

Statistical Meta-Analysis of Presentation Attacks for Secure Multibiometric Systems

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Abstract—Prior work has shown that multibiometric systems are vulnerable to presentation attacks, assuming that their matching score distribution is identical to that of genuine users, without fabricating any fake trait. We have recently shown that this assumption is not representative of current fingerprint and face presentation attacks, leading one to overestimate the vulnerability of multibiometric systems, and to design less effective fusion rules. In this paper, we overcome these limitations by proposing a statistical meta-model of face and fingerprint presentation attacks that characterizes a wider family of fake score distributions, including distributions of known and, potentially, unknown attacks. This allows us to perform a thorough security evaluation of multibiometric systems against presentation attacks, quantifying how their vulnerability may vary also under attacks that are different from those considered during design, through an uncertainty analysis. We empirically show that our approach can reliably predict the performance of multibiometric systems even under never-before-seen face and fingerprint presentation attacks, and that the secure fusion rules designed using our approach can exhibit an improved trade-off between the performance in the absence and in the presence of attack. We finally argue that our method can be extended to other biometrics besides faces and fingerprints.

Index Terms—statistical meta-analysis, uncertainty analysis, presentation attacks, security evaluation, secure multibiometric fusion

1 INTRODUCTION

THE widespread use of biometric identity recognition systems is severely limited by security threats arising from several kinds of potential attacks [1]–[3]. In particular, the use of fake biometric traits (e.g., gummy fingers [4]), also known as “direct”, “spoofing” or “presentation” attacks [1], [2], [5]–[7], has the greatest practical relevance as it does not require advanced technical skills. Accordingly, the potential number of attackers is very large. Vulnerability to presentation attacks has been studied mostly for unimodal fingerprint and face recognition systems [4], [5]–[10]. Multibiometric systems have been considered intrinsically more secure, instead, based on the intuition that an attacker should spoof all the biometric traits to successfully impersonate the targeted client [11], [12].

This claim has been questioned in subsequent work, showing that an attacker may successfully spoof a multibiometric system even if only one (or a subset) of the combined traits is counterfeited, if the fusion rule is not designed by taking that into account [13]–[15]. From a computer security perspective, this is not surprising: it is well-known that the security of a system relies the most on the security of its weakest link [16]. This vulnerability of multibiometric fusion has been shown under the assumption that the fake score distribution at the output of the attacked matcher is

identical to that of genuine users, without fabricating any fake trait. Under the same assumption, more secure fusion rules against presentation attacks have also been proposed.

In our recent work, through an extensive experimental analysis, we have shown that the aforementioned assumption is not representative of current face and fingerprint presentation attacks [17]–[19]. In fact, their fake score distributions do not only rarely match those of genuine users, but they can also be very different, depending on the technique, materials, and source images used to fabricate the presentation attack; *i.e.*, presentation attacks can have a different impact on the output of the targeted matcher. For these reasons, the methodology proposed in [13]–[15] may not only provide an overly-pessimistic security evaluation of multibiometric systems to presentation attacks, but also lead one to design secure fusion rules that exhibit a too pessimistic trade-off between the performance in the absence of attack and that under attack.

To perform a more complete analysis of the security of multibiometric systems, as shown in [17]–[21], considering only one or a few known attacks is not sufficient. One should thus face the cumbersome and time-consuming task of collecting or fabricating a large, representative set of presentation attacks (with different impact on the attacked matchers) for each biometric characteristic, and evaluate their subsequent effect on the fusion rule and on system security. However, even in this case, one may not be able to understand how multibiometric systems may behave under scenarios that are different from those considered during design, including presentation attacks fabricated with novel materials or techniques, that may produce different, *never-before-seen* fake score distributions at the matchers’ output.

In this paper, we propose a methodology for evaluating the security of multibiometric systems to presentation at-

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Statistical Meta Information Systems

Karl A. Froeschl



Statistical Meta Information Systems:

Metadata Management in Statistical Information Processing Karl A. Froeschl, 2013-12-21 As the integration of statistical data collected in various subject matter domains becomes more and more important in several socio economic etc investigation areas the management of so called metadata a formal digital processing of information about data gains tremendously increasing relevance Unlike current information technologies e.g. database systems computer networks facilitating merely the technical side of data collation a coherent integration of empirical data still remains cumbersome and thus rather costly very often because of a lack of powerful semantic data models capturing the very meaning and structure of statistical data sets Recognizing this deficiency Metadata Management proposes a general framework for the computer aided integration and harmonization of distributed heterogeneous statistical data sources aiming at a truly comprehensive statistical meta information system

OECD Glossary of Statistical Terms OECD, 2008-09-01 The OECD Glossary contains a comprehensive set of over 6 700 definitions of key terminology concepts and commonly used acronyms derived from existing international statistical guidelines and recommendations

