



BELGRADE  
METROPOLITAN  
UNIVERSITY

12TH INTERNATIONAL CONFERENCE



Belgrade Metropolitan University  
Belgrade, 3rd December 2021.  
[www.metropolitan.ac.rs](http://www.metropolitan.ac.rs)

PROCEEDINGS

**The Twelfth International Conference on Business Information Security**



Belgrade Metropolitan University

Belgrade, 3<sup>rd</sup> December 2021.

[www.metropolitan.ac.rs](http://www.metropolitan.ac.rs)

**Publisher**

Belgrade Metropolitan University  
Tadeuša Košćuška 63, Belgrade, Serbia  
<http://www.metropolitan.ac.rs>

**For Publisher**

Prof. Dr Dragan Domazet

**Editor**

Doc. Dr Nemanja Zdravković  
MSc Bojana Domazet

**Chair of Organizing Committee**

Doc. Dr Nemanja Zdravković

**Conference Secretariat:**

MSc Bojana Domazet

**Design**

Petar Cvetković  
Mladen Radić

**Printing**

Copy Centar Kruševac

**Circulation**

60

**Belgrade, 2021.**

## **CONTENT**

ALEKSANDRA BRADIĆ-MARTINOVIĆ.....	7
<b>“Personal Data Protection in Serbian Hotels”</b>	
NENAD O. VESIĆ.....	14
<b>“Advanced Cryptography by using Christoffel Symbols”</b>	
ZLATOGOR MINCHEV.....	18
<b>“Malicious future of AI: Transcendents in the digital age”</b>	
STEFAN TAFKOV.....	23
<b>“Cloud intelligence network for ransomware detection and infection effect reversing”</b>	
STEFAN TAFKOV, ZLATOGOR MINCHEV.....	27
<b>“Decentralized file storage and ransomware protection”</b>	
ANDREJA SAMČOVIĆ.....	31
<b>“Smart cards to improve security of biometric systems”</b>	
SINIŠA DOMAZET.....	37
<b>“Protection of personal data on the example of smart contracts”</b>	
KOMLEN LALOVIĆ.....	42
<b>“Result metric of fingerprint scanners done in Java GUI application”</b>	
DRAGAN Ž. ĐURĐEVIĆ, MIROSLAV D. STEVANOVIĆ.....	45
<b>“Effectiveness of new digital technologies in fighting terrorism and related money laundering”</b>	
JOVANA JOVIĆ, VIJAYAKUMAR PONNUSAMY, VLADIMIR MILIĆEVIĆ, NEMANJA ZDRAVKOVIĆ..	51
<b>“Securing Online Assessments in online educational systems using Blockchain”</b>	
MILOŠ S. DRAŽIĆ, MILOŠ JOVANOVIĆ, IGOR FRANC, DRAGAN DJOKIĆ, BOJANA TOMAŠEVIĆ DRAŽIĆ.....	55
<b>“Comparative analysis of digital signatures based on RSA cryptography and elliptic curve cryptography”</b>	
MILOŠ JOVANOVIĆ, IGOR FRANC, MILOŠ S. DRAŽIĆ, NENAD BIGA, BOJANA TOMAŠEVIĆ DRAŽIĆ.....	61
<b>“Security of government critical infrastructures with SCADA”</b>	

NEMANJA VESELINOVIĆ, MILOŠ JOVANOVIĆ, IGOR ORLIĆ, MILOŠ S. DRAŽIĆ, ACA ALEKSIĆ.....	66
<b>“Application of AI in data protection in the business environment”</b>	
DUŠAN J. SIMJANOVIĆ, NENAD O. VESIĆ, BRANISLAV M. RANDJELOVIĆ, NEMANJA ZDRAVKOVIĆ, DJORDJIJE VUJADINOVIĆ.....	71
<b>“A new cryptographic algorithm based on affine connection coefficients”</b>	
ACA ALEKSIĆ, MILOŠ JOVANOVIĆ, MILOŠ S. DRAŽIĆ, CHAD EHRLICH, BOJANA TOMAŠEVIĆ DRAŽIĆ, MILOŠ MILAŠINOVIĆ.....	75
<b>“The use of artificial intelligence to protect critical IT infrastructure”</b>	
NIKOLA DIMITRIJEVIĆ, ALEKSANDAR MESTEROVIĆ, MILENA BOGDANOVIĆ, NEMANJA ZDRAVKOVIĆ.....	81
<b>“Fraud detection and malicious code injection analysis in autograding systems”</b>	
MILENA BOGDANOVIĆ , NIKOLA DIMITRIJEVIĆ, VIJAYAKUMAR PONNUSAMY.....	86
<b>“On some application of the genetic algorithm in information security systems – a survey”</b>	

