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CURRENT EVIDENCE ON BIOINFORMATICS ROLE AND DIGITAL FORENSICS THAT CONTRIBUTE TO FORENSIC SCIENCE: UPCOMING THREAT

Rosyid R. Al Hakim [a,b,c], Esa R. C. Putri [d,e], Hexa Apriliana Hidayah [f,*], Agung Pangestu [g], Sri Riani [h]
[a] Graduate Program in Primatology, Graduate School, alhakimrosyid@apps.ipb.ac.id, IPB University
[b] Graduate Program in Department of Electrical Engineering, rosyidridlo@student.jgu.ac.id, Jakarta Global University
[c] School of Computer Science, rosyidridlo@nusaputra.ac.id, Nusa Putra University
[d] Department of Office Administration, esa.rinjani.c@mhs.unsoed.ac.id, Universitas Jenderal Soedirman
[e] Yunior Researcher, esarinjani31@gmail.com, Eudaimonia Institute Foundation Research Center
[f] Faculty of Biology, *hexa.apriliana6@gmail.com, Universitas Jenderal Soedirman
[g] Department of Electrical Engineering, agungp@jgu.ac.id, Jakarta Global University
[h] Department of Biology, sririani92@gmail.com, International Women University

ABSTRACT

Forensics has become an essential part of the disclosure of criminal evidence. A bioinformatics approach in the form of DNA forensics and digital forensics can be a good combination in disclosing digital-based criminal evidence. This study explains how the role of bioinformatics through the digital approach can be a means of forming new approaches in integration with digital forensics, called cyber-bioinformatics. Despite many hopes and challenges ahead, it does not rule out the possibility of criminal cases related to the privacy of human genomic data, so it proposes a new hypothesis, "cyber-bioinformatics." The role of cyber-bioinformatics is very central in this regard.

Keywords: Cyber-bioinformatics, DNA analysis, Forensic DNA, Forensic photography, Genomic data privacy.

ABSTRAK

Forensik telah menjadi bagian penting dari pengungkapan bukti kriminal. Pendekatan bioinformatika berupa forensik DNA dan forensik digital dapat menjadi kombinasi yang baik dalam mengungkapkan bukti kriminal berbasis digital. Penelitian ini menjelaskan bagaimana peran bioinformatika melalui pendekatan digital dapat menjadi sarana pembentukan pendekatan baru dalam integrasi dengan forensik digital, yang disebut cyber-bioinformatics. Meskipun banyak harapan dan tantangan ke depan, tidak menutup kemungkinan kasus kriminal terkait dengan privasi data genomik dari manusia, sehingga mengusulkan hipotesis baru, "*cyber-bioinformatics*". Peran cyber-bioinformatics sangat sentral dalam hal ini.

Kata Kunci: Analisis DNA, *Cyber-bioinformatics*, DNA forensik, Fotografi forensik, Privasi data genomik.

1. INTRODUCTION

Forensics comes from the Latin *forensis*, which means "*from the outside*" or "*public place*." Forensics can be interpreted as a field of science that is used to help the process of enforcing justice through the process of applying science or science [1]. Forensics is vital in revealing the truth in judicial cases [2]. One of the science that contribute to forensics is biology [3].

In the era of digital, today, anything else needed to prove the evidence in the criminal investigation, including forensic DNA and bioinformatics [4] also cyber or digital forensics [5], because one these digital forensics also can be used for legal evidence-based electronic in criminal justice system [6]. In addition, with bioinformatics, the biological evidence based on DNA analysis can contribute to some biological crimes, such as sexual cases [7], sex identification [8], person or disaster victim identification based on ethnicity [9], [10], determining the quality of DNA by room temperature effect [11], human identification in old skeletal cases [12], child sex trafficking cases [13], ancient DNA analysis [14], a missing person

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**Corresponding Author*

[15], biological relationship reconstruction [16]. Meanwhile, some cases were found in forensic microbiology [17], DNA analysis from extracted saliva [18], [19], forensic ecology in endangered primates [20], and also contribute to outbreaks [21]. Besides, digital forensics has been used to propose the digital-evidence based, like live forensic analysis on WhatsApp [22] and Web-based [23] also by using Support Vector Machine (SVM) on WhatsApp group [24], biometrics in forensic identification [25], static forensic with the framework from National Institute of Justice (NIJ) [26], Digital Forensic Readiness Index (DiFRI) Models [5], mobile forensics [27], NIST method for Facebook and Instagram investigation [28], and audio forensics [29]. Unique and challenging, a recent study reported that the internet is the most significant way to be a terrorist used [30], [31].

