Modelling the odds of false acceptance and false rejection of a privacy-preserved multimodal system involving face modality

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Talk abstract

In this talk, I propose a likelihood ratio framework that can model the odds of false acceptance and false rejection of the performance of a multimodal biometric system involving face and two palms. The methodology is generic and can be applied to any unimodal or multimodal systems.

To cope with limited training data, the quality conditions (which are manually annotated) are assumed to be independent of each other. Moreover, it is also assumed that there is no distinction between a probe sample and a gallery template.

This model was applied to a field study taking place in Africa. The software used Trust Stamp's privacy-preserved biometric representation known as Irreversibly Transformed Identity Token, or IT2.

Despite using the simplified assumptions above and that the model can only observe the fused score (without access to the underlying matching scores of the individual modalities), the model is found to be powerful enough to explain capture conditions that favour the face and palm biometric modalities *individually*.

For instance, the model found that, for the face modality, dark lighting increases the odds of false rejection and false acceptance at the same time; whereas indoor/well-lit conditions improve the odds of true acceptance and true rejection at the same time. Outdoor direct sunlight, on the other hand, increases false acceptance whereas outdoor shade improves the true rejection. This forms lighting-based intervention that can be used to build a gallery. In addition to the lighting-based intervention, a full intervention consist of taking off glasses and hats for the face modality and cleaning palms for the contactless palmprint modality.

Identification experiments were simulated with varying proportions of templates fulfilling the above interventions in the gallery without subjecting the probe samples to the same interventions. If the same interventions were applied to the probe samples, the identification error rates can improve even further, thus demonstrating the effectiveness of the proposed LLR model in relating biometric performance to the capture conditions.

- Project requirements:
  - Contactless biometrics – left and right palms and face
  - Biometric data never leaves the device
  - All biometric templates are represented using Trust Stamp's Irreversibly Transformed Identity Token, or IT2 (privacy-preserved biometrics) which was delivered in the form of an Android SDK
  - Must support 1:1 and 1:N at scale on device
  - Must operate offline most of the time. The biometric gallery is synched to server when it has access to the Internet
  - Affordable Android devices

Goal: Understand the factors that influence the multimodal smartphone-based capture solution in *the privacy-preserved domain (IT2)*

Training | Inference

Recruit volunteers → Capture images under specific conditions for face and palm → Aggregate data (IT2 tokens, capture conditions) → Fit statistical model → Identify “interventions” → Measure performance based on interventions

q

Binary covariates

Face

covar	value
⊟F.Facial Hair	No
	Yes
⊟F.Flashlight	Off
	On
⊟F.Lighting	Dark Light
	Indoor-Well Lit
	Outdoor/direct sun/overhead
	Outdoor/shade
	Semi dim condition
⊟F.Position	Full frontal
⊟F.Surface	Altered/dirty
	Unaltered
⊟F.wear_glasses	FALSE
	TRUE
⊟F.wear_hat	FALSE
	TRUE

Palm

covar	value
⊟P.Flashlight	On
⊟P.Lighting	Indoor/Dark-Lit
	Indoor/Dim-Lit
	Indoor/Well-Lit
	Outdoor/direct sun
	Outdoor/shade
⊟P.Surface	Dirty
	Unaltered

$q \in \{present, absent\}$

How to improve the “odds” of a correct outcome?

- Definition of a correct outcome

	System accepts claim	System rejects claim
Mated comparison, ω_1	Correct Acceptance	False Rejection
Nonmated comparison, ω_0	False Acceptance	Correct Rejection

$$P(correct|\boldsymbol{q}, y) = \sum_{\omega \in \{\omega_o, \omega_1\}} P(correct|\boldsymbol{q}, \omega) P(\omega|y)$$

CR

CA

If we can pick a subset of $\boldsymbol{q} = [q_0, q_1, \dots]$ as interventions, we can improve the odds of success

Map a comparison score to probability

Naïve Bayes assumption

Var	Domain	meaning
o	$o \in \{correct, wrong\}$	Outcome of the comparison: correct means true acceptance and true rejection
$\boldsymbol{q}$	$q = [q_1, \dots, q_Q]$	Quality conditions assigned during data collection. They contain the quality conditions of template and probe.
ω	$\omega \in \{\omega_o, \omega_1\}$	Non-mated and mated comparison, respectively
$P(\omega\|y)$	Probability (normalised score)	Calibrated probability, mapping from distance y to probability score

$$P(correct|\boldsymbol{q}, y) = \sum_{\omega \in \{\omega_o, \omega_1\}} P(correct|\boldsymbol{q}, \omega) P(\omega|y)$$

