FVC2002: Second Fingerprint Verification Competition

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Abstract

Two years after the first edition, a new Fingerprint Verification Competition (FVC2002) was organized by the authors, with the aim of determining the state-of-the-art in this challenging pattern recognition application. The experience and the feedback received from FVC2000 allowed the authors to improve the organization of FVC2002 and to capture the attention of a significantly higher number of academic and commercial organizations (33 algorithms were submitted). This paper discusses the FVC2002 database, the test protocol and the main differences between FVC2000 and FVC2002. The algorithm performance evaluation will be presented at the 16th ICPR.

1. Introduction

The First International Fingerprint Verification Competition (FVC2000) was organized by the authors in the year 2000 and the results were presented at 15th ICPR [1]. FVC2000 received great attention from both academic and commercial organizations; on the one hand, it established a common benchmark, allowing system developers to unambiguously compare their algorithms, on the other it provided the first overview of the state-of-the-art in fingerprint recognition and shed some light on fingerprint individuality [2]. In FVC2000,

- 11 algorithms were submitted (7 academic, 4 commercial);
- four databases were collected (one of them was synthetically generated);
- synthetic fingerprint generation [3,4] was validated as an effective instrument for comparing algorithms and in-house improvement of methods;
- a CD-ROM containing the four databases and a detailed report was created, more than 80 copies of which have been requested by major institutions and companies in the field. The web site [5] has been visited more than 18,000 times since September 2000;
- several scientific groups active in the field are currently using FVC2000 databases for their experimentation, allowing them to fairly compare their approaches to published results;
- some companies which initially did not participate in the competition requested to certify their performance on the FVC2000 benchmark after the competition [5].

The interest aroused by FVC2000, and the encouragement we received, induced us to set up this second competition. In the organization of FVC2002, we took into account the advices we received by experts in the field and by reviewers of the FVC2000 paper [1].

2. Organization of FVC2002

Starting in November 2001, when the FVC2002 web site was created [6], we extensively publicized this event. All companies and research groups in the field were invited to participate in the contest. FVC2002 was also announced through several mailing lists and biometric-related magazines.

To increase the number of companies participating and, therefore, to provide a more complete panorama of the state-of-the-art, we decided to allow the participants to remain anonymous. In FVC2000 some of the companies initially registered withdrew after the training sets were made available. From a commercial point of view, a company which participates in such a contest is quite exposed, due to the risk that the performance of its algorithm may not be completely favorable. In FVC2002, participants may decide not to publish the name of their organization in case their results are not as they expected.

The FVC2002 announcement clearly stated that, analogously to FVC2000, FVC2002 is not to be viewed as an official certification of fingerprint-based biometric systems, but simply as a technology evaluation [7,8], where algorithms compliant with a predefined protocol are evaluated on common databases. Neither hardware components nor proprietary modules outside the FVC2002 protocol are tested.

Four new databases have been collected by using three commercially available scanners (see section 3). The fourth database was synthetically generated by using SFinGE software [3,4]. A representative subset of each database was made available to the participants to let them tune their algorithms according to the image size and the variability of the fingerprints in the databases.

In the FVC2002 testing protocol (see section 4), new performance indicators (e.g. FMR100, FMR1000) have been added to those already used in FVC2000. Failure to enroll errors are now incorporated into the computation of the false non-match rate (FNMR) and false match rate (FMR) to make the results of the different algorithms directly comparable.

By January 10, 2002 (the deadline for FVC2002 registration, we had received 48 registrations (19 academic, 29 industrial), far more than our initial expectation. All the registered participants received the training sets and detailed instructions for the algorithm submission. By March 1, 2002 (the deadline for submission) we received a total of 33 algorithms from 29 participants (four participants submitted two algorithms). The percentage of resigns decreased from 56% in FVC2000 to 31% in FVC2002.

3. Database collection

Four databases constitute the FVC2002 benchmark. Three different scanners and the SFinGE synthetic generator were used to collect fingerprints (see Table 1). Figure 1 shows an image for each database, at the same scale factor.

	Technology	Scanner	Image Size – Res.
DB1	Optical	Identix TouchView II	388×374 - 500 dpi
DB2	Optical	Biometrika FX2000	296×560 - 569 dpi
DB3	Capacitive	Precise Biometrics 100 SC	300×300 - 500 dpi
DB4	Synthetic	SFinGE v2.51	288×384 - 500 dpi

Table 1. Scanners/technologies used for the collection of FVC2002 databases.

