paravision

Face Recognition Performance Assessment

NIST FRVT 1:N Identification

MARCH 2020
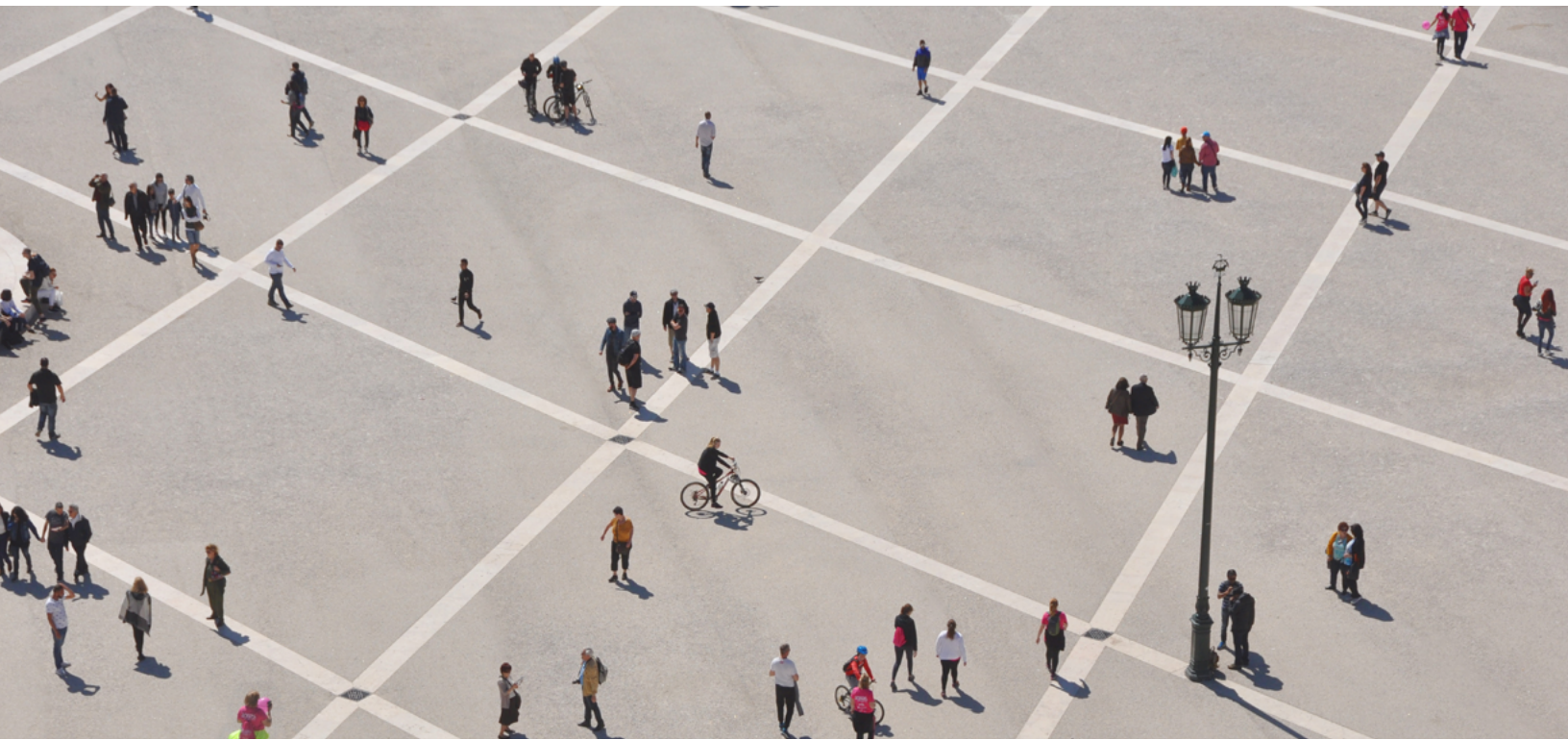
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BACKGROUND

On March 24, 2020, the National Institute of Standards and Technology (NIST) released a new report on the performance of leading face recognition algorithms. The report showed Paravision's strong and continually improving performance across several metrics, earning top ranks in particular on NIST's threshold-based matching and identification mode assessments.

NIST routinely evaluates algorithms on how well they can verify two pictures of the same person (1:1 Verification) and search through large collections of pictures to match an unknown face with an existing identity (1:N Identification). The NIST assessment summarized in this document evaluates algorithms on their 1:N performance.