Naïve Bayes

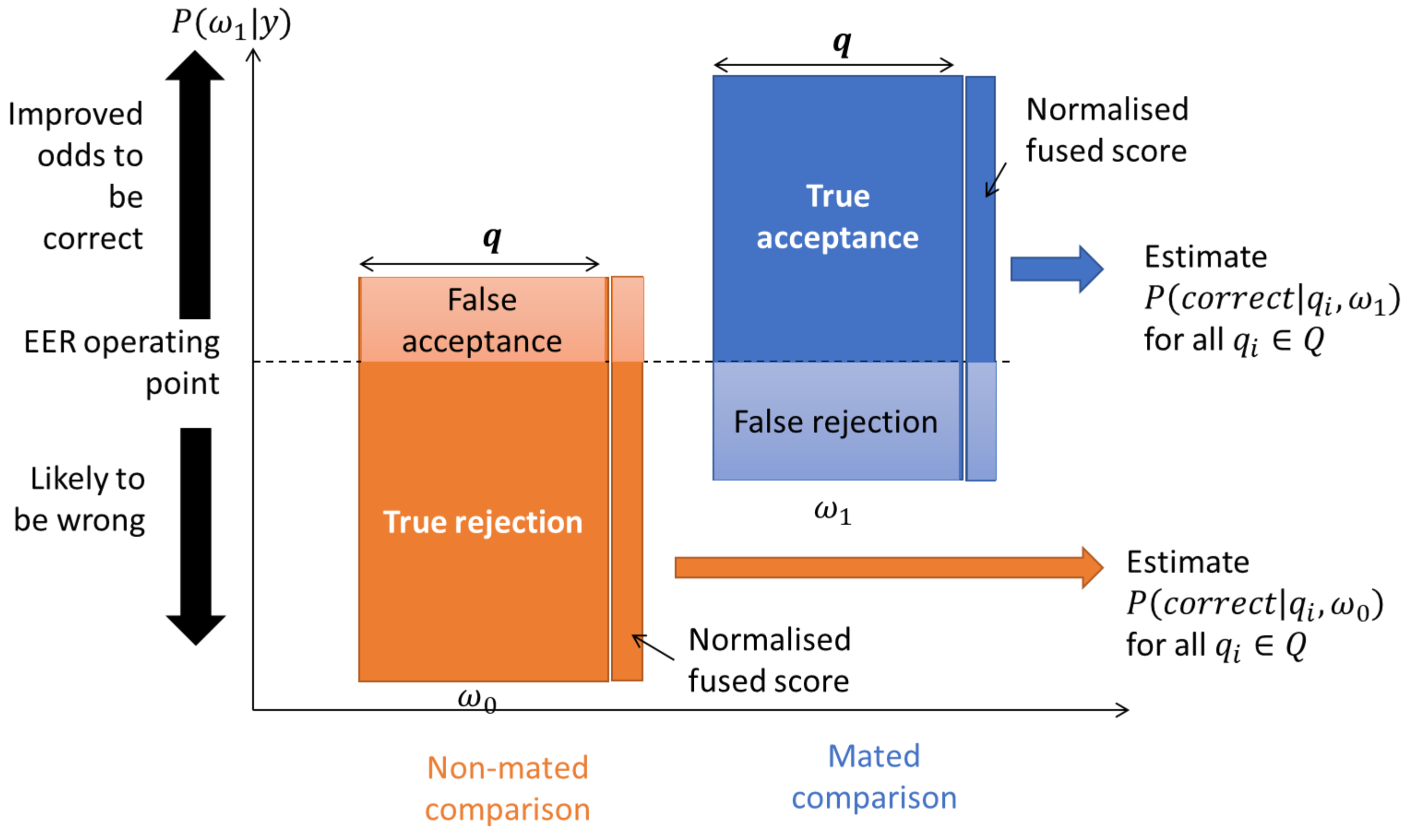
$$P(correct|\boldsymbol{q}, y, NB) = \sum_{\omega \in \{\omega_o, \omega_1\}} \prod_{i \in \{1 \dots Q\}} P(correct|q_i, \omega) P(\omega|y)$$

Don't care if it is a template or a probe

Terms	Meaning
$P(correct\|q_i, \omega_0)$	Probability of true rejection for quality condition q_i
$P(correct\|q_i, \omega_1)$	Probability of true acceptance for quality condition q_i

Bottom line: By estimating the probability of a correct decision, we can determine which covariates (quality conditions) are important.

