

When to fuse two biometrics

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TIFF (Uncompressed) decompressor
are needed to see this picture.

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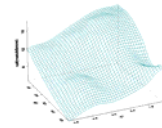
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motivation

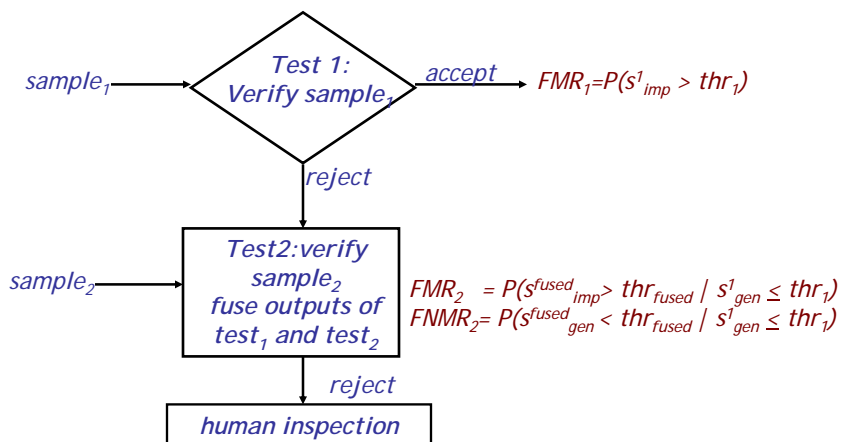
performance vs. efficiency

- biometric fusion improves the accuracy of biometric recognition, alleviates problem with noisy data, high failure to enroll, and intrusion
 - many literature on *how* to fuse (Kittler et. al, Wang et al, Toh et al, Jain et al, ...)
- however fusion requires acquisition and processing of more sample, and therefore increases the overall cost and complexity
 - none on *when* to fuse

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contingent fusion



$$FMR_{total}(\tau_1, \tau_2) = 1 - P(\text{neither test}_1 \text{ nor test}_2 \text{ produces False Match})$$

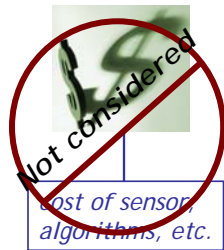
$$FMR_{total}(\tau_1, \tau_2) = 1 - (1 - FMR_1(\tau_1)) (1 - FMR_2(\tau_2))$$

$$FNMR_{total}(\tau_1, \tau_2) = FNMR_1(\tau_1) FNMR_2(\tau_2)$$

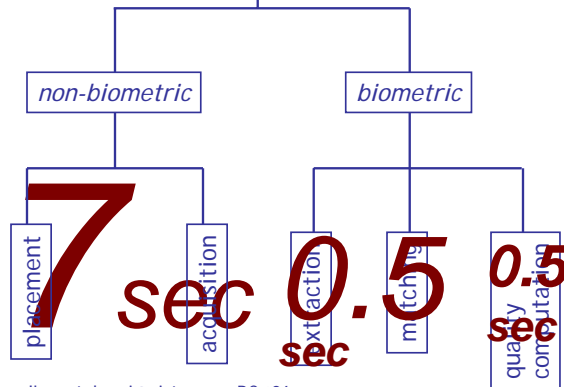
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cost of a biometric system



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objective function

$$\begin{aligned} & \text{minimize } C_{total}(\tau_1, \tau_2) \\ & \text{subject to } FMR_{total} \leq f \end{aligned}$$

where

$$C_{total}(\tau_1, \tau_2) = c_1 + c_2 \cdot FNMR_1(\tau_1) + c_3 \cdot FNMR_{total}(\tau_1, \tau_2)$$

f = maximum allowable false match rate

c_1 = transaction and processing time for test₁

c_2 = transaction and processing time for test₂

c_3 = time a human needs to check the claim of identity

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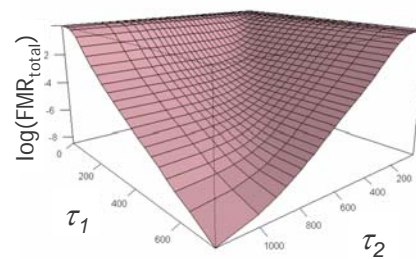
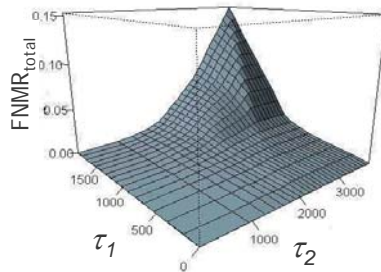
cost per fusion type

	contingent fusion	always fusing
multi-instance	$c_1 + c_1 FNMRI(\tau_1) + c_3 FNMRI(\tau_1, \tau_2)$	$2c_1 + c_3 FNMRI(\tau_1, \tau_2)$
multi-algorithm $c_2 = 1.5 \text{ sec}$	$c_1 + c_2 FNMRI(\tau_1) + c_3 FNMRI(\tau_1, \tau_2)$	$c_1 + c_2 + c_3 FNMRI(\tau_1, \tau_2)$
multi-modal $c_2 = 15 \text{ sec}$	$c_1 + c_2 FNMRI(\tau_1) + c_3 FNMRI(\tau_1, \tau_2)$	$c_1 + c_2 + c_3 FNMRI(\tau_1, \tau_2)$

