

Cross Media Evaluation of Digital Watermarking Schemes on the Example of Biometric Authentication System and User Distinction

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Structure

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Motivation

- Digital watermark development is connected to their evaluation
- Different evaluation strategies exist
 - Simple properties
 - Application Scenarios
- Application scenarios → real world evaluation

Motivation II

- Biometric system used for user authentication
- Two phases:
 - Enrollment phase
 - Verification/Identification phase
- Meta data collected and mostly separated stored →
Watermarking can help to embed meta data directly into the biometric data to enable for example:
 - Annotation watermarking
 - Manipulation recognition
 - Owner Identification and Tracking Usage
- Data base required

Motivation III

- State-of-the-art:
 - Application depending evaluation of digital watermarking schemes with so-called evaluation profiles, see for example in [SPIE07,06,05]
- Goal:
 - Focus **Transparency**, **Capacity** required of a biometric authentication system
 - How does a WM scheme effect the biometric system
- First idea presented in [MMUA] 2006 for speech biometric system
 - First tests with only LSB algorithm on 16 bit audio signals

Evaluation Profile P

- Is defined as:

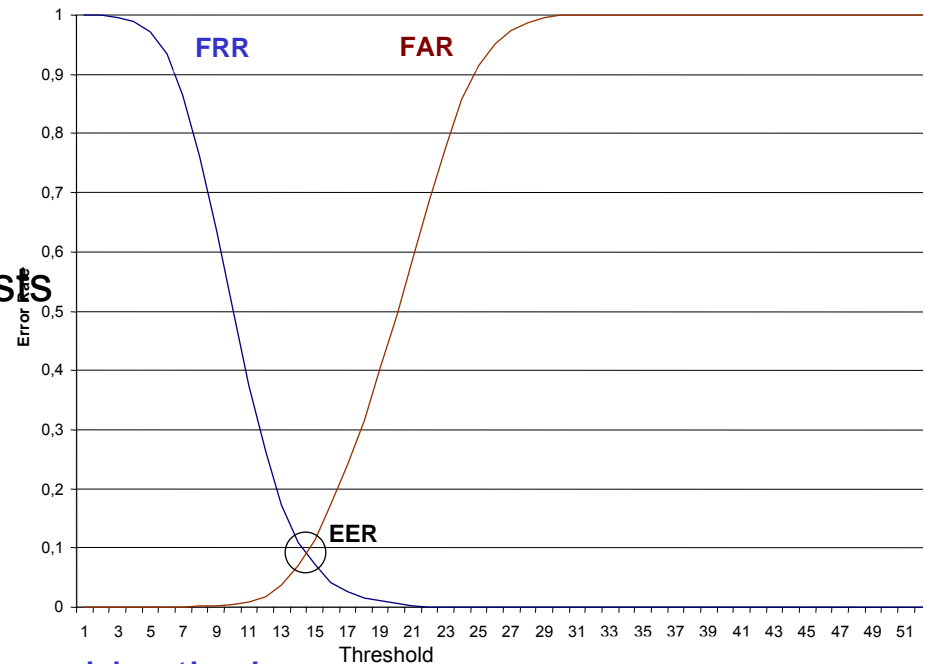
$P_{A\text{-Biometrics}}$ (in-signal || out-signal || more params)
more params = (bio-alg, bio-param)

- *in-signal*: original biometric reference signal S
- *out-signal*: marked biometric reference signal S'
- *bio-alg*: specifies the biometric authentication system
- *bio-param*: required parameters
- Measures: Transparency & Capacity requirements with the basic profiles $P_{E\text{-Transparency}}$ and $P_{E\text{-Capacity}}$

Introduction to Biometrics

- Error Rates For Verification
 - False Acceptance Rate (FAR)
 - Ratio between number of false acceptances of non-authentic persons and total number of tests
 - False Rejection Rate (FRR)
 - Ratio between number of false rejections of authentic persons and total number of tests
 - Equal Error Rate (EER)
 - Point where the FAR and FRR are identical
 - Do not represent optimal operating point of a biometric system
 - Used for comparison of authentication performance of biometric systems