Work in the log-likelihood ratio domain



$$LLR(q|\omega_1) = \log \frac{P(correct|q, \omega_1)}{P(wrong|q, \omega_1)} - CR$$

What is the merit of quality condition q to improve the odds of True Acceptance over False Rejection?

$$LLR(q|\omega_0) = \log \frac{P(correct|q, \omega_0)}{P(wrong|q, \omega_0)} - CR$$

What is the merit of quality condition q to improve the odds of True Rejection over False Acceptance?

LLR Estimator

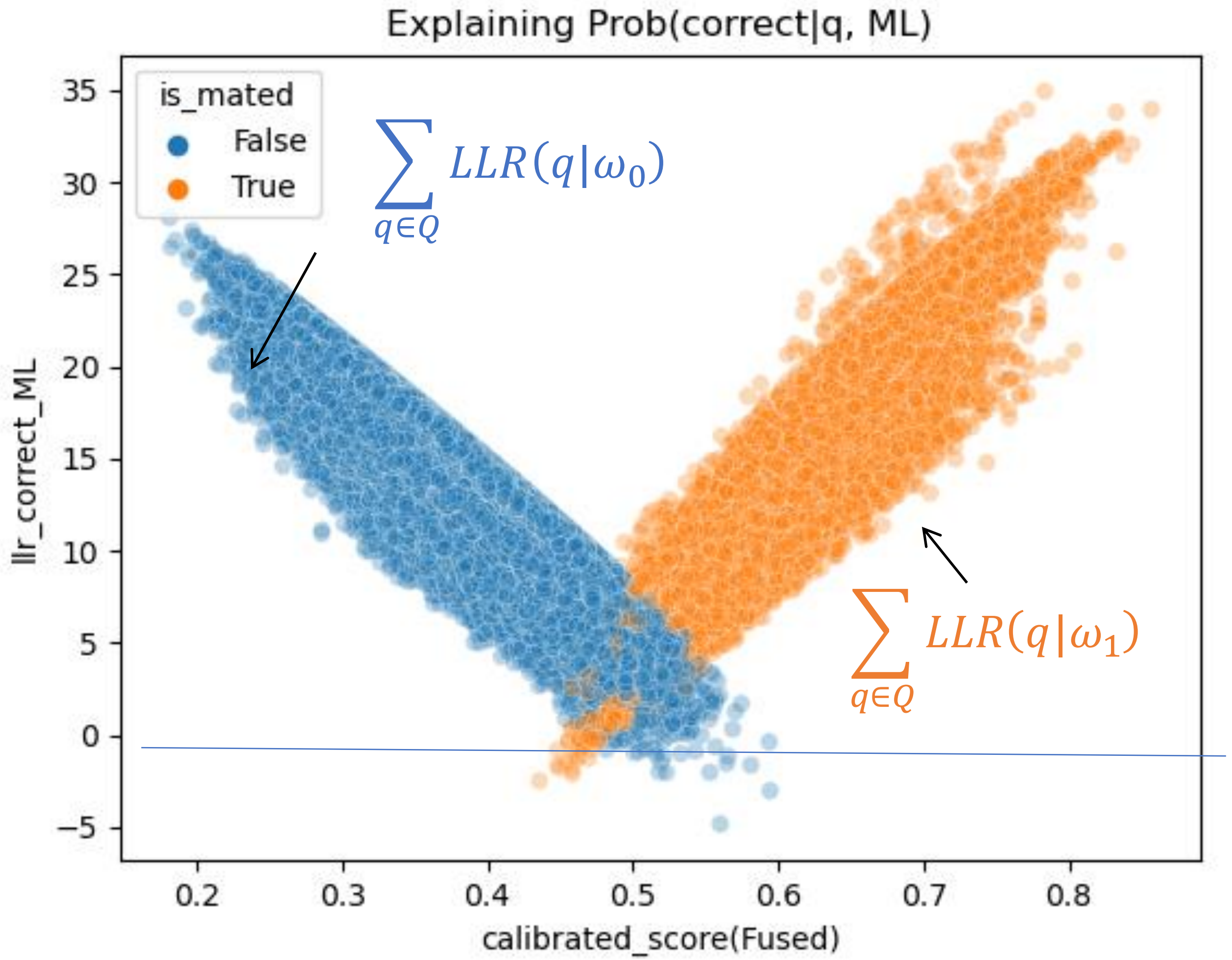
$$LLR(q|\omega) = \log \frac{\#\ correct\ \omega|q + 1}{\#\ wrong\ \omega|q + 1}$$