Along with the development of science−technology, the role of bioinformatics is crucial in revealing the truth of an investigation. On the other hand, information technology, often used as evidence in strengthening the truth for justice, is very meaningful in forensic science. When used in case investigations, these two things can undoubtedly provide opportunities for case resolution and fast and accurate disclosure of the truth. On the other hand, every technology allows a loophole for illegal actions. Forensic science has developed to help forensic doctors reveal biological supporting evidence and, assisted by digital technology support, can be faster and more accurate in completing investigations. The development of science and technology can help forensic doctors work, and abuse may occur. Several recent studies have proven the role of bioinformatics in DNA forensics. In addition, the role of digital forensics is to become supporting evidence for solving cases. Both are the result of technological developments. Bioinformatics puts forward a molecular and informatics approach, while digital forensics uses an information technology approach in the forensic field.

This study explains how bioinformatics and digital forensics can play an essential role in investigating criminal cases in forensic science, also the further threat that may affect income for the role of forensic sciences.

2. LITERATURE REVIEW

2.1. Pathway to Provide Evidence-Based with Science and Technology

What if these two inventions, bioinformatics and digital forensics, can become a dangerous sword if not used according to the applicable protocol. Of course, this is a particular concern. In addition to developing the latest molecular discoveries, technological developments are increasingly rapid and allow anyone to access them, even if they are not law enforcers. Bioinformatics and digital forensics were originally tools in medical forensics, but there were times when they boomeranged for truth enforcement. The ease of access to this technology needs attention in setting protocol standards for forensic science completion. Nevertheless, forensic doctors are the most valid truth-telling in forensics. Bioinformatics and digital forensics are the only tools to reveal the truth in forensic science.

2.1.1. Molecular Biology as the Key to Bioinformatics

Molecular biology is the science of organization, activity, and gene regulation on the molecular level [32]. Molecular biology can be used for species identification on the molecular level, which cannot be done at the level of morphological characteristics [33], [34]. At the molecular level, genetic diversity was becoming a challenge for determining the genetic structure and its relationship between environment, human activity, and impact on urbanization [35], also conservation success [36].

Interestingly, this molecular biology has been fundamental to the advancement of bioinformatics, particularly in gene analysis at the molecular level. It cannot be appreciated anymore that the development of bioinformatics, along with the development of information technology, allows bioinformatics to play a role quickly, precisely, and accurately in terms of identification of living things (biological parameters) at the molecular level. And of course, with this molecular evidence, a mystery of living things can be solved and can be known its identity. Besides, the role of bioinformatics also is part of forensic medical examination (FME) [7].

2.1.2. Bioinformatics and Information Technology

Since the human genome project was carried out [37], the development of information technology and biotechnology doesn't limit DNA information from the genome only, which is going to be the way of proteomics and metabolomics [38]; this is also made bioinformatics more beneficial for life sciences. Besides, gene coding usually uses a digital approach in bioinformatics. Bioinformatics needed the

information technology for genetic data management, sequencing, analyzing, mapping, genotyping, and many more [4]. Contribute information technology such as software for next-generation sequencing (NGS) for mitochondrial (mt) DNA analysis can be used for DNA−forensic analysis [39]. I.e., the AQME tool [40], Torrent Suite software [15], and other software for STR analysis such as GeneMapper-IDX software [12], [13]. In addition, an online genetic database was needed to support the DNA analysis, such as The ALlele FREquency Database (ALFRED) [9], [16], STR databases [4], [41], [42], and Thermo Fisher Scientific equipment [14], also based on some research facility [18].

2.1.3. Digital Forensics: Digital Breakthroughs to Uncover the Truth

According to Indonesian regulation about electronic information and transactions law Number 11 of 2008 [6] and Number 8 of 1981 Article 184 [23], explicitly and comprehensively regulated rules in use and transactions of electronics, including digital forensic regulation. In addition, other digital forensics' regulations, such as from the National Institute of Justice (NIJ) [26], National Institute of Standards and Technology (NIST) [23], and other forensic regulations in many countries.

