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Representation of Best Practices in IoT Systems by Using the SEMAT Essence Kernel

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Abstract. The Internet of Things (IoT) facilitates coordinated interaction among machines, devices, and users. Best practices in IoT encompass processes designed to enhance the efficiency of IoT systems implementation. While state-of-the-art reviews reveal diverse methods for modeling such practices, existing models in the literature remain fragmented: they often address isolated development phases and lack replicability due to insufficiently structured methodologies. This study addresses this gap by modeling IoT best practices found in scientific literature on IoT systems using the SEMAT Essence Kernel language (Software Engineering Method and Theory). From an analysis of 97 scientific papers, four best practices were selected and processed through a terminological extractor, generating a dictionary of 123,566 terms to standardize their nomenclature. Each practice's components were systematically mapped to SEMAT Essence Kernel elements. The resulting models represent best practices in power consumption, data security, cloud computing resource utilization, and Big Data integration for IoT systems. The proposed approach demonstrates the SEMAT Essence Kernel's efficacy in formalizing IoT best-practice knowledge. Validation by a panel of IoT experts yielded promising results, confirming the models' robustness and applicability.

Keywords. Best practices in IoT, knowledge representation, SEMAT essence kernel, terminological extraction.

1 Introduction

The Internet of Things (IoT) is a computing concept that involves a wide range of technologies enabling smart devices within everyday objects to connect via the Internet [11, 35, 17]. Best practices in IoT describe processes or activities that improve the efficiency and effectiveness of one practice over another [51]. Currently, IoT is present in all fields of humanity, from agriculture to medicine [9, 40], making it crucial to use a unified representation model that allows for easy implementation when working with these systems. The SEMAT Essence Kernel provides a structured language for representing best practices, facilitating the construction of models that are easy to understand and replicate [15, 22, 43]. Furthermore, the focus group technique enables the collection of opinions from various experts to validate models within the SEMAT Essence Kernel [20, 28].

Giray et al. [16] propose a system for developing IoT practices using the SEMAT Essence Kernel, and analyzing the Ignite and IoT-Meth methods. Similarly, Nebbione and Calzarossa [41] use proprietary models to illustrate the challenges of using IoT systems and the need for the correct implementation of various protocols to protect the system from vulnerabilities. Celaya-Echarri et al. [8] introduce a model for a smart parking

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system using an IoT-based architecture and fog computing. Costa et al. [11] employ a framework for IoT called SysML4IoT, which is based on SysML to support the analysis, specification, design, verification, and validation of complex systems. Reggio [50] implements the IotReq method for eliciting and specifying requirements in IoT systems using the service-oriented paradigm and UML as the primary tool. Morin et al.[38] present the ThingML modeling language, which combines UML, software modeling elements, and a set of tools to generate code in various programming languages.

According to the literature reviewed, these methods fail to fully involve all that IoT systems offer, as they are monolithic and unrelated. That is, each one has its own way of representing elements and relationships, highlighting the lack of a common foundation for the use of practices. This leads to the reuse of generalized practices in an attempt to adapt them to specific IoT practices [24]. Consequently, the newly defined practices are difficult for IoT system development teams to use and share, and they do not address all the issues involved [35].

Therefore, a common foundation is necessary to define practices and apply them appropriately when working on IoT projects [18]. Jacobson et al. [24] assert that the SEMAT Essence Kernel can involve the complexity of IoT system development, as its structure allows for the independent modeling of practices to support the creation of practice libraries. Barón Salazar [5] mentions that this kernel supports a unified definition that is correctly extrapolated with practices from different proposals, thereby allowing the modeling of a set of best practices using a unified and unambiguous model.

This paper aims to model four (4) best practices found in the scientific literature on IoT systems by using the SEMAT Essence Kernel language as the representation basis. This involves a structured process that results in models representing the elements and relationships involved in the activities of each selected practice. This work presents the general method proposed for this process and the models of four best practices in IoT.

This paper is structured as follows: Section 2 shows some theoretical concepts. Section 3 analyzes related works. Section 4 describes the method used to conduct the study. Section 5 presents the study's results. Section 6 discusses the findings. Finally, Section 7 presents the conclusions.

2 Theoretical Concepts

2.1 SEMAT Essence Kernel

SEMAT (Software Engineering Method and Theory) refers to a community of scholars and companies that investigate critical challenges in Software Engineering, such as the reliance on trends, the absence of a solid theoretical foundation, the proliferation of unique methods that are difficult to compare, the scarcity of empirical evaluation and validation, and the persistent gap between academic research and its practical application in industry [23, 43]. To address these issues, a kernel and a language were developed to describe the essential and universal actions and elements of any software development endeavor, grounded in theory and best practices. The primary objective is to represent existing methodological practices both graphically and textually through a standardized design [15, 22].

The SEMAT Essence kernel encompasses core concepts—including practices, alphas, activity spaces, work products, competencies, roles, and resources—which are organized into three distinct areas of concern in Software Engineering [22, 23, 43]. The kernel is structured into three specific areas: i) The Customer Area, which represents all aspects related to the actual use and exploitation of the developed software system; ii) The Solution Area, which contains everything pertaining to the specification and development of the software system; and iii)The Endeavor Area, which relates to all matters concerning the team and its approach to work [43].

Within these areas, alphas are used to capture the elementary concepts of Software Engineering. They enable the tracking and assessment of progress and provide a common ground for defining methods and practices [43]. A sub-alpha is a subordinate element that contributes to the progress of a higher-level alpha; these are considered extensions of the kernel and are not pre-defined within it [43].