## Organizer





## PERSONAL DATA PROTECTION IN SERBIAN HOTELS

ALEKSANDRA BRADIĆ-MARTINOVIĆ

Institute of Economic Sciences, abmartinovic@ien.bg.ac.rs

**Abstract:** *The personal data that guests make available to the hotels they are staying in is becoming more and more exposed to breaches. This has been influenced by at least two factors in the last twenty years - the exceptional global development of tourist travel and new technological solutions involving private data collection. This paper aims to analyse empirical data collected through a web-based survey and in-depth interviews with top managers to determine whether hotel management in Serbia respects its guests' data privacy by following legal regulations - the Law on Personal Data Protection of the Republic of Serbia and EU's General Data Protection Regulation (GDPR). We can conclude that management in the Serbian hotel industry provides compliance with the law's provisions regarding personal data protection. Even so, insight into specific procedures or inspection reports would give us more precise results to avoid biased or unqualified responses. Proper education is the best way to overcome unintentional law violations, while intentional illegal actions should be sanctioned. We also believe that it is essential for domestic hoteliers to be familiar with the provisions of the application of the GDPR in their objects.*

**Keywords:** *Personal Data, Hotels, Tourism, Legal framework, GDPR, Law on Personal Data Protection, Serbia*

### 1. INTRODUCTION

The process of rapid digitalisation is distinctive in all areas of business, regardless of a particular sector. The number of systems that collect, process and store personal data has been increased recently. Also, in the last two decades, a significant volume of data has become online. Additionally, the Covid-19 disease pandemic has opened up space for the implementation of digitised solutions to avoid unnecessary social contacts, further growing the volume of personal data collected. As a consequence of this trend, personal data security and protection of personal privacy are raised, given numerous cases of data breaches. We can declare two recent examples. British Airways was fined over 26 mil USD for the significant data breach that potentially affected 400,000 customers [1]. At the same time, Marriott Hotels chain has to pay 25.3 mil USD for, influencing 399 million guests globally. As a result of the hacker attack, due to a lack of proper safeguards, the clients' contact details were compromised, including their names, email addresses, telephone numbers, information about arrival and departure, VIP status, and numbers of loyalty programs.[2] The breaches were triggered by faults such as inadequate monitoring of privileged accounts, insufficient supervising of databases, lack or unsatisfactory management on critical systems and absence of encryption.

Based on only the two previously mentioned cases, we can gain insight into the extent of possible damage when it

comes to embezzling customer trust. This research focuses on particular businesses – hotels, the systems that provide accommodation within the tourism sector to a considerable number of visitors worldwide. Their importance in the business environment is reflected in the fact that the global hotel and resort market in 2019 was worth 1.2 trillion USD[5]. The latest trends in the hotel industry introduce even more personal data through the growth of contactless payments, voice search and voice control, enhanced personalisation, recognition technology, and similar.

The subject of this paper is the hotel industry in Serbia and its procedures regarding personal data, in line with legislation. This paper aims to analyse empirical data to determine whether hotel management in Serbia respects its guests' data privacy by following legal regulations.

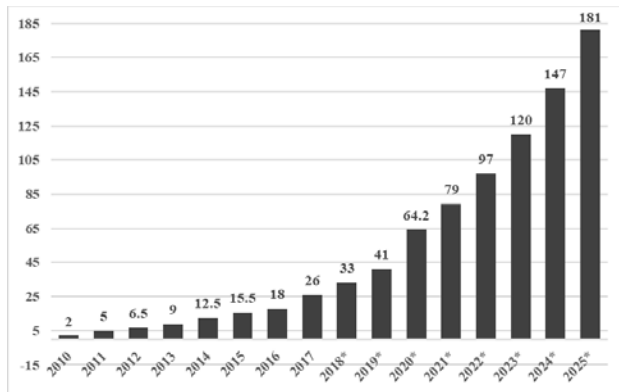
### 2. DATA BREACHES AND LEGAL RESPONSE

#### *Data breaches: Facts and Figures*

Today, data is the “fuel” that provides digital transformation and innovation. It permeates all areas of human activity - the state, economy, science, society. A tremendous amount of data is collected, processed, and shared in just one day on different bases. Data become ubiquitous, massively collected online, and enable much better connectivity.