$$CR = \log \frac{P(correct)}{P(wrong)}$$

How well does the model fit the data?

Improved odds to be correct

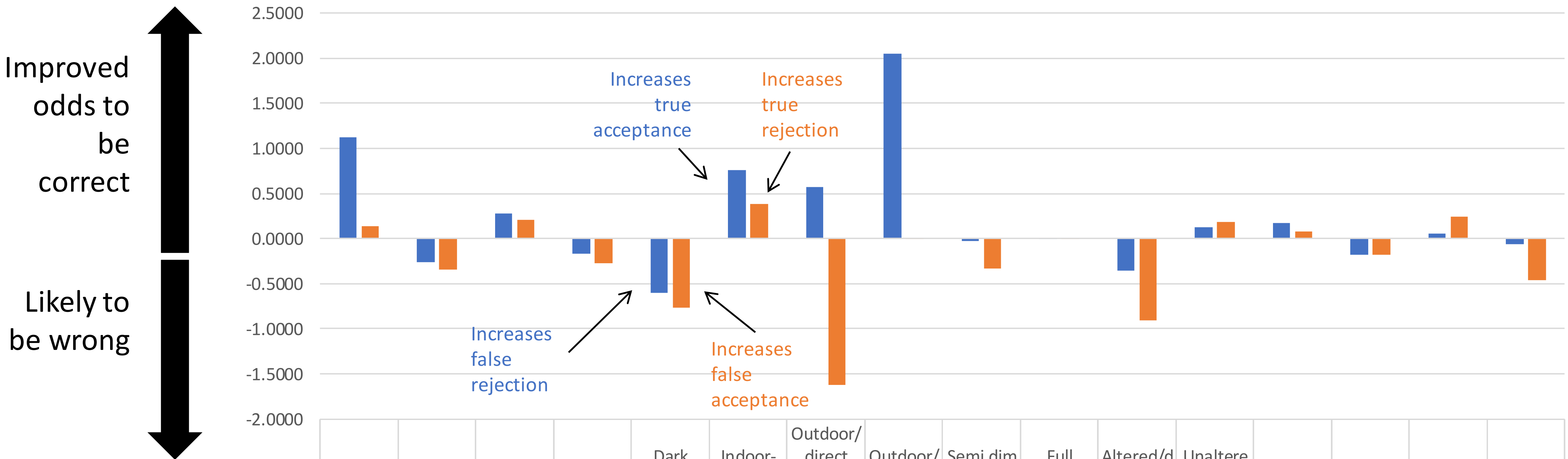
Likely to be wrong



Bottom line: The model fits the data very well, capable of explaining True acceptance and True rejection. So, in the subsequent slides, we are going to interpret the LLR for each individual quality condition (the covariate).

