

Statistical Meta-Analysis of Presentation Attacks for Secure Multibiometric Systems

Battista Biggio, Member, IEEE, Giorgio Fumera, Member, IEEE, Gian Luca Marcialis, Member, IEEE, and Fabio Roli, Fellow, IEEE

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 methodology 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 [11]–[12], [15]–[17], 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], [18]–[19]. 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 [36]. 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 matcher) 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-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-

• The authors are with the Department of Electrical and Electronic Engineering, University of Cagliari, Piazza d’Armi, 09123 Cagliari, Italy.
 • Battista Biggio: e-mail: battista.biggio@uni.cagliari.it, phone: +39 070 6275 5779, fax: +39 070 6275 5782.
 • Giorgio Fumera: e-mail: fumera@di.unipi.it, phone: +39 070 6275 5754, fax: +39 070 6275 5762.
 • Gian Luca Marcialis: e-mail: marcialis@di.unipi.it, phone: +39 070 6275 5868, fax: +39 070 6275 5782.
 • Fabio Roli (corresponding author): e-mail: roli@di.unipi.it, phone: +39 070 6275 5779, fax: +39 070 6275 5782.

Statistical Meta Information Systems

Claus Rautenstrauch, Susanne Patig

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

Web Information Systems Engineering - WISE 2010 Peter

Triantafillou, 2010 Annotation This book constitutes the proceedings of the 11th International Conference on Web Information Systems Engineering WISE 2010 held in Hong Kong China in December 2010 The 32 revised full papers and 19 revised short papers presented together with 4 keynote talks were carefully reviewed and selected from 170 submissions The papers are organized in topical sections on web service social networks web data mining keyword search web data modeling recommender systems RDF and web data processing XML and query languages web information systems and information retrieval and extraction

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 of 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 prove 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 *Advances in Object-Oriented Information Systems* Jean-Michel Bruel, Zohra Bellahsene, 2003-08-02 For the first time four workshops have been held in conjunction with the 8th Object Oriented Information Systems conference OOIS 2002 to encourage interaction between researchers and practitioners. Workshop topics are of course inline with the conference's scientific scope and provide a forum for groups of researchers and practitioners to meet together more closely and to exchange opinions and advanced ideas and to share preliminary results on focused issues in an atmosphere that fosters interaction and problem solving. The conference hosted four one day workshops. The four selected workshops were fully in the spirit of a workshop session hosted by a main conference. Indeed OOIS deals with all the topics related to the use of object oriented techniques for the development of information systems. The four workshops are very specific and contribute to enlarging the spectrum of the more general topics treated in the main conference. The first workshop focused on a very specific and key concept of object oriented development the specialization/generalization hierarchy. The second one explored the use of non traditional approaches at the edge of object oriented techniques such as aspects, AI etc to improve reuse. The third workshop dealt with optimization in Web based information systems. And finally the fourth workshop investigated issues related to model driven software development.

History & Computing, 1996 **Statistical Journal of the United Nations Economic Commission for Europe**, 1996 Regional Contribution to Statistical

Information Systems Development for Technical and Vocational Education and Training Unesco. Regional Office for

Education in Africa, 2009 *Qüestió*, 1995 **Information Systems** A. Sernadas, Janis Bubenko, A. Olivé, 1985 This book contains papers on the theoretical and formal aspects of information systems. The fifteen papers address two main problems in the area consolidation of the underlying concepts and identification of suitable formal tools for information system development. Several new modeling abstraction mechanisms and languages are presented and discussed as well as logical formalisms for correctness analysis of specifications.

Information Systems Interoperability Bernd Krämer, M. Papazoglou, Heinz-W. Schmidt, 1998 Interoperation technology is used to solve problems relating to the coexistence of a vast number of legacy systems, application software and information systems and repositories. This book provides a broad survey of research into the architecture, modelling and management of interoperable computing systems. Technology discussed in the text can be applied to information systems, electronic commerce systems, digital libraries and well enabled technologies, process design, information modelling and management, and design methods and support services for application engineering and management.