Activity spaces complement alphas by providing an activity-based view of Software Engineering practices. An activity is a manifestation of an activity space; it describes a unit of work to be performed and provides explicit guidance on how to produce or update work products [5]. A work product is defined as "an artifact of value and relevance to a software engineering endeavor that can be created, modified, used, or deleted during an endeavor" [5].

These encompass various types such as models, documents, specifications, code, tests, and executables. Competencies represent the combination of skills, abilities, achievements, and knowledge required to perform a specific type of work [43]. Roles are defined based on the activities to be performed and may vary from one practice to another. Resources are generic concepts that can be linked to any element within the Essence kernel [43].

A practice is a systematic, verifiable, and repeatable approach for achieving a specific objective. Crucially, the Essence kernel allows for the representation of a practice as a distinct, modular unit that teams can utilize and which can be a component of many broader methods [22, 23]. Each practice can be composed of the aforementioned elements: alphas, sub-alphas, activity spaces, activities, work products, competencies, roles, and resources [43].

3 Related Work

Model representation for IoT systems is performed in various ways, with each author presenting their unique approach to modeling. Giray et al. [16] aim to represent best practices in IoT systems using the SEMAT Essence Kernel as a foundation, drawing upon Ignite and IoT-Meth methods. They use the Essence Kernel as a framework to identify practice elements in IoT systems to guide their focus on identifying best practices. The outcome of their work is the representation of these best practices, although it stands out their lack of development in the relationships among practice elements in their research.

Nebbione and Calzarossa [41], by using proprietary models, highlight the vulnerabilities that arise when employing IoT systems and the necessity of correctly using various protocols created to protect these systems from vulnerabilities. The authors conclude that IoT devices are exposed to numerous security risks and propose best practices and measures to mitigate threats and attacks on these devices.

Celaya-Echarri et al. [8] introduce a model for implementing a low-latency centralized smart parking system. This model characterizes a real-world scenario and proposes using an IoT and fog computing-based communication architecture to provide smart parking services. The results of this work demonstrate that the proposed system can deliver information to drivers quickly without relying on remote servers.

Costa et al. [11] focus on creating the IdeA (IoT DevProcess & AppFramework) method, aimed at providing a high-level abstraction to address the diversity and heterogeneity of software and hardware components in the IoT context. Their method facilitates the design of multidisciplinary IoT applications using the SysML4IoT profile. As a result, they establish an efficient and effective mechanism for designing and developing IoT applications, simplifying the integration of different technologies and disciplines, thereby promoting the expansion and adoption of IoT solutions.

Reggio [50] proposes the IotReq method to address the elicitation and specification of requirements in IoT systems, utilizing UML as the main tool. This method's approach is based on the service-oriented paradigm and relies on simple, established software engineering practices. As a result, the IotReq method provides a clear and effective structure for defining requirements in IoT systems, enhancing understanding and communication among various stakeholders involved in the development process. Furthermore, IotReq contributes to the creation of more flexible and scalable solutions in the context of IoT because it focusses on the service-oriented paradigm.

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Table 1. References used to define the practices

Practice	References
1	Ahad et al. [2]; Aly et al. [3]; Celaya-Echarri et al. [8]; D'Amico et al. [12]; HaddadPajouh et al. [19]; Hatzivasilis et al.[21]; Machorro-Cano et al. [31]; Martín-Garín et al. [32]; Matsui [33]; Miah et al. [36]; Pereira et al. [47]; Pérez Colón et al. [48]; Wang et al. [55]; Zaidan et al. [58]
2	Ahad et al. [2]; Anh Khoa et al. [4]; Bawany et al. [6]; Bugeja et al. [7]; HaddadPajouh et al. [19]; Kalbo et al. [26]; Machorro-Cano et al. [31, 30];Martín-Garín et al. [32]; Nižetić et al. [42]; Trnka et al. [53]; Wang et al. [55]
3	Dingman et al. [14]; HaddadPajouh et al. [19]; Hatzivasilis et al. [21]; Kalbo et al. [26]; Mrabet et al. [39]; Nebbione & Calzarossa [41]; Oniga et al. [44]; Pătru et al. [49]; Payne & Abegaz [46]; Samaila et al. [52]; Zaidan et al. [58]
4	Abdullah et al. [1]; Ahad et al. [2]; Aly et al. [3]; D'Amico et al. [12]; Javed et al. [25]; Khan & Ndubuaku [27]; Leelavinodhan et al. [29]; Martín-Garín et al. [32]; Matsui [33]; Mrabet et al. [39]; Nebbione & Calzarossa [41]; Park et al. [45]; Payne & Abegaz [46]; Pereira et al. [47]; Samaila et al. [52]; H. Wang et al. [54]; Weber & Zarko [56]; D. Yuan et al. [57]

Morin et al. [38] introduce the ThingML approach, a modeling language that integrates UML, software modeling elements, and a suite of tools for generating cross-platform code in various programming languages. They also provide a detailed method for documenting development processes and the tools used. ThingML proves to be a versatile and robust solution for IoT systems development.

