Computationally Efficient Serial Combination of Rotation-invariant and Rotation Compensating Iris Recognition Algorithms

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Introduction

With the increasing popularity of biometrics, iris recognition has received attention due to its reliability and stability. The processing time required for large scale biometric systems in identification mode is a major topic, especially in distributed application scenarios including weak and low-power sensor devices.

The basic idea of extracting local intensity variations from iris texture has been followed by many algorithmic approaches, including the commercially most successful algorithm of J. Daugman. All these approaches share the property of being sensitive against eye tilt, i.e. they are intrinsically not rotation invariant due to the usage of local spatial information. Therefore, in order to compensate potential rotation, in all these algorithms the templates in the matching process are shifted against each other for a certain amount, and taking the minimal template distance among all shifted versions as the actual distance.

Obviously, depending on the amount of shift that is required for a certain application (i.e. the amount of rotation that is to be expected), these operations may amount to a significant number of matching operations performed, which can become prohibitive in an identification scenario.

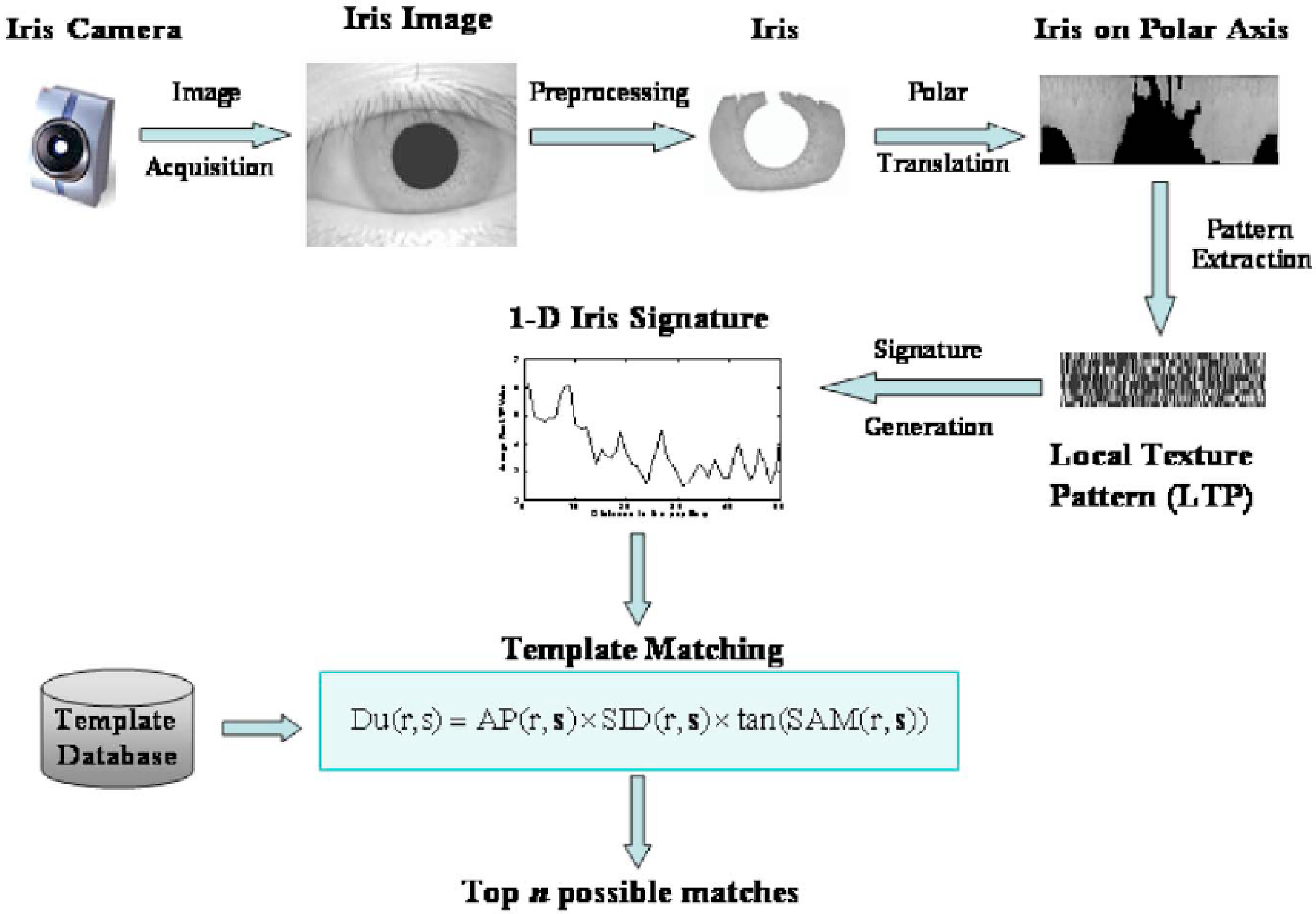
Serial Classifier Combination

Rotation-invariant iris features therefore represent an attractive alternative. Due to the significant computational demand associated with transform domain processing, spatial domain techniques working directly on the iris texture are of specific interest in our context.

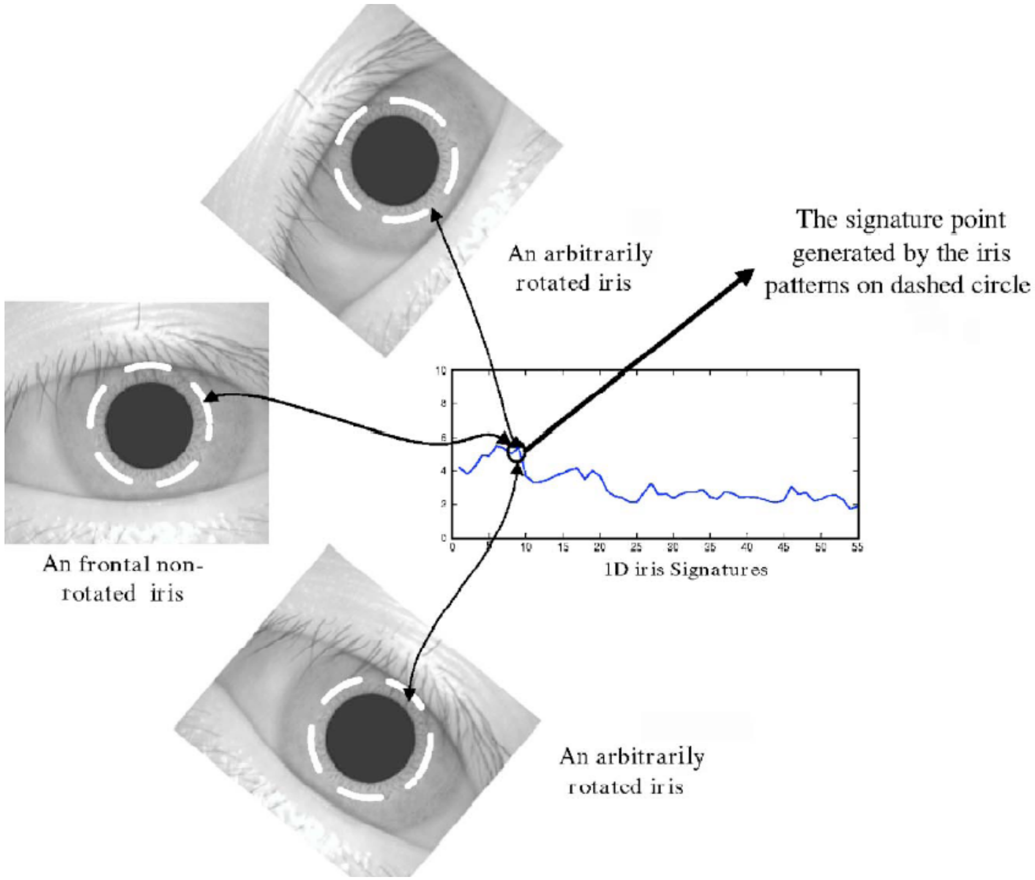
Existing rotation-invariant techniques are successful in providing fast matching procedures, but fail in terms of recognition accuracy.