Image 1 presents data volume created and consumed worldwide from 2010 to 2017 with a forecast from 2018 to 2025. The volume increased by 35% (CAGR).



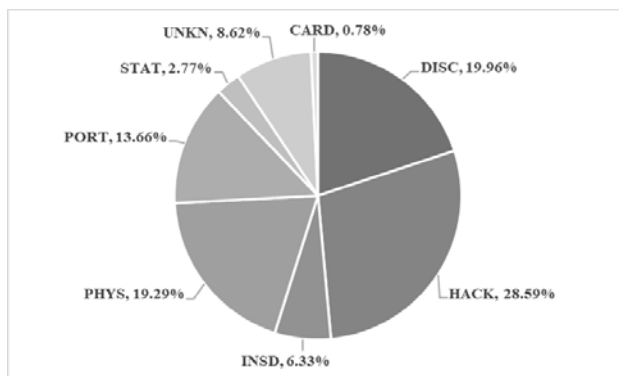
\* forecasted values

**Image 1:** Volume of data/information created, captured, copied, and consumed worldwide from 2010 to 2025 (in zettabytes) [6]

On the other side, negative phenomena are also present, and the most devastating are breaches, and with the rapid expansion of data volume, including personal data, they are also on the rise.

Privacy Rights Clearinghouse (PRS) define a data breach as “a security violation in which sensitive, protected or confidential data is copied, transmitted, viewed, stolen or used by an unauthorised individual”. According to their methodology, we can distinguish “hacking theft of credit/debit card numbers, lost, discarded or stolen documents/devices, and mishandled sensitive information”. Additionally, MDA divides data breaches into several categories: “confidentiality breach, availability breach and integrity breach” [8]. Garrison & Ncube [9] use breach division as follows: “stolen, hacker, insider, exposed and missing”.

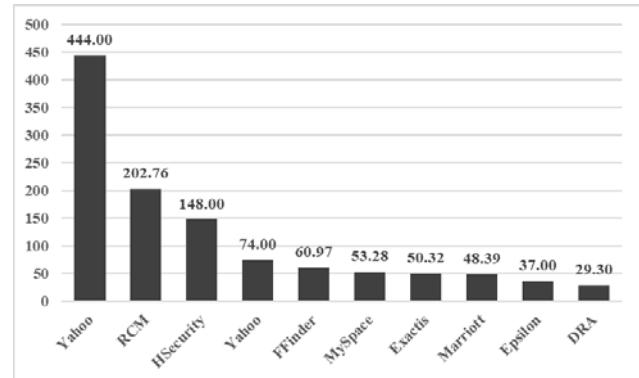
The distribution of different types of breaches in the United States, Asia and Europe is presented in Image 2.



INSD - an insider that intentionally breaches information; CARD - payment card fraud; PHYS - physical loss; PORT - lost or stolen portable device; HACK - being hacked by someone or infected by malware; STAT - stationary equipment loss; UNKN - an unknown method; DISC - an unintended disclosure like sending an email to the wrong person.

**Image 2:** Breaches type distribution [7]

Regardless of the type of breaches, the consequences of each of them can be harmful to the persons whose data are included, and the damage can be enormous. The same source [7] gives an overview of the largest breaches, according to record numbers/size, as presented in Image 3.



**Image 3:** Breaches by size (in terms of record numbers)

The three main ways these breaches can threaten companies are financial loss, legal misconduct, and reputational destruction. The consequences can cause enormous damage, so companies must protect themselves in this area.

