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Prototype of Blockchain-Based Diploma Transcript Authentication Method

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ABSTRACT

Each year, more than one million students receive their degrees from institutions of higher education. Some of them may make use of their diplomas and academic transcripts to apply for jobs or to pursue a career. To reduce the likelihood of diplomas being forged, the Ministry of Education and Culture of the Republic of Indonesia has implemented the Electronic Diploma Verification System (SIVIL). On the other hand, SIVIL storage is still carried out in a centralized way, which means that there is a risk that irresponsible parties could cause damage to the integration of diploma data that has been stored. The purpose of this research is to integrate blockchain theory and architecture to preserve the authenticity of diplomas, thereby resolving this issue. The identification of the problem, the review of the relevant literature, the analysis, the design, the production of the prototype, and the testing were done to accomplish this objective. According to the findings of the tests, the prototype that was developed can satisfy functional requirements and preserve the integrity of the data that is contained on diplomas and academic transcripts.

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1. INTRODUCTION

Based on the higher education data in Indonesia for the year 2020, over one million students completed their studies, and a portion of them will pursue employment in the industrial sector[1]. As part of the recruitment process, graduates are typically required to provide evidence of their academic accomplishment by submitting a copy of their diploma and academic transcript. Yet numerous issues arise, including the loss and forgery of those educational assets. Diploma forgery is a criminal offense involving the fabrication, modification, or use of a forged diploma with the purpose of obtaining employment prospects and advancing one's career[2]. This action constitutes academic fraud and violates Article 263 of the Criminal Code (KUHP). This has negative consequences for multiple stakeholders, including both the industry and institutions[3]. Given that accreditation by independent bodies like BAN-PT serves as a crucial mechanism for ensuring and standardizing the quality of higher education, the act of diploma forgery directly contradicts these efforts and erodes the trust placed in accredited qualifications.

On the other hand, blockchain, which was introduced by Satoshi Nakamoto in 2008, has had a significant impact on data storage methods in different industries[4]. Essentially, a blockchain is a collection of data blocks that are linked together through a hash value. Once a block is added, it cannot be easily changed. This makes blockchain highly resistant to data tampering [4], [5]. In the context of diploma authentication, blockchain offers an opportunity to prevent forgery by ensuring that any record (such as a student's graduation data) cannot be altered without detection. Furthermore, because each copy of the data is stored across many computers (called nodes), unauthorized changes on one computer will not affect the overall system.

Multiple related research studies implemented blockchain as a method of validating the authenticity of diplomas and transcripts. The majority of the research makes use of established blockchain platforms such as Blockcert and Ethereum [6] , [7] , [8] , [9] , [10] , [11]. Consequently, the diplomas and transcripts are maintained in the format of photographs or scanned images, demanding significant storage capacity. The diploma and transcript link in the form of a QR Code is then embedded in the original diploma and transcript document, or you can also use the client application provided. Embedding the QR Code is not in compliance with Regulation 59/2018 issued by the Minister of Research, Technology, and Higher Education of the Republic of Indonesia. This regulation specifically pertains to diplomas, competency certificates, professional certificates, degrees, and the protocols for documenting degrees in higher education institutions.

The objective of this research is to explore the implementation of blockchain technology in securing educational assets in higher education, to prevent the counterfeiting of these assets while complying with Indonesian laws, without providing additional information (such as a QR Code) on the diploma. Additionally, this research aims to identify methods that can do this while decreasing storage memory requirements.

2. METHODS

This research has eight distinct stages: problem identification, literature review, analysis, design, prototype development, and testing, as shown in **Figure 1**.