A digital approach can be used to determine the digital evidence in criminal cases [26] and, in some cases, malware attacks [5], [43]. A recent study reported that digital forensics could be used to prove the case of rife electronic transaction fraud [23]. Besides, with the development of digital forensics and information technology, audio forensics can be used to identify perpetrators of crimes [29]. In addition, mobile forensics is also one of the trends in digital forensics, which can contribute to proving the digital-based evidence [22], [27], [28]. Recently, biometrics has also can contribute to proving digital-based evidence [25].

Some of the results of these studies prove the success of digital forensics in proving legally valid digital evidence. In some judicial cases, the role of digital forensics is needed in uncovering cybercrime or electronic transactions.

3. DISCUSSION

Forensic science, including forensic pathology, toxicology, ecological forensics, forensic psychology, forensic accounting, genetics, and digital forensics, is vital in providing scientific evidence on criminal crimes. These approaches can also prove that and some cases of covert crimes. Some of the results of previous studies also reported that one of the things that led to the success of terrorism crimes is the results of technological developments, namely the internet [30]. In addition, cases that are difficult to prove at crime scenes can be through a bioinformatics approach, in the form of DNA analysis of live samples at the crime scene [44]. Although the two are different fields of science, the development of forensic science allows the two to be integrated and complementary.

The integration between molecular biology and digital technology can occur just like molecular machines based on digital [44]. Not only that, primers in DNA sequence analysis use a digital approach, gene databases (gene banks) are freely available in digital versions, and anyone can access even human genome data. Even though digital forensics.

The molecular medical approach indeed uses bioinformatics techniques. DNA forensics is an important part of proving the truth in forensic science. A forensic doctor can take a biological sample for DNA analysis with a molecular approach using bioinformatics tools [44]. On the other hand, these tools use digital technology. Although this digital technology is different from digital forensics, both are undeniably the result of the development of information technology or digitization.

This digitization is another nomenclature called cyber. Cyber development due to unlimited internet access can allow access to information quickly, cheaply, and accurately. This cyber capability can submit information on laboratory results. The digital version allows a person not to go directly to where the sample testing is carried out. This information is also supported by the electronic validation of each electronic document of information.

3.1. Bioinformatics is the Body of Forensic Biology

As we all know, forensic DNA has become a biologically valid evidence tool based on biological samples such as blood, hair, fingerprints, skin lining, feces, semen, sperm fluid [4], soft tissues, urine, vaginal fluid [45], saliva [18], [19], [46], and bone structure [14]). The samples can be analyzed bioinformatically to

reveal the truth of objective biological evidence. Forensic experts almost always submit an analysis of biological samples for clues. Not only that, but bioinformatics in practice is also inseparable from the digital approach. Of course, this has become a point of achievement in forensic science, especially forensic biology at the molecular level.

3.2. Digital Forensics As A Cyber−Forensic Science

Archivists borrow and adapt techniques used in criminal investigations to access data and files created in systems that are now obsolete [47]. The role of digital in forensic purposes can also be for scientific purposes, such as evidence of scientific photography that needs to be traced to its validity; this is important in scientific publications. Forensic software tracks change to images [48]. Forensic photography is central to the digital approach because photographic files are stored in hardware, so they must be digital files. Forensic photography used in medical approaches can provide scientific evidence such as digital dental models [49], dental photography [50], skeletal radiography [51], X-ray CT fossil [52], and CT images of human cranium [53].

In the case of image processing from digital forensic photography files, the contribution of artificial intelligence such as machine learning (ML) is essential to aid the identification process [54]. With the ML approach, some cases such as sex determination [52] and forensic entomology [53] can be revealed. Besides, all digital photography files must be stored privately for privacy [50].

As a cyber−forensic science, digital forensics also plays a role in biomedical engineering. For example, thermal 3D imaging can determine the human body condition post-mortem [55]. In addition, bioinformatics combined with digital forensics also can explain terrorism's case of Improvised Explosive Devices (IEDs) [56]. Besides, a recent study reported that minisatellite repeat coding had been completed with a digital approach [57], the case of a new forensic tool for dating pools of human blood [58], also genome technology for DNA profiling with a digital approach [59]. But, new challenges have come, which need genome data privacy [60], [61].