- All Error Rates obtained by experiment → test databases



Biometric Difference Grade

- Biometric Difference Grade (BDG) used defined as normalized transparency measure
- Based on the error rates FMR, FNMR \rightarrow EER

$$B(EER, \hat{EER}) \rightarrow [0,1] \quad \text{0-worst, 1-best}$$

$$bdg_{rel}(O, S) = \begin{cases} 1 - \frac{|EER - \hat{EER}|}{EER}, & \text{if } 1 - \frac{|EER - \hat{EER}|}{EER} > 0 \\ 0 & , \text{otherwise} \end{cases}$$

$$bdg_{ave}(O) = \frac{1}{|S|} \sum_{S \in S} bdg_{rel}(O, S)$$

$$bdg_{min}(O) = \min_{S \in S} \{ bdg_{rel}(O, S) \}$$

$$bdg_{max}(O) = \max_{S \in S} \{ bdg_{rel}(O, S) \}$$

O – watermarking scheme
S – audio signal $S \in \mathbf{S}$

Test Scenario, Test

Environment

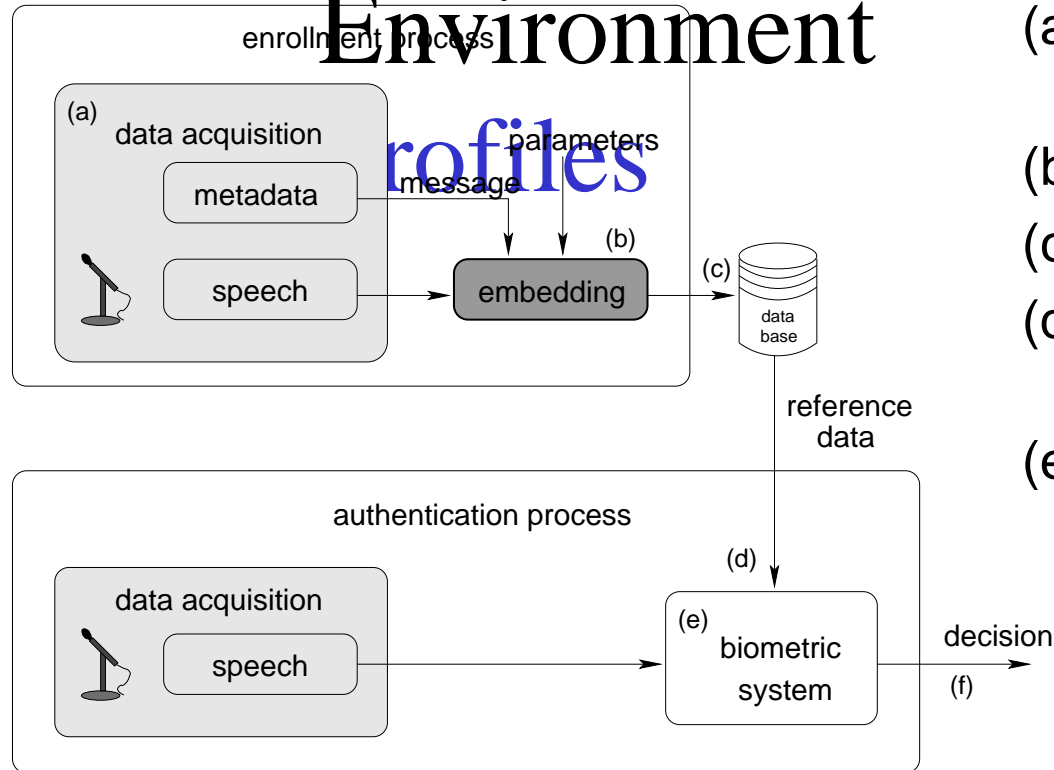
- Evaluation of 4 watermarking schemes (O_1, \dots, O_4) with its default embedding parameters
- 1620 captured spoken words/phrases, avg length: 1.8 seconds
- 44.1kHz, mono (one channel)
 - Test Set (A): 16 bit quantized
 - Test Set (B): 8 bit quantized
- 47 users from Germany, India, Italy and England, which spoke only in English
- Five different semantic classes were recorded