While the rankings published by NIST separate multiple algorithm versions from a given vendor, the tables in this report track company-level performance, which is measured by each company's top rank (across all of their submitted versions) in any individual NIST metric. This document focuses on identification mode and threshold-based matching rather than investigation mode as the former metrics are more relevant to Paravision's user base.

Performance Highlights

Paravision consistently performed in the top tier when benchmarked against a variety of domestic and international competitors, demonstrating leadership in multiple categories of testing. Some performance highlights include:

- *#1 in the US in 8 of 9 threshold-based matching categories*
- *Top 3 worldwide in identification mode accuracy*
- *Top 3 worldwide in threshold-based matching accuracy*
- *#1 worldwide in profile (side view) matching accuracy*

> With these results, **Paravision is the only company globally to be ranked in the top 5 for NIST FRVT 1:1 and 1:N** (Identification and Threshold-Based Matching) as of March 2020.

Performance Breakdown

Face recognition accuracy is judged on two broad metrics: Type I errors (false positives) and Type II errors (false negatives). False positives occur when a new face is incorrectly matched with a known face in the dataset; false negatives occur when a known face is not matched with its correct identity.

The NIST report's Identification Mode and Threshold-Based Matching scores both assess combined low False Positive Identification Rates (FPIRs) and False Negative Identification Rates (FNIRs).

Identification Mode is a subset of Threshold-Based Matching at FPIR=0.01. Strong performance on these tests shows an algorithm can process a high volume of face submissions accurately with minimal human review. Paravision scored in the top 5 worldwide in 8 of the 10 datasets below, while remaining the best performer in the US in all but one category.

Threshold-Based Matching Company Rankings

	Mugshots			Webcam Probes			Profile Probes		
	FPIR = 0.001	FPIR = 0.01	FPIR = 0.1	FPIR = 0.001	FPIR = 0.01	FPIR = 0.1	FPIR = 0.001	FPIR = 0.01	FPIR = 0.1
1	NEC	NEC	NEC	Sensetime	Sensetime	Sensetime	Microsoft	Paravision	Paravision
2	Sensetime	Sensetime	Sensetime	NEC	NEC	NEC	Sensetime	Microsoft	Microsoft
3	Paravision	Paravision	Paravision	Paravision	Paravision	Yitu	Visionlabs	Sensetime	Visionlabs
4	Yitu	Yitu	Microsoft	Yitu	Yitu	Paravision	Netchlab	Visionlabs	Sensetime
5	Microsoft	Microsoft	Yitu	Microsoft	Microsoft	Microsoft	Dahua	NtechLab	NtechLab

Figure 1: FRVT 1:N Report, March 2020, Tables 19 - 22: Paravision's performance in threshold-based matching relative to competitors on three NIST datasets across a series of False-Positive Identification Rate (FPIR) thresholds.

Identification Mode Company Rankings

	Enroll Lifetime Variable number of enrollment images					Enroll Most Recent Single enrollment image				
	N=0.64M	N=1.6M	N=3M	N=6M	N=12M	N=0.64M	N=1.6M	N=3M	N=6M	N=12M
1	NEC	NEC	NEC	Sensetime	Sensetime	Sensetime	Sensetime	NEC	Sensetime	IIT
2	Sensetime	Sensetime	Sensetime	NEC	NEC	NEC	NEC	Sensetime	NEC	Sensetime
3	Paravision	Paravision	Paravision	Paravision	Yitu	Paravision	Paravision	Paravision	Paravision	Innovatrics
4	Yitu	Yitu	Yitu	Yitu	Dahua	Yitu	Yitu	Yitu	Yitu	NEC
5	Microsoft	Microsoft	Microsoft	Dahua	Paravision	Microsoft	Microsoft	Microsoft	NtechLab	NtechLab

Figure 2: FRVT 1:N Report, March 2020, Tables 23 - 26: Paravision's strong performance in Identification Mode. This is ideal for assessing applications with a high volume of submissions and a low number of prior enrollment photos.

Profile Matching Performance

Figure 3: *A frontal enrollment, frontal probe, and profile probe photo from Figure 5 in the NIST report.*

Paravision performed especially well in NIST's profile-matching tests, where faces turned away from, or perpendicular to the camera could still be identified. Paravision scored #1 worldwide in the profile dataset in investigation and identification mode, and in two of the three threshold-based matching categories.