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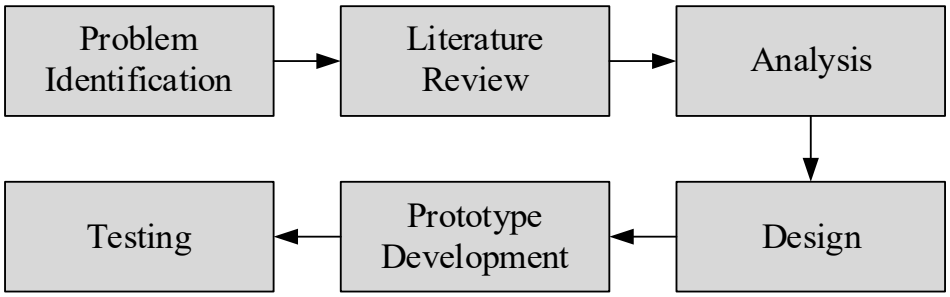

Figure 1. Research Methodology

2.1. Problem Identification

Problem Identification refers to identifying and characterizing problems or difficulties that are unique to blockchain technology and how it is used as a higher education certificate authentication method.

2.2. Literature Review

Once the problem has been identified and the underlying cause has been determined, the next step involves conducting a comprehensive review of existing literature. The objective is to acquire a fundamental theory that applies to the topic at hand. For this literary analysis, scholarly papers and other relevant sources on the subsequent subjects, i.e., hash functions, peer-to-peer networks, consensus algorithms, blockchain, and its architecture, will be consulted.

2.3. Analysis

Once the literature study is finished, the subsequent step involves doing a comprehensive analysis. This analysis encompasses examining the many components found on diplomas and transcripts, studying similar research conducted previously, and assessing the requirements of the method that is to be produced.

2.4. Design

Once the needs analysis is completed, the subsequent stage involves designing the proposed approach by developing a visual and conceptual representation. The design encompasses the creation of a blockchain architecture, the design of a process for storing and verifying educational asset data.

2.5. Prototype Development

Once the analysis and design of the system requirements are completed, a prototype will be developed. The Python programming language is utilized for prototype development.

2.6. Testing

The primary objective of this prototype testing is to obtain a profound understanding of the degree to which the prototype accomplishes the specified objectives and to identify any issues or enhancements that may be required.

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3. RESULTS AND DISCUSSION

3.1. Analysis

3.1.1. Existing Procedure

In Indonesia, the process of assigning numbers to national diplomas starts with higher education administrators correlating the diploma number with the student identification number of potential graduates. Subsequently, the identified data is reported to the validator at the Minister of Education, Culture, Research, and Technology of the Republic of Indonesia. The National Diploma Number will be deemed valid if it can be authenticated via SIVIL and it must be incorporated in the diploma issued by the university.

Despite the use of holograms and logo stamps on paper diplomas in Indonesia, the presence of these security features does not effectively prevent the occurrence of counterfeit diplomas and transcripts. Consequently, paper-based documents remain susceptible to fraud. In 2017, the Ministry of Research, Technology, and Higher Education of the Republic of Indonesia introduced a website-based system that allows for online verification of diplomas. The system is called "Sistem Verifikasi Ijazah Secara Elektronik" (SIVIL). However, another issue arises with the electronic storage of a diploma verification system on a centralized platform[6]. One disadvantage of centralized storage is that it increases the vulnerability of the database to hacking, as all the information is stored on a single centralized system.

3.1.2. Analysis of the components of diplomas and transcripts

As per Regulation 59/2018 issued by the Minister of Research, Technology and Higher Education of the Republic of Indonesia, diplomas in higher education consist of various essential components, which are: (a) national diploma identification number, (b) higher education institution logo, (c) higher education institution name, (d) higher education institution and/or study program accreditation decision identification number, (e) higher education program, (f) Study program name, (g) full name of the diploma holder, (h) place and date of birth of the diploma holder, (i) student ID, (j) resident registration number or passport number for international students, (k) the title given and its abbreviation, (l) graduation date (m) place and date of diploma issuing, (n) name and role of the individual in charge of a higher education institution who holds the authority to sign the diploma, (o) higher education institution stamp, (p) photo of the diploma holder.

On the other hand, an academic transcript typically includes the following components: (a) academic transcript identification number, (b) national diploma identification number, (c) higher education institution logo, (d) higher education institution name, (e) higher education program, (f) study program name, (g) full name of the academic transcript holder, (h) place and date of birth of the academic transcript holder, (i) student ID, (j) graduation date, (k) academic transcript publication date, (l) name and role of the individual in charge of a higher education institution who holds the authority to sign the academic transcript, (m) list of course taken, credits, and grades, (n) GPA and its predicate.