#### Data privacy risks in the hotel sector

PwC reported few major points when it comes to data privacy in the hotel sector:[10]

- It is of great importance to make an effort to raise awareness on this topic, as the protection of virtual systems and cyber risks has become an alarming issue. They also add that research, but also practice, shows that security and privacy are still not in focus.
- Existing experience shows that the weakest security point for hotels is data manipulation regarding payment cards. Numerous court cases in the US testify to this statement, which necessitated the development of new, improved protection systems, revision of existing ones and detailed investigation in the case of breaches. On the other hand, guests need to be aware of the potential risks, as well.
- Hotels should think in advance about building and maintaining the trust, confidence, and position of their brand, without corrective measures that must be implemented based on court decisions. Leaving the framework of good business practice leads to long-term capital value erosion, especially if the company is listed on the capital stock exchange. Therefore, hotels are exposed to both legal and reputational risks.
- When it comes to the EU, the introduction of the GDPR has significantly brought hotels into line with the legal framework and avoid unnecessary litigations.

- “There is much more to security and privacy than compliance and risk.” [10]. Hotels have the opportunity to use the available data to provide better and more personalised services. The best way to reconcile potential risks and opportunities is to create an appropriate vision. The next step would be to develop a strategy to achieve the set vision. Persons in charge of security and privacy must be involved in the strategic planning process to gain insight into the desired situation and find a way to reach it.
- be aware that all software they use need to be in line with GDPR,

### Legal framework

Most countries have faced this problem and accordingly adopted laws on personal data protection. UNCTAD keeps track of Data Protection and Privacy Legislation Worldwide. According to their evidence, 66% of countries have legislation, 10% have draft legislation, 19% are without legislation (Libya, Egypt, Sudan, Ethiopia, Cameroon, Afghanistan, Bangladesh, Sri Lanka, Thailand and a few more), and 5% countries have no data. These laws’ most essential and primary benchmark is “use and sharing of personal information to third parties without notice or consent of consumers” [3].

Starting from the fact that Serbia is on the path of integration with the EU and regional tourist gravity towards this market, we believe that the analysis of legislation should start from the GDPR - General Data Protection Regulation (2016/679). The GDPR is applicable as of May 25 2018, in all member states to harmonise data privacy laws across Europe. Additionally, the goal is to raise the user’s trust in business entities - service providers and enables a more effortless flow of personal data between EU member states.

GDPR has returned power to customers and forced business systems to be transparent regarding collecting, storing, and sharing personal data and related information about their guests and employees. When it comes to hotels, the legal basis for collecting private data is a reservation, which is in line with the law. However, there are several clauses related to the way data is manipulated. Hotels have to:

- include top management in the process of personal data protection, at least three positions, General Manager, Head of Marketing and Revenue Manager,
- document what kind of data they hold, how the data is collected and processed and take action to assure compliance with their rights: to be informed, to access or modify data, to give or withdraw consent, to erase data and to transfer data,
- pay attention or avoid collecting sensitive data (biometrics, racial or ethnic origin, political opinions, religious or philosophical beliefs, trade union membership and health status – which gained high importance during the Covid-19 pandemic),

<p><b>‘personal data’</b> any information relating to an identified or identifiable natural person (‘data subject’); an identifiable natural person is one who can be identified, directly or indirectly, in particular by reference to an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person;</p> <p><b>‘processing’</b> any operation or set of operations which is performed on personal data or on sets of personal data, whether or not by automated means, such as collection, recording, organisation, structuring, storage, adaptation or alteration, retrieval, consultation, use, disclosure by transmission, dissemination or otherwise making available, alignment or combination, restriction, erasure or destruction;</p> <p><b>‘controller’</b> means the natural or legal person, public authority, agency or other body which, alone or jointly with others, determines the purposes and means of the processing of personal data; where the purposes and means of such processing are determined by Union or Member State law, the controller or the specific criteria for its nomination may be provided for by Union or Member State law;</p> <p><b>‘processor’</b> means a natural or legal person, public authority, agency or other body which processes personal data on behalf of the controller;</p> <p><b>‘data protection officer’</b> (DPO) is a person whose primary role is to ensure that his/her organisation processes the personal data of its staff, customers, providers or any other individuals (also referred to as data subjects) in compliance with the applicable data protection rules;</p> <p><b>‘consent’</b> of the data subject means any freely given, specific, informed and unambiguous indication of the data subject’s wishes by which he or she, by a statement or by a clear affirmative action, signifies agreement to the processing of personal data relating to him or her.</p>
---