$c_1 = 7.5 \text{ sec}$ $c_3 = 15 \text{ min}$

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solving the objective function empirically



multi-instance sum fusion

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fusion schemes

- decision level fusion

- sum score fusion

$$S_{fused} = S_{test_1} + S_{test_2}$$

- quality based log likelihood fusion

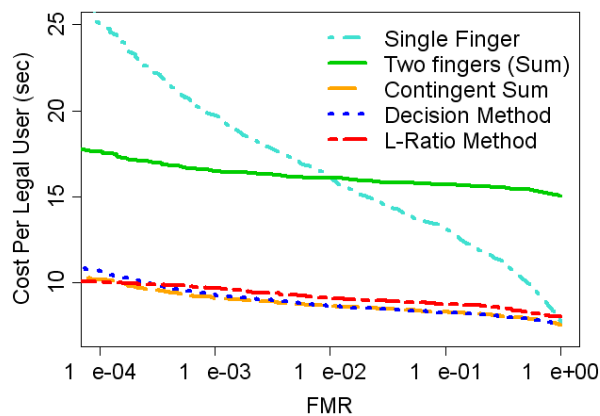
$$S_{fused} = \log \frac{m_1(s:q=j)}{n_1(s:q=j)} + \log \frac{m_2(s:q=k)}{n_2(s:q=k)}$$

$m_i(s:q=j)$ and $n_i(s:q=j)$ are genuine and impostor probability distribution function of test_{*i*}, (*i*=1,2) of samples with quality (NFIO) *j*, empirically computed while *j,k*=1,...,5 correspond to the qualities of samples presented to test₁ and test₂.

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multi-instance cost vs. FMR_{total}



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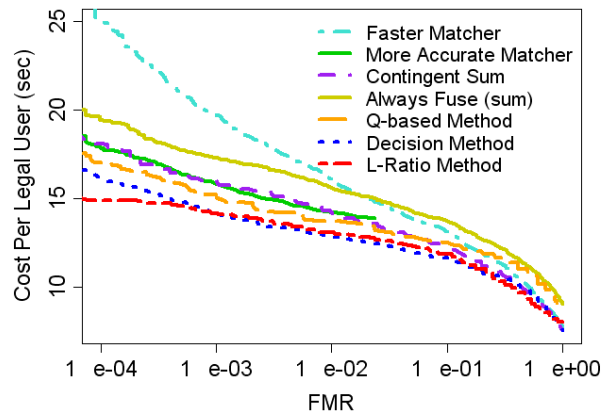
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multi-instance FNMR_{total} @ FMR_{total}=0.001

	FNMR _{total}	cost(sec)
single-instance	0.0136	19.7
contingent decision	0.0019	9.3
contingent sum	0.0016	9.1
contingent L-ratio	0.0017	9.7
always sum	0.0016	16.5

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multi-algorithm cost vs. FMR_{total}



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multi-algorithm

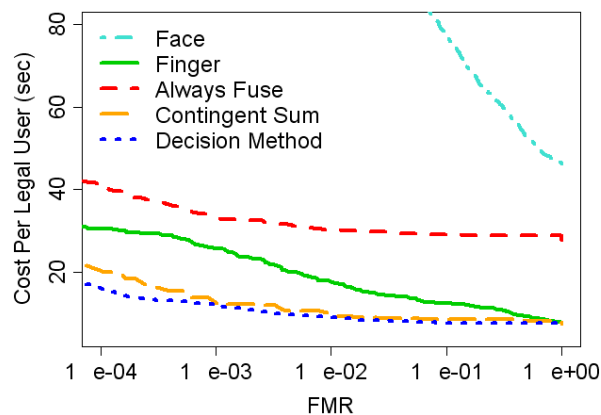
$\text{FNMR}_{\text{total}} @ \text{FMR}_{\text{total}} = 0.001$

	$\text{FNMR}_{\text{total}}$	cost(sec)
single alg - test ₁	0.0136	19.7
single alg - test ₂	0.0082	15.8
contingent decision	0.0074	14.2
contingent sum	0.0093	15.9
contingent L-ratio	0.0068	14.1
quality-based bypassing test ₁ for samples with NFIQ=4,5	0.0078	15.1
always sum	0.0092	17.3

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multi-modal

cost vs. $\text{FMR}_{\text{total}}$



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multi-modal

$\text{FNMR}_{\text{total}} @ \text{FMR}_{\text{total}} = 0.001$

	$\text{FNMR}_{\text{total}}$	cost(sec)
unimodal-finger	0.0205	25.9
unimodal-face	0.18	181.8
contingent decision	0.0042	11.8
Contingent sum	0.0065	13.8
always sum	0.0067	33.5

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conclusion

- all contingent fusion schemes (decision, sum fuse, likelihood ratio) consistently provide better performance (error rate and cost) than always fusing two-biometric method
- cost decreases about linearly with the log of the false match rate
- contingent decision fusion, while the simplest, works almost as well as contingent sum or likelihood ratio
- contingent multi-modal and multi-instance are more effective than contingent multi-algorithm

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Thank you.

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