3.3. Bioinformatics with Digital Forensics: From the Small Things to Evidence-Based Things

Benefit and Challenges: Bioinformatics needed a platform or tool for genetic management, such as [4]:

- Haploview (www.broad.mit.edu/mpg/haploview),
- Haplofreq (http://www.cs.princeton.edu/haplofreq/),
- Tagger (www.broad.mit.edu/mpg/tagger/),
- QTDT (http://bioinformatics.well.ox.ac.uk/project-ld.shtml),
- GOLD (http://bioinformatics.well.ox.ac.uk/project-ld.shtml),
- GRR (http://bioinformatics.well.ox.ac.uk/GRR),
- SNPtagger (http://www.well.ox.ac.uk/?xiayi/haplotype),
- PLINK (http://pngu.mgh.harvard.edu/?purcell/plink/haplo.shtml),
- PHASE (http://www.stat.washington.edu/stephens/software.html),
- Snphap (http://www-gene.cimr.cam.ac.uk/clayton/software/snphap.txt),
- Arlequin (http://anthro.unige.ch/arlequin/software/),
- some 'R' packages (http://lib.stat.cmu.edu/R/CRAN/),
- Other repositories with interesting software and data sets are http://www.nslij-genetics.org/soft/,
- http://linkage.rockefeller.edu/soft/,
- http://www.animalgenome.org/soft,
- www.hapmap.org/download/encode1.html,
- http://www.broad.mit.edu/tools/data.html;

Well, it can be proven that although bioinformatics is part of molecular biology, it requires a digital approach. These tools are evidence of using gene materials from gene banks or biological samples previously taken by forensic doctors during their examination. Depending on applicable policies, information from this gene bank can be freely accessible or commercially used. Access to this molecular-level information can be an advantage or disadvantage. Both can occur or be carried out by interested parties. Can bioethics be a guide in overcoming this bias? Of course, there is still a need for a comprehensive study related to this, and this study is independent of the issue.

Of course, this allows these two sciences, bioinformatics and digital forensics can become one multidisciplinary new forensic science, cyber-bioinformatics. In practice, digital forensics is a branch of forensics that specifically handles digital evidence. Today, the development of digitalization is increasingly widespread and proven in DNA analysis, which always requires a digital approach, both in the process of sequencing, determination, haplotyping, genotyping, and so on, in tandem with information technology, precisely the digital approach. Digital forensics plays an essential role in this, through a wide stance against cybercrime, on the other hand, supporting the smooth process of bioinformatics, such as DNA analysis in criminal cases.

Another possibility is that anyone can access the success of human genome project; this can be a gap in digital crime and bioinformatics. Can cyber-bioinformatics solve cases like this? By tracking DNA analysis on a particular tool on crimes related to the human genome? It is improbable to rule out the possibility of it. In support of that argument, the study sought to provide cyber-bioinformatics hypotheses as biologically valid evidence:

1) *Bioinformatics is part of molecular biology, so a molecular approach is needed in DNA forensics*.
2) *Bioinformatics requires the role of information technology and digital approaches:* therefore, there is a possibility of integration between bioinformatics and digital forensic forensics, called forensic cyber-bioinformatics.
3) *DNA forensics never lies, but its analysis allows bias, so the role of technology, platforms, tools, and databases, is of legal importance and must be carefully used in DNA forensics.*

The three points hypotheses were proposed because they saw the development of information technology and digital technology that is increasingly widespread, to be used in many fields of science, including the forensic science branch. An excellent legal approach or updating the latest legal forensic rules is needed to support these three points. Although the chances of cybercrime in the human genome are still small, there is no guarantee that it could be widely used as a bioterrorist and bioweapon threat.

4. CONCLUSION AND FUTURE SCOPE

This study explains how the role of bioinformatics through the digital approach can be a means of forming new approaches in integration with digital forensics, called cyber-bioinformatics. Despite many hopes and challenges ahead, it does not rule out the possibility of criminal cases related to the privacy of genomic data from humans. Cyber-bioinformatics's role is central in this regard, and it does not rule out the possibility of that in the future. There could be many challenges to scientific proof of criminal cases based on the approach of bioinformatics methods, digital forensics, to a new hypothesis called cyber-bioinformatics.

Authors' Contributions

Rosyid R. Al Hakim researched literature and conceived the study. Esa R.C. Putri was involved in the in-depth review and analysis. Hexa A. Hidayah and Sri Riani collected the bioinformatics literature. Agung Pangestu evaluated the manuscript. All authors wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version.

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Study Limitations

This study proposed a new hypothesis, and further research is needed for hypothesis testing.

Conflict of Interest

All authors declare that they do not have any conflict of interest.

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NOMENCLATURE

DNA meaning of deoxyribonucleic acid