**Table 1:** GDPR - Glossary of the most important terms[11]

- to have Data Processing Agreement in place with each vendor/provider; Hotels can use vendor services outside the EU, but the transfer must comply with the provisions of the GDPR. They must clearly define the data that the vendor will process and for what purpose. It is also obligatory for them to state the vendor’s name in the Privacy Policy, saying which data they use and for what purposes,
- ask for the consent of private persons whose data they handle if they want to use it for any purpose other than staying in a hotel based on reservations, e.g. for marketing and promotion purposes and loyalty programs, research, and profiling,
- to allow personal data to be removed at the request of the data subject (which is why they need to have mapped locations of all data they collect about persons);

- to appoint a Data Protection Officer or to seek guidance from a legal advisor, in case of small business systems,
- be aware that the GDPR does not apply to data made available by EU citizens to hotels outside the EU while staying in those hotels. Still, if the hotel uses an online booking system and the citizen fills in the form while in the EU, the hotel must comply with the provisions of the GDPR.

Based on the above-mentioned, DPP-GDPR[12] offers recommendations in case of a data breach. As a first step, they advise management to inform the Information Commissioner’s Office about the data breach in detail, then to assess the damage and try to reduce it while at the same time releasing a public statement. Further, to perform a detailed investigation and to use results as feedback for procedures and policies improvement.

In November 2018, Serbia adopted the Law on Personal Data Protection (“Official Gazette of RS” No. 97/08, 104/09 - other law, 68/12 – decision of the CC and 107/12), which came into force in August 2019. The law appliance is ensured through bylaws such as Rulebook on the Manner of Prior Review of Personal Data Processing (Official Gazette of the Republic of Serbia No. 35/2009); Decree on the Form for and Manner of Keeping Records of Personal Data Processing (Official Gazette of the Republic of Serbia No. 50/2009); Rulebook on the Form and Manner of Keeping Record of the Data Protection Officer (‘DPO’) (Official Gazette of the Republic of Serbia, No. 40/2019); Decision on the List of Countries, Parts of Their Territories or One or More Sectors of Certain Activities in Those Countries and International Organisations where it is Considered That an Adequate Level of Protection of Personal Data is Ensured (Official Gazette of the Republic of Serbia, No. 55/2019), and more.[4]

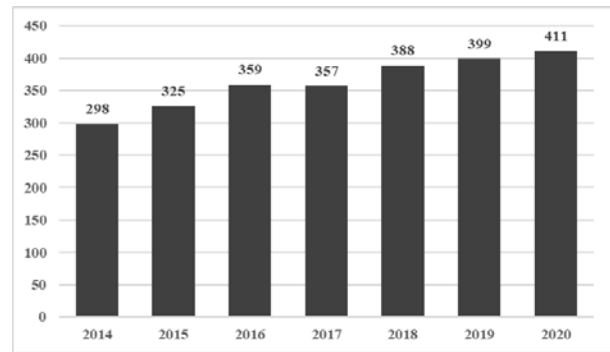
After two years of application, at the Tribune “How secure is the personal data in your company” held in June 2021, it was concluded that: “The Law on Personal Data Protection is not clear enough to those for whom it is intended, as well as to those who handle data.” [13] Insufficient understanding creates an ample space for errors and omissions in the data handling and processing, which endangers both private individuals and businesses to which the Law applies. On the example of the hotel sector in Serbia, we will explore the practice in this area.

Serbian National Strategy for Personal Data Protection in Serbia has been drafted to approach this topic thoroughly.

### 3. EMPIRICAL EVIDENCE FOR SERBIAN HOTELS

The tourism sector in Serbia has seen a sharp increase in accommodation capacity in recent years. Based on data provided by the Statistical Office of the Republic of Serbia, in the period 2014–2020 number of hotels (including garni

hotels) raised at a rate of 5.5% (CAGR), as presented in Image 3.



**Image 3:** Hotel accommodation in Serbia

Each of these hotels is a business system that needs to apply the Law on Personal Data Protection. To discover their attitudes toward this subject, we did a short web-based survey. We sent 150 invitations (including all categories, locations and sizes of hotels) by email and collected responses in the first half of August 2021. Finally, 38 correct and complete questionnaires were collected. The structure of our sample is as presented in Table 1.

Hotel category	Share
3-star hotel	42%
4-star hotel	48%
5-star hotel	10%
Hotel location	Share
City hotel	37%
Destination hotel	63%
Size of the hotel (number of rooms)	Share
Less then 50	26%
51-100	58%
101-300	16%

**Table 2:** Sample structure

Based on the sample structure, it is evident that lower category hotels were not included in this survey due to a lack of response. Hotels categorised as 1-stared and 2-stared hotels are included in the total hotel offer with 19% (1-stared - 4% and 2-stared - 15%).

