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REAL-TIME DISSOLVED OXYGEN MONITORING BASED ON THE INTERNET OF SMART FARMING PLATFORM

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ABSTRACT

The Internet of Things (IoT) has not only become a part of human life, it has become a tool being made important, especially in the 21st century for generating revenue and strengthening communities' economies. Smart farming on the other hand, is a management concept that is aimed at providing the agricultural industry with a system or infrastructure to leverage on advanced technology such as the cloud, IoT and even big data – for tracking, automating and monitoring operations. This study focus is on using the IoT on a smart farming platform for dissolved oxygen monitoring for aquaculture in the Songkhla Lake Basin, South of Thailand. We propose the fundamentals of real-time dissolved oxygen (DO) monitoring based on the internet of smart farming platform, in which the parameters studied are DO and water temperature (TEMP). The system is built to automatically detect data from the aquaculture pond or natural water sources, after which the data detected is sent to the host computer and/or user smart phone through the Wi-Fi cloud service network. The data collected for the DO and TEMP show that the relationship of both parameters are negatively related. In other words, when the water temperature rises, the DO value decreases accordingly and vice versa. The results were analyzed by the Pearson correlation statistical program at 99 percent confidence of -.732**.
Keywords: *Iot, Dissolved Oxygen, Pearson Correlation*

1. INTRODUCTION

The Songkhla Lake Basin is an important natural resource for surrounding communities living in the southern region of Thailand. The area of Songkhla Lake Basin is about 974 square kilometers, which measures approximately 20 kilometers wide from the west to the east, and 75 kilometers long from the north to the south, with an area around 1,040 square kilometers of lowland lakes. The lake is the largest natural lake in Thailand and lies on the Malay Peninsula in the southern part of the country. The provinces of Songkhla and Phasshaulung are the borders of the Songkhla Lake. This water feature, despite being called a lake is actually geologically a lagoon complex.

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Figure 1. Songkhla Lake Basin, South Of Thailand

The lake is known for its abundance in over 700 species of fishes, shrimps and crabs. Those are valuable resources for aiding the economy and nurturing more than 150 communities situated around the lake area. Over the past decade, the number of flower crabs have decreased tremendously due to their being hunted during the spawning season. Even though the control measure for catching fishes are in place it is still hard to control. The governance of Songkhla Lake Basin governance is a process of interaction and collaboration for the purpose of decisions made among various group playing a part in the development, which aimed to improve the sustainable solutions for the use of common resource, and ecosystem preservation of the lake basin [1].

In all seriousness, the environment in and around the Songkhla Lake Basin has been deteriorating gradually. The economic aquatic animals run out of the sea causing serious detrimental effects to the next generation of fishermen. Thus, our children in the future may lose their careers and family traditional values of existence. Ban Hua Khao Crab Nursery joined with group of approximately 200 fishermen who used sunk fishing nets to trap crabs living in the sea side of Songkhla Lake, Singha Nakhon District, Sathing Phra District, and Ranot District, Songkhla Province.

Ban Hua Khao Crab Nursery started by using general management system as a general crab bank. Head of Crab Nursery Center (Mr.Chamnan Manil) peruades the folk members to bring crabs with eggs outside the carapace (Belly area). Then, crab's eggs are cultured until the larval crabs get ready to return to the sea. This crab bank concept provides the natural resources for their living and returning to this fishing community's livelihood. The life cycle stages of flower crab as presented in Figure 2 [2].

This deterioration of the environment around the Songkhla Lake basin mentioned in Paragraph 2 above needs to be halted to prevent the aquatic animals from running out of the lake or even dying from starvation. Thus there is an urgent need to develop a real-time monitoring system using the Smart farming system based on the Internet of Things.

The remainder of this paper is organized as follows: Section 2 discusses the Internet of Smart Farming Application, Section 3 addresses the Community's benefits from the IoT application while Section 4 gives the experimental results and discussions. Section 5 concludes the paper and gives some ideas about future work in this area of study.