Face covariates

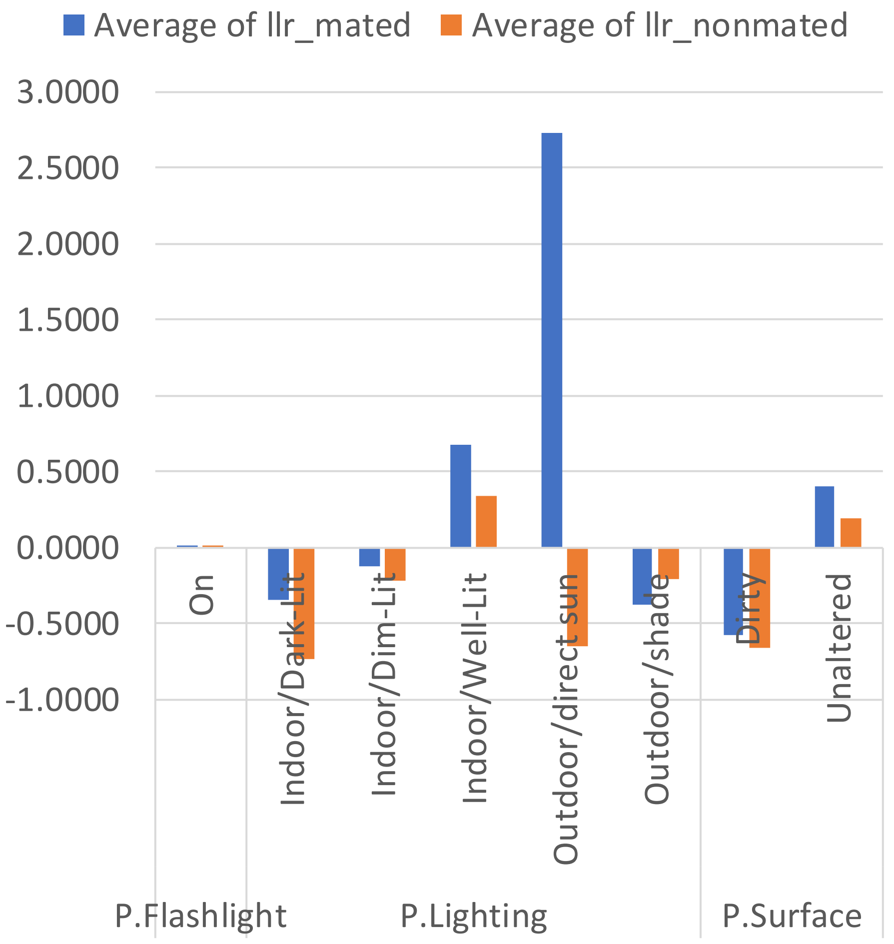
- Flashlight off, indoor well-lit, outdoor shade
- Take off glasses and hat
- Although no facial hair is better, it requires people to shave – this may not be culturally acceptable

