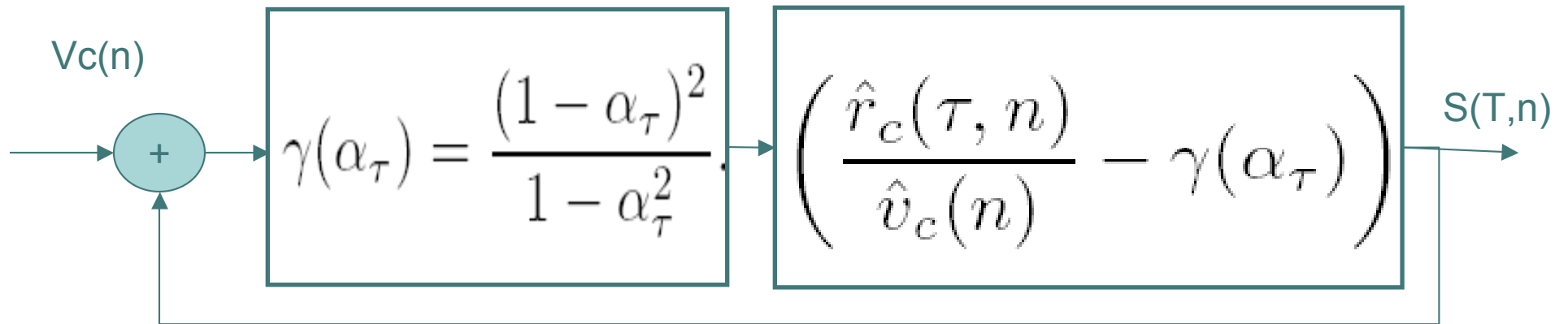


White Noise

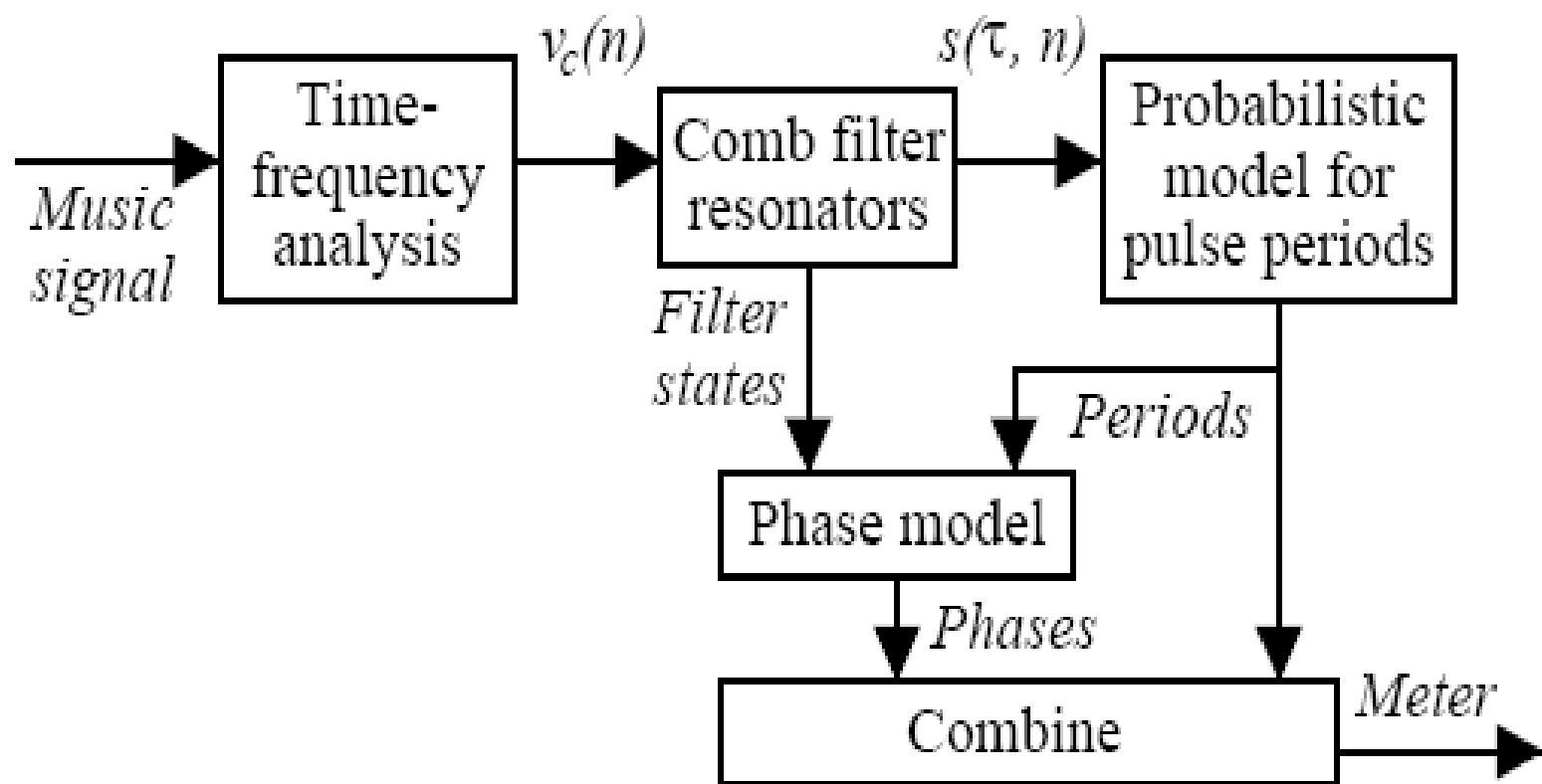




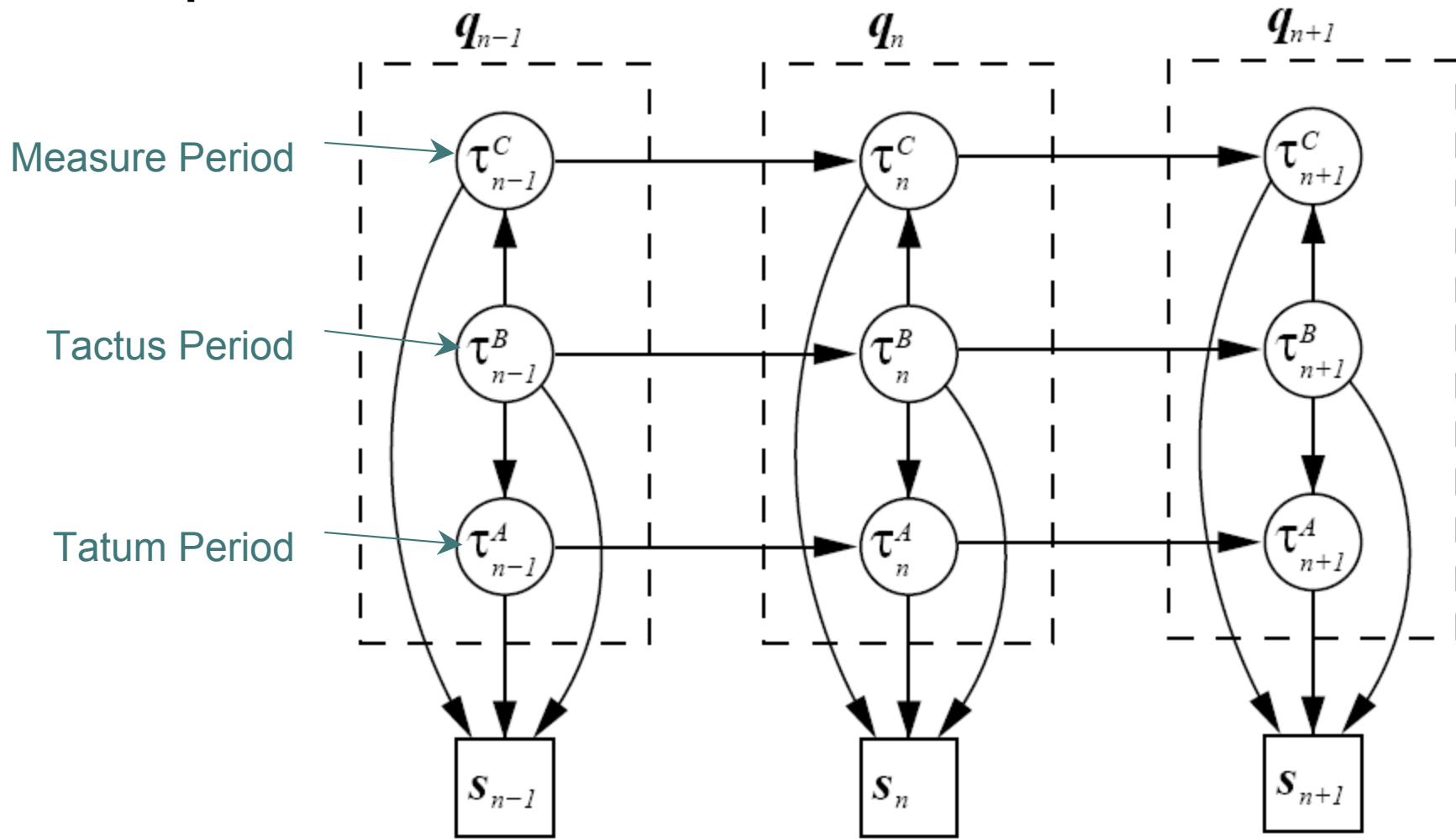
Comb Filter Resonators Feedback



Probabilistic model



● ● ● | Hidden Markov Model



Transition Probabilities

$$P(\tau_n^A | \tau_n^B, \tau_{n-1}^A) = P(\tau_n^A | \tau_{n-1}^A) \frac{P(\tau_n^A, \tau_n^B | \tau_{n-1}^A)}{P(\tau_n^A | \tau_{n-1}^A) P(\tau_n^B | \tau_{n-1}^A)}, \quad (18)$$