*Introduction of new acts and procedures* - We assume that in the last two years, hotels have had to change practices regarding personal data in order to harmonise their existing processes with the new law. To determine what personal data they collect, how, from whom, in what format, and for what purpose, determine how long the data is kept, what protection measures are applied, with whom this data can be shared, whether data are taken out of Serbia. We can

point a few not so obvious examples. Suppose a company uses video surveillance to ensure the safety of property and persons. In that case, it is crucial to introduce appropriate legal acts that will provide for how long the data collected by this video surveillance is kept, who takes care of the storage period, how the recordings are destroyed, etc. Also, web cookies are considered private data, and for that reason, it is obligatory to ask for permission.

According to the responses, the dominant number of hotels (91%) introduced changes. At the same time, other hotels (9%) are exposed to a much higher risk of endangering the privacy of their guests and employees.

*Privacy Policy* – Privacy Policy is a document created to explain what information a company or organisation collects about its customers and how they use that data and provide any other relevant information regarding their information.

Hotels should include in their Privacy Policy who is a data processor, basics or purpose for data collection, with whom they share data, duration of the processing, data security and (in some cases) how and why they transfer data outside of Serbia.

Purpose	Type of data
Fulfilling statutory obligations - registering a hotel guest with the competent authorities of the RS	<ul style="list-style-type: none"> <li>• name and surname;</li> <li>• date of birth;</li> <li>• place of birth;</li> <li>• residence (city, state, postal code);</li> <li>• citizenship;</li> <li>• gender;</li> <li>• length of stay at our hotel;</li> <li>• identification on the document information (ID or passport).</li> </ul>
Fulfilling contractual obligations - to register a guest at a hotel and provide it with e-services	<ul style="list-style-type: none"> <li>• name and surname;</li> <li>• gender;</li> <li>• address;</li> <li>• information on the identification document (ID or passport);</li> <li>• e-mail address;</li> <li>• telephone number;</li> <li>• credit card number and payment information;</li> <li>• preferences regarding room type, room views, extra packages and the like;</li> <li>• the license plate number to provide guests with a parking space.</li> </ul>

**Table 3:** Type of data according to the purpose – Example from “Hotel Mona”[14]

In Serbia, 85% of hotels have a Privacy Policy as a legal act. It would be interesting to find out if the management in these entities is fully acquainted with the purpose and content of this policy. So far, the practice has noticed that when the law imposes certain legal acts, their content is transcribed without a deeper consideration of specific circumstances.

Among the hotels that have adopted the Privacy Policy, only 69% have it publicly available on the Internet. At first glance, we can conclude that the situation in this area is good. Nevertheless, if we consider that 15% of hotels do not have this policy, published ones are much lower.

*Consent* - Hotels have the right to collect data if it is lawful, and two examples are listed in Table 3. However, suppose a hotel plans to use data without legal ground (for advertising, loyalty programs, web cookies). In that case, it must obtain consent from an informed person.

According to the response, only 70% of Serbian hotels provide consent.

*Data protection officer (DPO)* – The processor and the controller have to appoint the DPO if they are obliged under Article 56 of the Law – internal DPO. Otherwise, they may also nominate this position in case of need or use the consultancy services of the Commissioner (*Poverenik*) or another qualified person – external DPO. The primary role of the DPO is to monitor and control the processes and procedures and to give the assessment of the impact of processing on data protection.

The practice so far, especially in smaller organisations, has shown a lack of understanding of the importance and position of the DPO. There are even cases where organisations appoint a person without proper expertise or even basic knowledge to satisfy the form. The lack of professional support in this area can significantly jeopardise the data management process and thus the privacy of the persons whose data is collected and processed.

In Serbian hotels, 46% of respondents confirm that the management appoints DPO.

## 5. CONCLUSION

Protecting and preserving personal privacy in today’s digital society is becoming an increasing challenge. Numerous examples of accidental or malicious actions have led to the endangerment of this fundamental human right, followed by financial and/or other material losses and damages. Policymakers have recognised this threat, and in the last twenty years, most countries have adopted and then improved the legislation in this area. Business entities in Serbia, including hotels, are obliged to manage data under the Law on Personal Data Protection of the

Republic of Serbia. They also need to be aware of foreign trade, including online business, with the EU countries. In that case, they have to respect the General Data Protection Regulation (GDPR).

