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Information technology — Biometric performance estimation methodologies using statistical models

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Information technology — Biometric performance estimation methodologies using statistical models

Technologies de l'information — Méthodologies d'estimation des performances biométriques à l'aide de modèles statistiques

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Foreword

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 37, *Biometrics*.

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Introduction

This document provides a methodology for measuring the accuracy of biometric verification systems based on the statistics categorized as the extreme value theory.[1] The methodology is particularly useful when estimating the false match rate with a relatively small sample set. The methodology is an alternative to empirical accuracy measurement.

In order to measure the false match rate of biometric verification systems, evaluators need to prepare a dataset with a sufficiently large number of non-mated attempts in order to observe a sufficient number of false match cases for a reliable estimation of the false match rate. For highly accurate systems the quantity of attempts required to test the false match rate is likely to be extremely large. As performance of biometric verification systems improves dramatically, acquiring representative data of non-mated attempts in sufficient quantity becomes increasingly difficult in terms of the time, cost and practicality of creating datasets. Policy considerations that apply to biometric data collection and use can pose further constraints.

If no false match case is found within the evaluation samples, metrics based on statistics known as “the rule of three” (as is defined in ISO/IEC 19795-1) are widely used in the biometric industry. However, the rule of 3 is only applicable when no false match case is observed within the tested sample set and do not give any indication of the accuracy and confidence levels expected if more than zero false matches were tested. Only if at least 30 false matches were observed, the “rule of thirty” applies, i.e. the true error rate is with 90 % confidence within ± 30 % of the observed error rate.

In this document, two major statistical methods are introduced to estimate the false match rate with a relatively small number of samples. Both methods are widely used in a variety of industries including civil engineering, meteorology, hydrology and financial engineering. Both methods are proven to be highly reliable techniques to estimate the probability of the occurrence of rare, extreme events such as maximum wind velocity or tsunami heights. These statistical methods are applied to similarly rare events of false match cases in biometrics and used to estimate the probability of occurrence of such cases if a larger non-mated sample set is not available. The estimated false match rate is available in the form of cumulative distribution function (CDF) and its interval of confidence.

This document defines procedures for extrapolating performance metrics in technology evaluations. These procedures can also be applied in scenario evaluations and operational evaluations if comparison scores are obtained. This document defines the methodology to be used by evaluators to reliably estimate the false match rate in case of a limited number of false match cases or even no false match case at all. This document does not address certification or conformance.

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Information technology — Biometric performance estimation methodologies using statistical models

1 Scope

This document provides statistical methodologies to estimate false match rates (FMRs) from small biometric sample sets.

This document intends to:

— lay out a methodology for biometric performance estimation based on extrapolation using extreme value statistical models;

— provide statistical methodologies to estimate FMRs of biometric verification systems;

— be applicable to systems that include algorithms that produce likelihood dissimilarity or similarity scores;

NOTE Throughout the document, if not otherwise specified, scores refer to similarity scores.

— specify the methodology for data recording and result reporting;

— introduce metrics for the estimated biometric performance.

The following are not within the scope of this document.

— Estimation of false positive identification rates for one-to-many implementations.

— Estimation of false accept rates for verification transactions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 19795-1:2021, *Information technology — Biometric performance testing and reporting — Part 1: Principles and framework*

ISO/IEC 2382-37, *Information technology — Vocabulary — Part 37: Biometrics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 2382-37 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
extrapolated false match rate
extrapolated FMR
false match rate (FMR) that is estimated by using any statistical models such as those used in extreme value theory

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3.2
quantile-quantile plot
Q-Q plot
quantile-quantile comparison of two distributions, either or both of which may be empirical or theoretical[2]

4 Symbols and abbreviated terms

CDF cumulative distribution function

FMR false match rate

FNMR false non-match rate

GEV generalized extreme value

GP generalized Pareto

MLE maximum likelihood estimation

PDF probabilistic distribution function

σ scale parameter

ξ shape parameter

5 Conformance

To conform to this document, a biometric performance test shall be executed and reported in accordance with the requirements contained in Clauses 6 through 9.