A total of ninety students (20 years old on the average) enrolled in the first two years of the Computer Science degree program at the University of Bologna kindly agreed to act as volunteers for providing fingerprints:

- volunteers were randomly partitioned into three groups (30 persons each); each group was associated to a DB and therefore to a different fingerprint scanner;
- each volunteer was invited to present him/herself at the collection place in three distinct sessions, with at least two weeks time separating each session;
- forefinger and middle finger of both the hands (four fingers total) of each volunteer were acquired by interleaving the acquisition of the different fingers to maximize differences in finger placement;
- no efforts were made to control image quality and the sensor platens were not systematically cleaned;
- at each session, four impressions were acquired of each of the four fingers of each volunteer;
- during the second session, individuals were requested to exaggerate displacement (impressions 1 and 2) and rotation (3 and 4) of the finger, not to exceed 35 degrees;
- during the third session, fingers were alternatively dried (impressions 1 and 2) and moistened (3 and 4).

In FVC2002 the data collection was carried by two final-year students, completing their Laurea thesis at BioLab.

Fig. 1. One fingerprint image from each database.

At the end of the data collection, we had collected for each database a total of 120 fingers and 12 impressions per finger (1440 impressions) using 30 volunteers. The size of each database to be used in the FVC2002 test, however, is established as 110 fingers, 8 impressions per finger (880 impressions) (Fig. 2). Collecting some additional data gave us a margin in case of collection errors, and also allowed us to systematically choose from the collected impressions those to include in the test databases.

An automatic all-against-all comparison was first performed by using an internally-developed fingerprint matching algorithm, to discover possible data-collection errors. False match and false non-match errors were manually analyzed: two labeling errors were discovered and removed. Fingerprints in each database were then sorted by quality according to a quality index [9]. The top-ten quality fingers were removed from each database since they do not constitute an interesting case study. The remaining 110 fingers were split into set A (100 fingers - evaluation set) and set B (10 fingers - training set). To make set B representative of the whole database, the 110 collected fingers were ordered by quality, then the 8 images from every tenth finger were included in set B. The remaining fingers constituted set A.