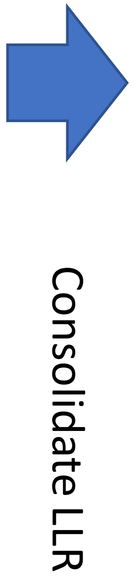


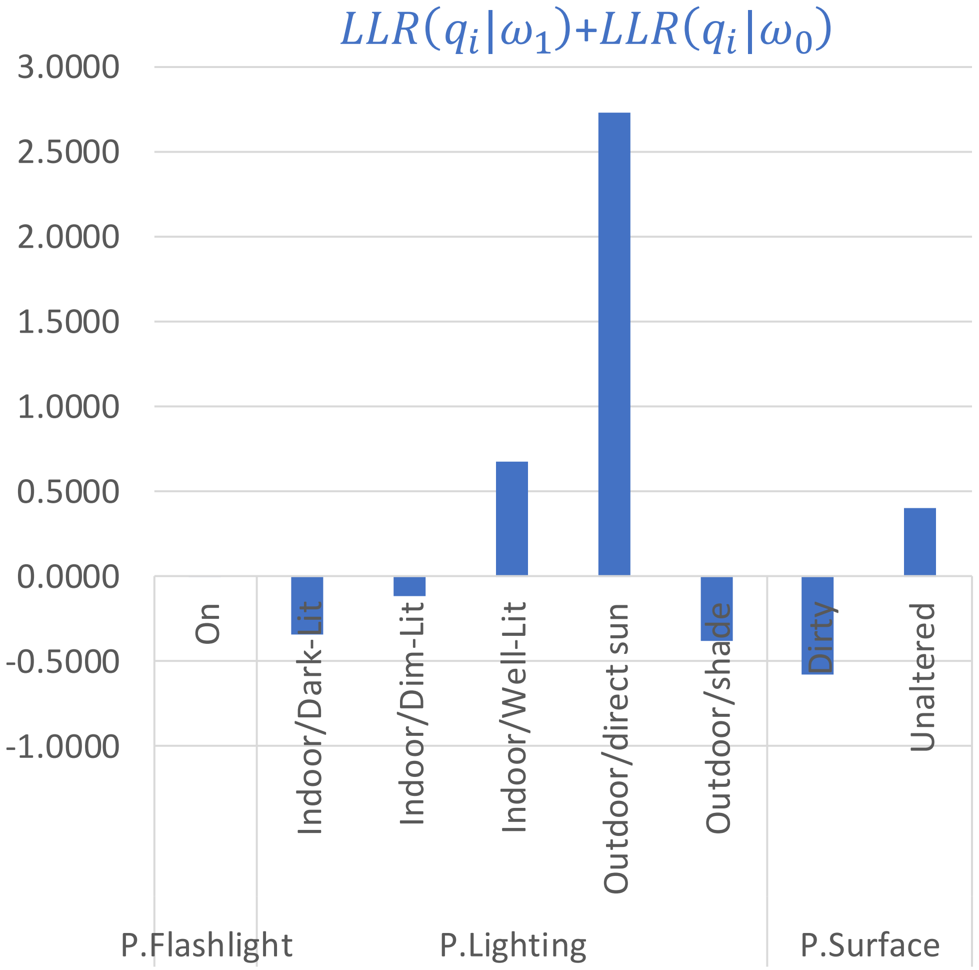
	F.Facial Hair		F.Flashlight		F.Lighting					F.Position	F.Surface		F.wear_glasses		F.wear_hat	
	No	Yes	Off	On	Dark Light	Indoor-Well Lit	Outdoor/direct sun/over head	Outdoor/shade	Semi dim condition	Full frontal	Altered/dirty	Unaltered	FALSE	TRUE	FALSE	TRUE
Average of llr_mated	1.1249	-0.2633	0.2733	-0.1640	-0.6000	0.7587	0.5733	2.0499	-0.0261	0.0001	-0.3617	0.1210	0.1689	-0.1837	0.0502	-0.0662
Average of llr_nonmated	0.1404	-0.3419	0.2118	-0.2705	-0.7633	0.3816	-1.6244	0.0089	-0.3328	0.0000	-0.9099	0.1895	0.0823	-0.1771	0.2414	-0.4614

Palmprint covariates

- Outdoor/direct-sun improves true acceptance but worsens false acceptance
- Indoor well-lit and "unaltered" improve both true acceptance and true rejection







Full vs lighting-based intervention

- chosen(t) = apply intervention to the gallery
- chosen(p) = apply intervention to the probe samples
- chosen(t&p) – apply intervention to the gallery and the probes