When it comes to hotels in Serbia, we found a high awareness of the need to adjust existing procedures to manipulate the personal data of guests and employees. Only a few hotels have not changed the processes and procedures that hopefully align with the previous law. Accordingly, most hotels have drawn up a Privacy Policy - the basic document they communicate with the persons whose data they process. Despite the importance of this document for the users of their services (hotel guests), not everyone has made it publicly available through a website. We would also like to point out that at least one-third of the hotels do not ask their guests for Consent, which gives them consent to expand the scope of the legal use of their personal data. Finally, most hotels do not appoint Data Protection Officers.

Based on the conducted research, we can conclude that management in the Serbian hotel industry provides compliance with the law's provisions regarding personal data protection. Even so, insight into specific procedures or inspection reports would give us more precise results to avoid biased or unqualified responses. Proper education is the best way to overcome unintentional law violations, while intentional illegal actions should be sanctioned. In response to this need, the Assistant Secretary-General held a training on implementing the Law on Personal Data Protection for hotels and tourist organizations on October 10, 2019, in the Chamber of Commerce and Industry of Vojvodina in Novi Sad.[15] We also believe that it is essential for domestic hoteliers to be familiar with the provisions of the application of the GDPR in their objects.

## 6. ACKNOWLEDGEMENT

This paper results from the research financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

## REFERENCES

[1] Tidy, J. British Airways fined £20m over data breach, BBC News, October 30 2020, Available at URL: <https://www.bbc.com/news/technology-54568784> (Accessed July 13 2021).

[2] Tidy, J. Marriott Hotels fined £18.4m for data breach that hit millions, BBC News, October 30 2020, Available at URL: <https://www.bbc.com/news/technology-54748843> (Accessed July 13, 2021).

[3] UNCTAD, Data Protection and Privacy Legislation Worldwide, Available at URL: <https://unctad.org/page/data-protection-and-privacy-legislation-worldwide> (Accessed July 11, 2021).

[4] Popović, U., Andrejević, M., Serbia - Data Protection Overview, December 2020, Available at URL: <https://www.dataguidance.com/notes/serbia-data-protection-overview> (Accessed July 20, 2021).

[5] Statista, Lock, S. Global hotel and resort industry market size worldwide 2011-2021, May 2021, Available at URL: <https://www.statista.com/statistics/1186201/hotel-and-resort-industry-market-size-global/> (Accessed July 13, 2021).

[6] Statista, Hoist, A. Amount of data created, consumed, and stored 2010-2025, Available at URL: <https://www.statista.com/statistics/871513/worldwide-data-created/> (Accessed July 20, 2021).

[7] Hammouchi, H., Cherqi, O., Mezzour, G., Ghogho, M., El Koutbi, M., Digging Deeper into Data Breaches: An Exploratory Data Analysis of Hacking Breaches Over Time, International Symposium on Machine Learning and Big Data Analytics for Cybersecurity and Privacy (MLBDACP), April 29 - May 2, 2019, Leuven, Belgium, doi: 10.1016/j.procs.2019.04.141.

[8] MDU, Data breaches, November 2020, Available at URL: <https://www.themdu.com/guidance-and-advice/guides/gdpr-data-breaches>, (Accessed July 21, 2021).

[9] Garrison, C.P., Ncube, M. A longitudinal analysis of data breaches, Information Management & Computer Security, Vol. 19 No. 4, 2011, pp. 216-230, doi: 10.1108/09685221111173049.

[10] PwC, Cyber and data security in the hotel industry, edited by Maddison, M. & Grinnell, A., 2016. Available at: <https://www.pwc.com/m1/en/publications/cyber-and-data-security-in-the-hotel-industry.html>. (Accessed July 20, 2021).