[New Techniques and Technologies for Statistics II](#), 1997 The compilation and deployment of statistical techniques is nowadays almost universally based on computing systems Rapidly changing technology is expanding the options available for improving the quality range and delivery of statistics whilst reducing the cost and at the same time is putting pressure on producers and users to keep up with the latest techniques both as management views develop of what is possible and simply through peer group pressure In the areas of official statistics it is clear that new technologies will change our approach to the whole range to activities from systems design through data collection processing analysis and dissemination to the structure of the European Statistical System and internal organization of national statistical institutes Eurostat has a central role in promoting and coordinating the development and use of statistics in public administrations which extends to the adoption of new techniques and technologies as they are proven validated An important aspect of this role is to anticipate needs to stimulate encourage and fund research work of common interest to support national initiatives and to provide a forum for discussion In this new book techniques and technologies in statistics are described The needs and constraints of official statisticians are described as well as the latest developments of researchers The book presents the research and development projects funded by the European Commission in the development of statistical tools and techniques under the R D framework programme and the progress to date in the current Development of Statistical Information Systems DOSIS programme

Terminology on Statistical Metadata United Nations. Statistical Commission, United Nations. Economic Commission for Europe, Conference of European Statisticians, 2000 This publication was prepared at the request of countries participating in the activities on statistical metadata organised by the United Nations Economic Commission for Europe Statistical Division The aim of the publication is to assist national and international statistical offices on problems dealing with the development and implementation of

statistical metainformation systems The development of standard terminology will also help to facilitate access sharing comparing and understanding of statistics across national boundaries Over 230 terms are defined relating to metadata collection storing organising and searching metadata metadata and metainformation system s functions identification location retrieval processing analysis and interpretation metadata models and holdings metadata administration and dissemination Concepts are defined in natural language and are organised in the thesaurus structure *Proceedings* ,1996

Statistical Journal of the United Nations Economic Commission for Europe ,1997 **Statistical Standards and Studies** ,2000 *Statistical Meta Information Systems* ,1993-01-01 *History & Computing* ,1996 *Proceedings* ,1996

Qüestió ,1997 **Journal of Official Statistics** ,2012 **Guidelines for Statistical Metadata on the Internet** United Nations. Statistical Commission,United Nations. Economic Commission for Europe,Conference of European Statisticians,2000 This paper proposes guidelines for some minimum standards for statistical metadata on the Internet The guidelines are intended for national statistical institutes and other national and international bodies responsible for the dissemination of statistics The guidelines main objectives are to support the worldwide dissemination of statistical data on the Internet to promote a consistent interpretation of statistics from different sources by considering data quality and international comparability as strategic issues and to promote proper usage and processing of public statistics

Encyclopedia of Statistical Sciences ,1997 Keeping pace with the latest developments in all branches of statistical science Encyclopedia of Statistical Sciences is the number one source of information on statistical theory methods and applications for researchers and clinicians This new volume is the last of three updates designed to bring the Encyclopedia in line with new and emerging topics and important advances in statistical science made over the past decade Each self contained entry is written by a leader in the field and easily understood by readers with a modest statistical background In addition to the main selections which feature fascinating discussions of developments in various branches of the statistical sciences readers will find a series of shorter entries ranging in subject matter from the lives of pioneers in statistics to updates of earlier articles and reviews of statistical agencies and journals Up to date bibliographies thorough cross referencing and extensive indexing facilitate quick access to specific information and provide an indispensable platform for further study and research A cumulative index and listing of all the entries in the 13 volumes of the Encyclopedia together with the corresponding authors are included With the publication of this update installment the Encyclopedia of Statistical Sciences retains its position as the only cutting edge reference of choice for those working in statistics probability theory biostatistics quality control and economics and in applications of statistical methods in sociology engineering computer and communication science biomedicine psychology and many other areas *9th International Conference on Scientific and Statistical Database Management* IEEE Computer Society,1997 Coverage in this text on database and information systems includes fundamental issues in statistical database management current problems in scientific databases new systems

implementation methods applications of data and process modelling and requirements and design *Seventh International Working Conference on Scientific and Statistical Database Management* James Cornelius French, Hans Hinterberger, 1994
Presents papers from the September 1994 conference plus a poster session addressing issues directly related to data management and keynote addresses on data infrastructure architecture and object databases for scientific computing
Sessions cover subjects such as interfaces and languages statistical databases scientific database management object oriented techniques multidimensional data and content retrieval from image databases No index Annotation copyright by Book News Inc Portland OR Regional Contribution to Statistical Information Systems Development for Technical and Vocational Education and Training Unesco. Regional Office for Education in Africa, 2009 *Statistics, Telematic Networks, and EDI Bulletin* ,2000 *Research in Official Statistics* ,1996 **Actes de la Session** International Statistical Institute, 1997

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