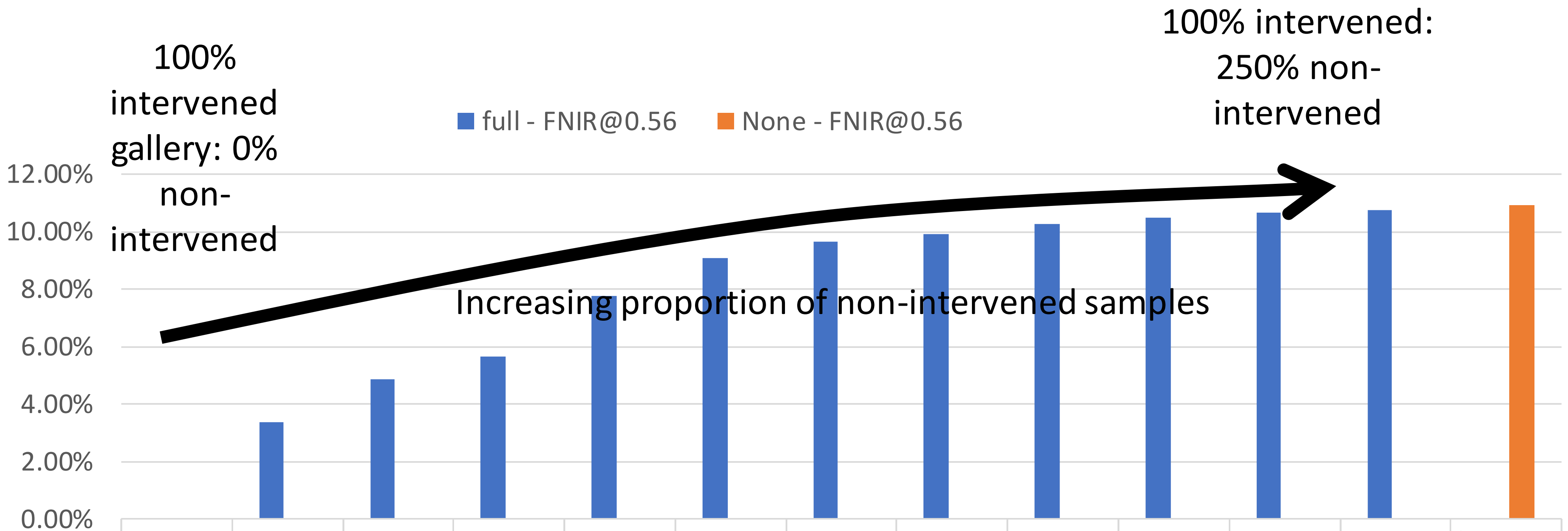
	covar	covar_conditions	full Average of percentage	Sum of count	lighting Average of percentage	Sum of count
Conjunction	**chosen(p)**	chosen(p)	17.39%	1261964	32.86%	2384496
	chosen(t&p)	chosen(t&p)	4.60%	333627	14.27%	1035396
	chosen(t)	chosen(t)	26.54%	1926147	43.50%	3156919
Individual selected criterion	**p.F.Flashlight on/off**	(p.F.Flashlight on/off==Off)	71.78%	5209384	71.78%	5209384
	p.F.Lighting	(p.F.Lighting==Indoor-Well Lit) | (p.F.Lighting==Outdoor/shade)	78.91%	5726147	78.91%	5726147
	p.F.wear_glasses	(p.F.wear_glasses==False)	72.83%	5285290		
	p.F.wear_hat	(p.F.wear_hat==False)	76.85%	5576930		
	p.L.Lighting	(p.L.Lighting==Indoor/Well-Lit)	65.19%	4730569	65.19%	4730569
	p.L.Surface	(p.L.Surface==Unaltered)	89.55%	6498276		
	p.R.Lighting	(p.R.Lighting==Indoor/Well-Lit)	65.19%	4730569	65.19%	4730569
	p.R.Surface	(p.R.Surface==Unaltered)	89.55%	6498713		
	t.F.Flashlight on/off	(t.F.Flashlight on/off==Off)	58.01%	4210046	58.01%	4210046
	t.F.Lighting	(t.F.Lighting==Indoor-Well Lit) | (t.F.Lighting==Outdoor/shade)	64.95%	4713254	64.95%	4713254
	t.F.wear_glasses	(t.F.wear_glasses==False)	67.59%	4904886		
	t.F.wear_hat	(t.F.wear_hat==False)	68.86%	4997222		
	t.L.Lighting	(t.L.Lighting==Indoor/Well-Lit)	55.61%	4035698	55.61%	4035698
	t.L.Surface	(t.L.Surface==Unaltered)	78.45%	5692816		
	t.R.Lighting	(t.R.Lighting==Indoor/Well-Lit)	55.61%	4035698	55.61%	4035698
	t.R.Surface	(t.R.Surface==Unaltered)	80.99%	5877720		

"Either or"

Prefix p means probe, t means template. F means face, L means Left palm, R means Right palm

Full intervention

Face – flashlight off, indoor well-lit, outdoor shade, take off glasses and hat
Palmprint – indoor well-lit, unaltered, outdoor direct sun