While these capabilities are still in their nascent stages, the NIST report notes that "a few algorithms correctly match side-view photographs to galleries of frontal photos, with search accuracy approaching that of the best c. 2010 algorithms executing frontal-frontal search.

The capability to recognize a 90-degree change in viewpoint - pose invariance - has been a long-sought milestone in face recognition research."

While Paravision scores highly, there remains room for improvement in matching profile-pose faces. At a highly constrained FPIR of 0.001, Paravision's algorithm has a 39% FNIR - a result which may be too high to be usable across multiple applications despite being the #1 score worldwide. At FPIR = 0.01 and 0.1, Paravision delivers much more usable FNIR, at 18% and 11%, respectively. Paravision's closest competitors have error rates nearly twice those.

Competitor Performance in Profile Threshold-Based Matching

	Company	FPIR = 0.01	Company	FPIR = 0.1
1	**Paravision**	0.181	**Paravision**	0.109
2	Microsoft	0.281	Microsoft	0.198
3	Sensetime	0.311	VisionLabs	0.203
4	VisionLabs	0.317	Sensetime	0.212
5	NtechLab	0.391	NtechLab	0.252

Figure 4: FRVT 1:N Report, March 2020, Tables 19 - 22: Breakdown of competitor performance in threshold-based matching.

Recognizing Aging Faces

As people get older, changes to the face's skin, muscle, and bone structure shift their appearance, sometimes substantially. These changes tend to become more extreme as age progresses. NIST notes that "this is a gradual process affecting all human faces and, absent surgical intervention, is essentially irreversible over long time-scales. Aging increases false negative rates. In some applications aging effects are avoided by policy: faces are re-enrolled periodically. In other applications, this is not possible." Effectively matching aging faces minimizes the number of re-enrollments needed, and makes applications that don't support re-enrollment—like surveillance—operable over a longer time period.

NIST measured the ability of algorithms to match search photos older than enrollment photos by 0 to 18 years, in two-year increments. Paravision achieved a top 3 rank worldwide, and is #1 in the US across all age categories, showing its algorithm's lasting performance even with extended time gaps between search and enrollment photos.

Identification Mode Company Rankings by Number of Years Between Enrollment and Search Photos

	0 - 2	2 - 4	4 - 6	6 - 8	8 - 10	10 - 12	12 - 14	14 - 18
1	Sensetime	Sensetime	Sensetime	Sensetime	Sensetime	Sensetime	Sensetime	Sensetime
2	NEC	NEC	NEC	NEC	NEC	NEC	NEC	NEC
3	**Paravision**	**Paravision**	**Paravision**	**Paravision**	**Paravision**	**Paravision**	**Paravision**	**Paravision**
4	Yitu	Yitu	Yitu	Yitu	Microsoft	Microsoft	Microsoft	Microsoft
5	Microsoft	Microsoft	Microsoft	Microsoft	Yitu	VisionLabs	VisionLabs	VisionLabs

Figure 5: FRVT 1:N Report, March 2020, Tables 7 - 8: Breakdown of competitor age performance in identification mode.

Investigation Mode Company Rankings by Number of Years Between Enrollment and Search Photos

	0 - 2	2 - 4	4 - 6	6 - 8	8 - 10	10 - 12	12 - 14	14 - 18
1	Sensetime	Sensetime	Sensetime	Sensetime	Sensetime	Sensetime	Sensetime	Sensetime
2	**Paravision**	**Paravision**	**Paravision**	**Paravision**	NEC	NEC	NEC	NEC
3	NtechLab	VisionLabs	NEC	NEC	**Paravision**	**Paravision**	**Paravision**	**Paravision**
4	VisionLabs	NtechLab	VisionLabs	VisionLabs	VisionLabs	VisionLabs	VisionLabs	VisionLabs
5	Microsoft	NEC	NtechLab	Dahua	Dahua	Dahua	Dahua	Dahua

Figure 5: FRVT 1:N Report, March 2020, Tables 7 - 8: Breakdown of competitor age performance in identification mode.

Performance Improvement over Time

Altogether, this NIST report shows how dramatically Paravision's algorithms have improved in a short time.
In the two years since Paravision first submitted algorithms to NIST, it has reduced its false-negative identification rates by up to 95%.