4 Methods

The scientific literature reviewed indicates that various methods are used for modeling practices in IoT. These methods are defined according to the specific needs of the context in which they are implemented, lack a common base for representation, define practices that are not easily implemented in different scenarios, and fail to cover all existing issues in IoT. This paper proposes a method for constructing models of best practices in IoT using the SEMAT Essence Kernel as the representation basis, which aids in unifying the modeling of best practices in IoT systems. This creates a common ground where stakeholders can easily access and replicate practices in different scenarios with a single representation [24]. The following sections detail each of the six phases of the proposed method.

4.1 Selection of Practices in IoT

Four (4) best practices in IoT are selected based on the Systematic Literature Review by Medina et al. [34]. In this study, various IoT practices are analyzed from 97 selected papers.

4.2 Creation of the IoT Terminology Dictionary

Using a terminological extraction tool [37], a dictionary of 123,566 specialized IoT language terms is created from the 97 papers mentioned by Medina et al. [34]. This dictionary is used for identifying elements and naming the practices.

4.3 Naming of IoT Practices

Following the guidelines of Barón Salazar [5], the naming of the four IoT practices is carried out with the following structure: a nominalized verb indicating what is done with the practice, an adjective explaining how it is done, and a noun indicating the object on which the practice is performed. The relevant verb, adjective, and noun are identified for each practice based on its component analysis, using the IoT dictionary created earlier.

4.4 Identification and Association of Practice Elements with the SEMAT Essence Kernel Components

After naming the practices following Barón Salazar's criteria [5], each of their elements is identified and then associated with the components of the SEMAT Essence Kernel.

4.5 Modeling of Practices

The four (4) models of the selected best practices in IoT are constructed based on the elements and language of SEMAT Essence Kernel. The Lucidchart modeling tool [13] are used to construct these models.

Table 2. Practice names (based on [5])

Practice	Practice Named According to Barón Salazar's Criteria [5]
1	Structured Implementation of Cloud Computing Services in IoT Systems
2	Structured Implementation of Big Data in IoT Systems
3	Structured data security through encryption in IoT systems
4	Functional improvement of IoT devices power consumption

4.6 Validating of the Models

Finally, the models are validated through a focus group of IoT experts following the guidelines of the Chalabi et al. method [10].

5 Results

In this study, four (4) models of best practices in IoT were constructed by using the SEMAT Essence Kernel. For this purpose, a structured method was proposed and implemented, following the phases described in the method. The developed models are unambiguous, useful, relevant, and easy to understand and implement in IoT environments. This section presents the results of the model construction process.

5.1 Selection of Practices in IoT

In the first phase of the method, four best practices in IoT are selected from the 97 papers found in the Systematic Literature Review by Medina et al. [34]. Table 1 displays the references used to define the practices.

5.2 Creation of the IoT Terminology Dictionary

After selecting the practices, the IoT terminology dictionary generated with a term extractor [37] is used to analyze the 97 papers selected in the study by Medina et al. [34]. A total of 123,566 terms consisting of two, three, or four words are obtained, which are used for naming the practices.

5.3 Naming of the IoT Practices

Based on the IoT terminology dictionary and following the guidelines of Barón Salazar [5], the selected best practices are named. Table 2 displays the results of the naming process.

5.4 Identification and Association of Practice Elements with the SEMAT Essence Kernel Components

After naming the practices, each of their elements is identified and correlated with the components of the SEMAT Essence Kernel (areas of interest, alphas, sub-alphas, activity spaces, roles, activities, work products, and competencies [43]). Table 3 shows the relationship between the elements of practice 1 and the components of the SEMAT Essence kernel.

Table 3. SEMAT essence kernel components vs. Practice 1 elements

SEMAT Essence Kernel Component	Practice element
Practice named according to the guidelines of Barón Salazar [5]	Structured Implementation of Cloud Computing Services in IoT Systems
Area of Concern	Solution
Alpha	Software System
Sub-alpha	IoT Software System
Activity Spaces	— Shape the System — Implement the System
Roles	— IoT Analyst — IoT Developer
Activities	— Interconnect IoT devices with cloud applications — Integrate local data and applications with cloud data and applications — Implement IoT projects on iPaaS (Integration Platform as a Service) based platforms — Encrypt data transmitted between devices and cloud applications using lightweight encryption — Implement hybrid architectures by integrating fog and edge computing with cloud computing — Implement platforms, protocols, and models used and tested in IoT systems
Work Product	Cloud Services Implementation Document
Competencies	— Analysis — Development

Table 4 presents the template used to record the information for practice 2. For this practice, an area of concern, an alpha, a sub-alpha, two activity spaces, two roles, six activities, a work product, and two competencies are defined.

Practice 3 is defined with an area of concern, an alpha, a sub-alpha, two activity spaces, two roles, five activities, two work products, and two competencies (see Table 5).

Practice 4 includes an area of concern, an

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Table 4. SEMAT Essence Kernel components vs. Practice 2 elements

SEMAT Essence Kernel Component	Practice element
Practice named according to the guidelines of Barón Salazar [5]	Structured Implementation of Big Data in IoT Systems
Area of Concern	Solution
Alpha	Software System
Sub-alpha	IoT Software System
Activity Spaces	— Shape the System — Implement the System
Roles	— IoT Analyst — IoT Developer
Activities	— Collect data in short and long periods — Perform regression and classification analysis using machine learning algorithms. — Code machine learning algorithms to study the behavior of users and IoT devices — Implement machine learning in the back-end for data mining — Implement statistical and machine learning methods for detecting attacks on IoT systems — Implement machine learning techniques with Wireless Sensor Networks (WSN)
Work Product	Big Data Implementation Protocols
Competencies	— Analysis — Development

alpha, and a sub-alpha, along with two activity spaces, two roles, a resource, four activities, a work product, and two competencies (see Table 6).