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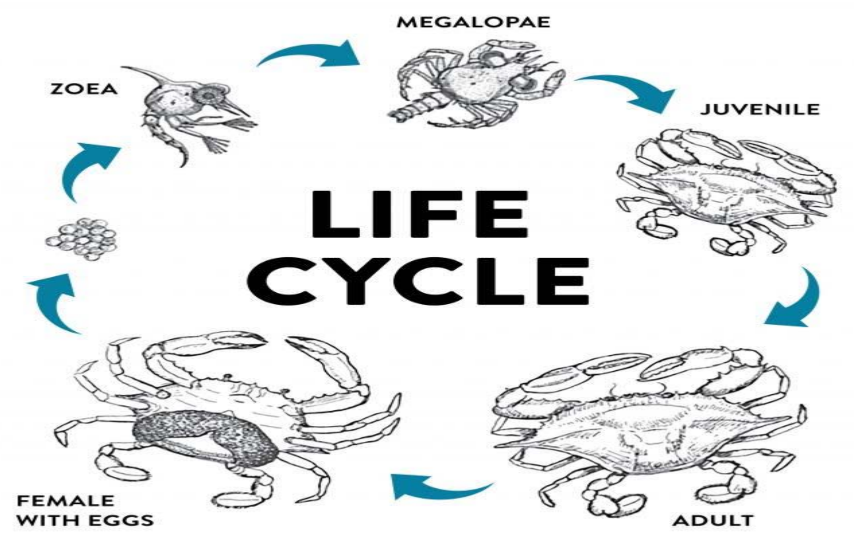

Figure 2. The Life Cycle Of A Flower Crab

2. INTERNET OF SMART FARMING APPLICATION

In this Section, the Internet of Things is explained; its meaning and various definitions by minent scholars and a detailed analysis on the composition of the IoT system is given. Thus, the domain of Internet of Things can be comprehensive and extensive in these references. An overview of the Internet of Things definitions and its different issues are discussed in Table 1.

Table.1 An Overview Of The Internet Of Things Definitions

Internet of Things (IoT) Applications	Definition
K. K. Patel et al. (2016) Internet of Things- IOT: Definition, Characteristics, Architecture, Enabling Technologies, Application & Future Challenges	Internet of Things (IoT) is a network of physical objects. It has evolved into a network of devices of all types and sizes, vehicles, smart phones, home appliances, toys, cameras, medical instruments and industrial systems, animals, people, building, all connected, all communicating & sharing information based on stipulated protocols in order to achieve smart reorganizations, positioning, tracing, safety & control & even personal real time online monitoring, online upgrade, process control & administration [3].
I. Ahmed et al. (2018) Internet of Things (IoT) Meaning, Application and Challenges	Internet of things shows the plurality it has, and indicates that it is sum of many objects, precisely smart objects [4].
S. Puengsungwan & K. Jirasereeamornkul (2019) Internet of Things (IoT)-based hydroponic lettuce farming with solar panels	Internet of Things-based farming applied with external and internal sensors to develop sustainable smart farming [5].
W. Boonsong (2019) Smart Intruder Notifying System Using NETPIE through Line Bot Based on Internet of Things Platform	Internet of Things is a cooperation technology that acts a middleware between various data sensors and users [6].

2.1 Internet of Things (IoT) for Smart Aquaculture Pond

The proposed Internet of Things (IoT) device for smart aquaculture pond includes an embedded wireless connectivity option and networking protocols. It needs the scalability for resource constrained devices, feature- rich display function, improved battery life, security for data storage and transmission, authentication with architecture support for cloud integration.

Apart from the embedded hardware requirements, the embedded software is also to be used to deliver feature-rich IoT platform and connected to other smart devices that also meet the reliability, security and power consumption requirements of smart farming and other related systems.

The proposed structure associates between an aquaculture pond and moderator; namely, each aquaculture pond is serviced by the proposed device, network communication, and product cloud. The final section is the utilized information, which is integrated with community/business sector. Product hardware consists of dissolved oxygen and temperature sensors, processor and element providing communication (antenna port, etc.) embedded in the proposed product and supporting its traditional mechanical and electrical components. Moreover, the product software is the programming system, on-board applications, user interface, and product control components embedded into the device. Thus, the internet of smart farm monitoring is impacting on modern enterprises and security system physically [7, 8].