Watermarking algorithms

Spoken Text	Hello, how are you?	She sells sea shells on the shore	Communi- cation	What is your good name?	Where are you from?
Class	Hello	SeaShells	Communi	GoodName	Where
#Recods	32	32	32	33	33

Test Scenario, Test

Environment



- (a) Enrollment with capturing
- (b) Watermark embedding
- (c) Storing in database
- (d) Reference data required for authentication
- (e) Matching process

Ω_{LSB} : time domain

Ω_{2A2W} : wavelet domain

Ω_{MS} : frequency domain

Ω_{SS} : frequency domain

m="SampleID: 13220, EventID: 12437, PersonID: 315, SemanticID: 21, Device: 1, Date/time: 2005-12-03 12:06:54, Textual content:, Language: EN, Environment: 0" → 206 Bytes

Test Results

EER of the Biometric System without WM

- EER about 3% better for 16 bit quantized audio signals instead of 8 bit.
- Best marked with light gray, worst marked with dark gray.

Class	EER	
	8 Bit	16 Bit
Communi	0.329	0.271
GoodName	0.295	0.289
Hello	0.304	0.251
SeaShells	0.364	0.340
Where	0.269	0.282
Arithm. Mean	0.312	0.282

Evaluation Results

Nationality	Language	Gender	#Users	bdg ^{ave} for S_{BIO}^g			
				Ω_{LSB}^*	$\Omega_{2\text{A}2\text{W}}^*$	Ω_{MS}^*	Ω_{SS}^*
				German	EN	+O	7
		Q	9	0.914	0.930	0.987	0.991
		+Q	16	0.971	0.919	0.973	0.978
	DE	+O	2	0.408	0.919	0.442	0.064
		+Q	3	0.528	0.968	0.966	0.975
Indian	EN	+O	2	0.720	0.673	0.750	0.728
		Q	14	0.932	0.789	0.983	0.944
		+Q	16	0.972	0.838	0.982	0.893
Italian	EN	Q	6	0.851	0.937	0.986	0.870
	IT	Q	6	0.850	0.975	0.925	0.944
AVG bdg ^{ave}				0.899	0.880	0.958	0.915

Evaluation Results

Nationality	Language	Gender	#Users	bdg ^{ave} for S _{BIO} ^{I6}			
				Ω_{LSB}^*	Ω_{2A2W}^*	Ω_{MS}^*	Ω_{SS}^*
				German	English	+O	7
O	9	1.000	0.886			0.980	0.993
O	16	0.998	0.885			0.988	0.987
German	+O	2	1.000		0.317	0.700	0.842
	O	3	1.000		0.673	0.926	0.940
Indian	English	+O	2	1.000	0.400	1.000	0.861
		O	14	1.000	0.710	0.998	0.980
		O	16	0.999	0.714	0.968	0.964
Italian	EN	O	6	0.999	0.826	0.943	0.990
	IT	O	6	0.997	0.952	0.991	0.991
AVG bdg^{ave}				0.999	0.786	0.971	0.974

Evaluation Results

Watermark Recommendation

	Time Domain	Wavelet Domain	Frequency Domain	
Algo.	Ω_{LSB}	Ω_{2A2W}	Ω_{MS}	Ω_{SS}
Capacity	✓	✓	✗	✗
Transparency	8 Bit Audio Test Set			
	0.899	0.880	0.958	0.915
	16 Bit Audio Test Set			
	0.999	0.786	0.971	0.974

Summary

- Application scenario used for digital watermarking algorithm evaluation
- Biometric Difference Grade enhanced and used as transparency measurement
- Evaluation results show:
 - Transparency and Capacity have to be sufficient
 - WM working in frequency domain does not provide enough marking positions
- Best Performance: time and wavelet domain
- Open: effect of robustness/complexity/security on the WM recommendation

Questions?