This is where our approach comes in: We combine a spatially-based **fast** rotation invariant iris recognition approach with a traditional local-feature based scheme into a serial classifier combination. The aim is to result in reduced overall computational demand as compared to classical rotation compensating schemes while at least maintaining their recognition accuracy. This is achieved by using the first scheme to determine a certain amount of the highest matching ranks of the entire database (this can be done quickly due to the high speed of the first scheme), while the second (and more accurate) scheme is then only applied to this predetermined subset to determine the final matching result.

Rotation-invariant Screening: Du et al.



Rotation-invariant Screening: 2D Extension



<u>2-D Extension</u>: Combine idea of Du et al. with histogram-based features which are rotation invariant as well – instead of using a single moment per iris-line, we use a histogram for each line. Histograms of different iris textures are compared on a per-line basis and the differernces are accumulated afterwards.

Rotation-compensating Iris Code

For the original iris code the polar images are subject to a 2D complex Gabor filtering process, subsequently the available phase information is quantized into four different levels, one for each of the four possible quadrants in the complex plane. Hence, for each pixel of the polar image, two bits are obtained which are combined and form the iris template (i.e. iris code) which can be compared to other iris codes by computing the Hamming distance.

This measure is highly localized and needs to compensate for possible rotation between irises – this is done by applying the Hamming distance calculation several times while shifting the polar images against each other. The lowest matching value then determines the final distance.

We use an open-source MatLAB implementation which applies a 1D Gabor-filter version of the iris code strategy for iris recognition. Due to its free availability and the lack of other publicly available iris recognition software, it has gained significant popularity in the community.

Experimental Settings: Iris Databases

For each database two different subsets are selected – a subset of users enrolled in the database, and another subset of impostors not being enrolled in the database and therefore unknown to the system (we aim at the open set identification scenario).

- **CASIA V1.0**: 756 images acquired from 108 eyes (7 images per eye), the first subset contains 630 iris images and the second subset combines 126 images.
- **CASIA V3.0 Interval**: The first subset consists of 1705 iris images acquired from 341 different eyes (5 images for each eye). The second subset includes 117 images from 53 eyes with various numbers of images per eye.
- **MMU V1.0**: The first dataset is composed of 400 iris images from 80 eyes, while the second set contains 50 images (again 5 images per eye).

Experimental Settings: Parameters

Out of all datasets, we extract polar iris images with 360×65 pixels, which results in 1D/2D signatures with length 59 since only 59 out of 65 LTP rows are used.

In the open-set scenario (or watchlist scenario) it is not guaranteed that the person that should be identified is truly member of the database. Hence, an identification attempt results in a correct detection and identification whenever an enrolled person is correctly recognized. If a not enrolled person is falsely labelled as database member, the attempt will result in a false alarm. The detection and identification rate as well as the false alarm rate is used in order to assess this type of system.

The amount of top ranked templates identified by the pre-screening and further passed-on to the second stage is denoted p. With respect to serial classifier combination, we investigate the proposed scheme for $p = 1, 5, 10, 15$. Rotation compensation for the "pure" iris code technique is conducted with 2, 4, and 8 shifts of the iris code in each direction (which sums up to 17 Hamming distance calculations for 8 shifts), for the serial combination rotation compensation is conducted using 8 shifts in the second stage of the identification.