3.1.3. Requirement Analysis

In Indonesia, the issuance of diplomas is governed by Regulation 59 of 2018, Article 3, which stipulates that it must adhere to three fundamental principles: prudence, accuracy, and legality. **Table 1** provides a comprehensive overview of the specific principles.

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Table 1. Principles regarding the issuance of diplomas

Principle	Explanation
Prudence	Preserve the genuineness of the certificate to prevent it from being readily counterfeited.
Accuracy	Correctness of the information and facts mentioned in the diploma.
Legality	As per the stipulations of regulations and legislation.

In addition to these principles, a university has the authority to revoke a diploma if it is demonstrated that the scientific work employed to achieve the diploma is a result of plagiarism. The specific regulation governing this matter can be found in Article 32 of Regulation Number 6 of 2022, issued by the Minister of Education, Culture, Research, and Technology of the Republic of Indonesia.

Based on these principles and regulations, and the shortcomings of the previous research, the functional requirements for the system to be constructed are subsequently outlined in **Table 2**.

Table 2. Principles regarding the issuance of diplomas

Requirement	Explanation
Data Integrity	Decentralized and unchangeable blockchain technology ensures the preservation of data integrity. This is because each block is tied to the preceding block through a hash value. Therefore, blockchain could comply with the principle of prudence and accuracy.
Non-repudiation	Once educational asset data is incorporated into the blockchain network by a university, the college will be unable to reject it since each block will be authenticated using a private key. This can satisfy the principle of accuracy.
Tracebility	Blockchain enables the ability to track the origin of stored data. It is crucial for parties seeking to verify the legitimacy of alumni diplomas to determine the current validity status of the credential in question.
Flexibility	The developed approach must possess the capability to adjust to the data format and requirements for diploma issuance that are applicable in Indonesian universities. This can satisfy the principle of legality.
Light and easy to use	The storage system has minimal memory consumption. In addition, it may be easily accessed without the need for any further installations.

3.2. Design

3.2.1. Architecture of the proposed blockchain

Blockchains have five separate layers: the application, data, consensus, network, and execution layers[12]. This research provides a detailed description of the layers as follows.

- The application layer governs the way in which users engage with the blockchain system. The prototype in this study remains a console or command-line interaction.
- The data layer is responsible for defining the data structure of a block and determining its storage mechanism. The prototype requires the form of a data block containing the specific information outlined in the section Design of the proposed method.
- The consensus layer takes charge of defining the consensus algorithm used. Consensus or agreement algorithms enable a cluster of computers to collaborate effectively, ensuring that they can continue operating even if some individual members fail. The importance lies in the engagement of multiple computers, including potential eavesdroppers, within a blockchain system. The consensus algorithm is designed to prevent eavesdroppers from disrupting the reliability of the blockchain. The prototype utilizes a Proof-of-Authority consensus mechanism, operating on the assumption that the university maintains the

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blockchain privately. Another possibility consensus could use a shared secret algorithm, such as Shamir [13], [14], [15].

- The network layer is responsible for the establishment and administration of communication between nodes or machines within a blockchain system. The prototype operates on a peer-to-peer network, allowing every unit or representation within the organization to have access to the blockchain.
- The execution layer is responsible for carrying out transactions that have been initiated by the user through the application layer. A detailed explanation regarding this process is written in the section Design of the proposed method.

3.2.2. Design of the proposed method

Generally, the suggested method consists of four phases, as seen in the **Figure. 2**. It should be noted that the numbering (i.e., 1-4) in the figure corresponds to the four phases described below.