5.5 Modeling of Practices

After identifying and correlating the elements of the practices, diagrams are constructed based on the structure of the SEMAT Essence Kernel language. For the construction of the diagram of practice 1 (see Figure **??**), 14 works are used as a reference. This practice emphasizes the importance of using cloud computing resources for the implementation of IoT systems.

Twelve works are used as a reference for the analysis of the structure of practice 2. Figure 2 shows the diagram of this practice, which includes the elements described in Table 4.

The structure of practice 3 was analyzed using eleven reference works. Figure 1 displays its diagram, containing all the elements described in Table 5.

Table 5. SEMAT Essence Kernel components vs. Practice 3 elements

SEMAT Essence Kernel Component	Practice element
Practice named according to the guidelines of Barón Salazar [5]	Structured data security through encryption in IoT systems
Area of Concern	Solution
Alpha	Software System
Sub-alpha	IoT Software System
Activity Spaces	— Shape the System — Implement the System
Roles	— IoT Analyst — IoT Developer
Activities	— Choose a method of encryption and decryption — Classify the information to be encrypted — Limit the use of multicast communications — Encrypt the message — Implement sending messages using unicast
Work Product	— Specification document for encryption — Messaging protocols
Competencies	— Analysis — Development

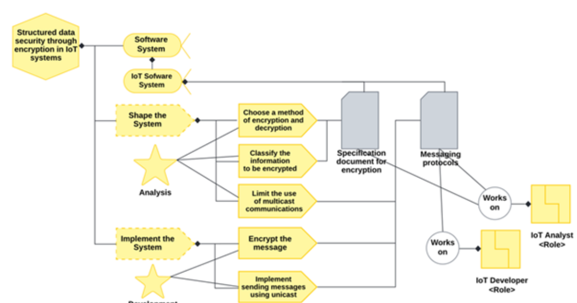

Fig. 1. SEMAT Essence Kernel Diagram of Practice 3

Eighteen reference works were analyzed to define the structure of practice 4. Figure 2 presents its conceptual diagram, incorporating all elements detailed in Table 6.

The SEMAT Essence Kernel enables the modeling of practices by supporting: (1) integration of multiple activity spaces with their associated activities and competencies, and (2) definition of

Table 6. SEMAT Essence Kernel components vs. Practice 4 elements

SEMAT Essence Kernel Component	Practice element
Practice named according to the guidelines of Barón Salazar [5]	Functional improvement of IoT devices power consumption
Area of Concern	Solution
Alpha	Requirements
Sub-alpha	Requirements of IoT Systems
Activity Spaces	— Shape the System — Implement the System
Roles	— IoT Analyst — IoT Developer
Resources	Devices with power-saving technology
Activities	— Identify the data transfer protocol that consumes less power — Recognize the size of the data — Calibrate the power consumption of devices — Implement machine learning algorithms to improve power consumption
Work Product	— - Power consumption reduction protocol
Competencies	— Analysis — Development

specific work products generated by individual or combined activities.

5.6 Validation of the Models

The constructed models are validated following the guidelines of the Chalabi et al. method [10]. A focus group with five IoT experts from different institutions were conducted. Table 7 shows the description of the profiles of the experts.

The steps of the validation method are presented in Table 8.

The experts use the following Likert scale: Totally Agree (5), Agree (4), Neither Agree nor Disagree (3), Disagree (2), Totally Disagree (1). They rate the diagrams constructed based on the following validation criteria: understanding, ease of implementation, usefulness, and relevance.

Table 9 present the expert focus group evaluation results for practices 1, 2, 3 and 4 diagrams respectively, showing consistently high ratings across all assessment criteria.

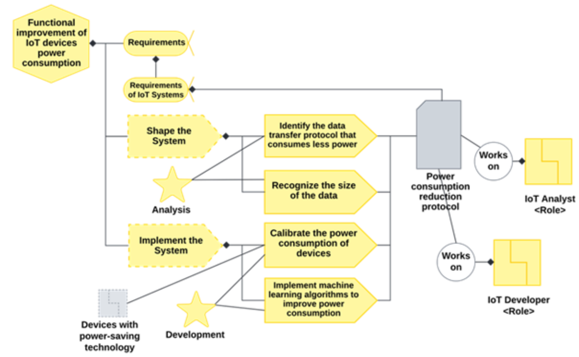

Fig. 2. SEMAT Essence Kernel Diagram of Practice 4

6 Discussion

This paper aims to construct models of best practices in IoT systems by using the components of the SEMAT Essence Kernel. The obtained models serve as a common representation base for future research to build IoT system models. It has been confirmed that employing the SEMAT Essence Kernel as a knowledge representation allows for the standardization of IoT practice models by providing methods that are easy to understand and apply in the implementation of IoT systems.

Some authors propose methods to group relevant activities in IoT based on high-level abstractions and design mechanisms involving stakeholders [11, 8]. However, unlike the models proposed in this paper, these activities are not grouped into practices. Other authors like Reggio [50] focus solely on the initial phase of IoT system development, such as requirement elicitation and specification, and employ best practices of Software Engineering that do not address all the needs of IoT systems.