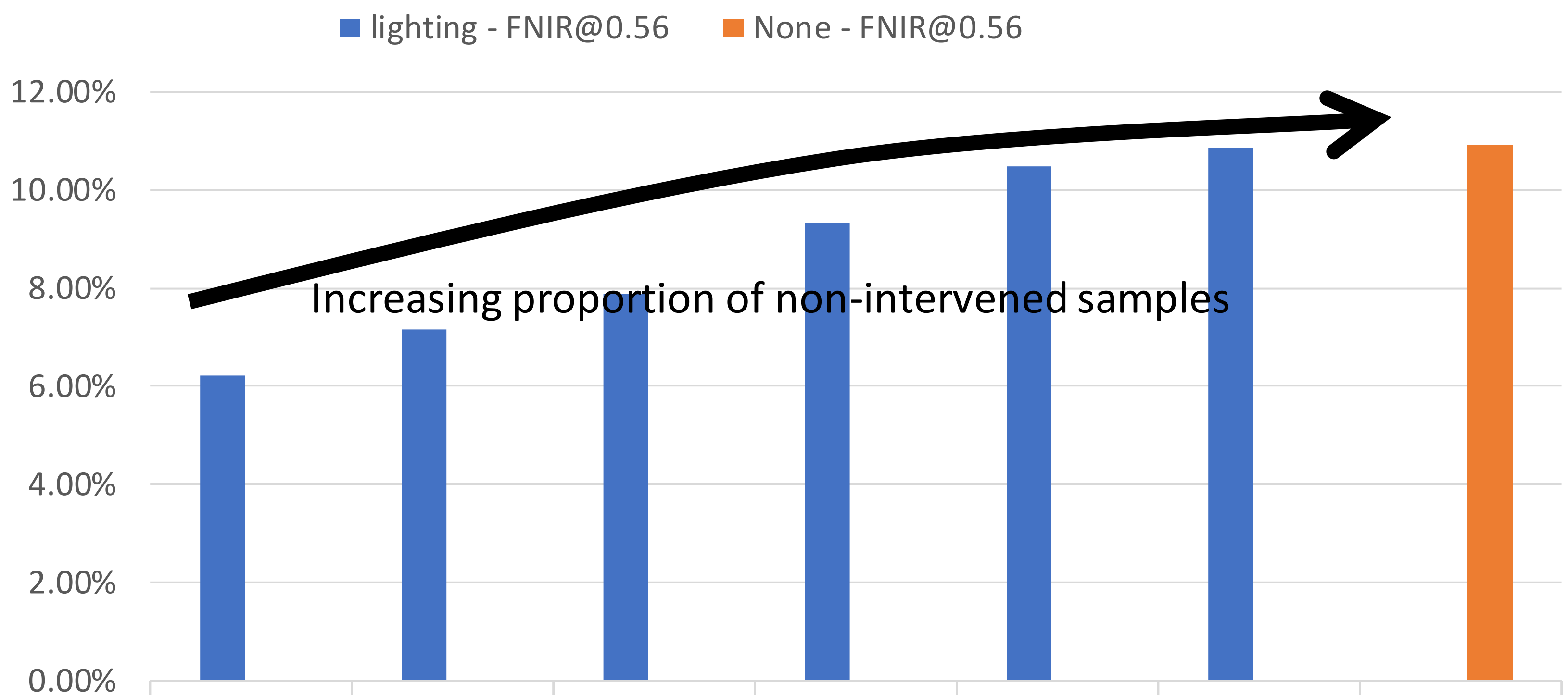


	op chosen(t&p)	op chosen(t)	op chosen(t|~t 0.1)	op chosen(t|~t 0.2)	op chosen(t|~t 0.5)	op chosen(t|~t 1.0)	op chosen(t|~t 1.2)	op chosen(t|~t 1.5)	op chosen(t|~t 1.8)	op chosen(t|~t 2.0)	op chosen(t|~t 2.2)	op chosen(t|~t 2.5)	baseline unfiltered
full - FNIR@0.56	0.00%	3.38%	4.85%	5.63%	7.77%	9.09%	9.64%	9.89%	10.27%	10.47%	10.64%	10.75%	
None - FNIR@0.56													10.91%

Note: FPIR has near zero error values at the identification threshold of 0.56 of the fused score

Lighting-based intervention

Face – flashlight off, indoor well-lit, outdoor shade
Palmprint – indoor well-lit, outdoor direct sun



	op chosen(t)	op chosen(t|~t 0.1)	op chosen(t|~t 0.2)	op chosen(t|~t 0.5)	op chosen(t|~t 1.0)	op chosen(t|~t 1.2)	baseline unfiltered
lighting - FNIR@0.56	6.22%	7.15%	7.88%	9.32%	10.47%	10.86%	
None - FNIR@0.56							10.91%

Summary

- We have developed a statistical method to identify capture conditions that are favourable during registration.
- The method only observes the fused score of a multimodal biometric system in the privacy preserved domain (IT2)
- The covariates found form the basis of a lighting-based or a full intervention
- The interventions were validated in the identification setting
- Future work:
  - Apply the same methodology to biometric sample quality (quality measures)
  - Apply it to analyse performance differentials