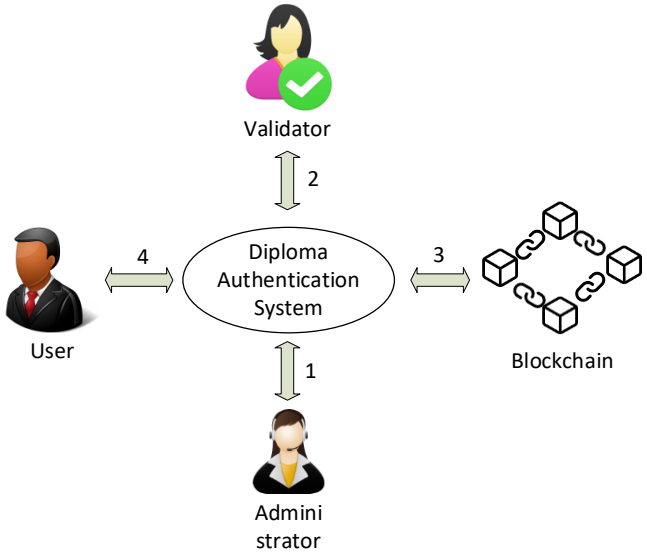

Figure 2. Proposed methods

1. Data gathering. This initial step will occur just once (with the exception that the diploma may be revised or revoked). The procedure for storing diplomas started with higher education administrators establishing a correlation between the diploma number and the student identification number of prospective graduates [16], [17].

   Let *S1* || *S2* be an operation to concatenate two strings *S1* and *S2*. The detailed procedure in this phase is described in **Figure 3**:

   - After the higher education administrator passes the authentication process to access the system, the diploma and academic transcript details are entered. This information will be kept as a string.
   - The default status of this diploma is "valid" unless the administrator opts to revoke or modify it. The system automatically stored the administrator's username and the timestamp of diploma submission. The combination of this information follows this operation *status* || *username* || *timestamp,* and it will be kept as string *b*.
   - Concatenate *a* and *b* to yield *c,* or it is denoted by *c = a || b*.
2. Data verification. The data that resulted in the first phase will be verified by the validator at the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia.

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Once the validator states that the submitted information is valid, the *information* about his username and timestamp will be added, denoted by *d = c || username || timestamp.*

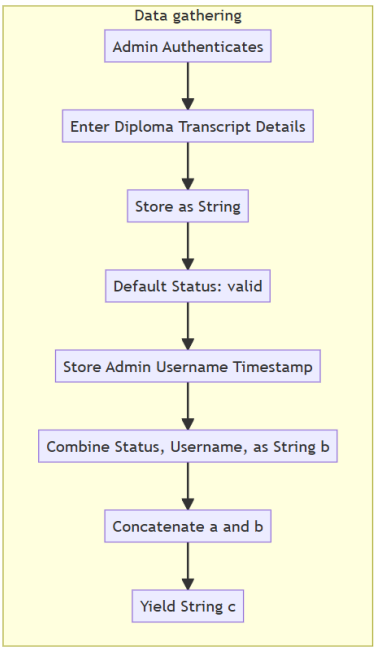

Figure 3. Data gathering workflow

3. Block generation. If the validator determines that the submitted data is valid, each diploma will be placed as a block on the blockchain that consists of three main components: index, diploma and transcript details, and previous hash as shown in Figure 3.
   Let *hash(a)* is a process to extract the hash value in a string *a* using a hash function such as MD5, SHA, etc. Let *block*[*max*] be the rightmost block in the blockchain system. The block generation is described in **Figure 4**:

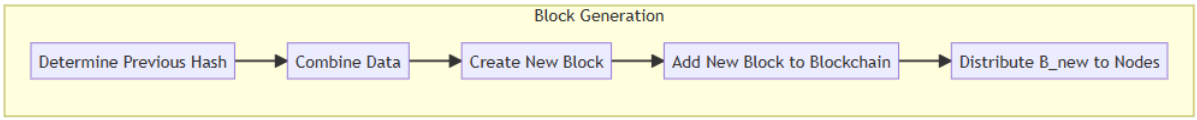

Figure 4. Block generation workflow

   - Determine the cryptographic hash value of the most recent block on the blockchain, called the previous hash $prevhash$. Or denoted by $prevhash = hash(block[max])$.
   - Combine the data from the verification phase (d) and its preceding hash to yield a new block, or it is denoted by $newblock = d||prevhash$.
   - Add the new block into the blockchain, which is denoted by $blockchain = dump(newblock)$
   - Lastly, distribute the newly created block to the nodes within the blockchain system.
4. Authentication procedure. Alumni are not required to include a duplicate of their diploma or academic transcript when seeking employment. To access the system, he simply needs to log in using his alumni credentials and retrieve the diploma number in the form, as shown in **Figure 5**. In order to verify the authenticity of the diploma, industry stakeholders just need to enter the system and scan the offered QR Code. Subsequently, the system will exhibit alumni diploma information, including transcripts and any record of credential revocation[18], [19].