6 Details of estimation

6.1 Estimation of biometric performance based on extreme value theory

Extreme value theory is used to properly estimate the tails of the distribution of comparison scores from different data subjects. By appropriately capturing the tail of the comparison score distribution, it becomes possible to extrapolate scores outside the observed score range, i.e. the score range larger than the maximum empirical score.

The method of extracting the tail of the comparison score distribution differs depending on whether the extreme value distribution model applied is a generalized extreme value distribution model (rGEV; the limiting joint generalized extreme value distribution for the r largest-order statistic) or generalized Pareto distribution model. More details on these models can be found in 6.3, 6.4 and Annex A.

The extreme value theory is applied to the extracted score set to estimate the optimum parameters of the distribution, and the comparison score distribution is approximated.

The result approximated by the extreme value statistic is compared with the original comparison score distribution using the diagnostic diagram. By extrapolating the estimated comparison score distribution, a distribution can be obtained for a section having no score value. Finally, the extrapolated FMR is obtained by setting a threshold value from the comparison score distribution.

This methodology can be applied if comparison scores are obtained. It can be applied not only in technology evaluations, but also in scenario evaluations and operation evaluations as long as the comparison scores are obtained.

If the scores are produced from a population where some subjects are genetically related, e.g. identical twins or siblings, the probability distribution at the extreme value domain can be higher than that without such

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related scores, which typically results in a small secondary peak. The extrapolated FMR methodology still works for such score distributions reflecting the increase of the probability. The evaluator shall report the estimated results together with the demographic information of the population.

If the dataset has an unintended peak(s) in the extreme value domain, and if these counts are not within an ignorable error range, it can be appropriate to introduce stratified analysis. A single dataset consists of *n* different subject groups. The distribution of the dataset will have synthesized characteristics of each group, reflecting each statistical parameter (e.g. mean, variance and the number of samples). If the differences between the groups are found to be statistically significant and the proportion of such groups cannot be ignored, these groups may be separated into up to *n* sub-datasets and evaluated independently. While these sub-datasets are dependent on the biometric modalities, they are typically characterized by the test crew properties such as:

a) kinship,

b) human races and genders,

c) occupations,

d) health conditions,

e) other factors that reduce the uniqueness of the biometric features of interest.

The extrapolated FMR for each sub-dataset shall be computed in the same manner as described in 6.3 and 6.4. The details of the sub-datasets shall be reported in accordance with the requirements defined in ISO/IEC 19795-1:2021, 12.1.

6.2 Estimation design

The sample size is determined considering the target FMR to measure and the accuracy of the estimation. Measuring an FMR of 0,000 1 % ± 30 % with 90 % confidence takes 30 false matches in 30 million non-mated comparisons ("rule of 30"; see ISO/IEC 19795-1). This typically means several thousand test subjects are necessary to calculate the FMR. This number can be reduced by using appropriate statistical estimations, and by accepting some errors.

Since the extrapolated FMR is estimated by using extreme values, it is always preferred to have a reasonably large number of samples for better accuracy, with accuracy being quantified by a confidence interval giving the best and the worst case FMR values for a certain confidence level. If the extrapolated FMR values are obtained at multiple thresholds, the extrapolated FMR value with the narrower confidence interval is regarded as more reliable.

As the confidence interval and the confidence level shall be reported, it is the evaluator who decides which threshold score and its corresponding extrapolated FMR value to report. If FNMR is reported, the same score threshold shall be applied.

6.3 Generalized extreme value distribution

The rGEV estimation is based on the generalized extreme value distribution model as described in Clause A.2. The validation processes are as follows:

1) Determine *n*, the number of samples in a block.

   n needs to be large enough for each block to contain some extreme values, i.e. large non-mated scores. On the other hand, when choosing *m*, the number of blocks, the trade-off between *m* and *n* needs to be considered, as the number of extreme samples per block decreases as *m* increases.

2) Specify the number of extreme values per block, *r*.

   The *r* value determines the number of extreme samples extracted from each block and hence the number of samples used for the estimation. For similarity scores, the largest *r* scores within the block are used for estimation. For dis-similarity scores, the smallest *r* scores are used. The larger the value

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