On the other hand, authors like Morin et al. [38], with their ThingML approach, acknowledge the complexity of IoT systems and recognize the need for a structured way to represent the unique challenges of these systems. However, their models are harder to comprehend compared to those created with the SEMAT Essence Kernel, which employs components that are more descriptive and closer to natural language.

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Table 7. Focus group expert profiles

Expert	Academic Degree	Professional experience (Years)	Research Areas
1	M.Sc.,Ph.D.	27	— IoT — Automatization and Control — Robotics and Intelligent Systems — Electrical Machines and Power Electronics
2	M.Sc.,Ph.D.	22	— IoT — IoT — Automatization — Measurement Systems — Applied Optics
3	M.Sc.,Ph.D.	13	— IoT — Test Automatization — Software Engineering — Artificial Intelligence and Data Science
4	M.Sc.	33	— IoT — Ubiquitous Computing — Development of Telematic Applications and Services — Smart Cities
5	M.Sc.	24	— IoT — Automatization and Control — Software Engineering

Table 8. Standardized focus group procedure for practice assessment

Stages	Description
Presentation of participants	The meeting begins with an introduction to the topic and a presentation of the participants
Recording of the meeting	With the participants' permission, the meeting is recorded for later analysis of the information
Delivery of materials	A virtual form is provided to the participants to rate the practices according to the defined evaluation criteria
Introduction of the focus group	Guidelines for evaluating the practices are presented, and any questions are addressed
Discussion and evaluation of the models	The models are presented, and the evaluators mention their observations. They then evaluate the models using the virtual form
Conclusion of the meeting	Feedback from the evaluators about the process is provided

In the IoT practice models by Nebbione and Calzarossa [41], more visual and specific elements such as routers, computers, or clouds are used to model the implementation of architectures based on commercial platforms, open hardware, IPv6 connectivity, and vulnerabilities in IoT system security. The issue with these models is that they do not employ a predefined method for construction, making them less replicable and only suitable for representing specific cases for which they were created. In contrast, models developed with the SEMAT Essence Kernel follow well-defined steps and are easily replicable.

Table 9. Expert focus group evaluation

Rating Average Evaluators / Evaluation Criterion	Practice 1	Practice 2	Practice 3	Practice 4
Understanding	5	5	5	5
Usefulness and Relevance	5	5	5	4,7
Ease of Implementation	4,7	4,7	4,7	4,7

Furthermore, some proposals focus on specific aspects of IoT system development, such as requirements gathering [50], hardware, software [11], or design [41], resulting in models that do not involve all areas in IoT system implementation. Models constructed with the components of the SEMAT Essence Kernel detail specific elements of IoT practices, allowing for greater adaptability in addressing various challenges in IoT.

7 Conclusions

In this paper, a method for constructing models of four best practices in IoT systems using the SEMAT Essence Kernel was implemented. Four practices were selected from a pool of 97 scientific papers on IoT. The conceptual elements were related, and a terminological dictionary was used to name the practices before being diagrammed and validated.

The study successfully demonstrated that the SEMAT Essence Kernel is a standard that allows for clear, precise, and unambiguous representation of elements in IoT practices found in scientific literature. To validate the diagrams, a focus group of experts was conducted based on the following evaluation criteria: understanding, ease of implementation, usefulness, and relevance. The results of this validation indicate that the SEMAT Essence Kernel enables the creation of understandable models for the development of best practices in IoT systems.

As future work, it is suggested to conduct practical validation of these models in business scenarios. Additionally, it is proposed to enhance the developed models by adding new elements based on the results of this validation and the analysis of scientific literature. Finally, it is recommended to construct models for other best practices in IoT using the SEMAT Essence Kernel and the method proposed in this study.

References

1. **Abdullah, M. A., Al-Hadhrami, T., Tan, C. W., Yatim, A. H. (2018).** Towards Green Energy for Smart Cities: Particle Swarm Optimization Based MPPT Approach. IEEE Access, Vol. 6, pp. 58427–58438. DOI: 10.1109/ACCESS.2018.2874525.

2. **Ahad, M. A., Paiva, S., Tripathi, G., Feroz, N. (2020).** Enabling technologies and sustainable smart cities. Sustainable Cities and Society, Vol. 61. DOI: 10.1016/j.scs.2020.102301.

3. **Aly, M., Khomh, F., Guéhéneuc, Y., Washizaki, H., Yacout, S. (2019).** Is Fragmentation a Threat to the Success of the Internet of Things?. IEEE Internet of Things Journal, Vol. 6, No. 1, pp. 472–487. DOI: 10.1109/JIOT.2018.2863180. Number: 1.

4. **Anh Khoa, T., Quang Minh, N., Hai Son, H., Nguyen Dang Khoa, C., Ngoc Tan, D., VanDung, N., Hoang Nam, N., Ngoc Minh Duc, D., Trung Tin, N. (2021).** Wireless sensor networks and machine learning meet climate change prediction. International Journal of Communication Systems, Vol. 34, No. 3. DOI: 10.1002/dac.4687. Number: 3.

5. **Barón Salazar, A. A. (2019).** Modelo para la definición unificada de la práctica como constructo teórico en Ingeniería de Software (A Model for the Unified Definition of Practice as a Theoretical Construct in Software Engineering). PH.D. Thesis, Universidad Nacional de Colombia, Medellín, Colombia.

