

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 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-

- The authors are with the Department of Electrical and Electronic Engineering, University of Cagliari, Piazza S. Armi, 09123 Cagliari, Italy.
- Battista Biggio: e-mail battista.biggio@diee.unica.it, phone +39 070 675 5776, fax +39 070 675 5782.
- Giorgio Fumera: e-mail fumera@diee.unica.it, phone +39 070 675 5754, fax +39 070 675 5782.
- Gian Luca Marcialis: e-mail marcialis@diee.unica.it, phone +39 070 675 5993, fax +39 070 675 5782.
- Fabio Roli (corresponding author): e-mail roli@diee.unica.it, phone +39 070 675 5779, fax +39 070 675 5782.

Statistical Meta Information Systems

PT Brinkman



Statistical Meta Information Systems:

Discover tales of courage and bravery in Explore Bravery with its empowering ebook, **Statistical Meta Information Systems** . In a downloadable PDF format (Download in PDF: *), this collection inspires and motivates. Download now to witness the indomitable spirit of those who dared to be brave.

<https://thebrandexperience.com/results/book-search/default.aspx/Uneasy%20State%20The%20United%20States%20From%2001915%20To%201945.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 Acrobats 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 :

uneasy state the united states from 1915 to 1945

understanding the sermon on the mount

underwater engineering surveys

underwater continent the continental shelves

understanding the great gatsby a student casebook to issues sources and historical documents

understanding sys

unfinished republic

united states and international markets commercial policy options in an age of controls

unexpected knowing

understanding the faith of the church

uninvited dilemma

unforgettable americans

uniformed services almanac 2002 uniformed services almanac 44th ed

united states and world war two the awakening giant

une paroisse raconte ses morts habituelle de leglise saintpaul a villeneuve

Statistical Meta Information Systems :

Playing the Matrix: A Program for Living... by Dooley, Mike Practical, logical, loving, creative, passionate... Such a clear pathway for us to transform our own unique life - Playing the Matrix is packed full of tools, ... Playing the Matrix: A Program for Living Deliberately and ... This is Mike Dooley's advanced course on living deliberately and creating consciously. The concepts he shares were born of material he's delivered to live ... Playing the Matrix In Playing the Matrix, New Thought leader and New York Times best-selling author Mike Dooley brings to bear his advanced course on living deliberately and ... Playing the Matrix Jul 23, 2019 — In Playing the Matrix, New Thought leader and New York Times best-selling author Mike Dooley shares his most impactful, transformational ... Playing the Matrix Online Course In this transformational online video course, Playing the Matrix, you'll: · Learn the secret mechanics of manifestation and reality creation from the ground up ... Playing the Matrix: The Laser-Focused Series Online Course In this premiere online series, Mike Dooley teaches you the crucial nuances of manifestation in the six major areas of life that most commonly need change: ... Playing the Matrix by Mike Dooley - Audiobook Playing the Matrix is a master class for creating the life you want to live. Tried and true, delivered