Journal of Official Statistics, 2012 **Environmental Information Systems in Industry and Public Administration** Claus Rautenstrauch, Susanne Patig, 2001 Environmental Information Systems in Industry and Public Administration provides an overview of worldwide research and development on Environmental Information Systems ENVIS. This book is the only topical documentation of the highly innovative approach of information systems for environmental

protection Issues are covered from the global and multinational level to industrial solutions for enterprises **Proceedings**,2000 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 *Towards an Integrated Three-dimensional Geographic Information System* Jung-Der Victor Tsai,1994 Research in Official Statistics ,1996 **Strategic Planning for Information Systems** John Ward,Pat Griffiths,1996-05-27 This comprehensive and practical book describes the impact IS has had on business performance and the contribution it makes to the strategic development and competitive abilities of organizations It provides the tools techniques and management framework for identifying and implementing opportunities explored The new edition places more stress on planning and includes updated references and examples as well as new information on EDI business process redesign outsourcing legacy systems and more *Library Herald* ,2005 Understanding Data and Information Systems for Recordkeeping Philip C. Bantin,2008 A comprehensive guide to the new technologies that can help information professionals and records managers better organise vital documents and information for preservation search and retrieval

Enjoying the Track of Phrase: An Psychological Symphony within **Statistical Meta Information Systems**

In some sort of taken by displays and the ceaseless chatter of immediate transmission, the melodic splendor and psychological symphony developed by the prepared word usually disappear in to the back ground, eclipsed by the constant noise and disturbances that permeate our lives. Nevertheless, nestled within the pages of **Statistical Meta Information Systems** an enchanting fictional value full of organic thoughts, lies an immersive symphony waiting to be embraced. Constructed by an outstanding composer of language, that interesting masterpiece conducts viewers on an emotional journey, skillfully unraveling the hidden songs and profound affect resonating within each carefully crafted phrase. Within the depths of this poignant evaluation, we can examine the book is main harmonies, analyze their enthralling publishing fashion, and surrender ourselves to the profound resonance that echoes in the depths of readers souls.

<https://auld.rmj.com/book/detail/default.aspx/john%20w%20lennon.pdf>

Table of Contents Statistical Meta Information Systems

1. Understanding the eBook Statistical Meta Information Systems
 - The Rise of Digital Reading Statistical Meta Information Systems
 - Advantages of eBooks Over Traditional Books
2. Identifying Statistical Meta Information Systems
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Statistical Meta Information Systems
 - User-Friendly Interface
4. Exploring eBook Recommendations from Statistical Meta Information Systems
 - Personalized Recommendations

- Statistical Meta Information Systems User Reviews and Ratings
 - Statistical Meta Information Systems and Bestseller Lists
5. Accessing Statistical Meta Information Systems Free and Paid eBooks
- Statistical Meta Information Systems Public Domain eBooks
 - Statistical Meta Information Systems eBook Subscription Services
 - Statistical Meta Information Systems Budget-Friendly Options
6. Navigating Statistical Meta Information Systems eBook Formats
- ePUB, PDF, MOBI, and More
 - Statistical Meta Information Systems Compatibility with Devices
 - Statistical Meta Information Systems Enhanced eBook Features
7. Enhancing Your Reading Experience
- Adjustable Fonts and Text Sizes of Statistical Meta Information Systems
 - Highlighting and Note-Taking Statistical Meta Information Systems
 - Interactive Elements Statistical Meta Information Systems
8. Staying Engaged with Statistical Meta Information Systems
- Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Statistical Meta Information Systems
9. Balancing eBooks and Physical Books Statistical Meta Information Systems
- Benefits of a Digital Library
 - Creating a Diverse Reading Collection Statistical Meta Information Systems
10. Overcoming Reading Challenges
- Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Statistical Meta Information Systems
- Setting Reading Goals Statistical Meta Information Systems
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Statistical Meta Information Systems
- Fact-Checking eBook Content of Statistical Meta Information Systems

- Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

Statistical Meta Information Systems Introduction

In the digital age, access to information has become easier than ever before. The ability to download Statistical Meta Information Systems has revolutionized the way we consume written content. Whether you are a student looking for course material, an avid reader searching for your next favorite book, or a professional seeking research papers, the option to download Statistical Meta Information Systems has opened up a world of possibilities. Downloading Statistical Meta Information Systems provides numerous advantages over physical copies of books and documents. Firstly, it is incredibly convenient. Gone are the days of carrying around heavy textbooks or bulky folders filled with papers. With the click of a button, you can gain immediate access to valuable resources on any device. This convenience allows for efficient studying, researching, and reading on the go. Moreover, the cost-effective nature of downloading Statistical Meta Information Systems has democratized knowledge. Traditional books and academic journals can be expensive, making it difficult for individuals with limited financial resources to access information. By offering free PDF downloads, publishers and authors are enabling a wider audience to benefit from their work. This inclusivity promotes equal opportunities for learning and personal growth. There are numerous websites and platforms where individuals can download Statistical Meta Information Systems. These websites range from academic databases offering research papers and journals to online libraries with an expansive collection of books from various genres. Many authors and publishers also upload their work to specific websites, granting readers access to their content without any charge. These platforms not only provide access to existing literature but also serve as an excellent platform for undiscovered authors to share their work with the world. However, it is essential to be cautious while downloading Statistical Meta Information Systems. Some websites may offer pirated or illegally obtained copies of copyrighted material. Engaging in such activities not only violates copyright laws but also undermines the efforts of authors, publishers, and researchers. To ensure ethical downloading, it is advisable to utilize reputable websites that prioritize the legal distribution of content. When downloading Statistical Meta Information Systems, users should also consider the potential security risks associated with online platforms. Malicious actors may exploit vulnerabilities in