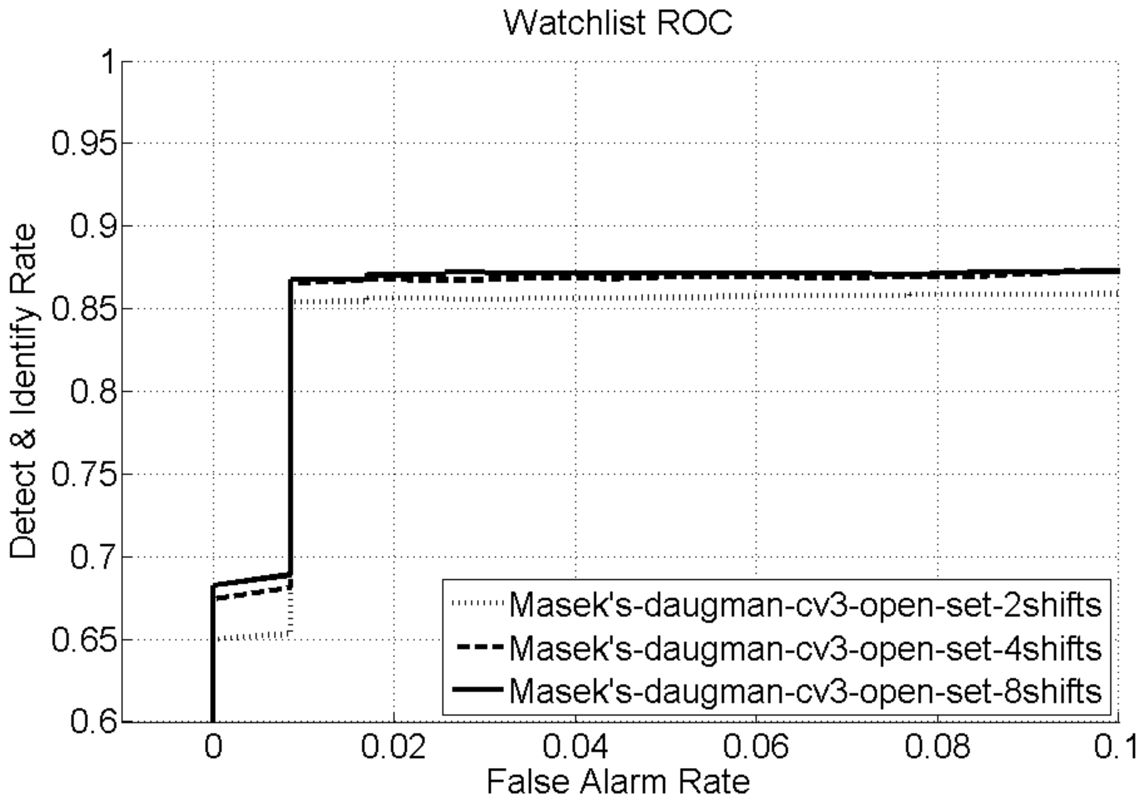
Results: Computational Impact of Rotation Compensation

	Du	Iris code 2s	Iris code 4s	Iris code 8s
Cv1	12.5 s	77.2 s	105.8 s	176.3 s
Cv3	32.1 s	215.7 s	322.7 s	507.1 s
MMU	8.1s	48.3 s	69.3 s	111.5 s

Note: The 2s(hifts) rotation compensation already involves 5 Hamming distance computations !