2.2 Proposed Embedded Duo Sensors with Cloud Service

This section explains the proposed real-time dissolved oxygen monitoring based on the IoT of smart farming platform. The proposed prototype consisted of duo sensors, which are dissolved oxygen and temperature sensors. Both parameters as mentioned are very important for water quality monitoring and related each other. The quantity of IoT data receiving from real-world smart objects with sensing, actuating, computing and communication capabilities is exploding. Both sensors and related modules are more deployed, within more applications and across industries.

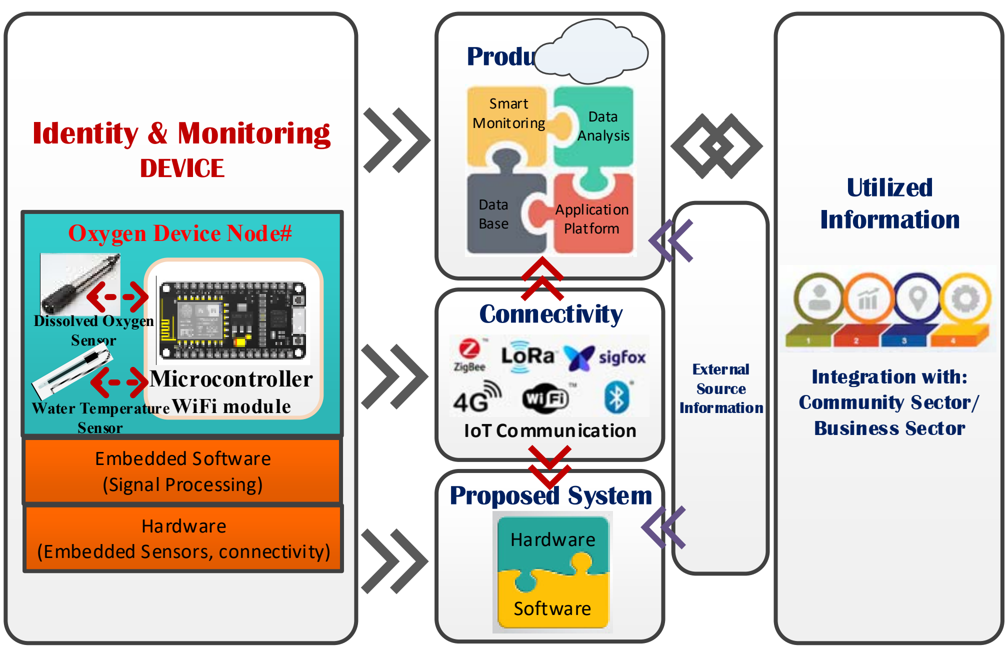

Figure 3. The Proposed IoT infrastructure

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Figure 3 shows the proposed IoT infrastructure for the dissolved oxygen monitoring based on internet of smart farming platform. The bulk of the monitoring system involves the IoT communication where the NodeMCU-ESP8266 is adopted and used as the main IoT section for programming and transfer of the received data to the internet network through a router for storage in the cloud server service.

This subsection is to consider the characteristics of collected data and then presents several data analytical techniques for finding the correlation between the study parameters. The volume and quantity of the data generated by the IoT devices are from very different sources. The proposed IoT data is dynamic, heterogeneous, imperfect, unprocessed, unstructured and real-time than other data sources. Therefore, it is a challenge, and demands more sophistication with IoT-specific analytics to make it meaningful.

2.3 Lifecycle of an IoT Sensing Service

The lifecycle of an IoT sensing service uses model for IoT/cloud services, provided by all public IoT/cloud infrastructures. The most public IoT cloud comes with a range of tools and related environments for water quality monitoring consisting of main IoT consideration as follows [9]:

On-demand: Service determine and delivery in OpenIoT should be performed on-demand, which is fulfilled by the middleware infrastructure. Therefore, this part is involved with the dynamically selecting duo sensors for oxygen monitoring in water in order to satisfy the service requests.

Cloud-based: OpenIoT services are provided in a cloud environment. It is the main section of this environment on a scalable sensors cloud infrastructure, which shall provide the sensor data access service. Thus, the OpenIoT service formulation strategies must take into account the need to access and combine services residing within the sensor/Information Commissioner's Office (ICO) cloud.