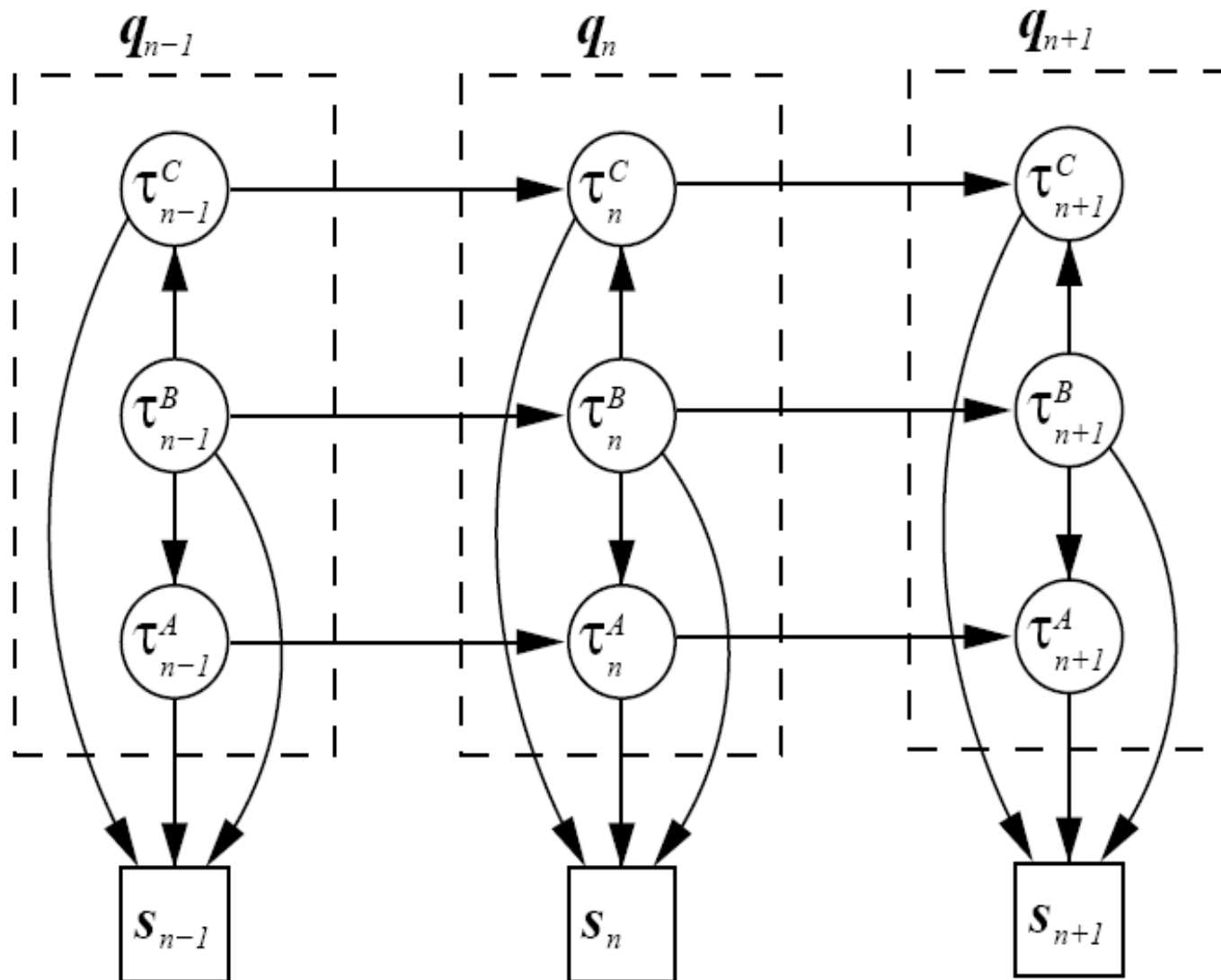
$$P(\tau_n^i | \tau_{n-1}^i) = P(\tau_1^i) \frac{P(\tau_n^i, \tau_{n-1}^i)}{P(\tau_n^i) P(\tau_{n-1}^i)} \approx P(\tau_1^i) f\left(\frac{\tau_n^i}{\tau_{n-1}^i}\right), \quad (20)$$

where $i \in \{A, B, C\}$. The function f ,

$$f\left(\frac{\tau_n^i}{\tau_{n-1}^i}\right) = \frac{1}{\sigma_1 \sqrt{2\pi}} \exp\left[-\frac{1}{2\sigma_1^2} \left(\ln\left(\frac{\tau_n^i}{\tau_{n-1}^i}\right)\right)^2\right], \quad (21)$$



Viterbi Algorithm



● ● ● | Phase Model

$$P(\varphi_n^i | \varphi_{n-1}^i) = \frac{1}{\sigma_3 \sqrt{2\pi}} \exp\left(-\frac{e^2}{2\sigma_3^2}\right),$$

where

$$e = \frac{1}{\hat{\tau}_n^i} \left\{ \left[\left(|\varphi_n^i - \varphi_{n-1}^i| + \frac{\hat{\tau}_n^i}{2} \right) \bmod \hat{\tau}_n^i \right] - \frac{\hat{\tau}_n^i}{2} \right\},$$



Results

TACTUS ANALYSIS PERFORMANCE (%) OF DIFFERENT METHODS.

Method	Continuity required			Individual estimates		
	Correct	Accept d/h	Period c.	Correct	Accept d/h	Period c.
Causal	57	68	74	63	78	76
Noncausal	59	73	74	64	80	75
Scheirer [20]	27	31	30	48	69	57
Dixon [16]	7	26	10	15	53	25
O+Dixon	12	39	15	22	63	30



Music Sample

○ Handel Sonata

Music from <http://www.cs.tut.fi/~klap/iiro/meter/examples.html>

- Claves (Tick) = Atomic tatum pulse
- Snare (Slide Stick) = Tactus pulse
- Bass drum = Measure pulse



References

- All images and equations were from:
A.P. Klapuri et al. “Analysis of the Meter of Acoustic Musical Signals”. IEEE Trans. Speech and Audio Proc. 2004.