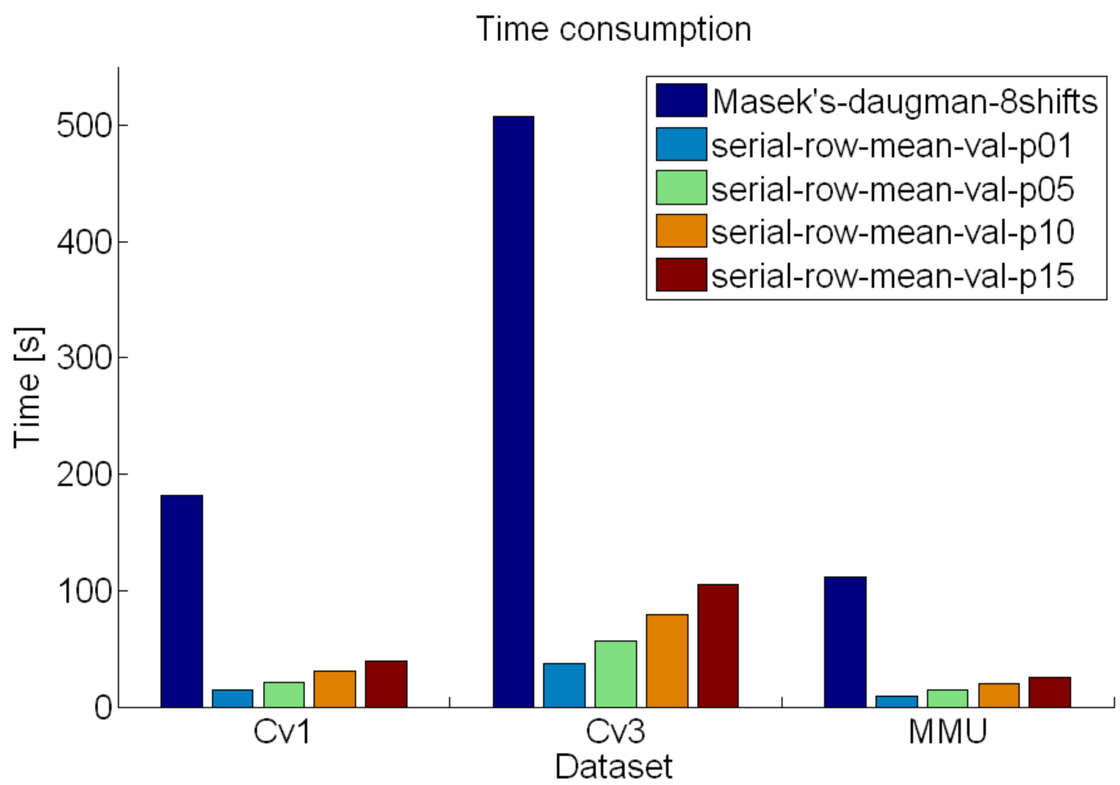
$\longrightarrow$ As expected, rotation compensation is expensive, contrasting to the inexpensive rotation-invariant feature extraction !

Results: Recognition Accuracy Impact of Rotation Compensation



$\longrightarrow$ Rotation compensation especially improves accuracy for the important case of lower false alarm rates !

Results: Computational Efficiency of Serial Combination (1D Signatures)



$\longrightarrow$ Even for $p = 15$, the time reduction as compared to the pure Iris Code scheme is impressive !

Results: Computational Efficiency of Serial Combination (2D Signatures)

2-D signatures					
	IC8s	S2Dp1	S2Dp5	S2Dp10	S2Dp15
Cv1	181.5 s	19.7 s	27.0 s	35.0 s	45.0 s
Cv3	507.1 s	52.5 s	71.7 s	95.7 s	120.0 s
MMU	111.5 s	13.4 s	18.1 s	23.9 s	29.8 s