ALGORITHM SUBMISSION DATES: ● **Q1 2018** ● **Q2 2018** ● **Q3 2018** ● **Q4 2018** ● **Q2 2019** ● **Q4 2019**

Paravision Face Recognition Performance - Threshold-Based Matching

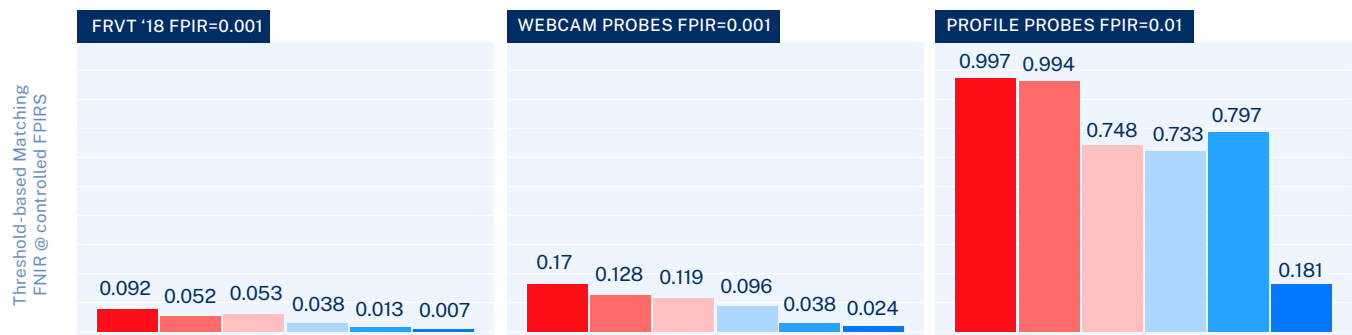NIST FRVT 1:N March 2020 - False Negative Identification Rate (FNIR) - lower is better

Figure 7: FRVT 1:N Report, March 2020, Tables 19 - 22: Paravision's improvement in threshold-based matching since its first NIST submission.
The FRVT '18 and Webcam datasets are shown at a more stringent FPIR threshold than the Profile Probes dataset based on expected practical usage.

Paravision Face Recognition Performance - Identification Mode

NIST FRVT 1:N March 2020 - False Negative Identification Rate (FNIR) - lower is better
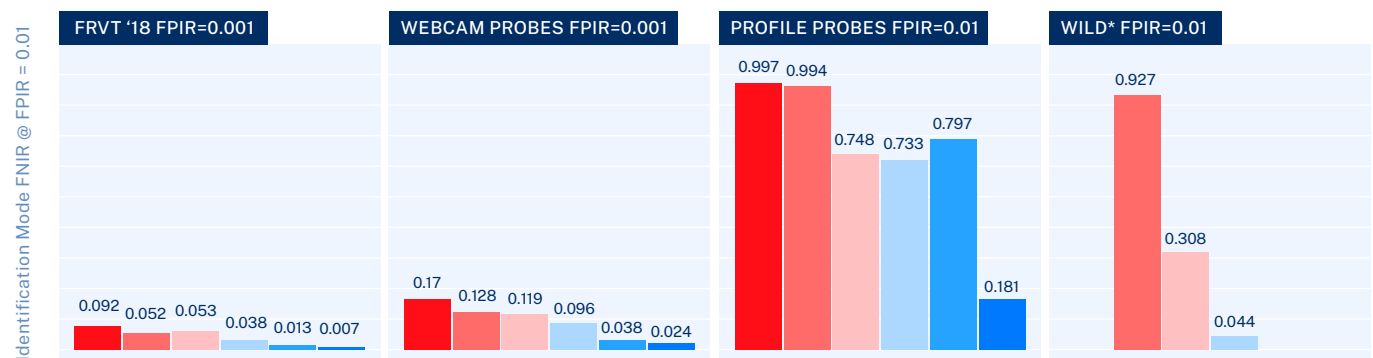
* Note: NIST did not perform analysis on the WILD dataset for Paravision Q2 2019 and Q4 2019 submissions.

Figure 8: FRVT 1:N Report, March 2020, Tables 23 - 26: Paravision's improvement in identification mode since its first NIST submission.

Over the past year and a half, Paravision has progressed dramatically, eclipsing both its competitors and its past scores. With NIST's latest results, Paravision has shown its leadership in both the 1:1 and 1:N categories evaluations.

The company's performance underscores its commitment to building computer vision that goes beyond human vision. Paravision will continue building industry-leading face recognition for its customers and will bring that same level of diligence to all future NIST evaluations.

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