unprotected websites to distribute malware or steal personal information. To protect themselves, individuals should ensure their devices have reliable antivirus software installed and validate the legitimacy of the websites they are downloading from. In conclusion, the ability to download Statistical Meta Information Systems has transformed the way we access information. With the convenience, cost-effectiveness, and accessibility it offers, free PDF downloads have become a popular choice for students, researchers, and book lovers worldwide. However, it is crucial to engage in ethical downloading practices and prioritize personal security when utilizing online platforms. By doing so, individuals can make the most of the vast array of free PDF resources available and embark on a journey of continuous learning and intellectual growth.

FAQs About Statistical Meta Information Systems Books

What is a Statistical Meta Information Systems PDF? A PDF (Portable Document Format) is a file format developed by Adobe that preserves the layout and formatting of a document, regardless of the software, hardware, or operating system used to view or print it.

How do I create a Statistical Meta Information Systems PDF? There are several ways to create a PDF: Use software like Adobe Acrobat, Microsoft Word, or Google Docs, which often have built-in PDF creation tools. Print to PDF: Many applications and operating systems have a "Print to PDF" option that allows you to save a document as a PDF file instead of printing it on paper. Online converters: There are various online tools that can convert different file types to PDF.

How do I edit a Statistical Meta Information Systems PDF? Editing a PDF can be done with software like Adobe Acrobat, which allows direct editing of text, images, and other elements within the PDF. Some free tools, like PDFescape or Smallpdf, also offer basic editing capabilities.

How do I convert a Statistical Meta Information Systems PDF to another file format? There are multiple ways to convert a PDF to another format: Use online converters like Smallpdf, Zamzar, or Adobe Acrobat's export feature to convert PDFs to formats like Word, Excel, JPEG, etc. Software like Adobe Acrobat, Microsoft Word, or other PDF editors may have options to export or save PDFs in different formats.

How do I password-protect a Statistical Meta Information Systems PDF? Most PDF editing software allows you to add password protection. In Adobe Acrobat, for instance, you can go to "File" -> "Properties" -> "Security" to set a password to restrict access or editing capabilities.

Are there any free alternatives to Adobe Acrobat for working with PDFs? Yes, there are many free alternatives for working with PDFs, such as: LibreOffice: Offers PDF editing features. PDFsam: Allows splitting, merging, and editing PDFs. Foxit Reader: Provides basic PDF viewing and editing capabilities.

How do I compress a PDF file? You can use online tools like Smallpdf, ILovePDF, or desktop software like Adobe Acrobat to compress PDF files without significant quality loss. Compression reduces the file size, making it easier to share and download.

Can I fill out forms in a PDF file? Yes, most PDF viewers/editors like Adobe Acrobat, Preview (on Mac), or various online tools allow you to fill out

forms in PDF files by selecting text fields and entering information. Are there any restrictions when working with PDFs? Some PDFs might have restrictions set by their creator, such as password protection, editing restrictions, or print restrictions. Breaking these restrictions might require specific software or tools, which may or may not be legal depending on the circumstances and local laws.

Find Statistical Meta Information Systems :

john w lennon

2014 results for mcse

bosch air brake study guide

earth science guided study workbook answers climate

ball state university event calendar 2014

manual repair cavalier

2003 dodge caravan sport owners manual

manual bombardier learjet 45

used toyota corolla manual

ecological studies of six endangered butterflies

american oddesy section review answers

onity ht 2lock technical service manual

2007 chevrolet impala owner manual

box cake from mix recipe

multiple choice sin and cosin law

Statistical Meta Information Systems :

Study Guide for Introduction to Clinical Pharmacology Worksheets in each chapter enhance your understanding of important pharmacology concepts with short answer, matching, multiple-choice, and multiple-select ... Study Guide for Introduction to Clinical Pharmac Study Guide for Introduction to Clinical Pharmacology, 10th Edition ; Variety of exercises reinforces your understanding with matching, multiple-choice, and ... Study Guide to Accompany Introductory Clinical ... Nov 15, 2021 — Study Guide to Accompany Introductory Clinical Pharmacology. Edition: 12. Read Reviews. 9781975163761. Format(s) Format: Paperback Book. \$48.99. introductory-clinical-pharmacology-7th-ed.pdf The seventh edition of Introductory Clinical.