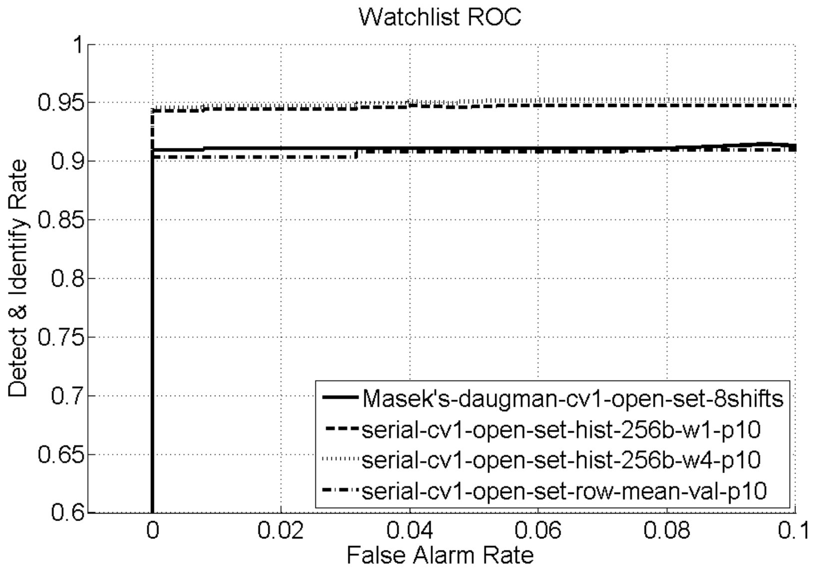
$\longrightarrow$ Although the application of 2D signatures raises the computational effort, with $p = 10$ the serial approach is faster by a factor of 5 !

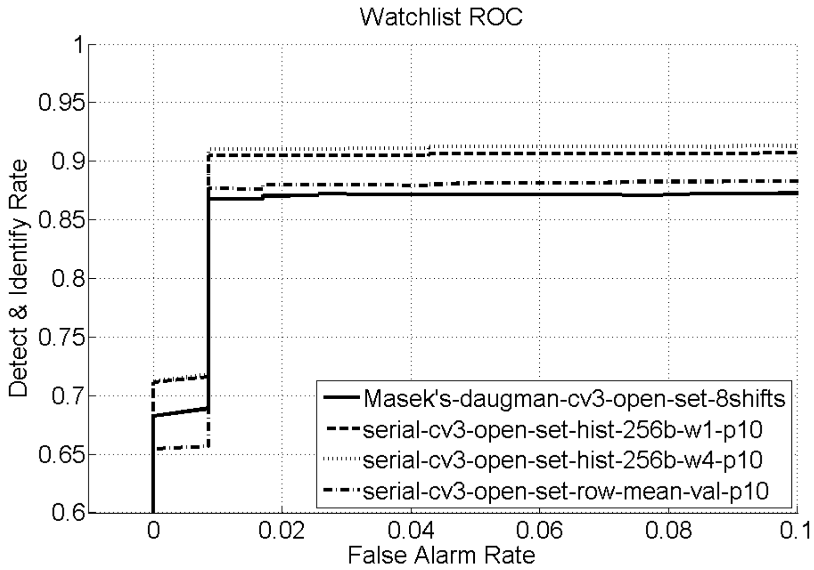
Results: Recognition Accuracy of Serial Combination

Casia V1.0					
FAR	IC8s	S1Dp1%	S1Dp5%	S1Dp10%	S1Dp15%
0%	90.9%	81.6%	88.1%	90.3%	**91.9%**
0.79%	91.1%	81.6%	88.6%	90.3%	**91.9%**
11.1%	91.1%	81.9%	89.2%	91.1%	**92.5%**
CASIA V3.0					
FAR	IC8s	S1Dp1%	S1Dp5%	S1Dp10%	S1Dp15%
0%	68.3%	69.2%	**76.1%**	65.5%	66.2%
0.85%	86.7%	77.9%	85.8%	87.7%	**88.4%**
11.1%	87.4%	78.4%	86.3%	88.3%	**89.0%**
MMU V1.0					
FAR	IC8s	S1Dp1%	S1Dp5%	S1Dp10%	S1Dp15%
0%	**84.5%**	49.8%	68.8%	73.8%	76.8%
0.85%	**85.8%**	52.5%	71.3%	75.8%	78.8%
11.1%	**86.0%**	53.3%	71.8%	76.3%	79.3%

$\longrightarrow$ Recognition performance of serial combination depends on the database investigated; increasing p can in some cases decrease accuracy (due to a lower chance for false positives when the pre-selected set is smaller).