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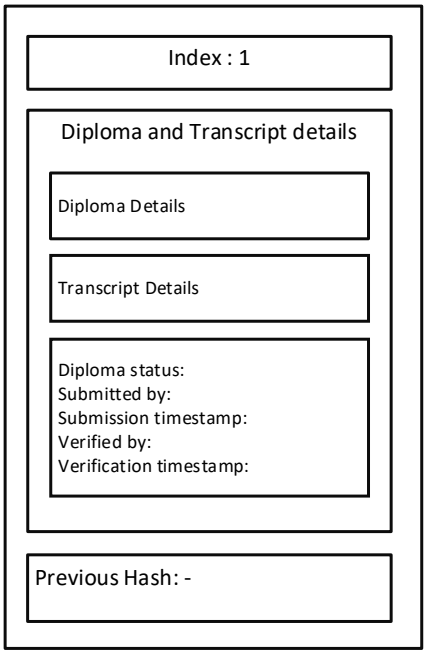

Figure 5. Illustration of the proposed block

3.3. Prototype

The Python programming language was utilized for the implementation of the prototype. Below are several prototype screenshots. Once the higher education administrators have successfully logged into the system, they are able to enter specific information regarding diplomas and transcripts [20]. Subsequently, it will generate a new block, as depicted in **Figure 6a**. To revoke a diploma, the administrator just needs to enter the corresponding diploma number. Because the blockchain is fixed, the status of a diploma cannot be revoked by simply altering the value in the "status" column. Instead, it is done by adding a block with the value "invalid" in the "status" column.

Other parties seeking to authenticate and confirm the educational credentials of potential employees or alumni just need to provide the national diploma number. Assuming the national diploma number is legitimate, the system will exhibit the educational resources of the job seeker, as shown in **Figure 6b**.

The prototype's data layer architecture is designed according to Regulation 59/2018 issued by the Minister of Research, Technology, and Higher Education of the Republic of Indonesia. This architecture enables the application of the prototype to all educational assets across universities in Indonesia. Therefore, it is possible to fulfil the flexibility requirements. Since the details of both the diploma and academic transcript are stored in a text format, the data consumption is certainly less than the image format.

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```
"id": 2,
"no_ijazah": "IJAZAH001",
"nama_pt": "Politeknik Negeri Bandung",
"no_akreditasi": "1681/SK/BAN-PT/Akred/Dipl-III/VII/2018",
"program": "Diploma-III",
"nama_prodi": "Teknik Informatika",
"nama_mhs": "Aprianti Nanda Sari",
"tempat_lahir": "Bandung",
"tgl_lahir": "12/12/1990",
"npm": "12345",
"nik": "123456789",
"gelar": "A.Md (Ahli Madya)",
"tgl_lulus": "10/10/2023",
"tempat_terbit_ijazah": "Bandung",
"tgl_terbit_ijazah": "10/12/2023",
"nama_pimpinan": "Marwansyah, Ph.D.",
"jabatan": "Direktur",
"status": "sah",
"no_transkrip": "TRANSKRIP001",
"tgl_lulus": "10/10/2023",
"tempat_terbit": "Bandung",
"tgl_terbit": "11/10/2023",
"nama_pimpinan": "Marwansyah, Ph.D",
"jabatan": "Direktur",
"ipk": "3.80",
"predikat": "Cumlaude",
"mk": [
        {
        "kode_mk": "123",
        "nama_mk": "Matematika Diskrit 1",
        "sks_mk": "3",
        "nilai_mk": "A"
        },
        {
        "kode_mk": "124",
        "nama_mk": "Matematika Diskrit 2",
        "sks_mk": "3",
        "nilai_mk": "B"
        }
    ]
"hash_transkrip": "212415ad051acf542432b3866d7063f6",
"timestamp": "2024-08-12 12:47:15.099325",
"username": "aprianti",
"previous_hash": "3299873001796b9c88e3d4e4a9e1507f"
```


Figure 6a. Newly formed block.