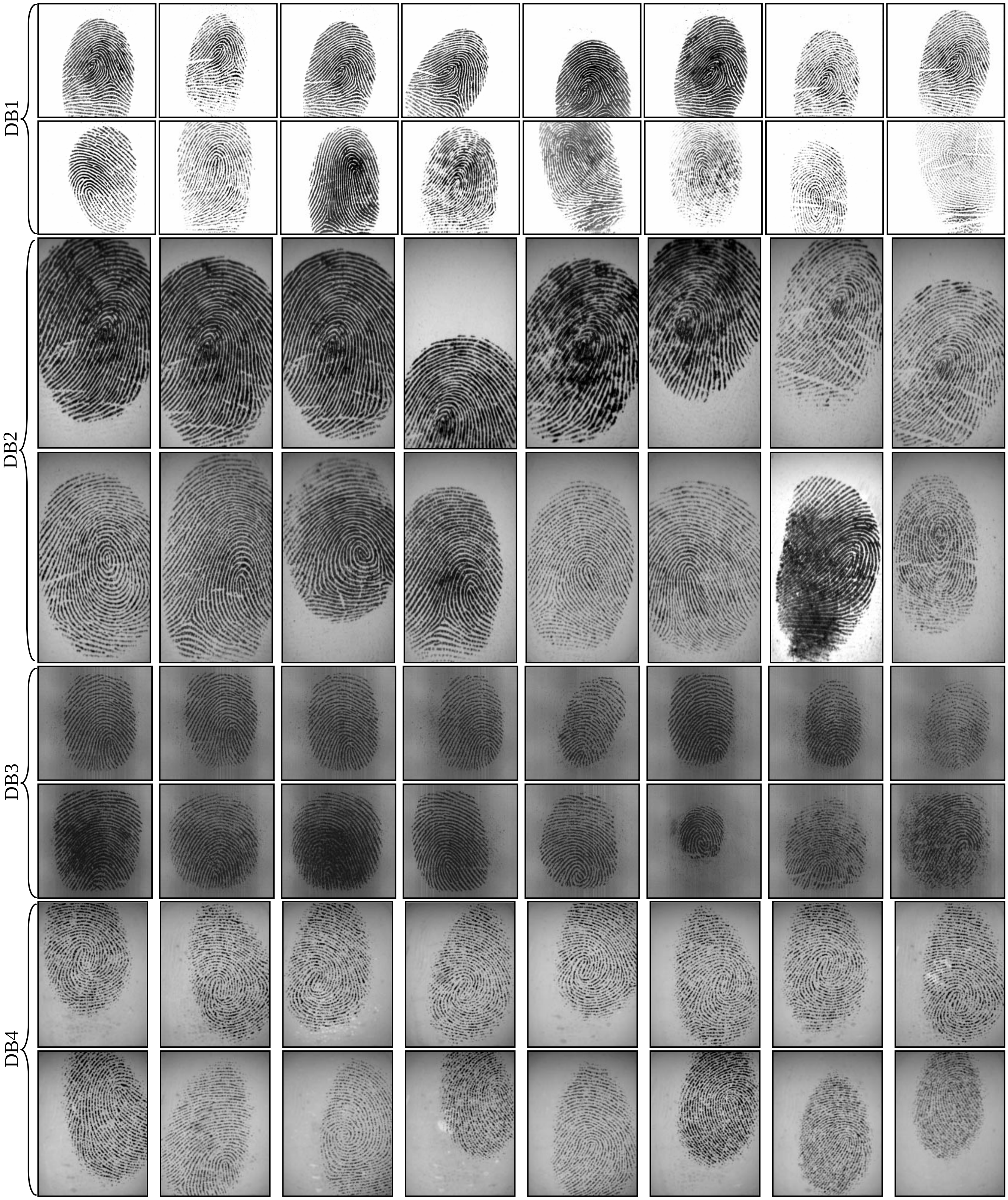

Fig. 2. Sample images from the four databases; for each database, the first row shows eight impressions of the same finger, the second row reports samples from different fingers, roughly ordered by quality (left: high quality, right: low quality).

After training sets B were made available to the participants, some of them informed us of the presence of fingerprint pairs whose relative rotation exceeded the maximum specification of about 35 degrees. We were not much surprised by this, since although the persons in charge of data collection were informed of the constraint, the requirement of "exaggerating rotation but remaining within a maximum of about 35 degrees between any two samples" is not simple to implement in practice, especially when the volunteers are untrained users. A further semi-automatic analysis was then necessary to ensure that, in the evaluation sets A, the samples were compliant with the initial specifications: maximum rotation and non-null overlap between any two impressions of the same finger. Software was developed to support us in this daunting task. All of the 12 originally collected impressions of the same fingers were displayed at the same time and the authors selected a subset of 8 impressions by point and click. Once the selection was made, the software automatically compared the selected impressions and a warning was issued in case the rotation or displacement between any two pairs exceeded the maximum allowed. Fortunately, the 12 samples at our disposal always allowed us to find a subset of 8 impressions compliant with the specification.

4. Test protocol and performance evaluation

Each competition participant was required to submit two executable computer programs: the first for enrolling a fingerprint image and producing the corresponding template, and the second for comparing a fingerprint template against a fingerprint image. Participants were allowed to submit four distinct configuration files, to adjust the algorithms' internal parameters according to each specific database. For practical testing reasons, the maximum response time of the algorithms was limited to 10 seconds for each enrollment and 5 seconds for each comparison (on a Pentium III – 933MHz PC).

As in FVC2000, for each database and for each algorithm, the following performance indicators are measured:

- Genuine and Impostor score distributions
- FMR (False Match Rate) and FNMR (False Non-Match Rate) curves, and ROC
- Failure To Enroll rate (FTE)
- EER (Equal Error Rate), ZeroFMR, and ZeroFNMR
- Average enrollment and average comparison times

Additionally, in FVC2002 we decided to measure FMR100 and FMR1000, which are the values of FNMR for FMR=1/100 and 1/1000, respectively. These data are useful to characterize the accuracy of fingerprint-based systems which are often operated far from the EER point, by using thresholds which reduce FMR at the cost of high FNMR.

In FVC2000, FTE errors were recorded separately from the FMR/FNMR errors. Algorithms rejecting poor quality fingerprints at enrollment time could be implicitly favored since many problematic comparisons could be avoided. This could make it difficult to directly compare the accuracy of different algorithms. To avoid this problem, FTE errors have been included into the computation of FNMR in FVC2002. In particular, we clarified from the beginning that each FTE error produces a "ghost" template which does not match (matching score 0) with the remaining fingerprints, thus increasing the FNMR. This approach is consistent with that used in [10].

Ranking the algorithms according to EER (as in FVC2000) may be sometimes misleading. On the other hand, mixing heterogeneous indicators into a unique goodness index is difficult and arbitrary. Therefore, we have decided to summarize the results in a sort of Olympic medal table where three medals (gold, silver and bronze) are assigned to the best three algorithms for each indicator over each database.

5. Conclusions

At the time of writing this paper, the evaluation of the 33 algorithms submitted to the second international Fingerprint Verification Competition (FVC2002) is in progress. Results will be presented for the first time at the 16th ICPR. By October 2002, a detailed report including all the results and a CD-ROM containing the four databases will be made available to the research community.

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