6. **Bawany, N. Z., Shamsi, J. A., Salah, K. (2017).** DDoS Attack Detection and Mitigation Using SDN: Methods, Practices, and Solutions. Arabian Journal for Science and Engineering, Vol. 42, No. 2, pp. 425–441. DOI: 10.1007/s13369-017-2414-5. Number: 2.

7. **Bugeja, J., Jacobsson, A., Davidsson, P. (2020).** Is your home becoming a spy?: A data-centered analysis and classification of smart connected home systems. IoT 2020 - 10th International Conference on the Internet of Things, Association for Computing Machinery, Malmö, Sweden. DOI: 10.1145/3410992.3411012.

8. **Celaya-Echarri, M., Froiz-Miguez, I., Azpilicueta, L., Fraga-Lamas, P., Lopez-Iturri, P., Falcone, F., Fernandez-Carames, T. (2020).** Building Decentralized Fog Computing-Based Smart Parking Systems: From Deterministic Propagation Modeling to Practical Deployment. IEEE Access, Vol. 8, pp. 117666–117688. DOI: 10.1109/ACCESS.2020.3004745.

9. **Celesti, A., Fazio, M., Galan Marquez, F., Glikson, A., Mauwa, H., Bagula, A., Celesti, F., Villari, M. (2019).** How to Develop IoT Cloud e-Health Systems Based on FIWARE: A Lesson Learnt. Journal of Sensor and Actuator Networks, Vol. 8, No. 1, pp. 7. DOI: 10.3390/jsan8010007. Number: 1.

10. **Chalabi, M., Mohamed, H., Mukhtar, M. (2021).** The Validation Of An e-voting Adoption Model using Focus Group. 2021 International Conference on Electrical Engineering and Informatics (ICEEI), Institute of Electrical and Electronics Engineers, Kuala Terengganu, Malaysia, pp. 1–6. DOI: 10.1109/ICEEI52609.2021.9611134.

11. **Costa, B., Pires, P. F., Delicato, F. C. (2016).** Modeling IoT Applications with SysML4IoT. 2016 42th Euromicro Conference on Software Engineering and Advanced Applications (SEAA), Limassol, Cyprus, pp. 157–164. DOI: 10.1109/SEAA.2016.19.

12. **D'Amico, G., L'Abbate, P., Liao, W., Yigitcanlar, T., Ioppolo, G. (2020).** Understanding Sensor Cities: Insights from Technology Giant Company Driven Smart

Urbanism Practices. Sensors, Vol. 20, No. 16. DOI: 10.3390/s20164391. Number: 16.

13. **Dilts, B., Sun, K. (2023).** Software de diagramación en línea y solución visual.

14. **Dingman, A., Russo, G., Osterholt, G., Uffelman, T., Camp, L. J. (2018).** Poster Abstract: Good Advice That Just Doesn't Help. 2018 IEEE/ACM Third International Conference on Internet-of-Things Design and Implementation (IoTDI), Bloomington, IN, USA, pp. 289–291. DOI: 10.1109/IoTDI.2018.00044.

15. **Durango Vanegas, C. E., Amariles C., M. J., Giraldo M., J. C., Zapata R., C. M., Díaz S., C., Zapata Jaramillo, C. M. (2015).** Representación en el núcleo de Semat de las competencias de Ingeniería Social necesarias para mejorar la Seguridad Informática. Proceedings of the Latin American Software Engineering Symposium, Bogotá, Colombia, pp. 41–56.

16. **Giray, G., Tekinerdogan, B., Tüzün, E. (2017).** Adopting the Essence Framework to Derive a Practice Library for the Development of IoT Systems. In **Mahmood, Z.**, editor, Connected Environments for the Internet of Things: Challenges and Solutions. Springer International Publishing, Cham, Switzerland, pp. 151–168.

17. **González García, A. J. (2017).** IoT: Dispositivos, tecnologías de transporte y aplicaciones. Master's thesis, Universitat Oberta de Catalunya, Barcelona, Spain.

18. **Gyrard, A., Serrano, M., Atemezing, G. A. (2015).** Semantic web methodologies, best practices and ontology engineering applied to Internet of Things. 2015 IEEE 2nd World Forum on Internet of Things (WF-IoT), Institute of Electrical and Electronics Engineers, Milan, Italy, pp. 412–417. DOI: 10.1109/WF-IoT.2015.7389090.

19. **HaddadPajouh, H., Dehghantanha, A., Parizi, R. M., Aledhari, M., Karimipour, H. (2021).** A survey on internet of things security: Requirements, challenges, and solutions. Internet of Things, Vol. 14. DOI: 10.1016/j.iot.2019.100129.

20. **Hamui-Sutton, A., Varela-Ruiz, M. (2013).** La técnica de grupos focales. Investigación en educación médica, Vol. 2, No. 5, pp. 55–60. Number: 5 Publisher: Universidad Nacional Autónoma de México, Facultad de Medicina.

21. **Hatzivasilis, G., Soultatos, O., Ioannidis, S., Verikoukis, C., Demetriou, G., Tsatsoulis, C. (2019).** Review of Security and Privacy for the Internet of Medical Things (IoMT). 2019 15th International Conference on Distributed Computing in Sensor Systems (DCOSS), Institute of Electrical and Electronics Engineers, Santorini, Greece, pp. 457–464. DOI: 10.1109/DCOSS.2019.00091.

22. **Jacobson, I., Ng, P.-W., McMahon, P. E., Spence, I., Lidman, S. (2013).** The Essence of Software Engineering: Applying the SEMAT Kernel. Addison Wesley, New Jersey, 1 edition.