Utility-based: Service data delivery in OpenIoT is utility-based with on-demand and cloud-based properties. Thus, the device application needs to consider the calculating utility, storing a range of utility parameters.

Optimized: OpenIoT incorporates a wide range of self-management algorithms.

2.4 The Application Programming Interface (API) Consideration

The Application Programming Interface (API) is a code that allows software programs to communicate with one another. It (API) is actually a way to request commands from the operation system (OS) or other applications.

Figure 4. The Iot Communication Platform Through API

API management refers to the process for distributing, controlling, and analyzing on a communication platform. It is connected with applications and data across the enterprise and across clouds. Thus, API allows users or organizations to create APIs for monitoring activity and ensure the requirements of the developers and applications.

3. THE COMMUNITY'S BENEFITS FROM THE SMART IOT APPLICATION

In this study, dissolved oxygen and temperature parameters are considered. Namely, the solubility of oxygen and other gases will decrease when temperature increases [10]. This means that cold water can hold more dissolved oxygen than warm water. If water is too warm, it will not hold enough oxygen for aquatic organisms to survive. With these important factors, the dissolved oxygen and temperature values are to be analyzed for smart farming of crab culture pond. The real-time quality monitoring of water in an aquaculture pond is necessary for the preparation of timely solution to the reduction of oxygen in the water because crabs are an important marine economy drivers for the community.

Figure 5. Water Quality Monitoring For Crab Culture Pond

Figure 5 shows the real-time water quality and dissolved oxygen monitoring setup for the crab culture pond. The setup is intended to provide real-time measurements which will be based on IoT on smart farming platform to lead up to machine-to-machine (M2M) communication, which connects environmental condition to open mobile alliance (OMA). The proposed IoT concept aims at the key configuration requirements to identify IoT devices and their associated management objects and attributes, ability to enable or disable a device capability, and the most important is the ability to update device parameters.

3.1 Data Management and Analytics

The class of IoT applications in this study is characterized with various parameters on a very large scale, in terms of the number of devices generating data, widespread geographical footprint
where these monitoring devices are deployed, vast amounts of data that need to be collected, aggregated, processed, and exposed to consuming entities, as well as real-time analytics or closed-loop control. Thus, the class of applications, i.e., data management and analytics will be handled in tandem with the need of the performance requirements. The data analytics will be described in more detail in the next section.

4. EXPERIMENTAL RESULTS AND DISCUSSIONS

This section considers the water tested in the crab pond. The relationship between dissolved oxygen and temperature in water parameters is obtained. Firstly the experiment was carried out using the proposed implementation instrument. The water monitoring module consisted of biological sensors, which are the dissolved oxygen and water temperature sensors. Two parameters, namely dissolved oxygen and water temperature are analyzed to study the relationship, which is consistent with the theory mentioned earlier. The graph in Figure 6 shows the temperature in aquaculture pond compared with dissolved oxygen value to observe their relationship. The data collected was sampled fifteen (15) times, and for each sampling it turned out that the obtained values were very close.