Pharmacology reflects the ever-changing science of pharmacology and the nurse's responsibilities in admin-. Study Guide for Introduction to Clinical Pharmacology | Rent Study Guide for Introduction to Clinical Pharmacology7th edition ; ISBN-13: 978-0323076968 ; Format: Paperback/softback ; Publisher: Elsevier HS (2/7/2012). Introduction to Clinical Pharmacology [7th Edition ... • Answer Keys to the Critical Thinking Questions, Case Studies, and Study Guide activities and exercises are available for your own use or for distribution ... Intro to Clinical Pharmacology Flashcards Edmunds 7th edition Learn with flashcards, games, and more — for free ... key to determining whether or not teaching was successful and learning occurred. Study Guide for Introduction to Clinical Pharmacology Review sheets help you remember common measures, formulas, and difficult concepts. A variety of learning activities includes short answer, matching, multiple- ... Study Guide for Introduction to Clinical Pharmacology Review sheets help you remember common measures, formulas, and difficult concepts. A variety of learning activities includes short answer, matching, multiple- ... I need the answer key for the Introduction to Clinical ... Jun 9, 2022 — I need the answer key for the Introduction to Clinical Pharmacology Study Guide book by Visovsky Zambroski and Holser. SCIENCE · HEALTH SCIENCE ... NAVFAC DM7-02 Foundations and Earth Structures soil mechanics in the design of foundations and earth structures for naval shore facilities. It is intended for use by experienced engineers. The contents ... Foundations and Earth Structures: NAVFAC DM 7.02 This manual covers the application of basic engineering principles of soil mechanics in the design of foundations and earth structures for naval shore. NAVFAC DM7-02 Foundations and Earth Structures soil mechanics in the design of foundations and earth structures for naval shore facilities. It is intended for use by experienced engineers. The contents ... Foundations and Earth Structures. Design Manual 7.2 1982 · Cited by 7 — Design guidance is presented for use by experienced engineers. The contents include excavations compaction, earthwork, and hydraulic fills analysis of walls ... Foundations and Earth Structures: NAVFAC DM 7.02 It covers a wide variety of topics, including excavations; compaction, earthwork and hydraulic fills; analysis of walls and retaining structures; shallow ... NAVFAC DM7.01 Soil Mechanics Sep 1, 1986 — Soil Mechanics. 7.02. Foundations and Earth Structures. 7.03. Soil Dynamics, Peep Stabilization and Special Geotechnical. Construction. Change 1 ... The "Before and After" of NAVFAC DM 7 - vulcanhammer.net Sep 28, 2022 — "DM-7" refers to the design manual for geotechnical engineering, entitled Soil Mechanics, Foundations and Earth Structures. The "original" DM-7 ... Foundations and Earth Structures: NAVFAC DM 7.02 Jul 25, 2009 — It covers a wide variety of topics, including excavations; compaction, earthwork and hydraulic fills; analysis of walls and retaining structures ... Foundations and Earth Structures: Navfac DM 7.02 It covers a wide variety of topics, including excavations; compaction, earthwork and hydraulic fills; analysis of walls and retaining structures; shallow ... Design Manual 7.2 - Foundations and Earth Structures S. NAVFAC Design Manual'DM-7.2. Design Criteria. Final. Foundations and Earth Structures ... portions of Soil Mechanics, Foundations, and Earth Structures, NAVFAC ... Pipe fitter NCCER Flashcards Study Flashcards On Pipe fitter NCCER at Cram.com. Quickly memorize the terms, phrases and much more. Cram.com

makes it easy to get the grade you want! Pipefitter Nccer V4 study guide Flashcards Study with Quizlet and memorize flashcards containing terms like OSHA approved anchorage point, 3 1/2, 30 PSI and more. Free Pipefitter Practice Test with Questions and Answers 2023 This is a free Pipefitter practice test with full answers and explanations, to give you a taste of the real exam. Pipefitter Test - Fill Online, Printable, Fillable, Blank | pdfFiller General pipefitter interview questions Tell us something about yourself. How did you know about this job opportunity? Do you know anyone already working for ...

Pipefitting Pipefitting covers key concepts of installation and repair of high- and low-pressure pipe systems used in manufacturing, in the generation of electricity and ... pipe fitter test Flashcards Study with Quizlet and memorize flashcards containing terms like What does TE in TE-601 stand for?, what does B.T.U stand for?, what is the boiling point of ... nccer pipefitter test answers Discover videos related to nccer pipefitter test answers on TikTok. Nccer Pipefitting Level 2 Drawings And Detail Sheets Study Flashcards On Nccer pipefitting level 2 drawings and detail sheets at Cram.com. Quickly memorize the terms, phrases and much more.