23. **Jacobson, I., Ng, P.-W., McMhon, P. E., Spence, I., Lidman, S. (2014).** La esencia de la ingeniería de software: Aplicando el núcleo de semat. Nueva librería, Argentina, 1 edition.

24. **Jacobson, I., Spence, I., Ng, P.-W. (2017).** Is there a single method for the internet of things?: Essence can keep software development for the IoT from becoming unwieldy.. Communications of the ACM, Vol. 60, No. 11, pp. 46–53. DOI: 10.1145/3106637.

25. **Javed, B., Iqbal, M. W., Abbas, H. (2017).** Internet of things (IoT) design considerations for developers and manufacturers. 2017 IEEE International Conference on Communications Workshops (ICC Workshops), Paris, France, pp. 834–839. DOI: 10.1109/ICCW.2017.7962762.

26. **Kalbo, N., Mirsky, Y., Shabtai, A., Elovici, Y. (2020).** The security of ip-based video surveillance systems. Sensors, Vol. 20, No. 17, pp. 1–27. DOI: 10.3390/s20174806. Number: 17.

27. **Khan, Y. I., Ndubuaku, M. U. (2018).** Ontology-based automation of security guidelines for smart homes. 2018 IEEE 4th

World Forum on Internet of Things (WF-IoT), Singapore, pp. 35–40. DOI: 10.1109/WF-IoT.2018.8355214.

28. **Kitzinger, J. (1994).** The methodology of Focus Groups: the importance of interaction between research participants. Sociology of Health & Illness, Vol. 16, No. 1, pp. 103–121. DOI: 10.1111/1467-9566.ep11347023. Number: 1.

29. **Leelavinodhan, P., Antonelli, F., Vecchio, M., Maestrini, A. (2020).** Energy-neutral weather stations for precision agriculture: Challenges and approaches. 2020 IEEE International Workshop on Metrology for Agriculture and Forestry (MetroAgriFor), Trento, Italy, pp. 24–28. DOI: 10.1109/MetroAgriFor50201.2020.9277565.

30. **Machorro-Cano, I., Alor-Hernández, G., Paredes-Valverde, M. A., Ramos-Deonati, U., Sánchez-Cervantes, J. L., Rodríguez-Mazahua, L. (2019).** PISIoT: A Machine Learning and IoT-Based Smart Health Platform for Overweight and Obesity Control. Applied Sciences, Vol. 9, No. 15. DOI: 10.3390/app9153037. Number: 15.

31. **Machorro-Cano, I., Alor-Hernández, G., Paredes-Valverde, M. A., Rodríguez-Mazahua, L., Sánchez-Cervantes, J. L., Olmedo-Aguirre, J. O. (2020).** HEMS-IoT: A Big Data and Machine Learning-Based Smart Home System for Energy Saving. Energies, Vol. 13, No. 5. DOI: 10.3390/en13051097. Number: 5.

32. **Martín-Garín, A., Millán-García, J. A., Baïri, A., Gabilondo, M., Rodríguez, A. (2020).** IoT and cloud computing for building energy efficiency. In **Pacheco-Torgal, F., Rasmussen, E., Granqvist, C.-G., Ivanov, V., Kaklauskas, A., Makonin, S.**, editors, Start-Up Creation (Second Edition), Woodhead Publishing Series in Civil and Structural Engineering. Woodhead Publishing, Cambridge, UK, pp. 235–265.

33. **Matsui, K. (2018).** An information provision system to promote energy conservation and maintain indoor comfort in smart homes using sensed data by IoT sensors. Future Generation Computer Systems, Vol. 82, pp. 388–394. DOI: 10.1016/j.future.2017.10.043.

34. **Medina Otalvaro, C. M., Blandón Andrade, J. C., Zapata Jaramillo, C. M., RiosPatiño, J. I. (2022).** IoT Best Practices and their components: A Systematic Literature Review. IEEE Latin America Transactions, Vol. 20, No. 10, pp. 2217–2228. DOI: 10.1109/TLA.2022.9885169.

35. **Merzouk, S., Cherkaoui, A., Marzak, A., Nawal, S. (2020).** IoT methodologies: comparative study. Procedia Computer Science, Vol. 175, pp. 585–590. DOI: 10.1016/j.procs.2020.07.084.

36. **Miah, S. J., Hasan, N., Hasan, R., Gammack, J. (2017).** Healthcare support for underserved communities using a mobile social media platform. Information Systems, Vol. 66, pp. 1–12. DOI: 10.1016/j.is.2017.01.001.

37. **Morales Ríos, A., Blandón Andrade, J. C., Medina Otalvaro, C. M., Zapata Jaramillo, C. M.**, **.** Computational tool for automatic term extraction - ATEM. .

38. **Morin, B., Harrand, N., Fleurey, F. (2017).** Model-Based Software Engineering to Tame the IoT Jungle. IEEE Software, Vol. 34, No. 1, pp. 30–36. DOI: 10.1109/MS.2017.11.

39. **Mrabet, H., Belguith, S., Alhomoud, A., Jemai, A. (2020).** A Survey of IoT Security Based on a Layered Architecture of Sensing and Data Analysis. Sensors, Vol. 20, No. 13. DOI: 10.3390/s20133625. Number: 13.