```
Data Ditemukan!
IJAZAH
-------------------------------------------------  ----------------------------
National diploma identification number:            IJAZAH001
Higher education name:                             Politeknik Negeri Bandung
Accreditation ID:                                  1681/SK/BAN-PT/Akred/Dipl-II
Higher education program:                          Diploma-III
Study program name:                                Teknik Informatika
Full name of the diploma holder:                   Aprianti Nanda Sari
Place of birth of the diploma holder :             Bandung
Date of birth of the diploma holder :              12/12/1990
Student ID:                                        12345
Resident registration number or passport number:   123456789
Title given and its abbreviation:                  A.Md (Ahli Madya)
Graduation date:                                   10/10/2023
Place of diploma publication:                      Bandung
Date of diploma publication:                       10/12/2023
Higher education in charge name:                   Marwansyah, Ph.D.
Higher education in charge role:                   Direktur
DIPLOMA STATUS:                                    sah
-------------------------------------------------  ----------------------------

ACADEMIC TRANSCRIPT
tidak ada
----------------------------  ----------------
No Ijazah:                    IJAZAH001
No Transkrip:                 TRANSKRIP001
Tempat Terbit Transkrip:      Bandung
Tanggal Terbit Transkrip:     10/12/2023
Nama Pimpinan Penandatangan:  Marwansyah, Ph.D
Jabatan Penandatangan:        Direktur
IPK:                          3.80
Predikat :                    Cumlaude
----------------------------  ----------------

DETAIL NILAI
 Kode Mata Kuliah   Nama Mata Kuliah        SKS  Nilai Mutu
------------------  --------------------  -----  ------------
       123          Matematika Diskrit 1      3  A
       124          Matematika Diskrit 2      3  B

Process finished with exit code 0
```

Figure 6b. Prototype displays details of diplomas and academic transcripts.

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3.4. Testing

In the context of security testing, specifically when examining the integrity of data on a diploma or academic transcript. For instance, an individual who lacks responsibility alters the graduation date to “10/12/2023. It should be noted that the system will present a notice indicating that the blockchain is invalid, as seen in **Figure 7**.

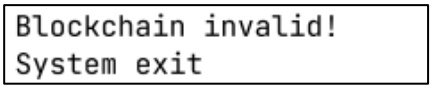

Figure 7. Prototype detects invalid blockchain

4. CONCLUSION

Based on the test findings, the prototype can fulfil the requirements of an educational asset verification and validation system. The preservation of data integrity is exemplified in the sub-chapter on security testing. The prototype is capable of presenting warning messages to users to indicate the invalidity of the blockchain. The prototype can also fulfil the need for non-repudiation and traceability since revoking a diploma involves the same procedure as adding a new block to the blockchain, but with a status of "invalid". Traceability can also be utilized to indicate the validity of a prospective worker's diploma, allowing the industry to easily determine its status.

As of now, the system remains at the prototype stage. In future research, efforts will be focused on collaborating with selected universities for pilot testing. This would involve assessing system performance in a real institutional environment and gathering structured feedback from both administrative and IT departments to evaluate usability, scalability, and integration readiness.

In general, the constructed prototype performs effectively, thereby mitigating the issue of diploma fabrication. Industry or companies conduct the verification and validation procedure transparently within the system to ensure accurate and secure educational asset information. The current prototype operates in a single-node environment. To simulate realistic deployment scenarios, future iterations will include deploying the blockchain system across multiple nodes representing various departments or units within a university. This will allow for testing fault tolerance, consensus behaviour, and data synchronization performance across distributed systems.

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6. AUTHORS’ NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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