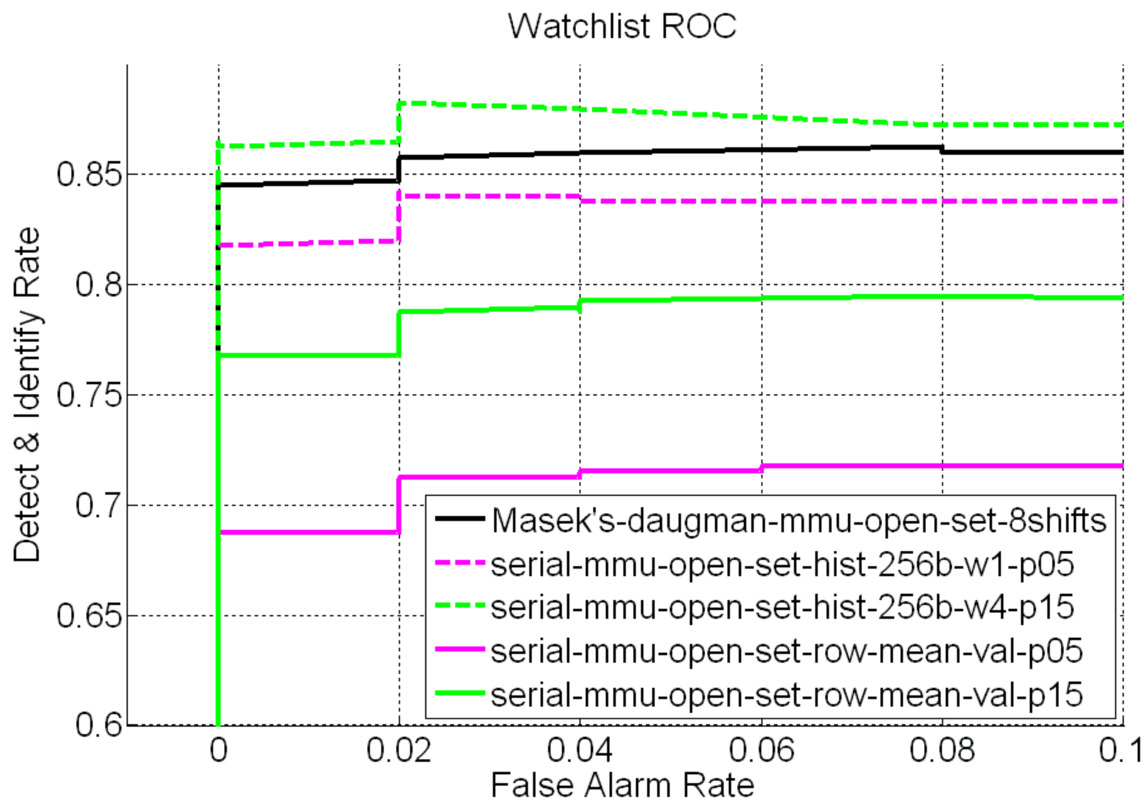
Results: Recognition Accuracy of Serial Combination (2D Signatures, CASIA V1 & V3)





⟶ 2D signatures additionally clearly improve accuracy, weighting brings an additional small gain for the data observed.

Results: Recognition Accuracy of Serial Combination (2D Signatures, MMU)



$\longrightarrow$ for $p = 15$ and weighting applied, the serial combination is able to outperform the iris Code approach for MMU data.

Conclusion

- We are able to reduce computational demands with our proposed serial classifier combination considerably.
- At a comparable recognition accuracy we suffice with 20% - 30% or even less computation time for identification (the actual value depends on the specific dataset considered).
- We are even able to outperform the recognition accuracy of iris code based recognition, since the serial classifier combination technique turns out to be more robust against false acceptances.
- **Future Work**: Currently, the rank information as obtained by the rotation invariant pre-selection stage is not used in the final decision which can be employed in a classifier fusion rule.
- **Future Work**: Which dataset property leads to good serial combination accuracy and which property does degrade this performance ?

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Thank you for your attention !

Questions ?