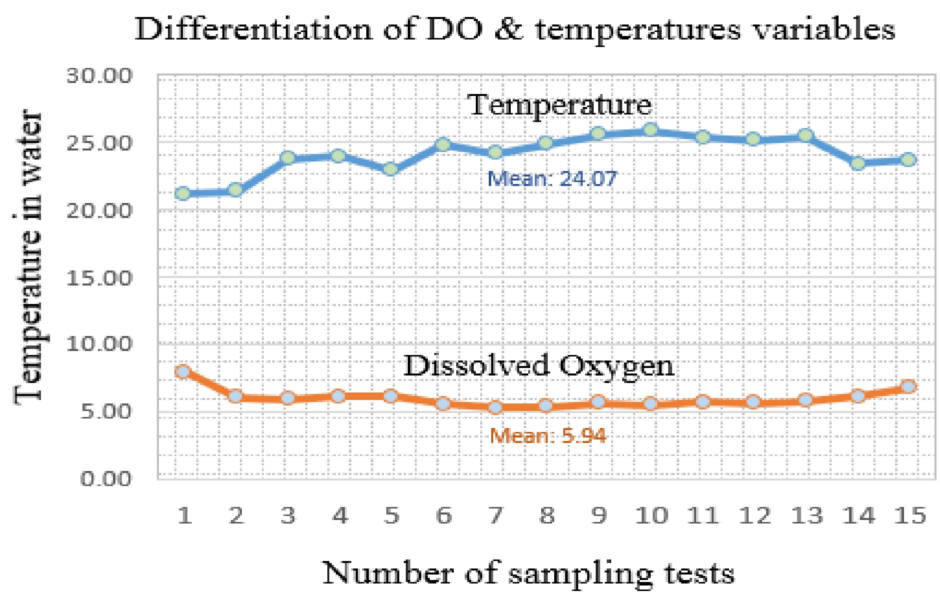

Figure 6. Differentiation Of The Dissolved Oxygen (DO) And Temperature In Water.

.This study considers the relationship between two variables, which are dissolved oxygen and temperature in the aquaculture pond. Thus, both parameters are to analyze a single variable using graphs and summary statistics. We expect that there is a relationship between the two variables "dissolved oxygen" and "temperature" whether they have a positive or negative relationship according to the scatter plot in Fig. 7(a).

(A) Presented Scatter Plot Of Correlation R-Value From The Experiment

Figure 7

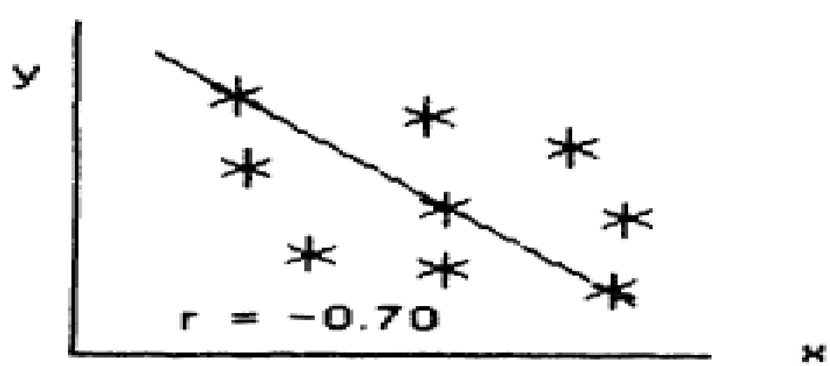

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Figure 7 presents the correlation coefficient (*r*-value) comparison between the experiment and theory which was reviewed by Richard Taylor [11]. The presented plot (*r*-value) is -.732 in the degree of association of measured variables. Thus, both variables, the dissolved oxygen and temperature in water pond are negatively correlated indicating an inverse relationship, that is, when one variable increases, the second variable decreases. The graph can be useful in illustrating the concept of correlation and visualize the relationship which exists between both variables. For illustration purposes, two variables are labeled as variable x and variable y and plotted on a graph. Note that in real-experiment situations, x and y would represent the two variables being statistically analyzed.

The calculation of the correlation coefficient is as follows, with *x* representing the values of the independent variable (temperature) and *y* representing the values of the dependent variable (dissolved oxygen). The formula to be used is:

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \cdot \sum_{i=1}^{n}(y_i - \bar{y})^2}} \quad (1)$$

where	*r*	=	Correlation coefficient
	x	=	Set of scores from variable x
	y	=	Set of scores from variable y
	N	=	the number of pairs of scores

The Pearson Correlation (Pearson Product Moment Correlation (PPMC)) is to be considered between sets of data related as shown in Figure 8. The correlation coefficient is a statistical measure of the strength of the relationship between the relative movements of two variables with range between -1.0 and 1.0.