40. **Navarro, E., Costa, N., Pereira, A. (2020).** A Systematic Review of IoT Solutions for Smart Farming. Sensors, Vol. 20, No. 15. DOI: 10.3390/s20154231. Number: 15.

41. **Nebbione, G., Calzarossa, M. (2020).** Security of IoT application layer protocols: Challenges and findings. Future Internet, Vol. 12, No. 3, pp. 55. DOI: 10.3390/fi12030055. Number: 3.

42. **Nižetić, S., Šolić, P., González-de Artaza, D. L.-d.-I., Patrono, L. (2020).** Internet of Things (IoT): Opportunities, issues and challenges towards a smart and sustainable future. Journal of Cleaner Production, Vol. 274. DOI: 10.1016/j.jclepro.2020.122877.

43. **Object Management Group (2018).** Essence-Kernel and language for software engineering methods.

44. **Oniga, B., Dadarlat, V., Poorter, E. D., Munteanu, A. (2017).** Analysis, design and implementation of secure LoRaWAN sensor networks. 2017 13th IEEE International Conference on Intelligent Computer Communication and Processing (ICCP), Cluj-Napoca, Romania, pp. 421–428. DOI: 10.1109/ICCP.2017.8117042.

45. **Park, J., Kim, T., Lee, C.-s. (2019).** Development of Thermal Comfort-Based Controller and Potential Reduction of the Cooling Energy Consumption of a Residential Building in Kuwait. Energies, Vol. 12, No. 17. DOI: 10.3390/en12173348. Number: 17.

46. **Payne, B. R., Abegaz, T. T. (2018).** Securing the Internet of Things: Best Practices for Deploying IoT Devices. In Computer and Network Security Essentials. Springer International Publishing, Cham, Switzerland, pp. 493–506.

47. **Pereira, F., Correia, R., Pinho, P., Lopes, S., Carvalho, N. (2020).** Challenges in resource-constrained iot devices: Energy and communication as critical success factors for future iot deployment. Sensors, Vol. 20, No. 22, pp. 1–30. DOI: 10.3390/s20226420. Number: 22.

48. **Pérez Colón, R., Navajas, S., Terry, E. (2019).** IoT IN LAC 2019: Taking the Pulse of the Internet of Things in Latin America and the Caribbean. Technical report, Inter-American Development Bank, Washington D.C., USA.

49. **Pătru, I.-I., Carabaş, M., Bărbulescu, M., Gheorghe, L. (2016).** Smart home IoT system. 2016 15th RoEduNet Conference: Networking in Education and Research, Institute of Electrical and Electronics Engineers, Bucharest, Romania, pp. 1–6. ISSN: 2247-5443.

50. **Reggio, G. (2018).** A UML-based proposal for IoT system requirements specification. Proceedings of the 10th International Workshop on Modelling in Software Engineering, Association for Computing Machinery, New York, NY, USA, pp. 9–16. DOI: 10.1145/3193954.3193956.

51. **Rossi, M., Kerga, E., Taisch, M., Terzi, S. (2014).** Engineering and Design Best Practices in New Product Development: an Empirical Research. Procedia CIRP, Vol. 21, pp. 455–460. DOI: 10.1016/j.procir.2014.03.184.

52. **Samaila, M. G., Sequeiros, J. B. F., Simões, T., Freire, M. M., Inácio, P. R. M. (2020).** IoT-HarPSecA: A Framework and Roadmap for Secure Design and Development of Devices and Applications in the IoT Space. IEEE Access, Vol. 8, pp. 16462–16494. DOI: 10.1109/ACCESS.2020.2965925.

53. **Trnka, M., Cerny, T., Stickney, N. (2018).** Survey of Authentication and Authorization for the Internet of Things. Security and Communication Networks, Vol. 2018. DOI: 10.1155/2018/4351603.

54. **Wang, H., Liu, Y., Wei, Y., He, Y., Tsang, K. F., Lai, L. L., Lai, C. S. (2020).** LP-INDEX: Explore the Best Practice of LPWAN Technologies in Smart City. 2020 IEEE International Smart Cities Conference (ISC2), Piscataway, NJ, USA, pp. 1–5. DOI: 10.1109/ISC251055.2020.9239030.

55. **Wang, S., Valluripally, S., Mitra, R., Nuguri, S. S., Salah, K., Calyam, P. (2019).** Cost-Performance Trade-Offs in Fog Computing for IoT Data Processing of Social Virtual Reality. 2019 IEEE International Conference on Fog Computing (ICFC), Institute of Electrical and Electronics Engineers, Prague, Czech Republic, pp. 134–143. DOI: 10.1109/ICFC.2019.00025.

56. **Weber, M., Zarko, I. P. (2019).** A Regulatory View on Smart City Services. Sensors, Vol. 19, No. 2. Number: 2.

57. **Yuan, D., Kanhere, S. S., Hollick, M. (2017).** Instrumenting Wireless Sensor Networks — A survey on the metrics that matter. Pervasive and Mobile Computing, Vol. 37, pp. 45–62. DOI: 10.1016/j.pmcj.2016.10.001.

58. **Zaidan, A., Zaidan, B., Qahtan, M., Albahri, O., Albahri, A., Alaa, M., Jumaah, F., Talal, M., Tan, K., Shir, W., Lim, C. (2018).** A survey on communication components for IoT-based technologies in smart homes. Telecommunication Systems, Vol. 69, No. 1, pp. 1–25. DOI: 10.1007/s11235-018-0430-8. Number: 1.

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