[11] GDPR official website, Available at URL: <https://gdpr.eu/>, (Assessed July 21, 2021)

[12] DPP-GDPR, How to Handle the Legal Implications of a Data Breach Effectively, Available at URL: <https://www.dpp-gdpr.com/news/legal-implications-of-a-data-breach/>, (Assessed July 21, 2021)

[13] "Danas" report on the Tribune, Available at URL: <https://www.danas.rs/drustvo/tribina-zakon-o-zastiti-podataka-o-licnosti-nejasan-i-onima-koji-ga-primenjuju/> (Accessed July 23, 2021)

[14] Official website of Hotel Mona, Available at URL: <https://monahm.com/en/politika-privatnosti/> (Accessed July 25, 2021)

[15] Report of the Commissioner for 2019, Available at URL:

<https://www.poverenik.rs/images/stories/dokumentacija-nova/izvestajiPoverenika/2019/Izvestaj-za2019.pdf>  
(Accessed August 1, 2021)

# ADVANCED CRYPTOGRAPHY BY USING CHRISTOFFEL SYMBOLS

NENAD O. VESIĆ

Mathematical Institute of Serbian Academy of Sciences and Arts, [n.o.vesic@outlook.com](mailto:n.o.vesic@outlook.com)

**Abstract:** In this paper, a metric tensor and the corresponding Christoffel symbols are applied for text-encryption. The uncountable infinities of real numbers and quadratic functions are used for better hiding of messages. The corresponding decryptions are relatively fast if the key is known. The paper is consisted of introduction and three parts. History of text-data-processing is recalled in introduction. In the first part of the paper, a small part of differential geometry necessary for this research is presented. In the second part, the encryption and decryption algorithms are presented. Finally, in the third part, the presented algorithm is tested. Program support is realized by software package Mathematica.

**Keywords:** encryption, decryption, safety, metric tensor, Christoffel symbols, differential equations

## 1. INTRODUCTION

Cryptography, often considered to provide secret communication over insecure channels has a long history, from antient times and pen-and-paper methods through machines and the well-known and applied new age algorithms. One of the major contributions of cryptography are the achievements of the mathematicians in Bletchley Park's team of scientists during the WWII. Using some of the encrypted data, scientists obtain as much as possible information about the original messages. One of the proved good procedures for such project is the solving the key, usually unique for a particular message. Depending on the number of keys used in the encryption and decryption process, we have two major parts of cryptography. Symmetric encryption handling the same key for both processes use block ciphers encrypting several bits as a single unit. DES (Data Encryption Standard) based on Shannon's idea was created in 1977 and considered unbreakable until Differential Cryptanalysis proposed by Biham and Shamir [1] and Linear Cryptanalysis method created by Matsui [2] required less complexity than a key-exhaustive search attack. Improvement came with a DES3 increasing the key size and AES with a 128- or 256-bit key size [3].

In [4] the initial idea for a common secret key over a public channel was created, enabling the creation of RSA algorithm [5] based on the number theory. Factorization of number obtained multiplying the large prime numbers guaranties the inviolability of the RSA system, demanding large 2048-bit key size. This problem can be overcome using significantly smaller key size in Elliptic Curve Cryptosystem.

The secrecy of transmitted messages holds an important part in modern electronic communication. As history has showed us, different authors have created different algorithms to hide the messages which should be sent to receiver [6].

From Caesar until now, people like to preserve their communication. Many different text data hiding algorithms are used [7]. Historically, the most famous code is Zimmermann's telegram [8]. After this message was broken, USA declared war on Germany (April 6, 1917).

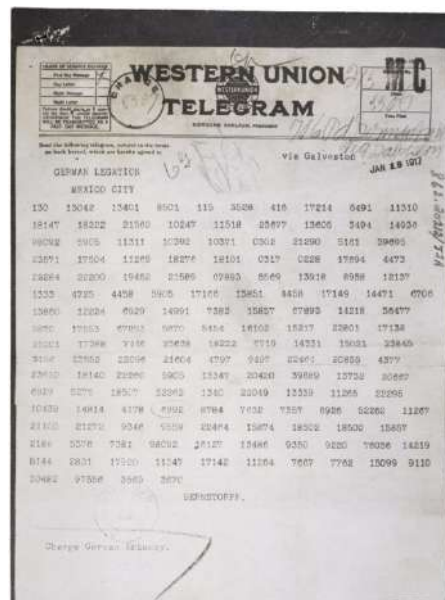


Image 1: Zimmermann Telegram

We are motivated with algorithm for text-data encryption and decryption presented in [9]. In this algorithm, authors used matrices and polynomials to encrypt text. In this