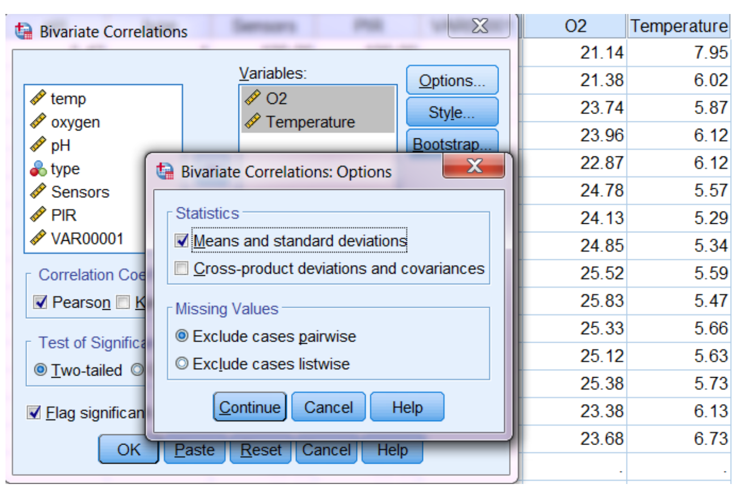

Figure 8. The Calculation Of Bivariate Correlations Using PPMC Test.

Upon obtaining those values for the two parameters, there is the need for credibility and proof of their validity, so the obtained values were analyzed to ascertain the obtained relationship by using the International Business Machines (IBM)'s Statistical Package for Social Sciences (SPSS). The experimental results obtained by using the SPSS program is shown in Figure 8. A correlation of -1.0 means a perfect negative correlation, while a correlation of 1.0 means a perfect positive correlation of both variables. In this investigation, the result value is -.732**,

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which shows that both variables are strongly negative relationship. Namely, the variables move in opposite directions.

Correlations

					Temperature	DO
Temperature	Pearson Correlation				1	-.732**
	Sig. (2-tailed)					.002
	N				15	15
	Bootstrap[c]	Bias			0	.007
		Std. Error			0	.135
		95% Confidence Interval	Lower		1	-.934
			Upper		1	-.437
DO	Pearson Correlation				-.732**	1
	Sig. (2-tailed)				.002	
	N				15	15
	Bootstrap[c]	Bias			.007	0
		Std. Error			.135	0
		95% Confidence Interval	Lower		-.934	1
			Upper		-.437	1

**. Correlation is significant at the 0.01 level (2-tailed).

c. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Figure 8. Relationships Of Water Temperature And Dissolved Oxygen Variation

The findings in Figure 8 can be interpreted as follows. Firstly, from the obtained results for statistical significance, it was found that statistical significance at the .01 level has a 99 % confidence of 15 units for analysis. Secondly, both variables have a high level of relationship in the negative direction; namely, when the water temperature increases the dissolved oxygen value will slightly decrease. In contrast, when the water temperature decreases, the dissolved oxygen value will increase. Thus, for this study it was found that the dissolved oxygen in water depends on the environmental condition.

5. CONCLUSION AND FUTURE WORK

As an application area of the Internet of Things (IoT), in this study it is applied to dissolved oxygen monitoring based on the internet of smart farming platform. The project's contribution is based on the problem statement from the learning center for hatching of crabs, which lacks efficient water quality monitoring. The proposed system is useful for real-time monitoring of data exchanges between the sensing IoT devices and users. The created IoT invention can make aquaculture clearly efficient. The detected data will be stored and can be retrieved at any time, which can be analyzed for solving water-related problems that occur occasionally or even frequently. All of these advantages can definitely reduce losses and improve efficiency through the adoption of the IoT-based farming.

In the future, we aim to study the other parameters of water quality monitoring. Actually, there are three types of water quality parameters, which are physical, chemical, and biological [12]. The concentration of hydrogen ions in a solution is subjectively to indicate an alkaline or acidic nature of a solution in terms of its pH value. Moreover, the particular parameter of interest is Nitrogen which occurs in natural water in various forms, including nitrate (NO_3), nitrogen dioxide (NO_2) and ammonia (NH_3). These three compounds are interrelated through the process of nitrification, the biological oxidation of ammonia to nitrate. After these parameters are studied and matched with the proper sensors, a more robust water quality monitoring can be carried out. In addition, instead of the crab ponds used in this study, other habitats like the fish ponds, algae ponds, etc can be used in future studies to investigate the relationship between the dissolved oxygen and the water temperature.

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