and perfected over a decade while being shared live ... Playing the Matrix: A Program for Living Deliberately and ... Mike Dooley is a former PricewaterhouseCoopers international tax consultant turned entrepreneur. He's the founder of a philosophical Adventurers Club on the ... Playing the Matrix: A Program for Living Deliberately and ... This is Mike Dooley's advanced course on living deliberately and creating consciously. The concepts he shares were born of material he's delivered to live ... Abnormal Psychology (text... by S. Johnson J. M. ... Kring. Abnormal Psychology (text only) 11th(eleventh) edition by A. Kring,S. Johnson,G. C. Davison,J. M. Neale. 4.2 4.2 out of 5 stars 70 Reviews. 3.9 on ... Abnormal Psychology 11th (eleventh) edition by Ann Kring Abnormal Psychology 11th (eleventh) edition ; Returns. Returnable until Jan 31, 2024 ; Payment. Secure transaction ; Print length. 0 pages ; Language. English. Abnormal Psychology | Rent | 9780470380086 Rent Abnormal Psychology 11th edition (978-0470380086) today, or search our site for other textbooks by Ann M. Kring. Every textbook comes with a 21-day ... Abnormal Psychology, 11th Edition Request a sample or learn about ordering options for Abnormal Psychology, 11th Edition by Ronald J. Comer from the Macmillan Learning Instructor Catalog. Abnormal Psychology 11th Edition Binder Ready ... Abnormal Psychology 11th Edition Binder Ready Version with Binder Rea. by Ann M. Kring | Loose Leaf. Be the first to write a review. discover-books 98.6 ... Abnormal Psychology, 1st Edition & Case Studies ... This e-text set contains Krings Abnormal Psychology, 1st Australasian Edition and Oltmanns Case Studies in Abnormal Psychology, 11 Edition. Abnormal Psychology Eleventh Edition Binder ... Abnormal Psychology Eleventh Edition Binder Ready Version. Ann Kring. Published by Wiley (2009). ISBN 10: 0470418362 ISBN 13: 9780470418369. Used Quantity: 1. Abnormal Psychology 11th Edition By Johnson ... The eleventh edition also demonstrates how context drives the definitions of normal and abnormal behavior. With the new features, psychologists will find the ... Pre-Owned Abnormal Psychology 11th Edition Binder ... Pre-Owned Abnormal Psychology 11th Edition Binder Ready Version with Binder Ready Survey Flyer Set Other 0470927267 9780470927267 Ann M. Kring. USDNow \$3.99. ABNORMAL PSYCHOLOGY ELEVENTH EDITION ... ABNORMAL PSYCHOLOGY ELEVENTH EDITION BINDER READY VERSION By Ann Kring ; Item Number. 335120362943 ; ISBN-10. 0470418362 ; Book Title. Abnormal Psychology Eleventh ... Explaining Psychological Statistics, 3rd... by Cohen, Barry H. This comprehensive graduate-level statistics text is aimed at students with a minimal background in the area or those who are wary of the subject matter. Explaining Psychological Statistics 3th (third) edition Explaining Psychological Statistics 3th (third) edition ; Print length. 0 pages ; Language. English ; Publication date. January 1, 2007 ; ASIN, B006QZ9VN0. Explaining psychological statistics, 3rd ed. by BH Cohen · 2008 · Cited by 1434 — Cohen, B. H. (2008). Explaining psychological statistics (3rd ed.). John Wiley & Sons Inc. Abstract. This edition retains the basic organization of the previous ... barry cohen - explaining psychological statistics - AbeBooks Explaining Psychological Statistics · Price: US\$ 5.76 ; Explaining Psychological Statistics, 3rd Edition · Price: US\$ 6.25 ; Explaining Psychological Statistics. Explaining Psychological Statistics - Barry H. Cohen This comprehensive graduate-level statistics text is aimed at students with a

minimal background in the area or those who are wary of the subject matter. Explaining Psychological Statistics Cohen 3rd Edition Pdf Explaining Psychological Statistics Cohen 3rd Edition Pdf. INTRODUCTION Explaining Psychological Statistics Cohen 3rd Edition Pdf Full PDF. Explaining Psychological Statistics, 3rd Edition - Hardcover This comprehensive graduate-level statistics text is aimed at students with a minimal background in the area or those who are wary of the subject matter. Explaining Psychological Statistics | Rent | 9780470007181 Rent Explaining Psychological Statistics 3rd edition (978-0470007181) today, or search our site for other textbooks by Barry H. Cohen. EXPLAINING PSYCHOLOGICAL STATISTICS, 3RD ... EXPLAINING PSYCHOLOGICAL STATISTICS, 3RD EDITION By Barry H. Cohen - Hardcover ; Item Number. 186040771674 ; ISBN-10. 0470007184 ; Book Title. Explaining ... Explaining Psychological Statistics, 3rd Edition, Cohen ... Explaining Psychological Statistics, 3rd Edition, Cohen, Barry H., Good Book ; Est. delivery. Wed, Dec 27 - Tue, Jan 2. From New York, New York, United States.